CBE, Sierra Club, Center, ForestEthics et al. Comments on the Revised Draft Environmental Impact Report for the Phillips 66 Company Rail Spur Extension and Crude Unloading Project

ATTACHMENT E:

Literature cited and materials for Biological Resources Section of Comment.

Literature Cited for Section IV. D. The RDEIR Fails to Adequately Analyze the Project's Impacts Related Biological Resources.

Andreassen, H.P. et al. 2005. The effect of scent-marking, forest clearing and supplemental feeding on moose-train collisions. Journal of Wildlife Management 69: 1125-1132.

[AP] Associated Press. 2011. Trains kill more than 800 antelope and deer on Montana tracks this winter. 6 March 2011.

Becker, E.F. and C.A. Grauvogel. 1991. Relationship of reduced train speed on moose-train collisions in Alaska. Alces 27: 161-168

Benn, B. and S. Herrero. 2002. Grizzly bear mortality and human access in Banff and Yoho National Parks, 1971-98. Ursus 13: 213-221.

Bhattacharya, M. et al. 2003. Are roads and railroads barriers to bumblebee movement in a temperate suburban conservation area? Biological Conservation 109: 37-45.

Blickley, J.L. et al. 2012. Experimental evidence for the effects of chronic anthropogenic noise on abundance of greater sage-grouse at leks. Conservation Biology 26:461-471.

Budzik, K.A. and K.M. Budzik. 2014. A preliminary report of amphibian mortality patterns on railways. Acta Herpetologica 9: 103-107.

Daily Inter Lake. 2014. Train kills grizzly bear; transplanted female grizzly bear may have been killed by train. April 2014.

Gundersen, H., and H.P. Andreassen. 1998. The risk of moose *Alces alces* collision: A predictive logistic model for moose-train accidents. Wildlife Biology 4(2):103-110.

Gundersen, H. et al. 1998. Spatial and temporal correlates to Norwegian moose-train collisions. Alces 34:385-394.

Iosif, R. 2012. Railroad-associated mortality hot spots for a population of Romanian Hermann's tortoise (*Testudo hermanni boettgeri*): a gravity model for railroad-segment analysis. Procedia Environmental Sciences 14:123-131.

Jackson, S.D. 1999. Overview of transportation related wildlife problems. University of Massachusetts.

Kendall, K.C. et al. 2009. Demography and genetic structure of a recovering grizzly bear population. Journal of Wildlife Management 73: 3-17.

Krebs, J. et al. 2004. Synthesis of survival rates and causes of mortality in North American wolverines. Journal of Wildlife Management 68: 493-502.

Kušta, T. et al. 2011. Mortality of large mammals on railway tracks. Scientia Agriculturae Boehmica 42.

Kušta, T. et al. 2014. Deer on the railway line: spatiotemporal trends in mortality patterns of roe deer. Turkish Journal of Zoology 38:479-485.

Modafferi, R.D. 1991. Train moose-kill in Alaska: characteristics and relationship with snowpack depth and moose distribution in lower Susitna Valley. Alces 27: 193-207.

Morley, E.L., G. Jones, and A.N. Radford. 2013. The importance of invertebrates when considering the impacts of anthropogenic noise. Proceedings of the Royal Society of Biological Sciences 281: 20132683.

Morner, T. et al. 2005. Diseases and mortality in free-ranging brown bear (*Ursus arctos*), gray wolf (*Canis lupus*), and wolverine (*Gulo gulo*) in Sweden. Journal of Wildlife Diseases 41: 298-303.

Ockenfels, R.A., W.K. Carrel and C. van Riper III. 1997. Home ranges and movements of pronghorn in northern Arizona. Proceedings of the Third Biennial Conference of Research on the Colorado Plateau 3: 45-61.

Pace, R.M., D.R. Anderson, and S. Shively. 2000. Sources and patterns of black bear mortality in Louisiana. Proceedings of the 54th Annual Conference of the Southeastern Association of Fish and Wildlife Agencies:365-373; 28 October-01 November 2000, Baton Rouge, Louisiana.

Pissot, J. 2007. Trains, grains, and grizzly bears: reducing wildlife mortality on railway tracks in Banff National Park. Road Ecology Center. http://escholarship.org/uc/item/8sf4b0jr.

Read, J. et al. 2014. Fitness costs as well as benefits are important when considering responses to anthropogenic noise. Behavioral Ecology 25:4-7.

Schroeder, J. et al. 2012. Passerine birds breeding under chronic noise experience reduced fitness. PLoS ONE 7(7):e39200.

Spencer, K.G. 1965. Avian casualties on railways. Bird Study 12: 257.

[USFWS]. U.S. Fish and Wildlife Service. 2013. NCDE Grizzly Bear Conservation Strategy. April 2013.

[USFWS]. U.S. Fish and Wildlife Service. 2014. Data on documented grizzly bear deaths per year in the NCDE population as a result of bear-train collisions during 1984-2013. Grizzly Bear Recovery Coordinator.

Van Why, K.R., and M.J. Chamberlain. 2003. Mortality of black bears, *Ursus americanus*, associated with elevated train trestles. Canadian Field-Naturalist 2003:113-115.

Waller, J.S. and C. Servheen. 2005. Effects of transportation infrastructure on grizzly bears in northwestern Montana. Journal of Wildlife Management 69: 985-1000.

BioOne RESEARCH EVOLVED

THE EFFECT OF SCENT-MARKING, FOREST CLEARING, AND SUPPLEMENTAL FEEDING ON MOOSE–TRAIN COLLISIONS

Author(s): HARRY P. ANDREASSEN, HEGE GUNDERSEN, TORSTEIN STORAAS
Source: Journal of Wildlife Management, 69(3):1125-1132. 2005.
Published By: The Wildlife Society
DOI: http://dx.doi.org/10.2193/0022-541X(2005)069[1125:TEOSFC]2.0.CO;2
URL: http://www.bioone.org/doi/full/10.2193/0022-541X%282005%29069%5B1125%3ATEOSFC%5D2.0.CO%3B2

BioOne (www.bioone.org) is a nonprofit, online aggregation of core research in the biological, ecological, and environmental sciences. BioOne provides a sustainable online platform for over 170 journals and books published by nonprofit societies, associations, museums, institutions, and presses.

Your use of this PDF, the BioOne Web site, and all posted and associated content indicates your acceptance of BioOne's Terms of Use, available at www.bioone.org/page/terms_of_use.

Usage of BioOne content is strictly limited to personal, educational, and non-commercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

BioOne sees sustainable scholarly publishing as an inherently collaborative enterprise connecting authors, nonprofit publishers, academic institutions, research libraries, and research funders in the common goal of maximizing access to critical research.

THE EFFECT OF SCENT-MARKING, FOREST CLEARING, AND SUPPLEMENTAL FEEDING ON MOOSE–TRAIN COLLISIONS

HARRY P. ANDREASSEN, Hedmark University College, Department of Forestry and Wildlife Management, Evenstad, N-2480 Koppang, Norway

HEGE GUNDERSEN,[1] Hedmark University College, Department of Forestry and Wildlife Management, Evenstad, N-2480 Koppang, and Centre for Ecological and Evolutionary Synthesis, University of Oslo, Oslo, Norway

TORSTEIN STORAAS, Hedmark University College, Department of Forestry and Wildlife Management, Evenstad, N-2480 Koppang, Norway

***Abstract*:** We analyzed how the application of scent-marking, forest clearing, and supplemental feeding correlated with the number of moose (*Alces alces*)–train collisions along the most vulnerable railroad stretch in Norway. Data on 1,045 collisions has been compiled for 18 years since 1985, and remedial actions have occurred during various periods since 1990. We used sections of the rail line where remedies had never been applied as control sections to estimate the expected number of collisions per year and per km. In this way, we took into account the yearly variation in the number of accidents by using the difference between the actual number of accidents and the expected number of accidents as our response variable. We compared the difference between periods when remedies were applied to periods without any remedy. We found a general 46% decrease in the number of accidents during years with a remedy compared to what would have been expected the same years without any remedy. Forest clearing and supplemental feeding seem to be reliable ways of reducing the number of collisions. Scent was only applied for short distances in a few years, and the beneficial effects we observed were questionable. We conclude that mitigative efforts may substantially reduce accidental mortality in moose populations if applied for long distances. We discuss the economics of game-vehicle collisions by performing a simple calculation to visualize the need for a bioeconomic approach to the problem.

JOURNAL OF WILDLIFE MANAGEMENT 69(3):1125–1132; 2005

Key words: *Alces alces* L., forest clearing, moose–vehicle accidents, scent-marking, supplemental feeding.

Human development in past decades has been followed by a considerable increase in ungulate–vehicle accidents. The high socioeconomic cost of ungulate–vehicle collisions (Jaren et al. 1991) and the unpredictable effects on population development (Peterson and Danell 1992) have motivated many attempts to identify effective mitigative techniques. Bruinderink and Hazebroek (1996) and Romin and Bissonette (1996) summarized the effectiveness of various remedial actions in reducing ungulate–vehicle accidents and concluded that techniques based on sound, light, or scent-marking were ineffectual. However, forest clearing along roads with heavy traffic had some positive effect, and fences significantly reduced the number of accidents. Romin and Bissonette (1996) also suggested that supplemental feeding could reduce accidents, but the lack of data precluded any conclusive recommendations regarding feed. Fences have proven to be the most effective way of hindering ungulate–vehicle accidents. However, because fences disrupt habitat connectivity with unknown impact on the ecological community, there is a need to explore the efficiency of other techniques.

[1] Corresponding author e-mail: hege.gundersen@bio.uio.no

In Norway, the moose is responsible for the majority of the ungulate–vehicle accidents (Gundersen et al. 1998), and the Norwegian National Rail Administration has registered a steady increase in moose–train collisions from approximately 50 accidents yearly in the 1950s up to 1,000 yearly accidents in early 1990s (Andreassen et al. 1997, Statistics Norway 2003). In North America, moose mortality on highways and railways is a recurrent management problem (Child 1983, Child et al. 1991, Modafferi 1991). One of the most severely affected areas in Norway is a section of the Rørosbanen railroad (Gundersen et al. 1998, Gundersen and Andreassen 1998) where collisions occur mainly during winter; more specifically, they occur during long winters with deep snow when a high proportion of the moose population in the surrounding area migrates to winter ranges close to the railroad (Gundersen et al. 1998). Due to the severe problems associated with the moose–train collisions in this specific area, several attempts have been made to introduce various mitigative techniques, such as fencing, forest clearing, scent-marking, and the use of moose feeding stations.

We analyzed the effect of forest clearing, scent-marking, and feeding stations in reducing the number of winter collisions along a stretch of the Røros-

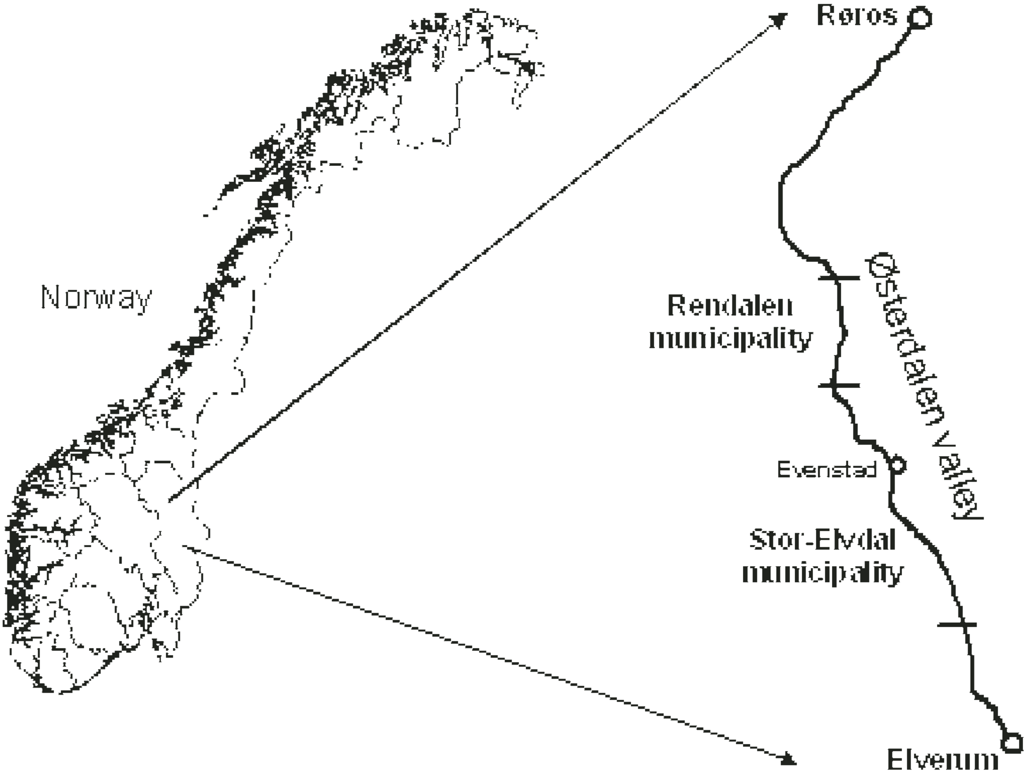


Fig. 1. The location of the Rørosbanen railroad and the 100-km section of the rail-line through Rendalen and Stor-Elvdal municipalities in Hedmark County, Norway, 2003.

banen railroad. These mitigative techniques were all replicated at several sites along the railroad in various years. To consider the yearly variation in the number of accidents, we estimated the expected number of accidents from control sections that were never treated. Hence, we used the difference between the actual number of collisions and the expected number of collisions as our response variable, and we compared years with and without any remedy. We also devised a simple calculation to estimate the economics of mitigative techniques.

STUDY AREA

We analyzed data on moose–train collisions from the most vulnerable stretch along Rørosbanen railroad line located in Stor-Elvdal and Rendalen municipalities, southeast Norway (Gundersen et al. 1998, Fig. 1). The railroad within these 2 municipalities was 100 km long (defined as 200- to 300-km rail-line from Oslo) and ran along the bottom of 1 of the main north-south valleys called Østerdalen. The valley is surrounded by hills of boreal forest, dominated by Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*), and interspersed with a few boreal deciduous species such as birch (*Betula* spp.). Thirty-eight percent of the moose population migrates down to the highly trafficked valley as soon as snow starts to accumulate in the hills during winter (usually around Nov–Dec; Gundersen et al. 1998, Gundersen 2003).

METHODS

Source of Moose–Train Collision Data

We collected data on moose killed by trains from The Norwegian State Railroad (NSB), The Norwegian National Rail Administration, and from the local Wildlife Committees of Stor-Elvdal and Rendalen municipalities from 1 July 1985 until 1 April 2003. Each record of a moose–train collision included time and position to the nearest 100 m along the 100-km railroad section. We obtained daily average temperatures and snow depths from the Evenstad meteorological station (61°24′N, 11°7′E).

Remedial Actions

Various remedial actions have been applied within the study area through the initiative of

NSB, The Norwegian National Rail Administration, landowners in Stor-Elvdal and Rendalen municipalities, and Hedmark University College Division of Forestry and Wildlife Management. Ten 0.5-km lengths were treated with scent in 1994–1995 and 1995–1996, respectively. Two feeding stations (6.0 and 8.0-km long) were established in 1994, and 1 station (4.0-km long) was established in 1995. Eight forest clearings (0.9 to 14 km long) were established from 1990 to 2002. Thirty-one sites were subjected to treatment.

Fences are assumed to be the best way to reduce ungulate-vehicle accidents (Bruinderink and Hazebroek 1996, Romin and Bissonette 1996), as they may act as a complete barrier to moose movement. Previous studies show that fencing reduces ungulate–vehicle accidents by as much as 60–100% (Lehtimaki 1981, Ludwig and Bremicker 1983, McDonald 1991, Gleason and Jenks 1993, Clevenger et al. 2001). However, in some instances, the number of accidents might actually increase at the ends of fences when animals enter the traffic artery and become trapped between the fences (Lehtimaki 1981, Clevenger et al. 2001). Fences can also trap animals that penetrate or climb over the fence. In 1995, a 1-km, wire-mesh fence was erected, and it eliminated collisions with moose except for 1 at a fence end. Because we had only 1 fenced length, and since it was nearly completely effective, we excluded this 1-km-long stretch from further analyses and instead analyzed other, more subtle, remedies.

Scent-Marking.—Scent is supposed to make ungulates more alert and aware of dangers, hence making them more vigilant when the scent is combined with sound and light from vehicles. However Lutz (1994) found that game stopped reacting to the scent after 2 days. A commonly used scent is Duftzaun® (HAGOPUR® GmbH, Landsberg am Lech, Germany), which consists of components from bears (*Ursus arctos*), wolves (*Canis lupus*), lynx (*Lynx lynx*) and humans. In our study, Duftzaun® scent was placed along the railroad during the winters of 1994–1995 and 1995–1996. Ten sections, each 500 m long, were chosen each winter. Duftzaun® was sprayed on trees and bamboo canes at 5-m intervals on along the railway. One treatment lasted for about 3–4 months, so only 1 spraying was needed each winter. The spraying was applied during the first days when accumulated snow exceeded 20 cm (i.e., late Nov 1994–1995 and early Jan 1995–1996).

Forest Clearing.—Clearing of vegetation along trafficked arteries has been suggested to reduce ungulate-vehicle accidents (Jaren et al. 1991, Gleason and Jenks 1993, Romin and Bissonette 1996, but see Rea 2003). It is recommended that trees and shrubs available for moose should be removed within 20–60 m from the track. Clearing of forest and browse was applied on 8 occasions along our study area. These sections were completely cleared of vegetation higher than 30 cm, so they were completely devoid of food and cover during winter conditions when they were covered by snow. Such clearings were maintained by repeated cutting of vegetation every year since.

Feeding.—Supplemental feeding seems to be an effective way to change moose movements, either by reducing migratory distances, or by making animals stay in certain locations (Carbaugh et al. 1975, Miller and Litvaitis 1992, Gundersen et al. 2005). Wood and Wolfe (1988) tested the efficacy of intercept feeding and found a reduction in the number of mule deer (*Odocoileus hemionus*)–vehicle collisions in 5 of 6 tests, although only 2 were significant. In our study, landowners initiated supplemental winter feeding of moose in 4 side-valleys used by moose during migration towards the winter range. Feeding stations were established by the landowners as an attempt to reduce traffic accidents in the area. Two of these side-valleys do, however, end up at the same location along the railroad (1 from the eastern and 1 from the western side). Hence, we analyzed 3 sections along the railroad for the effect of feeding on the number of collisions. The supplemental food consisted of baled and silaged graminoids and/or herbs of varying breeds and combinations, usually oat (*Avena sativa*) and canola (*Brassica napus*). One bale of silage weighs about 600 kg, and on average, 5.3 bales (range 1–36) were used at each feeding station each winter. All stations were placed near snow free roads with low human activity so that the food supplementation could easily be performed by car. The feeding period lasted from when the snow accumulated in the hillsides, usually in November, until the snow melted or summer migration began in April–May.

Analyses

We transformed the observed number of collisions per year in a remedied site by dividing the number of collisions with the length (km) of the site. This yielded the observed number of collisions per year (t) and km for each site ($O_{i,t}$).

Previously, we showed that 83% of the yearly variation in moose–train collisions in the area may be explained by the duration of the winter (Gundersen et al. 1998). Hence, we cannot simply compare the number of accidents during years when the remedy was applied with periods when it was not applied, as this may be confounded with winter conditions. To take into account the annual variation, we lumped all stretches that had never been allocated for a remedy, hereafter termed control section, and estimated the expected number of moose collisions per km every year (Et) by adding all moose collisions along control sections divided by 48.8 km (i.e., the total length of control section). The equivalent length where a remedy had been applied, hereafter termed remedy sections, was 51.2 km.

To compare the various remedial techniques, we employed a general linear mixed model with poisson error, log link, and ln(Et) as an offset using the SAS macro GLIMMIX (Littell et al. 1996). Hence, the predicted estimates of the model were the yearly deviations between the observed and expected number of collisions. Due to the log-transformations, the actual estimates were ln(Oi,t) – ln(Et) that, when back-transformed, gave the value of 1 if there was no difference between the actual and expected number of collisions (i.e., Oi,t/Et = 1), >1 if there were more collisions than expected, and <1 if there were fewer collisions than expected. We treated the 31 sites subject to remedies as random factors in the analyses to take into account innate variations within each section that was treated with a remedy for >1 year (i.e., forest clearing and supplemental feeding).

Within the remedy sections, we knew the observed number of collisions for years with and years without the application of the remedy. We included type of remedy and application (coded as yes and no) in the model as a between- and within-subject effect, respectively, with site as the subject defined as a random factor. Any difference in the effectiveness of various remedies was then found in a significant interaction between remedy and application, while the general effect of applying a remedy was found in a significant effect of the main factor application. Hence, a significant effect of application appeared when the Oi,t/Et differed between periods with and without the application of the remedy.

RESULTS

Effect of Remedies

We selected only the moose–train collisions that occurred during the winter from November to March (i.e., 86% of the total number of collisions registered) since feeding and scent-marking was performed only during winter. The mean number of collisions each winter was 0.58 (SE = 0.08) moose/km. Of the 1,045 collisions in the analysis, 672 (64%) were located within remedy sections in at least 1 year. Hence, since 64% of the collisions were located inside 51.2% of the railroad (total length of remedy sections), remedial actions were allocated within areas with high risk of collisions.

Except for 1 site treated with scent, all other 30 remedy sites showed a decrease in the number of accidents during application of the remedy compared to the control sections. Although this trend was not statistically significant (effect of application: $F_{1,30} = 3.54$, $P = 0.071$), there was an average reduction of 46% (95% CL: –5, 73) in the number of accidents during the application of remedies. Within the remedy sections there were 2.5 times more moose killed (i.e., odds ratio, 95% CL: 1.8, 3.5) per km and year compared to control sections before the initiation of the remedy. During the application of the remedy, the numbers of killed moose approached the numbers in control sections (i.e., odds ratio: 1.3; 95% CL: 0.8, 2.3). There was no difference in the efficiency of various remedial actions (interaction effect of remedy * application: $F_{2,28} = 0.34$, $P = 0.715$).

A closer examination into each of the 3 remedial actions we analyzed separately showed that in areas cleared of forest there was a 49% reduction in collisions (95% CL: 10%, 71%; $F_{1,14} = 5.66$, $P = 0.032$), in food supplemented areas a 40% reduction in collisions (95% CL: 17%, 57%; $F_{1,4} = 9.55$, $P = 0.037$), and in scent-marked areas a 85% reduction in collisions (95% CL: –8%, 100%; $F_{1,38} = 0.84$, $P = 0.366$). However, the large variation in the effectiveness of scent meant that this remedy was not statistically significant (Fig. 2).

If the overall number of accidents decreased over time, the remedies may have only seemed effective because they were in the later years of the study. However, while the number of moose killed per km in remedy sections remained constant through time, it tended to increase in control sections (Fig. 3).

At some sections of the railway, various applications were carried out simultaneously. We tested whether 2 remedies were more effective than only 1 remedy by comparing sections cleared of forest or supplemented with food with sections with both clearing and supplementation. Due to the high variation in the effect of scent applied over short distances over few years, we did not test the effect of including scent as a second remedy. Two remedies applied simultaneously did not reduce the number of collisions significantly compared to areas with only 1 remedy (reduction of 5%; 95% CL: –61%, 44%; $F_{1,15} = 0.04$, $P = 0.849$).

Quantifying the Reduction

Because most remedial actions are expensive, they may be more readily adopted if the application is effective and quantifiable. We illustrated the economic benefit of remedies using an example with forest clearing and supplemental feeding (Table 1). We limited the costs to the maintenance of remedies and the benefits to the value of moose meat (i.e., the predominant economic benefit of hunting in Norway).

We assumed an average winter with 58 moose–train collisions. As 2.5 times more moose were killed per km along remedy sections than elsewhere before the application of remedies, we expected 42 moose to be killed yearly along the 51.2 km of remedy sections.

If feed was applied to 18 km of the study area, a 40% reduction in moose collisions compared to expected collisions suggests that 5.9 moose were saved yearly due to feeding. If clearing was applied to 18 km of the railway, a 49% reduction in moose collisions due to clearing suggests that 7.2 moose were saved yearly. If this much meat was sold, the net benefit would be US$8,260 and US$10,080 due to feed and clearing, respectively.

Supplemental feeding in the study area costs on average US$18,000 a year (applied to 18 km), while maintenance of clearings cost approximately US$9,000 a year (US$500 per km; Storaas et al. 2001). We found that forest clearings are profitable, while feed yields a deficit (Table 1). However, initially clearing a forest costs approximately US$5,500 per km, and the cost and benefit do not necessarily accrue to the same person or agency.

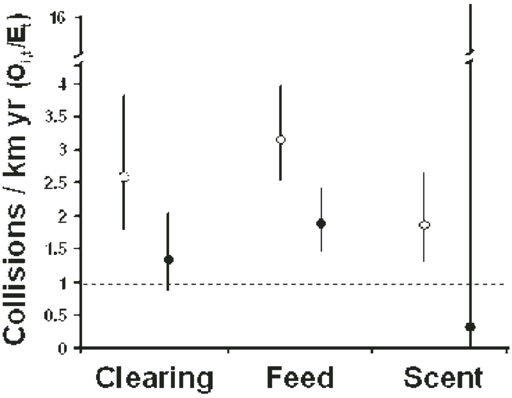


Fig. 2. The effect of various remedial actions against moose–train accidents in Rendalen and Stor-Elvdal municipalities, Hedmark County, Norway, Jul 1990–Apr 2003. The estimates are the back-transformed deviations between the observed (O) and expected (E) numbers, (i.e., Oi,t/Et). A value of 1 indicates that the number of collisions was as expected that year, according to the yearly variation. Black and white markers represent periods with and without the application of remedies, respectively.

DISCUSSION

Our analyses showed that remedial actions were allocated to high-risk sections where the number of accidents in general was higher than control sections. Within remedial sites, however, there was

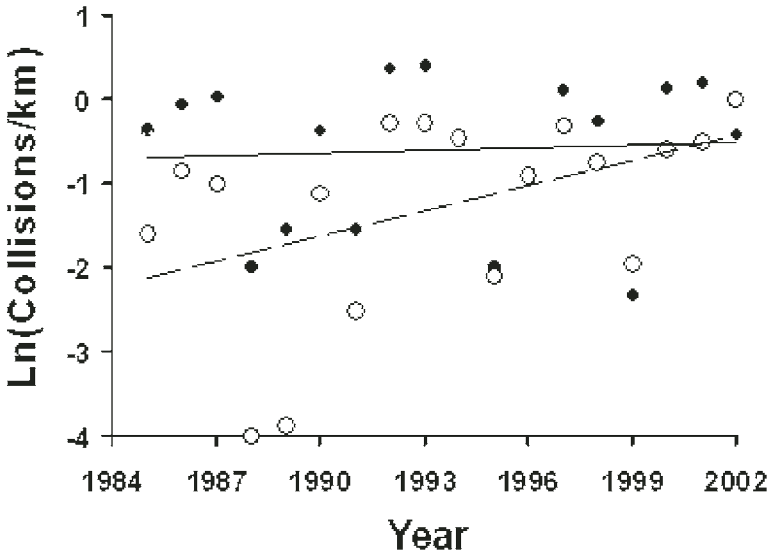


Fig. 3. Number of moose-train collisions per year in control sections (open circles) and sites allocated to remedies (black circles) in Rendalen and Stor-Elvdal municipalities, Hedmark County, Norway, from July 1990 through April 2003. Note that the site-specific deviation between these 2 was the response in our analyses. The linear predictor was positive in control sections (dotted line: F1,16 = 5.42, p = 0.033) and constant in remedy sections (continuous line: F1,16 = 0.18; p = 0.676). Removing the 2 outlying years with very few expected number of collisions (1988 and 1989) did not have any substantial effect on the analysis.

Table 1. A breakdown of the economics of remedies, assuming the number of moose killed per km in the remedy sections before application of a remedy. We calculated the costs and benefits based on 18 km, as this was the length applied with feed. Income per moose was limited to meat value.

Description	Suplemental feeding	Forest clearing
Background numbers		
Moose killed / km and year	0.82	0.82
Length of application (km)	18.0	18.0
Costs of remedy (per km)[a]	1,000	500
Efficiency of remedy	40%	49%
Number of moose saved[b]	5.9	7.2
Economic calculations		
Cost per year (US$)	18,000	9,000
Total income (US$)[c]	8,260	10,080
Total Profit (US$)	–9,740	1,080
Profit per km (US$)	–541	60

[a] Costs associated to supplemental feeding are actual values (K. Nicolaysen, Stor-Elvdal Landowner Organization, personal communication), while cost of forest clearing and meat income (US$1,400 per moose) are approximate values (Storaas et al. 2001).

[b] The number of moose saved is the product of moose killed, length of application, and efficiency of remedy.

[c] Total income is the product of income per moose and number of moose saved.

a reduction in number of accidents compared to control sections. Remedies prevented the general increase in collisions that we observed in control sections. We are confident that the reduced collision rate was due to the applied remedies since the beneficial reduction in collisions took place in 30 out of the 31 analyzed sites.

Scent-marking showed the highest average effect (85%) on reducing the number of collisions. In an experimental study, Lutz (1994) was not able to show that Duftzaun® reduced the number of ungulate-vehicle accidents in the long term. The high variation in our estimates of the success of scent might be due to the remedy being applied only in 500-m long distances. Such short distances yield small and accidental numbers of collisions and thus high variation. Scent-marking is, however, a method that might be worth pursuing if applied over longer distances or in combination with other treatments, such as forest clearing.

Forest clearing was applied for various distances along the train track, and its beneficial effect in reducing collisions was similar to what was found previously for moose–train collisions in Norway (Jaren et al. 1991). Forest clearings not only hinder the animal from browsing near the road/railroad but also reduce the time spent near roads or rail-lines since the animals move straight across the clearing (Jaren et al. 1991). Furthermore, forest clearings increases the visibility of moose for the locomotive conductor (or car–driver; Bashore et al. 1985).

Supplemental feeding of ungulates has frequently been applied as an emergency measure during hard winters (Cederlund 1982, Ozoga and Verme 1982, Baker and Hobbs 1985, Boyce 1989, Aagnes and Mathiesen 1995, Ouellet et al. 2001) and reduced the number of mule deer-vehicle collisions (Wood and Wolfe 1988). Our results suggest that feeding stations located at the side-valleys that guide moose to their winter range in Østerdalen might reduce collisions along the outlet of the valley. This might occur because fewer moose migrate all the way to the winter range, or they postpone their migration and thus spend a shorter time in the risky areas. However, feeding might only have a beneficial effect in certain areas characterized, for instance, by migration. The use of feeding stations by moose and its effectiveness at reducing forest damage has been described elsewhere (Gundersen et al. 2005). Hence, feeding stations might actually alter moose behavior in ways that are beneficial for industrial forestry and moose–vehicle accidents. The effect of feeding stations probably depends strongly on their location. Consequently, knowledge about the spatial distribution of local moose population is crucial. More studies on the allocation of feeding stations are needed.

The 3 methods applied were not instituted with a predetermined experimental design but rather as a practical experiment to reduce collisions. However, the application of several different treatments within the same general area provided an opportunity to compare the effect of various techniques. Complications arose, however, due to the yearly variation in winter conditions associated with the number of accidents. For this reason, we analyzed the yearly difference in the number of accidents within remedy sections (observed) and the number of accidents in control sections (expected). Furthermore, the number of collisions was highly site-specific (Gundersen et al. 1998) which hampers the comparison between remedies applied in different sites. However, the replicates (3–20) of each remedy may reduce some of the temporal site-specific factors that might confound the analyses, whereas the constant innate factors of site are taken into account as a random factor.

Other remedies have been suggested and applied in an attempt to reduce ungulate–vehicle accidents (see Bruinderink and Hazebroek 1996, Romin and Bissonette 1996, and Putman 1997 for reviews). For a remedy to have any effect it must prompt the animal to run away or otherwise change its behavior. Fencing is presumably the most effective way to prevent ungulate–vehicle accidents (e.g., Falk et al. 1978, Ludwig and Bremicker 1983), but its application is limited because it is expensive (Reed et al. 1982). The main problem with erecting a fence, however, is that it interferes drastically with the animals' normal movement patterns. Well-built bypasses, under, over, or at ground level limit the interference with the animals' movements (Reed et al. 1975, Reed 1981, Lehnert and Bissonette 1997), but they increase the economic costs considerably (Reed et al. 1982).

Our results suggest that remedies to reduce ungulate-vehicle accidents are generally beneficial, but they do not completely eliminate collisions. The reduction of such accidental mortality gives wildlife managers more predictable estimates of the population size when, for instance, planning hunting quotas. Reducing accidents might have substantial economic benefits (Jaren et al. 1991). There seems to be a net economic benefit of remedies according to our simple calculation; however, a more detailed and long-term, bio-economic analysis is needed. For instance, forest clearing is expensive to initiate, but it has a low maintenance cost and may be beneficial over the long-term. The long-term economic profit of remedies that we analyzed should be compared to the building of fences and bypasses that can be comparatively costly. A bio-economic approach should preferably include a cost–benefit analysis at the level of landowners, local community, and national society. This is important since collisions mean not only a loss of meat and hunting revenue at the local level but also more widespread costs such as personal stress and injuries.

MANAGEMENT IMPLICATIONS

Due to temporal and spatial differences in the application of the remedies, we can not strongly recommend 1 remedial action over another. Although scent-marking showed the best average effect, it was highly variable and the technique was questioned by Lutz (1994). Supplemental feeding seemed to be beneficial, but it is expensive on a yearly basis. Forest clearing may be more economical from a long-term perspective because initial cutting is the main expense. Whatever remedial action is chosen, we expect the best results when it is applied over long distances because the high-risk areas change considerably from year to year and may be unpredictable (Gundersen et al. 1998).

However, the selected mitigation also has to depend on the impact on the whole ecological community. For instance, forest clearing may affect the mobility of species that need cover to move safely, and feed increases browsing considerably close to feeding stations (Gundersen et al. 2005) with unknown consequences for the forest community or the economic consequences for the landowner.

ACKNOWLEDGMENTS

We thank The Norwegian National Rail Administration for financial support and for providing the data. We also thank E. B. Nilsen for valuable comments on the manuscript and K. Wibe and 2 anonymous reviewers for linguistic improvements.

LITERATURE CITED

AAGNES, T. H., AND S. D. MATHIESEN. 1995. Round baled grass silage as food for reindeer in winter. Rangifer 15:27–35.

ANDREASSEN, H. P., H. GUNDERSEN, AND T. STORAAS. 1997. Game-vehicles in Østerdalen. Part 1: remedial actions to reduce the presence of moose along the railroad. Hedmark University College report 5.

BAKER, D. L., AND N. T. HOBBS. 1985. Emergency feeding of mule deer during winter: tests of a supplemental ration. Journal of Wildlife Management 49:934–942.

BASHORE, T. L., W. M. TZILKOWSKI, AND E. D. BELLIS. 1985. Analysis of deer–vehicle collision sites in Pennsylvania USA. Journal of Wildlife Management 49:770–774.

BOYCE, M. S. 1989. The Jackson elk herd. Intensive wildlife management in North America. Cambridge University Press. Cambridge, New York, USA.

BRUINDERINK, W. T. A. G., AND E. HAZEBROEK. 1996. Ungulate traffic collision in Europe. Conservation Biology 10:1059–1067.

CARBAUGH, B., J. P. VAUGHAN, E. D. BELLIS, AND H. B. GRAVES. 1975. Distribution and activity of white-tailed deer along an interstate highway. Journal of Wildlife Management 39:570–581.

CEDERLUND, G. 1982. Mobility response of roe deer (*Capreolus capreolus*) to snow depth in a boreal habitat. Swedish Wildlife Research 12:39–68.

CHILD, K. N. 1983. Railways and moose in the central interior portion of British Columbia: a recurrent management problem. Alces 19:118–135.

———, S. P. BARRY, AND D. A. AITKEN. 1991. Moose mortality on highways and railways in British Columbia. Alces 27:41–49.

CLEVENGER, A. P., B. CHRUSZCZ, AND K. E. GUNSON. 2001. Highway mitigation fencing reduces wildlife-vehicle collisions. Wildlife Society Bulletin 29:646–653.

FALK, N. W., H. B. GRAVES, AND E. D. BELLIS. 1978. Highway right-of-way fences as deer deterrents. Journal of Wildlife Management 42:646–650.

GLEASON, J. S., AND A. JENKS. 1993. Factors influencing deer-vehicle mortality in east central South Dakota. Prairie Naturalist 25:281–288.

GUNDERSEN, H., AND H. P. ANDREASSEN. 1998. The risk of moose *Alces alces* collision: a predictive logistic model for moose-train accidents. Wildlife Biology 4:103–110.

———, ———, AND T. STORAAS. 1998. Spatial and temporal correlates to Norwegian moose-train collisions. Alces 34:385–394.

———, ———, AND ———. 2005. Supplemental feeding of migratory moose Alces alces: forest damages at two spatial scales. Wildlife Biology 10:213–223.

JAREN, V., R. ANDERSEN, M. ULLEBERG, P. H. PEDERSEN, AND B. WISETH. 1991. Moose–train collisions: the effects of vegetation removal with a cost-benefit analysis. Alces 27:93–99.

LEHNERT, M. E., AND J. A. BISSONETTE. 1997. Effectiveness of highway crosswalk structures at reducing deer-vehicle collisions. Wildlife Society Bulletin 25:809–818.

LEHTIMAKI, R. 1981. Fences for protection of traffic and deer. Summary. Transport and Road Research Laboratory, Helsinki, Finland.

LITTELL, R. C., G. A. MILLIKEN, W. W. STROUP, AND R. D. WOLFINGER. 1996. SAS systems for mixed models. SAS Institute, Cary, North Carolina, USA.

LUDWIG, J., AND T. BREMICKER. 1983. Evaluation of 2.4m fences and one-way gates for reducing deer–vehicle collisions in Minnesota. Transportation Research Record 913:19–22.

LUTZ, W. 1994. Trial results of the use of a "Duftzaun®" (scent fence) to prevent game losses due to traffic accidents. Zeitschrift fuer Jagdwissenschaft 40:91–108.

MCDONALD, M. G. 1991. Moose movement and mortality accosiated with the Glenn Highway expansion, Anchorage Alaska. Alces 27:208–219.

MILLER, B. K., AND J. A. LITVAITIS. 1992. Use of roadside salt licks by moose *Alces-alces* in northern New Hampshire. Canadian Field Naturalist 106:112–117.

MODAFFERI, R. D. 1991. Train-moose kill in Alaska: characteristics and relationships with snowpack depth and moose distribution in lower Susitna Valley. Alces 27:193–207.

OUELLET, J.-P., M. CRÊTE, J. MALTAIS, C. PELLETIER, AND J. HUOT. 2001. Emergency feeding of white-tailed deer: test of three feeds. Journal of Wildlife Management 65:129–136.

OZOGA, J. J., AND L. J. VERME. 1982. Physical and reproductive characteristics of a supplementally-fed white-tailed deer herd. Journal of Wildlife Management 46:271–301.

PETERSON, C. J., AND O. DANELL. 1992. Simulated production losses in reindeer herds caused by accidental death of animals. Rangifer 12:143–150.

PUTMAN, R. J. 1997. Deer and road traffic accidents: options for management. Journal of Environmental Management 51:43–57.

REA, R. V. 2003. Modifying roadside vegetation management practices to reduce vehicular collisions with moose *Alces alces*. Wildlife Biology 9:81–91.

REED, D. F. 1981. Mule deer behavior at a highway underpass exit. Journal of Wildlife Management 45:542–543.

———, T. D. I. BECK, AND T. N. WOODARD. 1982. Methods of reducing deer-vehicle accidents: benefit-cost analysis. Wildlife Society Bulletin 10:349–354.

———, T. N. WOODARD, AND T. M. POJAR. 1975. Behavioral response of mule deer to a highway underpass. Journal of Wildlife Management 39:361–367.

ROMIN, L. A., AND J. A. BISSONETTE. 1996. Deer-vehicle collisions: status of state monitoring activities and mitigation efforts. Wildlife Society Bulletin 24:276–283.

STATISTICS NORWAY. 2003. Registered non-harvest mortality of cervids, by causes. 1998/99–2002/03. Available at http://www.ssb.no/english/subjects/10/04/10/hjortavg_en/tab-2003-09-29-01-en.html. Accessed 2004 Aug17.

STORAAS, T., H. GUNDERSEN, H. HENRIKSEN, AND H. P. ANDREASSEN. 2001. The economic value of moose—a review. Alces 37:97–107.

WOOD P., AND M. L. WOLFE. 1988. Intercept feeding as a means of reducing deer-vehicle collisions. Wildlife Society Bulletin 16:376–380.

Associate Editor: Hudson.

http://missoulian.com/news/state-and-regional/trains-kill-more-than-antelope-and-deer-on-montana-tracks/article_3d955d6a-4831-11e0-84f6-001cc4c03286.html

Trains kill more than 800 antelope and deer on Montana tracks this winter

March 06, 2011 1:26 pm • By the Associated Press

GREAT FALLS - Hundreds of pronghorn antelope and deer have been killed by trains in Montana this winter after herds gathered on tracks to escape deep snows, a state wildlife official says.

Mark Sullivan, of Fish, Wildlife & Parks, said that a train recently killed about 270 pronghorn antelope near Vandalia in northeastern Montana, and 18 deer were found dead on the tracks by a grain elevator near Chinook.

Many antelope not killed by the impact had be destroyed by Blaine County authorities.

"To hunt and shoot animals is just different than shooting wounded animals like that," Blaine County Undersheriff Pat Pyette told the Great Falls Tribune. "You're close to it. You can look into their eyes. We see a lot of things, but (the deputy) was sick to his stomach after that."

Sullivan said hundreds of animals have been hit on Montana's Hi-Line.

"This is an exceptional winter on the Hi-Line," he said. "The numbers are getting close to 800 animals reported, and I'm sure there are a fair number of animals killed by trains that we don't know about."

Burlington Northern Santa Fe spokesman Gus Melonas said because of the deep snow, the company this year is working with state officials to track deer and antelope deaths. He said the company has always worked with Glacier National park to track the number of moose and bears killed by trains.

"The trains are designed to blow away the light snow, so to those animals it's clear ground for them," Melonas said. "Because of the weather, the animals migrated to the path of least resistance, and that's the railroad, unfortunately."

He said railroad truck drivers are called in to scare animals away from tracks when train operators spot a large herd. Also, he said, the company is trying not to leave grain and corn that might attract deer and antelope to the tracks.

The winter in general has been tough on wildlife, Sullivan said, and a prediction of a cold and snowy March has wildlife managers concerned.

"These animals have been fighting winter since November," he said. "How the spring is will have a lot to do with how many animals make it out alive."

Craig Miller, a biologist with the Bureau of Land Management, has tracked pronghorn migration for the last four years. He said he has lately spotted scattered groups of animals rather than the herds of hundreds he saw at the start of the winter.

"Perhaps they've broken into smaller groups, but I have a feeling that winter kill is going to be pretty high," he said.

Wildlife managers plan flights in April to count deer, and in July will count antelope when the animals return to summer feeding grounds. The number of hunting licenses will be set based on those numbers.

"I'm sure we'll be dropping our license numbers a fair amount so the animals can rebuild," Sullivan said.

RELATIONSHIP OF REDUCED TRAIN SPEED ON MOOSE-TRAIN COLLISIONS IN ALASKA

Earl F. Becker[1] and Carl A. Grauvogel[2]
[1]Alaska Department of Fish & Game, 333 Raspberry Road, Anchorage, AK 99518; [2]P.O. Box 1062, Palmer, AK 99645.

ABSTRACT: An experiment to test the effect of track site, train speed, direction of train travel, and train run (first versus second round trip of the day), on moose-train collision mortality along the Alaska Railroad in the lower Susitna River Valley of Alaska, was conducted in February 1988. Reduction of train speed from 79 kmph to 40 kmph did not result in a significant reduction in the number of moose hit by trains (P = 0.439), even though the probability of detecting a major reduction was substantial. Significantly more moose were hit in the northern test section than along the southern test section of track (P = 0.096) of the Alaska Railroad.

ALCES VOL. 27 (1991) pp.161-168

Collision with vehicles can be a major cause of moose (*Alces alces*) mortality especially where high speed highways transect heavily used moose winter range (Bangs *et al.* 1989). Collisions with trains are less widespread, but can become a major source of mortality in some areas. Muzzi and Bisset (1990) report that 40-50 moose per year are struck and killed by trains along a 225 km section of track in Ontario. Child (1983) estimated that annual moose mortality due to trains in the central interior of British Columbia range from hundreds to in excess of 1000 moose in winters of record snowfall. Similarly, the Alaska Railroad (ARR) has documented a mortality of 3054 moose in train collisions between May 1963 and April 1990, with an annual mortality ranging from 9 to 725 (Modafferi 1991a). During the winter of 1987-88, 173 moose were struck and killed by trains in Game Management Unit (GMU) 14B, a 5594 km^2 area in southcentral Alaska, in comparison to 43 by automobiles and 347 by hunters (Grauvogel 1990). The number of moose killed by trains in GMU 14B dropped to 87 during the winter of 1988-89 compared to 40 by automobiles and 140 by hunters (Grauvogel 1990). During the winter of 1989-90, record snowfalls resulted in a record 351 moose killed by trains and 47 by automobiles in GMU 14B, (Masteller pers. comm.) while hunters harvested 173 moose (Morgan 1991). This mortality coupled with poor overwinter survival caused an estimated 35% reduction in the GMU 14B moose population (Abbott 1991) and a closure of the moose hunting season (Morgan, 1991).

The ARR originates at the coastal port of Seward and extends approximately 756 km north through southcentral and interior Alaska to Fairbanks. Most moose-train collisions occurs in GMU 14B between Wasilla, ARR milepost (MP) 160, and Chulitna (MP 273) where the right-of-way passes through an important moose winter range on the lower Susitna River floodplain and nearby nonriparian lowland habitat (Modafferi 1991a). The number of moose inhabiting this area and the duration of use depends primarily upon timing and quantity of snowfall and the persistence of snowcover (Modafferi 1988, 1991b). The greatest concentration of moose occurs when deep snow persists into late winter covering browse species at higher elevations (Rausch 1958, Modafferi 1988). The ARR and the Alaska Department of Fish and Game (ADF&G) discussed various options for reducing this moose-train collision mortality, including reducing train traffic, reducing train speeds, and increasing the frequency of snow plowing. Reduced train speed was identified as one of the most feasible options.

METHODS

The experiment was conducted on a 85.3 km section of ARR track between Talkeetna (MP 225) and Houston (MP 173) (Fig. 1) from February 16-23, 1988, when snow depths exceeded 76 cm. This area was selected because it had the highest incidence of reported moose mortality, due to collisions with trains, along the entire track (Modafferi 1991a). This section of track also parallels the lower Susitna River Valley, which is an area used as winter range by a population of moose from the east and a population of moose from the west of the Susitna River (Modafferi 1988, 1991b).

A stepwise regression analysis (Neter and Wasserman 1974) of the 1984-85 winter moose kill on the ARR in GMU 14B was conducted to determine if factors such as snow depth, snow fall, temperature, train frequency, train type (freight, passenger), train timing (day, night), and previous moose-train collision mortality were associated with high moose collision mortality. A square root transformation was used on the kill data (Snedecor and Cochran 1980). The experiment was initiated when factors identified by the above analysis were present.

A 2^4 incomplete factorial repeated measures experimental design (Winer 1971:604-684, Milliken and Johnson 1984:80-84), was used to test the hypothesis that slower train speeds reduce the number of moose killed by trains. The train was run at 79 kmph (49 mph) along one-half of the test section of track between Talkeetna and Houston, and at 40 kmph (25 mph) along the other half. A speed of 79 kmph is the regular operating speed of trains and was used as the experimental control, whereas 40 kmph was the slowest speed which the ARR believed to be economically feasible for testing. To break the test section of track into 2 sites the Kashwitna River bridge, MP 199, was used as the halfway point (Fig. 1). On the return trip train speeds were reversed. A total of 2 round trips were run each day, with the speed in the second run being the reverse of the first run. The experiment was conducted for 8 consecutive days with the speeds reversed for each site-direction-run combination of the previous day (Fig. 2). In addition to testing for a train speed

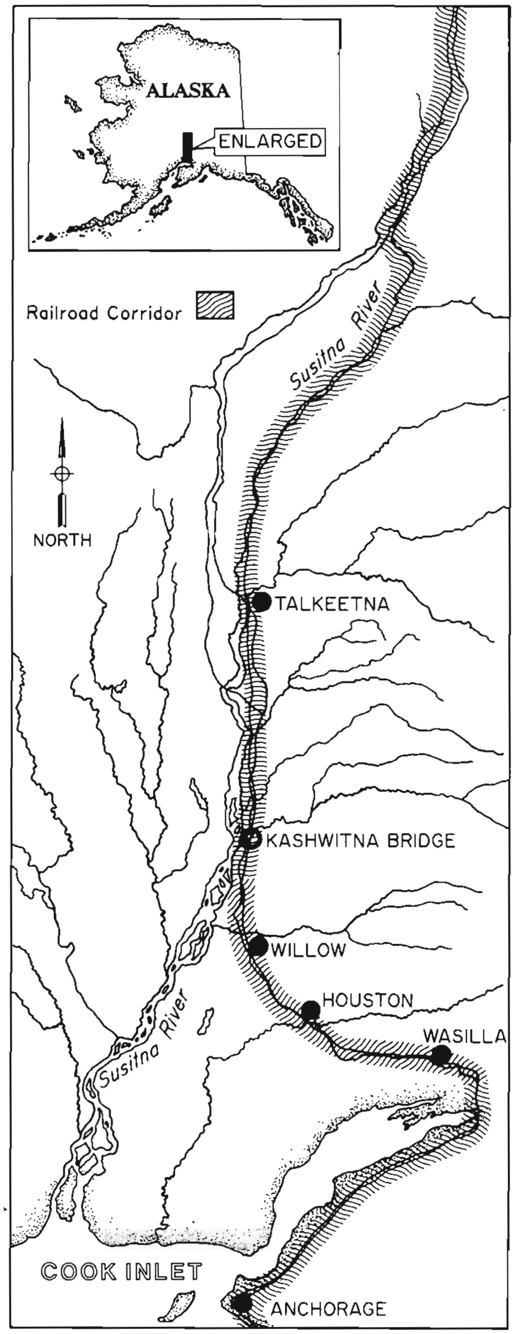


Fig. 1. The location of the Alaska Railroad rail line in the lower Susitna River valley, Alaska.

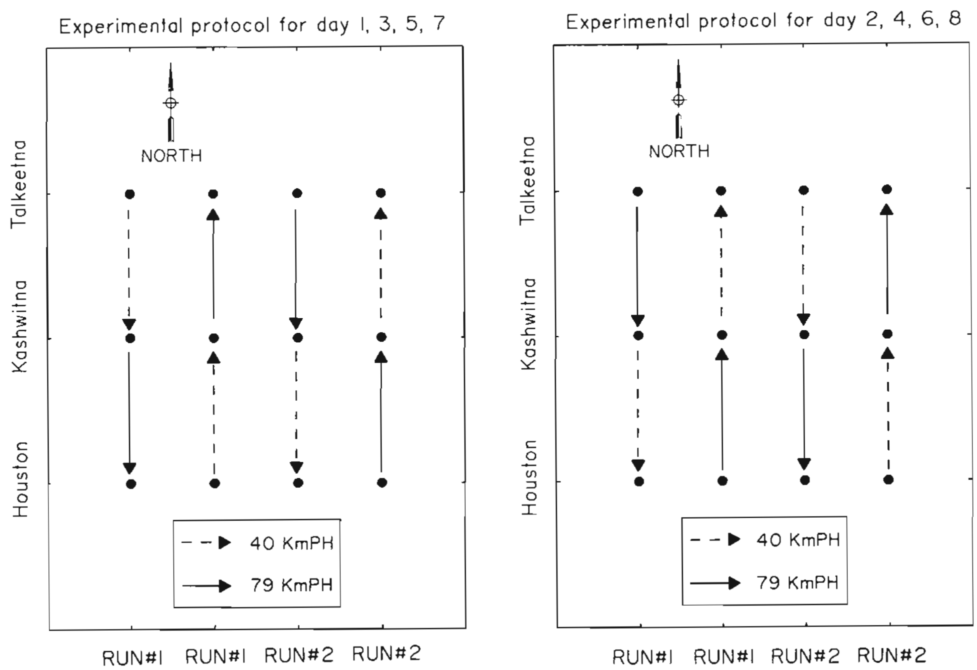


Fig. 2. Schematic of the 2^4 repeated measures factorial design employed from 16-23 February, 1988, in the lower Susitna River valley, Alaska, to determine the effects of track site, train speed, direction, and run on moose-train collisions.

effect; site, train direction, train run, and 3 of 11 possible interactions: train speed by train direction, train speed by site, and train direction by site; were tested for. It was felt that the other interactions were not biologically meaningful.

Snow depth on the tracks was removed as a variable by wing-plowing the tracks 5.5 m off the center line. The ARR provided two 2,500 HP locomotives (model GP35 manufactured by General Motors), connected back to back, so that after each run the crew could move to the other locomotive for the return trip.

The study was terminated when the sample size (number of moose struck) was large enough to ensure that the power to detect a 2:1 difference in the number of moose hit by the 79 kmph vs 40 kmph train was near 80%, at α=0.20. If reduced speeds resulted in fewer moose being struck, it was hoped that additional support could be obtained from the ARR to determine if the reduction was significant at an alpha of 0.05 with a power of 80%. The site, train direction, and train run main effects and the 3 interactions listed above were tested at a=0.10.

After the first day of the experiment, we modified the operational procedures to avoid killing moose. Instead of maintaining a steady 40 or 79 kmph, we instructed the train engineer to abruptly apply full braking when we were sure that continuing on at the designated speed would overtake the moose and kill it. Cows with calves were treated as one observation because the fate of the calf was dependent upon the behavior of the cow. Other than changing train speed, the engineer followed normal ARR operating procedures during the course of the study, these included using train whistles and lights to try to scare the moose off the tracks.

RESULTS

Regression Results

The regression model (Table 1) explained

Table 1. Linear regression coefficients for the square root of train moose kill in Alaska Game Management Unit 14 B for the winter of 1984-85.

	Coefficient	
Variable	Estimate	SE
Y-intercept	1.5074	0.1924
IMAV3SNF[a]	0.6942	0.1398
MAVPNOK[b]	-1.4447	0.2656
INTERACT[c]	-0.5391	0.2653
PREVKILL[d]	-0.2779	0.0919

[a]- Denotes a moving average of the previous 3 days snow fall when ground snow is 91.44 cm or greater, otherwise 0 is used.

[b]- Denotes the proportion of the previous 7 days in which 0 moose were killed.

[c]- Denotes an interaction term between IMAV3SNF and MAVPNOK.

[d]- Denotes the square root of the number of moose killed in the previous day.

a significant ($F_{4,132}$ = 29.389, P = 0.000) amount of the variation in moose kill along the tracks. The following explanatory variables were included in the final model: a moving average of snow fall on the previous 3 days when snow depth $\geq$91.4 cm. (IMAV3SNF), a moving average of the proportion of the previous 7 days in which 0 moose were killed (MAVPNOK), an interaction term between these 2 moving averages (INTERACT), and the square root of the number of moose killed on the previous day (PREVKILL). There was no positive serial correlation (Neter and Wasserman 1974) in the residuals (Durbin-Watson statistic = 2.021, p-1 = 4, n = 137). This model predicted that moose mortality due to collisions with trains would be high immediately following a snowstorm, when snow depths exceed 91 cm and the daily incidence of trains missing moose is low. The experiment was implemented when the above conditions were present.

Treatment Effects

During the study a total of 29 moose were 'struck' by the train, of which 20 were 'paper strikes' and 9 were actual collisions. Of the 20 moose recorded as 'paper strikes', 8 came to within 3-7 m of being struck by the deaccelerating train, 2 were missed by a matter of centimeters, and one was bumped. One collision occurred during braking when the train blew a fuse, and as a result, the brakes failed and the moose was killed. The effect of reducing train speed was not significant (P =

Table 2. Analysis of variance for a 2^4 incomplete factorial, repeated measures experiment on moose struck by trains in the lower Susitna River Valley, Alaska.

Source of Variation	MS	DJ	F	P-value
Train Speed (79,40)	0.0165	1	0.024	0.439[a]
Direction (North, South)	0.141	1	0.214	0.646
Site (MP 215-199, 199-173)	1.891	1	2.882*	0.096
Run (First, Second)	0.016	1	0.024	0.878
Speed x Direction	0.141	1	0.214	0.646
Speed x Site	1.266	1	1.930	0.171
Directon x Site	1.266	1	1.930	0.171
Error	0.656	49		

[a]Significant at = 0.20

α = 1 sided test

0.439) (Table 2). Of the 29 moose struck, 14 (48.3%) were hit by the 40 kmph train and the remaining 15 (51.7%) by the 79 kmph train. The site effect was significant (P = 0.096); 20 moose were struck in the northern site, while 9 were struck in the southern site.

The power curve for this experiment (Figure 3) indicates that a true difference of 20:9 in the number of moose struck by the 79 versus 40 kmph trains would result in a significant test statistic 80% of the time. This experiment had a high probability (large power) to detect differences of 2:1 or greater in the number of moose struck by the 79 versus 40 kmph trains.

Moose Behavior

Most moose 'struck' by the train behaved similarly. When first observed moose were usually standing or walking on the railroad bed, often between the rails. Most animals retreated from the train and increased the speed of their escape. Some moose would trot at a slow to medium gait; others would run (sometimes 24-32 kmph) as the train approached. Nearly all moose ran down the center of the track. Because of faster train speeds, moose running on the track were overtaken by the train. Moose recorded as a 'paper' strike often continued to trot in front of the train, sometimes for distances of over 2 km. Moose exhibited a strong tendency to remain on the track when chased, even if exhausted. However, when the train stopped, moose generally left the track after moving 200m. Most moose that were encountered on the track, but not recorded as a 'strike', were crossing the track and apparently not affected by the approaching train.

Moose generally avoided crossing railroad bridges. In one instance a train had slowed down to 5 mph to avoid hitting a moose. The moose trotted up to an unplanked railroad bridge and then turned, and walked back toward the slowly approaching train. After a few minutes of indecision the moose exited the tracks.

DISCUSSION

The main goal of this experiment was to determine if slower train speed would reduce moose kill adequately to solve this pressing management problem. Moose kill reduction had to be substantial to justify the economic costs of using slower train speeds. A 2:1 reduction seemed to be the minimum size which would meet this criteria. A reduction of this magnitude would have reduced the 1987 train kill of moose in GMU 14B from 173 (Grauvogel 1990) to 87 moose.

In our opinion, every animal recorded as a 'paper strike' would have been killed if the braking order was not given. This opinion is supported by the fact that 1 moose was struck and killed during a temporary brake failure and the proximity of the train to the other moose at the time of braking. Additionally, moose which collided with the train and were killed did not exhibit a last second attempt to jump out off the track.

Our results demonstrate that slowing ARR trains to 40 kmph does not result in a significant (2:1) reduction in the moose hit by trains in the lower Susitna River Valley. Obviously there exists train speeds below 40 kmph which would result in lower moose mortality. These speeds were not considered in this experiment, because the ARR would not have been able to implement slower speeds due to economic considerations. These results are probably applicable to any railroad right-of-way where snow depths exceed 76 cm and snow density off the railroad bed hinders the ability of moose to run.

We found differences in the number of moose struck by trains at the 2 different sites, with the northern site having a significantly higher rate of strikes. Abandoned homesteads with early successional stages of birch, willow, and aspen are more common in the northern site. The site difference may have occurred because more moose were wintering at the northern site in the vicinity of the tracks.

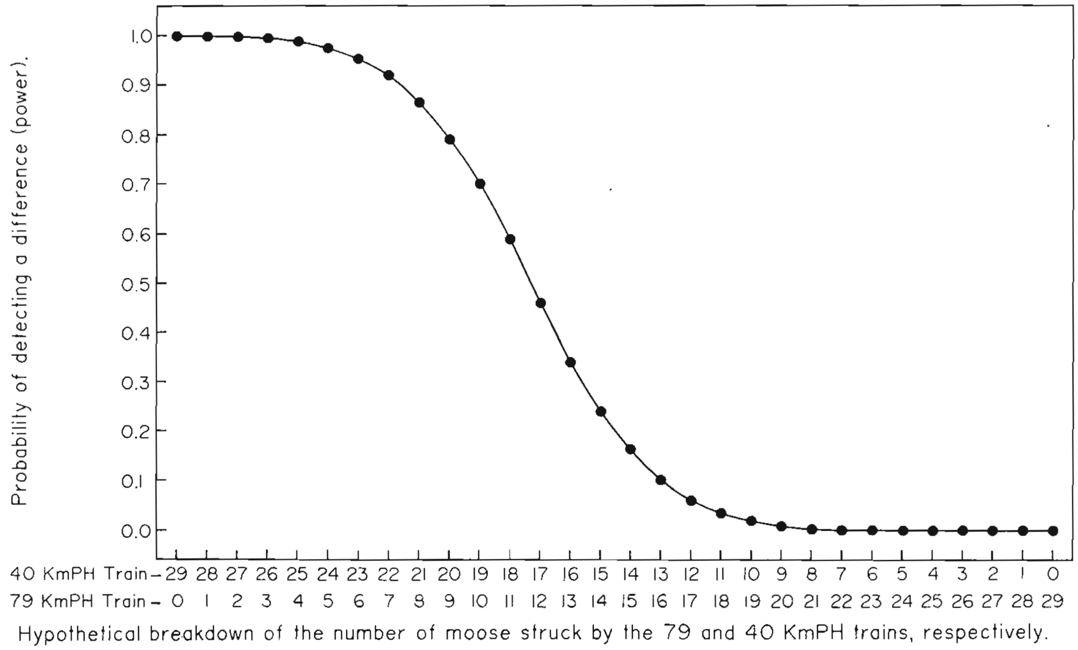


Fig. 3. Power curve for detecting if 40 kmph trains strike fewer moose than 79 kmph trains, at alpha = 0.2.

In order to obtain a more powerful test of the speed effect and separate the effects of potentially confounding factors, such as train direction, site, and run, the 2^4 incomplete factorial design was used instead of a one-way ANOVA or chi-square analysis. This design can be thought of as a specialized ANOVA and has the same assumptions as an ANOVA (normality, independence, and constant variance) plus a sphericity assumption on the residuals of the repeated observations at a site within a given day (Winer, 1971). In this design, the site becomes the experimental unit with regard to testing for a train speed effect, and hence 8 observations about this effect were made every day and a total of 49 df were associated with the variance (MSE) (Table 2) used in testing for a speed effect.

Ideally, the sample size would have been sufficient for the experiment to have large power to detect 2:1 differences with an alpha of 0.05. The duration of the experiment and thus the sample size, was constricted by the high cost of running a special train at an isolated location, and as a result, we had to choose between making a type I or II error (Ostle and Mensing 1982). In the context of this problem, it was much more important to identify a potential solution then to 'fail to detect' a difference due to inadequate sample size. If a significant difference was observed at a=0.20, subsequent data could have been collected to reduce the probability of a type I error while still maintaining large power. Sequential testing of data is often used in clinical experiments (Anscombe 1963, Berry 1989), and could have been used to obtain valid experimental results if subsequent data were collected. The other comparisons were done with an alpha of 0.10 to increase the ability of the experiment to identify potential factors which are important sources of variation in the number of moose struck in this section of track. No follow up study of significant results for these factors (train direction, train run, and track site) was planned because of the expense and the inability to reduce these factors with regard to railroad operations.

Most of the struck moose were using the tracks as a trail or corridor to make north-south movements. The majority of these had sufficient time to exit the tracks, but they usually tried to out run the train. Child (1983) observed similar moose behavior in Canada. He hypothesized that fleeing from oncoming trains was part of a moose's anti-predator behavior.

Our study and Child's (1983), found that moose have a strong tendency to stay on the tracks when fleeing trains. In our study, snow depth was approximately 90 cm, and when a moose left the track it floundered. Child's (1983) moose anti-preditor hypothesis coupled with moose floundering in deep snow off of the tracks would explain the reluctance of moose to leave the tracks.

ACKNOWLEDGEMENTS

We express our gratitude to R. Modafferi and N. Steen for assisting in the data collection, and P. Shake, G. Beitinger, C. Brown, D. Lamb, and D. Reedy, for their expert operation of the train, cooperation, patience, and many helpful suggestions. K. Schneider, D. Reed, and S. Miller, provided constructive comments. We gratefully acknowledge the insightful review, comments and advice by K. Child and an anonymous reviewer. The Alaska Railroad provided the train and crew to run the experiment. Federal Aid in Wildlife Restoration and the Alaska Department of Fish and Game provided funding for this work.

REFERENCES

ABBOTT, S. M., ed. 1991. Annual performance report of survey-inventory activities. Moose. Vol XXII, Part VIII. Alaska Dep. Fish and Game. Fed. Aid in Wildl. Rest. Proj. W-23-4, Study 1.0. 41pp.

ANSCOMBE, F. J. 1963. Sequential medical trials. J. Am. Statistical Asoc. 58:365-383.

BANGS, E. E., T. N. BAILEY, and M. F. PORTER. 1989. Survival rates of adult female moose on the Kenai Peninsula, Alaska. J. Wildl. Manage. 53(3):557-563.

BERRY, D. A. 1989. Monitoring accumulating data in a clinical trial. Biometrics 45:1197-1211.

CHILD, K. N. 1983. Railways and moose in the central interior of British Columbia: a recurrent management problem. Proc. N. Amer. Moose Conf. Workshop 9:118-135.

GRAUVOGEL, C. A. 1990. GMU 14B - Western Talkeetna Mountains (Willow to Talkeetna). Pages 127-137 in S. O. Morgan, ed. Annual report of survey-inventory activities. Part VIII. Moose. Vol. XX. Alaska Dept. Fish and Game. Fed. Aid in Wildl. Rest. Prog. Rep. Proj. W-23-2. Study 1.0. Juneau. 428pp.

MILLIKEN, G. A., and D. E. JOHNSON. 1984. Analysis of Messy Data, Vol. I: Designed Experiments. Van Nostrand Reinhold, New York, N.Y. 473pp.

MODAFFERI, R. D. 1988. Big game studies. Vol. I Moose-Downstream. Final Report Susitna Hydroelectric Proj. Alaska Dep. Fish and Game. Juneau. 211pp.

_______. 1991a. Train moose kill in Alaska: characteristics and relationship with snowpack depth and moose distribution in lower Susitna Valley. Alces 27:193-207.

_______. 1991b. Lower Susitna valley moose population identity and movement study. Alaska Dep. of Fish and Game. Fed Aid in Wildl. Rest. Research Prog. Rep. Project W-23-3 Study 1.38. 96pp.

MORGAN, S. O., ed. 1991. Annual performance report of survey-inventory activities. Moose. Vol XXI, Part VIII. Alaska Dep. Fish and Game. Fed. Aid in Wildl. Rest. Proj. W-23-3, Study 1.0. 32pp.

MUZZI, P. D.., and A. R. BISSET. 1990. Effectiveness of ultrasonic wildlife warning devices to reduce moose fatalities

along railway corridors. Alces. 26:37-43.
NETER, J., and W. WASSERMAN. 1974. Applied linear statistical models. Irwin Inc. Homewood, Ill. 842pp.
OSTLE, B., and R. W. MENSING. 1975. Statistics in research, 3 rd Ed. Iwoa State Univ. Press. Ames, Iowa. 596pp.
RAUSCH, R. A. 1958. The problem of railroad-moose conflicts in the Susitna Valley. Alaska Dep. Fish and Game. Fed. Aid in Wildl. Rest. Final Rep. Proj. W-3. Job 1-4. Juneau. 116pp.
SNEDECOR, G. W., and W. G. COCHRAN. 1980. Statistical Methods, 7 th Ed. Iowa State Univ. Press. Ames, Iowa. 507pp.
WINER, B. J. 1971. Statistical Principles in Experimental Design. McGraw-Hill, New York, N.Y. 907pp.

Grizzly Bear Mortality and Human Access in Banff and Yoho National Parks, 1971-98
Author(s): Bryon Benn and Stephen Herrero
Source: *Ursus*, Vol. 13 (2002), pp. 213-221
Published by: International Association for Bear Research and Management
Stable URL: http://www.jstor.org/stable/3873201
Accessed: 04/09/2014 17:25

Your use of the JSTOR archive indicates your acceptance of the Terms & Conditions of Use, available at
http://www.jstor.org/page/info/about/policies/terms.jsp

JSTOR is a not-for-profit service that helps scholars, researchers, and students discover, use, and build upon a wide range of content in a trusted digital archive. We use information technology and tools to increase productivity and facilitate new forms of scholarship. For more information about JSTOR, please contact support@jstor.org.

International Association for Bear Research and Management is collaborating with JSTOR to digitize, preserve and extend access to *Ursus.*

http://www.jstor.org

This content downloaded from 128.114.163.7 on Thu, 4 Sep 2014 17:25:02 PM
All use subject to JSTOR Terms and Conditions

GRIZZLY BEAR MORTALITY AND HUMAN ACCESS IN BANFF AND YOHO NATIONAL PARKS, 1971–98

BRYON BENN, Faculty of Environmental Design, University of Calgary, 2400 University Drive, Calgary, AB T2N 1N4, Canada
STEPHEN HERRERO, Faculty of Environmental Design, University of Calgary, 2400 University Drive, Calgary, AB T2N 1N4, Canada, email: herrero@ucalgary.ca

Abstract: We conducted spatial and temporal analyses to examine the relationship between access, changing grizzly bear management strategies, and grizzly bear (*Ursus arctos*) mortality for 1971–98 in Banff and Yoho National Parks, Canada. We summarized mortality by cause of death, sex, age, and cohort. The annual number of grizzly bear deaths declined significantly between 1971–84 and 1985–98. However, the female portion of this mortality was 80% from 1985–98 compared to 50% during the earlier period. Human-related causes were the primary sources of recorded grizzly bear mortality in the study area (119 of 131 known mortalities). Control of problem bears accounted for 71% of 119 known human-caused mortalities, followed by highway and railway mortalities (19%), unknown cause of death (9%), and research (<1%). All 95 human-caused mortalities with known accurate locations were within 500 m of roads or 200 m of trails. Eighty percent of these mortalities occurred below 2000 m. Kills were concentrated at Banff townsite, Lake Louise, and along the Trans Canada Highway. Management of development, trail access, and human food and garbage are critical for managing grizzly bear mortality in the national parks. We present specific recommendations.

Ursus 13:213–221 (2002)

Key words: access, Banff National Park, Canada, development, grizzly bear, mortality, *Ursus arctos*, Yoho National Park, zone of influence

Grizzly bears in Banff and Yoho National Parks are part of a regional ecosystem in Canada called the Central Rockies Ecosystem (Fig. 1). The Central Rockies Ecosystem is experiencing intensive exploration and development of coal, oil, gas, and timber reserves. Cattle production, housing and highway development, and outdoor recreation are also increasing. Moreover, present attitudes toward the grizzly bear, a potentially dangerous animal (Herrero 1985) and competitor with humans for food and space (Mattson 1990), challenge human–grizzly bear coexistence. As a result, the grizzly bear is suffering from continuing habitat degradation and potentially unsustainable mortality rates in some regions of the Central Rockies Ecosystem (Herrero et al. 2000).

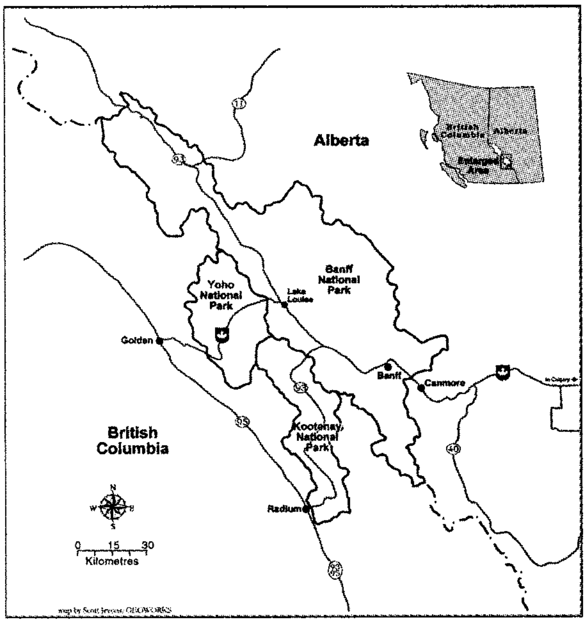


Fig. 1. The National Parks of the Central Rockies Ecosystem.

The national park portions of the Central Rockies Ecosystem continue to experience increases in human use, commercial development, and major transportation expansion with the doubling of the number of lanes of the Trans Canada Highway through Banff National Park (Banff-Bow Valley Study 1996). Grizzly bear hunting occurs on most provincial lands surrounding the parks. Interagency planning for effective land use at the regional scale (Herrero 1994), whereby bears can meet their energetic requirements and encounters between humans and bears can be reduced, may be the best option for reducing grizzly bear mortality (Mattson and Knight 1991).

Natural survival rates for adult grizzly bears in unhunted populations are high and consistent (Knight and Eberhardt 1985, McLellan 1990), whereas young bears die more frequently of natural causes such as intraspecific aggression (Stringham 1983), accidents (Nagy et al. 1983), and nutrition related causes (Nagy et al. 1983, Knight et al. 1988). However, tracking natural mortality is very difficult because habitat is often remote and heavily forested and carcasses are soon scavenged. Nonetheless, natural mortality is probably a minor cause of adult mortality (McLellan et al. 1999). Mortality data from North America show that human-caused mortality far outnumbers natural mortality (Craighead et al. 1988, McLellan 1990, Dood and Pac 1993, Gunson 1995). Historical (Storer and Tevis 1955, Noble 1972, McCrory and Herrero 1982) and recent works (McLellan and Shackleton 1988*a*, Mattson et al. 1996) consistently link the type and degree of human land use with grizzly bear mortality.

Sustainable total and harvest mortality rates for bears have been estimated in computer-simulated populations (Bunnell and Tait 1980, Harris 1986). However, the threshold mortality rate where grizzly bear populations begin to decline can rarely be determined precisely. The

This content downloaded from 128.114.163.7 on Thu, 4 Sep 2014 17:25:02 PM
All use subject to JSTOR Terms and Conditions

determination of population numbers and vital rates for grizzly bears requires long term study, and the number of undetected mortalities is typically estimated by inference. McLellan et al. (1999) used unreported mortality of radiocollared bears from various western cordilleran studies to estimate the percentage of unreported human-caused mortality. They found that management agencies would have only detected 45–51% of human-caused mortality of radiocollared grizzly bears.

Roads are frequently implicated in contributing to increased grizzly bear mortality. They facilitate access for a host of human activities, increase the frequency of energetically costly flight responses, and increase vehicle related mortalities (Mattson et al. 1987, Nagy et al. 1989, Gibeau et al. 1996). As well, roadside vegetation may attract bears to roads, compounding the risk. At some undetermined level of human use, grizzlies, in particular established adult females, cease crossing major transportation corridors (Gibeau and Herrero 1998).

We analyzed grizzly bear mortality for Banff and Yoho National Parks for 1971–98. Results are discussed before and after changes in grizzly bear management strategies and relative to access.

STUDY AREA

The study area was Banff (6,836 km^2) and Yoho national parks (1,313 km^2) (Fig. 1). The vegetation and climate for the entire Central Rockies Ecosystem was described in Benn (1998). Major transportation corridors dissect both national parks. Approximately 58% (4,726 km^2) of the study area is suitable grizzly bear habitat (<2,400 m), above which there is little grizzly bear foraging (Gibeau et al. 2001). Thus, grizzly bear habitat is restricted to major vegetated valley systems. Human use is also concentrated in these valleys. Zones of human influence around trails, roads, and other developments occupy about 25% of the suitable habitat (Gibeau et al. 2001). Grizzly bear population estimates for Banff National Park were 55–85 (G.W. Vroom, 1974, Grizzly and wolf observations, Banff National Park, Banff, Alberta, Canada) and 60–80 (Gibeau et al. 1996).

METHODS

Mortality and translocation databases for grizzly bears were supplied by Banff and Yoho National Parks for 1971–98. Additional mortality records came from other wildlife files provided by Parks Canada Western Region Office, annual warden and superintendent reports, a consultant's report (Millson 1978), and several graduate theses (Noble 1972, Taylor 1984). Mortalities included dead bears, bears translocated to remote areas north and west of the parks that were not known to have returned, translocated bears that died in other jurisdictions, and bears placed in zoos. We used these mortality data to summarize mortality by cause, sex, age, and cohort.

Spatial Analyses

Locations of bear mortalities were referenced to the universal transverse Mercator (UTM) grid to the nearest 100 m and included a descriptor such as a river, creek, or cultural feature. Interviews were conducted with past and present wardens and wildlife managers to collect additional information about specific mortalities and their locations. We classified locations as accurate, reasonable, and estimate. Accurate locations had a UTM designation to ±100 m and a geographic descriptor. Reasonable locations were within some stated distance from a known road, trail, drainage, or development. Mortalities with estimated locations were excluded.

Digital data containing human access information at a scale of 1:50,000 were supplied by Parks Canada. The road layer included railway lines and roads open to the public and negotiable by 2-wheel drive vehicle. The trail layer included roads closed to the public, utility corridors, and any other linear access features accessible by hiking, mountain biking, or horseback.

Access and mortality data were entered into a geographic information system, MapInfo 4.0 (MapInfo Corporation, Troy, New York, USA). Zones of influence (ZOI) of 500 m and 200 m were set around roads and trails, respectively, based on the judgment of the authors. Buffer widths of 500 m for motorized roads and 300 m for non-motorized trails were used in the cumulative effects model for grizzly bear in Yellowstone National Park (Mattson 1999). The Central Rockies Ecosystem has steeper and narrower valleys than Yellowstone, thus we are comfortable with 200 m for non-motorized trails in this forested mountain landscape. Road and trail buffers were combined into a single coverage and the area of overlap was only calculated once. Mortality locations in the area of overlap were analyzed as occurring within road buffers because roads were assumed to have a greater effect on mortality risk than trails.

Mortalities were tallied with respect to proximity to townsites and commercial tourist operations. We assumed that bears were attracted to these areas by the presence of food and garbage (Mattson et al. 1987, Weaver et al. 1987). This assumption was supported by limited data from mortality records and discussions with bear managers.

We recorded the elevation of 95 human-caused grizzly bear mortality locations and the elevations of some tourist destinations and park developments.

This content downloaded from 128.114.163.7 on Thu, 4 Sep 2014 17:25:02 PM
All use subject to JSTOR Terms and Conditions

Temporal Analyses

We stratified mortality data into 2 periods to relate changes in mortality characteristics with changing patterns of human use and evolving management concerns and actions. We chose 1984–85 as the break, although no major changes occurred in any single year. Rather, a series of events in the early 1980s led to a progressive modification in management practices. These events included (1) the 1980 Whiskey Creek bear maulings in Banff National Park (A. Westhaver and A. Williams, 1980, Report of the superintendent's review team on the bear mauling incidents, Banff National Park, Resource Conservation and Interpretive Service, Banff, Alberta, Canada; Herrero 1985), which stimulated improved garbage management and increased efforts at communication and public education with respect to bears, (2) closure of the Banff landfill in 1981, and (3) commencement of fencing of the Trans Canada Highway from Banff's east park gate in 1983. Also, we recognized that it would take a few years for the bear population to adapt behaviorally to events such as the landfill closure. Finally, for ease of comparison, these periods were of equal length (1971–84, 1985–98). The Mann-Whitney *U*-test was used to test for differences in the annual number of grizzly bear deaths between periods, with $\alpha = 0.05$. The following hypotheses were tested:

- H_{01}: The annual number of grizzly bear mortalities in Banff and Yoho National Parks did not decline significantly from 1971–84 to 1985–98.
- H_{02}: The annual number of problem grizzly bear mortalities in Banff and Yoho National Parks did not decline significantly from 1971–84 to 1985–98.

Finally, we analyzed cause of death by seasons. We used 3 seasons of importance to bears (Apr–Jul = preberry, Jul–Oct = berry, Oct–Dec = post-berry).

RESULTS

We collected 108 and 11 records of human-caused mortality from Banff and Yoho National Parks, respectively. The average annual mortality was 4.3 grizzly bears/year, with peaks of 15 recorded deaths in 1972 and 13 in 1980 (Fig. 2).

Management actions and vehicle and train collisions accounted for 71% and 19%, respectively, of the 119 human-caused grizzly bear deaths. The remaining 10% included 1 research related incident and 11 deaths from unknown causes. In addition to mortalities recorded within Banff and Yoho National Parks, at least 7 research grizzlies known to use Banff and Yoho National Parks were killed in British Columbia and Alberta (M.L. Gibeau and S. Herrero, 1998, Eastern Slopes Grizzly Bear Project, Year 4-1997, Progress Report for the Eastern Slopes Grizzly Bear Project Steering Committee, Calgary, Alberta, Canada). We knew the sex and age of 83 dead grizzly bears (Table 1). Adult females and dependent young (cubs-of-the-year and yearlings) accounted for 65% of this total. Females accounted for 51% of all mortalities of known sex since 1971 (Table 1), and even after closure of the Banff landfill in 1981, 18 of 22 bear mortalities with sex known were female (Fig. 3). An additional 11 mortalities were unclassified as to sex during this time.

Of 85 problem wildlife mortalities, 64.7% were destroyed and 35.3% were handled for translocation purposes. Fifteen of the grizzlies handled died accidentally, and 15 were translocated. Five of the translocated bears were placed in the Calgary Zoo and 5 died in Alberta within 1–2 years of capture (1 shot legally, 2 shot illegally, 1 problem wildlife, 1 unknown cause).

Eleven family groups consisting of at least 6 cubs-of-the-year and 10 yearlings were destroyed or translocated

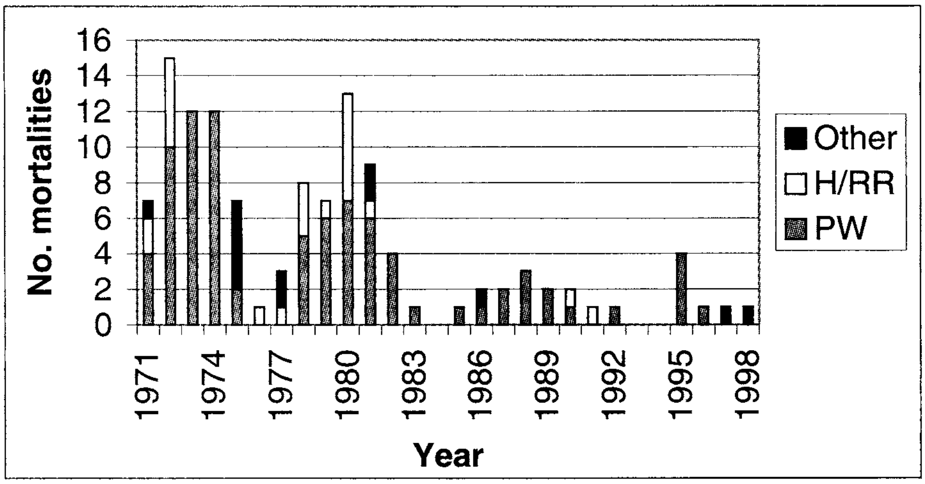


Fig. 2. Annual human-caused grizzly bear mortalities by type for Banff and Yoho National Parks, 1971—98, (*n* = 119). PW = problem wildlife, H/RR = highway/railway, Other = research or unknown.

This content downloaded from 128.114.163.7 on Thu, 4 Sep 2014 17:25:02 PM
All use subject to JSTOR Terms and Conditions

Table 1. Percent grizzly bear mortality (number) by sex, age, and cohort for Banff and Yoho National Parks, 1971–98 (n = 119).

Sex		Age		Cohort	
male	33.9 (40)	adult	34.7 (41)	dependent	29.4 (35)
female	35.3 (42)	dependent	29.7 (35)	adult female	16.0 (19)
unknown	31.1 (37)	subadult	12.7 (16)	adult male	15.1 (18)
		unknown	22.9 (27)	subadult female	7.6 (9)
				subadult male	1.7 (2)
				unknown	30.3 (36)

from the ecosystem. This was considered a minimum number as 69% of 64 recorded problem wildlife mortalities were adult females (17) and dependent (cubs-of-the-year or yearlings) bears (27). Twenty-one records had no sex or age attached. Of 15 vehicle and train collisions where the cohort was known, adult males accounted for 47%, dependent bears 33%, and adult and subadult females 20%.

Spatial Analyses

All 95 human-caused grizzly bear mortalities, classified as having accurate or reasonable locations, occurred within zones of influence along roads and trails or around human settlements (Fig. 4). Mortality concentrations occurred at Banff and Lake Louise townsites and along the Trans Canada Highway (Table 2). A minimum of 59 mortalities throughout the analysis period was associated with the presence of human food and garbage.

Eighty percent of all known mortality locations were below 1,800 m. The remaining 20% occurred at 1,800–2,100 m (Fig. 5).

Temporal Analyses

We rejected both Hypotheses 1 and 2. The mean annual number of mortalities declined significantly from 1971–84 ($\bar{x}$ = 7.07) to 1985–98 ($\bar{x}$ = 1.43; U = 164.5, P = 0.0010). The mean annual number of problem wildlife mortalities also declined significantly from 1971–84 ($\bar{x}$ = 4.93) to 1985–98 ($\bar{x}$ = 1.14; U = 151.0, P = 0.0066).

Most mortalities in both periods were problem bears (67% during 1971–84; 80% during 1985–98). Although the number of problem bear deaths declined during 1985–98, the percentage of females increased from 50% to 80%. Adult females and dependent bears (cubs-of-the-year and yearlings) increased from 66% of the total mortality in the early period to 79% during period 2. Only 2 of 22 highway and railway mortalities occurred in the latter period.

We knew the date of death in 72 instances. More deaths (57%) occurred during the berry season (mid-Jul–late Sep) than during the pre-berry (35%) and post-berry (8%) seasons. Seventy-five percent and 58% of 48 dated mortalities of problem bears occurred during the peak tourist

Table 2. Types of developments and land uses where human-caused grizzly bear mortalities occurred in Banff and Yoho National Parks, 1971–98 (n = 95; some sites are tallied twice so total is >95).

Location of kill	No.	Detail of location
highway/railway	22	Trans Canada (16), Banff-Jasper (2), other (1), railway (3)
townsite	27	Lake Louise (15), Chateau Lake Louise (7), Banff (2), Field (3)
garbage dump/landfill	19	Banff (15), Lake Louise (4)
campground	16	
ski resort	8	Lake Louise (3), Norquay (3), Sunshine (2)
commercial lodge	11	
warden cabin	3	

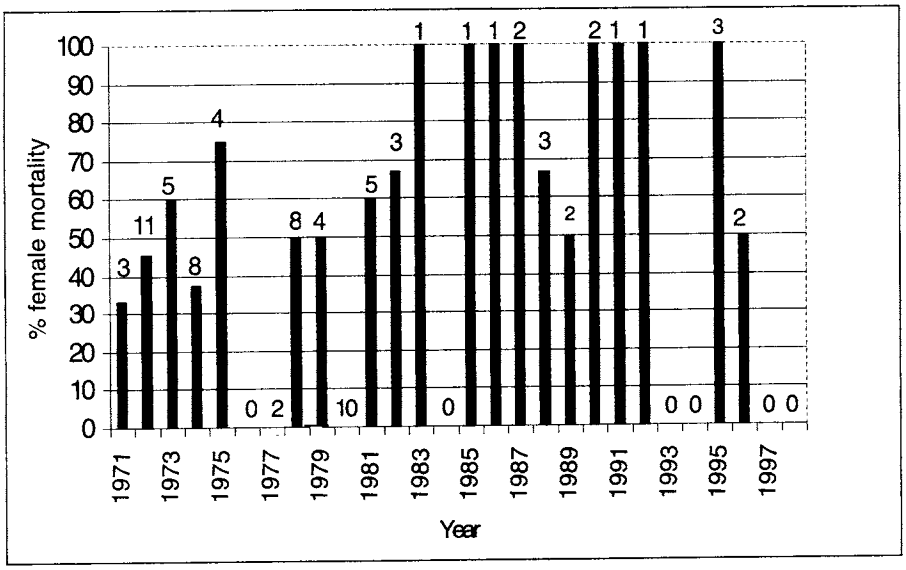


Fig. 3. Percent females in annual grizzly bear mortality. Numbers above the bars are the total mortalities with sex known for that year.

This content downloaded from 128.114.163.7 on Thu, 4 Sep 2014 17:25:02 PM
All use subject to JSTOR Terms and Conditions

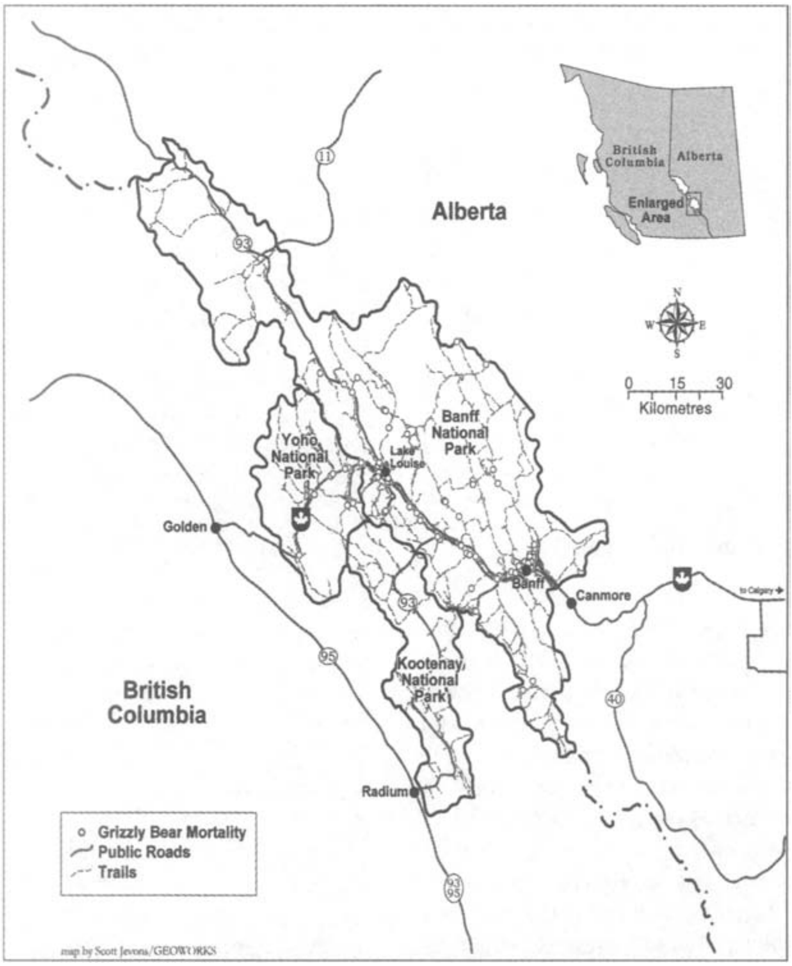


Fig. 4. Grizzly bear mortality locations in relation to roads and trails in Banff and Yoho National Parks, 1971–98.

season (late Jun–early Sep) and during the berry season, respectively.

DISCUSSION

The 119 recorded human-caused grizzly bear deaths in Banff and Yoho National Parks were considered to be the minimum number from 1971–98. Past and present wildlife managers suggested that there were probably more mortalities than were recorded, particularly during the 1970s (R. Kunelius, Banff National Park, Alberta, Canada, personal communication, 1998; M. Gibeau, Eastern Slopes Grizzly Bear Project, University of Calgary, Alberta, Canada, personal communication, 1998; D. Poll, Parks Canada, Western Region Office, Calgary, Alberta, Canada, personal communication, 1998). This large number of deaths caused by humans contrasts strongly with the adjacent and larger Jasper National Park, where in 1975–98 there were only 39 known grizzly bear mortalities (W. Bradford, Wildlife Warden, Jasper National Park, Alberta, Canada, personal communication, 1999).

Problem bear mortality was the most significant cause of death for this study. Management interventions helped reduce the total number of deaths (male and female) in 1985–98. However, the percent of female mortalities during this period increased from 50% to 80%, and the average annual female mortality was still higher than the total human-caused mortality target set based on the park's population estimate. This human-caused female mortality is the highest percent of total human-caused mortality reported for over 10 years for any grizzly bear population. As well, the human-caused mortality of dependent bears (cubs-of-the-year or yearlings) remained high throughout the study. These results may be explained by changing habitat use by specific cohorts over time. The higher male mortality in the early period was probably the result of more male bears feeding closer to people (in landfills and unsanitary campgrounds, Noble 1972). With the landfill closures and improved camper attitudes and garbage management, adult males may have selected habitats remote from human activity zones. Subadult grizzlies and adult females with young may have been more

This content downloaded from 128.114.163.7 on Thu, 4 Sep 2014 17:25:02 PM
All use subject to JSTOR Terms and Conditions

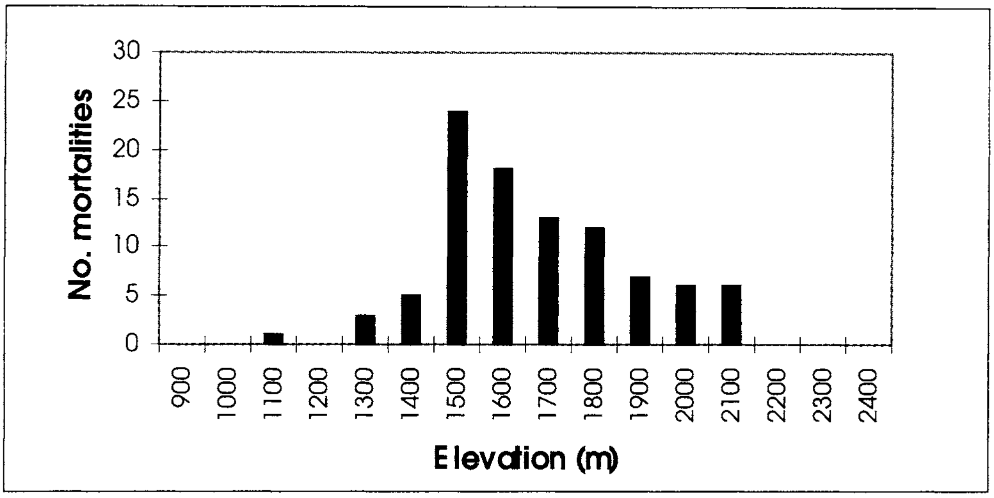


Fig. 5. Grizzly bear mortality locations by elevation in Banff and Yoho National Parks, 1971–98 (n = 95). Elevations of high human use areas in the parks: Banff, 1375 m; Castle Junction, 1430 m; Lake Louise, 1540 m; Chateau Lake Louise, 1740 m; Skoki Lodge, 2135 m; Moraine Lake Lodge, 1900 m; Lake O'Hara, 2000 m; Field, BC, 1250 m.

likely to use habitats near people, presumably to avoid adult males (Mattson et al. 1992, Gibeau et al. 1996). Thus, they may have been prone to habituation to humans and attraction to human food and garbage, increasing their mortality risk relative to males (Fig. 3) and their potential to be destroyed or translocated as problem animals (Mattson et al. 1987). This dynamic was previously described for the Yellowstone Ecosystem (Craighead et al. 1995).

The high accidental mortality of bears during management actions was the result of several points. All of these incidents occurred in the 1971–84 period. At this time, managers had less experience with tranquilizing drugs and handling techniques, and attitudes differed regarding animal welfare and grizzly bear conservation. We believe that all of these factors have improved in recent years.

Road mortality declined during 1985–98 even though traffic volumes increased. We have no definitive data to explain this; however, one likely cause is that the highway was fenced in stages to keep wildlife off the highway. Also, traffic became distributed over a 24-hour period and may have become so continuous as to act as a barrier to bears crossing unfenced portions of the corridor.

We found that grizzly bears died at low elevations and near human settlements and access. Roads, trails, and developments are almost always placed in valley bottoms, often fragmenting riparian habitats. Similarly, concentrations of kills at settlements and along roads and trails occurred throughout the Central Rockies Ecosystem (Benn 1998) and in other grizzly bear populations (Mattson et al. 1987, Nagy et al. 1989, Mace et al. 1996). Gibeau et al. (2001) showed that human use and developments reduced the amount of secure habitat for grizzly bears. Roads and trails improve access, and when placed in important seasonal habitats, increase the potential for negative bear–human encounters (McLellan and Shackleton 1988*b*). Increased access to the backcountry has been shown to alter bear behavior (McCullough 1982, Jope 1985), increase bear–human conflicts (Dalle-Molle and Van Horn 1989), increase the number of grizzly bear removals (Martinka 1982, Leonard et al. 1990), and displace certain cohorts, such as females with young (Mattson et al. 1987, Gilbert 1989).

The abrupt decline in grizzly bear mortality into the mid 1980s was correlated with closing the Banff landfill, improving garbage management, increasing public education regarding living and recreating in bear country, improving tolerance of grizzly bears, fencing of the Trans Canada Highway, and increasing use of aversive conditioning techniques over removals. However, the high mortality rate of the early period may have depressed the park's grizzly bear population. This effect could have continued through the 1985–98 period due to a lag effect and mortality concentrated in the female cohort. Closures of Yellowstone National Park landfills were followed by sharp declines in reproductive and survival rates (Craighead et al. 1974).

Finally, we found that a high proportion of mortalities occurred during the berry season. In mid-July to early October, grizzlies in the Central Rockies Ecosystem feed primarily on buffaloberry (*Shepherdia canadensis*) at lower elevation, often along roads and near people.

Human intolerance, inadequate management of access and food attractants, and a high rate of commercial development continue to be important contributing factors to grizzly bear mortality in Banff National Park. However, specific steps have been taken to reduce human-caused grizzly bear mortality. Recommendations by the Eastern Slopes Grizzly Bear Project to the Banff-Bow Valley Task Force (Gibeau et al. 1996) led to the implementation of

This content downloaded from 128.114.163.7 on Thu, 4 Sep 2014 17:25:02 PM
All use subject to JSTOR Terms and Conditions

an annual human-caused mortality target of <1% of the estimated grizzly bear population. Also, habitat effectiveness targets aimed at supporting grizzly bear habitat use have been set for most carnivore management units. By implementing measures aimed at reducing potential conflicts between humans and grizzlies, human-caused grizzly bear mortality and the potential for human injury can be reduced.

There is an urgent need for these measures to be successful in the national parks and the rest of the Central Rockies Ecosystem. Because precise measurements of population demographic rates are only now becoming available, management of mortality must be conservative and management plans must consider adjacent jurisdictions in Alberta and British Columbia (Herrero et al. 1998). A recent population and habitat viability assessment workshop predicted both population and habitat declines for grizzly bears in the Central Rockies Ecosystem (Herrero et al. 2000). Because Banff and Yoho national parks are assumed to serve as core refugia for sensitive species such as grizzly bears, and because grizzly bear hunting exists on most of the land surrounding these national parks, human-caused mortality inside the parks must be minimal. Ecological integrity is the stated priority of the national parks (Banff National Park 1997), and the grizzly bear serves as the premier indicator of the health of the terrestrial ecosystem (Banff-Bow Valley Study 1996). Managing grizzly bear mortality at a level that prevents population decline is fundamental.

MANAGEMENT IMPLICATIONS

The following recommendations are based on the stated goal of Parks Canada to maintain a naturally regulated population and distribution of grizzly bears in the mountain national parks (Banff National Park 1997). These recommendations are offered as ways to prevent future increases in mortality, to reduce the unnecessary killing of grizzly bears, and to assist in the inter-jurisdictional management of grizzly bear mortality.

During the analysis period, a considerable number of grizzly bear deaths went unrecorded in official park databases, and the records were often incomplete. This has improved in recent years and must continue to improve.

There is some variation in the way mortality data are classified between jurisdictions in the Central Rockies Ecosystem. Park wildlife managers should work with managers from other jurisdictions to develop the same coding conventions and to clearly define the different causes of death.

Acquiring accurate mortality locations is necessary for understanding and managing mortality with respect to access, development, and use of the landscape. Mortality needs to be monitored in the future to understand the effectiveness of management decisions. Additional information needs to be collected such as the distance a bear died from an access route or facility, the type of access route, the condition of the access route at the time of the mortality, the mode of travel of the person(s) responsible for the removal of the bear, presence of food attractants including natural foods, and what, if any, human behaviors played a role in the mortality.

Management of garbage and human and pet food continues to be a problem around Banff, Lake Louise, and in some campgrounds. Effective legislation and enforcement should be employed with respect to food and garbage handling. All backcountry users should be required to store food, garbage, and horse feed in bear-proof metal or seamless PVC containers, or effectively elevate attractants between trees or isolate camp within an effective portable electric fence.

To understand the effects that new management strategies and increases in human use of grizzly bear habitat have on grizzly bear mortality and population status, analyses should be repeated and reassessed in the future with more accurate population estimates.

The use of aversive conditioning programs on roadside- and campground-habituated bears, especially females, should be increased. On-site releases and aversive conditioning of many problem bears would reduce the costs and risks associated with translocating grizzlies.

Efforts should continue to inform the public about bear activity in high human use areas and to educate the public with respect to how to behave in bear country.

All of these recommendations will require adequate funding and administrative support.

ACKNOWLEDGMENTS

We thank D. Poll, B. Vroom, M. Gibeau, P. Paquet, A. Flegel, S. Jevons, and many from the Parks Canada Warden Service. We are also indebted to the Eastern Slopes Grizzly Project Steering Committee and the Faculty of Environmental Design, University of Calgary for funding and support. J. Nagy, C. White, and M. Gibeau reviewed and provided constructive comments on the manuscript.

LITERATURE CITED

BANFF-BOW VALLEY STUDY. 1996. Banff-Bow Valley: At the crossroads. Technical report of the Banff-Bow Valley Task Force. Prepared for the Minister of Canadian Heritage, Ottawa, Ontario, Canada.

BANFF NATIONAL PARK. 1997. Banff National Park Management Plan. Canadian Heritage, Parks Canada, Ottawa, Ontario, Canada.

This content downloaded from 128.114.163.7 on Thu, 4 Sep 2014 17:25:02 PM
All use subject to JSTOR Terms and Conditions

BENN, B. 1998. Grizzly bear mortality in the Central Rockies Ecosystem, Canada. Masters Degree Project, Faculty of Environmental Design, University of Calgary, Alberta, Canada.

BUNNELL, F.L., AND D.E.N. TAIT. 1980. Bears in models and reality — implications to management. International Conference on Bear Research and Management 4:15–23.

CRAIGHEAD, J.J., K.R. GREER, R.R. KNIGHT, AND H.I. PAC. 1988. Grizzly bear mortalities in the Yellowstone ecosystem 1959–1987. Montana Department of Fish, Wildlife and Parks, Craighead Wildlife-Wildlands Institute, Interagency Grizzly Bear Study Team, and National Fish and Wildlife Foundation, Bozeman, Montana, USA.

———, J.S. SUMNER, AND J.A. MITCHELL. 1995. The grizzly bears of Yellowstone. Their ecology in the Yellowstone Ecosystem, 1959–92. Island Press, Washington, D.C., USA.

———, J.R. VARNEY, AND F.C. CRAIGHEAD JR. 1974. A population analysis of the Yellowstone grizzly bears. Montana Forestry and Conservation Experimental Station Bulletin 40. University of Montana, Missoula, Montana, USA.

DALLE-MOLLE, J.L., AND J.C. VAN HORN. 1989. Bear–people conflict management in Denali National Park, Alaska. Pages 122–127 *in* M. Bromley, editor. Bear–people conflicts: Proceedings of a symposium on management strategies. Northwest Territories Department of Renewable Resources, Yellowknife, Northwest Territories, Canada.

DOOD, A.R., AND H.I. PAC. 1993. Five year update of the programmatic environmental impact statement: the grizzly bear in northwestern Montana. Montana Department of Fish, Wildlife and Parks, Helena, Montana, USA.

GIBEAU, M.L., AND S. HERRERO. 1998. Roads, rails and grizzly bears in the Bow River Valley, Alberta. Proceedings of State of Florida DOT Symposium 1998. Environmental Management Office, Tallahassee, Florida, USA.

———, ———, J.L. KANSAS, AND B. BENN. 1996. Grizzly bear population and habitat status in Banff National Park: Report to the Banff-Bow Valley Task Force. Banff, Alberta, Canada.

———, ———, B.N. MCLELLAN, AND J.G. WOODS. 2001. Managing for grizzly bear security areas in Banff National Park and the Central Canadian Rocky Mountains. Ursus12:121–130.

GILBERT, B.K. 1989. Behavioral plasticity and bear–human conflicts. Pages 1–8 *in* M. Bromley, editor. Bear–people conflicts: Proceedings of a symposium on management strategies. Northwest Territories Department of Renewable Resources, Yellowknife, Northwest Territories, Canada.

GUNSON, J.R. 1995. Analysis of grizzly bear mortalities in Alberta during 1972–1994. Occasional Paper No.16. Alberta Environmental Protection, Natural Resources Service, Wildlife Management Division, Edmonton, Alberta, Canada.

HARRIS, R.B. 1986. Modeling sustainable harvest rates for grizzly bears. Pages 268–279 *in* A. Dood, R. Brannon, and R. Mace, editors. Programmatic Environmental Impact Statement — The grizzly bear in northwestern Montana. Montana Department of Fish, Wildlife and Parks, Helena, Montana, USA.

HERRERO, S. 1985. Bear attacks. Their causes and avoidances. Winchester Press, Piscataway, New Jersey, USA.

———. 1994. The Canadian national parks and grizzly bear ecosystems: the need for interagency management. International Conference on Bear Research and Management 9(1):7–21.

———, P.S. MILLER, AND U.S. SEAL. 2000. Population and habitat viability assessment for the grizzly bear (*Ursus arctos*) of the Central Canadian Rockies Ecosystem. Eastern Slopes Grizzly Bear Project, University of Calgary, Calgary, Alberta, Canada, and Conservation Breeding Specialist Group, Apple Valley, Minnesota, USA.

———, D. POLL, M. GIBEAU, J. KANSAS, AND B. WORBETS. 1998. The Eastern Slopes Grizzly Bear Project: origins, organization, and direction. Proceedings of Canadian Council on Ecological Areas. Calgary, Alberta, Canada.

JOPE, K.L. 1985. Implications of grizzly bear habituation to hikers. Wildlife Society Bulletin 13:32–37.

KNIGHT, R.R, B.M. BLANCHARD, AND L.E. EBERHARDT. 1988. Mortality patterns and population sinks for Yellowstone grizzly bears, 1973–85. Wildlife Society Bulletin 16:121–125.

———, AND L.E. EBERHARDT. 1985. Population dynamics of the Yellowstone grizzly bear. Ecology 66:323–334.

LEONARD, R.D., R. BRENEMAN, AND R. FREY. 1990. A case history of grizzly bear management in the Slims River area, Kluane National Park Reserve, Yukon. International Conference on Bear Research and Management 8:113–123.

MACE, R.D., J.S. WALLER, T.L. MANLEY, L.J. LYON, AND H. ZUURING. 1996. Relationships among grizzly bears, roads, and habitat in the Swan Mountains, Montana. Journal of Applied Ecology 33:1395–1404.

MARTINKA, C.J. 1982. Rationale and options for management of grizzly bear sanctuaries. Transactions of the North American Wildlife and Natural Resources Conference 47:470–475.

MATTSON, D.J. 1990. Human impacts on bear habitat use. International Conference on Bear Research and Management 8:33–56.

———. 1999. Coefficients of productivity for Yellowstone's grizzly bear habitat. U.S. Geological Survey Forest and Rangeland Ecosystem Science Center and Department of Fish and Wildlife Resources, University of Idaho, Moscow, Idaho, USA.

———, B.M. BLANCHARD, AND R.R. KNIGHT. 1992. Yellowstone grizzly bear mortality, human habituation, and whitebark pine seed crops. Journal of Wildlife Management 56:432–442.

———, S. HERRERO, R.G. WRIGHT, AND C.M. PEASE. 1996. Science and management of rocky mountain grizzly bears. Conservation Biology 10:1013–1025.

———, AND R.R. KNIGHT. 1991. Effects of access on human-caused mortality of Yellowstone grizzly bears. U.S. Department of Interior, National Park Service, Interagency Grizzly Bear Study Team Report 1991B.

———, ———, AND B.M. BLANCHARD. 1987. The effects of developments and primary roads on grizzly bear habitat use in Yellowstone National Park, Wyoming. International Conference on Bear Research and Management 7:259–273.

MCCRORY, W., AND S. HERRERO. 1982. A review of the historical status of the grizzly bear in Kananaskis Country, Alberta.

This content downloaded from 128.114.163.7 on Thu, 4 Sep 2014 17:25:02 PM
All use subject to JSTOR Terms and Conditions

Alberta Fish and Wildlife Division, Calgary, Alberta, Canada.

MCCULLOUGH, D.R. 1982. Behavior, bears, and humans. Wildlife Society Bulletin 10:27–33.

MCLELLAN, B.N. 1990. Relationships between human industrial activity and grizzly bears. International Conference on Bear Research and Management 8:57–64.

———, F.W. HOVEY, R.D. MACE, J.G. WOODS, D.W. CARNEY, M.L. GIBEAU, W.L. WAKKINEN, AND W.F. KASWORM. 1999. Rates and causes of grizzly bear mortality in the interior mountains of British Columbia, Alberta, Montana, Washington, and Idaho. Journal of Wildlife Management 63:911–920.

———, AND D.M. SHACKLETON. 1988*a*. Grizzly bears and resource-extraction industries: effects of roads on behavior, habitat use, and demography. Journal of Applied Ecology 25:451–460.

———, AND ———. 1988*b*. Grizzly bears and resource-extraction industries: habitat displacement in response to seismic exploration, timber harvesting, and road maintenance. Journal of Applied Ecology 25:371–380.

MILLSON, R.R. 1978. A summary of black and grizzly bear statistics. Western Region National Parks, Parks Canada Contract WR41-77, Calgary, Alberta, Canada.

NAGY, J.A., A.W.L. HAWLEY, AND M.W. BARRETT. 1989. Population characteristics of grizzly and black bears in west-central Alberta. AEC Report V88-R1. Alberta Environmental Center, Vegreville, Alberta, Canada.

———, R.H. RUSSELL, A.M. PEARSON, M.C. KINGSLEY, AND C.B. LARSEN. 1983. A study of grizzly bears on the barren grounds of Tuktoyaktuk Peninsula and Richards Island, Northwest Territories, 1974–1978. Canadian Wildlife Service Report, Edmonton, Alberta, Canada.

NOBLE, L.B. 1972. Man and grizzly bear in Banff National Park, Alberta. Thesis, University of Calgary, Calgary, Alberta, Canada.

STORER, T.I., AND L.P. TEVIS JR. 1955. California grizzly. University of California Press, Berkeley, California, USA.

STRINGHAM, S.F. 1983. Roles of adult males in grizzly bear population biology. International Conference on Bear Research and Management 5:140–151.

TAYLOR, J.S. 1984. Bear management plans in Canadian national parks: fifteen essential elements. Master's Degree Project. Faculty of Environmental Design, University of Calgary, Alberta, Canada.

WEAVER, J.L., R.E. ESCANO, AND D.S. WINN. 1987. A framework for assessing cumulative effects on grizzly bears. Transactions of the North American Wildlife and Natural Resources Conference 52:364–376.

Received: 1 February 2001.
Accepted: 17 December 2001.
Associate Editor: Mace.

This content downloaded from 128.114.163.7 on Thu, 4 Sep 2014 17:25:02 PM
All use subject to JSTOR Terms and Conditions

ELSEVIER

Biological Conservation 109 (2003) 37–45

BIOLOGICAL CONSERVATION

www.elsevier.com/locate/biocon

Are roads and railroads barriers to bumblebee movement in a temperate suburban conservation area?

Madhumita Bhattacharya[a,*], Richard B. Primack[a], Joel Gerwein[b]

[a]*Department of Biology, Boston University, 5 Cummington Street, Boston, MA 02215, USA*
[b]*Biology Department, University of Massachusetts, 100 Morrisey Boulevard, Boston, MA 02125, USA*

Received 2 January 2001; received in revised form 15 December 2001; accepted 9 March 2002

Abstract

We investigated how habitat fragmentation affects the movement of marked bumblebees between plant patches in a temperate conservation area in metropolitan Boston, Massachusetts. Our study was conducted on populations of sweet pepperbush (*Clethra alnifolia* L. f.) separated by a road and natural woodland, and buttonbush (*Cephalanthus occidentalis* L.) separated by a railroad. Bumblebees showed high site fidelity and only rarely crossed roads or railroads. When bees captured at one sweet pepperbush population were moved across a road to a new sweet pepperbush population and released, they returned to their original site, some within 20 min of their capture. When all inflorescences were removed from one sweet pepperbush patch, most bees moved to another sweet pepperbush population on the same side of the road. The results show that while bumblebees have the ability to cross a road and railroad, these human structures may restrict bumblebee movement and act to fragment plant populations because of the innate site fidelity displayed by foraging bees. Moreover, marked bees were almost never observed to move between populations unless they were displaced, or forced to seek additional forage sites. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Habitat fragmentation; Bumblebees; *Bombus*; *Clethra alnifolia*; Anthropogenic barriers; Pollination

1. Introduction

Animal movement is important for the pollination and seed dispersal of plants. Fragmentation of habitats by roads, railroads, fields, buildings and other human activities can restrict animal movement (Mader, 1984; Didham et al., 1996; Forman and Alexander, 1998). If animals are unable to cross such barriers, they may not obtain sufficient nectar, pollen, and fruit resources to survive. Flowers may remain unvisited and fruits undispersed, leading to declines in gene flow (Oostermeijer et al., 1994; Westerbergh and Saura, 1994) and seed production and the eventual decline of plant populations (Jennersten, 1988; Lamont et al., 1993; Noderhaug, 1995; Steffan-Dewenter and Tscharntke, 1999).

Habitat fragmentation is becoming more of a danger to the persistence of plant populations due to an ever-increasing human population, and an increasing alteration of the natural environment (Saunders et al., 1991). Despite the recognized impact of habitat fragmentation on plant–pollinator interactions (Aizen and Feinsinger, 1994a,b; Steffan-Dewenter and Tscharntke, 1999), few field studies have been conducted on how artificial barriers affect pollinator movement. Evidence from fragmented forests in Brazil suggests that some understory butterflies (Lovejoy et al., 1986) and euglossine bees (Powell and Powell, 1987) may not readily cross pastures. Yet it is generally unknown how roads constructed across a landscape affects pollinator movement.

Bumblebees in the genus *Bombus* and related genera are important pollinators of numerous temperate plant species (Heinrich, 1976, 1979a). Therefore, it is valuable to document how habitat fragmentation affects bumblebee movement and thus, plant gene flow. Bumblebees are known to be strong fliers, and are able to travel considerable distances (Heinrich, 1979a; Osborne et al., 1999); they are certainly capable of crossing a human-dominated landscape interwoven with barriers such as roads and railroads. But do landscape elements such roads or railroads restrict bumblebee movement in their normal foraging activities, or will bumblebees cross such features as they would any other intervening

* Corresponding author. Tel.: +1-617-353-5559/6989; fax: +1-617-353-6340.

E-mail address: mita@bu.edu (M. Bhattacharya).

0006-3207/02/$ - see front matter © 2002 Elsevier Science Ltd. All rights reserved.
PII: S0006-3207(02)00130-1

space of natural habitat? If captured in one plant patch and released in another patch of the same species, will bumblebees cross a roadway or natural barrier to return to their original site or adopt the new patch as a foraging site? Will bumblebees forced to move from a site where all flowers have been removed, seek out replacement forage sites located across a road, or will they tend to relocate to new sites on the same side of the road as their original forage site? Such questions are critical to understanding the ability of pollinator and plant populations to persist in a fragmented landscape.

Bumblebees show high vagility and are known to display flower constancy and high site fidelity (Heinrich, 1976; Osborne and Williams, 2001). Therefore, it would be important to discern how habitat fragmentation superimposed on this behavior affects their foraging activity. We hypothesized that bees would be more likely to move between sites separated by natural habitat than sites separated by a road. To test this hypothesis we conducted a series of experiments using marked bumblebees in a suburban forest habitat.

2. Methods

2.1. Study location, plant species and bumblebee species

The study was conducted at the Webster conservation area (N 42° 19′ 33.1″, W 71° 10′ 31.9″), a deciduous temperate woodland, located in Newton, Massachusetts. The study focused on a small (~1225 m^2) wetland population of buttonbush (*Cephalanthus occidentalis* L., Rubiaceae) divided into two fragments (sites A and B) by a raised 14 m wide railroad bed, and scattered moist woodland populations of sweet pepperbush (*Clethra alnifolia* L. f, Clethraceae; Fig. 1) on either side of a 4-lane, 14 m wide road, the Hammond Pond Parkway. The four sweet pepperbush study populations are referred to as sites I, II, III and IV, with site I located on one side of the road and the remaining three sites on the other side of it (Fig. 1).

Buttonbush is a deciduous shrub that ranges in height from 1 to 4 m, and bears small white tubular flowers clustered on ball shaped inflorescences. Sweet pepperbush is a tall deciduous shrub that ranges in height from 1 to 3 m or more, with small white fragrant flowers borne on terminal racemes 5–15 cm long. Both shrub species are frequently visited by bumblebees, which are the primary pollinators of sweet pepperbush (Hemingson, 1986). In buttonbush, cross-pollination is known to enhance fruit set greatly compared to self-pollination (Imbert and Richards, 1993). The term 'bees' or 'bumblebees' referred to in this paper are worker bees of *Bombus impatiens* and *B. affinis*, and also include several (3–15%, depending on site and year) carpenter bees (*Xylocopa* species). For all observations and experiments, counts of bumblebees reported include only those bees whose tag numbers could be read.

2.2. Mark and recapture of bees

In July 1997, 93 bees were captured on the buttonbush plants in both fragments (Table 1), cooled to make them passive and marked with Opalithplättchen or numbered plastic tags (Kearns and Inouye, 1993) glued to their thorax. Marked bees were returned to the shrub where they were originally captured within 10–20 min of capture. The area was surveyed for marked bees for 1–2 h on 6 days over a 2-week period.

In August of 1997, 137 bumblebees were marked at four sweet pepperbush sites designated "site I", "site II", "site III" and "site IV" (Fig. 1), with most bees captured from site I and site II (Table 1). Sites were separated from each other by a road or by intervening forest. The sites were observed for 0.5–1.5 h for 5–6 days over a 7–9 day period. In late July and early August of 1998, 137 bees were marked but only at sites I and II that are separated by the Hammond Pond road.

2.3. Bee displacement experiments

In late July of 1998 and early August of 1999, we captured bumblebees at the site I sweet pepperbush population, marked them, and then released them at site II located across the road. In 1999, we conducted a similar displacement of bees from site II to site I. Reciprocal displacements were also carried out between site II and site III located within the woods and separated by trees and shrubs (Table 2). After the displacement of bees, the original capture sites were monitored for a total time range of 205–570 min (depending on site) over a 4-day period to determine how many bees returned to their capture site. A Chi-Square test was performed to determine whether fewer bees returned to their original site when separated from it by a road than when separated by natural, woodland habitat.

2.4. Experiment where bees are forced to seek new forage sites

In mid August 2000, we marked 102 bees at the sweet pepperbush site II. After marking the bees, we removed all flowers from the plants at that site in order to force bees to seek additional forage sites. We hypothesized that bees would be more likely to move to replacement populations separated from site II by natural woods rather than seek populations located across a road. Nearby sweet pepperbush sites (I, III and IV) and a field with flowering purple loosestrife (*Lythrum salicaria* L., Lythraceae)—a major weed of wetlands in temperate North America—were monitored on 6 days over a 9 day

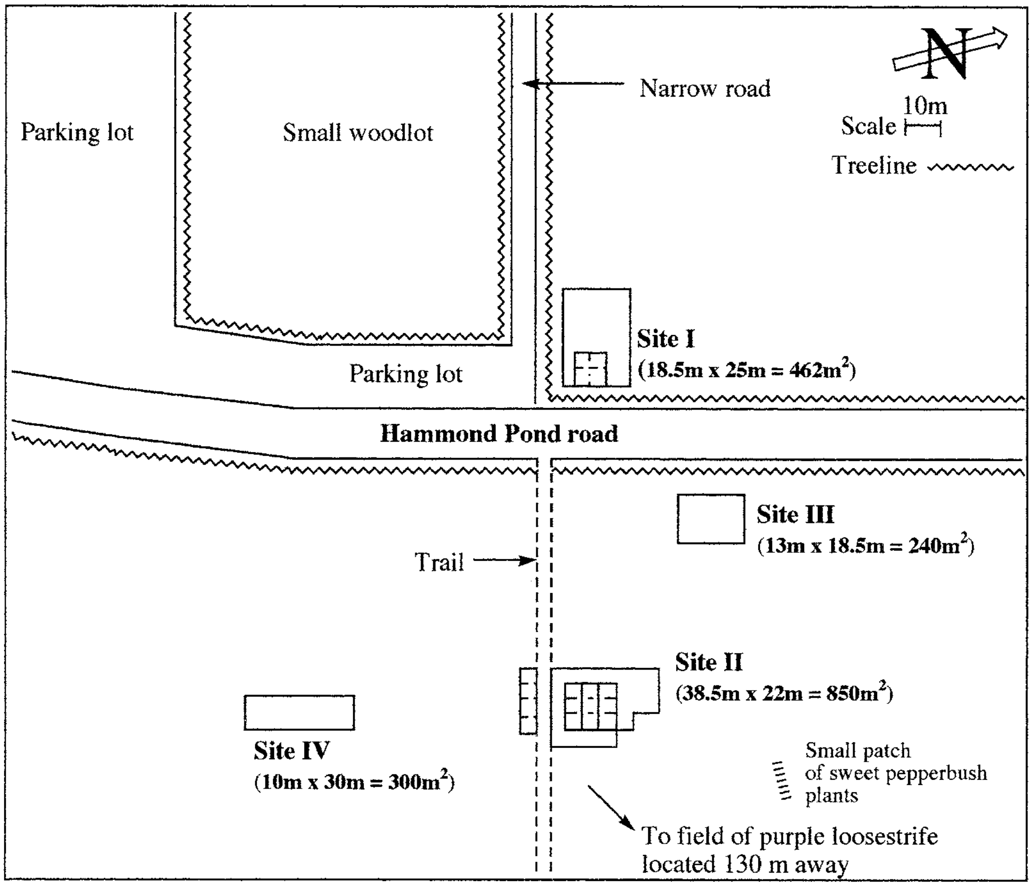


Fig. 1. Location and approximate area of sweet pepperbush populations (sites I–IV) in wetland patches in the Webster conservation reserve. Hatched areas at sites I and II show observation quadrats.

period for a total time range of 15–500 min (depending on site) for marked bees.

2.5. Site differences between sites I and II

Most of our experiments centered on the two bigger sweet pepperbush sites (I and II) separated by a road. Therefore, we decided to examine if these sites differed in aspects of inflorescence density that might determine bee visitation rates. Although fruit/seed set provide direct assessment of successful pollinator visits, we did not measure this, as fruit set is very high in sweet pepperbush (Jordan and Hartman, 1995). Since pollinator visitation is a function of plant density (Kunin, 1997), in 1998 we demarcated four quadrats (25 m^2 each) at site I and 11 quadrats of similar size at site II to census bees and record visitation rates of pollinating bees per quadrat at these sweet pepperbush sites (Fig. 1). Fewer quadrats were demarcated at site I because thick growth of the thorny greenbrier vine, (*Smilax rotundifolia* L., Liliaceae) hindered movement outside the marked quadrats. At site II, 11 quadrats were demarcated at the center of the population and to one side of the trail as fewer bees were seen at the peripheral plants of the population. Bees were censused on 8 days over a 12-day period from late July to early August. Observation sessions lasted 5 min per quadrat. Inflorescence density (number of inflorescences present per quadrat) was also determined at both sites. A Mann–Whitney U test was conducted to compare both sites on inflorescence density per quadrat.

In 2000, we counted the number of inflorescences on randomly selected plants at sites I and II. Sweet pepperbush plants primarily propagate vegetatively through the regeneration of clonal sprouts (Jordan and Hartman, 1995); therefore in a given area several ramets could belong to the same genet. To avoid picking stems belonging to the same genet, we randomly selected 20 single stems separated by a distance of 2 m or more in the general area of the demarcated quadrats at sites I and II to represent single plants (Fig. 1). This was done prior to the flower removal experiment. A t-test (two tailed) for independent samples was performed to determine if the two sites differed for mean inflorescence count per plant. We also determined if the two sites differed in bee visitation rates. On each of these plants we further selected one inflorescence (of similar size and number of open flowers) and counted the number of bumblebee visits to it during a 5-min observation session. Bumblebee visits per inflorescence per 5-min observation session were monitored between 13:30–16:50 on 4

Table 1
Number of bees (*Bombus* and *Xylocopa*) marked and observed later at study sites (excludes bees from the displacement and flower removal experiments)

Site	Number of bees marked		Number of marked bees observed		Fraction of marked bees observed	
	1997	1998	1997	1998	1997	1998
Buttonbush						
A (north)	80	–	18	–	0.23	–
B (south)	13	–	0	–	0.00	–
Total	93		18		0.19	
Sweet pepperbush						
I	55	82	19	37	0.35	0.45
II	59	55	18	18	0.31	0.33
III	12	–	4	–	0.33	–
IV	11	–	1	–	0.09	–
Total	137	137	42	55	0.40	0.40

August and 9:50–13:05 on 5 August 2000 for site II, and between 13:45–17:05 on 5 August and 9:00–13:30 on 8 August 2000 for site I.

3. Results

3.1. Observation and movement of marked bees across barriers

Of the 367 bees marked at all sites in 1997 and 1998, 31% were observed again on subsequent days (Table 1). These recapture rates conform to other studies of marked bees (Kwak et al., 1991; Dramstad, 1996; Osborne and Williams, 2001).

Marked bees were almost exclusively observed at the patches where they were originally captured, marked and released. Only three bees were observed at sites other than where they were marked (Table 2). In 1997 at the buttonbush sites, two of the 80 bees marked on the north side of the railroad tracks (site A) were subsequently observed on the south side of the tracks (site B) foraging on purple loosestrife. Bees marked on the sweet pepperbush plants that year were only observed at the original sites where they had been marked over the course of several weeks. In 1998, the 137 bees marked at the sweet pepperbush sites also showed the same site fidelity with one exception. A single bee (W9) marked at site II was observed 130 m away at a large patch of purple loosestrife, separated by intervening forest (Fig. 1).

3.2. Bee displacement experiments

Twelve (48%) of the 25 bees caught at site I in 1998, marked, and released 20 min later at site II, were observed again (Table 2). One of these bees was later observed foraging at site II. The remaining 11 bees were observed again only at site I, one of which was observed there only 20 minutes after being moved to site II.

In the 1999 experiments involving reciprocal displacement of bees between sites separated by a road (sites I and II) versus sites separated by natural forest (sites II and III), 36–59% of the displaced bees were observed again. Only two bees, one each from sites I and II were observed foraging at their site of release. The remaining 31 bees observed had crossed back to their original capture site. The reciprocal displacement between sites II and III showed a slightly greater tendency of bees to forage at the new site. One bee from site II continued to visit site III, while three bees from site III continued to visit site II. Of these three bees displaced from site III to site II, one bee (B37) was observed on subsequent days to forage at both its release and capture sites.

There was no significant difference between the effect of a road (separating site I and site II) or natural woodland (separating site II and site III) on bee movement between site of release and site of capture ($\chi^2 = 1.92$, df $= 1$, P-value > 0.05). However, the power of the test was low ($1-\beta = 0.28$). Contrary to our prediction, our results show a trend, albeit non-significant, for fewer bees to travel back to their original site when the sites were separated by forest than when separated by a road.

3.3. Response of bees forced to seek new forage sites

Of the 102 bees marked at site II from where all flowers were subsequently removed, 12 bees were observed again (Table 2). Eleven of the 12 bees observed were seen on sweet pepperbush plants located at sites on the same side of the road as site II (Fig. 1). Of these, seven were seen at site IV, which is located 35 m away from site II. One bee was seen at site III where not more

Table 2
Bumblebee movements across anthropogenic barriers at the Webster conservation area (the number of bees marked at each site are denoted in parentheses)

Direction of bee movement		Year	Number of marked bees observed across barrier	Barrier (width m)	Fraction of recoveries to marked bees observed across barrier	Number of marked bees displaced to release site
From site:	To site:					
Buttonbush						
A (80)	B (13)	1997	2	Railroad (14 m)	0.11	–
Sweet pepperbush						
Site II (55)	Field (0)	1998	1	Natural forest (130 m)	0.02	–
Bee displacement experiment						
Capture site	*Release site*					
Site I (25)	Site II	1998	11	Road and Natural forest (14 + 70 m)	0.92[a]	1
Site I (46)	Site II	1999	20	Road and Natural forest (14 + 70 m)	0.95	1
Site II (46)	Site I	1999	26	Road and Natural forest (14 + 70 m)	0.96	1
Site III (35)	Site II	1999	17	Natural forest (40 m)	0.85	3
Site II (33)	Site III	1999	11	Road and Natural forest (14 + 70 m)	0.92	1
Flower removal experiment						
Capture and release site	*Observation site*					
Site II (102)	Site I	2000	1	Natural forest (40 m)	0.08	–
Site II (102)	Site III	2000	1	Natural forest (40 m)	0.08	–
Site II (102)	Site IV	2000	7	Natural forest (35 m)	0.58[b]	–
Site II (102)	Patch near site II	2000	1	Natural forest (20 m)	0.08	–
Site II (102)	Site II	2000	2	–	–	–

[a] At this site, 11 of 12 (92%) marked bees observed had moved back to their original site.
[b] Of the 12 marked bees observed from those tagged at site II, seven (58%) were observed at site IV after flower removal at site II.

than 2% of the plants were flowering that year, and one bee was seen at a small patch of plants adjacent to the flowerless site II. Only a single bee was observed across the road at site I (located 84m from site II), which was flowering strongly. Two of the marked bees were seen to return to site II where we had missed removing flowers from one plant.

3.4. Differences between site I and site II

Sweet pepperbush sites I and II did not differ significantly in the density of inflorescences, but site I had higher bee visitation rates compared to site II. In 1998, mean inflorescence density per quadrat between sweet pepperbush site I and site II (Table 3) did not differ significantly ($U=16$, $P=0.47$). However, site I had on average almost double the number of bee visits per quadrat compared to site II. Similarly, in 2000, mean inflorescence count per plant between sites I and II did not vary significantly ($t_{stat}=0.70$, df = 29, P-value = 0.49). However, overall bee visitation rates to inflorescences from morning to late afternoon over the course of 2 days in 2000, were significantly higher at site I compared to site II (Table 3).

4. Discussion

4.1. Artificial and natural barriers

Regardless of the distances (35–110 m) that separate sweet pepperbush patches, or the presence of a natural or artificial barrier between them, none of the bees marked at any of the sweet pepperbush sites were observed to move on their own among patches. The high site fidelity of foraging bees was particularly unexpected at site III, which had very few inflorescences in 1997, and is located only 37 and 40 m from the larger sites I and II, respectively (Fig. 1). These observations match similar reports, where no bees were observed to cross a gap of 4–8 m separating two forage sectors within a patch (Comba, 1999). Rasmussen and Brødsgaard (1992), report 2.6% of bumblebees moved between patches separated by distances of 10–40 m, while Osborne and Williams (2001) report a slightly higher percentage of bumblebee movement (12–14%) between patch groups in an experimental area. We failed to observe inter-patch movement possibly because of the greater distances separating our study patches.

Bumblebees appear to be reluctant to cross barriers unless floral resources at their forage sites are declining or have been removed. We observed no instances of bee movement from one population of plants to another of the same species. The two bees that moved from buttonbush site A to site B were leaving an area with declining floral resources and moving to an area with abundant purple loosestrife flowers. A bumblebee (W9), which moved from the sweet pepperbush site II to an open field, was also observed to be visiting purple loosestrife flowers (Table 2). These instances of bee movement to purple loosestrife may reflect the need for bees to seek new floral resources as their current forage plants finish flowering and they shift their ‘‘majoring’’ to other flowering plants (Heinrich, 1979b). The response of bees forced to seek replacement sites when flowers at their foraging site were removed, shows bees tend to move to new flower patches of the same species available nearby. They likely expend less energy in moving to nearby familiar forage flowers, compared to looking for new species of flowers and learning to work them. We observed fewer marked bees in this experiment (~12%), perhaps due to survey constraints spread over a much wider area. Since the flowers at site II were removed during the peak of flowering, the bees probably did not make the gradual transition from declining floral resources to a new species of flowering plants, and preferred to switch to nearby sweet pepperbush patches instead. Only one bee was observed at site I located across the road on one day, which shows bees are capable of crossing barriers to look for familiar forage plants.

Table 3
Mean (±1 S.D.) visitation rates of marked and unmarked bumblebees on sweet pepperbush plants, and inflorescence counts per quadrat at sites I and II in 1998, and mean (±1 S.D.) visitation rates of bumblebees and inflorescence count per plant in 2000

Sweet pepperbush sites	1998					2000			
	N^a	Bumblebee visitor		N^b	Inflorescence count per quadrat	N^a	Bumblebee visits per inflorescence	N^c	Inflorescence count per plant
		Unmarked	Marked						
I	156	4.52±2.85*	1.77±0.96*	4	403.75±230.85	93	2.68±2.58*	20	22.65±3.90
II	28	2.21±1.62*	0.43±0.57*	11	316.91±237.27	80	0.90±1.13*	20	28.55±7.49

[a] Number of 5 min observation sessions.
[b] Number of quadrats observed per site.
[c] Number of plants per site.
* $P<0.01$, t-test for independent samples.

4.2. Bumblebee displacement

The fact that bees return to their original site after being experimentally transported between sites show that roads and railroads are not insurmountable barriers to bumblebee movement. However, the very low numbers of bees that crossed these barriers without being experimentally transported (Table 2), underscores the high site fidelity of foraging bees (Heinrich, 1976; Bowers, 1985; Dramstad, 1996; Saville et al., 1997; Comba, 1999; Wesselingh et al., 2000; Osborne and Williams, 2001). Our observations confirm those of other studies where bumblebee pollinators mostly remain site constant regardless of the availability of equally rewarding (Osborne and Williams, 2001) or even richer forage patches nearby (Comba, 1999), and tend to visit closest neighboring plants within patches (Rasmussen and Brødsgaard, 1992; Comba, 1999). We did not measure wind direction or wind speed during bee displacement, although wind is known to influence bumblebee flights with longer flights downwind than upwind (Comba, 1999). However, as part of a current study conducted by the authors, bees displaced 100–500 m from their foraging site in winds of 4–8 mph from all directions were eventually able to find their way back to their forage sites, some within 10–15 min. Therefore, in our displacement experiments it is unlikely that bees were influenced significantly by winds.

Our observations suggests that although a railroad and a road are not impassable barriers to bumblebee movement, they may constrain or discourage bee movement by contributing to spatial cues that determine bee site-specific foraging behavior. This may explain the trend observed for higher numbers of displaced bees to remain at the release site to which they were moved, when capture and release sites were separated by a more homogeneous natural habitat (Table 2). In uniform habitats, bumblebees react with longer interplant flights and fewer backward turns, and can perceive environmental landmarks that break the uniformity of their forage patches (Plowright and Galen, 1985). When bees reach the edge of a patch most bees turn back and continue to forage (Rasmussen and Brødsgaard, 1992). Thus, a road or railroad that bisects a plant population may be a strong landmark possibly acts as a barrier, as site-specific bees may turn back from the road and restrict their foraging to only one fragment of the divided population.

Site fidelity was also underscored by the rapid return of displaced bees to their original sites. Feeding site fidelity was strong enough to propel these bees across a road back to their original forage site. Bees are known to follow a fixed flight path to return to their original forage sites (Heinrich, 1976; Thomson et al., 1987; Thomson, 1995; Wesselingh et al., 2000). Studies by Manning (1956) and Kunin (1997) show bees use spatial cues to return to individual plants and flowers, often where they have obtained higher nectar rewards (Dreisig, 1995; Wesselingh et al., 2000). This suggests that bees are sensitive to site characteristics. However, the rapid return of bees to their capture site when released on the same species of plants at a different site, suggests site fidelity is a stronger cue in foraging behavior than flower constancy. Nevertheless, the few bees that did not return to their original site indicate that bees can adopt new patches as foraging sites. Perhaps these bees were young foragers with the flexibility of changing their traplines to adopt a new or richer forage site. The fraction (0.08–0.15) of displaced bees for sites II and III sweet pepperbush patches separated by forest was almost double that for sites I and II separated by a road (0.04–0.08; Table 2). Site quality—determined by size of forage area or inflorescence density—may play a role as suggested by the adoption of the larger site II by three bees displaced from the smaller site III to the larger site II. In contrast one displaced bee from site II adopted site III.

Although inflorescence density per quadrat or the number of inflorescence per plant did not significantly differ between the smaller site I and the larger site II, the rate of marked and unmarked bumblebee visits appear to be much higher at site I compared to site II (Table 3). We did not qualitatively or quantitatively measure nectar or pollen resources at the different sweet pepperbush sites. However, with fewer bees visiting inflorescences at site II compared to site I, flowers at site II were expected to have more nectar and pollen available. Therefore, bees displaced from site I to site II were expected to encounter less competition by exploitation or nectar removal, which should have facilitated their displacement to the more profitable site, and vice versa. This proved not to be the case. Thus patch size or profitability may not be the only qualities affecting bee displacement. For instance, the road could be a major landmark for "traplining" bees that facilitates in orientation and recognition of original forage sites.

4.3. Response of bumblebees forced to seek new forage sites

Bees can traverse roads in their quest for new forage plants but rarely do so when forage is available owing to their high site fidelity. This is demonstrated by the observation of a single marked bee at site I after being forced to move from site II. However, of the 12 marked bees observed after flowers were cut at site II, 11 were seen at sweet pepperbush patches occurring on the same side of the road as site II and separated from it by natural woods. The close proximity of site IV to site II may explain why seven of the 11 bees were seen at site IV, which is 35 m away from site II. In comparison, site I is located at 84 m from site II in addition to being separated from it by a road (Fig. 1). Yet site I is larger than site IV and appeared to have more bee visitors (personal observation) compared to it. However, it has been suggested patch size may not have as strong an effect on pollinator visitation rate as does flower density (Kunin, 1997) or plant density (Comba, 1999). Although we didn't compare inflorescence or plant densities and bee visitation rates between sites I and IV, the number of bees visiting site I were much higher compared to site IV (personal observation). Indeed, site I continued to attract a higher number of bees compared to site IV, although it was near the end of its flowering. This could be due to the sunnier location of site I near the road or due to the higher production of nectar by the remaining flowers, either of which were not quantified in our study. Within site IV, marked bees from site II were invariably observed within the same forage area of the population over a number of days. This conforms to similar observations by Comba (1999). Indeed a section of the plants at site IV were flowering strongly but had very few bees perhaps because the plants were under constant shade. Our observations suggest that bees are more likely to remain on one side of a barrier if continuing resources are available there, and will seek new food sources when the original supply begins to decline.

While bumblebee movement may not be impeded by habitat fragmentation, habitat loss through activities such as road construction can definitely result in loss of potential nest sites for bees—an important issue that needs to be addressed in future studies on habitat fragmentation (Cane, 2001). Further studies on spatial distribution and variation in plant population genetic structure at the landscape level, along with detailed investigations of bumblebee flights and the sources of origin of pollen carried by bumblebees will help to clarify the effects of habitat fragmentation on pollinator movement.

5. Conclusions

Bumblebee pollinators are not restricted by barriers such as roads and railroads at the landscape level, where normal plant patchiness is comparable to habitat fragmentation by artificial barriers. High site fidelity displayed by bumblebees may further restrict their movement more than previously suspected because of this aspect of their foraging behavior. Although bumblebees are occasionally long-distance pollinators (Heinrich, 1979a), especially where flowers are sparse, they do not appear to travel between patches frequently where sizable patches of flowers are available. This applies even when patches are separated by natural habitat and the intervening distance is fairly short (30–40 m). When a natural population is divided into two sections by a road, field, or railroad, individual bumblebees may tend to treat it as two separate populations and not readily cross the intervening area. This is particularly true where each smaller plant population is large enough to meet their foraging needs. Thus, division of plant patches by roads and other structures may further reduce the naturally low frequency of bumblebee movement between plant patches, leading to lower rates of visitation in small isolated populations. The result may have implications for decline in gene flow in fragmented populations of plant species that depend on bumblebee visitation.

Acknowledgements

Our thanks to the Newton Conservation Commission for permission to use field sites, and to Ambika Prokop, Jolie Dubowski, Jennifer Smith, Adam Belanger, Sevima Aktay, Grace Kwong, Daniel Primack, William Primack, Vikki Rodgers and Chris Balakrishnan for assistance with fieldwork. We are grateful to three anonymous reviewers for their valuable comments and suggestions, and to Richard Forman, David Inouye, Peter Feinsinger, James Traniello and Lisa Delissio for their helpful comments on earlier drafts of the manuscript. Partial funding for the project came from Boston University and the University of Massachusetts at Boston.

References

Aizen, M.A., Feinsinger, P., 1994a. Habitat fragmentation, native insect pollinators, and feral honey bees in Argentine "Chaco Serrano". Ecological Applications 42, 378–392.

Aizen, M.A., Feinsinger, P., 1994b. Forest fragmentation, pollination, and plant reproduction in a Chaco dry forest. Argentina. Ecology 75, 330–351.

Bowers, M.A., 1985. Bumblebee colonization, extinction, and reproduction in subalpine meadows in northeastern Utah. Ecology 66, 914–927.

Cane, J.H., 2001. Habitat fragmentation and native bees: a premature verdict? Conservation Ecology 5 (1), 3. Available: http://www.consecol.org/vol5/iss1/art3.

Comba, L., 1999. Patch use by bumblebees (Hymenoptera Apidae): temperature, wind and flower density and traplining. Ethology Ecology and Evolution 11, 243–264.

Didham, R.K., Ghazoul, J., Stork, N.E., Davis, A.J., 1996. Insects in fragmented forests: a functional approach. Trends in Ecology and Evolution 11, 255–260.

Dramstad, W.E., 1996. Do bumblebees (Hymenoptera: Apidae) really forage close to their nests? Journal of Insect Behavior 9, 163–182.

Dreisig, H., 1995. Ideal free distributions of nectar foraging bumblebees. Oikos 72, 161–172.

Forman, R.T.T., Alexander, L.E., 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics 29, 207–231.

Heinrich, B., 1976. The foraging specialization of individual bumblebees. Ecological Monographs 46, 105–128.

Heinrich, B., 1979a. Bumblebee Economics. Harvard University Press, Cambridge, Massachusetts.

Heinrich, B., 1979b. "Majoring" and "minoring" by foraging bumblebees, *Bombus vagans*: an experimental analysis. Ecology 60, 245–255.

Hemingson, J. C. 1986. The Pollination Biology of *Clethra alnifolia* L. (Clethraceae). PhD dissertation, The University of Connecticut, Biology Department, Storrs.

Imbert, F.M., Richards, J.H., 1993. Protandry, incompatibility and secondary pollen presentation in *Cephalanthus occidentalis* (Rubiaceae). American Journal of Botany 80, 395–404.

Jennersten, O., 1988. Pollination in *Dianthus deltoides* (Caryophyllaceae): effects of habitat fragmentation on visitation and seed set. Conservation Biology 2, 359–366.

Jordan, R.A., Hartman, J.M., 1995. Safe sites and the regeneration of *Clethra alnifolia* L. (Clethraceae) in wetland forests of central New Jersey. American Midland Naturalist 133, 112–123.

Kearns, C.A., Inouye, D.W., 193. Techniques for Pollination Biologists. University Press of Colorado, Niwot, Colorado.

Kwak, M.M., Kremer, P., Boerrichter, E., van den Brand, C., 1991. Pollination of the rare species *Phyteuma nigrum* (Campanulaceae): flight distances of bumblebees. Proceedings of Experimental and Applied Entomology 2, 131–136.

Kunin, W.E., 1997. Population size and density effects in pollinator foraging and plant reproductive success in experimental arrays of *Brassica kaber*. Journal of Ecology 85, 225–234.

Lamont, B.B., Klinkhamer, P.G.L., Witkowski, E.T.F., 1993. Population fragmentation may reduce fertility to zero in *Banksia goodii*—a demonstration of the Allee effect. Oecologia 94, 446–450.

Lovejoy, T.E., Bierregaard, R.O., Rylands Jr., A.B., Malcolm, J.R., Quintela, C.E., Harper, L.H., Brown, K.S., Powell Jr., A.H., Powell, G.V.N., Schubert, H.O.R., Hays, M.B., 1986. Edge and other effects of isolation on Amazon forest fragments. In: Soule, M.E. (Ed.), Conservation Biology. Sinauer Associates, Sunderland, MA, pp. 257–285.

Mader, H.J., 1984. Animal habitat isolation by roads and agricultural fields. Biological Conservation 29, 81–96.

Manning, A., 1956. Some aspects of the foraging behaviour of bumble-bees. Behaviour 9, 164–201.

Noderhaug, A., 1995. Mating systems of three meadow plant species. Nordic Journal of Botany 15, 243–250.

Oostermeijer, J.G.K., Van Eijck, M.W., Den Nijs, J.C.M., 1994. Offspring fitness in relation to population size and genetic variation in the rare perennial plant species *Gentiana pneumonanthe* (Gentianaceae). Oecologia 97, 289–296.

Osborne, J.L., Clark, S.J., Morris, R.J., Williams, I.H., Riley, J.R., Smith, A.D., Reynolds, D.R., Edwards, A.S., 1999. A landscape-scale study of bumble bee foraging range and constancy, using harmonic radar. Journal of Applied Ecology 36, 519–533.

Osborne, J.L., Williams, I.H., 2001. Site constancy of bumble bees in an experimentally patchy habitat. Agriculture, Ecosystems and Environment 83, 129–141.

Plowright, R.C., Galen, C., 1985. Landmarks or obstacles: the effects of spatial heterogeneity on bumble bee foraging behavior. Oikos 44, 459–464.

Powell, A.H., Powell, G.V.N., 1987. Population dynamics of male euglossine bees in Amazonian forest fragments. Biotropica 19, 176–179.

Rasmussen, I.R., Brødsgaard, B., 1992. Gene flow inferred from seed dispersal and pollinator behaviour compared to DNA analysis of restriction site variation in a patchy population of *Lotus corniculatus* L. Oecologia 89, 277–283.

Saunders, D.A., Hobbs, R.J., Margules, C.R., 1991. Biological consequences of ecosystem fragmentation: a review. Conservation Biology 5, 18–32.

Saville, N.M., Dramstad, W.E., Fry, G.L.A., Corbet, S.A., 1997. Bumblebee movement in a fragmented agricultural landscape. Agriculture Ecosystems and Environment 61, 145–154.

Steffan-Dewenter, I., Tscharntke, T., 1999. Effects of habitat isolation on pollinator communities and seed set. Oecologia 121, 432–440.

Thomson, J.D., Peterson, S.C., Harder, L.D., 1987. Response of traplining bumble bees to competition experiments: shifts in feeding location and efficiency. Oecologia 71, 295–300.

Thomson, J.D., 1995. Trapline foraging by bumblebees: I. Persistence of flight-path geometry. Behavioral Ecology 7, 158–164.

Wesselingh, R.A., Burgers, H.C.M., Den Nijs, H.C.M., 2000. Bumblebee pollination of understorey shrub species in a tropical montane forest in Costa Rica. Journal of Tropical Ecology 16, 657–672.

Westerbergh, A., Saura, A., 1994. Gene flow and pollinator behavior in *Silene dioica* populations. Oikos 71, 215–224.

Conservation Biology

Contributed Paper

Experimental Evidence for the Effects of Chronic Anthropogenic Noise on Abundance of Greater Sage-Grouse at Leks

JESSICA L. BLICKLEY,*† DIANE BLACKWOOD,*‡ AND GAIL L. PATRICELLI*

*Department of Evolution and Ecology and Graduate Group in Ecology, 2320 Storer Hall, One Shields Avenue, University of California, Davis, CA 95616, U.S.A.
‡Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, St. Petersburg, FL, U.S.A.

Abstract: *Increasing evidence suggests that chronic noise from human activities negatively affects wild animals, but most studies have failed to separate the effects of chronic noise from confounding factors, such as habitat fragmentation. We played back recorded continuous and intermittent anthropogenic sounds associated with natural gas drilling and roads at leks of Greater Sage-Grouse (*Centrocercus urophasianus*). For 3 breeding seasons, we monitored sage grouse abundance at leks with and without noise. Peak male attendance (i.e., abundance) at leks experimentally treated with noise from natural gas drilling and roads decreased 29% and 73%, respectively, relative to paired controls. Decreases in abundance at leks treated with noise occurred in the first year of the study and continued throughout the experiment. Noise playback did not have a cumulative effect over time on peak male attendance. There was limited evidence for an effect of noise playback on peak female attendance at leks or male attendance the year after the experiment ended. Our results suggest that sage-grouse avoid leks with anthropogenic noise and that intermittent noise has a greater effect on attendance than continuous noise. Our results highlight the threat of anthropogenic noise to population viability for this and other sensitive species.*

Keywords: chronic noise, energy development, *Centrocercus urophasianus*, roads

Evidencia Experimental de los Efectos de Ruido Antropogénico Crónico sobre la Abundancia de *Centrocercus urophasianus* en Leks

Resumen: *El incremento de evidencias sugiere que el ruido crónico de actividades humanas afecta negativamente a los animales silvestres, pero la mayoría de los estudios no separan los efectos del ruido crónico de los factores de confusión, como la fragmentación del hábitat. Reprodujimos sonidos antropogénicos intermitentes y continuos asociados con la perforación de pozos de gas natural y caminos en leks de* Centrocercus urophasianus. *Durante 3 épocas reproductivas, monitoreamos la abundancia de* C. urophasianus e *leks con y sin ruido. La abundancia máxima de machos (i.e., abundancia) en leks tratados con ruido de la perforación de pozos de gas natural y caminos decreció 29% y 73% respectivamente en relación con los controles pareados. La disminución en abundancia en leks tratados con ruido ocurrió en el primer año del estudio y continuó a lo largo del experimento. La reproducción de ruido no tuvo efecto acumulativo en el tiempo sobre la abundancia máxima de machos. Hubo evidencia limitada para un efecto de la reproducción de ruido sobre la abundancia máxima de hembras en los leks o sobre la asistencia de machos el año después de que concluyó el experimento. Nuestros resultados sugieren que* C. urophasianus *evita leks con ruido anropogénico y que el ruido intermitente tiene un mayor efecto sobre la asistencia que el ruido continuo. Nuestros*

†*Address for correspondence: J. Blickley, Department of Evolution and Ecology, 2320 Storer Hall, One Shields Ave, Davis, CA 95616, USA, email jlblickley@ucdavis.edu*
Paper submitted October 19, 2010; revised manuscript accepted November 20, 2011.

Conservation Biology, Volume 26, No. 3, 461–471
©2012 Society for Conservation Biology
DOI: 10.1111/j.1523-1739.2012.01840.x

resultados resaltan amenaza del ruido antropogénico para la viabilidad poblacional de esta y otras especies sensibles.

Palabras Clave: *Centrocercus urophasianus*, desarrollo energético, ruido crónico, caminos

Introduction

Noise associated with human activity is widespread and expanding rapidly in aquatic and terrestrial environments, even across areas that are otherwise relatively unaffected by humans, but there is still much to learn about its effects on animals (Barber et al. 2009). Effects of noise on behavior of some marine organisms are well-documented (Richardson 1995). In terrestrial systems, the effects of noise have been studied less, but include behavioral change, physiological stress, and the masking of communication signals and predator sounds (Slabbekoorn & Ripmeester 2008; Barber et al. 2009). These effects of noise on individual animals may lead to population decreases if survival and reproduction of individuals in noisy habitats are lower than survival and reproduction of individuals in similar but quiet habitats (Patricelli & Blickley 2006; Warren et al. 2006; Slabbekoorn & Ripmeester 2008). Population declines may also result if animals avoid noisy areas, which may cause a decrease in the area available for foraging and reproduction.

There is evidence of variation among species in their sensitivity to noise. Noise sensitivity may also differ with the type of noise, which varies in amplitude, frequency, temporal pattern, and duration (Barber et al. 2009). Duration may be particularly critical; most anthropogenic noise is chronic and the effects of chronic noise may differ substantially from those of short-term noise in both severity and response type. For example, brief noise exposure may cause elevated heart rate and a startle response, whereas chronic noise may induce physiological stress and alter social interactions. Therefore, when assessing habitat quality for a given species, it is critical to understand the potential effects of the full spectrum of anthropogenic noise present in the species' range.

The effects of noise on wild animals are difficult to study because noise is typically accompanied by other environmental changes. Infrastructure that produces noise may be associated with fragmentation of land cover, visual disturbance, discharge of chemicals, or increased human activity. Each of these factors may affect the physiology, behavior, and spatial distribution of animals, which increases the difficulty of isolating the effects of the noise.

Controlled studies of noise effects on wild animals in terrestrial systems thus far have focused largely on birds. Recent studies have compared avian species richness, occupancy, and nesting success near natural gas wells operating with and without noise-producing compressors. In these studies, spatial variation in noise was used to control for confounding visual changes due to infrastructure (Habib et al. 2007; Bayne et al. 2008; Francis et al. 2009). Results of these studies show that continuous noise affects density and occupancy of a range of bird species and leads to decreases or increases in abundance of some species and has no effect on other species (Bayne et al. 2008; Francis et al. 2009; Francis et al. 2011). Results of these studies also show that noise affects demographic processes, such as reproduction, by reducing the pairing or nesting success of individuals (Habib et al. 2007; Francis et al. 2009).

Although these studies in areas near natural gas wells controlled for the effects of most types of disturbance besides noise, they could not address the effect of noise on naïve individuals in areas without natural gas wells and compressors. Furthermore, there have been no controlled experiments that address the effects of chronic but intermittent noise, such as traffic, which may be more difficult for species to habituate. Road noise may have large negative effects because it is widespread (affecting an estimated 20% of the United States) (Forman 2000) and observational studies indicate that noise may contribute to decreases in abundance of many species near roads (e.g., Forman & Deblinger 2000).

Noise playback experiments offer a way to isolate noise effects on populations from effects of other disturbances and to compare directly the effects of noise from different sources. Playback experiments have been used to study short-term behavioral responses to noise, such as effects of noise on calling rate of amphibians (Sun & Narins 2005; Lengagne 2008), heart rate of ungulates (Weisenberger et al. 1996), diving and foraging behavior of cetaceans (Tyack et al. 2011), and song structure of birds (Leonard & Horn 2008), but have not been used to study effects of chronic noise on wild animals because producing long-term noise over extensive areas is challenging. We conducted a playback experiment intended to isolate and quantify the effects of chronic noise on wild animals. We focused on the effects of noise from natural gas drilling on Greater Sage-Grouse (*Centrocercus urophasianus*).

Greater Sage-Grouse occur in the western United States and Canada and have long been a focus of sexual selection studies (Wiley 1973; Gibson 1989; Gibson 1996). Greater Sage-Grouse populations are decreasing in density and number across the species' range, largely due to extensive habitat loss (Connelly et al. 2004; Garton et al. 2010). The species is listed as endangered under Canada's

Species at Risk Act and is a candidate species for listing under the U.S. Endangered Species Act. Deep natural gas and coal-bed methane development have been expanded rapidly across the species' range since 2000 and substantial evidence suggests that these processes may contribute to observed decreases in the number of Greater Sage-Grouse (Holloran 2005; Walker et al. 2007; Holloran et al. 2010). Many factors associated with deep natural gas and coal-bed methane development are thought to lead to these decreases, including habitat loss, increased occurrence of West Nile Virus, and altered fire regimes due to the expansion of nonnative invasive species (Naugle et al. 2004; Walker et al. 2007; Copeland et al. 2009).

The noise created by energy development may also affect sage grouse by disrupting behavior, causing physiological stress, or masking biologically important sounds. During the breeding season (February–May), male sage grouse gather on communal breeding grounds called leks. Male attendance (number of male birds on the lek) at sage grouse leks downwind of deep natural gas development decreases up to 50% per year compared with attendance at other leks, which suggests noise or aerial spread of chemical pollution as factors contributing to these decreases (Holloran 2005).

We sought to test the hypothesis that lek attendance by male and female sage grouse is negatively affected by both chronic intermittent and continuous noise from energy development. To do so, we conducted a noise playback experiment in a population that is relatively unaffected by human activity. Over 3 breeding seasons (late February to early May), we played noise recorded from natural gas drilling rigs and traffic on gas-field access roads at sage grouse leks and compared attendance patterns on these leks to those on nearby control leks.

We conducted our experiment at leks because lekking sage grouse are highly concentrated in a predictable area, which makes them good subjects for a playback experiment. More importantly, sage grouse may be particularly responsive to noise during the breeding season, when energetic demands and predation risk are high (Vehrencamp et al. 1989; Boyko et al. 2004). Additionally, noise may mask sexual communication on the lek. Lekking males produce a complex visual and acoustic display (Supporting Information) and females use the acoustic component of the display to find lekking males and select a mate (Gibson 1989; Gibson 1996; Patricelli & Krakauer 2010). Furthermore, lek attendance is commonly used as a metric of relative abundance of sage grouse at the local and population level (Connelly et al. 2003; Holloran 2005; Walker et al. 2007). We used counts of lek attendance (lek counts) to assess local abundance relative to noise versus control treatments.

Methods

Study Site and Lek Monitoring

Our study area included 16 leks (Table 1 & Supporting Information) on public land in Fremont County, Wyoming, U.S.A. (42° 50′, 108° 29′). Dominant vegetation in this region is big sagebrush (*Artemisia tridentata wyomingensis*) with a grass and forb understory. The primary land use is cattle ranching, and there are low levels of recreation and natural gas development.

We paired leks on the basis of similarity in previous male attendance and geographic location (Table 2 & Supporting Information). Within a pair, one lek was

Table 1. Pairing, treatment type, location, and baseline attendance for leks used in noise playback experiment.

Lek	*Pair*	*Pair noise type*	*Noise or control*	*Years of playback*	*Baseline attendance**
Gustin	A	drilling	control	3	26
Preacher Reservoir	A	drilling	noise	3	49
North Sand Gulch	B	road	control	3	32
Lander Valley	B	road	noise	3	67
East Twin Creek	C	drilling	control	3	44
Coal Mine Gulch	C	drilling	noise	3	83
East Carr Springs	D	road	control	3	67
Carr Springs	D	road	noise	3	92
Powerline	E	drilling	control	2	49
Conant Creek North	E	drilling	noise	2	44
Monument	F	road	control	2	53
Government Slide Draw	F	road	noise	2	55
Nebo	G	drilling	control	2	18
Arrowhead West	G	drilling	noise	2	24
Onion Flats 1	H	road	control	2	41
Ballenger Draw	H	road	noise	2	38

**Baseline attendance is the average peak male attendance value (annual maximum number of males observed averaged across years) for that lek from 2002 to 2005.*

Table 2. Mixed-effect candidate models used to assess change in peak attendance of male Greater Sage-Grouse at leks from pre-experiment baseline attendance during the natural gas drilling noise playback (2006–2008) and after the experiment (2009).

Model (year)[a]	K[b]	ΔAIC_c[c]	w_i[d]
Male experiment (2006–2008)			
treatment×type+season[e]	9	0	0.64
treatment×type[e]	7	1.8	0.26
treatment+experiment year	6	6.1	0.03
treatment+season	7	6.8	0.02
treatment	5	7.3	0.02
treatment×experiment year	7	8.0	0.01
treatment×type+treatment×season+experiment year	12	8.6	<0.01
treatment×type+treatment×season	11	9.9	<0.01
treatment×type+treatment×season+treatment×experiment year	13	10.0	<0.01
treatment+type	6	10.4	<0.01
treatment×season	9	16.2	<0.01
null- random effects only	4	57.0	<0.01
Male after experiment (2009)			
null, random effects only[e]	3	0.0	0.84
treatment	4	3.3	0.16

[a]*All models contain pair as a random effect, and experiment (2006–2008) models also include year as a random effect. Covariates: treatment, lek treatment (noise or control) assigned to individual leks within a pair; type, pair noise treatment type (road or drilling assigned to pair); season, time of year (early [late February to 1 week prior to peak female attendance for that lek; female peak ranged from 15 March to 6 April], mid [1 week before and after female peak], and late [starting 1 week after female peak]); experiment year, years of experimental noise exposure.*
[b]*Number of parameters in the model.*
[c]*Difference in AIC_c (Akaike's information criterion for small sample size) values from the model with lowest AIC_c.*
[d]*Akaike weight.*
[e]*Model with substantial support ($\Delta AIC_c < 2$).*

randomly assigned to receive experimental noise treatment and the other lek was designated a control. We randomly assigned the experimental leks to receive playback of either drilling or road noise. In 2006, we counted attendance at 8 leks (2 treated with drilling noise, 2 treated with road noise, and 4 control). In both 2007 and 2008, we included an additional 8 leks for a total of 16 leks (4 treated with drilling noise, 4 treated with road noise, and 8 controls).

Throughout the breeding season, we counted males and females on leks with a spotting scope from a nearby point selected to maximize our visibility of the lek. We visited paired leks sequentially on the same days between 05:00 and 09:00, alternating the order in which each member of the pair was visited. We visited lek pairs every day during the breeding season in 2006 and, after expanding our sample size in 2007, every 2–4 days in 2007 and 2008. Peak estimates of male attendance from >4 visits are a highly repeatable measure of abundance at individual leks (Garton et al. 2010), so the lower frequency of visits in 2007 and 2008 was unlikely to have a substantial effect on estimates of peak male attendance. At a minimum, we conducted 2 counts per visit at 10- to 15-min intervals. The annual peak attendance was the highest daily attendance value at each lek for the season for males or females. For males we also calculated the peak attendance in 3 nonoverlapping date ranges: early (late February to 1 week prior to peak female attendance for that lek; female peak ranged from 15 March to 6 April), mid (1 week before and after female peak), and late (starting 1 week after female peak).

Noise Introduction

We recorded noise used for playback near natural gas drilling sites and gas-field access roads in a region of extensive deep natural gas development in Sublette County, Wyoming (Pinedale Anticline Gas Field and Jonah Gas Field). We recorded drilling noise in 2006 within 50 m of the source on a digital recorder (model PMD670, 44.1 kHz/16 bit; Marantz, Mahwah, New Jersey) with a shotgun microphone (model K6 with an ME60 capsule; Sennheiser, Old Lyme, Connecticut). We recorded road noise in 2005 with a handheld computer (iPAQ h5550 Pocket PC, 44.1 KHz/16 bit; Hewlett Packard, Palo Alto, California) and omnidirectional microphone (model K6 with an ME62 capsule; Sennheiser). Drilling noise is relatively continuous and road noise is intermittent (Supporting Information). Both types of noise are predominantly low frequency (<2 kHz).

We played noise on experimental leks from 2 to 4 rock-shaped outdoor speakers (300 W Outdoor Rock Speakers; TIC Corporation, City of Industry, California) hooked to a car amplifier (Xtant1.1; Xtant Technologies, Phoenix, Arizona) and an MP3 player (Sansa m240; SanDisk, Milpitas, California). The playback system was powered with 12 V batteries that we changed every 1–3 days when no birds were present. We placed the speakers

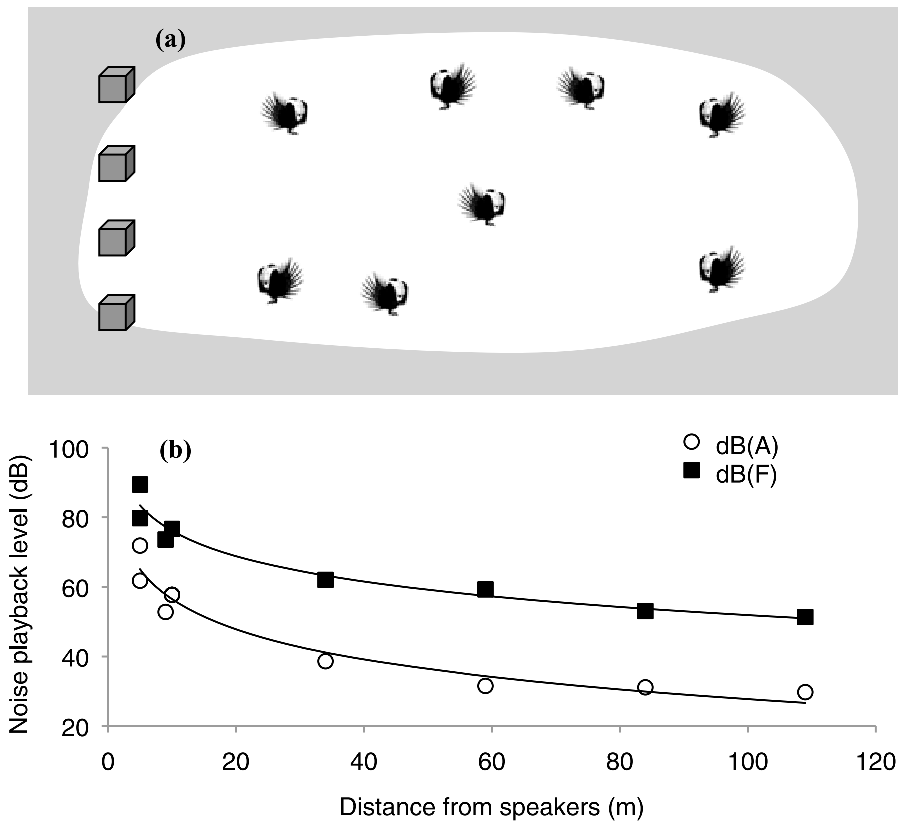


Figure 1. (a) Placement of speakers (on noise-treated leks) or dummy speakers (on control leks) (boxes) at Greater Sage-Grouse leks. (b) Mean maximum noise level (unweighted decibels, dB[F], and A-weighted decibels, dB[A], measured in Lmax [highest root-mean-square sound pressure level within the measurement period]) at Greater Sage-Grouse leks measured on transects at 25-m intervals from the line of speakers on a typical lek treated with road noise. Playback levels of natural gas drilling noise (measured in Leq) followed the same pattern. Ambient levels of noise at control leks ranged from 30 to 35 dB(A).

in a straight line across one end of the lek (Fig. 1a). In 2006 we placed 3 speakers at leks treated with drilling noise and 2 speakers at leks treated with road noise. In 2007 and 2008, we increased the number of speakers, placing 4 at each noise-treated lek to increase the area in which noise was present on the lek. At control leks, we placed dummy speakers of similar size and color to playback speakers (68-L plastic tubs). Within each lek pair, dummy and real speakers were placed in similar configurations. To control for playback-related disturbance, the leks in each pair were visited an equal number of times during the morning for counts of birds and in the afternoon for battery changes.

We played drilling noise and road noise on leks at 70 dB(F) sound pressure level (unweighted decibels) measured 16 m directly in front of the speakers (Fig. 1 & Supporting Information). This is similar to noise levels measured approximately 400 m from drilling rigs and main access roads in Pinedale (J. L. Blickley and G. L. Patricelli, unpublished data). Four hundred meters (0.25 miles) is the minimum surface disturbance buffer around leks at this location (BLM 2008). We calibrated and measured noise playback levels with a hand-held meter that provides sound-pressure levels (System 824; Larson-Davis, Depew, New York) when wind was <9.65 k/h. On drilling-noise-treated leks, where noise was continuous, we calibrated the noise playback level by measuring the average sound level (Leq [equivalent continuous sound level]) over 30 s. On leks treated with road noise, where the amplitude of the noise varied during playback to simulate the passing of vehicles, we calibrated the playback level by measuring the maximum sound level (Lmax [highest root-mean-square sound pressure level within the measurement period]).

For leks treated with drilling noise, recordings from 3 drilling sites were spliced into a 13-min mp3 file that played on continuous repeat. On leks treated with road noise, we randomly interspersed mp3 recordings of 56 semitrailers and 61 light trucks with 170 thirty-second silent files to simulate average levels of traffic on an access road (Holloran 2005). Noise playback on experimental leks continued throughout April in 2006, from mid February or early March through late April in 2007, and from late February through late April in 2008. We played back noise on leks 24 hours/day because noise from deep natural gas drilling and vehicular traffic is present at all times. This experimental protocol was reviewed and approved by the Animal Care and Use Committee at University of California, Davis (protocol 16435).

To measure noise levels across experimental leks, we measured the average amplitude (15 s Leq) of white-noise played at 1–5 points along transects that extended across the lek at 25-m intervals roughly parallel to the line of speakers. We calibrated white-noise measurements by measuring the noise level of both the white noise and either a representative clip of drilling noise or a semitrailer

10 m directly in front of each speaker. To minimize disturbance, we took propagation measurements during the day. Daytime ambient noise levels are typically 5–10 dBA higher than those in the early morning (J. L. Blickley and G. L. Patricelli, unpublished data) and are likely higher than those heard by birds at a lek.

After the experiment, we counted individuals on all leks 2–6 times from 1 March through 30 April 2009. In 2009 we continued to play noise on 2 experimental leks as part of a related experiment, so we did not include these lek pairs in our analysis of postexperiment male attendance at a lek.

Response Variables and Baseline Attendance Levels

Sage grouse leks are highly variable in size and, even within pairs, our leks varied up to 50% in size. To facilitate comparison of changes in attendance on leks of different sizes, we calculated the attendance relative to attendance levels before treatment (i.e., baseline attendance levels). We obtained male baseline abundance from the Wyoming Game and Fish Department. We used the standard lek-count protocol (Connelly et al. 2003) to count birds at leks approximately 3 times/breeding season. Due to the small number of counts in pre-experiment years, we calculated male baseline attendance by averaging the annual peak male attendance at each individual lek over 4 years (2002–2005). We assessed changes in early-, mid-, and late-season peak male attendance from this 4-year baseline attendance. Female attendance was highly variable throughout the season with a short (1–3 day) peak in attendance at each lek. Due to the limited number of annual counts, female counts from 2002 to 2005 were not reliable estimates of peak female attendance and could not be used as baseline attendance levels. Because we introduced noise to experimental leks after the peak in female attendance in 2006, we used maximum female counts from 2006 as a baseline for each of the 8 leks monitored that year. We assessed changes in annual peak female attendance from this 1-year baseline attendance. The 8 leks added to the experiment in 2007 were not included in statistical analyses of female attendance due to the lack of a baseline.

Statistical Analyses

We used an information-theoretic approach to evaluate the support for alternative candidate models (Table 2). All candidate models were linear mixed-effect models that assessed the relation between covariates and the proportional difference in annual and within-season peak attendance and baseline attendance (both males and female) (Tables 2 & 3). We ranked models on the basis of differences in Akaike's information criterion for small sample sizes (ΔAIC_c) (Burnham & Anderson 2002). Akaike weights (w_i) were computed for each model on the basis of ΔAIC_c scores. We calculated model-averaged variable coefficients, unconditional 95% CI, and variable importance (weight across models) for variables contained in models that were strongly supported ($\Delta AIC_c < 2$). All statistical analyses were performed in R (version 2.12.1) (R Development Team 2010).

Table 3. Mixed-effect candidate models used to assess change in peak annual attendance of female Greater Sage-Grouse at leks from pre-experiment baseline attendance in 2006 during noise playback.

Model[a]	K[b]	ΔAIC_c[c]	w_i[d]
Null, random effects only[e]	4	0	0.71
Treatment[e]	5	1.9	0.27
Treatment+experiment year	6	8	0.01
Treatment×experiment year	7	14	<0.001

[a] *All models contained pair and year as random effects. Due to the small sample size (4 pairs), pair type variable (road versus drilling) was not included in the model set. Covariates: treatment, lek treatment (noise or control assigned to individual leks within a pair); experiment year, years of experimental noise exposure.*
[b] *Number of parameters in the model.*
[c] *Difference in AIC_c (Akaike's information criterion for small sample size) values from the most strongly supported (lowest AICc) model.*
[d] *Akaike weight.*
[e] *Model with substantial support ($\Delta AIC_c < 2$).*

The detection probability for males and females is likely to vary across a season and among leks (Walsh et al. 2004). We sought to minimize sources of error and maximize detection by conducting frequent counts from locations with a clear view of the lek and by implementing a paired treatment design (each noise lek is compared with a similar control lek, monitored by the same observer on the same days). To ensure that detection probability did not differ among noise and control leks, we corrected our data for detection probability. First, we used detection error rates, estimated as difference between the maximum count and the count immediately before or after the maximum count within a day (for both males and females), and then we applied the bounded-count method (for males only; Walsh et al. 2004). With the multiple-count estimator, estimates of detection between noise and control leks did not differ (males: $t = 1.02$, df $= 6$, $p = 0.35$; females: $t = 0.21$, df $= 3$, $p = 0.84$). We analyzed both corrected and uncorrected counts and found that neither correction qualitatively changed our results; therefore, results are presented for uncorrected counts.

Results

Male Attendance

Peak male attendance at both types of noise leks decreased more than attendance at paired control leks, but the decreases varied by noise type. In the most strongly supported models of the candidate set ($w_i = 0.90$, all

Table 4. Model-averaged parameter direction and effect sizes and variable importance for all variables present in strongly supported models ($\Delta AIC_c < 2$ in Table 2) of changes in peak attendance of male greater sage-grouse at leks from baseline attendance during experimental noise playback.

Variable	*Percent effect size (SE)*	*Variable importance**
Intercept	31 (22)	1.0
Treatment, noise	−29 (7)	0.91
Type, road	33 (22)	0.91
Treatment, noise∗type, road	−40 (10)	0.91
Season, mid	18 (6)	0.66
Season, late	23 (6)	

**Variable importance is the summed weight of all models containing that variable.*

other models $\Delta AIC_c > 6.1$) (Table 2), there was an interaction of the effects of experimental treatment (control versus noise) and noise type (drilling versus road) on annual peak male attendance. At leks treated with road noise, decreases in annual peak male attendance were greater (73%), relative to paired controls, than at drilling noise leks (29%). As indicated by the effect size for the main effect of pair type, attendance at control leks paired with road noise leks was 33% greater relative to the baseline than control leks paired with drilling noise leks (Table 4). However, changes in attendance were compared within a pair to control for such differences. Male attendance increased over the course of a season, with 18% and 23% increases in peak male attendance in mid and late season from the early-season peaks, but seasonal increases were similar across noise and control leks (Table 4 & Fig. 2b).

There was no evidence that the effect of noise on attendance changed as years of exposure to noise increased. The models with substantial support did not contain a main effect of years of exposure or an interaction of years of exposure and treatment type (control versus noise) (Table 2). In spite of decreases in attendance throughout the experiment, peak male attendance exceeded baseline attendance on all leks in 2006, 13 leks in 2007, and 11 leks in 2008 (Table 4 & Fig. 2c). There was an increase in sage grouse abundance regionally in 2006 (Fig. 3).

After the experiment (2009), attendance at leks we experimentally exposed to drilling and road noise was lower relative to paired controls (Table 2). The model that included the treatment variable showed an effect size of −30% (across road and drilling noise leks) but had only moderate support ($\Delta AIC_c = 3.3$) relative to the null model.

Female Attendance

Peak female attendance at leks treated with noise in 2007 and 2008 decreased from the 2006 baseline, relative to control leks (Table 3). The most strongly supported model in the set was the null model; however, the model that included noise treatment was highly supported ($\Delta AIC_c < 2$). The effect size of noise treatment on female attendance was −48% (10% SE), which is similar to the effect of noise on male attendance averaged across both noise types (51%).

Discussion

Results of previous studies show abundance of Greater Sage-Grouse decreases when natural gas and coal-bed methane fields are developed (Holloran 2005; Walker et al. 2007; Doherty et al. 2008). Our results suggest that chronic noise may contribute to these decreases. Peak male attendance relative to the baseline was lower on noise leks than paired control leks, and the decrease was larger at road noise leks (73% decrease in abundance compared with paired controls) than drilling noise leks (29%; Fig. 3). These decreases were immediate and sustained. The effects of noise occurred in the first year of the study and were observed throughout the experiment, although patterns of male attendance within a season were similar at noise and control leks. Differences in male attendance between noise and control leks in the year after the experiment were not supported in the top models, which suggests attendance rebounded after noise ceased. However, the sample size for this analysis was small, and the effect size (30% average decreases in male attendance for both noise types) suggests a residual effect of noise.

There are 2 mechanisms by which noise may reduce male attendance. First, males on noise leks may have had higher mortality than males on control leks. Noise playback was not loud enough to cause direct injury to individuals, but mortality could be increased indirectly by noise playback if the sounds of predators (coyotes [*Canis latrans*] or Golden Eagles [*Aquila chrysaetos*]) were masked by noise. However, on-lek predation events were rare. We observed ≤1 predation event per lek per season during the experiment (observations of sage-grouse carcasses or feathers at a lek [J. L. Blickley, personal observation]). The cumulative effect of rare predation events would lead to a gradual decrease in attendance, rather than the rapid and sustained decrease we observed. Furthermore, experimental noise was likely too localized to substantially affect off-lek predation because noise levels decreased exponentially as distance to the speakers increased (Fig. 1b). To date, increased predation risk of adults due to anthropogenic noise has not been demonstrated in any species, but some species increase vigilance when exposed to noise, leaving less time for feeding, displaying, and other important behaviors (Quinn et al. 2006; Rabin et al. 2006). Noise may also affect off-lek mortality indirectly. For example, noise-stressed males may be more susceptible to disease due to a suppressed

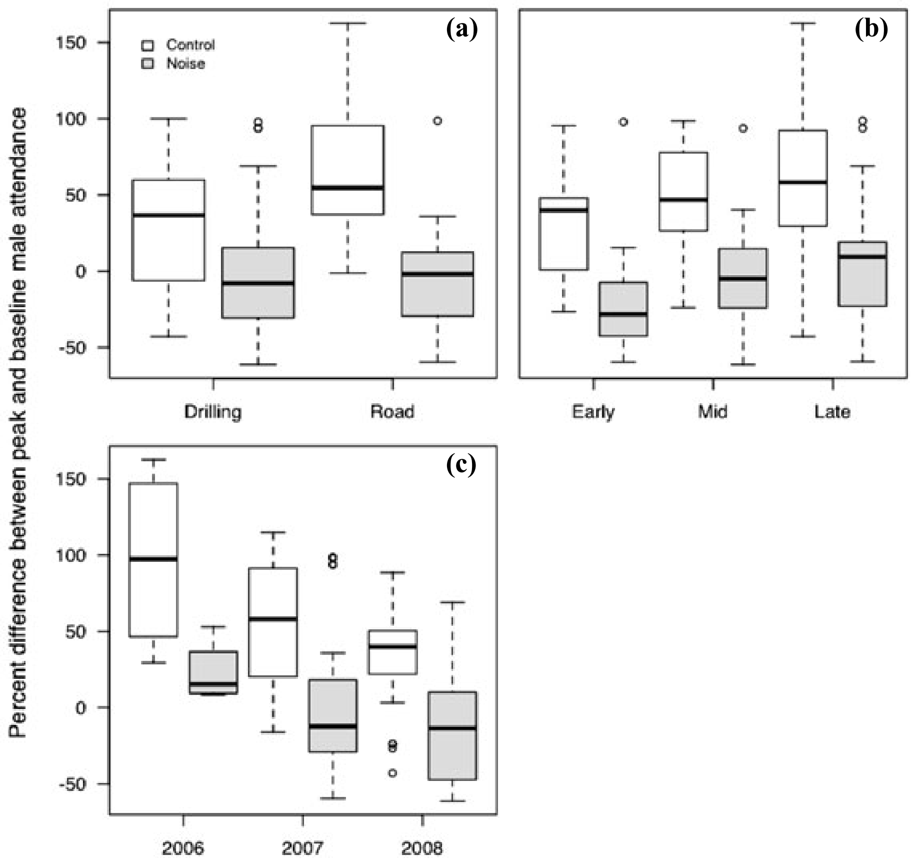


Figure 2. Percent difference between baseline attendance (i.e., abundance before experiments) of male Greater Sage-Grouse and (a) peak male attendance on control leks and leks treated with noise from natural gas drilling and road noise, (b) peak male attendance in the early (late February to 1 week prior to peak female attendance for that lek), mid (1 week before and after female peak [female peak ranged from 15 March to 6 April]), and late (starting 1 week after female peak) breeding season; on control leks and leks treated with noise, and (c) peak male attendance at control leks and leks treated with noise in experimental years 2006, 2007, and 2008 in Fremont County, Wyoming (U.S.A.) (horizontal lines, median value; box ends, upper and lower quartiles, whiskers, maximum and minimum values). Data are observed values, not model output.

immune response (Jankowski et al. 2010). Although long-term stress from noise is unlikely to be the primary cause of the rapid decreases in attendance we observed here, it may have been a contributing factor over the course of the experiment. Furthermore, in areas of dense industrial development, where noise is widespread, noise effects on mortality may be more likely.

Alternatively, noise may lower male attendance through displacement, which would occur if adult or juvenile males avoid leks with anthropogenic noise. Such behavioral shifts are consistent with the rapid decreases in attendance we observed. Adult male sage grouse typically exhibit high lek fidelity (Schroeder & Robb 2003) and visit leks regularly throughout the season, whereas juvenile males visit multiple leks and their attendance peaks late in the season (Kaiser 2006). If juveniles or adults avoid noise by visiting noisy leks less frequently or moving to quieter leks, overall attendance on noisy leks could be reduced. We could not reliably differentiate between juveniles and adults, so we do not know the relative proportion of adults and juveniles observed. Consistent with displacement due to noise avoidance, radio-collared juvenile males avoid leks near deep natural gas developments in Pinedale, Wyoming, which has resulted in decreases in attendance at leks in close proximity to development and increased attendance at nearby leks with less human activity (Kaiser 2006; Holloran et al. 2010). Reduced recruitment of juvenile males is unlikely to be the only driver of the patterns we observed because we did not observe larger decreases in lek attendance on noise-treated leks later in the season, when juvenile attendance peaks. Rather, we found immediate decreases in attendance early in the season when playback began (Fig. 2b), at which time there are few juveniles on the lek. This

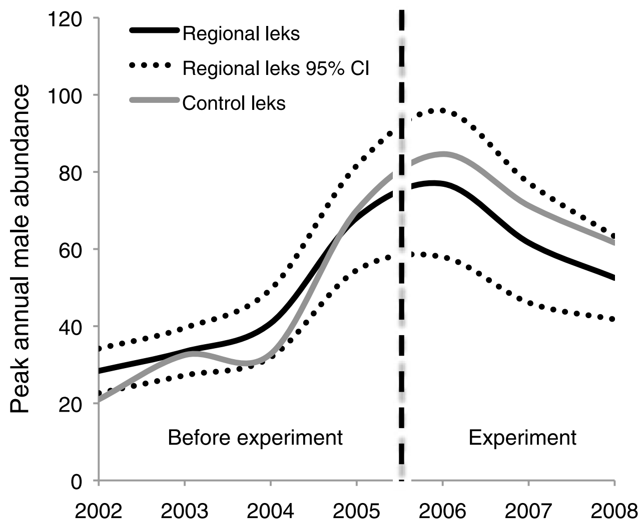


*Figure 3. Maximum abundance of male Greater Sage-Grouse from 2002 to 2008 at control leks (*n = 8*) (no anthropogenic sound played) and other leks in the region that were not part of the experiment (regional leks) (*n = 38*).*

is consistent with both adult and juvenile noise avoidance. We did not find evidence for a cumulative negative effect of noise on lek attendance, although cumulative effects may have been masked by regional population declines after 2006, a year of unusually high abundance (Fig. 3).

Female attendance at leks treated with noise was lower than that on control leks; however, the null model and the model that included noise treatment were both highly supported, providing only moderate support for the effects on noise on attendance. For this model, the overall estimated effect of noise on female attendance (−48%) was similar to that of the effect of noise on male attendance. Due to the high variability of female daily maximum attendance throughout the season and small sample size for this analysis (female attendance data available for only 4 of the 8 lek pairs), our statistical power to detect differences in female attendance was limited and effect sizes may not be representative of actual noise effects.

Our results suggest that males and possibly females avoid leks exposed to anthropogenic noise. A potential cause of avoidance is the masking of communication. Masked communication is hypothesized to cause decreases in abundance of some animal species in urban and other noisy areas. For example, bird species with low-frequency vocalizations are more likely to have low abundance or be absent from natural gas developments, roads, and urban areas than species with high-frequency vocalizations, which suggests that masking is the mechanism associated with differences in abundance (Rheindt 2003; Francis et al. 2009; Hu & Cardoso 2010). Sage-grouse may be particularly vulnerable to masked communication because their low-frequency vocalizations are likely to be masked by most sources of anthropogenic noise, including the noises we played in our experiment (Supporting Information). This may be particularly important for females if they cannot use acoustic cues to find leks or assess displaying males in noisy areas.

Alternatively, individuals may avoid noisy sites if noise is annoying or stressful, particularly if this noise is associated with danger (Wright et al. 2007). Intermittent road noise was associated with lower relative lek attendance than continuous drilling noise, in spite of the overall higher mean noise levels and greater masking potential at leks treated with drilling noise (Supporting Information). Due to the presence of roads in our study area, sage grouse may have associated road noise with potentially dangerous vehicular traffic and thus avoided traffic-noise leks more than drilling-noise leks. Alternatively, the pattern of decrease may indicate that an irregular noise is more disturbing to sage grouse than a relatively continuous noise. Regardless, our results suggest that average noise level alone is not a good predictor of the effects of noise (Slabbekoorn & Ripmeester 2008) and that species can respond differently to different types of noise.

Our results cannot be used to estimate the quantitative contribution of noise alone to observed decreases in Greater Sage-Grouse abundance at energy development sites because our experimental design may have led us to underestimate or overestimate the magnitude of these effects. Decreases in abundance due to noise could be overestimated in our study if adults and juveniles are displaced from noise leks and move to nearby control leks, which would have increased the difference in abundance between paired leks. Similar displacement occurs in areas of energy development, but over a much larger extent than is likely to have occurred in response to localized playbacks in our experiment (Holloran et al. 2010).

In contrast, we could have underestimated noise effects if there were synergistic effects of noise and other disturbances associated with energy development. For example, birds with increased stress levels due to poor forage quality may have lower tolerance for noise-induced stress, or vice versa. Noise in our experiment was localized to the immediate lek area and only played during the breeding season, so we cannot quantify the effects of noise on wintering, nesting, or foraging birds. Noise at energy development sites is less seasonal and more widespread than noise introduced in this study and may thus affect birds at all life stages and have a potentially greater effect on lek attendance. Leks do not represent discrete populations; therefore, local decreases in lek attendance do not necessarily reflect population-level decreases in abundance. However, at large energy development sites, similar displacement of Greater Sage-Grouse away from the ubiquitous noise may result in population-level declines due to spatially extensive changes in land use or increases in dispersal-related and density-dependent sources of mortality (Aldridge & Boyce 2007). Enforcement and refinement of existing seasonal restrictions on human activity could potentially reduce these effects.

We focused on the effect of noise associated with deep natural gas and coal-bed methane development on sage grouse, but our results may increase broader understanding of the effects of noise on animals. Both intermittent and constant noise from energy development affected sage grouse. Other noise sources with similar frequency range and temporal pattern, such as wind turbines, oil-drilling rigs, and mines, may have comparable effects. Similar effects may also be associated with highways, off-road vehicles, and urbanization so that the potential for noise to have an effect is large.

We believe that noise should be investigated as one potential cause of population declines in other lekking North American grouse species that are exposed to similar anthropogenic development. Populations of many bird (van der Zande et al. 1980; Rheindt 2003; Ingelfinger & Anderson 2004) and mammal (Forman & Deblinger 2000; Sawyer et al. 2009) species have been shown to decrease in abundance in response to road, urban, and energy development, and noise produced by these activities may contribute to these decreases. Our results also demonstrate that wild animals may respond differently to chronic intermittent and continuous noise, a comparison that should be expanded to other species. Additionally, we think these results highlight that experimental noise playbacks may be useful in assessing the response of wild animals to chronic noise (Blickley & Patricelli 2010).

Acknowledgments

We thank A. Krakauer, T. Rinkes, S. Oberlie, S. Harter, T. Christiansen, W. Elsberry, our many excellent field assistants, and reviewers. Funding was provided by the University of California, Davis, U.S. Bureau of Land Management, U.S. National Fish & Wildlife Foundation, Wyoming Sage-Grouse Conservation Fund, and the Wyoming Community Foundation Tom Thorne Sage-Grouse Conservation Fund.

Supporting Information

Spectrograms and power spectrums of drilling noise, road noise and male sage-grouse vocal display (Appendix S1), map of experimental and control leks (Appendix S2), and noise playback levels on experimental leks (Appendix S3) are available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

Literature Cited

Aldridge, C., and M. Boyce. 2007. Linking occurrence and fitness to persistence: habitat-based approach for endangered greater sage-grouse. Ecological Applications **17:**508–526.

Barber, J. R., K. R. Crooks, and K. M. Fristrup. 2009. The costs of chronic noise exposure for terrestrial organisms. Trends in Ecology & Evolution **25:**180–189.

Bayne, E., L. Habib, and S. Boutin. 2008. Impacts of chronic anthropogenic noise from energy-sector activity on abundance of songbirds in the boreal forest. Conservation Biology **22:**1186–1193.

Blickley, J. L., and G. L. Patricelli. 2010. Impacts of anthropogenic noise on wildlife: research priorities for the development of standards and mitigation. Journal of International Wildlife Law & Policy **13:**274–292.

BLM (Bureau of Land Management). 2008. Pinedale Anticline Project area. Supplemental environmental impact statement record of decision. Appendix A. BLM, Pinedale, Wyoming.

Boyko, A. R., R. M. Gibson, and J. R. Lucas. 2004. How predation risk affects the temporal dynamics of avian leks: greater sage grouse versus golden eagles. The American Naturalist **163:**154–165.

Burnham, K. P., and D. R. Anderson 2002. Model selection and multimodel inference: a practical information-theoretic approach. Springer-Verlag, New York.

Connelly, J. W., K. P. Reese, and M. A. Schroeder. 2003. Monitoring of greater sage-grouse habitats and populations. College of Natural Resources Experiment Station, University of Idaho, Moscow.

Connelly, J. W., S. T. Knick, M. A. Schroeder, and S. J. Stiver. 2004. Conservation assessment of greater sage-grouse and sagebrush habitats. Western Association of Fish and Wildlife Agencies, Cheyenne, Wyoming.

Copeland, H. E., K. E. Doherty, D. E. Naugle, A. Pocewicz, and J. M. Kiesecker. 2009. Mapping oil and gas development potential in the US intermountain west and estimating impacts to species. Public Library of Science One **4:**e7400. DOI: 10.1371.

Doherty, K., D. Naugle, B. Walker, and J. Graham. 2008. Greater sage-grouse winter habitat selection and energy development. Journal of Wildlife Management **72:**187–195.

Forman, R. T. T. 2000. Estimate of the area affected ecologically by the road system in the United States. Conservation Biology **14:** 31–35.

Forman, R. T. T., and R. D. Deblinger. 2000. The ecological road-effect zone of a Massachusetts(U. S. A.) suburban highway. Conservation Biology **14:**36–46.

Francis, C. D., C. P. Ortega, and A. Cruz. 2009. Noise pollution changes avian communities and species interactions. Current Biology **19:**415–419.

Francis, C., C. Ortega, and A. Cruz. 2011. Vocal frequency change reflects different responses to anthropogenic noise in two suboscine tyrant flycatchers. Proceedings of the Royal Society B: Biological Sciences **278:**2025–2031.

Garton, E. O., J. W. Connelly, J. S. Horne, C. A. Hagen, A. Moser, and M. A. Schroeder. 2010. Greater sage-grouse population dynamics and probablity of persistence. Pages 293–382. Studies in avian biology. University of California Press, Berkeley.

Gibson, R. M. 1989. Field playback of male display attracts females in lek breeding sage grouse. Behavioral Ecology and Sociobiology **24:**439–443.

Gibson, R. M. 1996. Female choice in sage grouse: the roles of attraction and active comparison. Behavioral Ecology and Sociobiology **39:**55–59.

Habib, L., E. M. Bayne, and S. Boutin. 2007. Chronic industrial noise affects pairing success and age structure of ovenbirds Seiurus aurocapilla. Journal of Applied Ecology **44:**176–184.

Holloran, M. J. 2005. Greater sage-grouse (*Centrocercus urophasianus*) population response to natural gas field development in western

Wyoming. Department of Zoology and Physiology, University of Wyoming, Laramie.
Holloran, M., R. Kaiser, and W. Hubert. 2010. Yearling greater sage-grouse response to energy development in Wyoming. Journal of Wildlife Management **74:**65–72.
Hu, Y., and G. C. Cardoso. 2010. Which birds adjust the frequency of vocalizations in urban noise? Animal Behaviour **79:**863–867.
Ingelfinger, F., and S. Anderson. 2004. Passerine response to roads associated with natural gas extraction in a sagebrush steppe habitat. Western North American Naturalist **64:**385–395.
Jankowski, M. D., J. C. Franson, E. Möstl, W. P. Porter, and E. K. Hofmeister. 2010. Testing independent and interactive effects of corticosterone and synergized resmethrin on the immune response to West Nile virus in chickens. Toxicology **269:**81–88.
Kaiser, R. 2006. Recruitment by greater sage-grouse in association with natural gas development in western Wyoming. Department of Zoology and Physiology, University of Wyoming, Laramie.
Lengagne, T. 2008. Traffic noise affects communication behaviour in a breeding anuran, *Hyla arborea*. Biological Conservation **141:**2023–2031.
Leonard, M., and A. Horn. 2008. Does ambient noise affect growth and begging call structure in nestling birds? Behavioral Ecology **19:**502–507.
Naugle, D. E., et al. 2004. West Nile virus: pending crisis for greater sage-grouse. Ecology Letters **7:**704–713.
Patricelli, G., and J. Blickley. 2006. Avian communication in urban noise: causes and consequences of vocal adjustment. The Auk **123:**639–649.
Patricelli, G., and A. Krakauer. 2010. Tactical allocation of effort among multiple signals in sage grouse: an experiment with a robotic female. Behavioral Ecology **21:**97–106.
Quinn, L., J. Whittingham, J. Butler, and W. Cresswell. 2006. Noise, predation risk compensation and vigilance in the chaffinch Fringilla coelebs. Journal of Avian Biology **37:**601–608.
Rabin, L. A., R. G. Coss, and D. H. Owings. 2006. The effects of wind turbines on antipredator behavior in California ground squirrels (*Spermophilus beecheyi*). Biological Conservation **131:**410–420.
Rheindt, F. E. 2003. The impact of roads on birds: does song frequency play a role in determining susceptibility to noise pollution? Journal of Ornithology **144:**295–306.
Richardson, W. J. 1995. Marine mammals and noise. Academic Press, San Diego, California.
Sawyer, H., M. Kauffman, and R. Nielson. 2009. Influence of well pad activity on winter habitat selection patterns of mule deer. Journal of Wildlife Management **73:**1052–1061.
Schroeder, M., and L. Robb. 2003. Fidelity of greater sage-grouse *Centrocercus urophasianus* to breeding areas in a fragmented landscape. Wildlife Biology **9:**291–299.
Slabbekoorn, H., and E. A. P. Ripmeester. 2008. Birdsong and anthropogenic noise: implications and applications for conservation. Molecular Ecology **17:**72–83.
Sun, J. W. C., and P. M. Narins. 2005. Anthropogenic sounds differentially affect amphibian call rate. Biological Conservation **121:**419–427.
Tyack, P. L., et al. 2011. Beaked whales respond to simulated and actual navy sonar. Public Library of Science One **6:**e17009. DOI: 10.1371.
van der Zande, A. N., W. J. ter Keurs, and W. J. van der Weijden. 1980. The impact of roads on the densities of four bird species in an open field habitat—evidence of a long-distance effect. Biological Conservation **18:**299–321.
Vehrencamp, S., J. Bradbury, and R. Gibson. 1989. The energetic cost of display in male sage grouse. Animal Behaviour **38:**885–896.
Walker, B. L., D. E. Naugle, and K. E. Doherty. 2007. Greater sage-grouse population response to energy development and habitat loss. Journal of Wildlife Management **71:**2644–2654.
Walsh, D. P., G. C. White, T. E. Remington, and D. C. Bowden. 2004. Evaluation of the lek-count index for greater sage-grouse. Wildlife Society Bulletin **32:**56–68.
Warren, P. S., M. Katti, M. Ermann, and A. Brazel. 2006. Urban bioacoustics: it's not just noise. Animal Behaviour **71:**491–502.
Weisenberger, M. E., P. R. Krausman, M. C. Wallace, D. W. D. Young, and O. E. Maughan. 1996. Effects of simulated jet aircraft noise on heart rate and behavior of desert ungulates. The Journal of Wildlife Management **60:**52–61.
Wiley, R. H. 1973. Territoriality and non-random mating in sage grouse (*Centrocercus urophasianus*). Animal Behaviour Monographs **6:**85–169.
Wright, A., et al. 2007. Anthropogenic noise as a stressor in animals: a multidisciplinary perspective. International Journal of Comparative Psychology **20:**250–273.

Acta Herpetologica 9(1): 103-107, 2014
DOI: 10.13128/Acta_Herpetol-12914

A preliminary report of amphibian mortality patterns on railways

Karolina A. Budzik[1], Krystian M. Budzik[2]

[1] *Department of Comparative Anatomy, Institute of Zoology, Jagiellonian University Gronostajowa 9, 30-387 Kraków, Poland. Corresponding author.* E-mail: coffee8b@gmail.com
[2] *Institute of Botany, Jagiellonian University Kopernika 27, 31-501 Kraków, Poland*

on 2013, 6th November; revised on 2014, 20th February; accepted on 2014, 4th April 2014

Abstract. In contrast to road mortality, little is known about amphibian railroad mortality. The aim of this study was to quantify amphibian mortality along a railway line as well as to investigate the relationship between the availability of breeding sites in the surrounding habitats and the monthly variation of amphibian railway mortality. The study was conducted from April to July 2011 along 45 km of the railway line Kraków - Tarnów (Poland, Małopolska province). Three species were affected by railway mortality: *Bufo bufo, Rana temporaria* and *Pelophylax* kl. *esculentus*. Most dead individuals (77%) were adult common toads. The largest number (14) of amphibian breeding sites was located in the most heterogeneous habitats (woodland and rural areas), which coincides with the sectors of highest amphibian mortality (42% of all accidents). As in the case of roads, spring migration is the period of highest amphibian mortality (87% of all accidents) on railroads. Our findings suggest that railroad mortality depends on the agility of the species, associated primarily with the ability to overcome the rails.

Keywords. Habitat effect, seasonality effect, common toad, Poland.

One of the main consequences of urbanization is the construction of new communication

networks, e.g. linear infrastructures such as roads and railways. Roads are physical barriers to animal migration, which may have negative consequences both in terms of animal mortality and habitat fragmentation (Andrews and Gibbons, 2005) and, in turn, may lead to isolation of populations through reduced movement and gene flow (Gibbs, 1998; St. Clair, 2003). Among vertebrates, amphibians are the most affected by these threats (Stuart et al., 2004). Their requirement of aquatic habitats and reproduction-dependent seasonal migrations make them particularly vulnerable to the negative impact of road traffic (Hels and Buchwald, 2001; Hamer and McDonnell, 2008). Apart from roads, railways may also act as migratory barriers and thus negatively affect amphibian populations (Berthoud and Antoniazza, 1998; Ray et al., 2002). To date, the impact of railways on amphibians has not been established and, in contrast to the issue of amphibian road mortality (Carr and Fahrig, 2001; Mazerolle, 2004; Sirello, 2008; Sutherland et al., 2010), data on amphibian mortality due to the presence of railways are very scarce (Berthoud and Antoniazza, 1998; Vos et al., 2001; Reshetylo and Briggs, 2010). The aim of this study was to quantify amphibian mortality along a railway line and to investigate the effect of the surrounding habitat and the seasonal variation of railway mortality of amphibians. The study was conducted along 45 km of the line Podłęże - Biadoliny (direction Kraków - Tarnów, southern Poland) (Fig. 1). The railroad is constituted by two rail lines that split into several others where large stations occur. The track spacing is 1.435 m wide, and the height of the rail profile is 0.172 m. The substrate of the tracks is made of stones. The average daily number of trains running on this route in both directions is about 60. The trains run between 3:00 am and 23:00 pm. The average frequency of trains is 2-3 trains / h, increasing up to 3-4 trains / h from 14:00 to 20:00 (due to a lack of data, freight trains were not included). The study site included highly urbanized and agricultural

ISSN 1827-9635 (print)
ISSN 1827-9643 (online)

© Firenze University Press
www.fupress.com/ah

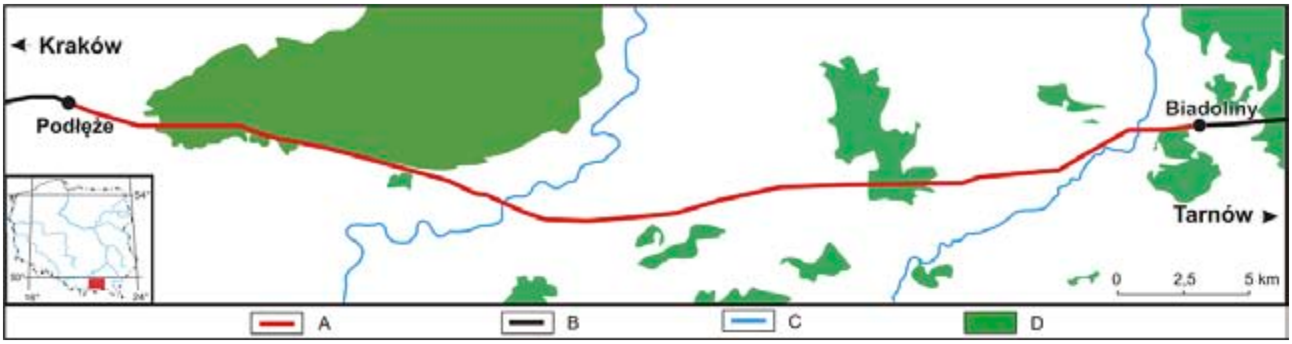


Fig. 1. Location of the surveyed transect in Poland. Legend: A - surveyed transect of railway line, B - further railway line, C - rivers, D - forests.

areas, grasslands and forests. Numerous ditches, oxbows and wetlands, as well as some larger water bodies, such as fish ponds, occur near the railway line and constitute potential breeding habitat for amphibians. The stretch was divided into 30 transects associated with different types of habitat. Five types of transects were established: 'woodland' transects with woodland on both sides of the railroad (six transects; total length: 11.35 km), 'woodland and rural areas' transects with woodland on one side of the railroad and rural areas on the other side (four transects; total length: 6.16 km), 'rural areas' transects with rural areas on both sides of the railroad (10 transects; total length: 14.74 km), 'open areas' transects with open, natural areas (eight transects; total length: 9.8 km) and 'urban areas' transects (two transects; total length: 3.25 km). The study was conducted from April to July 2011. In April and May each transect was monitored twice a month, while in June and July, once a month. All transects were surveyed on foot. The duration of each survey was 1 to 3 hours. The surveys were conducted from the morning until the evening (often three or four transects a day), usually in sunny and dry weather. All findings of dead amphibians were georeferenced, photographed, and information on amphibian species and age (juvenile or adult) were taken. This detailed information ensured that we avoided recounting of dead individuals, even though we did not remove dead amphibians from the rails. Additionally, the presence of dead reptiles was registered. A buffer zone of about 150 m on both sides of the railway was monitored for the presence of amphibians and potential reproductive sites at the same time as the railway mortality surveys. The inspections consisted of searching through all ditches, pools, puddles and water bodies, their edges and vicinities. The water reservoirs were also dipnetted. All individuals were released after identification in the field. The determination of amphibian presence was based on direct observations of adults and juveniles, as well as on observations of spawn, larvae and male mating calls. All observed green frogs were classified as *Pelophylax* kl. *esculentus*. Chi square tests were used to assess differences in railroad mortality depending on habitat type and month. Additionally, differences in number of breeding sites in different habitat types were assessed. The analysis included only breeding sites of species affected by railroad mortality. Then, differences between pairs of habitat types in respect to railroad mortality and breeding site abundance were tested. Spearman's correlation was used to measure the association between the number of dead specimens found on the railroad for each species with the number of reproductive sites found in the buffer zone.

Within the study area we found the following species (the number of breeding sites is given in parentheses): the agile frog *Rana dalmatina* (23 sites), the common frog *R. temporaria* (7 sites), the moor frog *R. arvalis* (1 site), the green frogs *Pelophylax* kl. *esculentus* (43 sites), the European tree frog *Hyla arborea* (1 site), the fire-bellied toad *Bombina bombina* (10 sites), the common toad *Bufo bufo* (5 sites), the great crested newt *Triturus cristatus* (4 sites), and the smooth newt *Lissotriton vulgaris* (1 site). A total of 62 dead individuals of three species (*B. bufo*, *R. temporaria* and *P.* kl *esculentus*) were found within the area of the railway tracks. Seven frog specimens were not identified. Most dead amphibians were adult common toads (77%), and a large proportion of dead frogs (73%) were juveniles. The transect differed in terms of amphibian mortality (χ^2 = 54.4, df = 4, p-value < 0.001): the majority of the amphibian mortality occurred in woodland and rural areas (Fig. 2, Table 1). The buffer zone areas (habitat types) varied in terms of amphibian breeding site abundance (χ^2 = 10.8, df = 4, p-value < 0.05). Most of the breeding sites (of amphibians affected by railroad mortality) were located in the 'woodland and rural areas' type (Table 2). The number of dead speci-

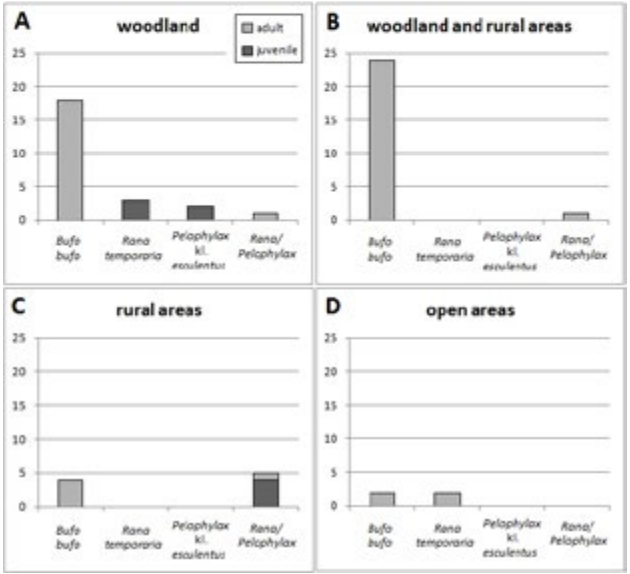


Fig. 2. Number of dead individuals (including their age) found in different types of habitat: woodland (A), woodland and rural areas (B), rural areas (C) and open areas (D).

mens and the number of reproductive sites occurring in the habitat types was not significantly correlated for any of the species. However, this association is present if all dead frogs (*Rana temporaria*, *Pelophylax* kl.*esculentus* and unspecified *Rana*/*Pelophylax*) are taken together (R = 0.436, p-value < 0.05). There is also a significant relationship between dead *B. bufo* and breeding sites abundance (R = 0.458, p-value < 0.001), if three breeding sites situated outside the buffer zone (up to 1.3 km in a straight line from the tracks) (Budzik K. M., pers. inf.) are taken into account. The majority of dead amphibians were found at the beginning of the reproductive season (χ^2 = 128.2, df = 3, p-value < 0.001; Fig. 3). Most dead amphibians found in April were spatially clustered, while in the following months the specimens were scattered. Many of the toads (58%) were found within the railroad tracks and their remains were fragmented. The remaining individuals, as well as other dead amphibians, were not mechanically damaged. All dead frogs were found outside of the railroad track. Additionally, in May we found one road-killed fire-bellied toad under one of the rail viaducts. We found six dead grass snakes (*Natrix natrix*), one of which was found near a dead common toad (Fig. 4).

To our knowledge, this study - despite being largely exploratory - reports the first empirical data on amphibian railway mortality. Our results show that railway mortality is a real threat for amphibians, an issue that requires deeper evaluation for conservation planning. The amphibians found in the study area are common in this region of Poland (Głowaciński and Rafiński, 2003). Furthermore, two of the three species affected by railroad mortality (*B. bufo, R. temporaria*), are among the most common European amphibians, for which there is evidence of great road-mortality (Orłowski, 2007; Bonardi et al., 2011; Matos et al., 2012). The high number of amphibians killed along woodland and rural areas is likely associated with the abundance of breeding sites in these types of habitats. However, the results predominantly relate to the common toad, therefore they are highly conditioned by this species, which typically inhabits heterogeneous habitats (Pavignano et al., 1990).

Table 1. Chi-square test comparing the railroad mortality between each pair of habitat types. "-" refers to low expected frequencies, test is not applicable.

	Woodland	Woodland and Rural	Rural	Open
Woodland and Rural	χ^2 = 5.4, df=1, p < 0.05			
Rural	χ^2 = 11.5, df=1, p < 0.001	χ^2 = 31.7, df=1, p < 0.001		
Open	χ^2 = 11.5, df=1, p < 0.001	χ^2 = 27.7, df=1, p < 0.001	-	
Urban	χ^2 = 6.9, df=1, p < 0.01	χ^2 = 13.2, df=1, p < 0.001	-	-

Table 2. Chi-square test comparing the number of *B. bufo*, *R. temporaria*, and *P.* kl *esculentus* breeding sites between each pair of habitat types. "-" refers to low expected frequencies, test is not applicable. NS: non significant p-value.

	Woodland	Woodland and Rural	Rural	Open
Woodland and Rural	χ^2 = 1.7, df=1, NS			
Rural	χ^2 = 2.7, df=1, NS	χ^2 = 8.4, df=1, p < 0.01		
Open	χ^2 = 1.1, df=1, NS	χ^2 = 4.8, df=1, p < 0.05	-	
Urban	χ^2 = 1.3, df=1, NS	χ^2 = 3.4, df=1, NS	-	-

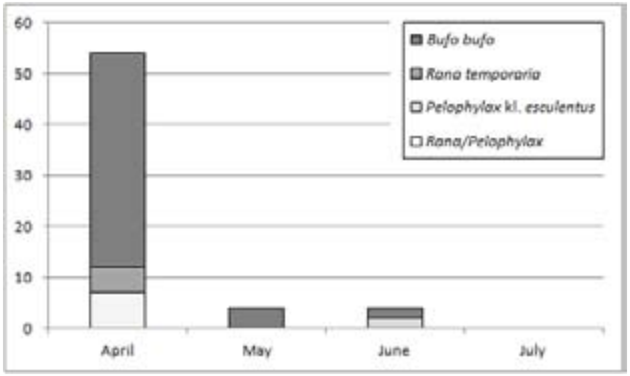


Fig. 3. Number of dead individuals found in each month of the survey.

Fig. 4. Dead common toad (*Bufo bufo*, arrow) on the tracks with dead grass snake (*Natrix natrix*). Photo by K.M. Budzik.

Most dead amphibians were spatially clustered in April but this result appears conditioned by the large number of common toads and their mass migrations to breeding sites. Toads were scattered after the breeding season, suggesting seasonal migrations towards feeding grounds. Additionally, as in the case of roads (Hels and Buchwald, 2001; Hamer and McDonnell, 2008), spring migration seems to be the period of highest amphibian mortality on railroad tracks. Undetermined frogs were probably representatives of the common frog or moor frog, which awakened from hibernation in April. The peak of green frog mortality in June may indicate dispersal in search of new habitats because of the gradual drying of habitat in ditches alongside the railroad tracks. The fragmentation of the remains of common toads clearly suggests that the direct cause of death was collision with a train. The short limbs of these animals reduce their ability of overcoming barriers such as rails. In addition, numerous studies have shown that amphibians are likely to remain immobile if faced with an approaching light (Cornell and Hailman, 1984; Mazerolle et al., 2005). Thus, it is possible that common toad activity can be disturbed under train light, increasing the risk of mortality. The toads that were not damaged, but trapped inside the track, probably died of dehydration. Because dead frog individuals were not mechanically damaged, we suppose that they were probably hit by a train while trying to overcome the rails. The majority of dead frogs were juveniles. We suggest that most adults, able to hop farther and faster than the juveniles, may migrate more successfully. We did not find any dead individuals of the agile frog, the European tree frog, the fire-bellied toad or newts. As regards the latter, small-sized species may avoid the tracks because they are unable to cross them. To successfully migrate, their only option may be to avoid the rails and rather move along the viaducts: this suggestion is worthy of further investigation. However, this result may also be due to a sampling issue: on the one hand, small-sized amphibians dry up faster; on the other hand they may be crushed by a train; either way, this would make them very difficult to detect (Dodd et al., 2004; Mazerolle et al., 2005). There is also the possibility that small-sized amphibians may migrate through a gap under the railway. The agile frog and probably the other frogs seem to successfully cross the rails, probably thanks to their jumping ability. Railroad mortality seems to depend on physical features (such as body size, limb length) and may be associated with the agility of the species. In the case of roads, agility was related mainly to velocity of the individual (Schlupp and Podloucky, 1994; Hels and Buchwald, 2001), while in the case of railroad tracks, agility relates primarily to the ability to overcome obstacles. Due to its physical features, the common toad was more likely to become stranded at the rail, indicating that this species is more vulnerable to railway mortality. However, other species that do not cross the track because of their small body size may also be affected by the railroad, but at the level of gene flow (Reh, 1989; Vos et al., 2001) which represents a conservation issue that is worthy of further study.

Further investigations examining in detail the effect of individual physical features on amphibian railroad mortality, railway-related migration behavior of amphibians, as well as gene flow among amphibian populations isolated by railway line, are warranted.

ACKNOWLEDGEMENT

We would like to thank Luca Corlatti and a second anonymous reviewer for providing comments that greatly improved previous versions of this manuscript.

REFERENCES

Andrews, K.M., Gibbons, J.W. (2005): How do highways influence snake movement? Behavioral responses to roads and vehicles. Copeia **2005**: 772-782.

Berthoud, G., Antoniazza, V. (1998): Protection des batraciens. Estimation des populations utilisant les passages aménagés sous la route Yverdon-Yvonand. Rapport de gestion no 52. Suivi scientifique. Gestion des zones naturelles de la rive sud du lac de Neuchâtel. GEG Grande Cariçaie, Cheseaux-Noréaz.

Bonardi, A., Manenti, R., Corbetta, A., Ferri, V., Fiacchini, D., Giovine, G., Macchi, S., Romanazzi, E., Soccini, C., Bottoni, L., Padoa-Schioppa, E., Ficetola, G.F. (2011): Usefulness of volunteer data to measure the large scale decline of "common" toad populations. Biol. Conserv. **144**: 2328-2334.

Carr, L.W., Fahrig, L. (2001): Impact of road traffic on two amphibian species of differing vagility. Conserv. Biol. **15**: 1071-1078.

Cornell, E., Hailman, J.P. (1984): Pupillary responses of two *Rana pipiens*-complex anuran species. Herpetologica **40**: 356-366.

Dodd, C.K., Jr., Barichivich, W.J., Smith, L.L. (2004): Effectiveness of a barrier wall and culverts in reducing wildlife mortality on a heavily traveled highway in Florida. Biol. Conserv. **118**: 619-631.

Gibbs, J.P. (1998): Amphibian movements in response to forest edges, roads, and streambeds in southern New England. J. Wildlife Manage. **62**: 584-589.

Głowaciński, Z., Rafiński, J. (2003): Atlas płazów i gadów Polski - status, rozmieszczenie, ochrona. Biblioteka Monitoringu Środowiska, IOŚ/IOP PAN, Kraków - Warszawa.

Hamer, A.J., McDonnell, M.J. (2008): Amphibian ecology and conservation in the urbanising world: a review. Biol. Conserv. **141**: 2432-2449.

Hels, T., Buchwald, E. (2001): The effect of road kills on amphibian populations. Biol. Conserv. **99**: 331-340.

Matos, C., Sillero, N., Argaña, E. (2012): Spatial analysis of amphibian road mortality levels in northern Portugal country roads. Amphibia-Reptilia **33**: 469-483.

Mazerolle, M.J. (2004): Amphibian road mortality in response to nightly variations in traffic intensity. Herpetologica **60**: 45-53.

Mazerolle, M.J., Huot, M., Gravel, M. (2005): Behavior of amphibians on the road in response to car traffic. Herpetologica **61**: 380-388.

Orłowski, G. (2007): Spatial distribution and seasonal pattern in road mortality of the common toad *Bufo bufo* in an agricultural landscape of south-western Poland. Amphibia-Reptilia **28**: 25-31.

Pavignano, I., Giacoma, C., Castellano, S. (1990): A multivariate analysis of amphibian habitat determinants in north western Italy. Amphibia–Reptilia **11**: 311-324.

Ray, N., Lehmann, A., Joly, P. (2002): Modeling spatial distribution of amphibian populations: a GIS approach based on habitat matrix permeability. Biodivers. Conserv. **11**: 2143-2165.

Reh, W. (1989): Investigations into the influence of roads on the genetic structure of populations of the common frog *Rana temporaris*. In: Amphibians and Roads, pp. 101-103. Langton, T.E.S., Eds, ACO Polymer Products, London.

Reshetylo, O., Briggs, L. (2010): Diversity of amphibians in the places of road and rail investment in Poland. In: Biologia płazów i gadów - ochrona herpetofauny, pp. 103-109. Zamachowski, W., Eds, Wyd. Nauk. UP Kraków.

Schlupp, I., Podloucky, R. (1994): Changes in breeding site fidelity: A combined study of conservation and behaviour in the common toad *Bufo bufo.* Biol. Conserv. **69**: 285-291.

Sirello, N. (2008): Amphibian mortality levels on Spanish country roads: descriptive and spatial analysis. Amphibia-Reptilia **29**: 337-347.

St. Clair, C.C. (2003): Comparative permeability of roads, rivers, and meadows to songbirds of Banff National Park. Conserv. Biol. **17**: 1151-1160.

Stuart, S.N., Chanson, J.S., Cox, N.A., Young, B.E., Rodrigues, A.S.L., Fischman, D.L., Waller, R.W. (2004): Status and trends of amphibian declines and extinctions worldwide. Science **306**: 1783-1786.

Sutherland, R.W., Dunning, P.R., Baker, W.M. (2010): Amphibian encounter rates on roads with different amounts of traffic and urbanization. Conserv. Biol. **24**: 1626-1635.

Vos, C.C., Antonisse-De Jong, A.G., Goedhart, P.W., Smulders, M.J.M. (2001): Genetic similarity as a measure for connectivity between fragmented populations of the moor frog (*Rana arvalis*). Heredity **86**: 598-608.

	Global and State Rank	CaCode	CNDDB Code
1. Mesomorphic Tree Vegetation (Forest and Woodland)			
1.C. Temperate Forest			
1.C.1. Warm Temperate Forest			
1.C.1.c. Madrean Forest and Woodland			
MG009. California Forest and Woodland			
Mixed North Slope Forest	G4 S4		CTT81500CA
Mixed North Slope Cismontane Woodland	G3 S3.2		CTT71420CA
***Aesculus californica* (California buckeye groves) Alliance**	G3 S3	*75.100.00	
Aesculus californica		*75.100.03	
Aesculus californica - Umbellularia californica / Diplacus aurantiacus		*75.100.02	
Aesculus californica - Umbellularia californica / Holodiscus discolor		*75.100.06	
Aesculus californica / Datisca glomerata		*75.100.04	
Aesculus californica / Lupinus albifrons		*75.100.05	
Aesculus californica / Toxicodendron diversilobum / moss		*75.100.01	
***Juglans californica* (California walnut groves) Alliance**	G3 S3	*72.100.00	
California Walnut Woodland	G2 S2.1		CTT71210CA
Walnut Forest	G1 S1.1		CTT81600CA
Juglans californica - Quercus agrifolia		*72.100.08	
Juglans californica / annual herbaceous		*72.100.03	
Juglans californica / Artemisia californica / Leymus condensatus		*72.100.04	
Juglans californica / Ceanothus spinosus		*72.100.05	
Juglans californica / Heteromeles arbutifolia		*72.100.06	
Juglans californica / Malosma laurina		*72.100.07	
***Lyonothamnus floribundus* (Catalina ironwood groves) Special Stands**	G2 S2	*77.000.00	
Island Ironwood Forest	G2 S2.1		CTT81700CA
***Quercus agrifolia* (Coast live oak woodland) Alliance**	G5 S4 (some associations are of high priority for inventory)	71.060.00	
Coast Live Oak Woodland	G4 S4		CTT71160CA
Coast Live Oak Forest	G4 S4		CTT81310CA
Central Coast Live Oak Riparian Forest	G3 S3.2		CTT61220CA
Southern Coast Live Oak Riparian Forest	G4 S4		CTT61310CA
Quercus agrifolia		71.060.02	
Quercus agrifolia - Acer macrophyllum / Frangula californica - Holodiscus discolor		71.060.03	
Quercus agrifolia - Aesculus californica		71.060.52	
Quercus agrifolia - Arbutus menziesii		71.060.40	
Quercus agrifolia - Arbutus menziesii - Toxicodendron diversilobum		71.060.41	
Quercus agrifolia - Arbutus menziesii - Umbellularia californica		71.060.26	
Quercus agrifolia - Arbutus menziesii / Corylus cornuta - Rubus spp.		71.060.10	
Quercus agrifolia - Juglans californica		71.060.27	
Quercus agrifolia - Pinus coulteri		71.060.23	
Quercus agrifolia - Platanus racemosa - Salix laevigata		71.060.43	
Quercus agrifolia - Platanus racemosa / Toxicodendron diversilobum		71.060.42	
Quercus agrifolia - Quercus douglasii		71.060.01	
Quercus agrifolia - Quercus engelmannii / Eriogonum fasciculatum		71.060.45	
Quercus agrifolia - Quercus kelloggii		*71.060.18	

Quercus agrifolia - Salix lasiolepis		71.060.47	
Quercus agrifolia - Umbellularia californica		71.060.48	
Quercus agrifolia - Umbellularia californica / Arctostaphylos glauca - Toxicodendron diversilobum		71.060.51	
Quercus agrifolia - Umbellularia californica / Ceanothus oliganthus		71.060.49	
Quercus agrifolia - Umbellularia californica / Heteromeles arbutifolia - Quercus berberidifolia		71.060.05	
Quercus agrifolia - Umbellularia californica / Toxicodendron diversilobum		71.060.50	
Quercus agrifolia / Adenostoma fasciculatum (- Salvia mellifera)		71.060.07	
Quercus agrifolia / Artemisia californica		71.060.08	
Quercus agrifolia / Ceanothus oliganthus		71.060.16	
Quercus agrifolia / Ceanothus spinosus		71.060.34	
Quercus agrifolia / chaparral		71.060.29	
Quercus agrifolia / coastal sage scrub		71.060.28	
Quercus agrifolia / Equisetum hymale		71.060.35	
Quercus agrifolia / Eriogonum wrightii		71.060.22	
Quercus agrifolia / Frangula californica - Heteromeles arbutifolia		71.060.06	
Quercus agrifolia / Frangula californica ssp. tomentella / Stachys pycnantha		71.060.36	
Quercus agrifolia / grass		71.060.09	
Quercus agrifolia / Heteromeles arbutifolia		71.060.14	
Quercus agrifolia / Heteromeles arbutifolia - Toxicodendron diversilobum		71.060.15	
Quercus agrifolia / Holodiscus discolor - Symphoricarpos albus		71.060.11	
Quercus agrifolia / Quercus berberidifolia		71.060.37	
Quercus agrifolia / Rubus spp. / Pteridium aquilinum		71.060.04	
Quercus agrifolia / Salvia leucophylla - Artemisia californica		71.060.38	
Quercus agrifolia / Symphoricarpos albus		71.060.17	
Quercus agrifolia / Toxicodendron diversilobum		71.060.13	
Quercus agrifolia / Toxicodendron diversilobum - (Corylus cornuta)		71.060.25	
Quercus agrifolia / Toxicodendron diversilobum / grass		71.060.12	
Quercus agrifolia / Toxicodendron diversilobum riparian		71.060.39	
***Quercus chrysolepis* (Canyon live oak forest) Alliance**	G5 S5 (some associations are of high priority for inventory)	71.050.00	
Canyon Live Oak Forest	G4 S4		CTT81320CA
Canyon Live Oak Ravine Forest	G3 S3.3		CTT61350CA
Pinus ponderosa - Quercus chrysolepis / Arctostaphylos viscida		71.050.31	
Quercus chrysolepis		71.050.04	
Quercus chrysolepis - Arbutus menziesii - Lithocarpus densiflorus var. densiflorus		71.050.01	
Quercus chrysolepis - Calocedrus decurrens		71.050.19	
**Quercus chrysolepis - Ceanothus integerrimus*		*71.050.03	
Quercus chrysolepis - Pinus jeffreyi		71.050.32	
**Quercus chrysolepis - Pinus lambertiana*		*71.050.02	
**Quercus chrysolepis - Pinus ponderosa*		*71.050.18	
Quercus chrysolepis - Pinus sabiniana		71.050.16	
**Quercus chrysolepis - Quercus garryana var. garryana / Pentagramma triangularis*		*71.050.07	
**Quercus chrysolepis - Quercus kelloggii - Acer macrophyllum*		*71.050.27	
Quercus chrysolepis - Quercus kelloggii / (Toxicodendron diversilobum)		71.050.26	
**Quercus chrysolepis - Quercus lobata / Vitis californica*		*71.050.28	
Quercus chrysolepis - Quercus wislizeni		71.050.29	

Quercus chrysolepis - Umbellularia californica		71.050.13	
**Quercus chrysolepis - Umbellularia californica / Vitis californica*		*71.050.30	
Quercus chrysolepis / Arctostaphylos mewukka		71.050.09	
Quercus chrysolepis / Arctostaphylos patula		71.050.15	
Quercus chrysolepis / Arctostaphylos viscida		71.050.14	
Quercus chrysolepis / Dryopteris arguta		71.050.17	
Quercus chrysolepis / Lithocarpus densiflorus var. echinoides		71.050.25	
Quercus chrysolepis / Polystichum imbricans		71.050.08	
Querecus chrysolepis / Rhamnus ilicifolia		71.050.33	
Quercus chrysolepis / Toxicodendron diversilobum		71.050.21	
***Quercus douglasii* (Blue oak woodland) Alliance**	G4 S4 (some associations are of high priority for inventory)	71.020.00	
Blue Oak Woodland	G3 S3.2		CTT71140CA
Quercus douglasii - Aesculus californica / Asclepias fascicularis		71.020.44	
Quercus douglasii - Aesculus californicus / grass		71.020.24	
Quercus douglasii - Pinus sabiniana		71.020.02	
Digger Pine Oak Woodland	G4 S4		CTT71410CA
Quercus douglasii - Pinus sabiniana / Arctostaphylos viscida		71.020.04	
Quercus douglasii - Pinus sabiniana / Ceanothus cuneatus - Cercocapus montanus		71.020.03	
Quercus douglasii - Pinus sabiniana / Cercocarpus montanus		71.020.25	
Quercus douglasii - Quercus agrifolia		71.020.01	
**Quercus douglasii - Quercus lobata*		*71.020.11	
Quercus douglasii - Quercus wislizeni		71.020.06	
Quercus douglasii - Quercus wislizeni - Pinus sabiniana		71.020.18	
Quercus douglasii - Quercus wislizeni / Bromus spp. - Daucus pusillus		71.020.17	
Quercus douglasii - Quercus wislizeni / Ceanothus cuneatus		71.020.07	
Quercus douglasii - Quercus wislizeni / Lithophragma cymbalaria		71.020.46	
Quercus douglasii / Juniperus californica - Cercocarpus montanus		71.020.42	
Quercus douglasii / Achnatherum lemmonii		71.020.43	
Quercus douglasii / Amsinckia intermedia - Plagiobothrys nothofulvus		71.020.27	
Quercus douglasii / Arctostaphylos manzanita / herbaceous		71.020.22	
Quercus douglasii / Brachypodium distachyon		71.020.28	
Quercus douglasii / Bromus hordeaceus - Lolium multiflorum		71.020.30	
Quercus douglasii / Bromus hordeaceus - Madia gracilis		71.020.29	
Quercus douglasii / Bromus hordeaceus - Triteleia laxa		71.020.31	
Quercus douglasii / Bromus spp. - Daucus pusillus		71.020.16	
Quercus douglasii / Ceanothus cuneatus		71.020.12	
**Quercus douglasii / Cercocarpus montanus / Bowlesia incana - Lithophragma affine*		*71.020.14	
Quercus douglasii / Collinsia sparsiflora - Rigiopappus leptocladus		71.020.32	
Quercus douglasii / Delphinium parryi - Phacelia imbricata		71.020.33	
Quercus douglasii / Ericameria linearifolia		71.020.08	
Quercus douglasii / Ericameria linearifolia - Juniperus californica		71.020.19	
Quercus douglasii / Eriogonum elongatum / Lotus subpinnatus - Plantago erecta		71.020.34	
Quercus douglasii / Eriogonum fasciculatum / herbaceous		71.020.20	
Quercus douglasii / Erodium moschatum - Hordeum leporinum		71.020.35	
Quercus douglasii / Euphorbia spathulata - Pentagramma triangularis		71.020.36	

Quercus douglasii / Galium andrewsii - Lupinus concinnus		71.020.37	
Quercus douglasii / grass		71.020.05	
Quercus douglasii / Hordeum leporinum - Viola pedunculata		71.020.38	
Quercus douglasii / Juniperus californica		71.020.26	
Juniper Oak Cismontane Woodland	G3 S3.2		CTT71430CA
**Quercus douglasii / Juniperus californica - Ceanothus cuneatus*		*71.020.23	
Quercus douglasii / Juniperus californica - Quercus john-tuckeri		71.020.41	
Quercus douglasii / Lotus subpinnatus - Nassella pulchra		71.020.40	
Quercus douglasii / Lupinus concinnus - Trifolium ciliolatum		71.020.39	
Quercus douglasii / Ribes californica / Bromus diandrus		71.020.15	
**Quercus douglasii / Selaginella hansenii - Navarretia pubescens*		*71.020.21	
Quercus douglasii / Toxicodendron diversilobum / grass		71.020.45	
Quercus douglasii / understory oak		71.020.09	
***Quercus engelmannii* (Engelmann oak woodland) Alliance**	G3 S3	*71.070.00	
Engelmann Oak Woodland	G2 S2.1		CTT71180CA
Open Engelmann Oak Woodland	G2 S2.2		CTT71181CA
Dense Engelmann Oak Woodland	G2 S2.1		CTT71182CA
**Quercus engelmannii - Quercus agrifolia / Artemisia californica*		*71.070.02	
**Quercus engelmannii - Quercus agrifolia / chaparral (Adenostoma fasciculatum - Quercus berberidifolia - Rhamnus ilicifolia)*		*71.070.03	
**Quercus engelmannii - Quercus agrifolia / Toxicodendron diversilobum / annual grass*		*71.070.04	
**Quercus engelmannii / Adenostoma fasciculatum - Arctostaphylos glauca*		*71.070.05	
**Quercus engelmannii / annual grass - herb*		*71.070.06	
**Quercus engelmannii / Quercus berberidifolia*		*71.070.07	
**Quercus engelmannii / Salvia apiana / grass - herb*		*71.070.08	
**Quercus engelmannii / Toxicodendron diversilobum / grass*		*71.070.09	
***Quercus kelloggii* (California black oak forest) Alliance**	G4 S4 (some associations are of high priority for inventory)	71.010.00	
Black Oak Forest	G4 S4		CTT81340CA
Black Oak Woodland	G3 S3.2		CTT71120CA
Quercus kelloggii		71.010.18	
Quercus kelloggii - Arbutus menziesii - Quercus agrifolia		71.010.22	
Quercus kelloggii - Calocedrus decurrens		71.010.21	
Quercus kelloggii - Pinus coulteri		71.010.32	
Quercus kelloggii - Pinus coulteri / Arctostaphylos glandulosa		71.010.33	
Quercus kelloggii - Pinus coulteri / Arctostaphylos pringlei		71.010.34	
Quercus kelloggii - Pinus ponderosa		71.010.26	
Westside Ponderosa Pine Forest	G3 S2.1		CTT84210CA
Quercus kelloggii - Pinus ponderosa / Arctostaphylos viscida		71.010.27	
Quercus kelloggii - Pinus ponderosa / Ceanothus integerrimus		71.010.28	
Quercus kelloggii - Pinus sabiniana / Styrax officinalis - Toxicodendron diversilobum		71.010.35	
**Quercus kelloggii - Pseudotsuga menziesii*		*71.010.17	
Quercus kelloggii - Pseudotsuga menziesii - Acer macrophyllum		71.010.16	
**Quercus kelloggii - Pseudotsuga menziesii - Umbellularia californica*		*71.010.29	
**Quercus kelloggii - Quercus agrifolia - pine / Holodiscus discolor*		*71.010.02	
Quercus kelloggii - Quercus chrysolepis		71.010.12	
Quercus kelloggii - Quercus chrysolepis / Toxicodendron diversilobum		71.010.01	

Quercus kelloggii - Quercus chrysolepis / Toxicodendron diversilobum		71.010.23	
**Quercus kelloggii - Quercus lobata / grass*		*71.010.11	
Quercus kelloggii / annual grass - herb		71.010.30	
Quercus kelloggii / Arctostaphylos mewukka / Chamaebatia foliosa		71.010.20	
Quercus kelloggii / Arctostaphylos patula		71.010.06	
Quercus kelloggii / Arctostaphylos viscida		71.010.24	
Quercus kelloggii / Ceanothus integerrimus		71.010.03	
Quercus kelloggii / Ceanothus integerrimus - Toxicodendron diversilobum / Pteridium aquilinum		71.010.04	
Quercus kelloggii / Heteromeles arbutifolia - Toxicodendron diversilobum		71.010.31	
Quercus kelloggii / Toxicodendron diversilobum		71.010.08	
**Quercus kelloggii / Toxicodendron diversilobum - Styrax officinalis / Triteleia laxa*		*71.010.10	
Quercus kelloggii / Toxicodendron diversilobum / grass		71.010.25	
Quercus kelloggii/ Triteleia spp.		71.010.05	
***Quercus lobata* (Valley oak woodland) Alliance**	G3 S3 (some associations are of high priority for inventory)	*71.040.00	
Valley Oak Woodland	G3 S2.1		CTT71130CA
**Quercus lobata - Acer negundo*		*71.040.15	
**Quercus lobata - Alnus rhombifolia*		*71.040.11	
**Quercus lobata - Fraxinus latifolia / Vitis californica*		*71.040.16	
**Quercus lobata - Quercus agrifolia / grass*		*71.040.06	
**Quercus lobata - Quercus agrifolia / Toxicodendron diversilobum*		*71.040.17	
**Quercus lobata - Quercus douglasii*		*71.040.18	
**Quercus lobata - Quercus kelloggii*		*71.040.19	
**Quercus lobata - Quercus wislizeni*		*71.040.12	
**Quercus lobata - Salix lasiolepis*		*71.040.20	
**Quercus lobata (Sacramento River)*		*71.040.14	
Great Valley Valley Oak Riparian Forest	G1 S1.1		CTT61430CA
**Quercus lobata / grass*		*71.040.05	
**Quercus lobata / herbaceous semi-riparian*		*71.040.13	
**Quercus lobata / Rhus trilobata*		*71.040.09	
**Quercus lobata / Rubus armeniacus*		*71.040.10	
***Quercus palmeri* (Palmer oak chaparral) Alliance**	G3 S2?	*37.419.00	
**Quercus palmeri - Eriogonum fasciculatum*		*37.419.01	
**Quercus palmeri - Eriogonum wrightii*		*37.419.02	
***Quercus parvula var. shrevei* (Shreve oak forests) Provisional Alliance**	G2 S2	*71.085.00	
***Quercus (agrifolia, douglasii, garryana, kelloggii, lobata, wislizeni)* (Mixed oak forest) Alliance**	G4 S4	71.100.00	
Mixed oak - Aesculus californica / grass		71.100.05	
Mixed oak - Pinus sabiniana / grass		71.100.07	
Mixed oak - Quercus agrifolia / Toxicodendron diversilobum		71.100.06	
Mixed oak - Quercus kelloggii / grass		71.100.04	
Mixed oak / Baccharis pilularis - Toxicodendron diversilobum		71.100.10	
Mixed oak / grass		71.100.08	
Quercus douglasii - Quercus lobata - Quercus agrifolia / Toxicodendron diversilobum		71.100.14	
***Quercus tomentella* (Island oak groves) Special Stands**	G3 S3	*71.090.00	
Island Oak Woodland	G2 S2.1		CTT71190CA

***Quercus wislizeni* (Interior live oak woodland) Alliance**	G4 S4	71.080.00	
Interior Live Oak Forest	G4 S4		CTT81330CA
Interior Live Oak Woodland	G3 S3.2		CTT71150CA
Quercus wislizeni - Aesculus californica		71.080.14	
Quercus wislizeni - Aesculus californica / Toxicodendron diversilobum		71.080.37	
Quercus wislizeni - Arbutus menziesii / Toxicodendron diversilobum		71.080.03	
**Quercus wislizeni - Pinus ponderosa*		*71.080.15	
Quercus wislizeni - Pinus sabiniana / annual grass - herb		71.080.42	
**Quercus wislizeni - Pinus sabiniana / Arctostaphylos manzanita*		*71.080.02	
Quercus wislizeni - Pinus sabiniana / Arctostaphylos viscida		71.080.08	
Quercus wislizeni - Quercus chrysolepis - Pinus coulteri		71.080.39	
Quercus wislizeni - Quercus chrysolepis tree		71.080.38	
Quercus wislizeni - Quercus douglasii - Aesculus californica		71.080.43	
Quercus wislizeni - Quercus douglasii - Pinus sabiniana / (grass)		71.080.01	
Quercus wislizeni - Quercus douglasii - Pinus sabiniana / Toxicodendron diversilobum		71.080.41	
Quercus wislizeni - Quercus douglasii / herbaceous		71.080.44	
Quercus wislizeni - Quercus douglasii / Toxicodendron diversilobum		71.080.46	
Quercus wislizeni - Quercus kelloggii		71.080.45	
Quercus wislizeni - Quercus kelloggii / Heteromeles arbutifolia - Toxicodendron diversilobum		71.080.47	
**Quercus wislizeni - Salix laevigata / Frangula californica*		*71.080.13	
Quercus wislizeni / Arctostaphylos viscida		71.080.04	
Quercus wislizeni / Eriodictyon californicum		71.080.05	
Quercus wislizeni / Heteromeles arbutifolia		71.080.40	
Quercus wislizeni / Toxicodendron diversilobum		71.080.48	
Quercus wislizeni / Toxicodendron diversilobum / Centaurea solstitialis		71.080.16	
****Umbellularia californica* (California bay forest) Alliance**	G4 S3	*74.100.00	
California Bay Forest	G3 S3.2		CTT81200CA
**Umbellularia californica*		*74.100.01	
**Umbellularia californica - Acer macrophyllum*		*74.100.10	
**Umbellularia californica - Aesculus californica / Holodiscus discolor*		*74.100.06	
**Umbellularia californica - Alnus rhombifolia*		*74.100.16	
**Umbellularia californica - Arbutus menziesii*		*74.100.03	
**Umbellularia californica - Juglans californica / Ceanothus spinosus*		*74.100.11	
**Umbellularia californica - Lithocarpus densiflorus*		*74.100.12	
**Umbellularia californica - Platanus racemosa*		*74.100.13	
**Umbellularia californica - Pseudotsuga menziesii / Rhododendron occidentale*		*74.100.17	
**Umbellularia californica - Quercus agrifolia / (Genista monspessulana)*		*74.100.15	
**Umbellularia californica - Quercus agrifolia / Heteromeles arbutifolia - Toxicodendron diversilobum / Melica torreyana*		*74.100.19	
**Umbellularia californica - Quercus agrifolia / Toxicodendron diversilobum (Corylus cornuta)*		*74.100.05	
**Umbellularia californica - Quercus chrysolepis*		*74.100.20	
**Umbellularia californica - Quercus wislizeni*		*74.100.18	
**Umbellularia californica / Ceanothus oliganthus*		*74.100.07	
**Umbellularia californica / Polystichum munitum*		*74.100.08	
**Umbellularia californica / Toxicodendron diversilobum*		*74.100.09	

Northern Interior Cypress Forest	G2 S2.2		CTT83220CA
Southern Interior Cypress Forest	G2 S2.1		CTT83230CA
***Callitropsis abramsiana* (Santa Cruz cypress groves) Special Stands**	G1 S1	*81.606.00	
***Callitropsis bakeri* (Baker cypress stands) Alliance**	G2 S2	*81.601.00	
**Callitropsis bakeri / Arctostaphylos patula*		*81.601.01	
***Callitropsis forbesii* (Tecate cypress stands) Alliance**	G2 S2	*81.607.00	
***Callitropsis goveniana* (Monterey pygmy cypress stands) Special Stands**	G1 S1	*81.603.00	
Monterey Pygmy Cypress Forest	G1 S1.1		CTT83162CA
***Callitropsis macnabiana* (McNab cypress woodland) Alliance**	G3 S3	*81.300.00	
**Callitropsis macnabiana / Arctostaphylos viscida*		*81.300.02	
***Callitropsis macrocarpa* (Monterey cypress stands) Special Stands**	G1 S1	*81.604.00	
Monterey Cypress Forest	G1 S1.2		CTT83150CA
***Callitropsis nevadensis* (Piute cypress woodland) Alliance**	G2 S2	*81.605.00	
**Callitropsis nevadensis*		*81.605.01	
***Callitropsis pigmaea* (Mendocino pygmy cypress woodland) Alliance**	G2 S2	*81.400.00	
Mendocino Pygmy Cypress Forest	G2 S2.1		CTT83161CA
**Callitropsis pigmaea / Cladonia bellidiflora*		*81.400.01	
**Callitropsis pigmaea / Ramalina tharusta*		*81.400.03	
**Callitropsis pigmaea / Usnea subfloridana*		*81.400.04	
**Callitropsis pigmaea / Cladina impexa*		*81.400.02	
***Callitropsis sargentii* (Sargent cypress woodland) Alliance**	G3 S3	*81.500.00	
**Callitropsis sargentii*		*81.500.01	
**Callitropsis sargentii / Arctostaphylos montana*		*81.500.03	
**Callitropsis sargentii / riparian*		*81.500.02	
***Callitropsis stephensonii* (Cuyamaca cypress stands) Special Stands**	G1 S1	*81.610.00	
***Juniperus californica* (California juniper woodland) Alliance**	G4 S4 (some associations are of high priority for inventory)	89.100.00	
Peninsular Juniper Woodland and Scrub	G3 S3.2		CTT72320CA
Cismontane Juniper Woodland and Scrub	G2 S2.1		CTT72400CA
Juniperus californica - (Yucca schidigera) / Pleuraphis rigida		89.100.08	
**Juniperus californica - Adenostoma fasciculatum - Eriogonum fasciculatum*		*89.100.01	
**Juniperus californica - Coleogyne ramosissima*		*89.100.04	
Juniperus californica - Coleogyne ramosissima - Yucca schidigera		89.100.06	
**Juniperus californica - Ericameria linearifolia / annual - perennial - herb*		*89.100.02	
Juniperus californica - Eriogonum fasciculatum - Artemisia californica		89.100.12	
**Juniperus californica - Fraxinus dipetala - Ericameria linearifolia*		*89.100.14	
Juniperus californica - Quercus cornelius - mulleri / Coleogyne ramosissima		89.100.05	
Juniperus californica - Yucca schidigera		89.100.18	
Juniperus californica / Agave deserti		89.100.03	
**Juniperus californica / annual herbaceous*		*89.100.15	
Juniperus californica / Hesperostipa comata		89.100.17	
Juniperus californica / Nolina parryi		89.100.11	
Juniperus californica / Prunus ilicifolia / moss		89.100.16	

***Pinus attenuata* (Knobcone pine forest) Alliance**	G4 S4	87.100.00	
Knobcone Pine Forest	G4 S4		CTT83210CA
Pinus attenuata - mixed oak / Arctostaphylos viscida		87.100.08.	
Pinus attenuata / Adenostoma fasciculatum		87.100.04	
Pinus attenuata / Arctostaphylos columbiana		87.100.01	
Pinus attenuata / Arctostaphylos glandulosa		87.100.06	
Pinus attenuata / Arctostaphylos patula		87.100.02	
Pinus attenuata / Arctostaphylos viscida		87.100.05	
Pinus attenuata / Ceanothus lemmonii		87.100.07	
Pinus attenuata / Quercus vacciniifolia		87.100.03	
***Pinus coulteri* (Coulter pine woodland) Alliance**	G4 S4 (some associations are of high priority for inventory)	87.090.00	
Coulter Pine Forest			CTT84140CA
**Pinus coulteri - Calocedrus decurrens - Pinus jeffreyi / Quercus durata*		*87.090.01	
**Pinus coulteri - Calocedrus decurrens / Frangula californica spp. tomentella / Aquilegia eximia*		*87.092.03	
**Pinus coulteri - Calocedrus decurrens / Quercus durata - Arctostaphylos glauca*		*87.090.02	
**Pinus coulteri - Pinus sabiniana / Quercus durata - Arctostaphylos pungens*		*87.090.03	
Pinus coulteri - Quercus chrysolepis		87.090.04	
**Pinus coulteri - Quercus chrysolepis / Arctostaphylos pringlei*		*87.090.06	
Pinus coulteri - Quercus kelloggii		87.092.08	
Pinus coulteri - Quercus wislizeni		87.092.05	
Pinus coulteri / Arctostaphylos glandulosa		87.092.07	
Pinus coulteri / Arctostaphylos glandulosa - Quercus wislizeni		87.092.01	
Pinus coulteri / Arctostaphylos glauca		87.092.02	
**Pinus coulteri / Quercus durata*		*87.092.04	
****Pinus muricata* (Bishop pine forest) Alliance**	G3 S3	*87.070.00	
Northern Bishop Pine Forest	G2 S2.2		CTT83121CA
Southern Bishop Pine Forest	G1 S1.1		CTT83122CA
**Pinus muricata - (Arbutus menziesii) / Vaccinium ovatum*		*87.070.01	
**Pinus muricata - Callitropsis pigmaea*		*87.070.10	
**Pinus muricata - Pinus contorta ssp. bolanderi*		*87.070.02	
**Pinus muricata - Pinus contorta ssp. bolanderi / Arnica discoidea*		*87.070.03	
**Pinus muricata - Pseudotsuga menziesii*		*87.070.04	
**Pinus muricata / Arctostaphylos glandulosa*		*87.070.07	
**Pinus muricata / Xerophyllum tenax*		*87.070.09	
****Pinus quadrifolia* (Parry pinyon woodland) Alliance**	G3 S2	*87.030.00	
**Pinus quadrifolia / Quercus cornelius - mulleri*		*87.030.01	
****Pinus radiata* (Monterey pine forest) Alliance**	G1 S1	*87.110.00	
Monterey Pine Forest	G1 S1.1		CTT83130CA
**Pinus radiata - Pinus muricata / Arctostaphylos tomentosa - Arctostaphylos hookeri*		*87.110.03	
**Pinus radiata - Quercus agrifolia / Toxicodendron diversilobum*		*87.110.04	
**Pinus radiata / Arctostaphylos tomentosa - Vaccinium ovatum*		*87.110.01	
**Pinus radiata / Toxicodendron diversilobum*		*87.110.02	
***Pinus sabiniana* (Ghost pine woodland) Alliance**	G4 S4	87.130.00	
Open Digger Pine Woodland	G4 S4		CTT71310CA
Pinus sabiniana - Juniperus californica / grass		87.130.02	

Pinus sabiniana - Quercus chrysolepis / Arctostaphylos viscida		87.130.12	
Pinus sabiniana - Quercus wislizeni / Adenostoma fasciculatum		87.130.11	
Pinus sabiniana - Quercus wislizeni / Ceanothus cuneatus		87.130.04	
Pinus sabiniana / Adenostoma fasciculatum		87.130.07	
Pinus sabiniana / Arctostaphylos viscida		87.130.08	
Pinus sabiniana / Artemisia californica - Ceanothus ferrisiae - Heteromeles arbutifolia		87.130.06	
Pinus sabiniana / Ceanothus cuneatus - Heteromeles arbutifolia		87.130.09	
Pinus sabiniana / Ceanothus cuneatus - Rhamnus illicifolia		87.130.10	
**Pinus sabiniana / Ceanothus cuneatus / Plantago erecta*		*87.130.03	
Pinus sabiniana / Frangula californica ssp. tomentella		87.130.13	
****Pinus torreyana* (Torrey pine stands) Special Stands**	G1 S1	*87.190.00	
Torrey Pine Forest	G1 S1.1		CTT83140CA
**Pinus torreyana / Artemisia californica - Rhus integrifolia*		*87.190.01	

1.C.2. Cool Temperate Forest

1.C.2.b. Western North America Cool Temperate Forest

MG023. Californian–Vancouverian Montane and Foothill Forest

Mixed Evergreen Forest	G4 S4		CTT81100CA
****Arbutus menziesii* (Madrone forest) Alliance**	G4 S3	*73.200.00	
**Arbutus menziesii - Quercus agrifolia*		*73.200.03	
**Arbutus menziesii - Umbellularia californica - (Lithocarpus densiflorus)*		*73.200.01	
**Arbutus menziesii - Umbellularia californica - Quercus kelloggii*		*73.200.02	
****Chrysolepis chrysophylla* (Golden chinquapin thickets) Alliance**	G2 S2	*37.417.00	
**Chrysolepis chrysophylla - Arctostaphylos glandulosa*		*37.417.02	
**Chrysolepis chrysophylla / Vaccinium ovatum*		*37.417.01	
****Lithocarpus densiflorus* (Tanoak forest) Alliance**	G4 S3	*73.100.00	
Tan Oak Forest	G4 S4		CTT81400CA
**Lithocarpus densiflorus - Acer circinatum*		*73.100.10	
**Lithocarpus densiflorus - Acer macrophyllum*		*73.100.11	
**Lithocarpus densiflorus - Arbutus menziesii*		*73.100.03	
**Lithocarpus densiflorus - Calocedrus decurrens / Festuca californica*		*73.100.12	
**Lithocarpus densiflorus - Chamaecyparis lawsoniana*		*73.100.13	
**Lithocarpus densiflorus - Chrysolepis chrysophylla*		*73.100.14	
**Lithocarpus densiflorus - Cornus nuttallii*		*73.100.15	
**Lithocarpus densiflorus - Cornus nuttallii / Toxicodendron diversilobum*		*73.100.16	
**Lithocarpus densiflorus - Pinus lambertiana / Toxicodendron diversilobum*		*73.100.01	
**Lithocarpus densiflorus - Quercus chrysolepis*		*73.100.17	
**Lithocarpus densiflorus - Quercus kelloggii*		*73.100.18	
**Lithocarpus densiflorus - Umbellularia californica*		*73.100.19	
**Lithocarpus densiflorus / Corylus cornuta*		*73.100.04	
**Lithocarpus densiflorus / Frangula californica*		*73.100.02	
**Lithocarpus densiflorus / Gaultheria shallon*		*73.100.05	
**Lithocarpus densiflorus / Mahonia nervosa*		*73.100.06	
**Lithocarpus densiflorus / Quercus vacciniifolia - Rhododendron macrophyllum*		*73.100.07	
**Lithocarpus densiflorus / Toxicodendron diversilobum - Lonicera hispidula var. vacillens*		*73.100.08	
**Lithocarpus densiflorus / Vaccinium ovatum*		*73.100.09	

***Pseudotsuga menziesii - Lithocarpus densiflorus* (Douglas fir - tanoak forest) Alliance**	G4 S4	82.500.00
Pseudotsuga menziesii - Lithocarpus densiflorus		82.500.48
Pseudotsuga menziesii - Lithocarpus densiflorus - (Acer macrophyllum) / Polystichum munitum		82.500.02
Pseudotsuga menziesii - Lithocarpus densiflorus - (Acer macrophyllum) / Polystichum munitum		82.500.50
Pseudotsuga menziesii - Lithocarpus densiflorus - (Calocedrus decurrens) / Festuca californica		82.500.22
Pseudotsuga menziesii - Lithocarpus densiflorus - (Chamaecyparis lawsoniana - Alnus rubra) / riparian		82.500.31
Pseudotsuga menziesii - Lithocarpus densiflorus - (Chamaecyparis lawsoniana - Umbellularia californica) / Vaccinium ovatum		82.500.24
Pseudotsuga menziesii - Lithocarpus densiflorus - (Chamaecyparis lawsoniana) / Mahonia nervosa / Linnaea borealis		82.500.25
Pseudotsuga menziesii - Lithocarpus densiflorus - (Chamaecyparis lawsoniana) / Acer circinatum		82.500.30
Pseudotsuga menziesii - Lithocarpus densiflorus - (Chamaecyparis lawsoniana) / Gaultheria shallon		82.500.29
Pseudotsuga menziesii - Lithocarpus densiflorus - (Chamaecyparis lawsoniana) / Vaccinium ovatum		82.500.26
Pseudotsuga menziesii - Lithocarpus densiflorus - (Chamaecyparis lawsoniana) / Vaccinium ovatum - Rhododendron occidentalis		82.500.27
Pseudotsuga menziesii - Lithocarpus densiflorus - (Chamaecyparis lawsoniana) / Vaccinium parvifolium		82.500.28
Pseudotsuga menziesii - Lithocarpus densiflorus - (Chrysolepis chrysophylla) / Gaultheria shallon		82.500.16
Pseudotsuga menziesii - Lithocarpus densiflorus - (Chrysolepis chrysophylla) / Pteridium aquilinum		82.500.12
Pseudotsuga menziesii - Lithocarpus densiflorus - (Chrysolepis chrysophylla) / Rhododendron macrophyllum - Gaultheria shallon		82.500.15
Pseudotsuga menziesii - Lithocarpus densiflorus - (Pinus lambertiana)		82.500.39
Pseudotsuga menziesii - Lithocarpus densiflorus - (Quercus chrysolepis) / Mahonia nervosa		82.500.13
Pseudotsuga menziesii - Lithocarpus densiflorus - (Quercus chrysolepis) / Mahonia nervosa - Gaultheria shallon		82.500.06
Pseudotsuga menziesii - Lithocarpus densiflorus - (Quercus chrysolepis) / rockpile		82.500.11
Pseudotsuga menziesii - Lithocarpus densiflorus - (Quercus chrysolepis) / Toxicodendron diversilobum		82.500.10
Pseudotsuga menziesii - Lithocarpus densiflorus - (Quercus chrysolepis) / Vaccinium ovatum		82.500.08
Pseudotsuga menziesii - Lithocarpus densiflorus - (Quercus chrysolepis, Quercus kelloggii) / Toxicodendron diversilobum		82.500.05
Pseudotsuga menziesii - Lithocarpus densiflorus - (Quercus kelloggii) / Rosa gymnocarpa		82.500.03
Pseudotsuga menziesii - Lithocarpus densiflorus - (Umbellularia californica) / Toxicodendron diversilobum		82.500.04
Pseudotsuga menziesii - Lithocarpus densiflorus / Iris		82.500.44
Pseudotsuga menziesii - Lithocarpus densiflorus - Thuja plicata / Vaccinium ovatum - Gaultheria shallon		82.500.51
Pseudotsuga menziesii - Lithocarpus densiflorus / Acer circinatum		82.500.36
Pseudotsuga menziesii - Lithocarpus densiflorus / Achlys triphylla		82.500.40
Pseudotsuga menziesii - Lithocarpus densiflorus / Chimaphila umbellata		82.500.01
Pseudotsuga menziesii - Lithocarpus densiflorus / Cornus nuttallii		82.500.43
Pseudotsuga menziesii - Lithocarpus densiflorus / Corylus cornuta		82.500.21
Pseudotsuga menziesii - Lithocarpus densiflorus / Gaultheria shallon		82.500.35
Pseudotsuga menziesii - Lithocarpus densiflorus / Mahonia nervosa		82.500.07
Pseudotsuga menziesii - Lithocarpus densiflorus / Quercus vacciniifolia - Holodiscus discolor		82.500.46
Pseudotsuga menziesii - Lithocarpus densiflorus / Rhododendron macrophyllum		82.500.49
Pseudotsuga menziesii - Lithocarpus densiflorus / Taxus brevifolia		82.500.38
Pseudotsuga menziesii - Lithocarpus densiflorus / Toxicodendron diversilobum - (Lonicera hispidula)		82.500.23
Pseudotsuga menziesii - Lithocarpus densiflorus / Vaccinium ovatum		82.500.19
Pseudotsuga menziesii - Lithocarpus densiflorus / Vaccinium ovatum - (Gaultheria shallon)		82.500.20
Pseudotsuga menziesii - Lithocarpus densiflorus / Whipplea modesta		82.500.47

***Quercus garryana* (Oregon white oak woodland) Alliance**	G4 S3	*71.030.00	
Oregon Oak Woodland	G3 S3.3		CTT71110CA
**Quercus garryana - Pseudotsuga menziesii / Festuca californica*		*71.030.03	
**Quercus garryana - Quercus kelloggii / Arrhenatherum elatius*		*71.030.01	
**Quercus garryana - Quercus kelloggii / Dichelostemma ida-maia*		*71.030.15	
**Quercus garryana - Quercus kelloggii / Toxicodendron diversilobum*		*71.030.14	
**Quercus garryana var. garryana - Quercus garryana var. breweri / Festuca californica*		*71.030.02	
**Quercus garryana / Bromus carinatus*		*71.030.11	
**Quercus garryana / Cynosurus cristatus*		*71.030.06	
**Quercus garryana / Dactylis glomerata*		*71.030.10	
**Quercus garryana / Delphinium trolliifolium*		*71.030.09	
**Quercus garryana / Melica subulata*		*71.030.13	
**Quercus garryana / Philadelphus lewisii*		*71.030.08	
**Quercus garryana / Ribes roezlii*		*71.030.07	
**Quercus garryana / Symphoricarpos albus*		*71.030.05	
**Quercus garryana / Toxicodendron diversilobum*		*71.030.04	
***Abies concolor - Pseudotsuga menziesii* (White fir - Douglas fir forest) Alliance**	G5 S4 (some associations are of high priority for inventory)	88.530.00	
Abies concolor - Pseudotsuga menziesii - (mixed conifer) / Acer circinatum - Chrysolepis sempervirens		88.530.34	
**Abies concolor - Pseudotsuga menziesii - (Quercus chrysolepis)*		*88.530.06	
Abies concolor - Pseudotsuga menziesii - Calocedrus decurrens		88.530.30	
Abies concolor - Pseudotsuga menziesii / Amelanchier utahensis		88.530.35	
Abies concolor - Pseudotsuga menziesii / Arnica cordifolia		88.530.14	
Abies concolor - Pseudotsuga menziesii / Cornus nuttallii		88.530.36	
Abies concolor - Pseudotsuga menziesii / Cornus nuttallii / Corylus cornuta		88.530.37	
**Abies concolor - Pseudotsuga menziesii / Corylus cornuta*		*88.530.15	
Abies concolor - Pseudotsuga menziesii / Corylus cornuta / Adenocaulon bicolor		88.530.32	
Abies concolor - Pseudotsuga menziesii / Melica subulata		88.530.16	
Abies concolor - Pseudotsuga menziesii / Pteridium aquilinum		88.530.29	
Abies concolor - Pseudotsuga menziesii / Quercus sadleriana		88.530.17	
Abies concolor - Pseudotsuga menziesii / Quercus sadleriana - Arctostaphylos nevadensis		88.530.18	
Abies concolor - Pseudotsuga menziesii / Quercus sadleriana - Quercus vacciniifolia		88.530.19	
Abies concolor - Pseudotsuga menziesii / Quercus sadleriana - Rhododendron macrophyllum		88.530.38	
Abies concolor - Pseudotsuga menziesii / Quercus vacciniifolia		88.530.20	
**Abies concolor - Pseudotsuga menziesii / Rhododendron macrophyllum - Quercus sadleriana*		*88.530.21	
Abies concolor - Pseudotsuga menziesii / Rosa gymnocarpa - Linnaea borealis - Symphoricarpos mollis		88.530.23	
Abies concolor - Pseudotsuga menziesii / Rosa gymnocarpa - Symphoricarpos mollis		88.530.24	
**Abies concolor - Pseudotsuga menziesii / Rosa gymnocarpa / Linnaea borealis*		*88.530.25	
Abies concolor - Pseudotsuga menziesii / Rubus ameniacus		88.530.31	
**Abies concolor - Pseudotsuga menziesii / Rubus parviflorus*		*88.530.26	
Abies concolor - Pseudotsuga menziesii / Trientalis latifolia		88.530.33	
Abies concolor - Pseudotsuga menziesii / Xerophyllum tenax		88.530.28	
***Acer macrophyllum* (Bigleaf maple forest) Alliance**	G4 S3	*61.450.00	
**Acer macrophyllum*		*61.450.01	
**Acer macrophyllum - Pseudotsuga menziesii / Adenocaulon bicolor*		*61.450.02	
**Acer macrophyllum - Pseudotsuga menziesii / Corylus cornuta*		*61.450.04	

**Acer macrophyllum - Pseudotsuga menziesii / Dryopteris arguta*		*61.450.03	
**Acer macrophyllum - Pseudotsuga menziesii / Philadelphus lewisii*		*61.450.05	
**Acer macrophyllum - Pseudotsuga menziesii / Polystichum munitum*		*61.450.06	
***Alnus rubra* (Red alder forest) Alliance**	G5 S4 (some associations are of high priority for inventory)	61.410.00	
Red Alder Forest	G4 S3.2		CTT81A00CA
**Alnus rubra - Pseudotsuga menziesii / Acer circinatum / Claytonia sibirica*		*61.410.01	
**Alnus rubra / Gaultheria shallon*		*61.410.02	
Alnus rubra / Rubus spectabilis		61.410.07	
Red Alder Riparian Forest	G3 S2.2		CTT61130CA
**Alnus rubra / Rubus spectabilis - Sambucus racemosa*		*61.410.06	
**Alnus rubra / Salix lasiolepis*		*61.410.05	
***Pseudotsuga menziesii* (Douglas fir forest) Alliance**	G5 S4 (some associations are of high priority for inventory)	82.200.00	
Upland Douglas Fir Forest	G4 S3.1		CTT82420CA
Pseudotsuga menziesii		82.200.77	
**Pseudotsuga menziesii - Chrysolepis chrysophylla - Lithocarpus densiflorus*		*82.200.12	
**Pseudotsuga menziesii - Chrysolepis chrysophylla - Lithocarpus densiflorus / Mahonia nervosa*		*82.200.13	
Pseudotsuga menziesii - Chrysolepis chrysophylla / Rhododendron macrophyllum - Gaultheria shallon		82.200.79	
**Pseudotsuga menziesii - Chrysolepis chrysophylla / Rhododendron macrophyllum - Mahonia nervosa*		*82.200.10	
**Pseudotsuga menziesii - Chrysolepis chrysophylla / Rhododendron macrophyllum - Quercus sadleriana - Xerophyllum tenax*		*82.200.11	
**Pseudotsuga menziesii - Chrysolepis chrysophylla / Xerophyllum tenax*		*82.200.09	
Pseudotsuga menziesii - Quercus agrifolia		82.200.71	
**Pseudotsuga menziesii - Quercus chrysolepis*		*82.300.03	
Pseudotsuga menziesii - Quercus chrysolepis - Acer macrophyllum / Toxicodendron diversilobum		82.300.07	
**Pseudotsuga menziesii - Quercus chrysolepis - Arbutus menziesii / Toxicodendron diversilobum*		*82.300.02	
**Pseudotsuga menziesii - Quercus chrysolepis - Lithocarpus densiflorus*		*82.300.05	
**Pseudotsuga menziesii - Quercus chrysolepis - mixed conifer / Polystichum munitum*		*82.300.01	
Pseudotsuga menziesii - Quercus chrysolepis / Arctostaphylos manzanita		82.300.06	
**Pseudotsuga menziesii - Quercus garryana var. garryana / grass*		*82.200.19	
**Pseudotsuga menziesii - Quercus kelloggii*		*82.200.60	
Pseudotsuga menziesii - Quercus kelloggii		82.200.80	
**Pseudotsuga menziesii - Umbellularia californica*		*82.200.66	
Pseudotsuga menziesii - Umbellularia californica / Frangula californica		82.200.70	
Pseudotsuga menziesii - Umbellularia californica / Holodiscus discolor		82.200.81	
Pseudotsuga menziesii - Umbellularia californica / Polystichum munitum		82.200.69	
**Pseudotsuga menziesii - Umbellularia californica / Toxicodendron diversilobum*		*82.200.05	
**Pseudotsuga menziesii / Acer circinatum - Mahonia nervosa*		*82.200.20	
**Pseudotsuga menziesii / Achlys triphylla*		*82.200.49	
**Pseudotsuga menziesii / Arbutus menziesii*		*82.200.50	
Pseudotsuga menziesii / Arctostaphylos patula		82.200.53	
Pseudotsuga menziesii / Baccharis pilularis		82.200.72	
**Pseudotsuga menziesii / Chimaphila umbellata*		*82.200.54	
**Pseudotsuga menziesii / Corylus cornuta*		*82.200.56	
**Pseudotsuga menziesii / Corylus cornuta / Adenocaulon bicolor*		*82.200.04	

**Pseudotsuga menziesii / Gaultheria shallon*		*82.200.59	
**Pseudotsuga menziesii / Linnaea borealis*		*82.200.55	
Pseudotsuga menziesii / Lithocarpus densiflorus var. echinoides / Iris douglasii		82.200.78	
**Pseudotsuga menziesii / Mahonia nervosa*		*82.200.64	
**Pseudotsuga menziesii / Quercus vacciniifolia*		*82.200.15	
**Pseudotsuga menziesii / Quercus vacciniifolia - Lithocarpus densiflorus var. echinoides*		*82.200.16	
**Pseudotsuga menziesii / Quercus vacciniifolia - Rhododendron macrophyllum*		*82.200.74	
**Pseudotsuga menziesii / Rhododendron spp.*		*82.200.58	
**Pseudotsuga menziesii / Vancouveria planipetala*		*82.200.57	
Pinus ponderosa - Pseudotsuga menziesii **(Ponderosa pine - Douglas fir forest) Alliance**	G4 S4 (some associations are of high priority for inventory)	82.400.00	
Coast Range Mixed Coniferous Forest	G4 S4		CTT84110CA
Pinus ponderosa - Pseudotsuga menziesii - Lithocarpus densiflorus / Chamaebatia foliolosa		82.400.08	
Pinus ponderosa - Pseudotsuga menziesii - Quercus chrysolepis / Galium bolanderi		82.400.09	
Pinus ponderosa - Pseudotsuga menziesii / Antennaria rosea - Eriogonum nudum		82.400.07	
Pinus ponderosa - Pseudotsuga menziesii / Purshia tridentata var. tridentata / Wyethia mollis		82.400.06	
**Pseudotsuga menziesii - Pinus ponderosa*		*82.400.04	
**Pseudotsuga menziesii - Pinus ponderosa - Calocedrus decurrens*		*82.400.02	
**Pseudotsuga menziesii - Pinus ponderosa - Pinus jeffreyi / Poa secunda*		*82.400.03	
****Pseudotsuga menziesii - Calocedrus decurrens*** **(Douglas fir - Incense cedar forest) Alliance**	G3 S3	*82.600.00	
Ultramafic Mixed Coniferous Forest	G4 S4		CTT84180CA
**Pseudotsuga menziesii - Calocedrus decurrens - (Pinus jeffreyi) / Nassella pulchra*		*82.600.15	
**Pseudotsuga menziesii - Calocedrus decurrens - (Quercus kellogii) / Nassella pulchra*		*82.600.14	
**Pseudotsuga menziesii - Calocedrus decurrens - Pinus jeffreyi*		*82.600.12	
**Pseudotsuga menziesii - Calocedrus decurrens - Pinus jeffreyi / Festuca californica*		*82.600.13	
**Pseudotsuga menziesii - Calocedrus decurrens - Umbellularia californica / Toxicodendron diversilobum*		*82.600.01	
**Pseudotsuga menziesii - Calocedrus decurrens / Festuca californica*		*82.600.02	
**Pseudotsuga menziesii - Calocedrus decurrens / Quercus vacciniifolia*		*82.600.04	
****Abies bracteata*** **(Santa Lucia fir groves) Alliance**	G3 S3	*88.300.00	
Santa Lucia Fir Forest	G2 S2.2		CTT84120CA
**Abies bracteata / Galium clementis*		*88.300.01	
**Abies bracteata / Polystichum munitum*		*88.300.02	
Abies concolor **(White fir forest) Alliance**	G5 S4 (some associations are of high priority for inventory)	88.500.00	
Southern California White Fir Forest	G4 S4		CTT85320CA
Desert Mountain White Fir Forest	G4 S1.2		CTT85330CA
Abies concolor - Calocedrus decurrens - Pinus jeffreyi		88.500.40	
Abies concolor - Calocedrus decurrens - Pseudotsuga macrocarpa - Pinus coulteri		88.510.10	
Abies concolor - Calocedrus decurrens - Quercus kelloggii		88.500.29	
Abies concolor - Calocedrus decurrens / Pyrola picta		88.500.31	
Abies concolor - Calocedrus decurrens / Symphoricarpos mollis		88.500.30	
**Abies concolor - Chrysolepis chrysophylla*		*88.500.37	
Abies concolor / (Rosa gymnocarpa) - Symphoricarpos mollis		88.500.35	
Abies concolor / Acer glabrum		88.500.60	
Abies concolor / Achlys triphylla		88.500.12	
Abies concolor / Amelanchier alnifolia		88.500.33	

Abies concolor / Arctostaphylos nevadensis		88.500.10	
Abies concolor / Arnica cordifolia		88.500.17	
Abies concolor / Chimaphila menziesii - Pyrola picta		88.500.32	
Abies concolor / Chimaphila umbellata		88.500.11	
Abies concolor / Goodyera oblongifolia		88.500.59	
Abies concolor / Mahonia nervosa		88.500.54	
Abies concolor / Prunus emarginata		88.500.58	
Abies concolor / Pseudostellaria jamesiana		88.500.61	
Abies concolor / Trillium ovatum		88.500.57	
Abies concolor / Vicia americana		88.500.53	
***Abies concolor - Pinus lambertiana* (White fir - sugar pine forest) Alliance**	G4 S4	88.510.00	
Sierran Mixed Coniferous Forest	G4 S4		CTT84230CA
Sierran White Fir Forest	G4 S4		CTT84240CA
Abies concolor - Pinus lambertiana		88.510.01	
Abies concolor - Pinus lambertiana - Calocedrus decurrens - Quercus chrysolepis		88.510.09	
Abies concolor - Pinus lambertiana - Calocedrus decurrens / Adenocaulon bicolor		88.510.06	
Abies concolor - Pinus lambertiana - Calocedrus decurrens / Chrysolepis sempervirens		88.510.07	
Abies concolor - Pinus lambertiana - Calocedrus decurrens / Cornus nuttallii / Corylus cornuta		88.510.05	
Abies concolor - Pinus lambertiana - Calocedrus decurrens / Symphoricarpos mollis / Kelloggia galioides		88.510.08	
Abies concolor - Pinus lambertiana - Pinus jeffreyi		88.510.04	
Abies concolor - Pinus lambertiana - Pinus ponderosa / Lithocarpus densiflorus var. echinoides		88.510.17	
Abies concolor - Pinus lambertiana - Pseudotsuga menziesii / Carex rossii		88.510.14	
Abies concolor - Pinus lambertiana / Ceanothus cordulatus		88.510.13	
Abies concolor - Pinus lambertiana / Maianthemum racemosa - Prosartes hookeri		88.510.03	
Abies concolor - Pinus ponderosa / Lithocarpus densiflorus var. echinoides		88.510.16	
Pinus ponderosa - Pinus lambertiana / Lithocarpus densiflorus var. echinoides		88.510.15	
***Abies magnifica - Abies concolor* (Red fir - white fir forest) Alliance**	G5 S4	88.520.00	
Abies magnifica - Abies concolor		88.520.01	
Abies magnifica - Abies concolor - Pinus jeffreyi		88.520.09	
Abies magnifica - Abies concolor / Acer glabrum		88.520.11	
Abies magnifica - Abies concolor / Achlys triphylla		88.520.08	
Abies magnifica - Abies concolor / Anemone deltoidea		88.520.16	
Abies magnifica - Abies concolor / Arctostaphylos nevadensis		88.520.07	
Abies magnifica - Abies concolor / Arctostaphylos nevadensis		88.520.12	
Abies magnifica - Abies concolor / Arnica cordifolia		88.520.03	
Abies magnifica - Abies concolor / Penstemon anguineus - Monardella odoratissima		88.520.13	
Abies magnifica - Abies concolor / Pinus lambertiana		88.520.10	
Abies magnifica - Abies concolor / Pteridium aquilinum		88.520.02	
Abies magnifica - Abies concolor / Pyrola picta		88.520.15	
Abies magnifica - Abies concolor / Quercus sadleriana		88.520.06	
Abies magnifica - Abies concolor / Quercus sadleriana		88.520.14	
Abies magnifica - Abies concolor / Symphoricarpos mollis - Rosa gymnocarpa		88.520.05	
Abies magnifica - Abies concolor / Symphoricarpos mollis / Pyrola picta		88.520.04	
***Calocedrus decurrens* (Incense cedar forest) Alliance** (marked *)	G4 S3	*85.100.00	
Calocedrus decurrens - Abies concolor / Senecio triangularis (marked *)		*85.100.05	
Calocedrus decurrens - Alnus rhombifolia (marked *)		*85.100.03	

**Calocedrus decurrens - Quercus chrysolepis - Quercus kelloggii*		*85.100.04	
**Calocedrus decurrens / Listera convallarioides*		*85.100.01	
****Picea breweriana* (Brewer spruce forest) Alliance**	G3 S2	*83.300.00	
Siskiyou Enriched Coniferous Forest	G1 S1.2		CTT85410CA
Salmon Scott Enriched Coniferous Forest	G1 S1.2		CTT85420CA
**Picea breweriana - Abies concolor / Chimaphila umbellata - Pyrola picta*		*83.300.03	
***Pinus jeffreyi* (Jeffrey pine forest) Alliance**	G4 S4 (some associations are of high priority for inventory)	87.020.00	
Jeffrey Pine Forest	G4 S4		CTT85100CA
Jeffrey Pine Fir Forest	G4 S4		CTT85210CA
Northern Ultramafic Jeffrey Pine Forest	G3 S3.2		CTT84171CA
Southern Ultramafic Jeffrey Pine Forest	G2 S2.1		CTT84172CA
Southern Ultramafic Mixed Coniferous Forest	G2 S2.1		CTT84182CA
Pinus jeffreyi - Abies concolor - Abies magnifica		87.205.03	
Pinus jeffreyi - Abies concolor / Chrysolepis sempervirens		87.020.30	
Pinus jeffreyi - Abies concolor / Iris innominata		87.205.06	
Pinus jeffreyi - Abies concolor / Quercus sadleriana		87.205.05	
Pinus jeffreyi - Abies concolor / Symphoricarpos rotundifolius / Elymus elymoides		87.205.07	
Pinus jeffreyi - Abies magnifica		87.020.39	
Pinus jeffreyi - Calocedrus decurrens / Ceanothus cuneatus		87.020.04	
Pinus jeffreyi - Calocedrus decurrens / Ceanothus pumila		87.020.28	
Pinus jeffreyi - Calocedrus decurrens / Quercus vacciniifolia		87.020.37	
Pinus jeffreyi - Calocedrus decurrens / Quercus vacciniifolia / Xerophyllum tenax		87.020.05	
Pinus jeffreyi - Pinus monophylla		87.020.26	
Pinus jeffreyi - Pinus ponderosa - Quercus kelloggii / Poa wheeleri / granite		87.200.08	
Pinus jeffreyi - Pinus ponderosa / Amelanchier alnifolia - Mahonia repens		87.200.09	
**Pinus jeffreyi - Pinus ponderosa / Purshia tridentata var. tridentata / Festuca idahoensis / Granite*		*87.200.03	
**Pinus jeffreyi - Pinus ponderosa / Symphoricarpos mollis / Wyethia mollis*		*87.200.07	
**Pinus jeffreyi - Pseudotsuga menziesii / Quercus vacciniifolia / Festuca californica*		*87.020.02	
Pinus jeffreyi - Quercus chrysolepis / Arctostaphylos viscida		87.020.38	
Pinus jeffreyi - Quercus kelloggii		87.020.25	
**Pinus jeffreyi - Quercus kelloggii / Poa secunda*		*87.020.15	
**Pinus jeffreyi - Quercus kelloggii / Rhus trilobata*		*87.020.16	
Pinus jeffreyi / Arctostaphylos nevadensis		87.020.24	
Pinus jeffreyi / Arctostaphylos patula		87.020.09	
Pinus jeffreyi / Arctostaphylos patula - Ceanothus velutinus		87.020.35	
Pinus jeffreyi / Artemisia tridentata / Penstemon centranthifolius		87.020.32	
**Pinus jeffreyi / Artemisia tridentata var. vaseyana / Festuca idahoensis*		*87.020.19	
**Pinus jeffreyi / Calamagrostis koelerioides*		*87.020.23	
Pinus jeffreyi / Ceanothus cordulatus		87.020.10	
Pinus jeffreyi / Ceanothus cordulatus - Artemisia tridentata		87.020.36	
**Pinus jeffreyi / Cercocarpus ledifolius*		*87.020.17	
**Pinus jeffreyi / Chrysolepis sempervirens*		*87.020.20	
**Pinus jeffreyi / Ericameria ophitidis*		*87.020.22	
**Pinus jeffreyi / Festuca idahoensis*		*87.020.03	
Pinus jeffreyi / Lupinus caudatus		87.020.11	

**Pinus jeffreyi / Purshia tridentata var. tridentata*		*87.020.21	
**Pinus jeffreyi / Purshia tridentata var. tridentata - Symphoricarpos longiflorus / Poa wheeleri*		*87.020.14	
**Pinus jeffreyi / Purshia tridentata var. tridentata / Cercocarpus ledifolius / Achnatherum occidentalis*		*87.020.13	
**Pinus jeffreyi / Purshia tridentata var. tridentata / Wyethia mollis*		*87.020.12	
Pinus jeffreyi / Quercus palmeri		87.020.33	
Pinus jeffreyi / Quercus sadleriana / Xerophyllum tenax		87.020.01	
Pinus jeffreyi / Quercus vacciniifolia		87.020.08	
Pinus jeffreyi / Quercus vacciniifolia - Arctostaphylos nevadensis / Festuca idahoensis		87.020.27	
Pinus jeffreyi / Quercus wislizeni		87.020.34	
**Pinus jeffreyi / Symphoricarpos longiflorus / Poa wheeleri*		*87.020.18	
****Pinus lambertiana* (Sugar pine forest) Alliance**	G4 S3	*87.206.00	
**Pinus lambertiana - Chrysolepis chrysophylla / Quercus vacciniifolia - Quercus sadleriana*		*87.206.01	
**Pinus lambertiana - Pinus contorta ssp contorta / Quercus vacciniifolia - Lithocarpus densiflorus var. echinoides*		*87.206.02	
**Pinus lambertiana - Pinus contorta ssp. contorta / Lithocarpus densiflorus var. echinoides - Rhododendron macrophyllum*		*87.206.03	
**Pinus lambertiana - Pinus monticola / Quercus vacciniifolia - Garrya buxifolia*		*87.206.04	
***Pinus ponderosa* (Ponderosa pine forest) Alliance**	G5 S4 (some associations are of high priority for inventory)	87.010.00	
Upland Coast Range Ponderosa Pine Forest	G3 S3.2		CTT84131CA
Eastside Ponderosa Pine Forest	G4 S2.1		CTT84220CA
Ponderosa Dune Forest	G1 S1.1		CTT84221CA
Maritime Coast Range Ponderosa Pine Forest	G1 S1.1		CTT84132CA
Pinus ponderosa - Abies concolor / Lithocarpus densiflorus var. echinoides		87.010.45	
Pinus ponderosa - Alnus rhombifolia		87.010.37	
Pinus ponderosa - Alnus rhombifolia		87.010.44	
Pinus ponderosa - Lithocarpus densiflorus		87.010.46	
**Pinus ponderosa - Pinus contorta ssp. murrayana / Amelanchier alnifolia*		*87.010.23	
Pinus ponderosa - Pinus jeffreyi / Achnatherum occidentalis		87.010.54	
**Pinus ponderosa - Pinus jeffreyi / Artemisia tridentata var. vaseyana - Purshia tridentata var. tridentata*		*87.010.25	
Pinus ponderosa - Pinus jeffreyi / Balsamorhiza sagittata		87.010.55	
Pinus ponderosa - Pinus jeffreyi / Cercocarpus ledifolius / Pseudoroegneria spicata		87.010.49	
Pinus ponderosa - Pinus jeffreyi / Frangula rubra / Poa secunda		87.010.51	
Pinus ponderosa - Pinus jeffreyi / Purshia tridentata var. tridentata / Senecio integerrimus / granite		87.010.50	
Pinus ponderosa - Pinus jeffreyi / Quercus vacciniifolia		87.010.53	
Pinus ponderosa - Pinus jeffreyi / Quercus vacciniifolia / Wyethia mollis		87.010.52	
Pinus ponderosa - Pinus lambertiana - Quercus chrysolepis / Lithocarpus densiflorus var. echinoides		87.010.48	
Pinus ponderosa - Pinus lambertiana / Arctostaphylos patula - Lithocarpus densiflorus var. echinoides		87.010.47	
**Pinus ponderosa / Achnatherum nelsonii*		*87.010.18	
**Pinus ponderosa / Amelanchier alnifolia - Mahonia repens / Arnica cordifolia*		*87.010.27	
Pinus ponderosa / Amelanchier alnifolia - Mahonia repens / Arnica cordifolia		87.010.42	
**Pinus ponderosa / Amelanchier alnifolia - Prunus virginiana*		*87.010.26	
**Pinus ponderosa / Arctostaphylos patula - Chamaebatia foliolosa*		*87.010.03	
Pinus ponderosa / Arctostaphylos viscida		87.010.39	
**Pinus ponderosa / Artemisia tridentata*		*87.010.04	
**Pinus ponderosa / Artemisia tridentata var. vaseyana / Festuca idahoensis*		*87.010.24	
**Pinus ponderosa / Bromus carinatus*		*87.010.06	
**Pinus ponderosa / Ceanothus cuneatus*		*87.010.09	

**Pinus ponderosa / Ceanothus prostratus*		*87.010.08	
**Pinus ponderosa / Ceanothus velutinus / Achnatherum nelsonii*		*87.010.28	
**Pinus ponderosa / Cercocarpus ledifolius - Purshia tridentata var. tridentata / Festuca idahoensis*		*87.010.19	
**Pinus ponderosa / Cercocarpus ledifolius / Pseudoroegneria spicata*		*87.010.20	
**Pinus ponderosa / Chamaebatia foliolosa*		*87.010.02	
**Pinus ponderosa / Galium angustifolium*		*87.010.07	
Pinus ponderosa / Lithocarpus densiflorus var. echinoides		87.010.43	
**Pinus ponderosa / Purshia tridentata var. tridentata*		*87.010.05	
**Pinus ponderosa / Purshia tridentata var. tridentata - Arctostaphylos patula / Achnatherum nelsonii*		*87.010.13	
**Pinus ponderosa / Purshia tridentata var. tridentata - Ceanothus velutinus*		*87.010.14	
Pinus ponderosa / Purshia tridentata var. tridentata - Prunus virginiana / Bromus orcuttianus		87.010.41	
**Pinus ponderosa / Purshia tridentata var. tridentata - Ribes cereum / Bromus orcuttianus*		*87.010.16	
**Pinus ponderosa / Purshia tridentata var. tridentata / Achnatherum nelsonii / pumice*		*87.010.12	
**Pinus ponderosa / Purshia tridentata var. tridentata / Balsamorhiza sagittata*		*87.010.10	
Pinus ponderosa / Purshia tridentata var. tridentata / Galium bolanderi		87.010.40	
**Pinus ponderosa / Purshia tridentata var. tridentata / Senecio integerrimus / granite*		*87.010.15	
**Pinus ponderosa / Symphoricarpos longiflorus*		*87.010.29	
Pinus ponderosa stream terrace		87.010.38	
***Pinus ponderosa - Calocedrus decurrens* (Mixed conifer forest) Alliance**	G4 S4	87.015.00	
Pinus ponderosa - Calocedrus decurrens - Quercus kelloggii		87.015.02	
Pinus ponderosa - Calocedrus decurrens (mixed conifer) - Quercus chrysolepis / Chamaebatia foliosa		87.015.04	
Pinus ponderosa - Calocedrus decurrens (mixed conifer) / Arctostaphylos sp. - Chamaebatia foliolosa		87.015.08	
Pinus ponderosa - Calocedrus decurrens (mixed conifer) / Galium bolanderi - Polygala cornuta		87.015.01	
Pinus ponderosa - Calocedrus decurrens / Ceanothus prostratus		87.015.10	
Pinus ponderosa - Calocedrus decurrens / Chamaebatia foliolosa / Galium bolanderi		87.015.11	
Pinus ponderosa - Calocedrus decurrens / Chamaebatia foliosa		87.015.03	
Pinus ponderosa - Calocedrus decurrens / Mahonia nervosa		87.015.09	
Pinus ponderosa - Calocedrus decurrens / Purshia tridentata / Achnatherum occidentalis		87.015.14	
Pinus ponderosa - Calocedrus decurrens / Purshia tridentata var. tridentata / (Balsamorhiza sagittata - Achnatherum occidentalis)		87.015.13	
Pinus ponderosa - Calocedrus decurrens / Quercus chrysolepis var. nana - Quercus vacciniifolia		87.015.12	
Pinus ponderosa - Calocedrus decurrens / Quercus vaccinifolia (serpentine)		87.015.05	
****Pinus washoensis* (Washoe pine woodland) Alliance**	G2 S2	*87.120.00	
Washoe Pine Fir Forest	G1 S1.2		CTT85220CA
**Pinus washoensis / Arctostaphylos nevadensis*		*87.120.03	
**Pinus washoensis / Lupinus caudatus*		*87.120.01	
**Pinus washoensis / Symphoricarpos longiflorus / Pseudostellaria jamesiana*		*87.120.02	
****Pseudotsuga macrocarpa* (Bigcone Douglas fir forest) Alliance**	G3 S3	*82.100.00	
Bigcone Spruce Canyon Oak Forest	G3 S3.2		CTT84150CA
**Pseudotsuga macrocarpa - Quercus agrifolia*		*82.100.01	
**Pseudotsuga macrocarpa - Quercus chrysolepis*		*82.100.02	
****Sequoiadendron giganteum* (Giant sequoia forest) Alliance**	G3 S3	*86.200.00	
Big Tree Forest	G3 S3.2		CTT84250CA
**Sequoiadendron giganteum - Pinus lambertiana / Cornus nuttallii*		*86.200.01	

MG020. Rocky Mountain Subalpine and High Montane Conifer Forest

Southern California Subalpine Forest	G3 S3.3		CTT86500CA
***Abies lasiocarpa* (Subalpine fir forest) Alliance**	G5 S2	*88.400.00	
**Abies lasiocarpa*		*88.400.01	
***Picea engelmannii* (Engelmann spruce forest) Alliance**	G5 S2	*83.100.00	
***Populus tremuloides* (Aspen groves) Alliance**	G5 S3	*61.111.00	
Aspen Forest	G5 S3.2		CTT81B00CA
Aspen Riparian Forest	G4 S3.2		CTT61520CA
**Populus tremuloides*		*61.111.02	
**Populus tremuloides - Pinus contorta / Artemisia tridentata / Poa pratensis*		*61.111.11	
**Populus tremuloides / Artemisia tridentata*		*61.111.06	
**Populus tremuloides / Artemisia tridentata / Monardella odoratissima - Kelloggia galioides*		*61.111.07	
**Populus tremuloides / Bromus carinatus*		*61.111.19	
**Populus tremuloides / dry graminoid*		*61.111.18	
**Populus tremuloides / mesic forb*		*61.111.17	
**Populus tremuloides / Monardella odoratissima*		*61.111.08	
**Populus tremuloides / Pinus jeffreyi*		*61.111.09	
**Populus tremuloides / Poa pratensis*		*61.111.20	
**Populus tremuloides / Prunus*		*61.111.14	
**Populus tremuloides / Rosa woodsii*		*61.111.10	
**Populus tremuloides / Symphoricarpos albus*		*61.111.15	
**Populus tremuloides / Symphoricarpos rotundifolius*		*61.111.16	
**Populus tremuloides / Symphyotricum foliaceum*		*61.111.05	
**Populus tremuloides / upland*		*61.111.04	
**Populus tremuloides / Veratrum californicum*		*61.111.03	
***Pinus albicaulis* (Whitebark pine forest) Alliance**	G5 S4	87.180.00	
Whitebark Pine Forest	G4 S4		CTT86600CA
Pinus albicaulis - Tsuga mertensiana		87.180.07	
Pinus albicaulis / Achnatherum californica		87.180.01	
Pinus albicaulis / Arenaria aculeata		87.180.03	
Pinus albicaulis / Carex filifolia		87.180.08	
Pinus albicaulis / Carex rossii		87.180.09	
Pinus albicaulis / Holodiscus discolor		87.180.04	
Pinus albicaulis / Penstemon davidsonii		87.180.06	
Pinus albicaulis / Penstemon gracilentus		87.180.02	
Pinus albicaulis / Poa wheeleri		87.180.05	
***Pinus balfouriana* (Foxtail pine woodland) Alliance**	G3 S3	*87.150.00	
Foxtail Pine Forest	G3 S3.3		CTT86300CA
**Pinus balfouriana*		*87.150.01	
**Pinus balfouriana - Abies magnifica*		*87.150.04	
**Pinus balfouriana - Pinus albicaulis*		*87.150.05	
**Pinus balfouriana - Pinus flexilis*		*87.150.07	
**Pinus balfouriana - Pinus monticola*		*87.150.06	
**Pinus balfouriana / Anemone drummondii*		*87.150.02	
**Pinus balfouriana / Chrysolepis sempervirens*		*87.150.03	

***Pinus flexilis* (Limber pine woodland) Alliance**	G5 S3	*87.160.00	
Limber Pine Forest	G4 S2.3		CTT86700CA
**Pinus flexilis - Pinus contorta / Chrysolepis sempervirens*		*87.160.02	
**Pinus flexilis - Pinus contorta ssp. murryana*		*87.160.03	
**Pinus flexilis / Cercocarpus ledifolius*		*87.160.01	
***Pinus longaeva* (Bristlecone pine woodland) Alliance**	G4 S2	*87.140.00	
Bristlecone Pine Forest	G4 S2.3		CTT86400CA
**Pinus longaeva*		*87.140.01	
**Pinus longaeva / Cercocarpus intricatus*		*87.140.02	
MG024. Vancouverian Rainforest			
***Abies grandis* (Grand fir forest) Alliance**	G4 S2	*88.100.00	
Grand Fir Forest	G1 S1.1		CTT82120CA
***Chamaecyparis lawsoniana* (Port Orford cedar forest) Alliance**	G3 S3	*81.100.00	
Port Orford Cedar Forest	G3 S2.1		CTT82500CA
**Chamaecyparis lawsoniana - Abies concolor / Acer circinatum*		*81.100.31	
**Chamaecyparis lawsoniana - Abies concolor / Alnus viridis*		*81.100.30	
**Chamaecyparis lawsoniana - Abies concolor / Chrysolepis sempervirens (-Rhododendron occidentale - Leucothoe davisiae)*		*81.100.14	
**Chamaecyparis lawsoniana - Abies concolor / herb*		*81.100.08	
**Chamaecyparis lawsoniana - Abies concolor / Quercus sadleriana*		*81.100.07	
**Chamaecyparis lawsoniana - Abies concolor / Quercus vacciniifolia*		*81.100.09	
**Chamaecyparis lawsoniana - Abies concolor / Rhododendron occidentale*		*81.100.06	
**Chamaecyparis lawsoniana - Abies x shastensis - Picea breweri / Quercus sadleriana - Quercus vacciniifolia*		*81.100.32	
**Chamaecyparis lawsoniana - Abies x shastensis / Alnus viridis - Quercus sadleriana*		*81.100.33	
**Chamaecyparis lawsoniana - Abies x shastensis / Alnus viridis / Darlingtonia californica*		*81.100.34	
**Chamaecyparis lawsoniana - Abies x shastensis / Quercus sadleriana - Vaccinium membranaceum*		*81.100.03	
**Chamaecyparis lawsoniana - Calocedrus decurrens - Alnus rhombifolia*		*81.100.39	
**Chamaecyparis lawsoniana - Calocedrus decurrens / Quercus vacciniifolia*		*81.100.40	
**Chamaecyparis lawsoniana - Pinus monticola / Alnus viridis*		*81.100.16	
**Chamaecyparis lawsoniana - Pinus monticola / dry herb complex*		*81.100.19	
**Chamaecyparis lawsoniana - Pinus monticola / Quercus vacciniifolia*		*81.100.10	
**Chamaecyparis lawsoniana - Pinus monticola / Rhododendron neoglandulosum / Darlingtonia californica*		*81.100.15	
**Chamaecyparis lawsoniana - Pinus monticola / Rhododendron occidentale - Lithocarpus densiflorus var. echinoides - Rhododendron neoglandulosum*		*81.100.37	
**Chamaecyparis lawsoniana - Pinus monticola / Vaccinium membranaceum*		*81.100.17	
**Chamaecyparis lawsoniana - Pinus monticola / wet herb complex*		*81.100.18	
**Chamaecyparis lawsoniana - Pseudotsuga menziesii - Lithocarpus densiflorus / Quercus vacciniifolia*		*81.100.25	
**Chamaecyparis lawsoniana - Pseudotsuga menziesii - Lithocarpus densiflorus / Rhododendron macrophyllum*		*81.100.26	
**Chamaecyparis lawsoniana - Pseudotsuga menziesii / Calycanthus occidentalis*		*81.100.22	
**Chamaecyparis lawsoniana - Pseudotsuga menziesii / Corylus cornuta*		*81.100.35	
**Chamaecyparis lawsoniana - Pseudotsuga menziesii / Quercus vacciniifolia*		*81.100.02	
**Chamaecyparis lawsoniana - Tsuga heterophylla / Chrysolepis sempervirens*		*81.100.20	
**Chamaecyparis lawsoniana - Tsuga heterophylla / Leucothoe davisiae*		*81.100.24	
**Chamaecyparis lawsoniana - Tsuga heterophylla / Rhododendron neoglandulosum*		*81.100.21	
**Chamaecyparis lawsoniana / Gaultheria shallon*		*81.100.05	

**Chamaecyparis lawsoniana / Quercus vacciniifolia - Rhododendron occidentale*		*81.100.12	
**Chamaecyparis lawsoniana / Rhododendron macrophyllum - Gaultheria shallon*		*81.100.04	
**Chamaecyparis lawsoniana / Rhododendron occidentale*		*81.100.01	
**Chamaecyparis lawsoniana / Rhododendron occidentale - Lithocarpus densiflorus var. echinoides*		*81.100.11	
****Picea sitchensis* (Sitka spruce forest) Alliance**	G5 S2	*83.200.00	
Sitka Spruce Forest	G1 S1.1		CTT82110CA
Sitka Spruce Grand Fir Forest	G4 S1.1		CTT82100CA
**Picea sitchensis - Tsuga heterophylla*		*83.200.04	
**Picea sitchensis / Maianthemum dilatatum*		*83.200.01	
**Picea sitchensis / Polystichum munitum*		*83.200.03	
**Picea sitchensis / Rubus spectabilis*		*83.200.02	
****Pinus contorta var. contorta* (Beach pine forest) Alliance**	G5 S3	*87.060.00	
Beach Pine Forest	G4 S2.1		CTT83110CA
**Pinus contorta var. contorta*		*87.060.01	
**Pinus contorta ssp. contorta - Picea sitchensis*		*87.060.02	
****Sequoia sempervirens* (Redwood forest) Alliance**	G3 S3	*86.100.00	
Upland Redwood Forest	G3 S2.3		CTT82320CA
**Sequoia sempervirens*		*86.100.04	
**Sequoia sempervirens - Acer macrophyllum - Umbellularia californica*		*86.100.14	
**Sequoia sempervirens - Acer macrophyllum / Polypodium californicum*		*86.100.01	
**Sequoia sempervirens - Alnus rubra / Rubus spectabilis*		*86.100.29	
North Coast Alluvial Redwood Forest	G2 S2.2		CTT61120CA
**Sequoia sempervirens - Arbutus menziesii / Vaccinium ovatum*		*86.100.15	
**Sequoia sempervirens - Chrysolepis chrysophylla / Arctostaphylos glandulosa*		*86.100.18	
**Sequoia sempervirens - Lithocarpus densiflorus / Carex globosa - Iris douglasiana*		*86.100.06	
**Sequoia sempervirens - Lithocarpus densiflorus / Vaccinium ovatum*		*86.100.16	
**Sequoia sempervirens - Pseudotsuga menziesii - Lithocarpus densiflorus - Chamaecyparis lawsoniana / Vaccinium ovatum*		*86.100.23	
**Sequoia sempervirens - Pseudotsuga menziesii - Umbellularia californica*		*86.100.20	
**Sequoia sempervirens - Pseudotsuga menziesii / Arbutus menziesii*		*86.100.10	
**Sequoia sempervirens - Pseudotsuga menziesii / Gaultheria shallon*		*86.100.11	
**Sequoia sempervirens - Pseudotsuga menziesii / Rhododendron macrophyllum*		*86.100.26	
**Sequoia sempervirens - Pseudotsuga menziesii / Vaccinium ovatum*		*86.100.12	
**Sequoia sempervirens - Tsuga heterophylla / Polystichum munitum*		*86.100.28	
**Sequoia sempervirens - Tsuga heterophylla / Rubus spectabilis*		*86.100.30	
**Sequoia sempervirens - Tsuga heterophylla / Vaccinium ovatum*		*86.100.27	
**Sequoia sempervirens - Umbellularia californica*		*86.100.21	
**Sequoia sempervirens / (Pteridium aquilinum) - Woodwardia fimbriata*		*86.100.02	
**Sequoia sempervirens / Arbutus menziesii*		*86.100.09	
**Sequoia sempervirens / Blechnum spicant*		*86.100.07	
**Sequoia sempervirens / Mahonia nervosa*		*86.100.08	
**Sequoia sempervirens / Marah fabaceus - Vicia angustifolia*		*86.100.05	
**Sequoia sempervirens / Oxalis oregana*		*86.100.13	
**Sequoia sempervirens / Polystichum munitum*		*86.100.25	
**Sequoia sempervirens / Pteridium aquilinum*		*86.100.24	
**Sequoia sempervirens / Pteridium aquilinum - Trillium ovatum*		*86.100.03	

***Tsuga heterophylla* (Western hemlock forest) Alliance**	G5 S2	*84.200.00	
Western Hemlock Forest	G4 S1.1		CTT82200CA
**Tsuga heterophylla - Pseudotsuga menziesii - Chamaecyparis lawsoniana*		*84.200.01	
Coastal Douglas Fir Western Hemlock Forest	G4 S2.1		CTT82410CA
MG025. Vancouverian Subalpine Forest			
***Abies amabilis* (Pacific silver fir forest) Alliance**	G5 S1	*88.800.00	
**Abies amabilis*		*88.800.01	
***Abies magnifica* (Red fir forest) Alliance**	G5 S4 (some associations are of high priority for inventory)	88.200.00	
Red Fir Forest	G4 S4		CTT85310CA
Abies magnifica		88.200.23	
Abies magnifica - Pinus monticola		88.200.30	
Abies magnifica - Tsuga mertensiana / Orthilia secunda		88.200.15	
Abies magnifica - Picea breweriana / Quercus sadleriana - Vaccinium membranaceum		88.200.14	
Abies magnifica - Pinus contorta / Sphenosciadium capitellatum		88.200.16	
Abies magnifica - Pinus contorta ssp. murrayana / Hieracium albiflorum		88.200.24	
Abies magnifica - Pinus monticola - Pinus contorta ssp. murrayana		88.200.29	
Abies magnifica - Pinus monticola / Quercus vacciniifolia		88.200.43	
**Abies magnifica - (Calocedrus decurrens)*		*88.200.10	
Abies magnifica / Achlys triphylla		88.200.03	
Abies magnifica / Arctostaphylos nevadensis		88.200.27	
Abies magnifica / Chimaphila umbellata		88.200.05	
Abies magnifica / Leucothoe davisiae		88.200.35	
Abies magnifica / Linnaea borealis		88.200.37	
Abies magnifica / Lupinus albifrons		88.200.41	
Abies magnifica / Orthilia secunda		88.200.11	
Abies magnifica / Penstemon gracilentus		88.200.06	
Abies magnifica / Pinus contorta ssp. murrayana		88.200.25	
Abies magnifica / Pinus monticola / Arctostaphylos nevadensis		88.200.28	
Abies magnifica / Pinus monticola / Chrysolepis sempervirens		88.200.31	
Abies magnifica / Pyrola picta		88.200.13	
Abies magnifica / Quercus sadleriana		88.200.01	
Abies magnifica / Quercus sadleriana - Arctostaphylos nevadensis		88.200.09	
Abies magnifica / Quercus vacciniifolia		88.200.36	
**Abies magnifica / Rhododendron macrophyllum*		*88.200.12	
**Abies magnifica / Vaccinium membranaceum*		*88.200.02	
Abies magnifica / Wyethia mollis		88.200.26	
***Callitropsis nootkatensis* (Alaska yellow-cedar stands) Alliance**	G4 S1	*81.200.00	
***Pinus contorta ssp. murrayana* (Lodgepole pine forest) Alliance**	G4 S4	87.080.00	
Lodgepole Pine Forest	G4 S4		CTT86100CA
Pinus contorta ssp. murrayana		87.080.01	
Pinus contorta ssp. murrayana - Pinus albicaulis / Carex filifolia		87.080.17	
Whitebark Pine Lodgepole Pine Forest	G4 S4		CTT86220CA
Pinus contorta ssp. murrayana - Pinus albicaulis / Carex rossii		87.080.11	
Pinus contorta ssp. murrayana / Artemisia tridentata		87.080.02	

Pinus contorta ssp. murrayana / Carex filifolia		87.080.10	
Pinus contorta ssp. murrayana / Carex rossii		87.080.06	
Pinus contorta ssp. murrayana / Carex spp.		87.080.13	
Pinus contorta ssp. murrayana / Cistanthe umbellata		87.080.05	
Pinus contorta ssp. murrayana / Ligusticum grayi		87.080.03	
Pinus contorta ssp. murrayana / Penstemon newberryi		87.080.12	
Pinus contorta ssp. murrayana / Rhododendron neoglandulosum		87.080.08	
Pinus contorta ssp. murrayana / Rhododendron neoglandulosum - Phyllodoce breweri		87.080.14	
Pinus contorta ssp. murrayana / Thalictrum fendleri		87.080.07	
Pinus contorta ssp. murrayana / Vaccinium caespitosum		87.080.15	
Pinus contorta ssp. murrayana / Vaccinium uliginosum		87.080.09	
Pinus contorta ssp. murrayana / Vaccinium uliginosum - Rhododendron neoglandulosum		87.080.16	
***Pinus monticola* (Western white pine forest) Alliance**	G5 S4 (some associations are of high priority for inventory)	87.170.00	
**Pinus monticola - Pinus contorta ssp. contorta / Lithocarpus densiflorus var. echinoides*		*87.170.01	
Pinus monticola - Pinus contorta var. ssp. Murrayana		87.170.07	
Pinus monticola - Pseudotsuga menziesii / Quercus vacciniifolia - Lithocarpus densiflorus var. echinoides		87.170.08	
Pinus monticola / Achnatherum occidentalis		87.170.06	
**Pinus monticola / Angelica arguta*		*87.170.04	
**Pinus monticola / Holodiscus discolor*		*87.170.02	
**Pinus monticola / Xerophyllum tenax*		*87.170.03	
Ultramafic White Pine Forest	G3 S3.2		CTT84160CA
***Tsuga mertensiana* (Mountain hemlock forest) Alliance**	G5 S4	84.100.00	
Tsuga mertensiana		84.100.04	
Tsuga mertensiana - Pinus contorta ssp. murrayana		84.100.15	
Tsuga mertensiana - Pinus contorta var. murrayana - Pinus monticola		84.100.11	
Tsuga mertensiana - Pinus monticola		84.100.10	
Tsuga mertensiana / Arnica cordifolia		84.100.09	
Tsuga mertensiana / Juncus parryi		84.100.02	
Tsuga mertensiana / Phyllodoce empetriformis		84.100.01	
Tsuga mertensiana / Pyrola picta		84.100.08	
Tsuga mertensiana / Quercus sadleriana		84.100.03	
Tsuga mertensiana / Quercus vacciniifolia		84.100.07	
Tsuga mertensiana / steep		84.100.14	
1.C.2.c. North American Intermountain Basins Scrub Woodland			
MG026. Intermountain Basins Pinyon–Juniper Woodland			
Great Basin Woodlands	G5 S5		CTT72100CA
***Juniperus grandis* (Mountain juniper woodland) Alliance**	G4 S4	89.200.00	
Juniperus grandis		89.200.01	
**Juniperus grandis - Cercocarpus ledifolius / Artemisia tridentata*		*89.200.03	
Juniperus grandis / Arctostaphylos nevadensis		89.200.05	
**Juniperus grandis / Artemisia tridentata*		*89.200.02	
Juniperus grandis / Holodiscus discolor		89.200.04	
****Juniperus osteosperma* (Utah juniper woodland) Alliance**	G5 S3	*89.300.00	
Great Basin Juniper Woodland and Scrub	G4 S4		CTT72123CA

Mojavean Juniper Woodland and Scrub	G4 S4		CTT72220CA
**Juniperus osteosperma*		*89.300.01	
**Juniperus osteosperma / Ambrosia dumosa*		*89.300.07	
**Juniperus osteosperma / Artemisia tridentata - Ephedra viridis*		*89.300.02	
**Juniperus osteosperma / Artemisia tridentata - Purshia glandulosa - Ephedra nevadensis*		*89.300.03	
**Juniperus osteosperma / Atriplex confertifolia - (Tetradymia axillaris)*		*89.300.06	
**Juniperus osteosperma / Coleogyne ramosissima / (Achnatherum speciosum)*		*89.300.08	
**Juniperus osteosperma / Coleogyne ramosissima / Pleuraphis jamesii*		*89.300.09	
**Juniperus osteosperma / Ephedra nevadensis / Achnatherium speciosum*		*89.300.11	
**Juniperus osteosperma / Eriogonum fasciculatum*		*89.300.04	
**Juniperus osteosperma / Gutierrezia microcephala*		*89.300.05	
**Juniperus osteosperma / Yucca baccata*		*89.300.10	
****Pinus edulis* (Two-needle pinyon stands) Special Stands**	G4 S2?	*87.050.00	
***Pinus monophylla* (Singleleaf pinyon woodlands) Alliance**	G5 S4	87.040.00	
Mojavean Pinon Woodland	G4 S3.2		CTT72210CA
Peninsular Pinon Woodland	G3 S3.2		CTT72310CA
Great Basin Pinon Juniper Woodland	G4 S4		CTT72121CA
Great Basin Pinon Woodland	G3 S3.2		CTT72122CA
Pinus monophylla - Juniperus californica / Achnatherum speciosum		87.040.14	
Pinus monophylla - Juniperus californica / Quercus cornelius-mulleri		87.040.18	
Pinus monophylla - Juniperus osteosperma / Artemisia tridentata		87.040.16	
Pinus monophylla - Juniperus osteosperma / Cercocarpus intricatus		87.040.17	
Pinus monophylla / Artemisia tridentata		87.040.02	
Pinus monophylla / Artemisia tridentata / Elymus elymoides		87.040.15	
Pinus monophylla / Cercocarpus ledifolius / Artemisia tridentata - Purshia tridentata		87.040.12	
Pinus monophylla / Ephedra viridis		87.040.03	
Pinus monophylla / Garrya flavescens		87.040.05	
Pinus monophylla / Juniperus californica / Artemisia tridentata - Coleogyne ramosissima		87.040.06	
Pinus monophylla / Juniperus osteosperma / Artemisia nova		87.040.07	
Pinus monophylla / Juniperus osteosperma / Purshia mexicana		87.040.13	
Pinus monophylla / Prunus fasciculata - Rhus trilobata		87.040.10	
Pinus monophylla / Quercus cornelius - mulleri / Nama californica		87.040.09	
Pinus monophylla / Ribes velutinum		87.040.11	
Pinus monophylla / Symphoricarpos rotundifolia - Ribes velutinum		87.040.04	
***Juniperus occidentalis* (Western juniper woodland) Alliance**	G5 S4	89.400.00	
Northern Juniper Woodland	G4 S4		CTT72110CA
Juniperus occidentalis		89.400.02	
Juniperus occidentalis - Pinus jeffreyi / (Purshia tridentata) - (Prunus virginiana		89.400.03	
Juniperus occidentalis / Artemisia arbuscula		89.400.04	

1.C.2.x. North American Introduced Evergreen Broadleaf and Conifer Forest

MG027. Introduced North American Mediterranean woodland and forest

***Eucalyptus (globulus, camaldulensis)* (Eucalyptus groves) Semi-natural Stands**		79.100.00	
***Schinus (molle, terebinthifolius) - Myoporum laetum* (Pepper tree or Myoporum groves) Semi-natural Stands**		79.200.00	
Myoporum laetum / Arundo donax		79.200.01	
Schinus molle		79.200.02	

Schinus molle / Lepidospartum squamatum		79.200.03	
1.C.3. Temperate Flooded and Swamp Forest			
1.C.3.b. Western North America Flooded and Swamp Forest			
MG031. Western cool temperate scrub swamp			
Freshwater Swamp	G2 S2.2		CTT52600CA
***Cornus sericea* (Red osier thickets) Alliance**	G4 S3?	*80.100.00	
**Cornus sericea*		*80.100.02	
**Cornus sericea - Salix exigua*		*80.100.03	
**Cornus sericea - Salix lasiolepis*		*80.100.04	
**Cornus sericea / Senecio triangularis*		*80.100.01	
MG034. Western Cordilleran montane–boreal riparian scrub			
Montane Riparian Scrub	G4 S4		CTT63500CA
Modoc Great Basin Riparian Scrub	G3 S2.1		CTT63600CA
***Betula occidentalis* (Water birch thicket) Alliance**	G4 S2	*63.610.00	
Water Birch Riparian Scrub	G? SNR		CTT63510CA
**Betula occidentalis / Salix spp.*		*63.610.01	
***Rosa woodsii* (Interior rose thickets) Provisional Alliance**	G5 S3	*63.320.00	
***Salix lutea* (Yellow willow thickets) Alliance**	G4 S3?	*61.210.00	
**Salix lutea / mesic forbs*		*61.210.01	
**Salix lutea / mesic graminoids*		*61.210.02	
**Salix lutea / Poa pratensis*		*61.210.03	
**Salix lutea/ Rosa woodsii*		*61.210.04	
***Acer glabrum* (Rocky Mountain maple thickets) Provisional Alliance**	G5 S3?	*61.430.00	
***Alnus incana* (Mountain alder thicket) Alliance**	G4 S3	*63.210.00	
**Alnus incana*		*63.210.01	
**Alnus incana / Glyceria elata*		*63.210.02	
**Alnus incana / bench*		*63.210.03	
***Alnus viridis* (Sitka alder thickets) Provisional Alliance**	G5 S3?	*63.220.00	
***Betula glandulosa* (Resin birch thickets) Provisional Alliance**	G5 S2?	*63.620.00	
***Dasiphora fruticosa* (Shrubby cinquefoil scrub) Alliance**	G5 S3?	*38.110.00	
**Dasiphora fruticosa*		*38.110.01	
**Dasiphora fruticosa / Danthonia intermedia*		*38.110.02	
**Dasiphora fruticosa / Danthonia unispicata*		*38.110.04	
**Dasiphora fruticosa / Potentilla breweri*		*38.110.03	
**Dasiphora fruticosa / Veratrum californicum*		*38.110.05	
***Salix bebbiana* (Bebb's willow thickets) Alliance**	G4 S2?	*61.213.00	
**Salix bebbiana / mesic forb type*		*61.213.01	
***Salix eastwoodiae* (Sierran willow thickets) Alliance**	G3 S3	*61.112.00	
**Salix eastwoodiae*		*61.112.01	
**Salix eastwoodiae / Carex scopulorum*		*61.112.02	
**Salix eastwoodiae / Oreostemma alpigenum*		*61.112.03	
**Salix eastwoodiae / Senecio triangularis*		*63.160.02	
***Salix geyeriana* (Geyer willow thickets) Alliance**	G4 S2?	*61.212.00	
**Salix geyeriana / grass*		*61.212.01	

**Salix geyeriana / mesic graminoid*		*61.212.02	
****Salix jepsonii* (Jepson willow thickets) Alliance**	G3 S3	*61.118.00	
**Salix jepsonii*		*61.118.01	
**Salix jepsonii - Cornus sericea*		*61.118.04	
**Salix jepsonii - Paxistima myrsinites*		*61.118.03	
**Salix jepsonii / Senecio triangularis*		*61.118.02	
****Salix lemmonii* (Lemmon's willow thickets) Alliance**	G4 S3	*61.113.00	
**Salix lemmonii*		*61.113.01	
**Salix lemmonii / Carex spp.*		*61.113.02	
**Salix lemmonii / mesic forb*		*61.113.04	
**Salix lemmonii / mesic graminoid*		*61.113.03	
**Salix lucida ssp. lasiandra / Urtica urens - Urtica dioica*		*61.204.01	
***Salix orestera* (Sierra gray willow thickets) Alliance**	G4 S4 (some associations are of high priority for inventory)	61.115.00	
**Salix orestera / Allium validum*		*63.160.03	
Salix orestera / Calamagrostis muiriana		61.115.01	
Salix orestera / Senecio triangularis		61.115.02	
Salix orestera / tall forb		61.115.03	
****Salix planifolia* (Tea-leaved willow thickets) Provisional Alliance**	G4 S2?	*61.119.00	
**Salix planifolia*		*61.119.01	
North Coast Riparian Scrub	G3 S3.2		CTT63100CA
****Morella californica* (Wax myrtle scrub) Alliance**	G3 S3	*37.930.00	
**Morella californica*		*37.930.01	
****Salix hookeriana* (Coastal dune willow thickets) Alliance**	G4 S3	*61.203.00	
**Salix hookeriana*		*61.203.01	
**Salix hookeriana / Rubus ursinus*		*61.203.02	
****Salix sitchensis* (Sitka willow thickets) Provisional Alliance**	G4 S3?	*61.206.00	
***Alnus rhombifolia* (White alder groves) Alliance**	G4 S4 (some associations are of high priority for inventory)	61.420.00	
White Alder Riparian Forest	G4 S4		CTT61510CA
Alnus rhombifolia		61.420.10	
Alnus rhombifolia - Acer macrophyllum		61.420.03	
**Alnus rhombifolia - Platanus racemosa*		*61.420.11	
Southern Sycamore Alder Riparian Woodland	G4 S4		CTT62400CA
Alnus rhombifolia - Platanus racemosa - Quercus chrysolepis		61.420.12	
**Alnus rhombifolia - Platanus racemosa - Salix laevigata*		*61.420.15	
Alnus rhombifolia - Pseudotsuga menziesii		61.420.29	
Alnus rhombifolia - Pseudotsuga menziesii - Calocedrus decurrens		61.420.31	
Alnus rhombifolia - Pseudotsuga menziesii / Darmera peltata		61.420.30	
Alnus rhombifolia - Pseudotsuga menziesii / Rubus armeniacus		61.420.04	
Alnus rhombifolia - Quercus chrysolepis		61.420.22	
**Alnus rhombifolia - Salix laevigata*		*61.420.13	
Alnus rhombifolia / Aruncus dioicus		61.420.02	
Alnus rhombifolia / Baccharis salicifolia		61.420.09	
Alnus rhombifolia / Carex nudata		61.420.24	
Alnus rhombifolia / Carex spp		61.420.23	

**Alnus rhombifolia / Cornus sericea*		*61.420.07	
Alnus rhombifolia / Cornus sessilis		61.420.06	
**Alnus rhombifolia / Darmera peltata*		*61.420.05	
Alnus rhombifolia / Galium trifolium		61.420.08	
Alnus rhombifolia / Galium trifolium - Stachys ajugoides		61.420.26	
Alnus rhombifolia / Leucothoe davisiae		61.420.21	
**Alnus rhombifolia / Polypodium californicum*		*61.420.01	
Alnus rhombifolia / Pteridium aquilinum		61.420.27	
**Alnus rhombifolia / Rhododendron occidentale*		*61.420.17	
**Alnus rhombifolia / Salix exigua - (Rosa californica)*		*61.420.18	
****Fraxinus latifolia* (Oregon ash groves) Alliance**	G4 S3	*61.960.00	
**Fraxinus latifolia*		*61.960.04	
**Fraxinus latifolia - Alnus rhombifolia*		*61.960.02	
**Fraxinus latifolia / Cornus sericea*		*61.960.03	
**Fraxinus latifolia / Toxicodendron diversilobum*		*61.960.01	
****Populus trichocarpa* (Black cottonwood forest) Alliance**	G5 S3	*61.120.00	
Montane Black Cottonwood Riparian Forest	G4 S3.2		CTT61530CA
North Coast Black Cottonwood Riparian Forest	G1 S1.1		CTT61110CA
**Populus trichocarpa*		*61.120.01	
**Populus trichocarpa - Pinus jeffreyi*		*61.120.03	
**Populus trichocarpa - Quercus agrifolia*		*61.120.08	
**Populus trichocarpa - Salix laevigata*		*61.120.09	
**Populus trichocarpa - Salix lasiolepis*		*61.120.10	
**Populus trichocarpa - Salix lucida*		*61.120.11	
**Populus trichocarpa / Artemisia tridentata ssp. vaseyana*		*61.120.04	
**Populus trichocarpa / Rhododendron occidentalis*		*61.120.07	
**Populus trichocarpa / Symphoricarpos rotundifolius*		*61.120.05	
**Populus / Salix*		*61.120.06	
****Salix lucida* (Shining willow groves) Alliance**	G4 S3	*61.204.00	
**Salix lucida / Poa pratensis*		*61.204.02	
**Salix lucida ssp. lasiandra*		*61.204.03	
**Salix lucida ssp. lasiandra / Cornus sericea*		*61.204.04	
**Salix lucida ssp. lasiandra / Equisetum arvense*		*61.204.05	
**Salix lucida ssp. lasiandra / Trifolium longipes*		*61.204.06	

1.C.3.c. Western North America Warm Temperate Flooded and Swamp Forest

MG036. Southwestern North American Riparian, Flooded and Swamp Forest

Mojave Riparian Forest	G1 S1.1		CTT61700CA
Great Valley Willow Scrub	G3 S3.2		CTT63410CA
Southern Mixed Riparian Forest	G2 S2.1		CTT61340CA
Southern Riparian Forest	G4 S4		CTT61300CA
Southern Riparian Scrub	G3 S3.2		CTT63300CA
Southern Willow Scrub	G3 S2.1		CTT63320CA
****Acer negundo* (Box-elder forest) Alliance**	G5 S2	*61.440.00	
**Acer negundo - Salix gooddingii*		*61.440.01	

***Juglans hindsii and Hybrids* (Hinds's walnut and related stands) Special Stands**	G1 S1	*61.810.00	
Hinds Walnut Woodland	G1 S1.1		CTT71220CA
***Platanus racemosa* (California sycamore woodlands) Alliance**	G3 S3	*61.310.00	
**Platanus racemosa - Populus fremontii*		*61.314.01	
**Platanus racemosa - Populus fremontii / Salix lasiolepis*		*61.314.03	
Central Coast Cottonwood Sycamore Riparian Forest	G3 S3.2		CTT61210CA
**Platanus racemosa - Populus fremontii / Salix lasiolepis - Salix exigua / Scirpus americanus*		*61.314.02	
**Platanus racemosa - Quercus agrifolia*		*61.312.01	
**Platanus racemosa - Quercus agrifolia - Populus fremontii - Salix laevigata*		*61.312.06	
**Platanus racemosa - Quercus agrifolia - Salix lasiolepis*		*61.312.03	
**Platanus racemosa - Quercus agrifolia / Baccharis salicifolia / Artemisia douglasiana*		*61.312.04	
**Platanus racemosa - Salix laevigata*		*61.312.07	
**Platanus racemosa - Salix laevigata / Salix lasiolepis - Baccharis salicifolia*		*61.312.05	
**Platanus racemosa / Adenostoma fasciculatum*		*61.313.03	
**Platanus racemosa / annual grass*		*61.311.03	
Sycamore Alluvial Woodland	G1 S1.1		CTT62100CA
**Platanus racemosa / Avena barbata*		*61.311.01	
**Platanus racemosa / Baccharis salicifolia*		*61.313.01	
**Platanus racemosa / Bromus hordeaceus*		*61.311.02	
**Platanus racemosa / Toxicodendron diversilobum*		*61.313.02	
***Populus fremontii* (Fremont cottonwood forest) Alliance**	G4 S3	*61.130.00	
Modoc Great Basin Cottonwood Willow Riparian Forest	G3 S2.1		CTT61610CA
Sonoran Cottonwood Willow Riparian Forest	G2 S1.1		CTT61810CA
Great Valley Cottonwood Riparian Forest	G2 S2.1		CTT61410CA
Great Valley Mixed Riparian Forest	G2 S2.2		CTT61420CA
Southern Cottonwood Willow Riparian Forest	G3 S3.2		CTT61330CA
**Populus fremontii*		*61.130.06	
**Populus fremontii - Juglans californica*		*61.130.18	
**Populus fremontii - Prosopis pubescens*		*61.130.19	
**Populus fremontii - Quercus agrifolia*		*61.130.20	
**Populus fremontii - Salix (laevigata, lasiolepis, lucida ssp. lasiandra)*		*61.130.24	
**Populus fremontii - Salix gooddingii / Baccharis salicifolia*		*61.130.14	
**Populus fremontii - Salix laevigata*		*61.130.15	
**Populus fremontii - Salix laevigata / Salix lasiolepis - Baccharis salicifolia*		*61.130.22	
**Populus fremontii - Salix laevigata / Salix lasiolepis / Vitis girdiana*		*61.130.21	
**Populus fremontii - Salix lasiolepis*		*61.130.23	
**Populus fremontii - Salix lucida ssp. lasiandra*		*61.130.25	
**Populus fremontii - Sambucus nigra*		*61.130.26	
**Populus fremontii / Acer negundo*		*61.130.07	
**Populus fremontii / Acer negundo / Rubus armeniacus*		*61.130.08	
**Populus fremontii / Artemisia douglasiana*		*61.130.09	
**Populus fremontii / Baccharis salicifolia*		*61.130.16	
**Populus fremontii / Galium aparine*		*61.130.10	
**Populus fremontii / Rubus ursinus*		*61.130.11	
**Populus fremontii / Salix exigua*		*61.130.17	
**Populus fremontii / Vitis californica*		*61.130.13	

***Salix gooddingii* (Black willow thickets) Alliance**	G4 S3	*61.211.00	
**Salix gooddingii*		*61.211.01	
**Salix gooddingi - Populus fremontii*		*61.211.04	
**Salix gooddingii - Quercus lobata / wetland herb*		*61.211.06	
**Salix gooddingii - Salix laevigata*		*61.211.05	
**Salix gooddingii - Salix lucida - Populus fremontii*		*61.211.08	
**Salix gooddingii / Baccharis salicifolia*		*61.211.02	
**Salix gooddingii / Lepidium latifolium*		*61.211.03	
**Salix gooddingii / Rubus armeniacus*		*61.211.07	
***Salix laevigata* (Red willow thickets) Alliance**	G3 S3	*61.205.00	
**Salix laevigata*		*61.205.01	
**Salix laevigata - Cornus sericea / Scirpus microcarpus*		*61.205.05	
**Salix laevigata - Salix lasiolepis*		*61.205.02	
**Salix laevigata - Salix lasiolepis / Artemisia douglasiana - Rubus ursinus*		*61.205.03	
**Salix laevigata - Salix lasiolepis / Baccharis salicifolia*		*61.205.07	
**Salix laevigata / Rosa californica*		*61.205.04	
**Salix laevigata / Salix lasiolepis / Artemisia douglasiana*		*61.205.06	
***Washingtonia filifera* (California fan palm oasis) Alliance**	G3 S3	*61.520.00	
Desert Fan Palm Oasis Woodland	G3 S3.2		CTT62300CA
**Washingtonia filifera - Platanus racemosa / Salix spp*		*61.520.04	
**Washingtonia filifera / spring (Atriplex - Baccharis - Pluchea)*		*61.520.03	
***Baccharis emoryi* (Emory’s baccharis thickets) Provisional Alliance**	G3 S2?	*63.520.00	
***Baccharis salicifolia* (Mulefat thickets) Alliance**	G5 S4	63.510.00	
Mule Fat Scrub	G4 S4		CTT63310CA
Baccharis salicifolia		63.510.01	
Baccharis salicifolia - Arundo donax		63.510.05	
Baccharis salicifolia - Lepidospartum squamatum - Hazardia squarrosa		63.510.02	
Baccharis salicifolia - Pluchea sericea		63.510.06	
Baccharis salicifolia - Sambucus mexicana		63.510.03	
Baccharis salicifolia - Tamarix ramosissima		63.510.07	
Baccharis salicifolia / Stachys albens		63.510.04	
***Baccharis sergiloides* (Broom baccharis thickets) Alliance**	G4 S3	*63.530.00	
**Baccharis sergiloides - Prunus fasciculata*		*63.530.01	
**Baccharis sergiloides - Prunus fasciculata - Rhus trilobata*		*63.530.02	
**Baccharis sergiloides / Muhlenbergia rigens*		*63.530.03	
***Cephalanthus occidentalis* (Button willow thickets) Alliance**	G5 S2	*63.300.00	
Buttonbush Scrub	G1 S1.1		CTT63430CA
**Cephalanthus occidentalis*		*63.300.01	
***Forestiera pubescens* (Desert olive patches) Alliance**	G3 S2	*61.580.00	
**Forestiera pubescens*		*61.580.01	
**Forestiera pubescens - Sambucus nigra*		*61.580.02	
Woodwardia Thicket	G3 S3.2		CTT63110CA
***Rhododendron occidentale* (Western azalea patches) Provisional Alliance**	G3 S2?	*63.310.00	
***Rosa californica* (California rose briar patches) Alliance**	G3 S3	*63.907.00	
**Rosa californica*		*63.907.02	
**Rosa californica - Baccharis pilularis*		*63.907.01	

**Rosa californica / Schoenoplectus spp.*		*63.907.03	
****Salix breweri*** **(Brewer willow thickets) Alliance**	G2 S2	*61.215.00	
**Salix breweri / Muhlenbergia asperifolia*		*61.215.01	
Salix exigua **(Sandbar willow thickets) Alliance**	G5 S4	61.209.00	
Salix exigua		61.209.01	
Salix exigua - (Saix lasiolepis) - Rubus discolor		61.209.07	
Salix exigua - Arundo donax		61.209.02	
**Salix exigua - Brickellia californica*		*61.209.06	
Salix exigua - Salix melanopsis		61.209.03	
Salix exigua / Baccharis sergiloides		61.209.04	
Salix exigua / Juncus spp.		61.209.05	
Salix lasiolepis **(Arroyo willow thickets) Alliance**	G4 S4 (some associations are of high priority for inventory)	61.201.00	
Southern Arroyo Willow Riparian Forest	G2 S2.1		CTT61320CA
Central Coast Riparian Scrub	G3 S3		CTT63200CA
Central Coast Arroyo Willow Riparian Forest	G3 S3.2		CTT61230CA
**Salix lasiolepis*		*61.201.01	
Salix lasiolepis - Salix lucida		61.201.04	
Salix lasiolepis / Artemisia douglasiana		61.201.02	
Salix lasiolepis / Baccharis pilularis - Rubus ursinus		61.201.05	
Salix lasiolepis / Baccharis salicifolia		61.201.06	
Salix lasiolepis / Malosma laurina		61.201.07	
Salix lasiolepis / Rosa californica		61.201.08	
Salix lasiolepis / Rubus spp.		61.201.03	
****Sambucus nigra*** **(Blue elderberry stands) Alliance**	G3 S3	*63.410.00	
Elderberry Savanna	G2 S2.1		CTT63440CA
**Sambucus nigra*		*63.410.01	
**Sambucus nigra - Heteromeles arbutifolia*		*63.410.03	
**Sambucus nigra / Leymus condensatus*		*63.410.02	
Arundo donax **(Giant reed breaks) Semi-natural Stands**		42.080.00	
Arundo donax		42.080.01	
Arundo donax - Salix exigua		42.080.02	
Tamarix spp. **(Tamarisk thickets) Semi-natural Stands**		63.810.00	
Tamarisk Scrub	G5 S4		CTT63810CA

2. Mesomorphic Shrub and Herb Vegetation (Shrubland and Grassland)

2.B. Mediterranean Scrub and Grassland

2.B.1. Mediterranean Scrub

2.B.1.a. California Scrub

MG043. California Chaparral

Non-Serpentine Digger Pine Chaparral Woodland	G4 S4		CTT71322CA
Serpentine Digger Pine Chaparral Woodland	G3 S3.2		CTT71321CA
Granitic Southern Mixed Chaparral	G3 S3.3		CTT37121CA
Mafic Southern Mixed Chaparral	G3 S3.2		CTT37122CA
Northern Mixed Chaparral	G4 S4		CTT37110CA
Gabbroic Northern Mixed Chaparral	G2 S1.1		CTT37111CA

Northern North Slope Chaparral	G3 S3.3		CTT37E10CA
Southern North Slope Chaparral	G3 S3.3		CTT37E20CA
Alluvial Fan Chaparral	G2 S2.1		CTT37H00CA
Coastal Sage Chaparral Scrub	G3 S3.2		CTT37G00CA
Flannel Bush Chaparral	G3 S3.3		CTT37J00CA
***Adenostoma fasciculatum* (Chamise chaparral) Alliance**	G5 S5 (some associations are of high priority for inventory)	37.101.00	
Chamise Chaparral	G4 S4		CTT37200CA
Adenostoma fasciculatum		37.101.16	
Adenostoma fasciculatum - (Arctostaphylos glandulosa)		37.101.07	
**Adenostoma fasciculatum - (Arctostaphylos manzanita)*		*37.101.19	
Adenostoma fasciculatum - (Arctostaphylos pungens)		37.101.26	
Adenostoma fasciculatum - (Arctostaphylos viscida)		37.101.27	
Adenostoma fasciculatum - (Ceanothus crassifolius)		37.101.08	
Adenostoma fasciculatum - (Ceanothus cuneatus)		37.101.10	
**Adenostoma fasciculatum - (Ceanothus greggii / mafic)*		*37.101.06	
Adenostoma fasciculatum - (Ceanothus tomentosus)		37.101.11	
Adenostoma fasciculatum - Arctostaphylos glandulosa - Ceanothus jepsonii / Calamagrostis ophitidis		37.101.32	
Adenostoma fasciculatum - Arctostaphylos pringlei		37.101.22	
**Adenostoma fasciculatum - Diplacus aurantiacus*		*37.101.12	
Adenostoma fasciculatum - Eriodictyon californicum (Lotus scoparius)		37.101.31	
Adenostoma fasciculatum - Eriogonum fasciculatum		37.101.14	
Adenostoma fasciculatum - Eriogonum fasciculatum - Salvia apiana		37.103.03	
Adenostoma fasciculatum - Hesperoyucca whipplei		37.101.04	
Adenostoma fasciculatum - Heteromeles arbutifolia / Melica torreyana		37.101.28	
Adenostoma fasciculatum - Malosma laurina		37.101.21	
Adenostoma fasciculatum - Malosma laurina - Eriodictyon crassifolium		37.101.33	
Adenostoma fasciculatum / annual grass - forb		37.101.24	
Adenostoma fasciculatum / Castilleja pruinosa		37.101.29	
Adenostoma fasciculatum / mixed herb - moss		37.101.25	
Adenostoma fasciculatum / Selaginella bigelovii		37.101.30	
Adenostoma fasciculatum disturbance		37.101.17	
**Adenostoma fasciculatum serpentine*		*37.101.15	
***Adenostoma fasciculatum - Salvia apiana* (Chamise - white sage chaparral) Alliance**	G3 S3	*37.103.00	
**Adenostoma fasciculatum - Salvia apiana*		*37.103.01	
**Adenostoma fasciculatum - Salvia apiana - Artemisia californica*		*37.103.02	
**Adenostoma fasciculatum - Salvia leucophylla*		*37.101.23	
***Adenostoma fasciculatum - Salvia mellifera* (Chamise - black sage chaparral) Alliance**	G5 S5 (some associations are of high priority for inventory)	37.102.00	
Adenostoma fasciculatum - Salvia mellifera - Artemisia californica		37.102.04	
Adenostoma fasciculatum - Salvia mellifera - Ceanothus crassifolius		37.102.05	
Adenostoma fasciculatum - Salvia mellifera - Malosma laurina		37.102.06	
Adenostoma fasciculatum - Salvia mellifera - Rhus ovata		37.102.07	
Adenostoma fasciculatum - Salvia mellifera / (herbaceous)		37.102.02	
**Adenostoma fasciculatum - Salvia mellifera / mixed shrub*		*37.102.03	

***Adenostoma fasciculatum - Xylococcus bicolor* (Chamise - mission manzanita chaparral) Alliance**	G4 S3	*37.109.00	
Southern Maritime Chaparral	G1 S1.1		CTT37C30CA
**Adenostoma fasciculatum - Xylococcus bicolor*		*37.109.01	
**Adenostoma fasciculatum - Xylococcus bicolor - Ceanothus crassifolius*		*37.109.05	
**Adenostoma fasciculatum - Xylococcus bicolor - Ceanothus crassifolius - Malosma laurina*		*37.109.14	
**Adenostoma fasciculatum - Xylococcus bicolor - Ceanothus tomentosus*		*37.109.02	
**Adenostoma fasciculatum - Xylococcus bicolor - Ceanothus verrucosus*		*37.109.08	
**Adenostoma fasciculatum - Xylococcus bicolor - Cneoridium dumosum*		*37.109.09	
**Adenostoma fasciculatum - Xylococcus bicolor - Eriogonum fasciculatum*		*37.109.10	
**Adenostoma fasciculatum - Xylococcus bicolor - Quercus berberidifolia*		*37.109.12	
**Adenostoma fasciculatum - Xylococcus bicolor - Rhus integrifolia*		*37.109.11	
**Adenostoma fasciculatum - Xylococcus bicolor - Salvia mellifera - Malosma laurina*		*37.109.13	
Upper Sonoran Manzanita Chaparral	G4 S4		CTT37B00CA
***Arctostaphylos glauca* (Bigberry manzanita chaparral) Alliance**	G4 S4 (some associations are of high priority for inventory)	37.301.00	
Arctostaphylos glauca		37.301.01	
Arctostaphylos glauca - Adenostoma fasciculatum		37.104.01	
Arctostaphylos glauca - Adenostoma fasciculatum - Ceanothus crassifolius		37.104.05	
Arctostaphylos glauca - Adenostoma fasciculatum - Ceanothus cuneatus		37.104.07	
Arctostaphylos glauca - Adenostoma fasciculatum - Ceanothus greggii		37.104.04	
Arctostaphylos glauca - Adenostoma fasciculatum - Ceanothus leucodermis		37.104.02	
Arctostaphylos glauca - Adenostoma fasciculatum - Diplacus aurantiacus		37.104.08	
Arctostaphylos glauca - Adenostoma fasciculatum - Hesperoyucca whipplei		37.104.03	
Arctostaphylos glauca - Adenostoma fasciculatum - Quercus berberidifolia		37.104.06	
Arctostaphylos glauca - Adenostoma fasciculatum - Rhus ovata		37.104.09	
Arctostaphylos glauca - Adenostoma fasciculatum - Salvia mellifera		37.104.10	
Arctostaphylos glauca - Adenostoma fasciculatum on serpentine		37.104.11	
Arctostaphylos glauca - Artemisia californica - Salvia mellifera		37.301.03	
Arctostaphylos glauca - Cercocarpus montanus		37.301.05	
**Arctostaphylos glauca - Quercus durata / Pinus sabiniana*		*37.301.04	
**Arctostaphylos glauca / Melica torreyana*		*37.301.02	
***Arctostaphylos hookeri* (Hooker's manzanita chaparral) Provisional Alliance**	G2 S2	*37.321.00	
***Arctostaphylos manzanita* (Spiny menodora scrub) Provisional Alliance**	G3? S3?	*37.313.00	
***Arctostaphylos viscida* (White leaf manzanita chaparral) Alliance**	G4 S4 (some associations are of high priority for inventory)	37.305.00	
Arctostaphylos viscida		37.305.01	
Arctostaphylos viscida - Heteromeles arbutifolia - Toxicodendron diversilobum		37.305.05	
Arctostaphylos viscida - Quercus wislizeni		37.305.07	
**Arctostaphylos viscida / Salvia sonomensis*		*37.305.03	
Arctostaphylos viscida ssp. pulchella		37.305.06	
Arctostaphylos viscida - Adenostoma fasciculatum		37.305.02	
**(Arctostaphylos viscida - Adenostoma fasciculatum) / Salvia sonomensis*		*37.305.04	
***Ceanothus crassifolius* (Hoary leaf ceanothus chaparral) Alliance**	G4 S4	37.208.00	
Ceanothus crassifolius Chaparral	G3 S3.2		CTT37830CA
Ceanothus crassifolius		37.208.01	
Ceanothus crassifolius - Adenostoma fasciculatum		37.208.02	

Ceanothus crassifolius - Adenostoma fasciculatum - Rhus ovata		37.208.04	
Ceanothus crassifolius - Adenostoma fasciculatum - Salvia mellifera		37.208.05	
Ceanothus crassifolius - Adenostoma fasciculatum - Malosma Laurina		37.208.03	
Ceanothus crassifolius - Adenostoma fasciculatum - Xylococcus bicolor		37.208.06	
Ceanothus crassifolius - Cercocarpus montanus		37.208.07	
Ceanothus crassifolius - Malosma laurina		37.208.08	
***Ceanothus cuneatus* (Wedge leaf ceanothus chaparral, Buck brush chaparral) Alliance**	G4 S4	37.211.00	
Buck Brush Chaparral	G4 S4		CTT37810CA
Ceanothus cuneatus		37.211.01	
Ceanothus cuneatus - Adenostoma fasciculatum		37.211.06	
Ceanothus cuneatus - Adenostoma fasciculatum - Salvia mellifera - Malosma laurina		37.211.10	
Ceanothus cuneatus - Eriodictyon californicum - (Fremontodendron californicum)		37.211.08	
Ceanothus cuneatus - Frangula californica - Arctostaphylos pungens		37.211.09	
Ceanothus cuneatus / Calocedrus decurrens		37.211.02	
Ceanothus cuneatus / Elymus elymoides		37.211.03	
Ceanothus cuneatus / Eriophyllum lanatum		37.211.11	
**Ceanothus cuneatus / Plantago erecta*		*37.211.05	
***Ceanothus megacarpus* (Big pod ceanothus chaparral) Alliance**	G4 S4	37.201.00	
Ceanothus megacarpus Chaparral	G3 S3.2		CTT37840CA
Ceanothus megacarpus		37.201.01	
Ceanothus megacarpus - Adenostoma fasciculatum		37.201.02	
Ceanothus megacarpus - Adenostoma sparsifolium		37.201.04	
Ceanothus megacarpus - Cercocarpus montanus		37.201.05	
Ceanothus megacarpus - Malosma laurina		37.201.06	
Ceanothus megacarpus - Prunus ilicifolia		37.201.09	
Ceanothus megacarpus - Rhamnus ilicifolia		37.203.01	
Ceanothus megacarpus - Salvia mellifera		37.201.08	
***Eriodictyon californicum* (California yerba santa scrub) Alliance**	G4 S4	37.080.00	
Eriodictyon californicum / herbaceous		35.080.01	
****Eriodictyon crassifolium* (Thick leaf yerba santa scrub) Provisional Alliance**	G3 S3	*37.090.00	
****Arctostaphylos (crustacea, tomentosa)* (Brittle leaf - Woolly leaf manzanita chaparral) Alliance**	G2 S2	*37.308.00	
Northern Maritime Chaparral	G1 S1.2		CTT37C10CA
Central Maritime Chaparral	G2 S2.2		CTT37C20CA
Island Chaparral	G3 S3.1		CTT37700CA
****Arctostaphylos canescens* (Hoary manzanita chaparral) Provisional Alliance**	G3? S3?	*37.311.00	
**Arctostaphylos canescens - Arctostaphylos glandulosa - Adenostoma fasciculatum*		*37.311.01	
**Arctostaphylos crustacea*		*37.308.03	
**Arctostaphylos crustacea - Adenostoma fasciculatum - Ceanothus (cuneatus, papillosus)*		*37.308.04	
**Arctostaphylos crustacea - Arctostaphylos gabilanensis*		*37.308.05	
****Arctostaphylos hooveri* (Hoover's manzanita chaparral) Alliance**	G2 S2	*37.312.00	
**Arctostaphylos hooveri*		*37.312.01	
****Arctostaphylos montereyensis* (Monterey manzanita chaparral) Provisional Alliance**	G1 S1	*37.314.00	
****Arctostaphylos morroensis* (Morro manzanita chaparral) Alliance**	G1 S1	*37.315.00	
****Arctostaphylos myrtifolia* (Ione manzanita chaparral) Alliance**	G1 S1	*37.304.00	
Ione Chaparral	G1 S1.1		CTT37D00CA
**Arctostaphylos myrtifolia*		*37.304.01	

***Arctostaphylos (nummularia, sensitiva)* (Glossy leaf manzanita chaparral) Alliance**	G2 S2	*37.306.00
***Arctostaphylos pajaroensis* (Pajaro manzanita chaparral) Alliance**	G1 S1	*37.316.00
**Arctostaphylos pajaroensis*		*37.316.01
***Arctostaphylos pumila* (Sandmat manzanita chaparral) Provisional Alliance**	G1 S1	*37.318.00
**Arctostaphylos sensitiva - Vaccinium ovatum - Chrysolepis chrysophylla var. minor*		*37.306.01
**Arctostaphylos sensitiva - Arctostaphylos glandulosa*		*37.306.02
***Arctostaphylos (purissima, rudis)* (Burton Mesa chaparral) Provisional Alliance**	G1 S1	*37.322.00
***Arctostaphylos silvicola* (Silverleaf manzanita chaparral) Provisional Alliance**	G1 S1	*37.320.00
***Arctostaphylos stanfordiana* (Stanford manzanita chaparral) Provisional Alliance**	G3 S3?	*37.319.00
***Ceanothus papillosus* (Wart leaf ceanothus chaparral) Alliance**	G3 S3	*37.215.00
**Ceanothus papillosus - Adenostoma fasciculata*		*37.215.01
***Ceanothus verrucosus* (Wart-stemmed ceanothus chaparral) Provisional Alliance**	G2 S2	*37.216.00
***Malosma laurina* (Laurel sumac scrub) Alliance**	G4 S4	45.455.00
Malosma laurina		45.455.01
Malosma laurina - Eriogonum cinereum		45.455.03
Malosma laurina - Eriogonum fasciculatum		45.455.04
Malosma laurina - Eriogonum fasciculatum - Salvia apiana		45.455.06
Malosma laurina - Eriogonum fasciculatum - Salvia mellifera		45.455.07
Malosma laurina - Rhus ovata - Ceanothus megacarpus		45.455.08
Malosma laurina - Salvia mellifera		45.455.09
Malosma laurina - Tetracoccus dioicus		45.455.10
***Quercus pacifica* (Island scrub oak chaparral) Alliance**	G3 S3	*37.416.00
**Quercus pacifica*		*37.416.01
***Rhus integrifolia* (Lemonade berry scrub) Alliance**	G3 S3	*37.803.00
**Rhus integrifolia*		*37.803.01
**Rhus integrifolia - Adenostoma fasciculatum - Artemisia californica*		*37.803.02
**Rhus integrifolia - Artemisia californica - Eriogonum cinereum*		*37.803.03
**Rhus integrifolia - Opuntia spp - Eriogonum cinereum*		*37.803.04
**Rhus integrifolia - Salvia mellifera - Artemisia californica*		*37.803.05
***Ceanothus spinosus* (Greenbark ceanothus chaparral) Alliance**	G4 S4	37.214.00
Ceanothus spinosus		37.214.01
Ceanothus spinosus - Ceanothus megacarpus		37.214.02
***Cercocarpus montanus* (Birch leaf mountain mahogany chaparral) Alliance**	G5 S4	76.100.00
Cercocarpus montanus - Adenostoma fasciculatum		76.100.06
Cercocarpus montanus - Adenostoma fasciculatum - Diplacus aurantiacus		76.100.17
Cercocarpus montanus - Arctostaphylos glauca		76.100.04
Cercocarpus montanus - Ceanothus cuneatus		76.100.16
Cercocarpus montanus - Ceanothus cuneatus - Fraxinus dipetala		76.100.15
Cercocarpus montanus - Ceanothus cuneatus - Quercus john-tuckeri		76.100.09
Cercocarpus montanus - Ceanothus spinosus		76.100.05
Cercocapus montanus - Eriogonum fasciculatum		37.600.01
Cercocapus montanus - Eriogonum fasciculatum - Eriogonum wrightii		37.600.02
Cercocarpus montanus - Fremontodendron californicum		76.100.10
Cercocarpus montanus - Juniperus californica		76.100.11
Cercocarpus montanus - Malosma laurina - Artemisia californica		76.100.12
Cercocarpus montanus - Prunus ilicifolia		76.100.14

Cercocarpus montanus - Prunus ilicifolia - Adenostoma sparsifolium		76.100.13	
Cercocarpus montanus var. glaber		76.100.03	
Cercocarpus montanus var. macrourus		37.610.01	
Cercocarpus montanus var. minutiflorus		37.610.02	
****Heteromeles arbutifolia* (Toyon chaparral) Alliance**	G5 S3	*37.911.00	
**Heteromeles arbutifolia - Artemisia californica*		*37.911.02	
**Heteromeles arbutifolia - Malosma laurina*		*37.911.03	
**Heteromeles arbutifolia - Quercus berberidifolia - Cercocarpus montanus - Fraxinus dipetala*		*37.911.04	
**Heteromeles arbutifolia / serpentine*		*37.911.01	
****Prunus ilicifolia* (Holly leaf cherry chaparral) Alliance**	G3 S3 (some associations are of high priority for inventory)	*37.910.00	
Island Cherry Forest	G2 S2.1		CTT81810CA
Mainland Cherry Forest	G1 S1.1		CTT81820CA
**Prunus ilicifolia ssp. ilicifolia*		*37.910.03	
**Prunus ilicifolia ssp. ilicifolia - Ceanothus cuneatus*		*37.910.05	
**Prunus ilicifolia ssp. ilicifolia - Fraxinus dipetala*		*37.910.06	
**Prunus ilicifolia ssp. ilicifolia - Heteromeles arbutifolia*		*37.910.02	
**Prunus ilicifolia ssp. ilicifolia - Toxicodendron diversilobum / grass*		*37.910.07	
**Prunus ilicifolia ssp. Ilicifolia / Sanicula crassicaulis*		*37.910.01	
**Prunus ilicifolia ssp. lyonii*		*37.910.04	
***Quercus berberidifolia* (Scrub oak chaparral) Alliance**	G4 S4 (some associations are of high priority for inventory)	37.407.00	
Scrub Oak Chaparral	G3 S3.3		CTT37900CA
Quercus berberidifolia		37.407.02	
Quercus berberidifolia - Arctostaphylos glauca		37.406.01	
Quercus berberidifolia - Ceanothus cuneatus		37.406.05	
Quercus berberidifolia - Ceanothus integerrimus		37.406.02	
Quercus berberidifolia - Ceanothus leucodermis		37.407.05	
**Quercus berberidifolia - Ceanothus oliganthus*		*37.406.03	
Quercus berberidifolia - Ceanothus spinosus		37.407.07	
Quercus berberidifolia - Ceanothus tomentosus		37.406.06	
Quercus berberidifolia - Cercocarpus montanus		37.407.06	
Quercus berberidifolia - Fraxinus dipetela - Heteromeles arbutifolia		37.407.09	
Quercus berberidifolia - Heteromeles arbutifolia		37.407.04	
Quercus berberidifolia - southern mixed chaparral		37.407.08	
Quercus berberidifolia / Aesculus californica		37.407.01	
***Quercus berberidifolia - Adenostoma fasciculatum* (Scrub oak - chamise chaparral) Alliance**	G4 S4	37.409.00	
Quercus berberidifolia - Adenostoma fasciculatum		37.409.03	
Quercus berberidifolia - Adenostoma fasciculatum - Arctostaphylos glandulosa		37.407.03	
Quercus berberidifolia - Adenostoma fasciculatum - Ceanothus crassifolius		37.409.01	
Quercus berberidifolia - Adenostoma fasciculatum - Ceanothus greggii		37.409.02	
****Arctostaphylos bakeri* (Stands of Baker manzanita) Special Stands**	G1 S1	*37.317.00	
****Arctostaphylos montana* (Mount Tamalpais manzanita chaparral) Alliance**	G2 S2	*37.307.00	
**Arctostaphylos montana*		*37.307.01	
**Arctostaphylos montana - Adenostoma fasciculatum*		*37.307.02	

Quercus durata **(Leather oak chaparral) Alliance**	G4 S4 (some associations are of high priority for inventory)	37.405.00	
Mixed Serpentine Chaparral	G2 S2.1		CTT37610CA
Leather Oak Chaparral	G3 S3.2		CTT37620CA
Quercus durata		37.405.02	
Quercus durata - Adenostoma fasciculatum - Quercus wislizeni		37.405.03	
**Quercus durata - Adenostoma fasciculatum / Salvia sonomensis*		*37.405.14	
**Quercus durata - Arctostaphylos glandulosa*		*37.405.01	
**Quercus durata - Arctostaphylos glauca - Artemisia californica / Grass*		*37.405.06	
**Quercus durata - Arctostaphylos glauca - Garrya congdonii / Melica torreyana*		*37.405.07	
Quercus durata - Arctostaphylos glauca / Pinus sabiniana		37.405.04	
**Quercus durata - Arctostaphylos pungens / Pinus sabiniana*		*37.405.08	
Quercus durata - Cercocarpus montanus		37.405.10	
**Quercus durata - Frangula californica - Arctostaphylos glauca*		*37.405.12	
Quercus durata - Heteromeles arbutifolia - Umbellularia californica		37.405.11	
**Quercus durata / Allium falcifolium - Streptanthus batrachopus*		*37.405.13	
Quercus durata / Pinus sabiniana		37.405.09	
Arctostaphylos glandulosa **(Eastwood manzanita chaparral) Alliance**	G4 S4 (some associations are of high priority for inventory)	37.302.00	
Arctostaphylos glandulosa		37.302.01	
Arctostaphylos glandulosa - Adenostoma fasciculatum		37.106.13	
Arctostaphylos glandulosa - Adenostoma fasciculatum - Arctostaphylos glauca		37.106.12	
Arctostaphylos glandulosa - Adenostoma fasciculatum - Ceanothus crassifolius		37.106.04	
Arctostaphylos glandulosa - Adenostoma fasciculatum - Ceanothus cuneatus		37.106.07	
Arctostaphylos glandulosa - Adenostoma fasciculatum - Ceanothus leucodermis		37.106.02	
Arctostaphylos glandulosa - Adenostoma fasciculatum - Cercocarpus montanus		37.106.01	
Arctostaphylos glandulosa - Adenostoma fasciculatum - Quercus berberidifolia		37.106.11	
Arctostaphylos glandulosa - Adenostoma fasciculatum - Quercus wislizeni		37.106.10	
**Arctostaphylos glandulosa - Adenostoma fasciculatum / mafic soils*		*37.106.05	
Arctostaphylos glandulosa - Adenostoma fasciculatum -Ceanothus greggii		37.106.03	
**Arctostaphylos glandulosa - Arctostaphylos pringlei*		*37.302.07	
Arctostaphylos glandulosa - Cercocarpus montanus		37.302.03	
Arctostaphylos glandulosa - Quercus wislizeni		37.302.04	
**Arctostaphylos glandulosa ssp. adamsii*		*37.302.02	
Arctostaphylos pringlei ssp. drupacea **(Pink-bract manzanita chaparral) Alliance**	G3 S3	*37.310.00	
**Arctostaphylos pringlei ssp. drupacea*		*37.310.02	
**Arctostaphylos pringlei ssp. drupacea - Arctostaphylos pungens*		*37.310.01	
Ceanothus leucodermis **(Chaparral white thorn chaparral) Alliance**	G4 S4	37.205.00	
Whitethorn Chaparral	G4 S4		CTT37532CA
Ceanothus leucodermis		37.205.01	
Ceanothus leucodermis / Toxicodendron diversilobum		37.205.02	
Ceanothus oliganthus **(Hairy leaf ceanothus chaparral) Alliance**	G3 S3	*37.207.00	
**Ceanothus oliganthus*		*37.207.01	
**Ceanothus oliganthus - Adenostoma fasciculatum*		*37.207.02	
**Ceanothus oliganthus - Adenostoma fasciculatum - Xylococcus bicolor*		*37.207.03	
**Ceanothus oliganthus - Adenostoma sparsifolium*		*37.207.04	

**Ceanothus oliganthus - Arctostaphylos glandulosa*		*37.207.05	
**Ceanothus oliganthus - Eriodictyon crassifolium*		*37.207.06	
**Ceanothus oliganthus - Heteromeles arbutifolia - Rhus ovata*		*37.207.07	
**Ceanothus oliganthus - Quercus berberidifolia*		*37.207.08	
****Quercus chrysolepis* (Canyon live oak chaparral) Alliance**	G3 S3	*37.413.00	
**Quercus chrysolepis*		*37.413.01	
***Quercus wislizeni* (Interior live oak chaparral) Alliance**	G4 S4	37.420.00	
Interior Live Oak Chaparral	G3 S3.3		CTT37A00CA
Quercus wislizen - Cercocarpus montanus - Arctostaphylos glandulosa		37.420.05	
Quercus wislizeni		37.420.01	
Quercus wislizeni - Arctostaphylos glandulosa		37.420.02	
Quercus wislizeni - Ceanothus leucodermis		37.403.01	
Quercus wislizeni - Ceanothus leucodermis - Arctostaphylos glandulosa		37.403.02	
Quercus wislizeni - Ceanothus leucodermis / Pinus coulteri		37.403.03	
Quercus wislizeni - Cercocarpus montanus		37.420.03	
Quercus wislizeni - Cercocarpus montanus - Adenostoma sparsifolium		37.420.04	
Quercus wislizeni - Quercus berberidifolia		37.404.01	
Quercus wislizeni - Quercus berberidifolia - Fraxinus dipetala		37.404.02	
Quercus wislizeni - Quercus chrysolepis shrub		37.402.01	
MG044. California Coastal Scrub			
Riversidian Upland Sage Scrub	G3 S3.1		CTT32710CA
Riversidian Alluvial Fan Sage Scrub	G1 S1.1		CTT32720CA
Riversidian Desert Scrub	G3 S3.1		CTT32730CA
Diegan Coastal Sage Scrub	G3 S3.1		CTT32500CA
Venturan Coastal Sage Scrub	G3 S3.1		CTT32300CA
Diablan Sage Scrub	G3 S3.3		CTT32600CA
***Artemisia californica* (California sagebrush scrub) Alliance**	G5 S5	32.010.00	
Artemisia californica		32.010.01	
Artemisia californica - Malosma laurina		45.455.02	
Artemisia californica - Baccharis pilularis / Leymus condensatus		32.010.15	
Artemisia californica - Ceanothus ferrisiae		32.010.08	
Artemisia californica - Diplacus aurantiacus		32.010.11	
Artemisia californica - Eriogonum cinereum		32.010.07	
Artemisia californica - Keckiella cordifolia		32.010.03	
Artemisia californica - Lepidospartum squamatum		32.010.09	
Artemisia californica - Lotus scoparius		32.010.02	
Artemisia californica - Malosma laurina		32.010.10	
Artemisia californica - Salvia leucophylla		32.010.04	
Artemisia californica / Amsinckia menziesii		32.010.12	
Artemisia californica / Eschscholzia californica		32.010.13	
Artemisia californica / Leymus condensatus		32.010.14	
***Artemisia californica - Eriogonum fasciculatum* (California sagebrush - California buckwheat scrub) Alliance**	G4 S4	32.110.00	
Artemisia californica - Eriogonum fasciculatum		32.110.05	
Artemisia californica - Eriogonum fasciculatum - Ephedra californica		32.110.07	
Artemisia californica - Eriogonum fasciculatum - Malosma laurina		32.110.06	

Artemisia californica - Eriogonum fasciculatum - Rhus ovata		32.110.01
Artemisia californica - Eriogonum fasciculatum - Salvia apiana		32.110.02
Artemisia californica - Eriogonum fasciculatum - Salvia leucophylla		32.110.03
Artemisia californica - Eriogonum fasciculatum - Salvia mellifera		32.110.04
***Artemisia californica - Salvia mellifera* (California sagebrush - black sage scrub) Alliance**	G4 S4	32.120.00
Artemisia californica - Salvia mellifera		32.120.01
Artemisia californica - Salvia mellifera - Baccharis sarothroides		32.120.03
****Diplacus aurantiacus* (Bush monkeyflower scrub) Alliance**	G3 S3?	*32.082.00
**Diplacus aurantiacus*		*32.082.01
****Encelia californica* (California brittle bush scrub) Alliance**	G4 S3	*32.050.00
**Encelia californica*		*32.050.02
**Encelia californica - Artemisia californica*		*32.050.01
**Encelia californica - Artemisia californica - Salvia mellifera - Baccharis pilularis*		*32.050.03
**Encelia californica - Eriogonum cinereum*		*32.050.04
**Encelia californica - Malosma laurina - Salvia mellifera*		*32.050.05
**Encelia californica - Rhus integrifolia*		*32.050.06
****Eriogonum cinereum* (Ashy buckwheat scrub) Alliance**	G3 S3	*32.035.00
**Eriogonum cinereum*		*32.035.01
****Eriogonum heermannii* (Heermann's buckwheat patches) Provisional Alliance**	G2 S2?	*32.035.00
***Eriogonum fasciculatum* (California buckwheat scrub) Alliance**	G5 S5 (some associations are of high priority for inventory)	32.040.00
Eriogonum fasciculatum		32.040.02
**Eriogonum fasciculatum - (Lepidospartum squamatum) alluvial fan*		*32.070.01
Eriogonum fasciculatum - Ambrosia dumosa		32.040.05
**Eriogonum fasciculatum - Artemisia tridentata*		*32.040.03
Eriogonum fasciculatum - Bebbia juncea		32.040.08
Eriogonum fasciculatum - Cylindropuntia californica		32.040.10
Eriogonum fasciculatum - Encelia farinosa		32.040.18
Eriogonum fasciculatum - Gutierrezia sarothrae		32.040.09
Eriogonum fasciculatum - Lotus scoparius		32.040.19
Eriogonum fasciculatum - Rhus ovata		32.040.11
Eriogonum fasciculatum - Salazaria mexicana		32.040.06
Eriogonum fasciculatum - Salvia mellifera		32.040.17
Eriogonum fasciculatum - Salvia mellifera - Malosma laurina		32.040.07
Eriogonum fasciculatum - Scrophularia californica - Phacelia ramosissima		32.040.01
Eriogonum fasciculatum - Simmondsia chinensis - Cylindropuntia californica		32.040.12
Eriogonum fasciculatum var. foliolosum - Hesperoyucca whipplei		32.040.16
Eriogonum fasciculatum var. foliolosum - Juniperus californica		32.040.13
Eriogonum fasciculatum var. polifolium / Eriastrum pluriflorum		32.040.15
***Eriogonum fasciculatum - Salvia apiana* (California buckwheat - white sage scrub) Alliance**	G4 S4 (some associations are of high priority for inventory)	32.100.00
**Eriogonum fasciculatum - Salvia apiana*		*32.100.01
****Deinandra clementina - Eriogonum giganteum* (Island buckwheat - Island tar plant scrub) Provisional Alliance**	G3? S3?	*43.110.00
****Eriogonum wrightii* (Wright's buckwheat patches) Alliance**	G3 S3	*32.041.00
**Eriogonum wrightii - Eriophyllum confertiflorum / Monardella antonina ssp. benitensis*		*32.041.01
**Eriogonum wrightii - Juniperus californica*		*32.041.02

**Eriogonum wrightii - Lessingia filaginifolia*		*32.041.03	
**Keckellia antirhinoides - Eriogonum fasciculatum*		*32.065.03	
**Keckellia antirrhinoides*		*32.065.01	
**Keckellia antirrhinoides - Artemisia californica*		*32.065.02	
****Keckiella antirrhinoides* (Bush penstemon scrub) Alliance**	G3 S3	*32.065.00	
**Keckiella antirrhinoides - Mixed Chaparral*		*32.065.04	
****Salvia apiana* (White sage scrub) Alliance**	G4 S3	*32.030.00	
**Salvia apiana - Artemisia californica*		*32.030.01	
**Salvia apiana - Encelia farinosa*		*32.030.02	
**Salvia apiana - Hesperoyucca whipplei*		*32.030.03	
***Salvia leucophylla* (Purple sage scrub) Alliance**	G4 S4	32.090.00	
Salvia leucophylla		32.090.03	
Salvia leucophylla - Artemisia californica		32.090.01	
Salvia leucophylla - Artemisia californica - Eriogonum cinereum / Nassella spp.		32.090.04	
Salvia leucophylla - Eriogonum cinereum / annual herb		32.090.05	
Salvia leucophylla - Malosma laurina		32.090.02	
***Salvia mellifera* (Black sage scrub) Alliance**	G4 S4 (some associations are of high priority for inventory)	32.020.00	
Salvia mellifera		32.020.03	
Salvia mellifera - Encelia californica		32.020.04	
**Salvia mellifera - Eriogonum cinereum*		*32.020.08	
Salvia mellifera - Eriogonum fasciculatum / Bromus rubens		32.020.06	
Salvia mellifera - Eriogonum fasciculatum var. foliolosum - Eriodictyon tomentosum		32.020.07	
Salvia mellifera - Lotus scoparius		32.020.09	
Salvia mellifera - Malosma laurina		32.020.01	
**Salvia mellifera - Opuntia littoralis*		*32.020.05	
Salvia mellifera - Rhus ovata		32.020.11	
***Dendromecon rigida* (Bush poppy scrub) Alliance**	G4 S4	37.750.00	
Dendromecon rigida		37.750.01	
Upper Sonoran Subshrub Scrub	G4 S3.2		CTT39000CA
****Ericameria linearifolia* (Narrowleaf goldenbush scrub) Provisional Alliance**	G3 S3?	*38.125.00	
****Ericameria palmeri* (Palmer's goldenbush scrub) Provisional Alliance**	G3 S3?	*38.130.00	
****Gutierrezia californica* (California match weed patches) Provisional Alliance**	G3? S3?	*32.042.00	
**Gutierrezia californica / Annual - perennial grass - herb*		*32.042.01	
****Hazardia squarrosa* (Sawtooth golden bush scrub) Alliance**	G3 S3	*32.055.00	
**Hazardia squarrosa - Artemisia californica*		*32.055.02	
**Hazardia squarrosa / Nassella pulchra - Deinandra fasciculata*		*32.055.01	
Isocoma menziesii (Menzies's golden bush scrub) Alliance	G4? S4? (some associations are of high priority for inventory)	32.044.00	
Isocoma menziesii - Lupinus albifrons		32.044.03	
**Isocoma menziesii / Astragalus miguelensis - Atriplex californica - Lasthenia californica*		*32.044.01	
Isocoma menziesii / Distichlis spicata - Paraphalis incurva		32.044.02	
***Lotus scoparius* (Deer weed scrub) Alliance**	G5 S5	52.240.00	
Lotus scoparius		52.240.01	

Lupinus albifrons **(Silver bush lupine scrub) Alliance**	G4 S4	32.081.00	
Lupinus albifrons		32.081.01	
Lupinus albifrons - Senecio flaccidus var. douglasii		32.081.03	
Lupinus albifrons coastal		32.081.02	
Malacothamnus fasciculatus **(Bush mallow scrub) Alliance**	G4 S4	45.450.00	
Malacothamnus fasciculatus		45.450.01	
Malacothamnus fasciculatus - Ceanothus megacarpus		45.450.02	
Malacothamnus fasciculatus - Ceanothus spinosus		45.450.03	
Malacothamnus fasciculatus - Malosma laurina		45.450.04	
Malacothamnus fasciculatus - Salvia leucophylla		45.450.05	
Malacothamnus fasciculatus - Salvia mellifera		45.450.06	
Broom (Cytisus scoparius and Others) **(Broom patches) Semi-natural Stands**		32.180.00	
Genista monspessulana		32.180.01	
**Spartium junceum*		*32.180.02	

2.B.2. Mediterranean Grassland and Forb Meadow

2.B.2.a. California Grassland and Meadow

MG045. California Annual and Perennial Grassland

Native Grassland	G3 S3.1		CTT42100CA
Serpentine Bunchgrass	G2 S2.2		CTT42130CA
Ambrosia psilostachya **(Western ragweed meadows) Provisional Alliance**	G4 S4?	33.065.00	
Amsinckia (menziesii, tessellata) **(Fiddleneck fields) Alliance**	G4 S4	42.110.00	
Amsinckia menziesii - Erodium spp.		42.110.01	
Amsinckia menziesii - Vulpia bromoides - Plagiobothrys canescens		42.110.02	
Artemisia dracunculus **(Wild tarragon patches) Alliance**	G4 S4	35.160.00	
Artemisia dracunculus		35.160.01	
Artemisia dracunculus - Pseudognaphalium canescens		35.160.02	
Eschscholzia (californica) **(California poppy fields) Alliance**	G4 S4	43.200.00	
Eschoscholzia californica		43.200.01	
Wildflower Field	G2 S2.2		CTT42300CA
Lasthenia californica - Plantago erecta - Vulpia microstachys **(California goldfields - Dwarf plantain - Six-weeks fescue flower fields) Alliance**	G4 S4 (some associations are of high priority for inventory)	44.108.00	
Lasthenia californica		44.109.03	
**Lasthenia californica - Atriplex coronata var. notatior*		*44.109.01	
**Lasthenia californica - Lupinus bicolor - Layia platyglossa - Bromus spp.*		*44.109.04	
**Lasthenia californica - Plantago erecta - Hesperevax sparsiflora*		*44.108.01	
**Lasthenia ferrisiae - Lasthenia conjugens*		*52.500.05	
Plantago erecta - Lolium perenne lichen-rocky		44.108.02	
**Vulpia microstachys - Elymus elymoides - Achnatherum lemmonii*		*44.108.08	
**Vulpia microstachys - Lasthenia californica - Agrostis elliottiana*		*44.109.05	
Vulpia microstachys - Mimulus guttatus - Pentagramma triangularis		44.108.05	
**Vulpia microstachys - Navarretia tagetina*		*44.108.09	
Vulpia microstachys - Parvisedum pumilum - Lasthenia californica		44.109.06	
**Vulpia microstachys - Plantago erecta*		*44.108.04	
Vulpia microstachys - Plantago erecta - Calycadenia (truncata, multiglandulosa)		44.108.03	
**Vulpia microstachys - Selaginella hansenii*		*44.108.10	

**Vulpia microstachys - Selaginella hansenii - Lupinus nanus*		*44.108.11	
**Vulpia microstachys - Selaginella hansenii - Lupinus spectabilis*		*44.108.07	
Lotus purshianus **(Spanish clover fields) Provisional Alliance**	G4? S4?	52.230.00	
Plagiobothrys nothofulvus **(Popcorn flower fields) Alliance**	G4 S4	43.300.00	
Plagiobothrys nothofulvus - Daucus pusillus - Bromus hordeaceus		43.300.01	
****Leymus condensatus*** **(Giant wild rye grassland) Alliance**	G3 S3	*41.265.00	
**Leymus condensatus*		*41.265.01	
****Melica torreyana*** **(Torrey's melic grass patches) Provisional Alliance**	G2 S2?	*41.275.00	
**Melica torreyana*		*41.275.01	
****Nassella cernua*** **(Nodding needle grass grassland) Provisional Alliance**	G4 S3?	*41.140.00	
****Nassella lepida*** **(Foothill needle grass grassland) Provisional Alliance**	G3? S3?	*41.110.00	
****Nassella pulchra*** **(Purple needle grass grassland) Alliance**	G4 S3?	*41.150.00	
Valley Needlegrass Grassland	G3 S3.1		CTT42110CA
**Nassella pulchra*		*41.150.04	
**Nassella pulchra - Avena fatua*		*41.150.02	
**Nassella pulchra - Avena spp. - Bromus spp.*		*41.150.05	
**Nassella pulchra - Distichlis spicata - Bromus spp.*		*41.150.10	
**Nassella pulchra - Erodium spp. - Avena barbata*		*41.150.06	
**Nassella pulchra - Leontodon taraxicoides*		*41.150.11	
**Nassella pulchra - Lolium perenne (-Trifolium spp.)*		*41.150.01	
**Nassella pulchra - Lolium perenne - Astragalus gambelianus - Lepidium nitidum*		*41.150.12	
**Nassella pulchra - Lolium perenne - Calystegia collina*		*41.150.13	
**Nassella pulchra - Melica californica - annual grass*		*41.150.09	
**Nassella pulchra - Sanicula bipinnatifida*		*41.150.03	
**Nassella pulchra / Baccharis pilularis*		*41.150.14	
**Nassella pulchra / Hazardia squarrosa*		*41.150.07	
Aegilops triuncialis **(Barbed goatgrass patches) Provisional Semi-natural Stands**		42.003.00	
Aegilops triuncialis - Hemizonia congesta		42.003.01	
Avena (barbata, fatua) **(Wild oats grasslands) Semi-natural Stands**		44.150.00	
Avena barbata		44.150.01	
Avena barbata - Avena fatua		44.150.02	
Avena barbata - Bromus hordeaceus		44.150.03	
Avena fatua		44.150.04	
Brassica nigra and other mustards **(Upland mustards) Semi-natural Stands**		42.011.00	
Brassica nigra		42.011.01	
Brassica nigra - Bromus diandrus		42.011.02	
Brassicas tournefortii / Ambrosia dumosa		42.011.03	
Raphanus sativus		42.011.04	
Non Native Grassland	G4 S4		CTT42200CA
Bromus (diandrus, hordeaceus) - Brachypodium distachyon **(Annual brome grasslands) Semi-natural Stands**		42.026.00	
Brachypodium distachyon		42.040.03	
Bromus diandrus		42.026.21	
Bromus diandrus - Avena spp.		42.026.22	
Bromus diandrus - Mixed herbs		42.026.11	
Bromus hordeaceus - Aira caryophyllea		42.026.20	
Bromus hordeaceus - Amsinckia menziesii - Hordeum murinum		42.026.23	

Bromus hordeaceus - Bromus tectorum	42.026.08
Bromus hordeaceus - Dichelostemma multiflorum	42.026.10
Bromus hordeaceus - Erodium botrys	42.026.09
Bromus hordeaceus - Erodium botrys - Plagiobothrys fulvus	42.026.13
Bromus hordeaceus - Holocarpha virgata - Lolium perenne	42.026.15
Bromus hordeaceus - Holocarpha virgata - Taeniatherum caput - medusa	42.026.14
Bromus hordeaceus - Leontodon taraxacoides	42.026.17
Bromus hordeaceus - Limnanthes douglasii	42.026.16
Bromus hordeaceus - Lupinus nanus - Trifolium spp.	42.026.18
Bromus hordeaceus - Taeniatherum caput - medusae	42.026.07
Bromus hordeaceus - Vulpia hirsuta	42.026.02
Bromus hordeaceus (-Vicia villosa - Lolium multiflorum) - Trifolium hirtum	42.026.19
Bromus rubens	42.024.01
Bromus rubens - mixed herbs	42.024.02
***Bromus rubens - Schismus (arabicus, barbatus)* (Red brome or Mediterranean grass grasslands) Semi-natural Stands**	42.024.00
Schimus playa	42.024.03
***Centaurea (solstitialis, meletensis)* (Yellow star-thistle fields) Semi-natural Stands**	42.042.00
Centaurea melitensis - Brassica nigra	42.042.01
Centaurea solstitialis	42.042.02
Centaurea spp. - Brachypodium distachyon.	42.040.04
***Centaurea (virgata)* (Knapweed and purple-flowered star-thistle fields) Provisional Semi-natural Stands**	42.043.00
***Conium maculatum - Foeniculum vulgare* (Poison hemlock or fennel patches) Semi-natural Stands**	45.556.00
Conium maculatum	45.556.01
Foeniculum vulgare	45.556.02
***Cortaderia (jubata, selloana)* (Pampas grass patches) Semi-natural Stands**	42.070.00
***Cynosurus echinatus* (Annual dogtail grasslands) Semi-natural Stands**	42.044.00
Cynosurus echinatus - Arrhenatherum elatius / Dichelostemma capitatum	42.044.07
Cynosurus echinatus - Bromus hordeaceus - Avena fatua	42.044.01
Cynosurus echinatus - Bromus hordeaceus - Madia elegans	42.044.02
Cynosurus echinatus - Bromus hordeaceus - Taeniatherum caput-medusae	42.044.04
Cynosurus echinatus - Bromus hordeaceus - Taraxacum officinale	42.044.03
Cynosurus echinatus - Lagophylla ramosissima	42.044.05
***Lolium perenne* (Perennial rye grass fields) Semi-natural Stands**	41.321.00
Lolium perenne	41.321.01
Lolium perenne - Bromus hordeaceus	41.321.02
Lolium perenne - Centaurium muehlenbergii	41.321.03
Lolium perenne - Convolvulus arvensis	41.321.08
Lolium perenne - Festuca arundinacea	41.321.09
Lolium perenne - Hemizonia congesta	41.321.04
Lolium perenne - Hordeum marinum - Ranunculus californicus	41.321.05
Lolium perenne - Lepidium latifolium	41.321.10
Lolium perenne - Leymus triticoides	41.321.06
Lolium perenne - Lotus corniculatus	41.321.11
Zigadenus fremontii (- Lolium perenne)	41.321.12
***Pennisetum setaceum* (Fountain grass swards) Semi-natural Stands**	42.085.00
Pennisetum setaceum - Coreopsis gigantea - Hesperoyucca whipplei - Malosma laurina	42.085.01

2.C. Temperate and Boreal Shrubland and Grassland

2.C.1. Temperate Grassland, Meadow, and Shrubland

2.C.1.a. Vancouverian and Rocky Mountain Grassland and Shrubland

MG047. Western Cordilleran montane-boreal wet meadow

****Carex douglasii* (Douglas' sedge meadows) Provisional Alliance**	G4? S2?	*45.169.00
***Iris missouriensis* (Western blue flag patches) Provisional Alliance**	G5 S4	45.401.00
***Muhlenbergia filiformis* (Pullup muhly meadows) Provisional Alliance**	G4? S4?	41.276.00
****Phyllodoce empetriformis* (Mountain heather mats) Provisional Alliance**	G5 S2?	*45.404.00
***Veratrum californicum* (White corn lily patches) Alliance**	G5 S4	45.423.00
Veratrum californicum		45.423.02
Veratrum californicum - Bistorta bistortoides		45.423.03
Veratrum californicum - Juncus nevadensis		45.423.04
Veratrum californicum - Senecio triangularis		45.423.01
****Carex heteroneura* (Different-nerve sedge patches) Provisional Alliance**	G3? S3?	*45.115.00
**Carex heteroneura - Achillea millefolium*		*45.115.01
****Carex integra* (Small-fruited sedge meadows) Provisional Alliance**	G4? S2?	*45.175.00
****Carex jonesii* (Jones's sedge turf) Alliance**	G4 S3	*45.162.00
**Carex jonesii*		*45.162.02
**Carex jonesii - Bistorta bistortoides*		*45.162.01
**Carex jonesii / Sphagnum subsecundum*		*45.162.03
****Carex lasiocarpa* (Slender sedge meadows) Provisional Alliance**	G5? S3?	*45.166.00
**Carex lasiocarpa*		*45.166.01
****Carex luzulina* (Woodland sedge fens) Provisional Alliance**	G3 S2?	*45.179.00
****Carex microptera* (Small-winged sedge meadows) Provisional Alliance**	G4 S2?	*45.181.00
***Carex nebrascensis* (Nebraska sedge meadows) Alliance**	G5 S4	45.130.00
Carex nebrascensis		45.130.01
Carex nebrascensis - Ptilagrostis kingii		45.130.02
****Carex simulata* (Short-beaked sedge meadows) Alliance**	G4 S3	*45.190.00
**Carex simulata*		*45.190.01
**Carex simulata - Carex utriculata*		*45.190.04
**Carex simulata - Carex vesicaria*		*45.190.05
**Carex simulata / Aulacomnium palustre*		*45.190.02
**Carex simulata / Philonotis fontana*		*45.190.03
****Carex straminiformis* (Mount Shasta sedge meadows) Provisional Alliance**	G3? S3?	*45.185.00
****Carex subnigricans* (Dark alpine sedge turf) Alliance**	G4 S3	*45.186.00
**Carex subnigricans - Antennaria media*		*45.186.01
**Carex subnigricans - Deschampsia caespitosa*		*45.186.05
**Carex subnigricans - Dodecatheon alpinum*		*45.186.03
**Carex subnigricans - Oreostemma alpigenum*		*45.186.02
**Carex subnigricans - Pedicularis attollens*		*45.186.04
Carex vernacula - Antennaria media		*45.110.22
***Deschampsia caespitosa* (Tufted hair grass meadows) Alliance**	G5 S4? (some associations are of high priority for inventory)	41.220.00
**Deschampsia caespitosa*		*41.220.08

**Deschampsia caespitosa - Anthoxanthum odoratum*		*41.220.05	
Deschampsia caespitosa - Bistorta bistortoides		41.220.12	
**Deschampsia caespitosa - Cardamine breweri*		*41.220.02	
Deschampsia caespitosa - Carex nebrascensis		41.220.01	
Deschampsia caespitosa - Danthonia californica		41.220.09	
**Deschampsia caespitosa - Horkelia marinensis*		*41.220.13	
**Deschampsia caespitosa - Lilaeopsis masonii*		*41.220.14	
Deschampsia caespitosa - Perideridia parishii		41.220.11	
Deschampsia caespitosa - Senecio scorzonella		41.220.03	
Deschampsia caespitosa - Senecio scorzonella - Achillea millefolium		41.220.04	
Deschampsia caespitosa - Solidago multiradiata		41.220.07	
**Deschampsia caespitosa - Trifolium longipes*		*41.220.10	
**Deschampsia caespitosa var. holciformis*		*41.220.15	
****Juncus nevadensis* (Sierra rush marshes) Alliance**	G3? S3?	*45.567.00	
**Juncus nevadensis*		*45.567.01	
**Juncus nevadensis - Carex leporinella*		*45.567.02	
**Juncus nevadensis - Eleocharis quinqueflora*		*45.567.03	
***Solidago canadensis* (Canada goldenrod patches) Provisional Alliance**	G4? S4?	45.420.00	
****Trifolium longipes* (Long-stalk clover meadows) Provisional Alliance**	G3? S3?	*45.426.00	
MG048. Western North American Temperate Grassland and Meadow			
****Aristida purpurea* (Purple three-awn meadows) Provisional Alliance**	G4 S3?	*45.425.00	
****Elymus glaucus* (Blue wild rye meadows) Alliance**	G3? S3?	*41.640.00	
**Elymus glaucus*		*41.640.01	
**Elymus glaucus - Carex feta*		*41.640.03	
**Elymus glaucus - Carex pellita*		*41.640.02	
**Elymus glaucus - Heracleum lanatum*		*41.640.04	
***Elymus multisetus* (Big squirreltail patches) Provisional Alliance**	G4 S4?	41.650.00	
Bald Hills Prairie	G2 S2.1		CTT41200CA
****Festuca idahoensis* (Idaho fescue grassland) Alliance**	G4 S3?	*41.250.00	
**Festuca idahoensis - Achillea millefolium*		*41.250.03	
**Festuca idahoensis - Bromus carinatus*		*41.250.01	
**Festuca idahoensis - Festuca rubra*		*41.250.02	
****Leymus cinereus* (Ashy ryegrass meadows) Alliance**	G4 S2	*41.020.00	
****Poa secunda* (Curly blue grass grassland) Alliance**	G4 S3?	*41.180.00	
Pine Bluegrass Grassland	G3 S2.2		CTT42150CA
**Poa secunda - Danthonia unispicata*		*41.180.04	
**Poa secunda ssp. juncifolia*		*41.180.03	
**Poa secunda ssp. secunda*		*41.180.02	
***Agrostis (gigantea, stolonifera) - Festuca arundinacea* (Bent grass - tall fescue meadows) Semi-natural Stands**		45.106.00	
Agrostis gigantea		45.106.01	
Agrostis stolonifera		45.106.02	
Agrostis stolonifera - Festuca arundinacea		45.106.03	
Holcus lanatus		42.050.08	
Holcus lanatus - Anthoxanthum odoratum		42.050.09	
***Holcus lanatus - Anthoxanthum odoratum* (Common velvet grass - sweet vernal grass meadows) Semi-natural Stands**		42.050.00	

Phalaris aquatica **(Harding grass swards) Semi-natural Stands**		42.051.00	
Phalaris aquatica		42.051.02	
Phalaris aquatica - Avena barbata		42.051.03	
Phalaris aquatica - Bromus hordeaceus - Centaurea solstitialis		42.051.01	
Poa pratensis **(Kentucky blue grass turf) Semi-natural Stands**		42.060.00	
Poa pratensis		42.060.05	
Poa pratensis - Carex (nebrascensis, pellita)		42.060.01	
Poa pratensis - Juncus patens - Luzula comosa		42.060.04	
Poa pratensis - Potentilla gracilis		42.060.02	
Poa pratensis ssp. pratensis		42.060.07	
Poa pratensis ssp.agassizensis		42.060.06	
Bromus tectorum **(Cheatgrass grassland) Semi-natural Stands**		42.020.00	
Bromus tectorum		42.020.01	
Bromus tectorum - Bromus diandrus		42.020.02	
MG049. Western Cordilleran Montane Shrubland and Grassland			
****Calamagrostis canadensis*** **(Bluejoint reed grass meadows) Alliance**	G5 S3	*41.224.00	
**Calamagrostis canadensis*		*41.224.01	
**Calamagrostis canadensis - Carex utriculata*		*41.224.02	
**Calamagrostis canadensis - Dodecatheon redolens*		*41.224.03	
**Calamagrostis canadensis - Scirpus microcarpus*		*41.224.04	
Dry Montane Meadow	G4 S3.2		CTT45120CA
Cistanthe (umbellata) - Gayophytum (diffusum) **(Pussypaws - groundsmoke openings) Alliance**	G4 S4	45.311.00	
Astragalus bolanderi - (Cistanthe umbellatum)		45.311.01	
Cistanthe umbellatum - Achnatherum occidentalis		45.311.02	
Cistanthe - Castilleja arachnoidea		45.311.03	
Polygonum douglasii - Gayophytum dffusum		45.311.04	
****Danthonia intermedia*** **(Wild mountain oat grass meadows) Alliance**	G4? S3?	*41.051.00	
**Danthonia intermedia - Antennaria rosea*		*41.051.01	
**Danthonia intermedia - Ptilagrostis kingii*		*41.051.02	
****Hordeum brachyantherum*** **(Meadow barley patches) Alliance**	G4 S3?	*42.052.00	
**Hordeum brachyantherum*		*42.052.01	
**Hordeum brachyantherum - Poa pratensis*		*42.052.04	
**Hordeum brachyantherum - Polypogon monspeliensis*		*42.052.02	
**Hordeum brachyantherum - Senecio triangularis*		*42.052.03	
Muhlenbergia richardsonis **(Mat muhly meadows) Provisional Alliance**	G4? S4?	41.277.00	
****Penstemon heterodoxus*** **(Heretic penstemon patches) Provisional Alliance**	G4? S3?	*45.414.00	
**Antennaria alpina - Penstemon heterodoxus*		*91.120.02	
Ptilagrostis kingii **(King's needle grass meadows) Alliance**	G4 S4	41.225.00	
Ptilagrostis kingii		41.225.01	
Ptilagrostis kingii - Oreostemma alpigenum		41.225.02	
Ptilagrostis kingii - Senecio scorzonella		91.120.25	
****Holodiscus discolor*** **(Ocean spray brush) Alliance**	G4 S3	*39.100.00	
**Holodiscus discolor - Arctostaphylos patula*		*39.100.03	
**Holodiscus discolor - Keckiella corymbosa*		*39.100.04	
**Holodiscus discolor - Sambucus racemosa*		*39.100.06	

**Holodiscus discolor / Achnatherum occidentalis - Eriogonum nudum*		*39.100.02	
**Holodiscus discolor / Mimulus suksdorfii*		*39.100.01	
**Holodiscus discolor / Sedum obsusatum ssp. boreale - Cryptogramma acrostichoides*		*39.100.05	
Juncus parryi **(Parry's rush outcrops) Alliance**	G4 S4	45.566.00	
Juncus parryi - Eriogonum incanum		45.566.01	
Penstemon newberryi **(Mountain pride patches) Alliance**	G4 S4	45.415.00	
Penstemon newberryi - Streptanthus tortuosus - Sedum obtusatum ssp. boreale - Muhlenbergia montana		45.415.03	
Penstemon newberryi - Streptanthus tortuosus / Selaginella watsonii		45.415.04	
Penstemon newberryi - Streptanthus tortuosus / Spiraea densiflora		45.415.02	
Phyllodoce breweri **(Mountain heather mats) Alliance**	G4 S4?	45.402.00	
Phyllodoce breweri - Cassiope mertensiana - Juncus parryi		45.402.02	
Phyllodoce breweri - Juncus parryi		45.402.01	
Phyllodoce breweri - Vaccinium caespitosum		45.405.01	
Ceanothus integerrimus **(Deer brush chaparral) Alliance**	G4 S4 (some associations are of high priority for inventory)	37.206.00	
Deer Brush Chaparral	G4 S4		CTT37531CA
Ceanothus integerrimus		37.206.01	
Ceanothus integerrimus - Arctostaphylos viscida		37.206.04	
**Ceanothus integerrimus - Quercus garryana var. fruticosa*		*37.206.05	
Ceanothus integerrimus / Lithocarpus densiflorus - Arbutus menziesii		37.206.03	
Ceanothus integerrimus / Quercus chrysolepis / Elymus glaucus		37.206.02	
Prunus emarginata **(Bitter cherry thickets) Provisional Alliance**	G4 S4	37.900.00	
Quercus garryana **(Brewer oak scrub) Alliance**	G4 S4	37.411.00	
Shin Oak Chaparral	G3 S3.3		CTT37541CA
Quercus garryana shrub		37.411.03	
Quercus garryana / Festuca californica		37.411.04	
Quercus garryana - Arctostaphylos patula		37.411.05	
Quercus garryana - Cercocarpus montanus		37.411.06	
****Artemisia cana*** **(Silver sagebrush scrub) Alliance**	G5 S3	*35.150.00	
**Artemisia cana - Muhlenbergia richardsonis*		*35.150.06	
**Artemisia cana / cold*		*35.150.01	
**Artemisia cana / dry graminoid*		*35.150.02	
**Artemisia cana / Iris missouriensis - Juncus arcticus var. balticus*		*35.150.05	
**Artemisia cana / Juncus arcticus var. balticus*		*35.150.04	
**Artemisia cana / mesic (Poa secunda - Poa cusickii)*		*35.150.07	
**Artemisia cana / warm*		*35.150.03	
****Rhus trilobata*** **(Basket bush thickets) Provisional Alliance**	G4 S3?	*37.802.00	
****Prunus virginiana*** **(Choke cherry thickets) Provisional Alliance**	G4 S2?	*37.905.00	
****Ribes quercetorum*** **(Oak gooseberry thickets) Provisional Alliance**	G2 S2?	*37.960.00	
MG050. Vancouverian Lowland Grassland and Shrubland			
Coastal Terrace Prairie	G2 S2.1		CTT41100CA
****Calamagrostis nutkaensis*** **(Pacific reed grass meadows) Alliance**	G4 S2	*41.190.00	
**Calamagrostis nutkaensis*		*41.190.03	
**Calamagrostis nutkaensis - Baccharis pilularis*		*41.190.01	
**Calamagrostis nutkaensis - Carex obnupta. - Juncus spp.*		*41.190.02	

***Danthonia californica* (California oat grass prairie) Provisional Alliance**	G4 S3	*41.050.00	
**Danthonia californica*		*41.050.05	
**Danthonia californiaca - Aira caryophyllea*		*41.050.04	
**Danthonia californica - Arrhenatherum elatius*		*41.050.01	
**Danthonia californica - Elymus elymoides*		*41.050.02	
**Danthonia californica - Muhlenbergia filiformis*		*41.050.03	
***Festuca rubra* (Red fescue grassland) Alliance**	G4 S3?	*41.255.00	
**Festuca rubra*		*41.255.01	
**Corylus cornuta / Polystichum munitum*		*37.950.01	
***Corylus cornuta var. californica* (Hazelnut scrub) Alliance**	G3 S2?	*37.950.00	
***Rubus (parviflorus, spectabilis, ursinus)* (Coastal brambles) Alliance**	G4 S3	*63.901.00	
**Gaultheria shallon - Rubus spectabiis - Rubus parviflorus*		*63.901.01	
**Rubus parviflorus*		*63.901.03	
**Rubus parviflorus - Rubus spectabilis - Rubus ursinus*		*63.901.02	
**Rubus spectabilis*		*63.901.04	
**Rubus ursinus*		*63.901.05	
***Toxicodendron diversilobum* (Poison oak scrub) Alliance**	G4 S4	37.940.00	
Poison Oak Chaparral	G3 S3.3		CTT37F00CA
Toxicodendron diversilobum - Artemisia californica / Leymus condensatus		37.940.02	
Toxicodendron diversilobum - Baccharis pilularis - Rubus parviflorus		37.940.01	
Toxicodendron diversilobum - Diplacus aurantiacus		37.940.03	
Toxicodendron diversilobum - Philadelphus lewisii		37.940.04	
Toxicodendron diversilobum / Bromus hordeaceus - Micropus californicus		37.940.05	
Toxicodendron diversilobum / Bromus hordeaceus - Vicia villosa - Madia gracilis		37.940.06	
Toxicodendron diversilobum / herbaceous		37.940.08	
Toxicodendron diversilobum / Pteridium aquilinum		37.940.07	
***Rubus armeniacus* (Himalayan black berry brambles) Semi-natural Stands**		63.906.00	
Rubus armeniacus		63.906.01	
Rubus armeniacus - Rubus ursinus		63.906.02	

2.C.1.x. Western North America Interior Sclerophyllous Shrubland

MG051. Warm Interior Chaparral

Semi Desert Chaparral	G3 S3.2		CTT37400CA
***Adenostoma sparsifolium* (Redshank chaparral) Alliance**	G4 S4 (some associations are of high priority for inventory)	37.501.00	
Red Shank Chaparral	G3 S3.2		CTT37300CA
**Adenostoma sparsifolium*		*37.501.01	
Adenostoma sparsifolium - Adenostoma fasciculatum - Arctostaphylos glauca		37.503.05	
**Adenostoma sparsifolium - Adenostoma fasciculatum - Arctostaphylos pungens*		*37.503.03	
Adenostoma sparsifolium - Adenostoma fasciculatum - Ceanothus crassifolius		37.503.04	
**Adenostoma sparsifolium - Adenostoma fasciculatum - Ceanothus greggii*		*37.503.02	
**Adenostoma sparsifolium - Adenostoma fasciculatum - Cercocarpus montanus*		*37.503.01	
Adenostoma sparsifolium - Adenostoma fasciculatum - Opuntia parryi		37.503.06	
Adenostoma sparsifolium - Artemisia tridentata		37.501.02	
Adenostoma sparsifolium - Ceanothus crassifolius		37.501.03	
Adenostoma sparsifolium - Ceanothus cuneatus		37.501.04	

Adenostoma sparsifolium - Cercocarpus montanus		37.502.01	
Adenostoma sparsifolium - Ericameria linearifolia - Eriogonum fasciculatum - Opuntia basilaris		37.501.06	
Adenostoma sparsifolium - Eriogonum fasciculatum - Lotus scoparius		37.501.07	
***Quercus cornelius-mulleri* (Muller oak chaparral) Alliance**	G4 S4	37.415.00	
Quercus cornelius-mulleri - Adenostoma sparsifolium - Ceanothus greggii		37.415.04	
Quercus cornelius-mulleri - Adenostoma sparsifolium - Cercocapus montanus		37.415.05	
Quercus cornelius-mulleri - Cercocapus montanus		37.415.03	
Quercus cornelius-mulleri - Eriogonum fasciculatum - Ericameria linearifolia		37.415.02	
Quercus cornelius-mulleri - Rhus ovata		37.415.01	
Quercus cornelius-mulleri -Coleogyne ramosissima		37.415.06	
***Quercus john-tuckeri* (Tucker oak chaparral) Alliance**	G4 S4	37.418.00	
Alvord Oak Woodland	G2 S2.2		CTT71170CA
Quercus john-tuckeri		37.418.04	
Quercus john-tuckeri - Adenostoma fasciculatum		37.418.01	
Quercus john-tuckeri - Juniperus californica - Ericameria linearifolia		37.418.05	
Quercus john-tuckeri - Juniperus californica - Fraxinus dipetala		37.418.02	
Quercus john-tuckeri - Quercus wislizeni - Garrya flavescens		37.418.03	
****Ceanothus greggii* (Cup leaf ceanothus chaparral) Alliance**	G4 S3	*37.212.00	
**Ceanothus greggii*		*37.212.01	
**Ceanothus greggii - Adenostoma fasciculatum*		*37.212.03	
****Quercus turbinella* (Sonoran live oak scrub) Alliance**	G4 S1	*71.095.00	
**Quercus turbinella - Baccharis sergiloides*		*71.095.02	
**Quercus turbinella / Pinus monophylla*		*71.095.01	
***Rhus ovata* (Sugarbush chaparral) Alliance**	G4 S4 (some associations are of high priority for inventory)	37.801.00	
Rhus ovata		37.801.01	
Rhus ovata - Salvia leucophylla - Artemisia californica		37.801.02	
**Rhus ovata - Ziziphus parryi*		*37.801.03	
MG052. Western North American Cool/Montane Sclerophyllous Evergreen Scrub			
Mixed Montane Chaparral	G4 S4		CTT37510CA
***Ceanothus cordulatus* (Mountain white thorn chaparral) Alliance**	G4 S4	37.209.00	
Ceanothus cordulatus		37.209.01	
****Chrysolepis sempervirens* (Bush chinquapin chaparral) Alliance**	G4 S3	*37.700.00	
Bush Chinquapin Chaparral	G3 S3.3		CTT37550CA
**Chrysolepis sempervirens*		*37.700.01	
****Lithocarpus densiflorus var. echinoides* (Shrub tanoak chaparral) Alliance**	G3 S3	*73.110.00	
**Lithocarpus densiflorus var. echinoides / Arctostaphylos nevadensis*		*73.110.01	
**Lithocarpus densiflorus var. echinoides / Pteridium aquilinum*		*73.110.02	
****Quercus sadleriana* (Sadler oak or deer oak brush fields) Alliance**	G3 S3	*37.412.00	
**Quercus sadleriana*		*37.412.01	
***Quercus vacciniifolia* (Huckleberry oak chaparral) Alliance**	G4 S4	37.414.00	
Huckleberry Oak Chaparral	G3 S3.3		CTT37542CA
Quercus vacciniifolia		37.414.01	
Quercus vacciniifolia - Arctostaphylos patula		37.414.03	
Quercus vacciniifolia - Chrysolepis sempervirens		37.414.02	

***Arctostaphylos patula* (Green leaf manzanita chaparral) Alliance**	G5 S4	37.303.00	
Montane Manzanita Chaparral	G4 S4		CTT37520CA
Arctostaphylos patula		37.303.01	
Arctostaphylos patula - Quercus vacciniifolia		37.303.02	
***Ceanothus velutinus* (Tobacco brush or snow bush chaparral) Alliance**	G5 S4	37.210.00	
Tobacco Brush Chaparral	G4 S3.3		CTT37533CA
Ceanothus velutinus		37.210.01	
Ceanothus velutinus - Prunus emarginata - Artemisia tridentata		37.210.02	

2.C.3. Temperate and Boreal Scrub and Herb Coastal Vegetation

2.C.3.b. Pacific Coast Scrub and Herb Littoral Vegetation

MG058. Vancouverian Coastal Dune and Bluff

Active Coastal Dunes	G3 S2.2		CTT21100CA
Northern Foredunes	G2 S2.1		CTT21210CA
Northern Foredune Grassland	G1 S1.1		CTT21211CA
Central Foredunes	G1 S1.2		CTT21220CA
Southern Foredunes	G2 S2.1		CTT21230CA
Northern Dune Scrub	G2 S1.2		CTT21310CA
Central Dune Scrub	G2 S2.2		CTT21320CA
Southern Dune Scrub	G1 S1.1		CTT21330CA
Northern Coastal Bluff Scrub	G2 S2.2		CTT31100CA
Northern Salal Scrub	G4 S3.2		CTT32120CA
Southern Coastal Bluff Scrub	G1 S1.1		CTT31200CA
***Abronia latifolia - Ambrosia chamissonis* (Dune mat) Alliance**	G3 S3	*21.100.00	
**Abronia latifolia - Erigeron glaucus*		*21.101.01	
**Abronia latifolia - Leymus mollis*		*21.101.02	
**Ambrosia chamissonis - Abronia maritima - Cakile maritima*		*21.102.02	
**Ambrosia chamissonis - Abronia umbellata*		*21.102.01	
**Ambrosia chamissonis - Eriophyllum staechadifolium (- Lupinus arboreus)*		*21.100.03	
**Ambrosia chamissonis - Malacothrix incana - Carpobrotus chilensis - Poa douglasii*		*21.102.03	
**Artemisia pycnocephala - Calystegia soldanella*		*21.100.01	
**Artemisia pycnocephala - Cardionema ramosissimum*		*21.110.01	
**Artemisia pycnocephala - Ericameria ericoides*		*21.110.03	
**Artemisia pycnocephala - Poa douglasii*		*21.110.04	
Artemisia pycnocephala - Polygonum paronychia		21.110.02	
**Poa douglasii - Lathyrus littoralis*		*21.100.06	
Cakile maritima - Abronia maritima		21.125.01	
Cakile maritima - Ambrosia chamissonis - Carpobrotus edulis		21.102.04	
***Carex pansa* (Sand dune sedge swaths) Provisional Alliance**	G4? S3?	*45.184.00	
***Leymus mollis* (Sea lyme grass patches) Alliance**	G4 S2	*41.260.00	
**Leymus mollis - Abronia latifolia - (Cakile sp.)*		*41.260.03	
**Leymus mollis - Ammophila arenaria*		*41.260.02	
**Leymus mollis - Carpobrotus edulis*		*41.260.01	

***Baccharis pilularis* (Coyote brush scrub) Alliance**	G5 S5 (some associations are of high priority for inventory)	32.060.00	
Northern Coyote Bush Scrub	G4 S4		CTT32110CA
Central Lucian Coastal Scrub	G3 S3.3		CTT32200CA
Baccharis pilularis		32.060.23	
Baccharis pilularis - Lupinus arboreus		32.060.06	
Baccharis pilularis - Artemisia californica		32.060.05	
Baccharis pilularis - Artemisia californica - Heteromeles arbutifolia		32.060.19	
Baccharis pilularis - Artemisia californica - Toxicodendron / Monardella villosa		32.060.18	
Baccharis pilularis - Ceanothus thyrsiflorus		32.060.14	
Baccharis pilularis - Corylus cornuta		32.060.25	
Baccharis pilularis - Frangula californica - Rubus parviflorus		32.060.16	
**Baccharis pilularis - Holodiscus discolor*		*32.060.12	
Baccharis pilularis - Lotus scoparius		32.060.29	
Baccharis pilularis - Prunus ilicifolia		32.060.26	
Baccharis pilularis - Rubus ursinus / weedy herb		32.060.15	
Baccharis pilularis - Salvia mellifera		32.060.27	
Baccharis pilularis - Toxicodendron diversilobum		32.060.17	
Baccharis pilularis / Ammophila arenaria		32.060.07	
Baccharis pilularis / Annual Grass - Herb		32.060.20	
**Baccharis pilularis / Carex obnupta - Juncus patens*		*32.060.13	
**Baccharis pilularis / Danthonia californica*		*32.060.11	
**Baccharis pilularis / Deschampsia caespitosa*		*32.060.02	
Baccharis pilularis / Dudleya farinosa		32.060.24	
**Baccharis pilularis / Eriophyllum staechadifolium*		*32.060.01	
**Baccharis pilularis / Leymus triticoides*		*32.060.03	
**Baccharis pilularis / Nassella pulchra*		*32.060.10	
Baccharis pilularis / Native Grass (Mixed)		32.060.21	
**Baccharis pilularis / Polystichum munitum*		*32.060.04	
Baccharis pilularis / Scrophularia californica		32.060.08	
Gaultheria shallon - Baccharis pilularis - Ceanothus thyrsiflorus		32.060.28	
***Ceanothus thyrsiflorus* (Blue blossom chaparral) Alliance**	G4 S4	37.204.00	
Blue Brush Chaparral	G4 S4		CTT37820CA
Ceanothus thyrsiflorus - Baccharis pilularis - Toxicodendron diversilobum		37.204.01	
Ceanothus thyrsiflorus - Rubus ursinus		37.204.02	
Ceanothus thyrsiflorus - Vaccinium ovatum - Rubus parviflorus		37.204.03	
***Frangula californica* (California coffee berry scrub) Alliance**	G4 S4 (some associations are of high priority for inventory)	37.920.00	
**Frangula californica spp. tomentella / Hoita macrostachya*		*37.920.04	
Frangula californica ssp. tomentella		37.920.02	
Frangula californica ssp. tomentella / Cirsium fontinale var. campylon - Mimulus guttatus		37.920.03	
**Frangula californica - Baccharis pilularis / Scrophularia californica*		*37.920.01	
***Garrya elliptica* (Coastal silk tassel scrub) Provisional Alliance**	G3? S3?	*39.040.00	
Silk Tassel Forest	G3 S3.2		CTT81900CA
Northern Silk Tassel Scrub	G3 S2.3		CTT32130CA

***Lupinus arboreus* (Yellow bush lupine scrub) Alliance**	G4 S4 (within native range), some associations are of high priority for inventory)	32.080.00	
Lupinus arboreus		32.080.02	
**Lupinus arboreus - Ericameria ericoides*		*32.080.03	
Lupinus arboreus / Anthoxanthum odoratum		32.080.04	
Lupinus arboreus / Bromus diandrus		32.080.01	
Lupinus arboreus / Scrophularia californica		32.080.05	
**Ericameria ericoides*		*32.160.01	
***Lupinus chamissonis - Ericameria ericoides* (Silver dune lupine - mock heather scrub) Alliance**	G3 S3	*32.160.00	
**Lupinus chamissonis*		*32.160.02	
**Lupinus chamissonis - Ericameria ericoides*		*32.160.03	
***Venegasia carpesioides* (Canyon sunflower scrub) Alliance**	G3 S3	*39.030.00	
**Venegasia carpesioides*		*39.030.01	
***Ammophila arenaria* (European beach grass swards) Semi-natural Stands**		42.010.00	
Ammophila arenaria		42.010.02	
Ammophila arenaria - Cardionema ramosissimum		42.010.03	
Ammophila arenaria - Erechtites minima		42.010.01	
Ammophila arenaria - Lupinus variicolor		42.010.04	
***Cakile (edentula, maritima)* (Sea rocket sands) Provisional Semi-natural Stands**		21.125.00	
***Carpobrotus edulis or other Ice Plants* (Ice plant mats) Semi-natural Stands**		21.200.00	

2.C.4. Temperate and Boreal Bog and Fen*

2.C.4.a. North American Scrub and Herb Peatland

MG063. Western North American Montane/Boreal Peatland

Fen	G2 S1.2		CTT51200CA
***Carex limosa* (Shore sedge fens) Alliance**	G4? S2?	*45.178.00	
**Carex limosa - Menyanthes trifoliata*		*45.178.02	
**Carex limosa - Mimulus primuloides*		*45.110.03	
**Carex limosa / Drepanocladus sordidus*		*45.178.01	
***Dulichium arundinaceum* (Three-way sedge meadows) Provisional Alliance**	G3? S1	*52.115.00	
**Dulichium arundinaceum*		*52.115.01	
Darlingtonia Seep	G4 S3.2		CTT51120CA
***Darlingtonia californica* (California pitcher plant fens) Alliance**	G4? S3	*51.200.00	
**Darlingtonia californica*		*51.200.01	
***Rhododendron neoglandulosum* (Western Labrador-tea thickets) Alliance**	G4 S2?	*63.425.00	
Ledum Swamp	G2 S2.1		CTT5261ACA
**Rhododendron neoglandulosum*		*63.425.01	
**Rhododendron neoglandulosum - Kalmia microphylla / Pinus contorta*		*63.425.02	
***Triantha occidentalis - Narthecium californicum* (Western false asphodel - California bog asphodel fens) Alliance**	G2? S2?	*45.135.00	
**Triantha occidentalis - Rhynchospora alba*		*45.135.01	
**Triantha occidentalis / Sphagnum teres*		*45.135.02	
**Triantha occidentalis - Narthecium californicum*		*45.135.03	
***Vaccinium uliginosum* (Bog blue berry wet meadows) Alliance**	G4 S3	*45.410.00	
**Vaccinium uliginosum*		*45.410.01	
**Vaccinium uliginosum / Aulacomnium palustre*		*45.410.03	

**Vaccinium uliginosum / Sphagnum teres*		*45.410.04	
**Vaccinium uliginosum ssp. occidentale / Bistorta bistortoides*		*45.410.02	
Sphagnum Bog	G3 S1.2		CTT51110CA
2.C.5. Temperate and Boreal Freshwater Marsh			
2.C.5.b. Western North American Freshwater Marsh			
MG073. Western North American Freshwater Marsh			
Coastal and Valley Freshwater Marsh	G3 S2.1		CTT52410CA
Transmontane Freshwater Marsh	G3 S2.2		CTT52420CA
***Phragmites australis* (Common reed marshes) Alliance**	G5 S4?	41.061.00	
Phragmites australis		41.061.01	
Phragmites australis - Scirpus spp.		41.061.02	
***Schoenoplectus acutus* (Hardstem bulrush marsh) Alliance**	G5 S4	52.122.00	
Schoenoplectus acutus		52.122.01	
Schoenoplectus acutus - Apocynum cannabinum		52.122.02	
Schoenoplectus acutus - Typha angustifolia		52.122.03	
Schoenoplectus acutus - Typha domingensis		52.102.02	
Schoenoplectus acutus - Typha latifolia		52.122.04	
Schoenoplectus acutus - Typha latifolia - Phragmites australis		52.122.05	
Schoenoplectus acutus - Xanthium strumarium		52.122.06	
***Schoenoplectus californicus* (California bulrush marsh) Alliance**	G5 S4?	52.114.00	
Schoenoplectus californicus		52.114.02	
Schoenoplectus californicus - Apocynum cannabinum		52.114.03	
Schoenoplectus californicus - Eichhornia crassipes		52.114.04	
Schoenoplectus californicus - Schoenoplectus acutus		52.114.01	
Schoenoplectus californicus - Schoenoplectus acutus / Rosa californica		52.114.06	
Schoenoplectus californicus - Typha latifolia		52.114.05	
***Typha (angustifolia, domingensis, latifolia)* (Cattail marshes) Alliance**	G5 S5	52.050.00	
Typha angustifolia		52.050.01	
Typha angustifolia - Distichlis spicata		52.050.02	
Typha angustifolia - Typha latifolia - Typha domingensis		52.050.05	
Typha angustifolia - Typha latifolia - Typha domingensis / Distichlis spicata		52.050.06	
Typha angustifolia - Typha latifolia - Typha domingensis / Echinocloa crus-galli		52.050.07	
Typha angustifolia - Typha latifolia - Typha domingensis / Phragmites australis		52.050.08	
Typha angustifolia - Typha latifolia - Typha domingensis / Schoenoplectus americanus		52.050.09	
Typha domingensis		52.050.03	
Typha latifolia		52.103.02	
Typha latifolia - Typha angustifolia		52.050.04	
****Argentina egedii* (Pacific silverweed marshes) Alliance**	G4 S2	*38.140.00	
**Argentina egedii*		*38.140.01	
**Argentina egedii - Eleocharis macrostachya*		*38.140.03	
**Argentina egedii - Alopecurus aequalis*		*38.140.02	
**Argentina egedii - Lotus uliginosus*		*38.140.04	
****Carex obnupta* (Slough sedge swards) Alliance**	G4 S3	*45.183.00	
**Carex obnupta*		*45.183.01	
**Carex obnupta - Juncus lescurii*		*45.183.02	

**Carex obnupta - Juncus patens*		*45.183.03	
***Juncus effusus* (Soft rush marshes) Alliance**	G4 S4?	45.561.00	
Juncus effusus		45.561.01	
****Juncus lescurii* (Salt rush swales) Alliance**	G3 S2?	*45.569.00	
**Juncus lescurii*		*45.569.01	
**Juncus (lescurii) - Distichlis spicata*		*45.569.02	
***Juncus patens* (Western rush marshes) Provisional Alliance**	G4? S4?	45.564.00	
****Oenanthe sarmentosa* (Water-parsley marsh) Alliance**	G4 S2?	*52.119.00	
**Oenanthe sarmentosa*		*52.119.01	
****Scirpus microcarpus* (Small-fruited bulrush marsh) Alliance**	G4 S2	*52.113.00	
**Scirpus microcarpus*		*52.113.01	
**Scirpus microcarpus - Oxypolis occidentalis*		*52.113.02	
**Scirpus microcarpus - Scirpus congdonii*		*52.113.03	
MG074. Western North America Vernal Pool			
Northern Basalt Flow Vernal Pool	G3 S2.2		CTT44131CA
Northern Volcanic Ash Vernal Pool	G1 S1.1		CTT44133CA
Northern Volcanic Mud Flow Vernal Pool	G1 S1.1		CTT44132CA
Northern Vernal Pool	G2 S2.1		CTT44100CA
Northern Hardpan Vernal Pool	G3 S3.1		CTT44110CA
Northern Claypan Vernal Pool	G1 S1.1		CTT44120CA
San Diego Mesa Claypan Vernal Pool	G2 S2.1		CTT44322CA
San Diego Mesa Hardpan Vernal Pool	G2 S2.1		CTT44321CA
Southern Interior Basalt Flow Vernal Pool	G1 S1.2		CTT44310CA
Southern Vernal Pool	G? SNR		CTT44300CA
Vernal Marsh	G2 S2.1		CTT52500CA
****Alopecurus geniculatus* (Water foxtail meadows) Provisional Alliance**	G3? S3?	*42.006.00	
****Lasthenia fremontii - Downingia (bicornuta)* (Fremont’s goldfields - Downingia vernal pools) Alliance**	G3 S3	*42.007.00	
**Downingia (bicornuta, cuspidata)*		*42.007.02	
**Downingia bicornuta*		*42.007.01	
**Eryngium (vaseyi, castrense)*		*42.007.06	
**Lasthenia californica - Downingia bicornuta*		*42.007.08	
**Lasthenia fremontii*		*42.007.07	
**Lasthenia fremontii - Downingia bicornuta*		*42.007.03	
**Lasthenia fremontii - Downingia ornatissima*		*42.007.04	
Ranunculus bonariensis - Holocarpha virgata		*42.007.05	
***Eleocharis macrostachya* (Pale spike rush marshes) Alliance**	G4 S4 (some associations are of high priority for inventory)	45.230.00	
Eleocharis macrostachya		45.230.01	
**Eleocharis macrostachya - (Pleuropogon californicus)*		*45.230.07	
**Eleocharis macrostachya - Callitriche hermaphroditica*		*45.230.02	
**Eleocharis macrostachya - Eryngium aristulatum ssp. parishii*		*45.230.04	
**Eleocharis macrostachya - Lasthenia glaberrima*		*45.230.05	
**Eleocharis macrostachya - Marsilea vestita*		*45.230.06	
**Eleocharis macrostachya - Sagittaria montevidensis*		*45.230.03	

***Eleocharis acicularis* (Needle spike rush stands) Alliance**	G4? S3?	*45.231.00
**Eleocharis acicularis - Eryngium castrense*		*45.231.01
**Navarretia spp. - (Eleocharis acicularis - Eryngium alismaefolium)*		*45.231.03
**Plagiobothrys mollis - (Eleocharis acicularis - Eryngium mathiasiae)*		*45.231.02
***Eryngium aristulatum* (California button-celery patches) Alliance**	G3 S3?	*42.004.00
**Eryngium aristulatum - Lupinus bicolor*		*42.004.01
***Grindelia (stricta)* (Gum plant patches) Provisional Alliance**	G3? S3?	*52.206.00
***Centromadia (pungens)* (Tar plant fields) Alliance**	G2? S2?	*44.160.00
**Centromadia pungens - Downingia bella*		*44.160.02
**Centromadia pungens ssp. laevis*		*44.160.01
***Deinandra fasciculata* (Clustered tarweed fields) Alliance**	G3? S3?	*44.161.00
**Deinandra fasciculata - annual grass-herb*		*44.161.01
**Deinandra fasciculata - Hordeum depressum - Atriplex coronata var. notatior*		*44.161.02
***Lasthenia fremontii - Distichlis spicata* (Fremont’s goldfields - Saltgrass alkaline vernal pools) Alliance**	G4 S3	*44.119.00
**Lasthenia fremontii - Distichlis spicata*		*44.119.11
**Downingia bella - Lilaea scilloides*		*44.119.01
**Downingia cuspidata - Myosurus minimus*		*44.119.02
**Downingia insignis - Psilocarphus brevissimus*		*44.119.03
**Downingia pulchella - Cressa truxillensis*		*44.119.04
**Downingia pulchella - Distichlis spicata*		*44.119.05
**Lasthenia fremontii - Pleuropogon californicus*		*44.119.07
**Limnanthes douglasii ssp. rosea - Pleuropogon californicus*		*44.119.10
**Lasthenia platycarpha - Lepidium latipes*		*44.119.09
***Lasthenia glaberrima* (Smooth goldfields vernal pool bottoms) Alliance**	G3 S3	*44.140.00
**Lasthenia glaberrima - Atriplex persistens*		*44.119.08
**Lasthenia glaberrima - Downingia bicornuta*		*44.140.01
**Lasthenia glaberrima - Downingia insignis*		*44.140.05
**Lasthenia glaberrima - Lupinus bicolor*		*44.140.06
**Lasthenia glaberrima - Pleuropogon californicus*		*44.140.02
**Lasthenia glaberrima - Pogogyne douglasii*		*44.140.03
**Lasthenia glaberrima - Trifolium variegatum*		*44.140.04
***Layia fremontii - Achyrachaena mollis* (Fremont’s tidy-tips - Blow wives vernal pools) Alliance**	G3 S3?	*42.002.00
**Layia fremontii - Achyrachaena mollis*		*42.002.01
**Layia fremontii - Lasthenia californica - Achyrachaena mollis*		*42.002.02
**Layia fremontii - Leontodon taraxacoides - Plagiobothrys greenei*		*42.002.03
**Plagiobothrys austina - Achyrachaena mollis*		*42.002.04
***Montia fontana - Sidalcea calycosa* (Water blinks - Annual checkerbloom vernal pools) Alliance**	G2 S2	*44.113.00
**Montia fontana - Sidalcea calycosa*		*44.113.01
***Trifolium variegatum* (White-tip clover swales) Alliance**	G3? S3?	*42.005.00
**Trifolium gracilentum - Hesperevax caulescens*		*42.005.02
**Trifolium variegatum*		*42.005.01
**Trifolium variegatum - Lolium perenne - Leontodon taraxacoides*		*42.005.03
**Trifolium variegatum - Vulpia bromoides (Hypochaeris glabra - Leontodon taraxacoides)*		*42.005.04
**(Trifolium variegatum - Vulpia bromoides) - Hypochaeris glabra - Leontodon taraxacoides*		*42.005.05

MG075. Western North America Wet Meadow and Low Shrub Carr

Wet Montane Meadow	G3 S3.2		CTT45110CA
Freshwater Seep	G4 S3.2		CTT45400CA
Montane Freshwater Marsh	G3 S3.2		CTT52430CA
Wet Subalpine or Alpine Meadow	G3 S3.2		CTT45210CA
***Bistorta bistortoides - Mimulus primuloides* (Western bistort - primrose monkey flower meadows) Alliance**	G4 S4	45.413.00	
Bistorta bistortoides		45.413.02	
***Camassia quamash* (Small camas meadows) Alliance**	G4? S3?	*45.416.00	
**Camassia quamash / Sphagnum subsecundum*		*45.416.01	
***Carex (aquatilis, lenticularis)* (Water sedge and Lakeshore sedge meadows) Alliance**	G5 S3	*45.168.00	
**Carex aquatilis*		*45.168.01	
**Carex aquatilis - Carex lenticularis*		*45.168.04	
***Carex densa* (Dense sedge marshes) Provisional Alliance**	G2? S2?	*45.165.00	
**Carex densa - Juncus xiphioides*		*45.165.02	
**Carex densa - Lolium perenne - Juncus spp.*		*45.165.03	
**Carex lenticularis / Aulacomnium palustre*		*45.168.02	
**Carex lenticularis / Perideridia parishii*		*45.168.03	
***Carex nigricans* (Showy sedge sod) Provisional Alliance**	G4 S3?	*45.164.00	
***Carex scopulorum* (Sierra alpine sedge turf) Alliance**	G4 S3	*45.120.00	
**Carex scopulorum*		*45.120.01	
**Carex scopulorum - Allium validum*		*45.120.07	
**Carex scopulorum - Eleocharis quinquefolia*		*45.120.04	
**Carex scopulorum - Eriophorum crinigerum*		*45.120.03	
**Carex scopulorum - Mimulus primuloides*		*45.120.08	
**Carex scopulorum - Pedicularis groenlandica*		*45.120.02	
**Carex scopulorum / Aulacomnium palustre*		*45.120.06	
**Carex scopulorum / Oreostemma alpigenum*		*45.120.05	
***Carex (utriculata, vesicaria)* (Beaked sedge and blister sedge meadows) Alliance**	G5 S4	52.121.00	
Carex utriculata		52.120.01	
Carex utriculata - Mimulus primuloides		52.121.01	
Carex vesicaria		45.170.01	
***Eleocharis quinqueflora* (Few-flowered spike rush marshes) Alliance**	G4 S4 (some associations are of high priority for inventory)	45.220.00	
Eleocharis quinqueflora		45.220.01	
**Eleocharis quinqueflora - Mimulus primuloides*		*45.220.02	
**Eleocharis quinqueflora / Aulacomnium palustre*		*45.220.03	
**Eleocharis quinqueflora / Campylium stellatum*		*45.220.04	
**Eleocharis quinqueflora / Drepanocladus aduncus - Drepanocladus sordidus*		*45.220.05	
**Eleocharis quinqueflora / Philonotis fontana*		*45.220.06	
***Glyceria (elata, striata)* (Manna grass meadows) Alliance**	G4 S3?	*41.222.00	
**Glyceria elata*		*41.222.01	
**Glyceria elata - Lotus oblongifolius*		*41.222.03	
**Glyceria elata - Scirpus microcarpus*		*41.222.02	
**Glyceria striata*		*41.222.04	

***Glyceria occidentalis* (Northwest manna grass marshes) Provisional Alliance**	G3? S3?	*41.223.00	
**Oxypolis occidentalis (* Western cowbane meadows) Alliance	G3 S3	*45.418.00	
**Oxypolis occidentalis - Bistorta bistortoides*		*45.418.02	
**Oxypolis occidentalis - Carex amplifolia*		*45.418.03	
**Oxypolis occidentalis - Eleocharis montevidensis*		*45.418.04	
**Oxypolis occidentalis - Senecio triangularis*		*45.418.05	
**Oxypolis occidentalis / Philonotis fontana*		*45.418.06	
***Senecio triangularis* (Herb-rich meadows) Alliance**	G4 S4	45.419.00	
Senecio triangularis - Athyrium filix-femina		45.419.04	
Senecio triangularis - Lupinus latifolius		45.419.01	
Senecio triangularis - Lupinus polyphyllus		45.419.05	
***Torreyochloa pallida* (Floating mats of weak manna grass) Alliance**	G3 S3?	*45.171.00	
**Torreyochloa pallida*		*45.171.01	
**Torreyochloa pallida - Isoetes bolanderi*		*45.171.02	
***Carex barbarae* (White-root beds) Alliance**	G2? S2?	*45.142.00	
**Carex barbarae*		*45.142.01	
***Carex nudata* (Torrent sedge patches) Alliance**	G3 S3	*45.182.00	
**Carex nudata*		*45.182.01	
***Carex serratodens* (Twotooth sedge seeps) Provisional Alliance**	G3 S3?	*45.180.00	
***Cirsium fontinale* (Fountain thistle seeps) Alliance**	G1 S1	*42.100.00	
**Cirsium fontinale var. campylon - Carex serratodens - Hordeum brachyantherum*		*42.100.01	
**Cirsium fontinale var. campylon - Hemizonia congesta var. luzulifolia*		*42.100.02	
**Cirsium fontinale var. campylon - Mimulus guttatus - Stachys pycnantha*		*42.100.03	
***Juncus arcticus (var. balticus, mexicanus)* (Baltic and Mexican rush marshes) Alliance**	G5 S4	45.562.00	
Juncus arcticus var. balticus		45.562.07	
Juncus arcticus var. balticus		91.120.21	
Juncus arcticus var. balticus - Argentina egedii		45.562.05	
Juncus arcticus var. balticus - Carex praegracilis		45.562.04	
Juncus arcticus var. balticus - Conium maculatum		45.562.01	
Juncus arcticus var. balticus - Lepidium latifolium		45.562.06	
Juncus arcticus var. mexicanus		45.562.02	
***Juncus (oxymeris, xiphioides)* (Iris-leaf rush seeps) Provisional Alliance**	G2? S2?	*45.568.00	
***Leymus triticoides* (Creeping rye grass turfs) Alliance**	G4 S3	*41.080.00	
Valley Wildrye Grassland	G2 S2.1		CTT42140CA
**Leymus triticoides*		*41.080.01	
**Leymus triticoides - Anemopsis californica*		*41.080.05	
**Leymus triticoides - Bromus spp. - Avena spp.*		*41.080.02	
**Leymus triticoides - Carduus pycnocephalus - Geranium dissectum*		*41.080.04	
**Leymus triticoides - Lolium perenne*		*41.080.03	
**Leymus triticoides - Poa secunda*		*41.080.06	
***Mimulus (guttatus)* (Common monkey flower seeps) Alliance**	G4? S3?	*44.111.00	
**Mimulus guttatus*		*44.111.01	
**Mimulus guttatus - (Mimulus spp.)*		*44.111.03	
**Mimulus guttatus - Vulpia microstachys*		*44.111.02	
**Mimulus lewisii*		*44.111.04	
**Mimulus primuloides*		*45.413.03	

*Muhlenbergia rigens (Deer grass beds) Alliance	G3 S2?	*41.278.00
*Muhlenbergia rigens		*41.278.01
Lepidium latifolium (Perennial pepper weed patches) Semi-natural Stands		52.205.00
Lepidium latifolium		52.205.02
Lepidium latifolium - Distichlis spicata.		52.205.01
Persicaria lapathifolia - Xanthium strumarium (Smartweed - cocklebur patches) Provisional Alliance	G4 S4	42.207.00

2.C.6. Temperate and Boreal Salt Marsh

2.C.6.c. Temperate and Boreal Pacific Coastal Salt Marsh

MG081. North American Pacific Coastal Salt Marsh

Distichlis spicata (Salt grass flats) Alliance	G5 S4 (some associations are of high priority for inventory)	41.200.00
Distichlis spicata - Agrostis viridis		41.200.14
*Distichlis spicata - Ambrosia chamissonis		*41.200.11
Distichlis spicata - Atriplex triangularis		41.200.15
Distichlis spicata - Bromus diandrus		41.200.16
Distichlis spicata - Cotula coronopifolia		41.200.17
*Distichlis spicata - Frankenia salina - Jaumea carnosa		*41.200.07
Distichlis spicata - Hordeum murninum		41.200.18
*Distichlis spicata - Jaumea carnosa		*41.200.06
Distichlis spicata - Juncus arcticus ssp. balticus (J. arcticus ssp. mexicanus)		41.200.05
*Distichlis spicata - Juncus cooperi		*41.200.02
Distichlis spicata - Leymus triticoides / Lupinus (albifrons, arboreus)		41.200.19
Distichlis spicata - Parapholis strigosa		41.200.10
*Distichlis spicata - Sarcocornia pacifica		*41.200.20
*Distichlis spicata / Allenrolfea occidentalis		*41.200.01
Distichlis spicata / annual grasses		41.200.13
*Distichlis spicata / Chrysothamnus albidus		*41.200.04
*Distichlis spicata / Sarcobatus vermiculatus		*41.200.03
*Bulboschoenus maritimus (Salt marsh bulrush marshes) Alliance	G4 S3	*52.112.00
*Bolboschoenus maritimus		*52.112.03
*Bolboschoenus maritimus / Sarcocornia pacifica (depressa)		*52.112.04
*Bolboschoenus maritimus / Sesuvium verrucosum		*52.112.05
*Sarcocornia pacifica (Salicornia depressa) (Pickleweed mats) Alliance	G4 S3	*52.215.00
*Sarcocornia pacific - Lepidium latifolium		*52.215.12
*Sarcocornia pacifica		*52.215.04
*Sarcocornia pacifica - Jaumea carnosa - Batis maritima		*52.215.22
*Sarcocornia pacifica - Atriplex prostrata		*52.215.06
*Sarcocornia pacifica - Bolboschoenus maritimus		*52.215.07
*Sarcocornia pacifica - Brassica nigra		*52.215.15
*Sarcocornia pacifica - Cotula coronopifolia		*52.215.16
*Sarcocornia pacifica - Crypsis schoenoides		*52.215.17
*Sarcocornia pacifica - Cuscuta salina - Spartina densiflora		*52.215.01
*Sarcocornia pacifica - Distichlis spicata		*52.215.02
*Sarcocornia pacifica - Echinochloa crus-galli - Polygonum - Xanthium strumarium		*52.215.18
*Sarcocornia pacifica - Frankenia salina		*52.215.09

**Sarcocornia pacifica - Frankenia salina - Suaeda taxifolia*		*52.215.21	
**Sarcocornia pacifica - Grindelia stricta*		*52.215.10	
**Sarcocornia pacifica - Jaumea carnosa*		*52.215.11	
**Sarcocornia pacifica - Jaumea carnosa - Distichlis spicata*		*52.215.03	
**Sarcocornia pacifica - Sesuvium verrucosum*		*52.215.20	
**Sarcocornia pacifica - Spartina foliosa*		*52.215.13	
**Sarcocornia pacifica / algae*		*52.215.14	
**Sarcocornia pacifica/annual grasses (Polypogon, Hordeum, Lolium)*		*52.215.19	
****Spartina foliosa*** **(California cordgrass marsh) Alliance**	G3 S3	*52.020.00	
**Spartina foliosa*		*52.020.02	
**Spartina foliosa - Sarcocornia pacifica*		*52.020.01	
****Spartina (alterniflora, densiflora)*** **(Smooth or Chilean cordgrass marshes) Semi-natural Stands**		*41.070.00	
Spartina densiflora		41.070.02	
****Sesuvium verrucosum*** **(Western sea-purslane marshes) Alliance**	G3? S2	*52.210.00	
**Sesuvium verrucosum*		*52.210.01	
**Sesuvium verrucosum - Cotula coronopifolia*		*52.210.02	
**Sesuvium verrucosum - Distichlis spicata*		*52.210.03	
**Sesuvium verrucosum - Lolium perenne*		*52.210.04	
Atriplex prostrata - Cotula coronopifolia **(Fields of fat hen and brass buttons) Semi-natural Stands**		52.211.00	
Atriplex prostrata		52.211.01	
Atriplex prostrata / annual grasses		52.211.02	
Atriplex prostrata / Distichlis spicata		52.211.03	
Atriplex prostrata / Schoenoplectus maritimus		52.211.04	
Atriplex prostrata / Sesuvium verrucosum		52.211.05	
Cotula coronopifolia		52.211.06	
Coastal Brackish Marsh	G2 S2.1		CTT52200CA
Northern Coastal Salt Marsh	G3 S3.2		CTT52110CA
Southern Coastal Salt Marsh	G2 S2.1		CTT52120CA
2.C.6.d. Western North American Interior Alkali–Saline Wetland			
MG082. Cool Semi-Desert Alkali–Saline Wetlands			
****Sarcobatus vermiculatus*** **(Greasewood scrub) Alliance**	G5 S4 (some associations are of high priority for inventory)	*36.400.00	
Desert Greasewood Scrub	G4 S3.2		CTT36130CA
Sarcobatus vermiculatus		36.400.01	
**Sarcobatus vermiculatus - Atriplex confertifolia*		*36.400.02	
MG083. Warm Semi-Desert/Mediterranean Alkali–Saline Wetland		*52.214.00	
Alkali Meadow	G3 S2.1		CTT45310CA
Alkali Seep	G3 S2.1		CTT45320CA
Cismontane Alkali Marsh	G1 S1.1		CTT52310CA
Desert Sink Scrub	G4 S3.1		CTT36120CA
Transmontane Alkali Marsh	G3 S2.1		CTT52320CA
****Anemopsis californica*** **(Yerba mansa meadows) Alliance**	G3 S2?	*52.214.00	
**Anemopsis californica - Juncus arcticus var. mexicanus*		*52.214.01	

***Juncus cooperi* (Cooper's rush marsh) Alliance**	G3 S3	*45.563.00	
**Juncus cooperi*		*45.563.01	
***Schoenoplectus americanus* (American bulrush marsh) Alliance**	G5 S3	*52.111.00	
**Schoenoplectus americanus*		*52.111.04	
**Schoenoplectus americanus - Eleocharis rostellata*		*52.111.05	
**Schoenoplectus americanus / Argentina egedii*		*52.111.02	
**Schoenoplectus americanus / Lepidium latifolium*		*52.111.03	
**Schoenoplectus americanus / Schoenoplectus californicus - Schoenoplectus acutus*		*52.111.06	
***Spartina gracilis* (Alkali cordgrass marsh) Alliance**	GU S1	*52.030.00	
**Spartina gracilis - Sporobolus airoides*		*52.030.01	
***Sporobolus airoides* (Alkali sacaton grassland) Alliance**	G4 S2	*41.010.00	
Valley Sacaton Grassland	G1 S1.1		CTT42120CA
**Sporobolus airoides*		*41.010.01	
**Sporobolus airoides / Allenrolfea occidentalis*		*41.010.03	
**Sporobolus airoides / Ericameria nauseosa*		*41.010.02	
***Allenrolfea occidentalis* (Iodine bush scrub) Alliance**	G4 S3	*36.120.00	
Valley Sink Scrub	G1 S1.1		CTT36210CA
**Allenrolfea occidentalis*		*36.120.04	
**Allenrolfea occidentalis - Sporobolus airoides*		*36.120.03	
**Allenrolfea occidentalis - Suaeda moquinii*		*36.120.02	
***Arthrocnemum subterminale* (Parish's glasswort patches) Alliance**	G4 S2	*52.212.00	
**Arthrocnemum subterminale*		*52.212.01	
**Arthrocnemum subterminale - Monanthocloe littoralis*		*52.212.03	
**Arthrocnemum subterminale - Sarcocornia pacifica*		*52.212.02	
***Atriplex lentiformis* (Quailbush scrub) Alliance**	G4 S4	36.370.00	
Atriplex lentiformis		36.370.01	
***Atriplex spinifera* (Spinescale scrub) Alliance**	G3 S3	*36.350.00	
Relictual Interior Dunes	G1 S1.1		CTT23200CA
Stabilized Interior Dunes	G1 S1.1		CTT23100CA
Valley Saltbush Scrub	G2 S2.1		CTT36220CA
**Atriplex spinifera*		*36.350.01	
**Atriplex spinifera - Picrothamnus desertorum*		*36.350.03	
**Atriplex spinifera / annual herb*		*36.350.02	
***Cressa truxillensis - Distichlis spicata* (Alkali weed - Salt grass playas and sinks) Alliance**	G4 S4	46.100.00	
Chamaesyce hooveri - Bolboschoenus maritimus		46.100.02	
Neostapfia colusana - Malvella leprosa		46.100.03	
Neostapfia colusana - Polypogon maritimus		46.100.04	
Orcuttia pilosa		46.100.05	
Hordeum (depressum, murinum spp. leporinum)		44.119.06	
***Frankenia salina* (Alkali heath marsh) Alliance**	G4 S3	*52.500.00	
**Frankenia salina*		*52.500.02	
**Frankenia salina - Limonium californicum - Monanthochloe littoralis - Sarcocornia pacifica*		*52.500.01	
**Frankenia salina / Agrostis avenacea*		*52.500.03	
**Frankenia salina / Distichlis spicata*		*52.500.04	
**Suaeda taxifolia / Hordeum murinum*		*52.500.06	

***Suaeda moquinii* (Bush seepweed scrub) Alliance**	G5 S3	*36.200.00	
**Suaeda moquinii*		*36.200.01	
**Suaeda moquinii - Allenrolfea occidentalis*		*36.200.02	
**Suaeda moquinii - Atriplex canescens*		*36.200.03	

3. Xeromorphic Scrub and Herb Vegetation (Semi-Desert)

3.A. Warm Semi-Desert Scrub and Grassland

3.A.1. Warm Semi-Desert Scrub and Grassland

3.A.1.a. Sonoran and Chihuahuan Semi-Desert Scrub and Grassland

MG088. Mojavean–Sonoran Desert Scrub

Sonoran Mixed Woody Scrub	G3 S3.2		CTT33210CA
Mojave Mixed Woody and Succulent Scrub	G3 S3.2		CTT34240CA
Mojave Mixed Woody Scrub	G3 S3.2		CTT34210CA
Mojave Mixed Steppe	G3 S2.2		CTT34220CA
***Ambrosia dumosa* (White bursage scrub) Alliance**	G5 S4 (some associations are of high priority for inventory)	33.060.00	
**Ambrosia dumosa*		*33.060.02	
**Ambrosia dumosa - Acamptopappus sphaerocephalus*		*33.060.01	
Ambrosia dumosa - Atriplex hymenolytra		33.060.03	
Ambrosia dumosa - Encelia farinosa		33.060.06	
Ambrosia dumosa - Ephedra californica / sandy		33.060.07	
Ambrosia dumosa - Olneya tesota - Calliandra eriophylla		33.060.09	
**Ambrosia dumosa / Pleuraphis rigida*		*33.060.04	
***Ambrosia salsola* (Cheesebush scrub) Alliance**	G5 S4 (some associations are of high priority for inventory)	33.200.00	
Ambrosia salsola		33.200.01	
**Ambrosia salsola - Ambrosia eriocentra*		*33.200.06	
Ambrosia salsola - Atriplex confertifolia		33.200.04	
Ambrosia salsola - Bebbia juncea		33.200.05	
Ambrosia salsola - Brickellia incana		33.200.07	
Ambrosia salsola - Eriogonum fasciculatum		33.200.02	
Ambrosia salsola - Larrea tridentata		33.200.10	
Ambrosia salsola - Psorothamnus schottii		33.200.09	
Ambrosia salsola - Senna armata		33.200.08	
Ambrosia salsola -Petalonyx thurberi		33.200.11	
***Atriplex polycarpa* (Allscale scrub) Alliance**	G5 S4	36.340.00	
Sierra Tehachapi Saltbush Scrub	G2 S2.1		CTT36310CA
Interior Coast Range Saltbush Scrub	G2 S2.1		CTT36320CA
Desert Saltbush Scrub	G4 S3.2		CTT36110CA
Atriplex polycarpa		36.340.04	
Atriplex polycarpa - Atriplex confertifolia		36.340.01	
Atriplex polycarpa sparse playa		36.340.05	

***Encelia farinosa* (Brittle bush scrub) Alliance**	G5 S4 (some associations are of high priority for inventory)	33.030.00	
Encelia farinosa - coastal sage scrub		33.030.05	
Encelia farinosa - warm desert		33.030.01	
Encelia farinosa - Ambrosia dumosa - Fouquieria splendens		33.030.07	
Encelia farinosa - Ambrosia dumosa - Salvia greatae		33.030.08	
Encelia farinosa - Ambrosia dumosa - Senna armata		33.030.09	
Encelia farinosa - Artemisia californica		33.030.04	
**Encelia farinosa - Eriogonum fasciculatum - Agave deserti*		*33.030.03	
Encelia farinosa - Mirabilis californica		33.030.06	
**Encelia farinosa - Peucephyllum schottii*		*33.030.02	
***Larrea tridentata* (Creosote bush scrub) Alliance**	G5 S5 (some associations are of high priority for inventory)	33.010.00	
Larrea tridentata		33.140.04	
Larrea tridentata - Atriplex confertifolia		33.010.17	
Larrea tridentata - Atriplex hymenelytra		33.010.16	
Larrea tridentata - Atriplex polycarpa		33.010.12	
Larrea tridentata - Ephedra nevadensis		33.010.10	
**Larrea tridentata - Krameria grayi - Pleuraphis rigida*		*33.010.07	
**Larrea tridentata - Pleuraphis rigida*		*33.010.13	
**Larrea tridentata - Pleuraphis rigida - Lycium andersonii*		*33.010.14	
Larrea tridentata / cryptogamic crust		33.010.19	
Larrea tridentata / Eriogonum inflatum		33.010.09	
Larrea tridentata / wash		33.010.06	
Larrea tridentata - Ambrosia salsola		33.010.08	
***Larrea tridentata - Ambrosia dumosa* (Creosote bush - white burr sage scrub) Alliance**	G5 S5 (some associations are of high priority for inventory)	33.140.00	
Sonoran Creosote Bush Scrub	G4 S4		CTT33100CA
Mojave Creosote Bush Scrub	G4 S4		CTT34100CA
Larrea tridentata - Ambrosia dumosa		33.140.42	
Larrea tridentata - Ambrosia dumosa - / Atriplex hymenelytra		33.140.09	
Larrea tridentata - Ambrosia dumosa - Amphipappus fremontii		33.140.40	
Larrea tridentata - Ambrosia dumosa - Atriplex canescens		33.140.37	
Larrea tridentata - Ambrosia dumosa - Atriplex confertifolia		33.140.39	
Larrea tridentata - Ambrosia dumosa - Atriplex confertifolia - Psorothamnus arborescens		33.140.45	
Larrea tridentata - Ambrosia dumosa - Atriplex polycarpa		33.140.38	
Larrea tridentata - Ambrosia dumosa - Bebbia juncea		33.140.36	
Larrea tridentata - Ambrosia dumosa - Cylindropuntia acanthocarpa		33.140.46	
Larrea tridentata - Ambrosia dumosa - Cylindropuntia ramosissima		33.140.18	
**Larrea tridentata - Ambrosia dumosa - Echinocactus polycephalus*		*33.140.33	
**Larrea tridentata - Ambrosia dumosa - Encelia farinosa*		33.140.32	
**Larrea tridentata - Ambrosia dumosa - Encelia virginensis*		*33.140.31	
**Larrea tridentata - Ambrosia dumosa - Ephedra californica*		*33.140.30	
**Larrea tridentata - Ambrosia dumosa - Ephedra funerea*		*33.140.29	
Larrea tridentata - Ambrosia dumosa - Ephedra nevadensis		33.140.20	
Larrea tridentata - Ambrosia dumosa - Ephedra viridis		33.140.47	

Larrea tridentata - Ambrosia dumosa - Ericameria cooperi		33.140.48	
Larrea tridentata - Ambrosia dumosa - Eriogonum fasciculatum		33.140.28	
Larrea tridentata - Ambrosia dumosa - Eriogonum inflatum		33.140.27	
Larrea tridentata - Ambrosia dumosa - Fouquieria splendens		33.140.44	
*Larrea tridentata - Ambrosia dumosa - Galium angustifolium - Lyrocarpa coulteri		*33.140.10	
Larrea tridentata - Ambrosia dumosa - Grayia spinosa		33.140.26	
Larrea tridentata - Ambrosia dumosa - Gutierrezia sarothrae		33.140.25	
Larrea tridentata - Ambrosia dumosa - Krameria erecta		33.140.23	
Larrea tridentata - Ambrosia dumosa - Krameria grayii		33.140.22	
Larrea tridentata - Ambrosia dumosa - Lepidium fremontii		33.140.21	
Larrea tridentata - Ambrosia dumosa - Lycium andersonii		33.140.19	
Larrea tridentata - Ambrosia dumosa - Olneya tesota		33.140.49	
Larrea tridentata - Ambrosia dumosa - Opuntia basilaris		33.140.43	
*Larrea tridentata - Ambrosia dumosa - Petalonyx thurberi		*33.140.24	
*Larrea tridentata - Ambrosia dumosa - Pleuraphis rigida		*33.140.17	
Larrea tridentata - Ambrosia dumosa - Psorothamnus arborescens		33.140.15	
*Larrea tridentata - Ambrosia dumosa - Psorothamnus emoryi - sandy		*33.140.08	
Larrea tridentata - Ambrosia dumosa - Psorothamnus fremontii		33.140.16	
*Larrea tridentata - Ambrosia dumosa - Psorothamnus schottii		*33.140.07	
Larrea tridentata - Ambrosia dumosa - Psorothamnus spinosus		33.140.50	
Larrea tridentata - Ambrosia dumosa - Salazaria mexicana		33.140.14	
Larrea tridentata - Ambrosia dumosa - Senna armata		33.140.13	
Larrea tridentata - Ambrosia dumosa - Viguiera parishii		33.140.12	
Larrea tridentata - Ambrosia dumosa - Yucca schidigera		33.140.11	
*Larrea tridentata - Ambrosia dumosa / Crytogrammic crust		*33.140.35	
*Larrea tridentata - Ambrosia dumosa / Dalea mollissima		*33.140.34	
Larrea tridentata - Encelia farinosa (Creosote bush - brittle bush scrub) Alliance	G5 S4	33.027.00	
Larrea tridentata - Encelia farinosa		33.027.05	
Larrea tridentata - Encelia farinosa - Ambrosia dumosa		33.027.03	
Larrea tridentata - Encelia farinosa - Bebbia juncea		33.027.02	
Larrea tridentata - Encelia farinosa - Fouquieria splendens		33.027.04	
Larrea tridentata - Encelia farinosa - Peucephyllum schottii		33.027.06	
Larrea tridentata - Encelia farinosa - Pleurocoronis pluriseta		33.027.07	
Sonoran Mixed Woody and Succulent Scrub	G4 S3.2		CTT33220CA
*Cylindropuntia bigelovii (Teddy bear cholla patches) Alliance	G4 S3	*33.050.00	
*Cylindropuntia bigelovii		*33.050.01	
*Pleuraphis rigida (Big galleta shrub-steppe) Alliance	G3 S2	*41.030.00	
*Pleuraphis rigida		*41.030.01	
*Pleuraphis rigida - Dalea mollissima		*41.030.04	
*Pleuraphis rigida / Acamptopappus sphaerocephalus		*41.030.02	
*Pleuraphis rigida / Ambrosia dumosa		*41.030.06	
*Pleuraphis rigida / Atriplex canescens		*41.030.05	
*Pleuraphis rigida / Ephedra californica		*41.030.07	
*Pleuraphis rigida / Ericameria cooperi		*41.030.03	
*Pleuraphis rigida / Larrea tridentata		*41.030.08	
*Tidestromia oblongifolia (Arizona honey sweet sparse scrub) Provisional Alliance	G3 S3	*33.330.00	

***Parkinsonia microphylla* (Foothill palo verde desert scrub) Alliance**	G4 S1	*33.150.00	
Arizonan Woodland	G3 S1.2		CTT75400CA
***Prunus fremontii* (Desert apricot scrub) Alliance**	G4 S3	*33.220.00	
**Prunus fremontii*		*33.220.01	
***Simmondsia chinensis* (Jojoba scrub) Provisional Alliance**	G4 S3?	*33.005.00	
**Simmondsia chinensis - Eriogonum fasciculatum - Opuntia parryi*		*33.005.01	
***Tetracoccus hallii* (Hall's shrubby-spurge patches) Provisional Alliance**	G2 S1	*33.350.00	
***Viguiera parishii* (Parish's goldeneye scrub) Alliance**	G4 S4 (some associations are of high priority for inventory)	33.032.00	
Viguiera parishii		33.032.03	
**Viguiera parishii - Agave deserti*		*33.032.01	
Viguiera parishii - Encelia farinosa		33.032.04	
Viguiera parishii - Eriogonum fasciculatum		33.032.02	
**Viguiera parishii - Salvia dorrii*		*33.032.05	
***Ziziphus obtusifolia* (Graythorn patches) Special Stands**	G2 S2?	*33.225.00	
***Menodora spinescens* (Spiny menodora scrub) Alliance**	G4 S3	*33.290.00	
**Menodora spinescens - Atriplex confertifolia*		*33.290.01	
**Menodora spinescens - Ephedra nevadensis*		*33.290.02	
***Salazaria mexicana* (Bladder sage scrub) Alliance**	G4 S4	33.310.00	
Salazaria mexicana		33.310.01	
Salazaria mexicana - Ambrosia salsola - Eriogonum fasciculatum		33.310.03	
Salazaria mexicana - Viguieria reticulata - Atriplex confertifolia		33.310.02	
***Yucca brevifolia* (Joshua tree woodland) Alliance**	G4 S3	*33.170.00	
Joshua Tree Woodland	G4 S3.2		CTT73000CA
**Yucca brevifolia*		*33.170.01	
**Yucca brevifolia / Ephedra nevadensis*		*33.170.20	
**Yucca brevifolia / Yucca baccata / Pleuraphis jamesii*		*33.170.18	
**Yucca brevifolia / Artemisia tridentata - Atriplex confertifolia*		*33.170.04	
**Yucca brevifolia / Coleogyne ramosissima*		*33.170.02	
**Yucca brevifolia / Cylindropuntia acanthocarpa*		*33.170.06	
**Yucca brevifolia / Gutierrezia microcephala / Pleuraphis rigida*		*33.170.14	
**Yucca brevifolia / Juniperus californica / Coleogyne ramosissima*		*33.170.03	
**Yucca brevifolia / Juniperus californica / Ephedra nevadensis*		*33.170.19	
**Yucca brevifolia / Larrea tridentata - Yucca schidigera*		*33.170.10	
**Yucca brevifolia / Larrea tridentata - Ambrosia dumosa - Eriogonum fasciculatum*		*33.170.11	
**Yucca brevifolia / Larrea tridentata - Pleuraphis rigida*		*33.170.15	
**Yucca brevifolia / Lycium andersonii*		*33.170.08	
**Yucca brevifolia / Pleuraphis (rigida, jamesii)*		*33.170.07	
**Yucca brevifolia / Pleuraphis rigida*		*33.170.16	
**Yucca brevifolia / Pleuraphis rigida - Muhlenbergia porteri*		*33.170.17	
**Yucca brevifolia / Prunus fasciculata*		*33.170.13	
**Yucca brevifolia / Salazaria mexicana*		*33.170.09	
***Yucca schidigera* (Mojave yucca scrub) Alliance**	G4 S4 (some associations are of high priority for inventory)	33.070.00	
Mojave Yucca Scrub and Steppe	G3 S3.2		CTT34230CA
Yucca schidigera		33.070.01	

Yucca schidigera - Ambrosia dumosa		33.070.03	
Yucca schidigera - Coleogyne ramosissima		33.070.04	
**Yucca schidigera - Cylindropuntia acanthocarpa*		*33.070.08	
Yucca schidigera - Ephedra nevadensis		33.070.02	
Yucca schidigera - Eriogonum fasciculatum		33.070.07	
**Yucca schidigera - Larrea tridentata - Agave deserti*		*33.070.11	
Yucca schidigera - Larrea tridentata - Ambrosia dumosa		33.070.05	
Yucca schidigera - Larrea tridentata - Ephedra nevadensis		33.070.06	
**Yucca schidigera - Larrea tridentata - Simmondsia chinensis*		*33.070.10	
Yucca schidigera - Viguiera parishii		33.070.09	
Yucca schidigera / Pleuraphis rigida		33.070.12	
MG089. Viscaino–Baja California Desert Scrub			
***Coreopsis gigantea* (Giant coreopsis scrub) Alliance**	G3 S3?	*43.100.00	
**Coreopsis gigantea - Artemisia californica - Eriogonum cinereum*		*43.100.01	
**Coreopsis gigantea - Ericameria ericoides - Encelia californica*		*43.100.02	
***Lycium californicum* (California desert-thorn) Provisional Alliance**	G2? S2?	*33.365.00	
***Opuntia littoralis* (Coast prickly pear scrub) Alliance**	G4 S3	*32.150.00	
Maritime Succulent Scrub	G2 S1.1		CTT32400CA
**Opuntia littoralis - Eriogonum fasciculatum - Malosma laurina*		*32.150.01	
**Opuntia littoralis - mixed coastal sage scrub*		*32.150.02	
***Bursera microphylla* (Elephant tree stands) Special Stands**	G4 S1	*33.120.00	
Elephant Tree Woodland	G3 S1.2		CTT75100CA
MG092. Madrean Warm Semi-Desert Wash Woodland/Scrub		33.040.00	
Desert Dry Wash Woodland	G3 S3.2		CTT62200CA
Mojave Wash Scrub	G3 S3.2		CTT34250CA
Mojave Desert Wash Scrub	G3 S3.2		CTT63700CA
***Acacia greggii* (Catclaw acacia thorn scrub) Alliance**	G5 S4 (some associations are of high priority for inventory)	33.040.00	
**Acacia greggii - Ambrosia eriocentra*		*33.040.08	
Acacia greggii - Ambrosia salsola		33.040.05	
Acacia greggii - annual herbs (Bromus rubens)		33.040.02	
Acacia greggii - Bebbia juncea		33.040.10	
Acacia greggii - Encelia virginensis		33.040.12	
Acacia greggii - Eriogonum fasciculatum		33.040.13	
Acacia greggii - Hyptis emoryi		33.040.03	
Acacia greggii - Prunus fasciculata		33.040.07	
Acacia greggii - Salvia dorrii		33.040.09	
Acacia greggii - Viguiera parishii		33.040.06	
**Acacia greggii / Eriogonum nudum var. pauciflorum*		*33.040.11	
Acacia greggii wash (Justicia californica)		33.040.01	
***Ephedra californica* (California joint fir scrub) Alliance**	G3 S3	*33.270.00	
Monvero Residual Dunes	G1 S1.2		CTT23300CA
**Ephedra californica*		*33.270.01	
**Ephedra californica - Ambrosia salsola*		*33.270.02	

**Ephedra californica - Gutierrezia californica / Eriastrum pluriflorum*		*33.270.04
**Ephedra californica / annual - perennial herb*		*33.270.03
***Ericameria paniculata* (Black-stem rabbitbrush scrub) Alliance**	G4 S3	*35.340.00
**Ericameria paniculata*		*35.340.01
**Ericameria paniculata - Ambrosia eriocentra*		*35.340.03
**Ericameria paniculata - Ambrosia salsola*		*35.340.02
***Ericameria parryi* (Parry's rabbitbrush scrub) Alliance**	G4 S3	*35.340.00
**Ericameria parryi / Gayophytum diffusum*		*35.320.01
***Lepidospartum squamatum* (Scale broom scrub) Alliance**	G3 S3	*32.070.00
**Lepidospartum squamatum - Artemisia californica*		*32.070.09
**Lepidospartum squamatum - Atriplex canescens*		*32.070.04
**Lepidospartum squamatum - Baccharis salicifolia*		*32.070.05
**Lepidospartum squamatum - Eriodictyon crassifolium - Hesperoyucca whipplei*		*32.070.02
**Lepidospartum squamatum - Eriodictyon trichocalyx - Hesperoyucca whipplei*		*32.070.08
**Lepidospartum squamatum - Eriogonum fasciculatum*		*32.070.06
**Lepidospartum squamatum / Amsinckia menziesii*		*32.070.07
**Lepidospartum squamatum / ephemeral annuals*		*32.070.03
***Prunus fasciculata* (Desert almond scrub) Alliance**	G4 S3	*33.300.00
**Prunus fasciculata*		*33.300.01
**Prunus fasciculata - (Viguiera reticulata - Mortonia utahensis) limestone*		*33.300.06
**Prunus fasciculata - Ambrosia eriocentra*		*33.300.05
**Prunus fasciculata - Purshia stansburiana*		*33.300.04
**Prunus fasciculata - Rhus trilobata*		*33.300.03
**Prunus fasciculata - Salazaria mexicana*		*33.300.02
***Viguiera reticulata* (Net-veined goldeneye scrub) Alliance**	G3 S3?	*33.033.00
**Viguiera reticulata*		*33.033.01
***Agave deserti* (Desert agave scrub) Alliance**	G3 S3	*33.075.00
**Agave deserti - Ambroia salsola (wash and terrace)*		*33.075.01
**Agave deserti - Yucca schidigera*		*33.075.02
***Castela emoryi* (Crucifixion thorn stands) Special Stands**	G2 S1	*33.110.00
***Chilopsis linearis* (Desert willow woodland) Alliance**	G4 S3	*61.550.00
**Chilopsis linearis*		*61.550.01
**Chilopsis linearis / Ambrosia salsola*		*61.550.02
**Chilopsis linearis / Atriplex polycarpa*		*61.550.08
**Chilopsis linearis / Ericameria paniculata*		*61.550.07
**Chilopsis linearis / Prunus fasciculata*		*61.550.04
**Chilopsis linearis / Prunus fasciculata - Ambrosia salsola*		*61.550.03
**Chilopsis linearis / Salvia dorrii*		*61.550.05
**Chilopsis linearis / Viguiera parishii*		*61.550.06
***Hyptis emoryi* (Desert lavender scrub) Alliance**	G4 S3	*33.190.00
**Hyptis emoryi*		*33.190.01
**Hyptis emoryi - Psorothamnus schottii*		*33.190.02
***Justicia californica* (Chuparosa patches) Provisional Alliance**	G2 S2?	*33.340.00
***Koeberlinia spinosa* (Crown-of-thorns stands) Special Stands**	G2 S1	*33.100.00
All Thorn Woodland	G3 S1.1	CTT75300CA

***Parkinsonia florida - Olneya tesota* (Blue palo verde - Ironwood woodland) Alliance**	G4 S3	*61.545.00	
**Parkinsonia florida*		*61.545.05	
**Parkinsonia florida - Acacia greggii - Encelia frutescens Parkinsonia florida*		*61.545.06	
**Parkinsonia florida - Olneya tesota*		*61.545.10	
**Parkinsonia florida - Olneya tesota / Cylindropuntia munzii*		*61.545.12	
**Parkinsonia florida - Olneya tesota / Hyptis emoryi*		*61.545.11	
**Parkinsonia florida / Chilopsis linearis*		*61.545.07	
**Parkinsonia florida / Hyptis emoryi*		*61.545.08	
**Parkinsonia florida / Larrea tridentata - Peucephyllum schottii*		*61.545.09	
**Olneya tesota*		*61.545.01	
**Olneya tesota - Psorothamnus schottii*		*61.545.02	
**Olneya tesota / Hyptis emoryi*		*61.545.04	
**Olneya tesota / Larrea tridentata - Encelia farinosa*		*61.545.03	
***Pluchea sericea* (Arrow weed thickets) Alliance**	G3 S3	*63.710.00	
Arrowweed Scrub	G3 S3.3		CTT63820CA
**Pluchea sericea*		*63.710.01	
**Pluchea sericea - Allenrolfea occidentalis*		*63.710.02	
**Pluchea sericea - Atriplex canescens*		*63.710.03	
***Prosopis glandulosa* (Mesquite bosque, mesquite thicket) Alliance**	G5 S3	*61.512.00	
Great Valley Mesquite Scrub	G1 S1.1		CTT63420CA
Mesquite Bosque	G3 S2.1		CTT61820CA
**Prosopis glandulosa*		*61.512.01	
**Prosopis glandulosa - Salix exigua - Salix lasiolepis*		*61.512.09	
**Prosopis glandulosa - Sambucus nigra*		*61.512.02	
**Prosopis glandulosa / Atriplex canescens*		*61.512.04	
**Prosopis glandulosa / Atriplex spp. (alkaline)*		*61.512.03	
**Prosopis glandulosa / Bebbia juncea - Petalonyx thurberi (wash)*		*61.512.05	
**Prosopis glandulosa / Pluchea sericea - Atriplex canescens (alkaline spring)*		*61.512.06	
**Prosopis glandulosa / Rhus ovata (upper desert spring)*		*61.512.07	
**Prosopis glandulosa / Suaeda moquinii*		*61.512.08	
***Prosopis pubescens* (Screwbean mesquite bosques) Alliance**	G3 S2	*61.513.00	
**Prosopis / Atriplex spp. (alkaline)*		*61.513.01	
**Prosopis / Bebbia juncea - Petalonyx thurberi (wash)*		*61.513.03	
**Prosopis / Pluchea sericea - Atriplex canescens (alkaline spring)*		*61.513.02	
***Psorothamnus spinosus* (Smoke tree woodland) Alliance**	G4 S3	*61.570.00	
**Psorothamnus spinosus*		*61.570.01	
**Psorothamnus spinosus - Acacia greggii - Chrysothamnus sp*		*61.570.06	
**Psorothamnus spinosus / Ambrosia salsola - Bebbia juncea*		*61.570.02	
**Psorothamnus spinosus / Ephedra californica - Ambrosia salsola*		*61.570.03	
**Psorothamnus spinosus / Hyptis emoryi - Acacia greggii*		*61.570.04	
Crucifixion Thorn Woodland	G3 S1.2		CTT75200CA

3.B. Cool Semi-Desert Scrub and Grassland

3.B.1. Cool Semi-Desert Scrub and Grassland

3.B.1.a. Western North American Cool Semi-Desert Scrub and Grassland

MG093. Cool Semi-Desert Alkali–Saline Flats

***Atriplex confertifolia* (Shadscale scrub) Alliance**	G5 S4	36.320.00	
Atriplex confertifolia		36.320.10	
Atriplex confertifolia - Grayia spinosa - Encelia virginensis var. actoni		36.320.09	
Atriplex confertifolia - Ambrosia dumosa		36.320.03	
Atriplex confertifolia - Atriplex canescens		36.320.06	
Atriplex confertifolia - Coleogyne ramosissima		36.320.04	
Atriplex confertifolia - Ephedra nevadensis		36.320.02	
Atriplex confertifolia - Gutierrezia microcephala - Tetradymia axillaris		36.320.05	
Atriplex confertifolia - Krascheninnikovia lanata		36.320.08	
Atriplex confertifolia - Lycium andersonii		36.320.07	
Atriplex confertifolia / cryptogramic crust		36.320.11	
***Atriplex canescens (* Fourwing saltbush scrub) Alliance**	G5 S4	36.310.00	
Atriplex canescens		36.310.01	
Atriplex canescens - Krascheninnikovia lanata		36.310.02	
Shadscale Scrub	G4 S3.2		CTT36140CA
MG095. Cool Semi-desert wash and disturbance scrub			
Mono Pumice Flat	G1 S1.2		CTT35410CA
****Encelia virginensis* (Virgin River brittle brush scrub) Alliance**	G4 S3	*33.025.00	
**Encelia virginensis*		*33.025.01	
**Encelia virginensis - Salvia dorrii*		*33.025.02	
***Ericameria nauseosa* (Rubber rabbitbrush scrub) Alliance**	G5 S5	35.310.00	
Rabbitbrush Scrub	G5 S5		CTT35400CA
Ericameria nauseosa - Juniperus californica / annual to perennial herb		35.310.01	
Ericameria nauseosa / Sporobolus airoides		35.310.02	
***Ericameria teretifolia* (Needleleaf rabbitbrush scrub) Alliance**	G4 S4	35.330.00	
Ericameria teretifolia		35.330.01	
****Gutierrezia sarothrae* (Broom snake weed scrub) Provisional Alliance**	G3 S3	*32.043.00	
****Salvia dorrii* (Desert purple sage scrub) Alliance**	G3 S2	*33.320.00	
**Salvia dorrii*		*33.320.01	
MG096. Western North America Tall Sage Shrubland and Steppe			
****Artemisia rothrockii* (Rothrock's sagebrush) Alliance**	G3 S3	*35.140.00	
**Artemisia rothrockii / Monardella odoratissima*		*35.140.02	
**Artemisia rothrockii / Penstemon heterodoxus*		*35.140.01	
***Artemisia tridentata* (Big sagebrush) Alliance**	G5 S5	35.110.00	
Big Sagebrush Scrub	G4 S4		CTT35210CA
Sagebrush Steppe	G2 S2.1		CTT35300CA
Artemisia tridentata		35.110.02	
Artemisia tridentata - Artemisia nova		35.110.11	
Artemisia tridentata - Chrysothamnus viscidiflorus		35.110.12	
Artemisia tridentata - Coleogyne ramosissima		35.110.05	
Artemisia tridentata - Encelia virginensis		35.110.06	
Artemisia tridentata - Ephedra nevadensis		35.110.13	
Artemisia tridentata - Ericameria nauseosa		35.110.01	
Artemisia tridentata - Ericameria teretifolia		35.110.14	

Artemisia tridentata - Eriogonum fasciculatum		35.110.09	
Artemisia tridentata - Eriogonum wrightii		35.110.10	
Artemisia tridentata - Purshia tridentata		35.110.07	
Artemisia tridentata - Purshia tridentata / Hesperostipa comata		35.110.15	
Artemisia tridentata - Symphoricarpos longiflorus		35.110.04	
***Artemisia tridentata ssp. vaseyana* (Mountain big sagebrush) Alliance**	G5 S5	35.111.00	
Subalpine Sagebrush Scrub	G3 S3.2		CTT35220CA
Artemisia tridentata ssp. vaseyana		35.111.02	
Artemisia tridentata ssp. vaseyana - Purshia tridentata / Festuca idahoensis		35.111.03	
Artemisia tridentata ssp. vaseyana / Carex exserta		35.111.01	
Artemisia tridentata ssp. vaseyana / Monardella odoratissima		35.111.04	
MG097. Western North America Dwarf Sage Shrubland and Steppe			
***Artemisia arbuscula ssp. arbuscula* (Little sagebrush scrub) Alliance**	G5 S4 (some associations are of high priority for inventory)	35.120.00	
Artemisia arbuscula		35.120.07	
**Artemisia arbuscula - Eriogonum microthecum*		*35.120.05	
Artemisia arbuscula / Carex exserta		35.120.06	
Artemisia arbuscula / Castilleja applegatei		35.120.08	
Artemisia arbuscula / Castilleja schizotrichia		35.120.09	
Artemisia arbuscula / Eriogonum nudum - Monardella odoratissima		35.120.10	
**Artemisia arbuscula / Festuca idahoensis*		*35.120.03	
Artemisia arbuscula / Leptodactylon pungens		35.120.04	
Artemisia arbuscula / Stenotus acaulis - Geum canescens		35.120.02	
Artemisia arbuscula / Stenotus acaulis - Linanthus pungens		35.120.11	
Artemisia arbuscula / Stenotus acaulis - Tetradymia canescens		35.120.12	
**Artemisia arbuscula / Trifolium andersonii ssp. monoense*		*35.120.01	
***Artemisia arbuscula ssp. longicaulis* (Lahontan sagebrush scrub) Provisional Alliance**	G5 S4?	35.121.00	
***Artemisia nova* (Black sagebrush scrub) Alliance**	G4 S3	*35.130.00	
Pebble Plains	G1 S1.1		CTT47000CA
**Artemisia nova*		*35.130.01	
**Artemisia nova - Ambrosia salsola*		*35.130.03	
**Artemisia nova - Echinocereus engelmannii*		*35.130.02	
Great Basin Mixed Scrub	G4 S4		CTT35100CA
MG098. Inter-Mountain Dry Shrubland and Grassland			
***Ephedra nevadensis* (Nevada joint fir scrub) Alliance**	G4 S4	33.280.00	
Ephedra nevadensis		33.280.01	
Ephedra nevadensis - Atriplex confertifolia		33.280.02	
Ephedra nevadensis - Ericameria cooperi		33.280.05	
Ephedra nevadensis - Lycium andersonii		33.280.04	
Ephedra nevadensis - Salazaria mexicana		33.280.03	
***Ephedra viridis* (Mormon tea scrub) Alliance**	G4 S4 (some associations are of high priority for inventory)	33.285.00	
Ephedra viridis - Artemisia tridentata		33.285.01	

***Grayia spinosa* (Spiny hop sage scrub) Alliance**	**G5 S3**	*33.180.00	
**Grayia spinosa - Atriplex confertifolia*		*33.180.02	
**Grayia spinosa - Ephedra viridis*		*33.180.06	
**Grayia spinosa - Larrea tridentata*		*33.180.03	
**Grayia spinosa - Lycium andersonii*		*33.180.04	
**Grayia spinosa - Picrothamnus desertorum / Achnatherum hymenoides*		*33.180.07	
**Grayia spinosa / Eriogonum ovalifolium*		*33.180.05	
***Krascheninnikovia lanata* (Winterfat scrubland) Alliance**	G4 S2	*36.500.00	
**Krascheninnikovia lanata*		*36.500.01	
***Lycium andersonii* (Anderson's boxthorn scrub) Alliance**	G4 S3	*33.360.00	
**Lycium andersonii*		*33.360.02	
**Lycium andersonii - Simmondsia chinensis - Pleuraphis rigida*		*33.360.01	
***Cercocarpus intricatus* (Small leaf mountain mahogany scrub) Provisional Alliance**	G4 S3?	*76.300.00	
**Cerocarpus intricatus*		*76.300.01	
***Cercocarpus ledifolius* (Curl leaf mountain mahogany scrub) Alliance**	G5 S4	76.200.00	
Cercocarpus ledifolius		76.200.03	
Cercocarpus ledifolius - Artemisia tridentata		76.200.01	
Cercocarpus ledifolius / Symphoricarpos rotundifolia		76.200.02	
***Coleogyne ramosissima* (Black brush scrub) Alliance**	G5 S4 (some associations are of high priority for inventory)	33.020.00	
Blackbush Scrub	G3 S3.2		CTT34300CA
**Coleogyne ramosissima*		*33.020.01	
Coleogyne ramosissima - Atriplex confertifolia		33.020.02	
Coleogyne ramosissima - Atriplex hymenelytra - Tetradymia axillaris		33.020.10	
Coleogyne ramosissima - Ephedra nevadensis		33.020.03	
Coleogyne ramosissima - Eriogonum fasciculatum		33.020.05	
Coleogyne ramosissima - Eriogonum fasciculatum - Larrea tridentata		33.020.06	
Coleogyne ramosissima - Grayia spinosa		33.020.11	
Coleogyne ramosissima - Guiterrezia microcephala		33.020.12	
Coleogyne ramosissima - Larrea tridentata - Ambrosia dumosa		33.020.07	
Coleogyne ramosissima - Lycium andersonii		33.020.08	
Coleogyne ramosissima - Salazaria mexicana		33.020.09	
***Nolina (bigelovii, parryi)* (Nolina scrub) Alliance**	G3 S2	*33.080.00	
**Nolina bigelovii*		*33.080.02	
**Nolina parryi*		*33.080.01	
***Purshia stansburiana* (Stansbury cliff rose scrub) Alliance**	G3 S3	*33.240.00	
**Purshia stansburiana*		*33.240.01	
***Purshia tridentata* (Bitter brush scrub) Alliance**	G4 S3	*35.200.00	
**Purshia tridentata - Artemisia tridentata - Symphoricarpos rotundifolia*		*35.200.03	
**Purshia tridentata - Artemisia tridentata - Tetradymia canescens*		*35.200.01	
**Purshia tridentata - Artemisia tridentata / Achnatherum hymenoides*		*35.200.02	
**Purshia tridentata / Achnatherum nelsonii*		*35.200.04	
**Purshia tridentata / Eriogonum umbellatum*		*35.200.05	
Great Basin Grassland	G1 S1.1		CTT43000CA
***Achnatherum hymenoides* (Indian rice grass grassland) Alliance**	G4 S1	*41.120.00	
**Achnatherum hymenoides - Leptodactylon pungens*		*41.120.01	

**Achnatherum hymenoides - Sphaeralcea ambigua*		*41.120.02	
****Pseudoroegneria spicata*** **(Bluebunch wheat grass grassland) Alliance**	G4 S2	*41.040.00	
Agropyron cristatum **(Crested wheatgrass rangelands) Semi-natural Stands**		42.030.00	
****Achnatherum speciosum*** **(Desert needlegrass grassland) Alliance**	G4 S2	*41.090.00	
**Achnatherum speciosum*		*41.090.01	
****Pleuraphis jamesii*** **(James' galleta shrub-steppe) Alliance**	G3 S2	*41.610.00	
**Pleuraphis jamesii / Ephedra nevadensis*		*41.610.03	
**Pleuraphis jamesii / Eriogonum fasciculatum*		*41.610.01	
**Pleuraphis jamesii / Lycium andersonii*		*41.610.02	
4. Cryomorphic Shrub and Herb Vegetation (Polar and High Montane Vegetation)			
4.B. Temperate and Boreal Alpine Vegetation			
4.B.1. Alpine Scrub, Forb Meadow, and Grassland			
4.B.1.b. Western North America Alpine Scrub, Forb Meadow, and Grassland			
MG099. Rocky Mountain Alpine Scrub, Forb Meadow, and Grassland			
****Kobresia myosuroides*** **(Pacific bog sedge meadows) Alliance**	G5 S1	*91.115.00	
**Kobresia myosuroides - Thalictrum alpinum*		*91.115.01	
****Salix petrophila*** **(Alpine willow turf) Alliance**	G5 S3	*61.116.00	
**Salix petrophila*		*61.116.01	
**Salix petrophila - Calamagrostis muiriana*		*61.116.03	
**Salix petrophila - Calamagrostis muriana - Vaccinium caespitosum - Antennaria media*		*61.116.02	
****Salix nivalis*** **(Snow willow mats) Provisional Alliance**	G4 S1?	*91.127.00	
MG101. Vancouverian Alpine Scrub, Forb Meadow, and Grassland			
Klamath Cascade Fell Field	G4 S4		CTT91110CA
Sierra Nevada Fell Field	G4 S4		CTT91120CA
Southern California Fell Field	G1 S1.2		CTT91130CA
White Mountains Fell Field	G2 S2.2		CTT91140CA
Wet Alpine Talus and Scree Slope	G5 S4		CTT91210CA
Dry Alpine Talus and Scree Slope	G5 S4		CTT91220CA
Alpine Dwarf Scrub	G5 S4		CTT94000CA
Montane Dwarf Scrub	G3 S3.2		CTT38000CA
Dry Subalpine or Alpine Meadow	G3 S3.2		CTT45220CA
Calamagrostis muiriana **(Shorthair reed grass meadows) Alliance**	G4 S4	45.141.00	
Calamagrostis muiriana - Oreostemma alpigenum		45.141.02	
Calamagrostis muiriana - Ptilagrostis kingii		45.141.03	
Calamagrostis muiriana - Trisetum spicatum		45.141.04	
Calamagrostis muriana - Juncus drummondii		45.141.01	
****Carex breweri*** **(Brewer sedge mats) Alliance**	G4 S3	*45.150.00	
**Carex breweri*		*45.150.01	
**Carex breweri - Cistanthe umbellata*		*45.150.03	
**Carex breweri - Poa wheeleri*		*45.150.02	
Carex filifolia **(Shorthair sedge turf) Alliance**	G4 S4	45.140.00	
Carex filifolia		45.140.06	
Carex filifolia - Calamagrostis muiriana		45.140.09	
Carex filifolia - Cistanthe monosperma		45.140.10	

Carex filifolia - Erigeron algidus		45.140.05
Carex filifolia - Erigeron petiolaris		45.140.11
Carex filifolia - Penstemon heterodoxus		45.140.08
Carex filifolia - Saxifraga aprica		45.140.07
Carex filifolia - Trisetum spicatum		45.140.01
***Festuca brachyphylla* (Alpine fescue fell-fields) Alliance**	G4? S3?	*91.170.00
**Festuca brachyphylla - Penstemon davidsonii*		*91.170.02
**Festuca brachyphylla - Eriogonum ovalifolium*		*91.170.01
***Kalmia microphylla* (Alpine laurel heath) Provisional Alliance**	G4 S3?	*45.406.00
***Vaccinium cespitosum* (Dwarf bilberry meadows and mats) Alliance**	G4? S3?	*45.405.00
**Vaccinium cespitosum - Calamagrostis muiriana*		*45.405.03
**Vaccinium cespitosum - Carex filifolia*		*45.405.04
**Vaccinium cespitosum - Carex nigricans*		*45.400.02
**Vaccinium cespitosum - Kalmia microphylla*		*45.405.02
***Carex helleri* (Heller's sedge fell-fields) Alliance**	G4 S2	*45.145.00
**Carex helleri - Saxifraga tolmiei - Luzula divaricata*		*45.145.03
**Carex helleri - Arabis platysperma - Penstemon heterodoxus*		*45.145.06
**Carex helleri - Eriogonum incanum - Raillardella argentea*		*45.145.05
**Carex helleri - Poa suksdorfii*		*45.145.04
***Carex spectabilis* (Showy sedge sod) Alliance**	G4 S3	*45.155.00
**Carex spectabilis - Senecio triangularis*		*45.155.02
**Carex spectabilis - Sibbaldia procumbens*		*45.155.01
***Cassiope mertensiana* (White mountain heather heath) Provisional Alliance**	G5 S3?	*91.126.00
***Saxifraga nidifica* (Pink saxifrage patches) Provisional Alliance**	G4? S3?	*91.124.00
**Polygonum minimum*		*91.124.03
**Rhodiola integrifolia - Selaginella watsonii*		*91.124.02
***Saxifraga tolmiei* (Patches of Tolmie's alpine saxifrage) Provisional Alliance**	G4 S3?	*91.125.00
***Calamagrostis purpurascens* (Fell-fields with purple reed grass) Alliance**	G4? S4?	41.211.00
Calamagrostis purpurascens - Ericameria parryi var. monocephala - Linanthus pungens		41.211.02
Calamagrostis purpurascens - Linanthus pungens		41.211.01
Calamagrostis purpurascens / Ribes cereum		41.211.03
***Carex congdonii* (Congdon's sedge talus) Provisional Alliance**	G2 S2	*45.160.00
**Arnica amplexicaulis - Carex congdonii*		*45.160.01
***Ericameria discoidea - Hulsea algida* (Fell-fields with California heath-goldenrod and Pacific alpine gold) Alliance**	G3? S3?	*38.120.00
**Ericameria discoidea - Linanthus pungens*		*38.120.02
**Ericameria discoidea - Minuartia nuttallii*		*38.120.01
**Hulsea algida*		*38.120.04
**Hulsea algida - Ericameria discoidea - Phacelia hastata*		*38.120.05
**Hulsea algida - Muhlenbergia richardsonis - Achnatherum pinetorum*		*38.120.06
***Oxyria digyna* (Mountain sorrel patches) Provisional Alliance**	G4 S3?	*91.122.00
**Astragalus kentrophyta - Draba oligosperma*		*91.123.03
***Phlox covillei* (Coville's phlox fell-fields) Alliance**	G4 S3	*91.123.00
**Draba oligosperma - Poa glauca ssp. Rupicola*		*91.123.04
**Festuca minutiflora - Penstemon davidsonii*		*91.120.36
**Ivesia muirii*		*91.120.06
**Phlox covillei - Elymus elymoides - Podistera nevadensis*		*91.123.01

**Phlox covillei - Elymus elymoides - Podistera nevadensis - Erigeron pygmaeus*		*91.123.02
**Phlox covillei - Eriogonum gracilipes*		*91.123.09
**Phlox covillei - Eriogonum incanum*		*91.123.05
**Phlox (covillei) - Ivesia shockleyi*		*91.123.07
**Phlox covillei - Linum lewisii*		*91.123.08
**Podistera nevadensis - Arenaria kingii*		*91.120.08
**Podistera nevadensis - Erigeron pygmaeus*		*91.123.06
****Phlox pulvinata* (Cushion phlox fell-fields) Alliance**	G4 S3	*91.150.00
**Phlox pulvinata - Anelsonia eurycarpa*		*91.150.02
**Phlox pulvinata - Ericameria suffruticosa - Ipomopsis congesta*		*91.150.03
**Phlox pulvinata - Festuca brachyphylla*		*91.150.05
**Phlox pulvinata - Ivesia gordonii*		*91.150.06
**Phlox pulvinata - Lupinus argenteus var. montigenus*		*91.150.04

5. Hydromorphic Vegetation (Aquatic Vegetation)

5.A. Saltwater Aquatic Vegetation

5.A.1. Marine and Estuarine Saltwater Aquatic Vegetation

5.A.1.c. Temperate Pacific Saltwater Aquatic Vegetation

MG106. Temperate Pacific Intertidal Shore

****Ruppia (cirrhosa, maritima)* (Ditch-grass or widgeon-grass mats) Alliance**	G4? S2	*52.202.00
**Ruppia cirrhosa - algae*		*52.202.02
****Stuckenia (pectinata) - Potamogeton spp.* (Pondweed mats) Alliance**	G3G5 S3?	*52.107.00
**Potomogeton spp.*		*52.107.02
**Stuckenia pectinata*		*52.107.01

5. Hydromorphic Vegetation (Aquatic Vegetation)

5.B. Freshwater Aquatic Vegetation

5.B.1. Freshwater Aquatic Vegetation

5.B.1.a. North American Freshwater Aquatic Vegetation

MG109. Western North American Freshwater Aquatic Vegetation

****Hydrocotyle (ranunculoides, umbellata)* (Mats of floating pennywort) Alliance**	G4 S3?	*52.117.00
**Hydrocotyle ranunculoides*		*52.117.01
**Hydrocotyle ranunculoides - Schoenoplectus pungens*		*52.117.02
****Isoetes (bolanderi, echinospora, howellii, nuttallii, occidentalis)* (Quillwort beds) Provisional Alliance**	G3 S3?	*52.109.00
****Nuphar lutea* (Yellow pond-lily mats) Provisional Alliance**	G5 S3?	*52.110.00
****Sparganium (angustifolium)* (Mats of bur-reed leaves) Alliance**	G4 S3?	*52.010.00
**Sparganium angustifolium*		*52.010.01
***Azolla (filiculoides, mexicana)* (Mosquito fern mats) Provisional Alliance**	G4 S4	52.106.00
***Lemna (minor) and Relatives* (Duckweed blooms) Provisional Alliance**	G5 S4?	52.105.00
***Ludwigia (hexapetala, peploides)* (Water primrose wetlands) Provisional Semi-natural Stands**		52.118.00

6. Lithomorphic Vegetation (Nonvascular and Sparse Vascular Rock Vegetation)

6.B. Mediterranean, Temperate, and Boreal Nonvascular and Sparse Vegetation

6.B.1. Mediterranean Cliff, Scree, and Rock Vegetation

6.B.1.a. North American Mediterranean Rock Outcrop, Scree, and Talus Nonvascular and Sparse Vascular Vegetation

MG110. California Cliff, Scree, and Other Rock Vegetation

***Sedum spathulifolium* (Coast Range stonecrop draperies) Provisional Alliance**	G4? S4?	43.400.00	
***Selaginella bigelovii* (Bushy spikemoss mats) Alliance**	G4 S3	*42.062.00	
**Selaginella bigelovii / Eriogonum fasciculatum*		*42.062.01	
6.B.2.b Western North American Temperate Cliff, Scree and Rock Vegetation			
MG114. Vancouverian Cliff, Scree and Other Rock Vegetation			
Alpine Glacier	G5 S2.3		CTT93200CA
Alpine Snowbank Margin	G5 S4		CTT91300CA
Alpine Snowfield	G5 S5		CTT93100CA
6. Lithomorphic Vegetation (Nonvascular and Sparse Vascular Rock Vegetation)			
6.C. Semi-Desert Nonvascular and Sparse Vascular Vegetation			
6.C.1. Warm Semi-Desert Cliff, Scree, and Rock Vegetation			
6.C.1.a. North American Warm Semi-Desert Cliff, Scree, and Rock Vegetation			
MG117. North American Warm Semi-Desert Cliff, Scree, and Other Rock Vegetation			
Alkali Playa Commmunity	G4 S3.2		CTT46000CA
Active Desert Dunes	G4 S2.2		CTT22100CA
Stabilized and Partially Stabilized Desert Dunes	G4 S3.2		CTT22200CA
Stabilized and Partially Stabilized Desert Sand Fields	G4 S3.2		CTT22300CA
***Dicoria canescens - Abronia villosa* (Desert dunes) Alliance**	G3 S2	*22.100.00	
**Dicoria canescens*		*22.100.01	
***Panicum urvilleanum* (Desert panic grass patches) Alliance**	G3 S1	*42.095.00	
**Panicum urvilleanum*		*42.095.01	
***Swallenia alexandrae* (Patches of Eureka Valley dune grass) Special Stands**	G1 S1	*41.600.00	
***Atriplex hymenelytra* (Desert holly scrub) Alliance**	G5 S4	36.330.00	
Atriplex hymenelytra		36.330.01	
Atriplex hymenelytra - Ambrosia dumosa		36.330.02	
Atriplex hymenelytra - Encelia farinosa		36.330.06	
Atriplex hymenelytra - Larrea tridentata - Ambrosia dumosa		36.330.03	
Atriplex hymenelytra - Tidestromea oblongifolia		36.330.04	
Atriplex hymenelytra / rock		36.330.05	
***Ephedra funerea* (Death Valley joint fir scrub) Provisional Alliance**	G3? S2?	*33.275.00	

Staff Report on Burrowing Owl Mitigation

State of California

Natural Resources Agency

Department of Fish and Game

March 7, 2012[1]

[1] This document replaces the Department of Fish and Game 1995 Staff Report On Burrowing Owl Mitigation.

TABLE OF CONTENTS

INTRODUCTION AND PURPOSE

Maintaining California's rich biological diversity is dependent on the conservation of species and their habitats. The California Department of Fish and Game (Department) has designated certain species as "species of special concern" when their population viability and survival is adversely affected by risk factors such as precipitous declines or other vulnerability factors (Shuford and Gardali 2008). Preliminary analyses of regional patterns for breeding populations of burrowing owls (*Athene cunicularia*) have detected declines both locally in their central and southern coastal breeding areas, and statewide where the species has experienced modest breeding range retraction (Gervais et al. 2008). In California, threat factors affecting burrowing owl populations include habitat loss, degradation and modification, and eradication of ground squirrels resulting in a loss of suitable burrows required by burrowing owls for nesting, protection from predators, and shelter (See Appendix A).

The Department recognized the need for a comprehensive conservation and mitigation strategy for burrowing owls, and in 1995 directed staff to prepare a report describing mitigation and survey recommendations. This report, "1995 Staff Report on Burrowing Owl Mitigation," (Staff Report) (CDFG 1995), contained Department-recommended burrowing owl and burrow survey techniques and mitigation measures intended to offset the loss of habitat and slow or reverse further decline of this species. Notwithstanding these measures, over the past 15+ years, burrowing owls have continued to decline in portions of their range (DeSante et al. 2007, Wilkerson and Siegel, 2010). The Department has determined that reversing declining population and range trends for burrowing owls will require implementation of more effective conservation actions, and evaluating the efficacy of the Department's existing recommended avoidance, minimization and mitigation approaches for burrowing owls.

The Department has identified three main actions that together will facilitate a more viable, coordinated, and concerted approach to conservation and mitigation for burrowing owls in California. These include:

1. Incorporating burrowing owl comprehensive conservation strategies into landscape-based planning efforts such as Natural Community Conservation Plans (NCCPs) and multi-species Habitat Conservation Plans (HCPs) that specifically address burrowing owls.
2. Developing and implementing a statewide conservation strategy (Burkett and Johnson, 2007) and local or regional conservation strategies for burrowing owls, including the development and implementation of a statewide burrowing owl survey and monitoring plan.
3. Developing more rigorous burrowing owl survey methods, working to improve the adequacy of impacts assessments; developing clear and effective avoidance and minimization measures; and developing mitigation measures to ensure impacts to the species are effectively addressed at the project, local, and/or regional level (the focus of this document).

This Report sets forth the Department's recommendations for implementing the third approach identified above by revising the 1995 Staff Report, drawing from the most relevant and current knowledge and expertise, and incorporating the best scientific information available pertaining to the species. It is designed to provide a compilation of the best available science for Department staff, biologists, planners, land managers, California Environmental Quality Act (CEQA) lead agencies, and the public to consider when assessing impacts of projects or other activities on burrowing owls.

This revised Staff Report takes into account the California Burrowing Owl Consortium's Survey Protocol and Mitigation Guidelines (CBOC 1993, 1997) and supersedes the survey, avoidance, minimization and mitigation recommendations in the 1995 Staff Report. Based on experiences gained from implementing the 1995 Staff Report, the Department believes revising that report is warranted. This document also includes general conservation goals and principles for developing mitigation measures for burrowing owls.

DEPARTMENT ROLE AND LEGAL AUTHORITIES

The mission of the Department is to manage California's diverse fish, wildlife and plant resources, and the habitats upon which they depend, for their ecological values and for their use and enjoyment by the public. The Department has jurisdiction over the conservation, protection, and management of fish, wildlife, native plants, and habitats necessary to maintain biologically sustainable populations of those species (Fish and Game Code (FGC) §1802). The Department, as trustee agency pursuant to CEQA (See CEQA Guidelines, §15386), has jurisdiction by law over natural resources, including fish and wildlife, affected by a project, as that term is defined in Section 21065 of the Public Resources Code. The Department exercises this authority by reviewing and commenting on environmental documents and making recommendations to avoid, minimize, and mitigate potential negative impacts to those resources held in trust for the people of California.

Field surveys designed to detect the presence of a particular species, habitat element, or natural community are one of the tools that can assist biologists in determining whether a species or habitat may be significantly impacted by land use changes or disturbance. The Department reviews field survey data as well as site-specific and regional information to evaluate whether a project's impacts may be significant. This document compiles the best available science for conducting habitat assessments and surveys, and includes considerations for developing measures to avoid impacts or mitigate unavoidable impacts.

CEQA

CEQA requires public agencies in California to analyze and disclose potential environmental impacts associated with a project that the agency will carry out, fund, or approve. Any potentially significant impact must be mitigated to the extent feasible. Project-specific CEQA mitigation is important for burrowing owls because most populations exist on privately owned parcels that, when proposed for development or other types of modification, may be subject to the environmental review requirements of CEQA.

Take

Take of individual burrowing owls and their nests is defined by FGC section 86, and prohibited by sections 3503, 3503.5 and 3513. Take is defined in FGC Section 86 as "hunt, pursue, catch, capture or kill, or attempt to hunt, pursue, catch, capture or kill."

Migratory Bird Treaty Act

The Migratory Bird Treaty Act (MBTA) implements various treaties and conventions between the United States and Canada, Japan, Mexico, and Russia for the protection of migratory birds, including the burrowing owl (50 C.F.R. § 10). The MBTA protects migratory bird nests from possession, sale, purchase, barter, transport, import and export, and collection. The other prohibitions of the MBTA - capture, pursue, hunt, and kill - are inapplicable to nests. The regulatory definition of take, as defined in Title 50 C.F.R. part 10.12, means to pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to hunt, shoot, wound, kill, trap, capture, or collect. Only the verb "collect" applies to nests. It is illegal to collect, possess, and by any means transfer possession of any migratory bird nest. The MBTA prohibits the destruction of a nest when it contains birds or eggs, and no possession shall occur during the destruction (see Fish and Wildlife Service, Migratory Bird Permit Memorandum, April 15, 2003). Certain exceptions to this prohibition are included in 50 C.F.R. section 21. Pursuant to Fish & Game Code section 3513, the Department enforces the Migratory Bird Treaty Act consistent with rules and regulations adopted by the Secretary of the Interior under provisions of the Migratory Treaty Act.

Regional Conservation Plans

Regional multiple species conservation plans offer long-term assurances for conservation of covered species at a landscape scale, in exchange for biologically appropriate levels of incidental take and/or habitat loss as defined in the approved plan. California's NCCP Act (FGC §2800 et seq.) governs such plans at the state level, and was designed to conserve species, natural communities, ecosystems, and ecological processes across a jurisdiction or a collection of jurisdictions. Complementary federal HCPs are governed by the Endangered Species Act (7 U.S.C. § 136, 16 U.S.C.§ 1531 et seq.) (ESA). Regional conservation plans (and certain other landscape-level conservation and management plans), may provide conservation for unlisted as well as listed species. Because the geographic scope of NCCPs and HCPs may span many hundreds of thousands of acres, these planning tools have the potential to play a significant role in conservation of burrowing owls, and grasslands and other habitats.

Fish and Game Commission Policies

There are a number of Fish and Game Commission policies (see FGC §2008) that can be applied to burrowing owl conservation. These include policies on: Raptors, Cooperation, Endangered and Threatened Species, Land Use Planning, Management and Utilization of Fish and Wildlife on Federal Lands, Management and Utilization of Fish and Wildlife on Private Lands, and Research.

GUIDING PRINCIPLES FOR CONSERVATION

Unless otherwise provided in a statewide, local, or regional conservation strategy, surveying and evaluating impacts to burrowing owls, as well as developing and implementing avoidance, minimization, and mitigation and conservation measures incorporate the following principles. These principles are a summary of Department staff expert opinion and were used to guide the preparation of this document.

1. Use the Precautionary Principle (Noss et al.1997), by which the alternative of increased conservation is deliberately chosen in order to buffer against incomplete knowledge of burrowing owl ecology and uncertainty about the consequences to burrowing owls of potential impacts, including those that are cumulative.
2. Employ basic conservation biology tenets and population-level approaches when determining what constitutes appropriate avoidance, minimization, and mitigation for impacts. Include mitigation effectiveness monitoring and reporting, and use an adaptive management loop to modify measures based on results.
3. Protect and conserve owls in wild, semi-natural, and agricultural habitats (conserve is defined at FGC §1802).
4. Protect and conserve natural nest burrows (or burrow surrogates) previously used by burrowing owls and sufficient foraging habitat and protect auxiliary "satellite" burrows that contribute to burrowing owl survivorship and natural behavior of owls.

CONSERVATION GOALS FOR THE BURROWING OWL IN CALIFORNIA

It is Department staff expert opinion that the following goals guide and contribute to the short and long-term conservation of burrowing owls in California:

1. Maintain size and distribution of extant burrowing owl populations (allowing for natural population fluctuations).
2. Increase geographic distribution of burrowing owls into formerly occupied historical range where burrowing owl habitat still exists, or where it can be created or enhanced, and where the reason for its local disappearance is no longer of concern.
3. Increase size of existing populations where possible and appropriate (for example, considering basic ecological principles such as carrying capacity, predator-prey relationships, and inter-specific relationships with other species at risk).
4. Protect and restore self-sustaining ecosystems or natural communities which can support burrowing owls at a landscape scale, and which will require minimal long-term management.
5. Minimize or prevent unnatural causes of burrowing owl population declines (e.g., nest burrow destruction, chemical control of rodent hosts and prey).
6. Augment/restore natural dynamics of burrowing owl populations including movement and genetic exchange among populations, such that the species does not require future listing and protection under the California Endangered Species Act (CESA) and/or the federal Endangered Species Act (ESA).
7. Engage stakeholders, including ranchers; farmers; military; tribes; local, state, and federal agencies; non-governmental organizations; and scientific research and education communities involved in burrowing owl protection and habitat management.

ACTIVITIES WITH THE POTENTIAL TO TAKE OR IMPACT BURROWING OWLS

The following activities are examples of activities that have the potential to take burrowing owls, their nests or eggs, or destroy or degrade burrowing owl habitat: grading, disking, cultivation, earthmoving, burrow blockage, heavy equipment compacting and crushing burrow tunnels, levee maintenance, flooding, burning and mowing (if burrows are impacted), and operating wind turbine collisions (collectively hereafter referred to as "projects" or "activities" whether carried out pursuant to CEQA or not). In addition, the following activities may have impacts to burrowing owl populations: eradication of host burrowers; changes in vegetation management (i.e. grazing); use of pesticides and rodenticides; destruction, conversion or degradation of nesting, foraging, over-wintering or other habitats; destruction of natural burrows and burrow surrogates; and disturbance which may result in harassment of owls at occupied burrows.

PROJECT IMPACT EVALUATIONS

The following three progressive steps are effective in evaluating whether projects will result in impacts to burrowing owls. The information gained from these steps will inform any subsequent avoidance, minimization and mitigation measures. The steps for project impact evaluations are: 1) habitat assessment, 2) surveys, and 3) impact assessment. Habitat assessments are conducted to evaluate the likelihood that a site supports burrowing owl. Burrowing owl surveys provide information needed to determine the potential effects of proposed projects and activities on burrowing owls, and to avoid take in accordance with FGC sections 86, 3503, and 3503.5. Impact assessments evaluate the extent to which burrowing owls and their habitat may be impacted, directly or indirectly, on and within a reasonable distance of a proposed CEQA project activity or non-CEQA project. These three site evaluation steps are discussed in detail below.

Biologist Qualifications

The current scientific literature indicates that only individuals meeting the following minimum qualifications should perform burrowing owl habitat assessments, surveys, and impact assessments:

1. Familiarity with the species and its local ecology;
2. Experience conducting habitat assessments and non-breeding and breeding season surveys, or experience with these surveys conducted under the direction of an experienced surveyor;
3. Familiarity with the appropriate state and federal statutes related to burrowing owls, scientific research, and conservation;
4. Experience with analyzing impacts of development on burrowing owls and their habitat.

Habitat Assessment Data Collection and Reporting

A habitat assessment is the first step in the evaluation process and will assist investigators in determining whether or not occupancy surveys are needed. Refer to Appendix B for a definition of burrowing owl habitat. Compile the detailed information described in Appendix C when conducting project scoping, conducting a habitat assessment site visit and preparing a habitat assessment report.

Surveys

Burrowing owl surveys are the second step of the evaluation process and the best available scientific literature recommends that they be conducted whenever burrowing owl habitat or sign (see Appendix B) is encountered on or adjacent to (within 150 meters) a project site

(Thomsen 1971, Martin 1973). Occupancy of burrowing owl habitat is confirmed at a site when at least one burrowing owl, or its sign at or near a burrow entrance, is observed within the last three years (Rich 1984). Burrowing owls are more detectable during the breeding season with detection probabilities being highest during the nestling stage (Conway et al. 2008). In California, the burrowing owl breeding season extends from 1 February to 31 August (Haug et al. 1993, Thompsen 1971) with some variances by geographic location and climatic conditions. Several researchers suggest three or more survey visits during daylight hours (Haug and Diduik 1993, CBOC 1997, Conway and Simon 2003) and recommend each visit occur at least three weeks apart during the peak of the breeding season, commonly accepted in California as between 15 April and 15 July (CBOC 1997). Conway and Simon (2003) and Conway et al. (2008) recommended conducting surveys during the day when most burrowing owls in a local area are in the laying and incubation period (so as not to miss early breeding attempts), during the nesting period, and in the late nestling period when most owls are spending time above ground.

Non-breeding season (1 September to 31 January) surveys may provide information on burrowing owl occupancy, but do not substitute for breeding season surveys because results are typically inconclusive. Burrowing owls are more difficult to detect during the non-breeding season and their seasonal residency status is difficult to ascertain. Burrowing owls detected during non-breeding season surveys may be year-round residents, young from the previous breeding season, pre-breeding territorial adults, winter residents, dispersing juveniles, migrants, transients or new colonizers. In addition, the numbers of owls and their pattern of distribution may differ during winter and breeding seasons. However, on rare occasions, non-breeding season surveys may be warranted (i.e., if the site is believed to be a wintering site only based on negative breeding season results). Refer to Appendix D for information on breeding season and non-breeding season survey methodologies.

Survey Reports

Adequate information about burrowing owls present in and adjacent to an area that will be disturbed by a project or activity will enable the Department, reviewing agencies and the public to effectively assess potential impacts and will guide the development of avoidance, minimization, and mitigation measures. The survey report includes but is not limited to a description of the proposed project or proposed activity, including the proposed project start and end dates, as well as a description of disturbances or other activities occurring on-site or nearby. Refer to Appendix D for details included in a survey report.

Impact Assessment

The third step in the evaluation process is the impact assessment. When surveys confirm occupied burrowing owl habitat in or adjoining the project area, there are a number of ways to assess a project's potential significant impacts to burrowing owls and their habitat. Richardson and Miller (1997) recommended monitoring raptor behavior prior to developing management recommendations and buffers to determine the extent to which individuals have been sensitized to human disturbance. Monitoring results will also provide detail necessary for developing site-specific measures. Postovit and Postovit (1987) recommended an analytical approach to mitigation planning: define the problem (impact), set goals (to guide mitigation development), evaluate and select mitigation methods, and monitor the results.

Define the problem. The impact assessment evaluates all factors that could affect burrowing owls. Postovit and Postovit (1987) recommend evaluating the following in assessing impacts to raptors and planning mitigation: type and extent of disturbance, duration and timing of disturbance, visibility of disturbance, sensitivity and ability to habituate, and influence of environmental factors. They suggest identifying and addressing all potential direct and indirect impacts to burrowing owls, regardless of whether or not the impacts will occur during the breeding season. Several examples are given for each impact category below; however, examples are not intended to be used exclusively.

Type and extent of the disturbance. The impact assessment describes the nature (source) and extent (scale) of potential project impacts on occupied, satellite and unoccupied burrows including acreage to be lost (temporary or permanent), fragmentation/edge being created, increased distance to other nesting and foraging habitat, and habitat degradation. Discuss any project activities that impact either breeding and/or non-breeding habitat which could affect owl home range size and spatial configuration, negatively affect onsite and offsite burrowing owl presence, increase energetic costs, lower reproductive success, increase vulnerability to predation, and/or decrease the chance of procuring a mate.

Duration and timing of the impact. The impact assessment describes the amount of time the burrowing owl habitat will be unavailable to burrowing owls (temporary or permanent) on the site and the effect of that loss on essential behaviors or life history requirements of burrowing owls, the overlap of project activities with breeding and/or non-breeding seasons (timing of nesting and/or non-breeding activities may vary with latitude and climatic conditions, which should be considered with the timeline of the project or activity), and any variance of the project activities in intensity, scale and proximity relative to burrowing owl occurrences.

Visibility and sensitivity. Some individual burrowing owls or pairs are more sensitive than others to specific stimuli and may habituate to ongoing visual or audible disturbance. Site-specific monitoring may provide clues to the burrowing owl's sensitivities. This type of assessment addresses the sensitivity of burrowing owls within their nesting area to humans on foot, and vehicular traffic. Other variables are whether the site is primarily in a rural versus urban setting, and whether any prior disturbance (e.g., human development or recreation) is known at the site.

Environmental factors. The impact assessment discusses any environmental factors that could be influenced or changed by the proposed activities including nest site availability, predators, prey availability, burrowing mammal presence and abundance, and threats from other extrinsic factors such as human disturbance, urban interface, feral animals, invasive species, disease or pesticides.

Significance of impacts. The impact assessment evaluates the potential loss of nesting burrows, satellite burrows, foraging habitat, dispersal and migration habitat, wintering habitat, and habitat linkages, including habitat supporting prey and host burrowers and other essential habitat attributes. This assessment determines if impacts to the species will result in significant impacts to the species locally, regionally and range-wide per CEQA Guidelines §15382 and Appendix G. The significance of the impact to habitat depends on the extent of habitat disturbed and length of time the habitat is unavailable (for example: minor – several days, medium – several weeks to months, high - breeding season affecting juvenile survival, or over winter affecting adult survival).

Cumulative effects. The cumulative effects assessment evaluates two consequences: 1) the project's proportional share of reasonably foreseeable impacts on burrowing owls and habitat caused by the project or in combination with other projects and local influences having impacts on burrowing owls and habitat, and 2) the effects on the regional owl population resulting from the project's impacts to burrowing owls and habitat.

Mitigation goals. Establishing goals will assist in planning mitigation and selecting measures that function at a desired level. Goals also provide a standard by which to measure mitigation success. Unless specifically provided for through other FGC Sections or through specific regulations, take, possession or destruction of individual burrowing owls, their nests and eggs is prohibited under FGC sections 3503, 3503.5 and 3513. Therefore, a required goal for all project activities is to avoid take of burrowing owls. Under CEQA, goals would consist of measures that would avoid, minimize and mitigate impacts to a less than significant level. For individual projects, mitigation must be roughly proportional to the level of impacts, including cumulative impacts, in accordance with the provisions of CEQA (CEQA Guidelines, §§ 15126.4(a)(4)(B), 15064, 15065, and 16355). In order for mitigation measures to be effective, they must be specific, enforceable, and feasible actions that will improve environmental conditions. As set forth in more detail in Appendix A, the current scientific literature supports the conclusion that mitigation for permanent habitat loss necessitates replacement with an equivalent or greater habitat area for breeding, foraging, wintering, dispersal, presence of burrows, burrow surrogates, presence of fossorial mammal dens, well drained soils, and abundant and available prey within close proximity to the burrow.

MITIGATION METHODS

The current scientific literature indicates that any site-specific avoidance or mitigation measures developed should incorporate the best practices presented below or other practices confirmed by experts and the Department. The Department is available to assist in the development of site-specific avoidance and mitigation measures.

Avoiding. A primary goal is to design and implement projects to seasonally and spatially avoid negative impacts and disturbances that could result in take of burrowing owls, nests, or eggs. Other avoidance measures may include but not be limited to:

- Avoid disturbing occupied burrows during the nesting period, from 1 February through 31 August.
- Avoid impacting burrows occupied during the non-breeding season by migratory or non-migratory resident burrowing owls.
- Avoid direct destruction of burrows through chaining (dragging a heavy chain over an area to remove shrubs), disking, cultivation, and urban, industrial, or agricultural development.
- Develop and implement a worker awareness program to increase the on-site worker's recognition of and commitment to burrowing owl protection.
- Place visible markers near burrows to ensure that farm equipment and other machinery does not collapse burrows.
- Do not fumigate, use treated bait or other means of poisoning nuisance animals in areas where burrowing owls are known or suspected to occur (e.g., sites observed with nesting

owls, designated use areas).
- Restrict the use of treated grain to poison mammals to the months of January and February.

Take avoidance (pre-construction) surveys. Take avoidance surveys are intended to detect the presence of burrowing owls on a project site at a fixed period in time and inform necessary take avoidance actions. Take avoidance surveys may detect changes in owl presence such as colonizing owls that have recently moved onto the site, migrating owls, resident burrowing owls changing burrow use, or young of the year that are still present and have not dispersed. Refer to Appendix D for take avoidance survey methodology.

Site surveillance. Burrowing owls may attempt to colonize or re-colonize an area that will be impacted; thus, the current scientific literature indicates a need for ongoing surveillance at the project site during project activities is recommended. The surveillance frequency/effort should be sufficient to detect burrowing owls if they return. Subsequent to their new occupancy or return to the site, take avoidance measures should assure with a high degree of certainty that take of owls will not occur.

Minimizing. If burrowing owls and their habitat can be protected in place on or adjacent to a project site, the use of buffer zones, visual screens or other measures while project activities are occurring can minimize disturbance impacts. Conduct site-specific monitoring to inform development of buffers (see Visibility and sensitivity above). The following general guidelines for implementing buffers should be adjusted to address site-specific conditions using the impact assessment approach described above. The CEQA lead agency and/or project proponent is encouraged to consult with the Department and other burrowing owl experts for assistance in developing site-specific buffer zones and visual screens.

Buffers. Holroyd et al. (2001) identified a need to standardize management and disturbance mitigation guidelines. For instance, guidelines for mitigating impacts by petroleum industries on burrowing owls and other prairie species (Scobie and Faminow, 2000) may be used as a template for future mitigation guidelines (Holroyd et al. 2001). Scobie and Faminow (2000) developed guidelines for activities around occupied burrowing owl nests recommending buffers around low, medium, and high disturbance activities, respectively (see below).

Recommended restricted activity dates and setback distances by level of disturbance for burrowing owls (Scobie and Faminow 2000).

Location	Time of Year	Level of Disturbance		
		Low	Med	High
Nesting sites	April 1-Aug 15	200 m*	500 m	500 m
Nesting sites	Aug 16-Oct 15	200 m	200 m	500 m
Nesting sites	Oct 16-Mar 31	50 m	100 m	500 m

* meters (m)

Based on existing vegetation, human development, and land uses in an area, resource managers may decide to allow human development or resource extraction closer to these area/sites than recommended above. However, if it is decided to allow activities closer than the setback distances recommended, a broad-scale, long-term, scientifically-rigorous monitoring program ensures that burrowing owls are not detrimentally affected by alternative approaches.

Other minimization measures include eliminating actions that reduce burrowing owl forage and burrowing surrogates (e.g. ground squirrel), or introduce/facilitate burrowing owl predators. Actions that could influence these factors include reducing livestock grazing rates and/or changing the timing or duration of grazing or vegetation management that could result in less suitable habitat.

Burrow exclusion and closure. Burrow exclusion is a technique of installing one-way doors in burrow openings during the non-breeding season to temporarily exclude burrowing owls, or permanently exclude burrowing owls and close burrows after verifying burrows are empty by site monitoring and scoping. Exclusion in and of itself is not a take avoidance, minimization or mitigation method. Eviction of burrowing owls is a potentially significant impact under CEQA.

The long-term demographic consequences of these techniques have not been thoroughly evaluated, and the fate of evicted or excluded burrowing owls has not been systematically studied. Because burrowing owls are dependent on burrows at all times of the year for survival and/or reproduction, evicting them from nesting, roosting, and satellite burrows may lead to indirect impacts or take. Temporary or permanent closure of burrows may result in significant loss of burrows and habitat for reproduction and other life history requirements. Depending on the proximity and availability of alternate habitat, loss of access to burrows will likely result in varying levels of increased stress on burrowing owls and could depress reproduction, increase predation, increase energetic costs, and introduce risks posed by having to find and compete for available burrows. Therefore, exclusion and burrow closure are not recommended where they can be avoided. The current scientific literature indicates consideration of all possible avoidance and minimization measures before temporary or permanent exclusion and closure of burrows is implemented, in order to avoid take.

The results of a study by Trulio (1995) in California showed that burrowing owls passively displaced from their burrows were quickly attracted to adjacent artificial burrows at five of six passive relocation sites. The successful sites were all within 75 meters (m) of the destroyed burrow, a distance generally within a pair's territory. This researcher discouraged using passive relocation to artificial burrows as a mitigation measure for lost burrows without protection of adjacent foraging habitat. The study results indicated artificial burrows were used by evicted burrowing owls when they were approximately 50-100 m from the natural burrow (Thomsen 1971, Haug and Oliphant 1990). Locating artificial or natural burrows more than 100 m from the eviction burrow may greatly reduce the chances that new burrows will be used. Ideally, exclusion and burrow closure is employed only where there are adjacent natural burrows and non-impacted, sufficient habitat for burrowing owls to occupy with permanent protection mechanisms in place. Any new burrowing owl colonizing the project site after the CEQA document has been adopted may constitute changed circumstances that should be addressed in a re-circulated CEQA document.

The current scientific literature indicates that burrow exclusion should only be conducted by qualified biologists (meeting the Biologist’s Qualifications above) during the non-breeding season, before breeding behavior is exhibited and after the burrow is confirmed empty by site surveillance and/or scoping. The literature also indicates that when temporary or permanent burrow exclusion and/or burrow closure is implemented, burrowing owls should not be excluded from burrows unless or until:

- A Burrowing Owl Exclusion Plan (see Appendix E) is developed and approved by the applicable local DFG office;
- Permanent loss of occupied burrow(s) and habitat is mitigated in accordance with the Mitigating Impacts sections below. Temporary exclusion is mitigated in accordance with the item #1 under Mitigating Impacts below.
- Site monitoring is conducted prior to, during, and after exclusion of burrowing owls from their burrows sufficient to ensure take is avoided. Conduct daily monitoring for one week to confirm young of the year have fledged if the exclusion will occur immediately after the end of the breeding season.
- Excluded burrowing owls are documented using artificial or natural burrows on an adjoining mitigation site (if able to confirm by band re-sight).

Translocation (Active relocation offsite >100 meters). At this time, there is little published information regarding the efficacy of translocating burrowing owls, and additional research is needed to determine subsequent survival and breeding success (Klute et al. 2003, Holroyd et al. 2001). Study results for translocation in Florida implied that hatching success may be decreased for populations of burrowing owls that undergo translocation (Nixon 2006). At this time, the Department is unable to authorize the capture and relocation of burrowing owls except within the context of scientific research (FGC §1002) or a NCCP conservation strategy.

Mitigating impacts. Habitat loss and degradation from rapid urbanization of farmland in the core areas of the Central and Imperial valleys is the greatest of many threats to burrowing owls in California (Shuford and Gardali, 2008). At a minimum, if burrowing owls have been documented to occupy burrows (see Definitions, Appendix B) at the project site in recent years, the current scientific literature supports the conclusion that the site should be considered occupied and mitigation should be required by the CEQA lead agency to address project-specific significant and cumulative impacts. Other site-specific and regionally significant and cumulative impacts may warrant mitigation. The current scientific literature indicates the following to be best practices. If these best practices cannot be implemented, the lead agency or lead investigator may consult with the Department to develop effective mitigation alternatives. The Department is also available to assist in the identification of suitable mitigation lands.

1. Where habitat will be temporarily disturbed, restore the disturbed area to pre-project condition including decompacting soil and revegetating. Permanent habitat protection may be warranted if there is the potential that the temporary impacts may render a nesting site (nesting burrow and satellite burrows) unsustainable or unavailable depending on the time frame, resulting in reduced survival or abandonment. For the latter potential impact, see the permanent impact measures below.
2. Mitigate for permanent impacts to nesting, occupied and satellite burrows and/or burrowing owl habitat such that the habitat acreage, number of burrows and burrowing owls impacted are replaced based on the information provided in Appendix A. Note: A

minimum habitat replacement recommendation is not provided here as it has been shown to serve as a default, replacing any site-specific analysis and discounting the wide variation in natal area, home range, foraging area, and other factors influencing burrowing owls and burrowing owl population persistence in a particular area.

3. Mitigate for permanent impacts to nesting, occupied and satellite burrows and burrowing owl habitat with (a) permanent conservation of similar vegetation communities (grassland, scrublands, desert, urban, and agriculture) to provide for burrowing owl nesting, foraging, wintering, and dispersal (i.e., during breeding and non-breeding seasons) comparable to or better than that of the impact area, and (b) sufficiently large acreage, and presence of fossorial mammals. The mitigation lands may require habitat enhancements including enhancement or expansion of burrows for breeding, shelter and dispersal opportunity, and removal or control of population stressors. If the mitigation lands are located adjacent to the impacted burrow site, ensure the nearest neighbor artificial or natural burrow clusters are at least within 210 meters (Fisher et al. 2007).
4. Permanently protect mitigation land through a conservation easement deeded to a non-profit conservation organization or public agency with a conservation mission, for the purpose of conserving burrowing owl habitat and prohibiting activities incompatible with burrowing owl use. If the project is located within the service area of a Department-approved burrowing owl conservation bank, the project proponent may purchase available burrowing owl conservation bank credits.
5. Develop and implement a mitigation land management plan to address long-term ecological sustainability and maintenance of the site for burrowing owls (see Management Plan and Artificial Burrow sections below, if applicable).
6. Fund the maintenance and management of mitigation land through the establishment of a long-term funding mechanism such as an endowment.
7. Habitat should not be altered or destroyed, and burrowing owls should not be excluded from burrows, until mitigation lands have been legally secured, are managed for the benefit of burrowing owls according to Department-approved management, monitoring and reporting plans, and the endowment or other long-term funding mechanism is in place or security is provided until these measures are completed.
8. Mitigation lands should be on, adjacent or proximate to the impact site where possible and where habitat is sufficient to support burrowing owls present.
9. Where there is insufficient habitat on, adjacent to, or near project sites where burrowing owls will be excluded, acquire mitigation lands with burrowing owl habitat away from the project site. The selection of mitigation lands should then focus on consolidating and enlarging conservation areas located outside of urban and planned growth areas, within foraging distance of other conserved lands. If mitigation lands are not available adjacent to other conserved lands, increase the mitigation land acreage requirement to ensure a selected site is of sufficient size. Offsite mitigation may not adequately offset the biological and habitat values impacted on a one to one basis. Consult with the Department when determining offsite mitigation acreages.
10. Evaluate and select suitable mitigation lands based on a comparison of the habitat attributes of the impacted and conserved lands, including but not limited to: type and structure of habitat being impacted or conserved; density of burrowing owls in impacted and conserved habitat; and significance of impacted or conserved habitat to the species range-wide. Mitigate for the highest quality burrowing owl habitat impacted first and foremost when identifying mitigation lands, even if a mitigation site is located outside of

a lead agency's jurisdictional boundary, particularly if the lead agency is a city or special district.

11. Select mitigation lands taking into account the potential human and wildlife conflicts or incompatibility, including but not limited to, human foot and vehicle traffic, and predation by cats, loose dogs and urban-adapted wildlife, and incompatible species management (i.e., snowy plover).
12. Where a burrowing owl population appears to be highly adapted to heavily altered habitats such as golf courses, airports, athletic fields, and business complexes, permanently protecting the land, augmenting the site with artificial burrows, and enhancing and maintaining those areas may enhance sustainability of the burrowing owl population onsite. Maintenance includes keeping lands grazed or mowed with weed-eaters or push mowers, free from trees and shrubs, and preventing excessive human and human-related disturbance (e.g., walking, jogging, off-road activity, dog-walking) and loose and feral pets (chasing and, presumably, preying upon owls) that make the environment uninhabitable for burrowing owls (Wesemann and Rowe 1985, Millsap and Bear 2000, Lincer and Bloom 2007). Items 4, 5 and 6 also still apply to this mitigation approach.
13. If there are no other feasible mitigation options available and a lead agency is willing to establish and oversee a Burrowing Owl Mitigation and Conservation Fund that funds on a competitive basis acquisition and permanent habitat conservation, the project proponent may participate in the lead agency's program.

Artificial burrows. Artificial burrows have been used to replace natural burrows either temporarily or long-term and their long-term success is unclear. Artificial burrows may be an effective addition to in-perpetuity habitat mitigation if they are augmenting natural burrows, the burrows are regularly maintained (i.e., no less than annual, with biennial maintenance recommended), and surrounding habitat patches are carefully maintained. There may be some circumstances, for example at airports, where squirrels will not be allowed to persist and create a dynamic burrow system, where artificial burrows may provide some support to an owl population.

Many variables may contribute to the successful use of artificial burrows by burrowing owls, including pre-existence of burrowing owls in the area, availability of food, predators, surrounding vegetation and proximity, number of natural burrows in proximity, type of materials used to build the burrow, size of the burrow and entrance, direction in which the burrow entrance is facing, slope of the entrance, number of burrow entrances per burrow, depth of the burrow, type and height of perches, and annual maintenance needs (Belthoff and King 2002, Smith et al. 2005, Barclay et al. 2011). Refer to Barclay (2008) and (2011) and to Johnson et al. 2010 (unpublished report) for guidance on installing artificial burrows including recommendations for placement, installation and maintenance.

Any long-term reliance on artificial burrows as natural burrow replacements must include semi-annual to annual cleaning and maintenance and/or replacement (Barclay et al. 2011, Smith and Conway 2005, Alexander et al. 2005) as an ongoing management practice. Alexander et al. (2005), in a study of the use of artificial burrows found that all of 20 artificial burrows needed some annual cleaning and maintenance. Burrows were either excavated by predators, blocked by soil or vegetation, or experienced substrate erosion forming a space beneath the tubing that prevented nestlings from re-entering the burrow.

Mitigation lands management plan. Develop a Mitigation Lands Management Plan for projects that require off-site or on-site mitigation habitat protection to ensure compliance with and effectiveness of identified management actions for the mitigation lands. A suggested outline and related vegetation management goals and monitoring success criteria can be found in Appendix E.

Mitigation Monitoring and Reporting

Verify the compliance with required mitigation measures, the accuracy of predictions, and ensure the effectiveness of all mitigation measures for burrowing owls by conducting follow-up monitoring, and implementing midcourse corrections, if necessary, to protect burrowing owls. Refer to CEQA Guidelines Section 15097 and the CEQA Guidelines for additional guidance on mitigation, monitoring and reporting. Monitoring is qualitatively different from site surveillance; monitoring normally has a specific purpose and its outputs and outcomes will usually allow a comparison with some baseline condition of the site before the mitigation (including avoidance and minimization) was undertaken. Ideally, monitoring should be based on the Before-After Control-Impact (BACI) principle (McDonald et al. 2000) that requires knowledge of the pre-mitigation state to provide a reference point for the state and change in state after the project and mitigation have been implemented.

ACKNOWLEDGEMENTS

We thank Jack Barclay, Jeff Lincer, David Plumpton, Jeff Kidd, Carol Roberts and other reviewers for their valuable comments on this report. We also want to acknowledge all the hard work of the Department team, especially T. Bartlett, K. Riesz, S. Wilson, D. Gifford, D. Mayer, J. Gan, L. Connolly, D. Mayer, A. Donlan, L. Bauer, L. Comrack, D. Lancaster, E. Burkett, B. Johnson, D. Johnston, A. Gonzales, S. Morey and K. Hunting.

REFERENCES

Alexander, A. K., M. R. Sackschewsky, and C. A. Duberstein. 2005. Use of artificial burrows by burrowing owls (athene cunicularia) at the HAMMER Facility on the U.S. Department of Energy Hanford Site. Pacific Northwest National Lab-15414. U.S. Department of Energy, DE-AC05-76RL01830, Richland, Washington, USA.

BIOS. California Department of Fish and Game. The Biogeographic Information Observation System (http://bios.dfg.ca.gov/)

Barclay, J. H. 2008. A simple artificial burrow design for burrowing owls. Journal of Raptor Research. 42: 53-57.

Barclay, J. H. 2012. Albion Environmental, Inc, personal communication.

Barclay, J. H., K. W. Hunting, J. L. Lincer, J. Linthicum, and T. A. Roberts, editors. 2007. Proceedings of the California Burrowing Owl Symposium, 11-12 November 2003, Sacramento, California, USA. Bird Populations Monographs No. 1. The Institute for Bird Populations and Albion Environmental, Inc., Point Reyes Station, CA.

Barclay, J. H., N. Korfanta, and M. Kauffman. 2011. Long-term population dynamics of a managed burrowing owl colony. Journal of Wildlife Management 75: 1295–1306.

Belthoff, J R., R. A. King. 2002. Nest-site characteristics of burrowing owls (athene cunicularia) in the Snake River Birds of Prey National Conservation Area, Idaho, and applications to artificial burrow installation. Western North American Naturalist 62: 112-119.

Botelho, E. S. 1996. Behavioral ecology and parental care of breeding western burrowing owls (Speotyto cunicularia hupugaea) in southern New Mexico, USA. Dissertation, New Mexico State University, Las Cruces, New Mexico, USA.

Burkett, E. E., and B. S. Johnson. 2007. Development of a conservation strategy for burrowing owls in California. Pages 165-168 *in* J. H. Barclay, K. W. Hunting, J. L. Lincer, J. Linthicum, and T. A. Roberts, editors. Proceedings of the California Burrowing Owl Symposium, 11-12 November 2003, Sacramento, California, USA. Bird Populations Monographs No. 1. The Institute for Bird Populations and Albion Environmental, Inc., Point Reyes Station, CA.

CBOC (California Burrowing Owl Consortium). 1997. Burrowing owl survey protocol and mitigation guidelines. Pages 171-177 *in* Lincer, J. L. and K. Steenhof (editors). 1997. The burrowing owl, its biology and management. Raptor Research Report Number 9.

CDFG (California Department of Fish and Game). 1995. Staff report on burrowing owl mitigation. Unpublished report. Sacramento, California, USA.

CNDDB. California Department of Fish and Game. The California Natural Diversity Database (CNDDB) (http://www.dfg.ca.gov/biogeodata/cnddb/), Sacramento, California, USA.

Catlin, D. H. 2004. Factors affecting within-season and between-season breeding dispersal of Burrowing Owls in California. Thesis, Oregon State University, Corvallis, Oregon, USA

Catlin, D. H., and D. K. Rosenberg. 2006. Nest destruction increases mortality and dispersal of Burrowing Owls in the Imperial Valley, California. Southwest Naturalist 51: 406–409.

Catlin, D. H., D. K. Rosenberg, and K. L. Haley. 2005. The effects of nesting success and mate fidelity on breeding dispersal in burrowing owls. Canadian Journal of Zoology 83:1574–1580.

Conway, C. J., and J. Simon. 2003. Comparison of detection probability associated with burrowing owl survey methods. Journal of Wildlife Management 67: 501-511.

Conway, C. J., V. Garcia, M. D., and K. Hughes. 2008. Factors affecting detection of burrowing owl nests during standardized surveys. Journal of Wildlife Management 72: 688-696.

Coulombe, H. N. 1971. Behavior and population ecology of the burrowing owl, Speotyto cunicularia, in the Imperial Valley of California. Condor 73: 162–176.

Dechant, J. A., M. L. Sondreal, D. H. Johnson, L. D. Igl, C. M. Goldade, P. A. Rabie, and B. R. Euliss. 2003. Effects of management practices on grassland birds: burrowing owl. Northern Prairie Wildlife Research Center, Jamestown, North Dakota. Northern Prairie Wildlife Research Center Online. <http://www.npwrc.usgs.gov/resource/literatr/grasbird/buow/buow.htm>.

DeSante, D. F., E. D Ruhlen, and R. Scalf. 2007. The distribution and relative abundance of burrowing owls in California during 1991–1993: Evidence for a declining population and thoughts on its conservation. Pages 1-41 *in* J. H. Barclay, K. W. Hunting, J. L. Lincer, J. Linthicum, and T. A. Roberts, editors. Proceedings of the California Burrowing Owl Symposium, 11-12 November 2003 Sacramento, California, USA. Bird Populations Monographs No. 1. The Institute for Bird Populations and Albion Environmental, Inc., Point Reyes Station, CA.

Desmond, M. J., and J. A. Savidge. 1998. Burrowing Owl conservation in the Great Plains. Proceedings of the Second International Burrowing Owl Symposium, 29-30 September 1999, Ogden, Utah, USA.

Desmond, M. J., and J. A. Savidge. 1999. Satellite burrow use by burrowing owl chicks and its influence on nest fate. Pages 128-130 *in* P. D. Vickery and J. R. Herkert, editors. Ecology and conservation of grassland birds of the western hemisphere. Studies in Avian Biology 19.

Emlen, J. T. 1977. Estimating breeding season bird densities from transects counts. Auk 94: 455-468.

Fisher, J. B., L. A. Trulio, G. S. Biging, and D. Chromczack. 2007. An analysis of spatial clustering and implications for wildlife management: a burrowing owl example. Environmental Management 39: 403-11.

Gervais, J. A., D. K. Rosenberg, and L. A. Comrack. Burrowing Owl (Athene cunicularia) *in* Shuford, W.D. and T. Gardali, editors. 2008. California Bird Species of Special Concern: A ranked assessment of species, subspecies, and distinct populations of birds of immediate conservation concern in California. Studies of Western Birds 1. Western Field Ornithologists, Camarillo, California, and California Department of Fish and Game, Sacramento, California, USA.

Gervais, J. A., D. K. Rosenberg, R. G. Anthony. 2003. Space use and pesticide exposure risk of male burrowing owls in an agricultural landscape. Journal of Wildlife Management 67: 155-164.

Green, G.A.; Anthony, R.G. 1989. Nesting success and habitat relationships of burrowing owls in the Columbia Basin, Oregon. The Condor 91: 347-354.

Haug, E. A. 1985. Observations on the breeding ecology of burrowing owls in Saskatchewan.

Thesis, University of Saskatchewan, Saskatoon, Saskatchewan, Canada.

Haug, E. A., B. A. Millsap, and M. S. Martell. 1993. Burrowing owl (Speotyto cunicularia), *in* A. Poole and F. Gill, editors, The Birds of North America, The Academy of Natural Sciences, Philadelphia, Pennsylvania, and The American Ornithologists' Union, Washington, D.C., USA.

Haug, E. A., and L. W. Oliphant. 1990. Movements, activity patterns, and habitat use of burrowing owls in Saskatchewan. Journal of Wildlife Management 54: 27-35.

Holroyd, G. L., R. Rodriguez-Estrella, and S. R. Sheffield. 2001. Conservation of the burrowing owl in western North America: issues, challenges, and recommendations. Journal of Raptor Research 35: 399-407.

James, P. C., T. J. Ethier, and M. K. Toutloff. 1997. Parameters of a declining burrowing owl population in Saskatchewan. Pages 34-37. *in* J. L. Lincer, and K. Steenhof, editors. The burrowing owl, its biology and management: including the proceedings of the first international symposium. 13-14 November 1992, Bellevue, WA, USA. Raptor Research Report Number 9.

Johnson, D. H., D. C. Gillis, M. A. Gregg, J. L.Rebholz, J. L. Lincer, and J. R. Belthoff. 2010. Users guide to installation of artificial burrows for burrowing owls. Unpublished report. Tree Top Inc., Selah, Washington, USA.

Klute, D. S., A. W. Ayers, M. T. Green, W. H. Howe, S. L Jones, J. A. Shaffer, S. R. Sheffield, and T. S. Zimmerman. 2003. Status assessment and conservation plan for the western burrowing owl in the United States. U.S. Department of the Interior, Fish and Wildlife Service, Biological Technical Publication FWS/BTP-R6001-2003, Washington, D.C, USA.

Koenig, W. D., D. D. Van Vuren, and P. N. Hooge. 1996. Detectability, philopatry, and the distribution of dispersal distances in vertebrates. Trends in Ecology and Evolution 11: 514–517.

LaFever, D. H., K. E. LaFever, D. H. Catlin, and D. K. Rosenberg. 2008. Diurnal time budget of burrowing owls in a resident population during the non-breeding season. Southwestern Naturalist 53: 29-33.

Lincer, J. L., and P. W. Bloom. 2007. The status of the burrowing owl (Athene cunicularia) in San Diego County, CA. Pages 90-102 *in* Proceedings of the California Burrowing Owl Symposium, 11-12 November 2003, Sacramento, California, USA. Bird Populations Monographs No. 1. The Institute for Bird Populations and Albion Environmental, Inc., Point Reyes Station, CA.

Lutz, R. S. and D. L. Plumpton. 1999. Philopatry and nest site reuse by burrowing owls: implications for management. Journal of Raptor Research 33: 149-153.

MacCracken, J. G., D. W. Uresk, and R. M. Hansen. 1985a. Vegetation and soils of burrowing owl nest sites in Conata Basin, South Dakota. Condor 87: 152-154.

Manning, J. A., and R. S. A. Kaler. 2011. Effects of survey methods on burrowing owl behaviors. Journal of Wildlife Management 75: 525-30.

McDonald, T. L., W. P. Erickson, and L. L. McDonald. 2000. Analysis of count data from before-after control-impact studies. Journal of Agricultural, Biological and Environmental Statistics 5: 262-279.

Millsap, B. A., and C. Bear. 2000. Density and reproduction of burrowing owls along an urban development gradient. Journal of Wildlife Management 64:33-41.

Nixon, P A. 2006. Effects of translocation on the Florida burrowing owl (Athene cunicularia floridana). Thesis. University of South Florida, Tampa, Florida, USA.

Noss, R. F., M. A. O'Connell, and D. D. Murphy. 1997. The science of conservation planning:

habitat conservation under the Endangered Species Act. Island Press, Washington D.C., USA.
Postovit, H. R., and B. C. Postovit. 1987. Impacts and mitigation techniques. Pages 183-213 in Raptor management techniques manual scientific technical series number 10, National Wildlife Federation, Washington, D. C., USA
Remsen, J. V., Jr. 1978. Bird species of special concern in California: An annotated list of declining or vulnerable bird species. California Department of Fish and Game, Nongame Wildlife. Investigations, Wildlife Management Branch Administrative Report 78-1, Sacramento, California, USA.
Rich, T. 1984. Monitoring burrowing owl populations: implications of burrow re-use. Wildlife Society Bulletin 12: 178-189.
Richardson, C. T. and C. K. Miller. 1997. Recommendations for protecting raptors from human disturbance: a review. Wildlife Society Bulletin 25: 634-38.
Ronan, N. A. 2002. Habitat selection, reproductive success, and site fidelity of burrowing owls in a grassland ecosystem. Thesis, Oregon State University, Corvallis, Oregon, USA.
Rosenberg, D., 2009 Oregon State University, Corvallis, personal communication.
Rosenberg, D. K., J. A. Gervais, D. F. DeSante, and H. Ober. 2009. An updated adaptive management plan for the burrowing owl population at NAS Lemoore. The Oregon Wildlife Institute, Corvallis, OR and The Institute for Bird Populations, Point Reyes Station, CA. OWI Contribution No. 201 and IBP Contribution No. 375.
Rosenberg, D. K., J. A. Gervais, H. Ober, and D. F. DeSante. 1998. An adaptive management plan for the burrowing owl population at Naval Air Station Lemoore, California, USA. Publication 95, Institute for Bird Populations, P.O. Box 1346, Pt. Reyes Station, CA 94956.
Rosenberg, D. K., and K. L. Haley. 2004. The ecology of burrowing owls in the agroecosystem of the Imperial Valley, California. Studies in Avian Biology 27:120-135.
Rosenberg, D. K., L. A. Trulio, D. H. Catlin, D. Chromczack, J. A. Gervais, N. Ronan, and K. A. Haley. 2007. The ecology of the burrowing owl in California, unpublished report to Bureau of Land Management.
Rosier, J. R., N. A., Ronan, and D. K. Rosenberg. 2006. Post-breeding dispersal of burrowing owls in an extensive California grassland. American Midland Naturalist 155: 162–167.
Sawyer, J. O., T. Keeler-Wolf, and J. M. Evens. 2009. A manual of California vegetation, Second edition. California Native Plant Society, Sacramento, California, USA.
Scobie, D., and C. Faminow. 2000. Development of standardized guidelines for petroleum industry activities that affect COSEWIC Prairie and Northern Region vertebrate species at risk. Environment Canada, Prairie and Northern Region, Edmonton, Alberta, Canada.
Shuford, W. D. and T. Gardali, editors. 2008. California Bird Species of Special Concern: a ranked assessment of species, subspecies, and distinct populations of birds of immediate conservation concern in California. Studies of Western Birds 1. Western Field Ornithologists, Camarillo, California, and California Department of Fish and Game, Sacramento. Gervais, J. A., D. K. Rosenberg, and L. Comrack. 2008. Burrowing Owl (Athene cunicularia).
Smith, M. D., C. J. Conway, and L. A. Ellis. 2005. Burrowing owl nesting productivity: a comparison between artificial and natural burrows on and off golf courses. Wildlife Society Bulletin 33: 454-462.
Thelander, C. G., K. S. Smallwood, and L. Rugge. 2003. Bird risk behaviors and fatalities at the Altamont Pass Wind Resource Area, period of performance: March 1998–

December 2000. U.S. Department of Energy, National Renewable Energy Laboratory, Golden, Colorado, USA.

Thomsen, L. 1971. Behavior and ecology of burrowing owls on the Oakland Municipal Airport. Condor 73: 177-192.

Thompson, C. D. 1984. Selected aspects of burrowing owl ecology in central Wyoming. Thesis, University of Wyoming, Laramie, Wyoming, USA.

Trulio, L. 1995. Passive relocation: A method to preserve burrowing owls on disturbed sites. Journal of Field Ornithology 66: 99–106.

U.S. Fish and Wildlife Service (USFWS). 2002. Birds of conservation concern 2002. U.S. Department of Interior, Division of Migratory Bird Management, Arlington, Virginia, USA.

U.S. Fish and Wildlife Service (USFWS). 2008. Birds of Conservation Concern 2008. U.S. Department of Interior, Division of Migratory Bird Management, Arlington, Virginia, USA.

Wesemann, T. and M. Rowe. 1985. Factors influencing the distribution and abundance of burrowing owls in Cape Coral, Florida. Pages 129-137 *in* L. W. Adams and D. L. Leedy, editors. Integrating Man and Nature in the Metropolitan Environment. Proceedings National Symposium. on Urban Wildlife, 4-7 November 1986, Chevy Chase, Maryland, USA.

Wilkerson, R. L. and R. B. Siegel. 2010. Assessing changes in the distribution and abundance of burrowing owls in California, 1993-2007. Bird Populations 10: 1-36.

Zarn, M. 1974. Burrowing owl. U.S. Department of the Interior, Bureau of Land Management. Technical Note T-N-250, Denver, Colorado, USA.

Appendix A. Burrowing Owl Natural History and Threats

Diet

Burrowing owl diet includes arthropods, small rodents, birds, amphibians, reptiles, and carrion (Haug et al. 1993).

Breeding

In California, the breeding season for the burrowing owl typically occurs between 1 February and 31 August although breeding in December has been documented (Thompson 1971, Gervais et al. 2008); breeding behavior includes nest site selection by the male, pair formation, copulation, egg laying, hatching, fledging, and post-fledging care of young by the parents. The peak of the breeding season occurs between 15 April and 15 July and is the period when most burrowing owls have active nests (eggs or young). The incubation period lasts 29 days (Coulombe 1971) and young fledge after 44 days (Haug et al. 1993). Note that the timing of nesting activities may vary with latitude and climatic conditions. Burrowing owls may change burrows several times during the breeding season, starting when nestlings are about three weeks old (Haug et al. 1993).

Dispersal

The following discussion is an excerpt from Gervais et al (2008):

> "The burrowing owl is often considered a sedentary species (e.g., Thomsen 1971). A large proportion of adults show strong fidelity to their nest site from year to year, especially where resident, as in Florida (74% for females, 83% for males; Millsap and Bear 1997). In California, nest-site fidelity rates were 32%–50% in a large grassland and 57% in an agricultural environment (Ronan 2002, Catlin 2004, Catlin et al. 2005). Differences in these rates among sites may reflect differences in nest predation rates (Catlin 2004, Catlin et al. 2005). Despite the high nest fidelity rates, dispersal distances may be considerable for both juveniles (natal dispersal) and adults (postbreeding dispersal), but this also varied with location (Catlin 2004, Rosier et al. 2006). Distances of 53 km to roughly 150 km have been observed in California for adult and natal dispersal, respectively (D. K. Rosenberg and J. A. Gervais, unpublished data), despite the difficulty in detecting movements beyond the immediate study area (Koenig et al. 1996)."

Habitat

The burrowing owl is a small, long-legged, ground-dwelling bird species, well-adapted to open, relatively flat expanses. In California, preferred habitat is generally typified by short, sparse vegetation with few shrubs, level to gentle topography and well-drained soils (Haug et al. 1993). Grassland, shrub steppe, and desert are naturally occurring habitat types used by the species. In addition, burrowing owls may occur in some agricultural areas, ruderal grassy fields, vacant lots and pastures if the vegetation structure is suitable and there are useable burrows and foraging habitat in proximity (Gervais et al 2008). Unique amongst North

American raptors, the burrowing owl requires underground burrows or other cavities for nesting during the breeding season and for roosting and cover, year round. Burrows used by the owls are usually dug by other species termed host burrowers. In California, California ground squirrel (*Spermophilus beecheyi*) and round-tailed ground squirrel (*Citellus tereticaudus*) burrows are frequently used by burrowing owls but they may use dens or holes dug by other fossorial species including badger (*Taxidea taxus*), coyote (*Canis latrans*), and fox (e.g., San Joaquin kit fox, *Vulpes macrotis mutica*; Ronan 2002). In some instances, owls have been known to excavate their own burrows (Thompson 1971, Barclay 2007). Natural rock cavities, debris piles, culverts, and pipes also are used for nesting and roosting (Rosenberg et al. 1998). Burrowing owls have been documented using artificial burrows for nesting and cover (Smith and Belthoff, 2003).

Foraging habitat. Foraging habitat is essential to burrowing owls. The following discussion is an excerpt from Gervais et al. (2008):

> "Useful as a rough guide to evaluating project impacts and appropriate mitigation for burrowing owls, adult male burrowing owls home ranges have been documented (calculated by minimum convex polygon) to comprise anywhere from 280 acres in intensively irrigated agroecosystems in Imperial Valley (Rosenberg and Haley 2004) to 450 acres in mixed agricultural lands at Lemoore Naval Air Station, CA (Gervais et al. 2003), to 600 acres in pasture in Saskatchewan, Canada (Haug and Oliphant 1990). But owl home ranges may be much larger, perhaps by an order of magnitude, in non-irrigated grasslands such as at Carrizo Plain, California (Gervais et al. 2008), based on telemetry studies and distribution of nests. Foraging occurs primarily within 600 m of their nests (within approximately 300 acres, based on a circle with a 600 m radius) during the breeding season."

Importance of burrows and adjacent habitat. Burrows and the associated surrounding habitat are essential ecological requisites for burrowing owls throughout the year and especially during the breeding season. During the non-breeding season, burrowing owls remain closely associated with burrows, as they continue to use them as refuge from predators, shelter from weather and roost sites. Resident populations will remain near the previous season's nest burrow at least some of the time (Coulombe 1971, Thomsen 1971, Botelho 1996, LaFever et al. 2008).

In a study by Lutz and Plumpton (1999) adult males and females nested in formerly used sites at similar rates (75% and 63%, respectively) (Lutz and Plumpton 1999). Burrow fidelity has been reported in some areas; however, more frequently, burrowing owls reuse traditional nesting areas without necessarily using the same burrow (Haug et al. 1993, Dechant et al. 1999). Burrow and nest sites are re-used at a higher rate if the burrowing owl has reproduced successfully during the previous year (Haug et al. 1993) and if the number of burrows isn't limiting nesting opportunity.

Burrowing owls may use "satellite" or non-nesting burrows, moving young at 10-14 days, presumably to reduce risk of predation (Desmond and Savidge 1998) and possibly to avoid nest parasites (Dechant et al. 1999). Successful nests in Nebraska had more active satellite burrows within 75 m of the nest burrow than unsuccessful nests (Desmond and Savidge

1999). Several studies have documented the number of satellite burrows used by young and adult burrowing owls during the breeding season as between one and 11 burrows with an average use of approximately five burrows (Thompsen 1984, Haug 1985, Haug and Oliphant 1990). Supporting the notion of selecting for nest sites near potential satellite burrows, Ronan (2002) found burrowing owl families would move away from a nest site if their satellite burrows were experimentally removed through blocking their entrance.

Habitat adjacent to burrows has been documented to be important to burrowing owls. Gervais et al. (2003) found that home range sizes of male burrowing owls during the nesting season were highly variable within but not between years. Their results also suggested that owls concentrate foraging efforts within 600 meters of the nest burrow, as was observed in Canada (Haug and Oliphant 1990) and southern California (Rosenberg and Haley 2004). James et al. (1997), reported habitat modification factors causing local burrowing owl declines included habitat fragmentation and loss of connectivity.

In conclusion, the best available science indicates that essential habitat for the burrowing owl in California must include suitable year-round habitat, primarily for breeding, foraging, wintering and dispersal habitat consisting of short or sparse vegetation (at least at some time of year), presence of burrows, burrow surrogates or presence of fossorial mammal dens, well-drained soils, and abundant and available prey within close proximity to the burrow.

Threats to Burrowing Owls in California

Habitat loss. Habitat loss, degradation, and fragmentation are the greatest threats to burrowing owls in California. According to DeSante et al. (2007), “the vast majority of burrowing owls [now] occur in the wide, flat lowland valleys and basins of the Imperial Valley and Great Central Valley [where] for the most part,...the highest rates of residential and commercial development in California are occurring.” Habitat loss from the State’s long history of urbanization in coastal counties has already resulted in either extirpation or drastic reduction of burrowing owl populations there (Gervais et al. 2008). Further, loss of agricultural and other open lands (such as grazed landscapes) also negatively affect owl populations. Because of their need for open habitat with low vegetation, burrowing owls are unlikely to persist in agricultural lands dominated by vineyards and orchards (Gervais et al. 2008).

Control of burrowing rodents. According to Klute et al. (2003), the elimination of burrowing rodents through control programs is a primary factor in the recent and historical decline of burrowing owl populations nationwide. In California, ground squirrel burrows are most often used by burrowing owls for nesting and cover; thus, ground squirrel control programs may affect owl numbers in local areas by eliminating a necessary resource.

Direct mortality. Burrowing owls suffer direct losses from a number of sources. Vehicle collisions are a significant source of mortality especially in the urban interface and where owls nest alongside roads (Haug et al. 1993, Gervais et al. 2008). Road and ditch maintenance, modification of water conveyance structures (Imperial Valley) and discing to control weeds in fallow fields may destroy burrows (Rosenberg and Haley 2004, Catlin and Rosenberg 2006) which may trap or crush owls. Wind turbines at Altamont Pass Wind Resource Area are known to cause direct burrowing owl mortality (Thelander et al. 2003). Exposure to pesticides may pose a threat to the species but is poorly understood (Klute et al. 2003, Gervais et al. 2008).

Appendix B. Definitions

Some key terms that appear in this document are defined below.

Adjacent habitat means burrowing owl habitat that abuts the area where habitat and burrows will be impacted and rendered non-suitable for occupancy.

Breeding (nesting) season begins as early as 1 February and continues through 31 August (Thomsen 1971, Zarn 1974). The timing of breeding activities may vary with latitude and climatic conditions. The breeding season includes pairing, egg-laying and incubation, and nestling and fledging stages.

Burrow exclusion is a technique of installing one-way doors in burrow openings during the non-breeding season to temporarily exclude burrowing owls or permanently exclude burrowing owls and excavate and close burrows after confirming burrows are empty.

Burrowing owl habitat generally includes, but is not limited to, short or sparse vegetation (at least at some time of year), presence of burrows, burrow surrogates or presence of fossorial mammal dens, well-drained soils, and abundant and available prey.

Burrow surrogates include culverts, piles of concrete rubble, piles of soil, burrows created along soft banks of ditches and canals, pipes, and similar structures.

Civil twilight - Morning civil twilight begins when the geometric center of the sun is 6 degrees below the horizon (civil dawn) and ends at sunrise. Evening civil twilight begins at sunset and ends when the geometric center of the sun reaches 6 degrees below the horizon (civil dusk). During this period there is enough light from the sun that artificial sources of light may not be needed to carry on outdoor activities. This concept is sometimes enshrined in laws, for example, when drivers of automobiles must turn on their headlights (called lighting-up time in the UK); when pilots may exercise the rights to fly aircraft. Civil twilight can also be described as the limit at which twilight illumination is sufficient, under clear weather conditions, for terrestrial objects to be clearly distinguished; at the beginning of morning civil twilight, or end of evening civil twilight, the horizon is clearly defined and the brightest stars are visible under clear atmospheric conditions.

Conservation for burrowing owls may include but may not be limited to protecting remaining breeding pairs or providing for population expansion, protecting and enhancing breeding and essential habitat, and amending or augmenting land use plans to stabilize populations and other specific actions to avoid the need to list the species pursuant to California or federal Endangered Species Acts.

Contiguous means connected together so as to form an uninterrupted expanse in space.

Essential habitat includes nesting, foraging, wintering, and dispersal habitat.

Foraging habitat is habitat within the estimated home range of an occupied burrow, supports suitable prey base, and allows for effective hunting.

Host burrowers include ground squirrels, badgers, foxes, coyotes, gophers etc.

Locally significant species is a species that is not rare from a statewide perspective but is rare or uncommon in a local context such as within a county or region (CEQA §15125 (c)) or is so designated in local or regional plans, policies, or ordinances (CEQA Guidelines, Appendix G). Examples include a species at the outer limits of its known range or occurring in a unique habitat type.

Non-breeding season is the period of time when nesting activity is not occurring, generally September 1 through January 31, but may vary with latitude and climatic conditions.

Occupied site or occupancy means a site that is assumed occupied if at least one burrowing owl has been observed occupying a burrow within the last three years (Rich 1984). Occupancy of suitable burrowing owl habitat may also be indicated by owl sign including its molted feathers, cast pellets, prey remains, eggshell fragments, or excrement at or near a burrow entrance or perch site.

Other impacting activities may include but may not be limited to agricultural practices, vegetation management and fire control, pest management, conversion of habitat from rangeland or natural lands to more intensive agricultural uses that could result in “take”. These impacting activities may not meet the definition of a project under CEQA.

Passive relocation is a technique of installing one-way doors in burrow openings to temporarily or permanently evict burrowing owls and prevent burrow re-occupation.

Peak of the breeding season is between 15 April and 15 July.

Sign includes its tracks, molted feathers, cast pellets (defined as 1-2” long brown to black regurgitated pellets consisting of non-digestible portions of the owls’ diet, such as fur, bones, claws, beetle elytra, or feathers), prey remains, egg shell fragments, owl white wash, nest burrow decoration materials (e.g., paper, foil, plastic items, livestock or other animal manure, etc.), possible owl perches, or other items.

Appendix C. Habitat Assessment and Reporting Details

Habitat Assessment Data Collection and Reporting

Current scientific literature indicates that it would be most effective to gather the data in the manner described below when conducting project scoping, conducting a habitat assessment site visit and preparing a habitat assessment report:

1. Conduct at least one visit covering the entire potential project/activity area including areas that will be directly or indirectly impacted by the project. Survey adjoining areas within 150 m (Thomsen 1971, Martin 1973), or more where direct or indirect effects could potentially extend offsite. If lawful access cannot be achieved to adjacent areas, surveys can be performed with a spotting scope or other methods.
2. Prior to the site visit, compile relevant biological information for the site and surrounding area to provide a local and regional context.
3. Check all available sources for burrowing owl occurrence information regionally prior to a field inspection. The CNDDB and BIOS (see References cited) may be consulted for known occurrences of burrowing owls. Other sources of information include, but are not limited to, the Proceedings of the California Burrowing Owl Symposium (Barclay et al. 2007), county bird atlas projects, Breeding Bird Survey records, eBIRD (http://ebird.org), Gervais et al. (2008), local reports or experts, museum records, and other site-specific relevant information.
4. Identify vegetation and habitat types potentially supporting burrowing owls in the project area and vicinity.
5. Record and report on the following information:
    a. A full description of the proposed project, including but not limited to, expected work periods, daily work schedules, equipment used, activities performed (such as drilling, construction, excavation, etc.) and whether the expected activities will vary in location or intensity over the project's timeline;
    b. A regional setting map, showing the general project location relative to major roads and other recognizable features;
    c. A detailed map (preferably a USGS topo 7.5' quad base map) of the site and proposed project, including the footprint of proposed land and/or vegetation-altering activities, base map source, identifying topography, landscape features, a north arrow, bar scale, and legend;
    d. A written description of the biological setting, including location (Section, Township, Range, baseline and meridian), acreage, topography, soils, geographic and hydrologic characteristics, land use and management history on and adjoining the site (i.e., whether it is urban, semi-urban or rural; whether there is any evidence of past or current livestock grazing, mowing, disking, or other vegetation management activities);
    e. An analysis of any relevant, historical information concerning burrowing owl use or occupancy (breeding, foraging, over-wintering) on site or in the assessment area;
    f. Vegetation type and structure (using Sawyer et al. 2009), vegetation height, habitat types and features in the surrounding area plus a reasonably sized (as supported with logical justification) assessment area; (Note: use caution in discounting habitat based on grass height as it can be a temporary condition variable by season and conditions (such as current grazing regime) or may be distributed as a mosaic).

g. The presence of burrowing owl individuals or pairs or sign (see Appendix B);
h. The presence of suitable burrows and/or burrow surrogates (>11 cm in diameter (height and width) and >150 cm in depth) (Johnson et al. 2010), regardless of a lack of any burrowing owl sign and/or burrow surrogates; and burrowing owls and/or their sign that have recently or historically (within the last 3 years) been identified on or adjacent to the site.

Appendix D. Breeding and Non-breeding Season Surveys and Reports

Current scientific literature indicates that it is most effective to conduct breeding and non-breeding season surveys and report in the manner that follows:

Breeding Season Surveys

Number of visits and timing. Conduct 4 survey visits: 1) at least one site visit between 15 February and 15 April, and 2) a minimum of three survey visits, at least three weeks apart, between 15 April and 15 July, with at least one visit after 15 June. Note: many burrowing owl migrants are still present in southwestern California during mid-March, therefore, exercise caution in assuming breeding occupancy early in the breeding season.

Survey method. Rosenberg et al. (2007) confirmed walking line transects were most effective in smaller habitat patches. Conduct surveys in all portions of the project site that were identified in the Habitat Assessment and fit the description of habitat in Appendix A. Conduct surveys by walking straight-line transects spaced 7 m to 20 m apart, adjusting for vegetation height and density (Rosenberg et al. 2007). At the start of each transect and, at least, every 100 m, scan the entire visible project area for burrowing owls using binoculars. During walking surveys, record all potential burrows used by burrowing owls as determined by the presence of one or more burrowing owls, pellets, prey remains, whitewash, or decoration. Some burrowing owls may be detected by their calls, so observers should also listen for burrowing owls while conducting the survey.

Care should be taken to minimize disturbance near occupied burrows during all seasons and not to “flush” burrowing owls especially if predators are present to reduce any potential for needless energy expenditure or burrowing owl mortality. Burrowing owls may flush if approached by pedestrians within 50 m (Conway et al. 2003). If raptors or other predators are present that may suppress burrowing owl activity, return at another time or later date for a follow-up survey.

Check all burrowing owls detected for bands and/or color bands and report band combinations to the Bird Banding Laboratory (BBL). Some site-specific variations to survey methods discussed below may be developed in coordination with species experts and Department staff.

Weather conditions. Poor weather may affect the surveyor’s ability to detect burrowing owls, therefore, avoid conducting surveys when wind speed is >20 km/hr, and there is precipitation or dense fog. Surveys have greater detection probability if conducted when ambient temperatures are >20º C, <12 km/hr winds, and cloud cover is <75% (Conway et al. 2008).

Time of day. Daily timing of surveys varies according to the literature, latitude, and survey method. However, surveys between morning civil twilight and 10:00 AM and two hours before sunset until evening civil twilight provide the highest detection probabilities (Barclay pers. comm. 2012, Conway et al. 2008).

Alternate methods. If the project site is large enough to warrant an alternate method, consult current literature for generally accepted survey methods and consult with the Department on the proposed survey approach.

Additional breeding season site visits. Additional breeding season site visits may be necessary, especially if non-breeding season exclusion methods are contemplated. Detailed information, such as approximate home ranges of each individual or of family units, as well as foraging areas as related to the proposed project, will be important to document for evaluating impacts, planning avoidance measure implementation and for mitigation measure performance monitoring.

Adverse conditions may prevent investigators from determining presence or occupancy. Disease, predation, drought, high rainfall or site disturbance may preclude presence of burrowing owls in any given year. Any such conditions should be identified and discussed in the survey report. Visits to the site in more than one year may increase the likelihood of detection. Also, visits to adjacent known occupied habitat may help determine appropriate survey timing.

Given the high site fidelity shown by burrowing owls (see Appendix A, Importance of burrows), conducting surveys over several years may be necessary when project activities are ongoing, occur annually, or start and stop seasonally. (See Negative surveys).

Non-breeding Season Surveys

If conducting non-breeding season surveys, follow the methods described above for breeding season surveys, but conduct at least four (4) visits, spread evenly, throughout the non-breeding season. Burrowing owl experts and local Department staff are available to assist with interpreting results.

Negative Surveys

Adverse conditions may prevent investigators from documenting presence or occupancy. Disease, predation, drought, high rainfall or site disturbance may preclude presence of burrowing owl in any given year. Discuss such conditions in the Survey Report. Visits to the site in more than one year increase the likelihood of detection and failure to locate burrowing owls during one field season does not constitute evidence that the site is no longer occupied, particularly if adverse conditions influenced the survey results. Visits to other nearby known occupied sites can affirm whether the survey timing is appropriate.

Take Avoidance Surveys

Field experience from 1995 to present supports the conclusion that it would be effective to complete an initial take avoidance survey no less than 14 days prior to initiating ground disturbance activities using the recommended methods described in the Detection Surveys section above. Implementation of avoidance and minimization measures would be triggered by positive owl presence on the site where project activities will occur. The development of avoidance and minimization approaches would be informed by monitoring the burrowing owls.

Burrowing owls may re-colonize a site after only a few days. Time lapses between project activities trigger subsequent take avoidance surveys including but not limited to a final survey conducted within 24 hours prior to ground disturbance.

Survey Reports

Report on the survey methods used and results including the information described in the Summary Report and include the reports within the CEQA documentation:

1. Date, start and end time of surveys including weather conditions (ambient temperature, wind speed, percent cloud cover, precipitation and visibility);
2. Name(s) of surveyor(s) and qualifications;
3. A discussion of how the timing of the survey affected the comprehensiveness and detection probability;
4. A description of survey methods used including transect spacing, point count dispersal and duration, and any calls used;
5. A description and justification of the area surveyed relative to the project area;
6. A description that includes: number of owls or nesting pairs at each location (by nestlings, juveniles, adults, and those of an unknown age), number of burrows being used by owls, and burrowing owl sign at burrows. Include a description of individual markers, such as bands (numbers and colors), transmitters, or unique natural identifying features. If any owls are banded, request documentation from the BBL and bander to report on the details regarding the known history of the banded burrowing owl(s) (age, sex, origins, whether it was previously relocated) and provide with the report if available;
7. A description of the behavior of burrowing owls during the surveys, including feeding, resting, courtship, alarm, territorial defense, and those indicative of parents or juveniles;
8. A list of possible burrowing owl predators present and documentation of any evidence of predation of owls;
9. A detailed map (1:24,000 or closer to show details) showing locations of all burrowing owls, potential burrows, occupied burrows, areas of concentrated burrows, and burrowing owl sign. Locations documented by use of global positioning system (GPS) coordinates must include the datum in which they were collected. The map should include a title, north arrow, bar scale and legend;
10. Signed field forms, photos, etc., as appendices to the field survey report;
11. Recent color photographs of the proposed project or activity site; and
12. Original CNDDB Field Survey Forms should be sent directly to the Department's CNDDB office, and copies should be included in the environmental document as an appendix. (http://www.dfg.ca.gov/bdb/html/cnddb.html).

Appendix E. Example Components for Burrowing Owl Artificial Burrow and Exclusion Plans

Whereas the Department does not recommend exclusion and burrow closure, current scientific literature and experience from 1995 to present, indicate that the following example components for burrowing owl artificial burrow and exclusion plans, combined with consultation with the Department to further develop these plans, would be effective.

Artificial Burrow Location

If a burrow is confirmed occupied on-site, artificial burrow locations should be appropriately located and their use should be documented taking into consideration:

1. A brief description of the project and project site pre-construction;
2. The mitigation measures that will be implemented;
3. Potential conflicting site uses or encumbrances;
4. A comparison of the occupied burrow site(s) and the artificial burrow site(s) (e.g., vegetation, habitat types, fossorial species use in the area, and other features);
5. Artificial burrow(s) proximity to the project activities, roads and drainages;
6. Artificial burrow(s) proximity to other burrows and entrance exposure;
7. Photographs of the site of the occupied burrow(s) and the artificial burrows;
8. Map of the project area that identifies the burrow(s) to be excluded as well as the proposed sites for the artificial burrows;
9. A brief description of the artificial burrow design;
10. Description of the monitoring that will take place during and after project implementation including information that will be provided in a monitoring report.
11. A description of the frequency and type of burrow maintenance.

Exclusion Plan

An Exclusion Plan addresses the following including but not limited to:

1. Confirm by site surveillance that the burrow(s) is empty of burrowing owls and other species preceding burrow scoping;
2. Type of scope and appropriate timing of scoping to avoid impacts;
3. Occupancy factors to look for and what will guide determination of vacancy and excavation timing (one-way doors should be left in place 48 hours to ensure burrowing owls have left the burrow before excavation, visited twice daily and monitored for evidence that owls are inside and can't escape i.e., look for sign immediately inside the door).
4. How the burrow(s) will be excavated. Excavation using hand tools with refilling to prevent reoccupation is preferable whenever possible (may include using piping to stabilize the burrow to prevent collapsing until the entire burrow has been excavated and it can be determined that no owls reside inside the burrow);
5. Removal of other potential owl burrow surrogates or refugia on site;
6. Photographing the excavation and closure of the burrow to demonstrate success and sufficiency;

7. Monitoring of the site to evaluate success and, if needed, to implement remedial measures to prevent subsequent owl use to avoid take;
8. How the impacted site will continually be made inhospitable to burrowing owls and fossorial mammals (e.g., by allowing vegetation to grow tall, heavy disking, or immediate and continuous grading) until development is complete.

Appendix F. Mitigation Management Plan and Vegetation Management Goals

Mitigation Management Plan

A mitigation site management plan will help ensure the appropriate implementation and maintenance for the mitigation site and persistence of the burrowing owls on the site. For an example to review, refer to Rosenberg et al. (2009). The current scientific literature and field experience from 1995 to present indicate that an effective management plan includes the following:

1. Mitigation objectives;
2. Site selection factors (including a comparison of the attributes of the impacted and conserved lands) and baseline assessment;
3. Enhancement of the conserved lands (enhancement of reproductive capacity, enhancement of breeding areas and dispersal opportunities, and removal or control of population stressors);
4. Site protection method and prohibited uses;
5. Site manager roles and responsibilities;
6. Habitat management goals and objectives:
    a. Vegetation management goals,
        i. Vegetation management tools:
            1. Grazing
            2. Mowing
            3. Burning
            4. Other
    b. Management of ground squirrels and other fossorial mammals,
    c. Semi-annual and annual artificial burrow cleaning and maintenance,
    d. Non-natives control – weeds and wildlife,
    e. Trash removal;
7. Financial assurances:
    a. Property analysis record or other financial analysis to determine long-term management funding,
    b. Funding schedule;
8. Performance standards and success criteria;
9. Monitoring, surveys and adaptive management;
10. Maps;
11. Annual reports.

Vegetation Management Goals

- Manage vegetation height and density (especially in immediate proximity to burrows). Suitable vegetation structure varies across sites and vegetation types, but should generally be at the average effective vegetation height of 4.7 cm (Green and Anthony 1989) and <13 cm average effective vegetation height (MacCracken et al. 1985*a)*.
- Employ experimental prescribed fires (controlled, at a small scale) to manage vegetation structure;

- Vegetation reduction or ground disturbance timing, extent, and configuration should avoid take. While local ordinances may require fire prevention through vegetation management, activities like disking, mowing, and grading during the breeding season can result in take of burrowing owls and collapse of burrows, causing nest destruction. Consult the take avoidance surveys section above for pre-management avoidance survey recommendations;
- Promote natural prey distribution and abundance, especially in proximity to occupied burrows; and
- Promote self-sustaining populations of host burrowers by limiting or prohibiting lethal rodent control measures and by ensuring food availability for host burrowers through vegetation management.

Refer to Rosenberg et al. (2009) for a good discussion of managing grasslands for burrowing owls.

Mitigation Site Success Criteria

In order to evaluate the success of mitigation and management strategies for burrowing owls, monitoring is required that is specific to the burrowing owl management plan. Given limited resources, Barclay et al. (2011) suggests managers focus on accurately estimating annual adult owl populations rather than devoting time to estimating reproduction, which shows high annual variation and is difficult to accurately estimate. Therefore, the key objective will be to determine accurately the number of adult burrowing owls and pairs, and if the numbers are maintained. A frequency of 5-10 years for surveys to estimate population size may suffice if there are no changes in the management of the nesting and foraging habitat of the owls.

Effective monitoring and evaluation of off-site and on-site mitigation management success for burrowing owls includes (Barclay, pers. comm.):

- Site tenacity;
- Number of adult owls present and reproducing;
- Colonization by burrowing owls from elsewhere (by band re-sight);
- Evidence and causes of mortality;
- Changes in distribution; and
- Trends in stressors.

http://www.dailyinterlake.com/news/local_montana/train-kills-grizzly-bear/article_2c4c6c0b-6ccb-5313-9f21-5a0f1dbaa726.html?mode=jqm

Train kills grizzly bear

Updated 5 months ago

The Daily Inter Lake

Apr 17, 2014 - A 500-pound grizzly bear has been hit and killed by a train on the west shore of Whitefish Lake, and a female grizzly caught in the Foothill Road area has been relocated.

The 7-year-old male bear's carcass was picked up by Tim Manley, a Montana Fish, Wildlife and Parks grizzly bear manager, and BNSF Railway employees on July 3.

The bear was a transplant, originally captured near Simms last fall after getting into beehives along the Sun River. The bear was relocated to the Marias Pass area and it was last located in the Great Bear Wilderness last October.

On July 5, Manley captured the yearling female on private land near Krause Creek. He said the 120-pound bear had been getting into garbage and dog food in the Foothill Road and Echo Lake areas.

The same bear was captured several weeks ago in the same area and moved to the Wounded Buck Creek Area on the east slopes of the Swan Range, in hopes of reuniting the bear with its radio-collared mother.

This time the bear was moved farther north and released in the Whale Creek area of the North Fork Flathead River drainage.

http://www.dailyinterlake.com/news/local_montana/transplanted-female-grizzly-may-have-been-killed-by-train/article_30161e3c-f468-54b2-b4cc-7b03226ed35f.html?mode=jqm

Transplanted female grizzly may have been killed by train

Updated 4 months ago

The Daily Inter Lake

Apr 22, 2014 - Two dead grizzly bears recently have been found by wildlife officials in Northwest Montana.

One is a young female bear that was relocated to the Cabinet Mountains as part of a population augmentation program.

The 3-year-old grizzly was found in the Clark Fork River west of Noxon, and was most likely hit by a train on tracks that skirt the river.

Montana Fish, Wildlife and Parks Warden Sgt. Jon Obst and Wayne Kasworm, a biologist with the U.S. Fish and Wildlife Service, recovered the carcass after Montana Rail Link reported that a train had possibly hit a bear the night of Oct. 20. A signal from a GPS collar on the bear helped them find the carcass.

The bear was X-rayed in Kalispell, determining that there was no evidence it had been shot.

The bear had been captured and moved July 24 from the Stillwater drainage near Trego to the Cabinet Mountains as part of a program aimed at boosting the region's imperiled grizzly bear population.

Several bears have been moved in the last couple of years from the Northern Continental Divide Ecosystem to the Cabinet-Yaak grizzly bear recovery area.

State and federal wardens also are investigating the death of another grizzly bear that was found dead on Oct. 24 in the Fishtrap drainage of the Thompson River, about 18 miles north of Thompson Falls. The bear's carcass was significantly decomposed.

Those with any information related to the bear's death are urged to contact Warden Captain Lee Anderson at 751-4561 or the U.S. Fish and Wildlife Service in Missoula at 329-3000 or by dialing 1-800-TIP-MONT.

Callers may be eligible for a reward.

SPATIAL AND TEMPORAL CORRELATES TO NORWEGIAN MOOSE - TRAIN COLLISIONS

Hege Gundersen[1], Harry P. Andreassen[1], and Torstein Storaas[2]

[1]Department of Biology, Division of Zoology, University of Oslo, P. O. Box 1050 Blindern, N-0316 Oslo, Norway; [2]Hedmark College, Department of Forestry and Wilderness Management, Evenstad, N-2480 Koppang, Norway

ABSTRACT: We have analyzed how temporal variation (i.e., climatic factors and moose (*Alces alces*) population density) and spatial variation (i.e., landscape pattern and food availability) correlate with moose - train collisions along the railway running through the Østerdalen valley in SE Norway. A total of 1,177 train kills were registered from July 1985 to March 1997. The number of collisions increased with increasing snow depth and colder ambient temperature, and were located with the outlets of side valleys. The duration of a collision period lasting from when the snow depth exceeded 30 cm until the temperature stabilized above 0°C explained 82% of the yearly variation in moose - train collisions. Changes in the food availability, due to logging, increased the number of moose collisions considerably in local areas. We conclude that seasonal migrations are the main cause of moose - train collisions in Østerdalen.

ALCES VOL. 34(2): 385-394 (1998)

Key words: *Alces alces*, landscape, migrations, moose - train collisions, snow depth

---

During the last century natural landscapes have been intensively fragmented due to urbanization processes (Fahrig and Merriam 1994). One of the most severe changes brought upon landscapes by humans is the construction of infrastructures, like roads and railways (Forman and Godron 1986, Forman 1995). These linear elements in nature particularly affect migratory species, which follow certain routes inherited through generations (LeResche 1974; Pulliainen 1974; Cederlund *et al.* 1987; Sweanor and Sandegren 1989; Andersen 1991a, b; Sæther *et al.* 1992; Odden *et al.* 1996), as they function as barriers for the natural movements of wildlife species. In addition, because the linear elements of infrastructure often are heavily trafficked arteries, the possibility for conflict exists between the public need for transportation and the migratory behavior of game, resulting in a high number of game - vehicle collisions (Groot Bunderink and Hazebroek 1996, Romin and Bisonette 1996).

In Norway, during the period 1993 - 1996 there have been 4,189 recorded losses of game and domestic animals to train collisions, of which moose (*Alces alces*) constitute 65% (Table 1). Hence, the large number of moose - train collisions are causing great burdens both economically (e.g., by material damages and loss of a resource to the owner of the hunting rights), psychologically (e.g., by stressing train personnel), and ecologically (e.g., by complicating wildlife management (Lutz 1991, Foster and Humphrey 1995)). Moreover, each year a large number of injured moose have to be dealt with by The Wildlife Committee to reduce suffering. The need for remedial actions to reduce the number of moose - train collisions is obvious. However, to suggest where and when to introduce mitigative techniques, there is a need to know the temporal and spatial variation in the number of collisions. The temporal variation in the

Table 1. The number of game and domestic animals killed due to train collisions in Norway during the period 1993 - 1996.

Species	Number of train-killed individuals
Moose (*Alces alces*)	2705
Roe-deer (*Capreolus capreolus*)	521
Deer (*Cervus elaphus*)	54
Reindeer (*Rangifer tarandus*)	118
Muskox (*Ovibus moschatus*)	7
Lynx (*Felis lynx*)	3
Bear (*Ursus arctos*)	1
Fox (*Vulpes vulpes*)	3
Golden eagle (*Aquila chrysaetos*)	3
Sheep (*Ovis aries*)	568
Goat (*Capra hircus*)	3
Cattle (*Bos taurus*)	50
Horse (*Equus caballus*)	3
Dog (*Canis familiaris*)	150

number of collisions, may be expected to correlate to yearly variations in population densities (McCaffery 1973, Lavsund and Sandegren 1991, Lutz 1991), or to seasonal variations in climate and migratory behavior (Andersen *et al.* 1991). Whereas the spatial variation in the number of collisions may be expected to correlate to landscape features and resource availability (Carbaugh *et al.* 1975, Bashore *et al.* 1985, Feldhamer *et al.* 1986, Gleason and Jenks 1993).

In this study we examined how temporal variation (i.e., climatic factors and moose population density) and spatial variation (i.e., landscape pattern and changes in food availability) correlate with moose - train collisions in the part of Norway most burdened by wildlife collisions.

STUDY AREA

The study was restricted to Stor-Elvdal and Rendalen municipalities along the Rørosbanen railway which runs at the bottom of the Østerdalen valley from Elverum (60°53'N, 11°34'E) to Røros (62°35'N, 11°20'E) (Fig. 1). Rørosbanen is 240 km long, and is the railway line in Norway with the highest frequency of moose - train collisions, averaging 0.36 moose killed yearly per km (Andreassen *et al.* 1997) (Table 2). The most vulnerable stretch along Rørosbanen is located in Stor-Elvdal and Rendalen municipalities, where 72% of all moose - train collisions occur within a distance of 100 km (0.62 collisions yearly per km). The railway runs through the valley, surrounded by hills of boreal forest, dominated by Norwegian spruce (*Picea abies*) and Scots pine (*Pinus silvestris*), interspersed with a few boreal deciduous species such as birch (*Betula* spp.).

METHODS

Data Material

Data on train-kills stem from registra-

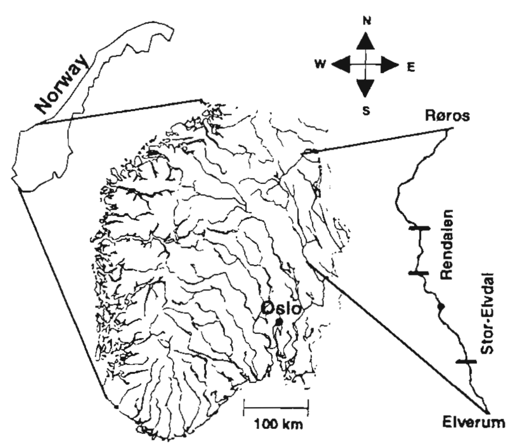


Fig. 1. The study area in Hedmark County, Norway, showing location of the Rørosbanen railway, and the 100 km section of the line including Rendalen and Stor-Elvdal municipalities analyzed in the present study. The dot along the line shows the location of the meteorological station (Evenstad).

Table 2. The number of moose - train collisions per km per year recorded in some of the longest railway lines in Norway, during the period 1993 - 1996.

Railway line	Number of train-killed moose per km per year
Rørosbanen	0.36
Gjøvikbanen	0.34
Bratsbergbanen	0.34
Vestfoldbanen	0.28
Nordlandsbanen	0.25
Meråkerbanen	0.20
Bergensbanen	0.18
Sørlandsbanen	0.18
Randsfjordbanen	0.17
Hovedbanen+Dovrebanen	0.11
Raumabanen	0.07
Kongsvingerbanen	0.06
Solørbanen	0.05
Østfoldbanen	0.02

tions performed by The Norwegian State Railway (NSB), The Norwegian National Rail Administration, and from the local Wildlife Committees of Stor-Elvdal and Rendalen municipalities from July 1, 1985, until March 1, 1997. Each registration of a moose - train collision consists of the time and the position to the nearest 100 m. Daily average temperature and snow depth were obtained from Evenstad meteorological station (61°24'N, 11°7'E) (Fig. 1). The size of the moose population was estimated by the population model "Cersim" which is based on observations made by hunters the previous hunting season (Lanestedt *et al.* 1988).

Analyzing Procedures

We have grouped our analyses into 2 categories: (1) temporal factors (i.e., climatic factors and population density), and (2) spatial factors (i.e., landscape patterns and food availability).

Temporal factors.— We compared the frequency distribution of days with certain weather conditions (expected) with the frequency distribution of collisions at the various weather conditions (observed) by a goodness of fit-test. General linear models were used to correlate moose population size and the number of collisions.

Spatial Factors.— To explain the spatial variation of collisions on a regional scale we analyzed the correlation between landscape patterns and the number of collisions. The number of collisions per 1-km-long segment of the railway was correlated to an estimate of topography and to the distance to the nearest side valley. Topography was measured as the difference in height from the bottom of the valley to the highest point within 2.5 km to the east and to the west of the line, averaged for both sides. Topography was chosen as a relevant landscape parameter as moose in Østerdalen tend to migrate from the hills down to the valley during winters (Sæther and Heim 1991, Odden *et al.* 1996). Furthermore, high hills create a narrow valley which could function as a funnel aggregating moose in a narrow area along the railway. Also side valleys were chosen as a landscape parameter due to migratory behavior, as the side valleys have been assumed to channel moose down to Østerdalen (Sæther and Heim 1991, Odden *et al.* 1996). Due to spatial autocorrelation of adjacent segments of the line we performed a preliminary analysis which showed that the number of collisions were not significantly autocorrelated if separated by 3 km or longer ($r < 0.1$, $P > 0.340$). Thus, the analysis of landscape pattern was performed by entering 3 of the 1 km long segments as a random factor in linear models including both topography and distance to side valleys.

To explain the spatial variation of collisions on a local scale we compared the number of collisions before and after changes in food availability due to logging activity in 2 areas, named Nabben and Storholmen. At Nabben food availability increased because branches of pines were available as food in a logging area near the railway. Whereas at Storholmen food availability decreased as a result of logging and clearing of an area for farmland. A linear model including factors that significantly correlated to the yearly variation in collisions (e.g., climatic factors and population density) was used to obtain an estimate of the expected number of collisions before- and after the change in food availability. The expected number of collisions before- and after the change occurred was compared with the observed number of collisions by a goodness of fit-test.

RESULTS

The number of collisions were particularly high during winter seasons, as 56% of the collisions occurred in January and February (Fig. 2). For the analyses of the yearly variation in number of collisions we counted

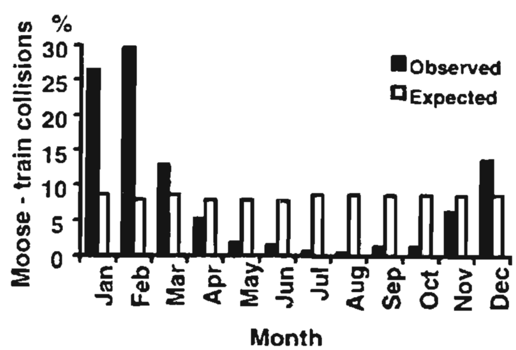


Fig. 2. Proportion of moose - train collisions per month. Goodness of fit between observed number of moose - train collisions and expected number of moose - train collisions (frequency distribution of days per month): $\chi^2 = 965.5$, 11 df, $P < 0.001$.

the number of collisions occurring during a winter season, starting July 1 and ending June 30 the following year,

A total of 692 collisions were registered in Stor-Elvdal and Rendalen municipalities from July 1, 1985, until March 1, 1997. The number of collisions varied considerably from year to year (Fig. 3), and also the location of collisions showed both a temporal and spatial variation (Fig. 4).

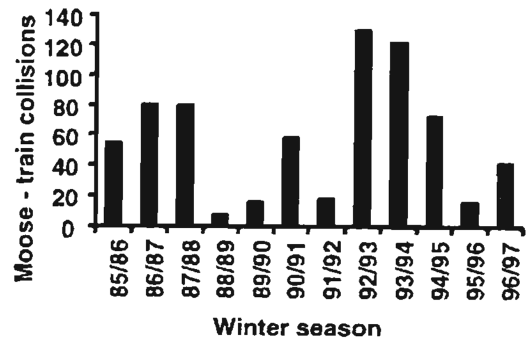


Fig. 3. The number of moose - train collisions recorded per winter season (July 1 - June 30).

Temporal Effects

There was an association between the number of collisions and temperature (Fig. 5a) and also between the number of collisions and snow depth (Fig. 5b). On days with temperatures below 0°C the risk of collision was 5.5 times higher than on days with temperatures above 0°C. The risk of collision was 12.4 times higher on days with snow depths exceeding 30 cm than on days of little (< 30 cm) or no snow. We combined temperature and snow into a variable called collision period, which started when snow depth exceeded 30 cm and lasted until the temperature stabilized above 0°C. The number of days in the collision period explained 82% of the yearly variation in moose collisions (Fig. 6).

Population density tended to correlate positively with the number of collisions, if

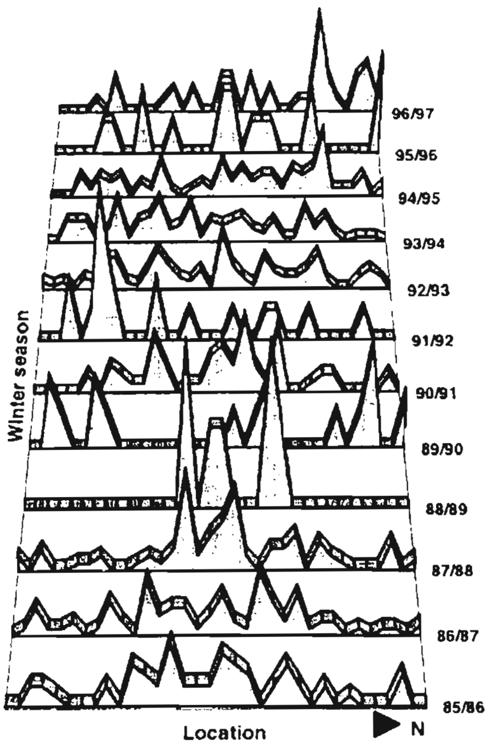


Fig. 4. The spatiotemporal variation in the number of moose-train collisions, depicted as the proportion of accidents recorded per year per 3-km along Stor-Elvdal and Rendalen municipalities. The lines were smoothed by using a running mean procedure.

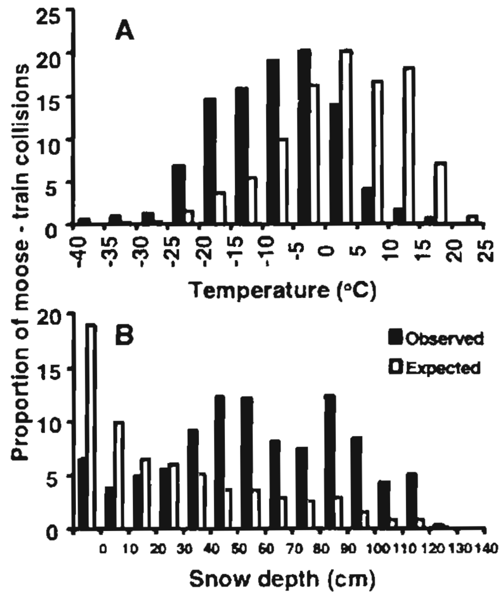


Fig. 5. (A) Proportion of days with different temperatures (expected) and proportion of train-killed moose (observed) ($\chi^2 = 851.0$, 12 df, $P < 0.001$). (B) Proportion of days with different amounts of snow (expected) and proportion of train-killed moose (observed) ($\chi^2 = 1458.0$, 14 df, $P < 0.001$).

included in a general linear model together with the collision period (slope = 0.04 ± 0.02; partial r^2 = 0.06; $F_{1,9}$ = 5.04; P = 0.052). The model including both the collision period and population density explained 88% of the yearly variation in the number of collisions.

Spatial Effects

There was a significant negative correlation between the number of collisions and distance to nearest side valley (Fig. 7), whereas there was no association between number of collisions and topography (P = 0.223).

At the 2 sites chosen to study the effects of change in food availability, the expected number of collisions was calculated from the linear model including collision period and population density. At both sites the change in food availability was

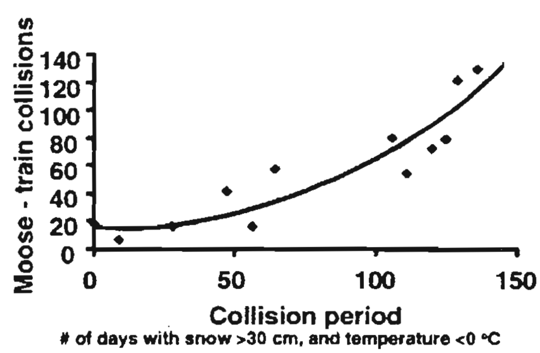


Fig. 6. The relation between the number of collisions and collision period (number of days per year starting when snow depth exceeds 30 cm and ending when the ambient temperature stabilizes above 0° C) ($F_{1,10}$ = 50.04, P < 0.001). The number of collisions were log-transformed in the statistical analysis.

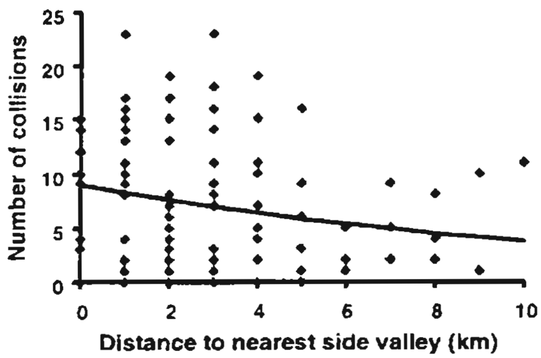


Fig. 7. The relationship between the number of collisions recorded and distance to the nearest crossing side valley. The number of collisions were log-transformed in the statistical analysis.

strongly associated to the number of collisions (Table 3). There was a 4 times higher risk for collisions at Nabben 2 years after logging than the years without logging (6 years before and 4 years after logging). At Storholmen, the cutting and clearing increased the risk of collision by a factor of 10.5.

DISCUSSION

In this study we have analyzed different spatial and temporal correlates to moose - train collisions at one highly vulnerable railway. The variation in moose - train collisions between years was mainly associated with climatic factors. Moose were killed during winter, particularly on days with great amounts of snow and temperatures below 0°C. Andersen *et al.* (1991) also found an association between snow depth and temperature and the number of moose - train collisions in a northern Norwegian railway. As moose are highly tolerant to low temperatures (-30°C) (Renecker and Hudson 1986), the lower number of train kills around 0°C suggests that moose decrease activity at high ambient temperatures in order to reduce heat production (see also Andersen *et al.* 1991).

We combined climatic factors into the collision period variable lasting from when snow depths exceeded 30 cm until the ambient temperature stabilized around 0°C. This collision period was strongly positively associated to train collisions. As Andersen *et al.* (1991) suggested, such a strong correlation between winter conditions and train kills may be due to the migratory behavior of moose populations (LeResche 1974; Pulliainen 1974; Cederlund *et al.* 1987; Sweanor and Sandegren 1989; Andersen 1991a, b; Andersen *et al.* 1991). Deep snow during a long period of time forces the moose to migrate to lower elevation areas containing a higher availability of food

Table 3. The expected and observed number of moose - train collisions at Nabben and Storholmen recorded for the years before and after the change in food availability. The expected number is corrected for the collision period and moose population density.

		Before	After	χ^2	*P*
	Expected	46	10		
Nabben				31.1	<0.001
	Observed	30	26		
	Expected	23.09	0.91		
Storholmen				42.6	<0.001
	Observed	17	7		

(Andersen and Sæther 1996). This results in a high density of moose in valley bottoms where railway lines are located. Radio telemetry studies of moose in Østerdalen have also shown that the moose migrate to valley bottoms in winter time (Sæther and Heim 1991, Odden *et al.* 1996). The radio telemetry studies of Sæther and Heim (1991) and Odden *et al.* (1996) also suggest that migratory moose utilize side valleys during migration. Hence the disproportionate high amount of collisions close to side valleys in our study also suggest that winter train kills is associated with the migratory behavior of the moose in the Østerdalen valley. Actually, a combination of the migratory direction reported by Sæther and Heim (1991) and Odden *et al.* (1996), and the spatial distribution of precipitation in Østerdalen, shows that the moose tend to migrate from local areas with high, to local areas with low, precipitation during winter (Fig. 8).

Although the presence of side valleys explained some of the spatial variation in the number of collisions, locations most exposed to collisions varied considerably from year to year. Food availability resulting from logging activities, as exemplified by Nabben and Storholmen, may partially account for such local variation. Our results

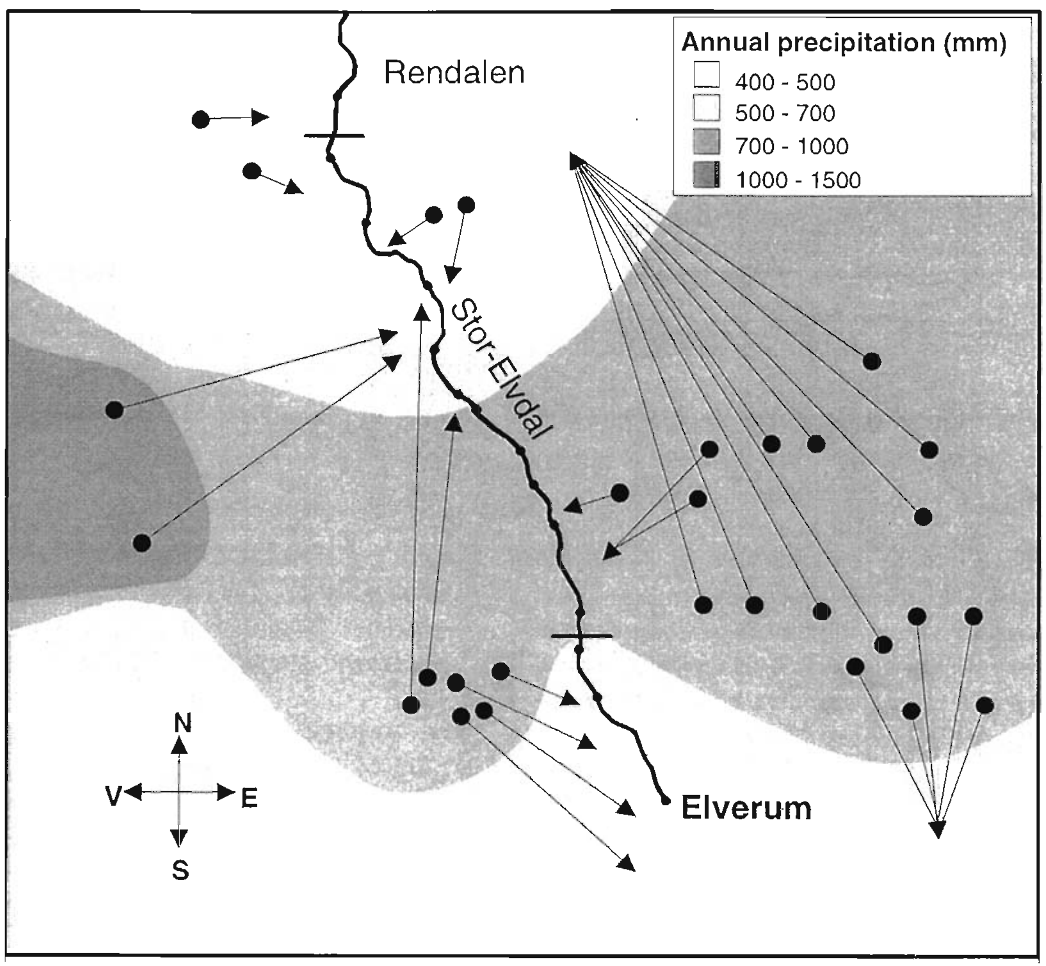


Fig. 8. Some general migratory directions for moose in Østerdalen from summer (black circles) to winter (arrows) habitats (source: Sæther and Heim 1991 and Odden *et al.* 1996) combined with a map of precipitation (source: Anonymous 1996).

suggest that, at Nabben, moose were attracted to the railway line due to the availability of branches of Scots pine, whereas at Storholmen moose had to move from a frequently used winter area due to the lack of food. Both events, although contrary in nature, resulted in a local, but probably short term increase in number of collisions. The availability of resources, such as food and water, have often been reported as a main cause of game - vehicle collisions (Peek and Bellis 1969, Carbaugh *et al.* 1975, Bashore *et al.* 1985, Feldhammer *et al.* 1986, Gleason and Jenks 1993).

We conclude that between year variation in collision frequency in Østerdalen is caused by climatic factors forcing moose down to the valley in search for food. The spatial variation in collision frequency may be explained by migratory routes, and local variations in the site of collisions by variations in food availability.

MANAGEMENT IMPLICATIONS

Previous studies have shown equivocal results with regard to population size and number of collisions (McCaffery 1973, Case 1978, Story and Kitchings 1979, Vincent *et al.* 1988, Lavsund and Sandegren 1991, Lutz 1991, Groot Bruinderink and Hazebroek 1996). The weak association between moose density and number of collisions offered little support for the opinion that a small decrease in population size would decrease the number of collisions substantially. We suggest that remedial actions to reduce the number of moose - train collisions should focus on feeding and migratory behavior of moose. For example clearing of forest vegetation along the railway to reduce foraging activity (Andersen *et al.* 1991, Jaren *et al.* 1991), and establishing feeding stations along migration routes (side valleys) may be more valuable mitigative techniques, preferably in combination with fences with overpasses in areas known to be located along traditional migration routes.

ACKNOWLEDGEMENTS

We would like to thank The Norwegian National Rail Administration for financial support to this study. H. Brenden, H. Haave, S. Hanestad, H. Haug, L. Hesthagen, O. Kristiansen, K. Nicolaysen, S. Sletten, L. Sælthun, G. Vestby, T. Øfstaas for ideas, comments, and data.

REFERENCES

ANDERSEN, R. 1991a. Dokka-utbyggingens innvirkning på en elgstammes trekkadferd, stedstrohet og størrelse på sommerområder. Nina forskningsrapport 30: 1-27. (In Norwegian)

______. 1991b. Habitat changes in moose ranges: effects on migratory behavior, site fidelity and size of summer home-range. Alces 27: 85-92.

______ and B.-E. SÆTHER. 1996. Elg i Norge: Biologi, atferd og forvaltning. Teknologisk forlag, Norway. (In Norwegian)

______, B. WISETH, P. H. PEDERSEN, and V. JAREN. 1991. Moose - train collisions: Effects of environmental conditions. Alces 27: 79-84.

ANDREASSEN, H. P., H. GUNDERSEN, and T. STORAAS. 1997. Vilt-trafikk i Østerdalen: Del 1, Tiltak for å begrense elg nær jernbanelinja. Høgskolen i Hedmark, Rapport 1997. (In Norwegian)

ANONYMOUS. 1996. Kunnskapsforlagets store Norgesatlas. Kunnskapsforlaget, H. Aschehoug and Co. (W. Nygaard) A/S and A/S Gyldendal Norsk Forlag. (In Norwegian)

BASHORE, T. L., W. M. TZILKOWSKI, and E. D. BELLIS. 1985. Analysis of deer-vehicle collision sites in Pennsylvania USA. J. Wildl. Manage. 49: 770-774.

CARBAUGH, B., J. P. VAUGHAN, E. D. BELLIS, and H. B. GRAVES. 1975. Distribution and activity of white-tailed deer along an interstate highway. J. Wildl. Manage. 39: 570-581.

CASE, R. M. 1978. Interstate highway road killed animals: a data source for biologists. Wildl. Soc. Bull. 6: 8-13.

CEDERLUND, G., F. SANDEBERG, and K. LARSSON. 1987. Summer movements of female moose and dispersal of their offspring. J. Wildl. Manage. 51: 342-352.

FAHRIG, L. and G. MERRIAM. 1994. Conservation of fragmented populations. Conserv. Biol. 8: 50-59.

FELDHAMER, G. A., J. E. GATES, D. M. HARMAN, A. J. LORANGER, and K. R. DIXON. 1986. Effects of interstate highway fencing on white-tailed deer activity. J. Wildl. Manage. 50: 497-503

FORMAN, R. T. T. 1995. Land Mosaics, The ecology of landscapes and regions. Cambridge University Press, Cambridge, U.K. 632pp.

______ and M. GODRON. 1986. Landscape Ecology. John Wiley, New York, NY. 619pp.

FOSTER, M. L. and S. R. HUMPHREY. 1995. Use of highway underpasses by Florida panthers and other wildlife. Wildl. Soc. Bull. 23: 95-100.

GLEASON, J. S. and J. A. JENKS. 1993. Factors influencing deer-vehicle mortality in east central South Dakota. Prairie Naturalist 25: 281-288.

GROOT BRUINDERINK, G. W. T. A. and E. HAZEBROEK. 1996. Ungulate traffic collision in Europe. Conserv. Biol. 10: 1059-1067.

JAREN, V., R. ANDERSEN, M. ULLEBERG, P. H. PEDERSEN, and B. WISETH. 1991. Moose - train collisions: the effects of vegetation removal with a cost - benefit analysis. Alces 27: 93-99.

LANESTEDT, G., I. NORDHUUS, V. JAREN, P. H. PEDERSEN, J.-E. ANDERSEN, and B.-E. SÆTHER 1988. CERSIM-bestandsmodell for elgforvaltningen. DN Rapport 6:1-78. (In Norwegian)

LAVSUND, S. and F. SANDEGREN. 1991. Moose- vehicle relations in Sweden: a review. Alces 27: 118-126.

LERESCHE, R. E. 1974. Moose migrations in North America. Naturaliste can. 101: 393-415.

LUTZ, W. 1991. The evaluation of roe deer mortality in north Rhine Westfalia from 1982-83 to 1989-90 in comparison to the hunting kill. Z. Jagdwissenschaft 37: 240-249.

MCCAFFERY, K. R. 1973. Road-kills show trends in Wisconsin deer populations. J. Wildl. Manage. 37: 212-216.

ODDEN, J., J. D. C. LINNELL, O. G. STØEN, L. GANGÅS, E. NESS, and R. ANDERSEN. 1996. Trekk og områdebruk hos elg i østre deler av Hedmark. Nina oppdragsmelding 415: 1-34. (In Norwegian)

PEEK, F. W. and E. D. BELLIS. 1969. Deer movements and behavior along an interstate highway. Highway Research News 36: 36-42.

PULLIAINEN, E. 1974. Seasonal movements of moose in Europe. Naturaliste can. 101: 379-392.

RENECKER, L. A. and R. J. HUDSON. 1986. Seasonal energy expenditures and thermoregulatory responses of moose. Can. J. Zool. 64: 322-327.

ROMIN, L. A. and J. A. BISSONETTE. 1996. Deer-vehicle collisions: status of state monitoring activities and mitigation efforts. Wildl. Soc. Bull. 24: 276-283.

SÆTHER, B.-E. and M. HEIM. 1991. Trekk - og vandringsforhold til elg merket i Løten og Stor-Elvdal kommuner. Nina oppdragsmelding 92:

1-37. (In Norwegian)

______, K. SOLBRAA, D. P. SØLDAL, and O. HJELJORD. 1992. Sluttrapport Elg-Skog-Samfunn. NINA forskningsrapport 28: 1-153. (In Norwegian)

STORY, J. D. and J. T. KITCHINGS. 1979. White-tailed deer (*Odocoileus virginianus*) on the department of energy's Oak Ridge reservation: Data on road-killed animals, 1969-1977. National Technical Information Service, Spingfield, USA.

SWEANOR, P. Y. and F. SANDEGREN. 1989. Winter-range philopatry of seasonally migratory moose. J. Appl. Ecol. 26:25-33.

VINCENT, J. P., E. BIDEAU, C. CIBIEN, and J. P. QUERE. 1988. Traffic deaths in roe deer *Capreolus-capreolus* example of woodland area in the Paris France basin. Z. Jagdwissenschaft 34: 63-68.

Gundersen, H., and H.P. Andreassen. The risk of moose *Alces alces* collision: A predictive logistic model for moose-train accidents. Wildlife Biology 4(2):103-110.

Abstract:

We used logistic models to estimate the risk of moose-train collisions for the Rorosbanen railway in Norway. During 1990-1997, a total of 13,506 train departures were registered along Rorosbanen during the months when the risk of collision was highest (December to March). The statistical model selected to predict the risk of moose-train collisions included train route, time of day, lunar phase and average train speed, as well as two climatic covariables, i.e. snow depth and temperature. Trains running at night, in the morning or in the evening experienced a higher risk of collision with moose Alces alces than day trains. The probability of collision was also higher during nights of full moons than during nights of half or no moons. As observed previously with trains in Norway moose-kills increased with increasing snow depth and decreasing temperatures. To test the predictability of the model, we used a logistic model based on train departures during 1990-1996 to predict the number of moose-train accidents during winter 1996/97. Although the model had a satisfactorily high predictability, the best models would probably be those based on a combination of both temporal and spatial aspects. We discuss how logistic models may be applied to introduce remedial actions on high-risk routes or during high-risk periods.

Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Environmental Sciences 14 (2012) 123 – 131

Procedia
Environmental Sciences

Landscape, Environment, European Identity, 4-6 November, 2011, Bucharest

Railroad-associated mortality hot spots for a population of Romanian Hermann's tortoise (*Testudo hermanni boettgeri*): a gravity model for railroad-segment analysis

Ruben Iosif*

Centre for Environmental Research and Impact Studies, University of Bucharest, 1 Nicolae Bălcescu, 010041, Bucharest, Romania

Abstract

Road-kill can lead to a sharp local decline of herpetofauna species. For this reason, transportation agencies are more and more interested to implement mitigation measures in order to eliminate this threat. The present study proposes to identify the railroad network induced threats at a railroad segment spatial scale on Getic Tableland, south-western Romania, by highlighting associated mortality hot spots for *Testudo hermanni boettgeri*. The railroad segment was chosen due to the reported road-kills and high traffic volume. In order to identify road associated mortality hot spots, we adapted a gravity model by including a weighting coefficient for overtaking obstacles. The model was adapted after observing that the cuts, fills, ditches and guardrails can change the tortoises behavior, making them avoid dangerous crossings, thus influencing the distribution of hot spots. As a main result, our study managed to adapt a gravity model for a more accurate assessment of railroad associated mortality. The average value of inter-habitat interaction is reduced by 23.37% after introducing the coefficient of overtaking the obstacles. However, despite the numerous obstacles, at a home range spatial scale, the maximum inter-habitat interaction value is not decreased, the range being stable (range = 0 - 99.66). Instead, the spatial extent of the hot spots is modified because of the increased territorial dependence and home range multi-annual stability, both severely threatening the tortoise that have a home range bisected by a major railroad. Our study accurately identifies the hot spots, which is particularly important in planning mitigation efforts, for building effective underpasses and fences systems.

© 2011 Published by Elsevier B.V. Selection and/or peer-review under responsibility of University of Bucharest , Faculty of Geography, Department of Regional Geography and Environment, Centre for Environmental Research and Impact Studies.

Keywords: Testudo hermanni boettgeri; road-kill; gravity model; railroad related obstacles; mitigation efforts; Romania.

*Corresponding author. *Tel.*: +40-0213103872
E-mail address: ios_ruben@yahoo.com

1878-0296 © 2011 Published by Elsevier B.V. Selection and/or peer-review under responsibility of University of Bucharest , Faculty of Geography, Department of Regional Geography and Environment, Centre for Environmental Research and Impact Studies.
doi:10.1016/j.proenv.2012.03.012

1. Introduction

Although at the European level the Hermann's tortoises (*Testudo hermanni*) are considered near threatened species, habitat loss, road-kill, illegal trade, and diseases can turn them into vulnerable ones [1]. Road mortality threat is becoming more and more obvious due to urbanization and infrastructure development all over Europe [2]. *Testudo hermanni boettgeri* or Eastern Hermann's tortoise is a strictly protected species and in Romania occurs only in the south-western part of the country [3]. A large part of the Romanian range is protected by European Natura 2000 sites [4]. The average road network density inside its range is 1.17 km/km^2 (SD = 1.24, range = 0 - 9.28) probably isolating new subpopulations which are more or less viable and, individually, are exposed to more violent threats [5].

Road ecology studies have focused not only on large mammals [6, 7] but also on herpetofauna [5, 8] [9]. There are two situations in which the road network causes the decline of different amphibians and reptiles species [10]: through road kill if roads can be crossed [9] and by habitat isolation if roads are impassable barriers [11, 12].

Methods for assessing road mortality hot spots are mainly based on landscape resistance models [13] or logistic regression models [9]. Although less used, spatial interaction models, such as gravity models, can predict the relative road associated mortality of different species [14]. Gravity models [GM] are flexible models which asses the spatial interactions between different points [15, 16, 17] and have been used in a wide variety of studies such us trade studies [18], epidemiology and invasive species dispersal [19, 20]. Only recently they were used to estimate the relative frequency of turtles movements between points located on opposite sides of the road [14]. The many cases of reported road-kill suggest that railroads are not impassable barriers for herpetofauna [11, 21], however the complete absence of tortoises from attractive habitat patches (e.g., shrubs and grasslands) can be explained by the presence of other ecological barriers [22].

Recent studies have shown that inter-habitat movements depend on the habitat quality and the distance between them [14], however, obstacles encountered by individual on his path have not been taken yet into consideration. Removing such a variable in the case of Eastern Hermann's tortoise, may result in overestimating the spatial extent of road-kill, due to biological characteristics of the species [23]. It is unclear how the tortoises behave depending on obstacles with different degrees of slope and depending on the distance from the point where the tortoise interacts with the obstacle, to the obstacle's extremities. Still their ability to overtake a railroad related obstacle can be estimated based on field observations and literature data. The introduction of a new random variable in a gravity equation was only implemented on a theoretical level [24, 15], and its usage in road ecology still remains a major challenge.

At the entire population scale, road mortality is not yet considered a severe threat [25] because tortoises does not engage in very long seasonal movements which would expose them [26], like in the case of amphibians or fresh water turtles [14, 27]. Still, in a home range bisected by a major railroad, the tortoises are exposed to more severe threats, given the species increased territorial dependence and lack of adaptability when it comes to threats [28, 29].

The aim of this study is to identify railroad-associated mortality hot spots, at a spatial scale of a railroad segment. Identifying the exact locations for intervention can facilitate conservation measures and reduce their costs.

3. Methods

1.1. Study site

The study was conducted on a railroad segment of Bucharest-Timişoara main railroad (Romanian railroad code = 900), recognized for high traffic volume. The segment is approximately 7 km long, situated on Getic Tableland from the south-western part of Romania (Fig.1) and it crosses favourable tortoises habitats, influenced by human activities such as orchards and pastures [30]. Based on spatial data digitized from 2005 aerial images, the road network density of the study area is up to 4.35 km/km^2 (mean = 2.54, SD = 0.79).

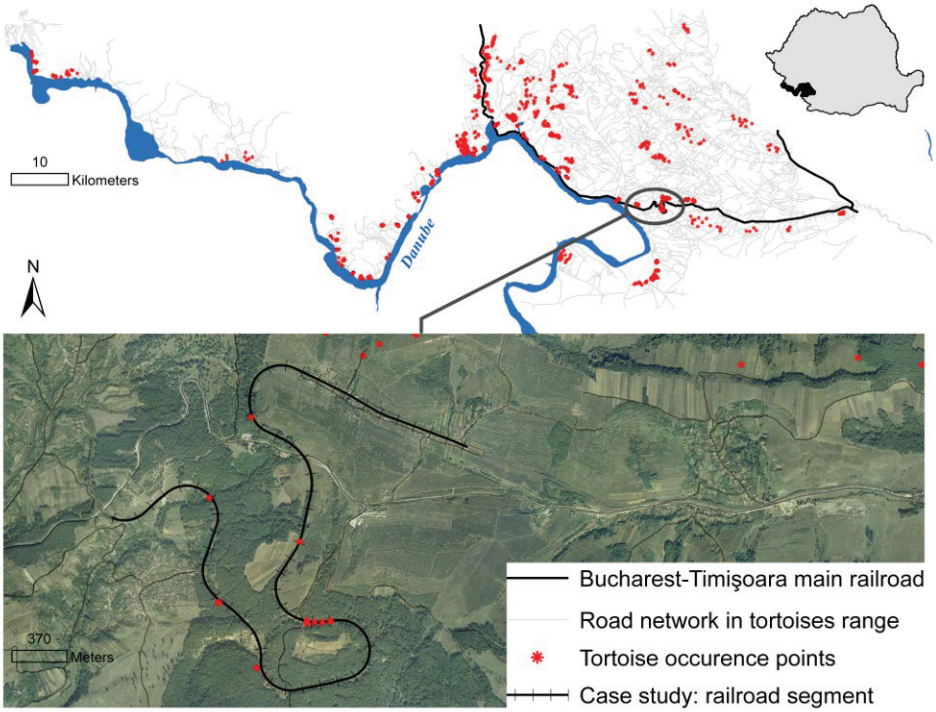


Fig. 1. Study site: a railroad segment of Bucharest-Timisoara main railroad situated on Getic Tableland, SW Romania

Adjacent obstacles such as cuts, fills, ditches, and guardrails made mostly of concrete, are found on approximately 4.4 km of the studied segment (62.4%). The railroad related obstacles have different degrees of slope (i.e. from 40° to 90°) and average lengths of 277.6 m (SD = 154.3, range = 58 - 545).

We analyzed the study area terrain slope and the average is 7.91° (SD = 5.19, range = 0 - 51.5) but after adding obstacles angles values obtained through field measurements using a raster calculator tool in a GIS we obtained an average slope of 8.19° (SD = 7.03, range = 0-90).

Because the elevation data are digitized from topographic maps at a scale of 1:25 000, the details of topographic surface are being lost. As an example, the field next to the railroad has many places with slope of 50 - 60°, covered with vegetation, which can be bypassed by tortoises. However, angles over 60° consisting of concrete or rock are becoming impassable barriers.

1.2. Gravity model

We delineate seven types of habitats with different degrees of attractiveness for Eastern Hermann's tortoise, from less attractive arable land to attractive grasslands, which offer food and shelter.

The first step of the analysis consists in calculating the selection index or attractiveness index (W_i) for each of the seven habitat classes [14, 31].

The initial equation was simplified given the lack of habitat usage data for Eastern Hermann's tortoise.

Using this simplified equation (eq. 1) we arbitrary assume that an individual can use all seven types of habitats in the study area. The guidance values obtained are presented in Table 1. Our purpose is to allow the modelling of gravity equation.

$$W_i = u_i / \sum^{n}_{j=1} \pi_{ij} \times u_j \qquad (1)$$

Where W_i is the selection index for habitat *i* class, u_i is the total number of *i* class habitat patches, π_{ij} is the proportion of available *i* class habitat in the study area and u_j is the total number of habitat patches regardless of their class, used by each individual.

The second variable introduced in our gravity model (i.e. distance between habitat patches centres) was obtained using Ad XY Coordinates To Table and Convert Points To Lines commands in Geospatial Modelling Environment (Spatial Ecology LLC) for creating the lines between center points located on opposite sides of the railroad segments.

Table 1. Guidance habitat attractiveness index for each of the seven habitat classes in the study site

Code	Description	Area(ha)	Habitat attractiveness (W_i)
DECIDUOUS	Large forest patches with: *Quercus* spp. *Carpinus* spp.	268.9	0.17
GRASS	Attractive patches with food resources and security: *Arenaria* ssp., *Carex* ssp., *Cardamine* ssp.	36.1	0.63
MIXT	Grassland with scattered trees	85.9	0.43
ORCHARD	Large patches with plum or apple trees	191.5	0.21
PASTURE	Large, open patches used for grazing	49.9	0.31
SHRUBS	Narrow patches of shrubs along the roads, paths, and forest edge, primarily with *Prunus spinosa*, *Rubus* ssp.	7.3	0.54
UNATTRACTIVE	Buildings. courtyards, arable land, paved roads	51	-

The generated lines with lengths of over 500 m were excluded from the analysis as they exceeded twice the maximum of the seasonal movements recorded for *Testudo hermanni boettgeri* [26]. We chose lines smaller than twice the maximum of seasonal movements because we consider as being potentially dangerous to cross, both the movement from starting point to interaction point and from interaction point to reaching point. Therefore we arbitrary assume that the tortoises have a linear path and can cross from both directions equally or with the same intensity.

At the crossing point of these lines with the railroad we created 418 interaction points.

The obstacle angle and the distance from the interaction point to the obstacle's extremities were obtained from field measurements.

In order to estimate the species ability to cross the danger zone bypassing the obstacles, we calibrate the GM.

The standard equation (eq. 2) was adapted to a constrained one (eq. 3), where T_{ij} represents inter habitat interaction values; *k* is scalar factor; W_i, W_j represents habitat attractiveness indexes; *d* is the distance between habitat patches centres; *C* is a coefficient of overtaking the obstacles. The adaptation consisted in introducing a coefficient for overtaking the obstacles (*C*) as a new random variable in the statistical approach of formulating and calibrating the GM [15].

$$T_{ij} = k \times W_i \times W_j / d^2 \qquad (2)$$

$$T'_{ij} = k \times W_i \times W_j \times C / d^2 \qquad (3)$$

C was proposed for linear weighting of inter habitat patches flows [15] which takes values between 0 and 1 (eq. 4), where c_1 and c_2 are coefficients of overtaking the obstacles based on distance to the obstacle's extremities and angle of the obstacle.

$$C = (c_1 + c_2)/ 2 \tag{4}$$

This weighting coefficient is a function of distance from the interaction point to the obstacle's extremities, and the angle of the obstacles. We assume the fact that there is a linear relation between the capacity of overtaking an obstacle and the two variables.

Hence a value of 1 (i.e., no cost in overtaking an obstacle) was used for the interaction points with no obstacle and a value of 0 for the interaction points with complete barriers to tortoises movements.

The functions of distance and angle (c_1, c_2) also take values between 0 and 1 and are mathematical defined as:

$$c_1 = \begin{cases} 1 - l / l_{critical}; & 0 \le l \le l_{critical} \\ 0; & l > l_{critical} \end{cases} \tag{5}$$

$$c_2 = \begin{cases} 1 - \alpha / \alpha_{critical}; & 0 \le \alpha \le \alpha_{critical} \\ 0; & \alpha > \alpha_{critical} \end{cases} \tag{6}$$

Where $l_{critical}$ and $\alpha_{critical}$ are the thresholds that force the gravity equation to 0.

The overtaking coefficient related to the distance (eq. 5) uses the value of 100 m as a critical distance. The critical value was established after the results obtained in the radio telemetry studies which concerned the Eastern Hermann's tortoise. The average daily distance travelled, for both males and females, is 31.18 m (SError = 1.59) (Laurențiu Rozylowicz, pers. comm.). Only as an exception, a tortoise moved about 200 m in the same direction [26]. The critical distance is the distance which is close to 0 as a probability to be achieved by tortoises in their attempt to overtake obstacles.

Choosing the critical value for the angle of the obstacles is partly subjective (eq. 6), this being considered the weak point of the model. Although we analyzed the average slope for 740 occurrence points, which was 10.83° (range = 0 - 58.5), we chose the $\alpha_{critical}$ mostly on field practice and observations regarding the behavior of the tortoises. Is known that tortoises prefer the sandy soils on the highest slopes for laying their eggs [32] thus the critical value was fixed at 60°, over which the tortoises can't cross.

The last step was to convert the interaction points using ArcGis Desktop 10 Geostatistical Analyst (ESRI, CA) into a 10 m cell size raster, using IDW with a fixed radius of 20 m, interpolating both the field value of T_{ij} as well as the field value of T'_{ij}.

2. Results

The presence of an obstacle in each individual's path decreases the relative frequency of tortoise movements between habitat patches on the other sides of the railroad. The average inter-habitat interaction value decrease after we entered the weighting coefficient *C* from 1.07 (SD = 5.38) to 0.82 (SD = 5.31) while the range is stable (range = 0 - 99.66).

The weighting coefficient *C* has an important effect on gravity model behaviour: it modifies the spatial distribution of the hot spots.

The distance from the interaction points to the extremities of the obstacles and the angle of the obstacles influences the capacity of the tortoises to overtake an obstacle and decreases the value of inter-habitat interaction values, down to zero. This weighting even affect the railroad segments which cross clusters of attractive habitat patches like grasslands and shrubs (Fig. 2). For example, the average inter-habitat interaction value decreased from 0.34 (SD = 0.63) to 0 for railroad segments designed with obstacles lengths > $l_{critical}$, and from 0.48 (SD = 1.40) to 0 for railroad segments designed with obstacles slopes > $\alpha_{critical}$.

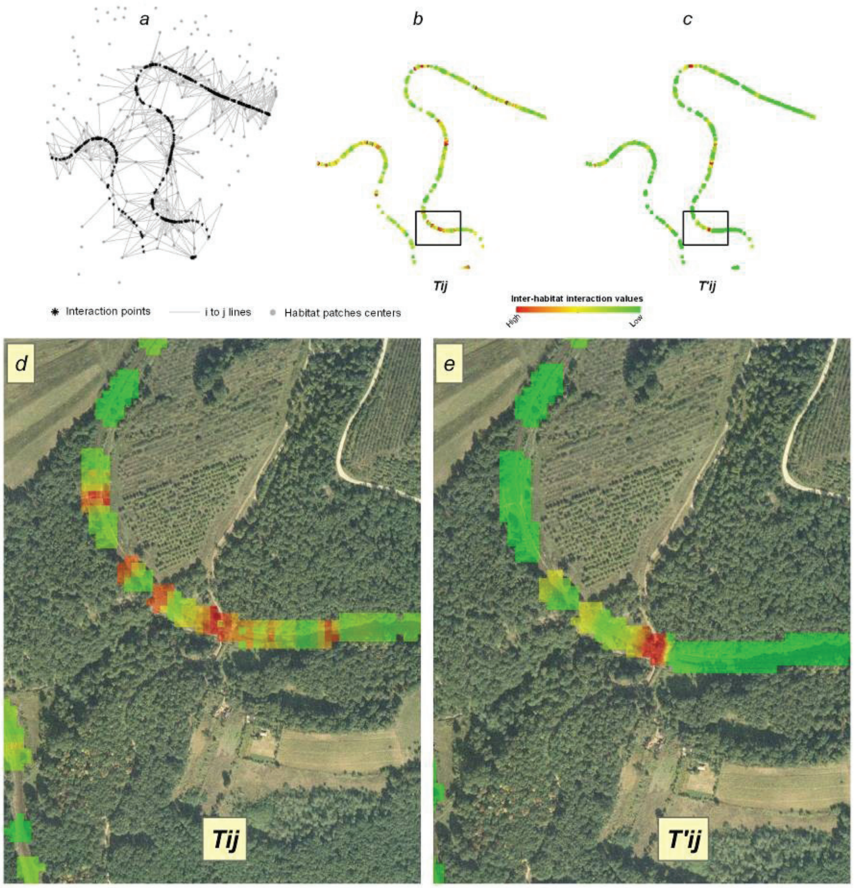


Fig. 2. Spatial interaction pattern at the railroad segment spatial scale (a) and spatial expression of gravity equation without (b) and with (c) weighting coefficient for overtaking obstacles. In the close-up, spatial extent of the hot spots is modified from a wide extending of the simple gravity equation (d) to a focused extending (e) covering a transition area from grassland to shrubs and forest

The hot spots are overlap on transition areas from grassland to shrubs and forest while cold spots are extended along the large forest patches or open pastures bisected by the railroad. We divided the railroad segment into four types of obstacles (i.e. $l_{critical}$ < 100m and $\alpha_{critical}$ <60°, $l_{critical}$ <100m and $\alpha_{critical}$ >60°, $l_{critical}$ >100m and $\alpha_{critical}$<60°, $l_{critical}$ >100m and $\alpha_{critical}$>60°). We observed that there are statistically significant differences of inter-habitat interactions values between them, caused by tortoises capacity to overtake adjacent obstacles (Kruskal Wallis $\chi^2 = 304.3$, df = 3, $p < 0.001$).

The inter-habitat interaction values are reduced through a linear relation by the spatial variation across the railroad of the distance from the interaction point up to the ends of the obstacles, and by their angle (Fig. 3). The low capacity of overtaking the obstacles does not reduce the maximum mortality in this home range, bisected by a major road, because the individuals search for water resources, food or territory, with the same intensity. This simply modify the spatial distribution of mortality hot spots, along the road segment.

3. Discussion

Our GM takes into account the biological characteristics of *Testudo hermanni boettgeri* and the species behaviour in its attempt to cross the railroad [23, 28].

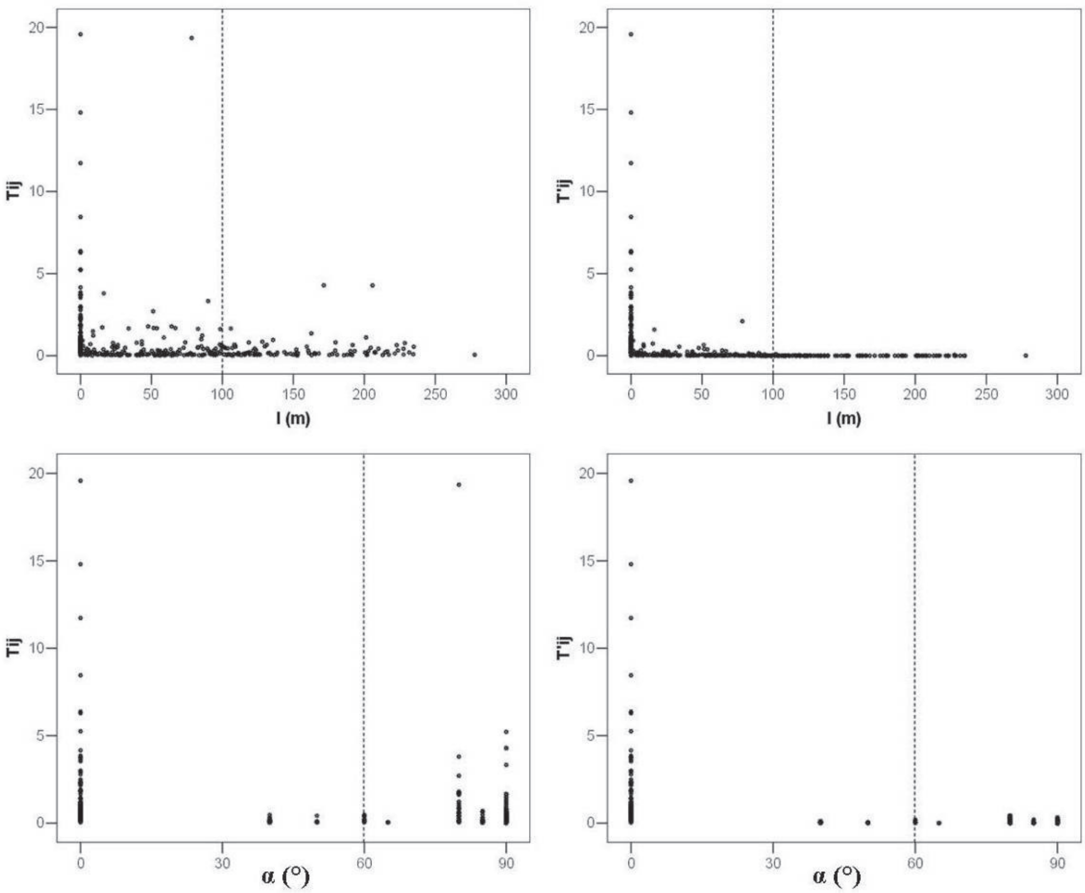


Fig. 3. Relationship between inter-habitat interaction values and the distance from interaction points to obstacles extremities (upper row) and between inter-habitat interaction values and the obstacle slope (lower row). In the left column the gravity equation does not take into account the coefficient for overtaking an obstacle. The dashed lines represent critical values of the two variables mentioned above

The adapted GM limited the spatial extension of the hot spots, being closer to the field reality, facilitating the conservation measures. Although we speculate that at a population scale, the mortality is reduced by obstacles we indicated that the impossibility to overtake them does not reduce the maximum mortality in a home range bisected by a major road, and it only modifies the spatial distribution of the hot spots along the road.

Road associated mortality (i.e. inter-habitat interaction) reached maximum values at the ends of the obstacles, in presence of attractive habitats on both sides of the railroad [14]. The highest interactions occurs where the railroad bisects fragmented patches of grassland at the forest and orchard edges where the tortoises finds both food and shelter [26].

No interaction occurs in the middle of the railroad sectors which have high concrete dams along, with an angle of over 60°, regardless of the habitat attractiveness.

Predicting the occurrence of wildlife vehicle collisions modelling variables related to obstacles or barriers, reduces the spatial errors [7] and facilitates the conservation measures. The road mortality spatial patterns for herpetofauna can be detected even after one survey [14] but we consider that adding additional road-kill points to database is required. This being usually required for temporary patterns assessment [34].

The most important limitation of our study is the use of the guidance values of the selection index for Eastern Hermann's tortoise. The second limitation it choosing the partly subjective critical values, for asses the tortoises capacity of overtaking an obstacle. There are necessary further experiments to validate this hypothesis. Access to movement data is required for a more precisely prediction of road associated mortality.

Our study suggest that it is essential to modify the gravity equation for the railroad segments without an obstacle ($C = 1$), by including the interactions which are deviated by the obstacles, towards their ends, since the value of the inter-habitat interaction value can grow up to the obstacles extremities.

Also significant for further studies is to model the attractiveness of the habitats which succeed in the tortoise path, from the starting point to the interaction point, as a resistance matrix [35]. Assessment of this succession, which can be determinant in selection of the interaction point for crossing the railroad, facilitates an extended road-kill analysis to population scale. The moment of the day in which the dangerous crossing event takes place, or the air temperature and the active surface temperature must be analyzed in further studies.

The validity of spatial interaction models is critical in planning mitigation efforts. Overestimating the relative frequency of tortoises movements over roads leads to wasting of financial resources and underestimating it can cause the decline of the populations whose home range is bisected by a major road.

Acknowledgements

I'am grateful to anonymous reviewers for their helpful comments and to my collegues who rigorously comment on the early versions of the manuscript. Special thanks we address to Dr. Laurențiu Rozylowicz, for providing access to field research equipment and for his carefully guidance troughout this study.

References

[1] van Dijk PP, Corti C, Mellado VP, Cheylan M. *Testudo hermanni*. In: *IUCN Red List of Threatened Species*. IUCN 2011; Version 2, accesed 10.01.2012.

[2] Stubbs D. *Testudo hermanni*. In: IUCN. *The Conservation Biology of Tortoises*; 1989. p. 34-36; Gland, Switzerland.

[3] Rozylovicz L, Tetelea C, Popescu V. Assessing the distribution of Hermann's tortoise (*Testudo hermanni boettgeri* Mojsisovics, 1888) in the Iron Gates Natural Park, Romania. In: Patroescu M, Matache ML editors. *Proceedings of the First International Conference on Environmental Research and Assessment*. Bucharest; 2003.

[4] Ioja CI, Pătroescu M, Rozylowicz L, Popescu V, Verghelеț M, Zotta M, et al. The efficacy of Romania's protected areas network in conserving biodiversity. *Biological Conservation* 2010; **143**: 2468-2476.

[5] Guyot G, Clobert J. Conservation measures for a population of Hermann's tortoise *Testudo hermanni* in southern France bisected by a major Highway. *Biological Conservation* 1997; **79**: 251-256.

[6] Clevenger A, Chruszcz B, Gunson K. Drainage culverts as habitat linkages and factors affecting passage by mammals. *Journal of Applied Ecology* 2001; **38**: 1340-1349.

[7] Gunson K, Clevenger A, Ford A, Bissonette J, Hardy A. A comparison of data sets varying in spatial accuracy used to predict the occurrence of wildlife-vehicle collisions. *Environmental Management* 2009; **44**: 268-277.

[8] Gibbs J, Shriver G. Estimating the effects of road mortality on turtle populations. *Conservation Biology* 2002; **16**(6): 1647-52.

[9] Langen T, Ogden K, Schwarting L. Predicting hot spots of herpetofauna road mortality along highway networks. *The Journal of Wildlife Management* 2009; **73**(1): 104-114.

[10] Buchwald E, Hels T. The effect of road kills on amphibian populations. *Biological Conservation* 2001; **99**(3): 331-340.

[11] Wederkinch E. Population size, migration barriers and other features of *Rana dalmatina* populations near Koge, Zealand, Denmark. *Memoranda Societatis pro Fauna et Flora Fennica* 1988; **64**(3): 101-103.

[12] Jaeger J, Fahrig L, Haber W. Reducing habitat fragmentation by roads: a comparison of measures and scales. In *Proceedings of the 2005 International Conference on Ecology and Transportation*; 2005: 13-17.

[13] Gunson K, Ireland D, Schuele F. Incorporating road-mortality hot spot modeling and connectivity analyses into road mitigation planning in Ontario. In *International Conference of Ecology and Transportation*; 2009.

[14] Beaudry F, deMaynadier P, Hunter Jr. M. Identifying road mortality threat at multiple spatial scales for semi-aquatic turtles. *Biological Conservation* 2008; **141**: 2550-2563.

[15] Viton P. Calibrating the Gravity Model problem set-up. *Transportation*. 1995; p. 1-19.

[16] Constantin DL. The use of Gravity Models for spatial interaction analysis. *Economy Informatics* 2004; **1**(4): 116-118.

[17] Haynes K, Fotheringham S. *Gravity model overview, gravity and spatial interaction models*: Sage Publ.; 1984.

[18] Anderson J. *A theoretical foundation for the gravity equation*. 1979; 69(1): p. 106-116.

[19] Xia Y, Bjørnstad O, Grenfell B. Measles metapopulation dynamics: a gravity model for epidemiological coupling and dynamics. *The American Naturalist* 2004; **164**(2): 267-281.

[20] Bossenbroek J, Kraft C, Nekola J. Prediction of long-distance dispersal using gravity models: Zebra Mussel invasion of inland lakes. *Ecological Applications* 2001; **11**(6): 1778–1788.

[21] Hitchings SP, Beebee TJC. Genetic substructuring as a result of barriers to gene flow in urban *Rana temporaria* (common frog) populations: implications for biodiversity conservation. *Heredity*. 1997; **79**: 117–127.

[22] Joly P, Morand C, Cohas A. Habitat fragmentation and amphibian conservation: building a tool for assessing landscape matrix connectivity. *Comptes Rendus Biologies* 2003; **326**: 132–139.

[23] Cruce M, Răducan I. Cicle d'activite chez la tortue terrestre (*Testudo hermanni hermanni* Gmel.). *Rev. Roum. Biol., Ser.Zool*. 1975; **20**: 285-289.

[24] Tobler W. Spatial interaction patterns. *Journal of Environmental Systems* 1976; **4**: 271-301.

[25] Rozylowicz L, Dobre M. Assessing the threatened status of *Testudo hermanni boettgeri* Mojsisovics, 1889 (Reptilia: Testudines: Testudinidae) population from Romania. *North-Western Journal of Zoology*. 2010; **6**(2): 190-202.

[26] Rozylowicz L. *Metode de analiză a distribuției areal-geografice a țestoasei lui Hermann (Testudo hermanni Gmelin, 1789) în România. Studiu de caz: Parcul Natural Porțile de Fier*. Bucharest: Bucharest University Publishing; 2008 (in Romanian).

[27] Ashley JP, Robinson JT. Road mortality of amphibians, reptiles and other wildlife on the Long Point Causeway, Lake Erie, Ontario. *Canadian Field-Naturalist* 1996; **110**: 403-412.

[28] Fuhn J, Vancea S. Reptilia - Amphibia. In *Fauna Rep. Pop. Romania*. Ed. Acad R.P.R.: Bucharest; 1961 (in Romanian).

[29] Stubbs D, Swingland I, Hailey A, Pulford E. The ecology of the mediterranean tortoise *Testudo hermanni* in northern Greece (the effects of a catastrophe on population structure and density). *Biological Conservation* 1985; **31**(2): 125-152.

[30] Roman N. *Flora şi vegetația din sudul Podişului Mehedinți*. Ed. Acad. R.S.R.: Bucharest; 1974 (in Romanian).

[31] Johnson D. The comparison of usage and availability measurements for evaluating resource preference. *Ecology* 1980; **61**(1): 65-71.

[32] Cruce M, Răducanu L. Reproducerea la broasca țestoasă de uscat (*Testudo hermanni hermanni*). *Stud. Cerc. Biol. Anim.* 1976; **28**(2): 175-180 (in Romanian).

[33] Gunson K, Clevenger A, Ford A, Bissonette J, Hardy A. A comparison of data sets varying in spatial accuracy used to predict the occurrence of wildlife-vehicle collisions. *Environmental Management*. 2009; **44**: 268–277.

[34] Beaudry F, Demaynadier P, Hunter JR M. Identifying hot moments in road-mortality risk for freshwater turtles. Journal of *Wildlife Management*. 2010; **74**(1): 152-159.

[35] Ray N, Lehmann A, Joly P. Modeling spatial distribution of amphibian populations: a GIS approach based on habitat matrix permeability. *Biodiversity and Conservation*. 2002; **11**: 2143–2165.

OVERVIEW OF TRANSPORTATION RELATED WILDLIFE PROBLEMS

Scott D. Jackson
University of Massachusetts
Amherst, Massachusetts

Abstract

Highways and railways are sources of road mortality that threaten wildlife populations. They also have the potential to undermine ecological processes through the fragmentation of wildlife populations, restriction of wildlife movements, and the disruption of gene flow and metapopulation dynamics. A variety of techniques have been used to mitigate the impacts of transportation systems on wildlife movements. Factors influencing the effectiveness of these structures include: placement, size, openness, light, moisture, hydrology, temperature, noise, human disturbance, substrates, and the nature of the approaches and fencing systems. Important issues and challenges include: 1) fostering greater appreciation of the problems caused by highways and railways, 2) conducting landscape analyses to identify "connectivity zones", 3) enlisting transportation engineers to help solve technical problems, 4) monitoring of mitigation techniques, and 5) information sharing. In particular it is important not just to monitor wildlife use of crossing structures but also to develop and implement monitoring techniques that are sufficient for evaluating mitigation success.

Impacts of Highways and Railways on Wildlife

As long linear features on the landscape, railways, roads and highways have impacts on wildlife and wildlife habitat that are disproportionate to the area of land that they occupy. These elements of transportation infrastructure impact wildlife in a variety of ways.

1. Direct loss of habitat.
2. Degradation of habitat quality. Storm water discharges, air emissions and exotic plants can degrade habitats ranging up to several hundred feet from railways and highways.
3. Habitat fragmentation. Railways and highways dissect contiguous habitat patches resulting in smaller patch sizes and higher edge to interior ratios.
4. Road avoidance. Some wildlife species avoid areas adjacent to highways due to noise and human activity associated with roads.
5. Increased human exploitation. Roads and highways increase human access for hunting and poaching. This may reduce wildlife populations in areas adjacent to roads and highways and contributes to road avoidance.
6. Road mortality leading to loss of populations.
7. Reduced access to vital habitats. Railways and highways reduce access to vital habitats for a variety of wildlife species. Examples include:
   - Summer and winter ranges for ungulates
   - Access to mineral licks
   - Amphibian wetland breeding sites
   - Upland nesting habitat for turtles
   - Snake hibernacula
8. Population fragmentation. Railways and highways create barriers to movement that subdivide animal populations. Smaller populations are more vulnerable to genetic changes due to genetic drift and inbreeding depression, and extinction due to chance events.
9. Disruption of processes that maintain regional populations. Based on metapopulation theory, regional populations may persist in the face of local extinctions because the movement of individual animals among populations: a) supplement declining populations, b) maintain gene exchange, and c) re-colonize habitats after local population extinctions. By disrupting animal movements among populations, railways and highways undermine these processes that are vital for the long-term viability of regional wildlife populations.

For additional summaries of highway and railway effects on wildlife, including effects of habitat fragmentation, see Andrews (1990), Bennett (1991), and De Santo and Smith (1993).

Techniques for Mitigating Transportation Impacts on Wildlife Movement

Over the years a variety of techniques have been used to reduce animal-vehicle collisions and mitigate railway and highway impacts on wildlife.

Modified Drainage Culverts. Culverts originally constructed to convey water have been modified to provide passage for wildlife. In the Netherlands shelves have been attached to the sides of culverts to provide dry passageways for wildlife. Floating docks within drainage ways adjust to changing water levels and are used to maximize clearance for wildlife passage.

Wildlife/Drainage Culverts. Culverts designed to convey water only intermittently can be used for passage by wildlife when the culverts are dry. Drainage culverts have been designed to serve a dual role for water and wildlife passage. In some cases benches have been constructed within culverts so that passing wildlife can avoid flowing water within the culvert. Another, potentially more effective design involves channeling water through a trench within the culvert allowing a wider passageway for wildlife.

Upland Culverts. Not all species of wildlife readily use stream or river corridors for travel routes. Upland culverts facilitate overland movement between wetlands and uplands, uplands and uplands, and from wetlands to other wetlands. Movements to and from wetlands are particularly important for amphibians and turtles. Box culverts are generally preferable over pipes. Larger culverts will generally accommodate more species than smaller ones. Open-top culverts provide more light and moisture, and will be more effective for facilitating amphibian movements than standard culverts.

Oversize Stream Culverts. Where culverts are used to cross streams and small rivers, oversize culverts, large enough to allow for wildlife passage may be used. Box culverts generally provide more room for travel than large pipes. Open bottom arches and box culverts that maintain natural streambeds are preferred. Efforts to provide natural substrate, including large flat rocks as cover for small animals, will likely enhance their use by some species. Construction of benches on one or both sides of the stream to allow dry passage during normal high water periods will also enhance these structures. The optimum size for these structures is not known, but generally, the larger the better.

Expanded Bridges. Where railways and highways cross rivers and streams, expanded bridges that provide upland travel corridors adjacent to the waterway can provide passageways for many species of riverine wildlife, as well as other species that may utilize stream corridors for travel. Higher and wider bridges tend to be more successful than low bridges and culverts. Expanded bridges are more expensive than expanded bridges, but also are generally more effective.

Viaducts. Viaducts are elevated bridges used to span entire valleys. They typically provided relatively unrestricted wildlife movement across highway and railway alignments. For wildlife passage, viaducts are generally preferred over bridges and culverts.

Wildlife Underpasses. Wildlife underpasses are larger than upland culverts and can provide relatively unconfined passage for some wildlife species. Underpasses may be either large culverts or bridges. If appropriately sized these structures provide plenty of light and air movement, but may be too dry for some species of amphibians. Wildlife underpasses with open medians can provide a certain amount of intermediate habitat for small mammals, reptiles and amphibians. Open median designs are less confining and are generally preferred over continuous underpasses. However, open median designs are noisier than continuous bridges and may be less suitable for species that are sensitive to human disturbance.

Wildlife Overpasses. Wildlife overpasses have been constructed in a number of European countries but have been rarely used in North America. The most effective overpasses range in width from 50 m on each end narrowing to 8-35 m in the center to structures 200 m wide. Soil on these overpasses, ranging in depth from 0.5 to 2 m, allows for the growth of herbaceous vegetation, shrubs and small trees. Some contain small ponds fed by rain water. Wildlife overpasses appear to accommodate more species of wildlife than do underpasses. Primary advantages over underpasses are that they are less confining, quieter, maintain ambient conditions of rainfall, temperature and light, and can serve both as passage ways for wildlife and intermediate habitat for small animals such as reptiles, amphibians and small mammals.

Fencing. Fencing for large and medium-sized mammals are required for underpass and overpass systems to be effective. Standard fencing may not be effective for some species (black bears, coyotes), but manipulations of wildlife trails and vegetation can also be used to guide animals to passage ways and learning may enhance their effectiveness for these species over time. Fencing for large mammals may also include one-way gates or other structures to prevent animals that get onto roadways from being trapped between fences on both sides of the road. Fencing for small mammals, reptiles and amphibians must be specifically designed to prevent animals climbing over and through, or tunneling under the fencing. Short retaining walls can provide relatively maintenance-free barriers for reptiles, amphibians and small mammals.

Evaluations of wildlife crossing structures indicate the need for careful design and placement, and that effectiveness is dependent on a variety of variables, including: **size and openness** (Reed et al. 1975, Reed 1981, Hunt et al. 1987, Dexel 1989, Foster and Humphrey 1995, Yanes et al. 1995, Rodriguez et al. 1996, Rosell et al. 1997), **placement** (Singer and Doherty 1985, Podloucky 1989, Beier 1995, Paquet and Callaghan 1996, Roof and Wooding 1996, Rosell et al. 1997), **noise levels** (Singer and Doherty 1985, Pedevillano and Wright 1987, Beier 1995, , Foster and Humphrey 1995, Santolini et al. 1997), **human disturbance** (Clevenger 1998) **substrate** (Mansergh and Scotts 1989, Yanes et al. 1995, Linden 1997, Rosell et al. 1997), **vegetative cover** (Hunt et al. 1987, Pedevillano and Wright 1987, Beier 1995, Rodriguez et al. 1996, Rosell et al. 1997, Santolini et al. 1997), **moisture** (Brehm 1989, Jackson 1996), **hydrology** (Jackson and Tyning 1989, Janssen et al. 1997, Rosell et al. 1997, Santolini et al. 1997), **temperature** (Langton 1989) and **light** (Krikowski 1989, Beier 1993, Jackson 1996).

Many mitigation projects are primarily designed to facilitate movements of a single species or small groups of similar species. Some attempts to construct wildlife passage systems for a broad range of species are being tried in Europe and Canada (Banff National Park). Viaducts and large overpass systems for wildlife appear to the most effective designs for accommodating the needs of a broad range of wildlife species.

Current and Future Issues and Challenges

Much progress has been made in the past several years in understanding the impacts of transportation infrastructure on wildlife and developing techniques and approaches for mitigated those impacts. None-the-less several challenges remain.

Fostering Greater Appreciation of the Problems Caused by Highways and Railways. One important challenge is getting people to understand the scope and complexity of transportation impacts on wildlife. Too often the issue is viewed as one of an incidental take of animals rather than as a threat to wildlife populations. We must seek to frame the issue not as concern for individual animals but rather that of maintaining the ecological integrity of natural systems intersected by railways and highways. The movement of animals through the landscape is one of many ecological processes that must be maintained in order to insure the integrity of ecosystems over time. The impacts of railways and highways do not simply occur at the time of construction but accumulate over time as populations fail due to transportation impacts and pathways for re-colonization are precluded. Appropriate planning and mitigation at the time of construction can go a long way in preventing long-term degradation of wildlife populations and the ecosystems in which wildlife are important components.

Landscape Analyses to Identify "Connectivity Zones". The most effective techniques for facilitating wildlife movement (overpasses, viaducts, and large underpasses) are also quite expensive. Therefore, it is generally not practical to make entire highways or railways permeable to wildlife movement. A practical strategy for mitigating transportation impacts on wildlife movement may dictate that comprehensive efforts utilizing expensive elements be reserved for areas that are identified and designated as important travel corridors or connections between areas of significant habitats (Jackson and Griffin 1998). These landscape analyses are common in Europe (see Canters 1997) and there are some notable examples from North America (Wagner et al. 1998, Carr et al. 1998). To the extent that these areas can be identified ahead of time, planning for new transportation infrastructure can more effectively focus on minimizing and mitigating impacts to these critical areas.

Enlisting Transportation Engineers to Help Solve Technical Problems. There still is much work to be done in designing wildlife crossing structures that are effective for facilitating animal passage and practical for use in transportation systems. Biologists need to establish the performance standards for such structures based on the characteristics and needs of wildlife. The assistance of transportation engineers is needed to provide technical solutions and approaches so that crossing structures more effectively meet the standards identified by biologists. An example of a problem in need of a technical solution is how best to provide a wet environment within crossing structures to facilitate amphibian use during migration. Given the incredible feats of engineering accomplished over the years by transportation engineers, collaborative partnerships between biologists and engineers should be able to find practical solutions to many technical problems related to animal passage.

Monitoring and Evaluation of Wildlife Crossing Structures. Monitoring studies that evaluate the effectiveness of wildlife crossing structures have provided valuable information that is now available for use in designing future mitigation. As new structures are built it is particularly important that these efforts be monitored and the lessons learned from these mitigation experiments shared with others. There are a variety of techniques that can be used to monitor animal passage structures and evaluate their effectiveness.

Tracks and Track Beds

One of the simplest methods to monitor use of animal passage structures is surveys for animal tracks. In some instances tracks may be obvious in naturally occurring mud or soil within the crossing structure. A more effective technique involves the preparation of track beds. Track beds may involve simply raking and smoothing naturally occurring soil to facilitate track detection and identification. Use of marble dust or fine white sand will generally increase the effectiveness of track beds. Soot or ink panels with paper can be used along narrow passages and are useful for recording the tracks of small animals such as amphibians, lizards, and small mammals.

Track beds ideally should be 1-2 m wide and extend the entire width of the passage. Where underpasses and culverts contain streams or rivers, track beds will only be useful for recording those animals that pass along the banks and will not provide accurate counts (animals traveling in the stream channel will be missed). Fluctuating water levels within the passage structure may provide serious problems for track beds, as rising water levels are likely to wash away tracks.

In order to provide the most useful information about wildlife use of crossing structures, track beds should be established at both ends of the structure. This will allow monitors to determine whether animals that entered the passage actually passed through the crossing structure.

Automatic Cameras

Automated cameras have been used in a few studies of animal passage systems and have provided evidence that these structures are used by a variety of large animals. If properly installed they may be useful for detecting passage by large animals, although they may not be reliable enough to provide accurate counts of animals using a passage. One of the particular difficulties with using camera setups is detecting small animals. Photographs of large animals are usually identifiable even at some distance. Small animals must be photographed up close for proper identification. In some settings it may be possible to channel small animals through a narrow shute to facilitate photo-documentation.

Infrared beam triggers present a variety of problems for documenting small animals. Infrared beams are difficult to position for reliable results on uneven ground. It also is difficult to use a single beam that will work for animals that jump or bound (frogs, chipmunks, jumping mice). Camera setups positioned low to the ground also are vulnerable to vandalism.

Camera setups with motion detectors may be more effective than infrared beam triggers for documenting mammals, provided that they are well positioned. In large culverts or underpasses, both the camera and triggering mechanism can be mounted high in the structure out of the reach of people. None-the-less, they will need to be armored to prevent damage from stone-throwing vandals. One important disadvantage to using motion detector triggers is that they are only effective for detecting "warm-blooded" animals.

Counters

Counters make use of either infrared beam or motion detector triggers without cameras to count the number of animal passages at a particular point. The advantages of using counters without cameras is that they are less obvious and easier to protect from vandals, less expensive (no camera, film or photo processing required) and more reliable than camera setups, and require less attention (no need to change film). The obvious major disadvantage is that when using counters alone it is impossible to know what species are being documented. Further, the counters also possess the same limitations of triggering devises discussed in the section on automatic cameras. In some cases use of counters with track beds may provide a practical means of monitoring wildlife use of crossing structures.

Video Cameras

The advantage of using video cameras is that it allows observations of behavior that may indicate hesitancy or stress in animals using a crossing structure. Standard video cameras have been used in the day time. In Europe wildlife crossing structures have been monitored by infrared video cameras allowing observations at night (when many animals are more active). The primary disadvantages of this technique are: 1) they are not generally suitable for monitoring small animals (unless the crossing structure is small), 2) the high cost (approximately $10,000 for an infrared unit), and 3) the amount of time needed to review a large volume of videotape.

Radio Tracking

Tracking of radio tagged wildlife can provide some information about the crossing rates for individual animals. However, while records of animals on both sides of a highway or railway indicate that a crossing has occurred, it is usually not possible to know for certain whether the animal utilized a particular crossing structure. In some areas, such as where fencing may effectively limit crossing points, it might be credibly inferred that animals are using crossing structures. Another important limitation of radio-tracking is that it is not possible to get an absolute count of how often crossings occur. Unless tracking is continuous, an animal could cross several times in between times when its location is recorded via radio telemetry.

Radio tracking is most useful for comparing crossing rates or home range configuration between areas along transportation corridors and areas remote from highways and railways, or between highway and railway stretches with crossing structures versus areas lacking structures. Radio tracking is particularly well suited for studies to document 1) whether home ranges for a particular species change when a highway or railway is constructed and 2) the degree to which crossing structures affect that change.

Mark-Recapture Studies

For small animals, especially small mammals, trapping studies can provide similar information as radio-tracking, with many of the same limitations. Recaptures of marked animals have been used to evaluate the degree to which railways and highways inhibit the movement of small mammals. Comparing mark-recapture data for stretches of transportation infrastructure with and without crossing structures may be the only effective method for evaluating the effectiveness of such structures in facilitating movements of small mammals.

Passage Use versus Mitigation Success

Most attempts to evaluate the success or failure of wildlife crossing structures have focused on documenting wildlife use of the structures. Use of tracking beds, cameras, and counters do provide information about animals that use the structures. Unfortunately, monitoring structure use provides little information on species or individuals that fail or refuse to use the structure. Radio-tracking and trapping studies provide less information about structure use, but are more useful for determining the extent to which railways and highways inhibit wildlife movement and the degree to which crossing structures are able to mitigate these effects. In order to fully assess the effectiveness of wildlife crossing structures it may be necessary to use a combination of two or more techniques that will evaluate both structure use and the degree to which railway or highway effects on animal movement are mitigated.

<u>Information Sharing</u>. Recent conferences on this topic (ICOWET I & II, and the International Conference on Habitat Fragmentation, Infrastructure and the Role of Ecological Engineering, 1995 in The Hague) have played an important role in drawing attention to issues of wildlife ecology and transportation. They also have been invaluable as forums for information sharing among the diverse groups of people who are working on wildlife ecology and transportation issues. It is essential that we continue to document and share information about mitigation successes and failures. The information shared at this conference will be a valuable addition to this process.

References Cited

Andrews, A. 1990. Fragmentation of habitat by roads and utility corridors: a review. Aust. Zool. 26(3&4):130-141.

Beier, P. 1993. Determining minimum habitat areas and habitat corridors for cougars. Cons. Biol. 7(1):94-108.

Beier, P. 1995. Dispersal of juvenile cougars in fragmented habitat. J. Wildl. Manage. 59(2):228-237.

Bennett, A.F. 1991. Roads, roadsides, and wildlife conservation: a review. Pp. 99-118 *In* D.A. Saunders and R.J. Hobbs (eds.) Nature Conservation 2: The Role of Corridors. Surrey Beatty & Sons, London.

Brehm, K. 1989. The acceptance of 0.2 m tunnels by amphibians during their migration to the breeding site. Pp. 29-42 *In* T.E.S. Langton (ed.) Amphibians and Roads, proceedings of the toad tunnel conference. ACO Polymer Products, Shefford, England.

Canters, K. (ed.). 1997. Habitat fragmentation and Infrastructure: Proceedings of the International Conference on Habitat Fragmentation, Infrastructure and the Role of Ecological Engineering. Ministry of Transport, Public Works and Water Management, Delft, The Netherlands. 474 pp.

Carr, M.H., P.D. Zwick, T. Hoctor, W. Harrell, A. Goethals, and M. Benedict. 1998. Using GIS for identifying the interface between ecological greenways and roadway systems at the state and sub-state scales. Pp. 68-77 *In* G.L. Evink, P. Garrett, D. Zeigler, and J. Berry (eds.) Proceedings of the International Conference on Wildlife Ecology and Transportation. Florida Department of Transportation, Tallahassee, Florida.

Clevenger, A.P. 1998. Permeability of the Trans-Canada Highway to wildlife in Banff National Park: importance of crossing structures and factors influencing their effectiveness. Pp. 109-119 *In* G.L. Evink, P. Garrett, D. Zeigler, and J. Berry (eds.) Proceedings of the International Conference on Wildlife Ecology and Transportation. Florida Department of Transportation, Tallahassee, Florida.

De Santo, R.S. and D.G. Smith. 1993. Environmental auditing: an introduction to issues of habitat fragmentation relative to transportation corridors with special reference to high-speed rail (HSR). Environmental Management 17:111-114.

Dexel, R. 1989. Investigations into the protection of migrant amphibians from the threats from road traffic in the Federal Republic of Germany: a summary. Pp. 43-49 *In* T.E.S. Langton (ed.) Amphibians and Roads, proceedings of the toad tunnel conference. ACO Polymer Products, Shefford, England.

Foster, M.L. and S.R. Humphrey. 1995. Use of highway underpasses by Florida panthers and other wildlife. Wildlife Society Bulletin 23(1):95-100.

Hunt, A., J. Dickens and R.J. Whelan. 1987. Movement of mammals through tunnels under railway lines. Aust. Zool. 24(2):89-93.

Jackson, S.D. 1996. Underpass systems for amphibians. 4 pp. *In* G.L. Evink, P. Garrett, D. Zeigler and J. Berry (eds.) Trends in Addressing Transportation Related Wildlife Mortality, proceedings of the transportation related wildlife mortality seminar. State of Florida Department of Transportation, Tallahassee, FL. FL-ER-58-96.

Jackson, S.D. and C.R. Griffin. 1998. Toward a practical strategy for mitigating highway impacts on wildlife. Pp. 17-22 *In* G.L. Evink, P. Garrett, D. Zeigler, and J. Berry (eds.) Proceedings of the International Conference on Wildlife Ecology and Transportation. Florida Department of Transportation, Tallahassee, Florida.

Jackson, S.D. and T.F. Tyning. 1989. Effectiveness of drift fences and tunnels for moving spotted salamanders Ambystoma maculatum under roads. Pp. 93-99 *In* T.E.S. Langton (ed.) Amphibians and Roads, proceedings of the toad tunnel conference. ACO Polymer Products, Shefford, England.

Janssen, A.A.W., H.J.R.Lenders, and R.S.E.W. Leuven. 1995. Technical state and maintenance of underpasses for badgers in the Netherlands. Pp. 362-366 *In* K. Canters (ed.) Habitat Fragmentation & Infrastructure, proceedings of the international conference on habitat fragmentation, infrastructure and the role of ecological engineering. Ministry of Transport, Public Works and Water Management, Delft, The Netherlands.

Krikowski, L. 1989. The 'light and dark zones': two examples of tunnel and fence systems. Pp. 89-91 *In* T.E.S. Langton (ed.) Amphibians and Roads, proceedings of the toad tunnel conference. ACO Polymer Products, Shefford, England.

Langton, T.E.S. 1989. Tunnels and temperature: results from a study of a drift fence and tunnel system at Henley-on-Thames, Buckinghamshire, England. Pp. 145-152 *In* T.E.S. Langton (ed.) Amphibians and Roads, proceedings of the toad tunnel conference. ACO Polymer Products, Shefford, England.

Linden, P.J.H. van der, 1997. A wall of tree-stumps as a fauna-corridor. Pp. 409-417 *In* K. Canters (ed.) Habitat Fragmentation & Infrastructure, proceedings of the international conference on habitat fragmentation, infrastructure and the role of ecological engineering. Ministry of Transport, Public Works and Water Management, Delft, The Netherlands.

Mansergh, I.M. and D.J. Scotts. 1989. Habitat continuity and social organization of the Mountain Pygmy-possum restored by tunnel. J. Wildl. Manage. 53(3):701-707.

Paquet, P.C. and C. Callaghan. 1996. Effects of linear developments on winter movements of gray wolves in the Bow River Valley of Banff National Park, Alberta. 21 pp. *In* G.L. Evink, P. Garrett, D. Zeigler and J. Berry (eds.) Trends in Addressing Transportation Related Wildlife Mortality, proceedings of the transportation related wildlife mortality seminar. State of Florida Department of Transportation, Tallahassee, FL. FL-ER-58-96.

Pedevillano, C. and R.G. Wright. 1987. The influence of visitors on mountain goat activities in Glacier National Park, Montana. Biol. Conserv. 39:1-11.

Podloucky, R. 1989. Protection of amphibians on roads: examples and experiences from Lower Saxony. Pp. 15-28 *In* T.E.S. Langton (ed.) Amphibians and Roads, proceedings of the toad tunnel conference. ACO Polymer Products, Shefford, England.

Rodriguez, A., G. Crema and M. Delibes. 1996. Use of non-wildlife passages across a high speed railway by terrestrial vertebrates. J. Appl. Ecol. 33:1527-1540.

Reed, D.F. 1981. Mule deer behavior at a highway underpass exit. J. Wildl. Manage 45(2):542-543.

Reed, D.F., T.N. Woodard and T.M. Pojar. 1975. Behavioral response of mule deer to a highway underpass. J. Wildl. Manage 39(2):361-367.

Roof, J. and J. Wooding. 1996. Evaluation of the S.R. 46 wildlife crossing in Lake County, Florida. 7 pp. *In* G.L. Evink, P. Garrett, D. Zeigler and J. Berry (eds.) Trends in Addressing Transportation Related Wildlife Mortality, proceedings of the transportation related wildlife mortality seminar. State of Florida Department of Transportation, Tallahassee, FL. FL-ER-58-96.

Rosell, C., J. Parpal, R. Campeny, S. Jove', A. Pasquina and J.M. Velasco. 1997. Mitigation of barrier effect of linear infrastructures on wildlife. Pp. 367-372 *In* K. Canters (ed.) Habitat Fragmentation & Infrastructure, proceedings of the international conference on habitat fragmentation, infrastructure and the role of ecological engineering. Ministry of Transport, Public Works and Water Management, Delft, The Netherlands.

Santolini, R., G. Sauli, S. Malcevschi, and F. Perco. 1997. The relationship between infrastructure and wildlife: problems, possible solutions and finished works in Italy. Pp. 202-212 *In* K. Canters (ed.) Habitat Fragmentation & Infrastructure, proceedings of the international conference on habitat fragmentation, infrastructure and the role of ecological engineering. Ministry of Transport, Public Works and Water Management, Delft, The Netherlands.

Singer, F.J. and J.L. Doherty. 1985. Managing mountain goats at a highway crossing. Wild. Soc. Bull. 13:469-477.

Wagner, P., M. Carey, and J. Lehmkuhl. 1998. Assessing habitat connectivity through transportation corridors on a broad scale: an interagency approach. Pp. 66-67 *In* G.L. Evink, P. Garrett, D. Zeigler, and J. Berry (eds.) Proceedings of the International Conference on Wildlife Ecology and Transportation. Florida Department of Transportation, Tallahassee, Florida.

Yanes, M. J.M. Velasco and F. Suarez. 1995. Permeability of roads and railways to vertebrates: the importance of culverts. Biol. Cons. 71:217-222.

BioOne RESEARCH EVOLVED

Demography and Genetic Structure of a Recovering Grizzly Bear Population

Author(s): Katherine C. Kendall, Jeffrey B. Stetz, John Boulanger, Amy C. Macleod, David Paetkau, and Gary C. White

Source: Journal of Wildlife Management, 73(1):3-17. 2009.
Published By: The Wildlife Society
DOI: http://dx.doi.org/10.2193/2008-330
URL: http://www.bioone.org/doi/full/10.2193/2008-330

BioOne (www.bioone.org) is a nonprofit, online aggregation of core research in the biological, ecological, and environmental sciences. BioOne provides a sustainable online platform for over 170 journals and books published by nonprofit societies, associations, museums, institutions, and presses.

Your use of this PDF, the BioOne Web site, and all posted and associated content indicates your acceptance of BioOne's Terms of Use, available at www.bioone.org/page/terms_of_use.

Usage of BioOne content is strictly limited to personal, educational, and non-commercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

BioOne sees sustainable scholarly publishing as an inherently collaborative enterprise connecting authors, nonprofit publishers, academic institutions, research libraries, and research funders in the common goal of maximizing access to critical research.

Demography and Genetic Structure of a Recovering Grizzly Bear Population

KATHERINE C. KENDALL,[1] *United States Geological Survey–Northern Rocky Mountain Science Center, Glacier Field Station, Glacier National Park, West Glacier, MT 59936, USA*

JEFFREY B. STETZ, *University of Montana Cooperative Ecosystem Studies Unit, Glacier Field Station, Glacier National Park, West Glacier, MT 59936, USA*

JOHN BOULANGER, *Integrated Ecological Research, 924 Innes Street, Nelson, BC V1L 5T2, Canada*

AMY C. MACLEOD, *University of Montana Cooperative Ecosystem Studies Unit, Glacier Field Station, Glacier National Park, West Glacier, MT 59936, USA*

DAVID PAETKAU, *Wildlife Genetics International, Box 274, Nelson, BC V1L 5P9, Canada*

GARY C. WHITE, *Department of Fish, Wildlife and Conservation Biology, Colorado State University, Fort Collins, CO 80523, USA*

ABSTRACT Grizzly bears (brown bears; *Ursus arctos*) are imperiled in the southern extent of their range worldwide. The threatened population in northwestern Montana, USA, has been managed for recovery since 1975; yet, no rigorous data were available to monitor program success. We used data from a large noninvasive genetic sampling effort conducted in 2004 and 33 years of physical captures to assess abundance, distribution, and genetic health of this population. We combined data from our 3 sampling methods (hair trap, bear rub, and physical capture) to construct individual bear encounter histories for use in Huggins–Pledger closed mark–recapture models. Our population estimate, $\hat{N} = 765$ (95% CI = 715–831) was more than double the existing estimate derived from sightings of females with young. Based on our results, the estimated known, human-caused mortality rate in 2004 was 4.6% (95% CI = 4.2–4.9%), slightly above the 4% considered sustainable; however, the high proportion of female mortalities raises concern. We used location data from telemetry, confirmed sightings, and genetic sampling to estimate occupied habitat. We found that grizzly bears occupied 33,480 km^2 in the Northern Continental Divide Ecosystem (NCDE) during 1994–2007, including 10,340 km^2 beyond the Recovery Zone. We used factorial correspondence analysis to identify potential barriers to gene flow within this population. Our results suggested that genetic interchange recently increased in areas with low gene flow in the past; however, we also detected evidence of incipient fragmentation across the major transportation corridor in this ecosystem. Our results suggest that the NCDE population is faring better than previously thought, and they highlight the need for a more rigorous monitoring program. (JOURNAL OF WILDLIFE MANAGEMENT 73(1):3–17; 2009)

DOI: 10.2193/2008-330

KEY WORDS abundance estimation, genetic structure, grizzly bear, mark–recapture modeling, noninvasive sampling, Northern Continental Divide Ecosystem, northwestern Montana, population monitoring, *Ursus arctos.*

Worldwide, large carnivores are increasingly becoming endangered (Gittleman and Gompper 2001, Cardillo et al. 2005), but efforts to detect and reverse such declines are often hampered by limited data (Gibbons 1992, Andelman and Fagan 2000). Large carnivores tend to be sparsely distributed over large areas and are difficult to observe (Schonewald-Cox et al. 1991). Grizzly bears (brown bears; *Ursus arctos*) exemplify these challenges and are threatened in many parts of their holarctic range.

The 5 remaining grizzly bear populations in the conterminous United States were listed as threatened in 1975 (U.S. Fish and Wildlife Service [USFWS] 1993; Fig. 1). Only 2 of these populations are currently thought to support more than approximately 50 individuals: the recently delisted population in the isolated Greater Yellowstone Ecosystem and our study population in the Northern Continental Divide Ecosystem (NCDE; Fig. 1) in northwestern Montana, USA. The NCDE population is the only large population that remains connected to Canadian populations.

The Recovery Plan for the NCDE population identifies 6 recovery thresholds related to mortality rates and distribution of breeding females (Appendix). The program is based on the best available science and relies on data acquired during routine agency activities rather than design-driven sampling (USFWS 1993, Vucetich et al. 2006). Multiyear counts of females with cubs are used to estimate population size and mortality rates because, in the absence of marked animals, individual females can be more easily identified than lone bears based on the number of cubs accompanying them.

Despite strong public interest and costly management programs, there has been no rigorous, ecosystem-wide assessment of distribution and abundance in the NCDE, and the status of the population was unclear. Although sightings at the edge of the population's range have increased, suggesting population growth, allowable human-caused mortality thresholds have been exceeded every year for the last decade (USFWS 1993; Appendix).

To more rigorously assess the current status of this population, we conducted intensive noninvasive genetic sampling (NGS) across all lands occupied by grizzly bears in the NCDE and augmented these data with information collected during 33 years of research and management activities. We estimated abundance, distribution, and genetic population structure using individuals identified from multilocus genotypes of hair and tissue samples collected from bears that occupied our study area during

[1] *E-mail: kkendall@usgs.gov*

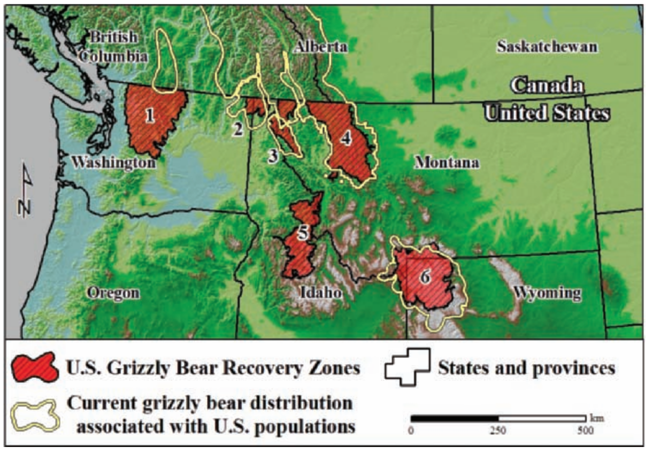


Figure 1. Location of remaining grizzly bear populations and Recovery Zones (established in the U.S. Fish and Wildlife Service [1993] Grizzly Bear Recovery Plan) south of Canada. Recovery zones: North Cascade (1), Selkirk (2), Cabinet–Yaak (3), Northern Continental Divide (4), Bitterroot (5), and Yellowstone (6).

our 2004 field season. We used our results to test assumptions about DNA-based mark–recapture analyses, estimate genetic error rates, and evaluate the USFWS program established to monitor this population.

STUDY AREA

Our 31,410-km^2 study area in the northern Rocky Mountains of Montana encompassed the NCDE Grizzly Bear Recovery Zone (USFWS 1993) and extended to the edge of surrounding lands thought to have grizzly bears present during our study (Fig. 2A). The only exception was along the northern edge where the study area boundary was delineated by the United States–Canada border, which was open to bear movement. Black bears (*Ursus americanus*) occurred throughout the NCDE. The study area had a central core of rugged mountains managed as national park, wilderness, and multiple-use forest, surrounded by lower elevation tribal, state, and corporate timber lands, state game preserves, private ranch lands, and towns. Approximately 75% of the study area was mountainous and 35% was roadless. The study area included all of Glacier National Park, portions of 5 national forests (Flathead, Kootenai, Lewis and Clark, Lolo, and Helena), 5 wilderness areas (Bob Marshall, Great Bear, Scapegoat, Mission Mountains, and Rattlesnake), parts of the Blackfeet Nation and Confederated Salish and Kootenai Indian reservations, and hundreds of private land holdings. The east–west running United States Highway 2 and Burlington Northern–Santa Fe (BNSF) railroad form the largest and busiest transportation corridor in the NCDE (Fig. 2).

METHODS

Sampling Methods

To maximize coverage, we used 2 independent, concurrent NGS methods to sample the NCDE grizzly bear population. Our primary effort was based on systematically distributed hair traps using a grid of 641 7 × 7-km cells during 15 June–18 August 2004. We placed one trap in a different location in each cell during 4 14-day sampling occasions. Hair traps consisted of one 30-m length of 4-prong barbed wire encircling 3–6 trees or steel posts at a height of 50 cm (Woods et al. 1999). We poured 3 L of scent lure, a 2:1 mix of aged cattle blood and liquid from decomposed fish, on forest debris piled in the center of the wire corral. We hung a cloth saturated with lure in a tree 4–5 m above the center of the trap. We collected hair from barbs, the ground near the wire, and the lure pile. All hairs from one set of barbs constituted a sample; we used our best judgment to define samples from the ground and lure pile. We placed each hair sample in a paper envelope labeled with a uniquely numbered barcode.

We selected hair trap locations before the field season using consistent criteria throughout the study area based on Geographic Information System (GIS) layers and expert knowledge. We based selection on evidence of bear activity, presence of natural travel routes, seasonal vegetation characteristics, and indices of recent wildfire severity. Each trap was located ≥1 km from all other hair traps, ≥100 m from maintained trails, and ≥500 m from developed areas, including campsites. To help field personnel navigate to hair traps, we loaded all coordinates into Global Positioning System (GPS) units and made custom topographic and orthophoto maps for each site.

We also collected hair during repeated visits to bear rubs during 15 June–15 September 2004. Bear rubbing was a result of natural behavior; we used no attractant. We surveyed rubs on approximately 80% of the study area; we omitted lands along the eastern edge of study area due to insufficient personnel and a relative scarcity of rubs. We identified 4 primary types of bear rubs for hair collection: trees (85%), power poles (8%), wooden sign and fence posts (5%), and barbed wire fences (2%). We focused on bear rubs located along trails, forest roads, and power and fence lines to facilitate access and ensure that we could reliably find the rubs. Each rub received a uniquely numbered tag and short pieces of barbed wire nailed to the rubbed surface in a zigzag pattern. We used barbless wire mounted vertically on bear rubs that had been bumped by horse packs. We found that the separated ends of double-stranded wire were effective at snaring hair but would not damage passing stock. During each rub visit, we collected all hair from each barb to ensure that we knew the hair deposition interval. We collected hair only from the barbed wire and passed a flame under each barb after collection to prevent contamination between sessions.

We compiled capture, telemetry, mortality, age, and past DNA detection data for 766 grizzly bears handled for research or management or identified during other hair sampling studies (Kendall et al. 2008) in the NCDE during 1975–2007. Of the bears for which tissue samples were available, 426 were successfully genotyped at ≥7 loci for individual identification. We used these data 1) to identify bears that had been live-captured before 2004 for use as a covariate in mark–recapture modeling, 2) to investigate independence of capture probabilities among females and their dependent offspring, and 3) for our analysis of temporal trend in genetic structure. To determine the proportion of sex–age classes of bears detected with hair trap and bear rub sampling, we assumed that bears that met all of the following criteria were potentially available to be sampled: 1) ≥1 location on the NCDE study area during 15 June–15 September 1995–2006, 2) alive and ≤20 years old in 2004 (we included older bears if documented on the study area post-2003), and 3) not known to have died before 2004. We only included bears with reliable genotypes that were known to be present on our study area during our sampling period in our mark–recapture analysis.

Genetic Methods

We stored hair samples on silica desiccant at room temperature and blood and muscle samples either frozen or in lysis buffer. Samples were analyzed at a laboratory that specialized in low DNA quantity and quality samples, following standard protocols (Woods et al. 1999, Paetkau 2003, Roon et al. 2005). We analyzed all samples with ≥1 guard hair follicle or 5 underfur hairs, and we used up to 10 guard hairs plus underfur when available.

The number and variability of the markers used to identify individuals determine the power of the multilocus genotypes to differentiate individuals. We used 7 nuclear microsatellite loci to define individuals: G10J, G1A, G10B, G1D, G10H, G10M, and G10P (Paetkau et al. 1995). Preliminary data from this population suggested that randomly drawn, unrelated individuals would have identical genotypes (P_{ID}) with probability 1×10^{-7}, and full siblings would share identical genotypes with probability (P_{SIB}) 0.0018 for this marker set. These match probabilities assume a specified level of relationship, making it difficult to interpret them in the context of a study population in which the distribution of consanguinity is unknown. We obtained a more direct empirical estimate of match probability by extrapolating from observed mismatch distributions (Paetkau 2003). For each individual identified, we attempted to extend genotypes to 17 loci using the following markers: G10C, G10L, CXX110, CXX20, Mu50, Mu59, G10U, Mu23, G10X, and amelogenin (for gender; Ennis and Gallagher 1994).

For the first phase of the analysis, we used one microsatellite marker (G10J), which has a high success rate and at which alleles with an odd number of base pairs are diagnostic of black bears. The only exception to this rule is a 94–base pair allele that exists in both species in our ecosystem. When this allele is present, species must be confirmed through additional analyses. We set aside samples that failed at this marker twice, as well as samples with 2 odd-numbered alleles. We analyzed all individuals with ≥1 94–base pair allele at G10J at all 7 markers that we used for individual identification, whether or not the second allele was even-numbered (presumed grizzly bears) or odd-numbered (presumed black bears).

During the next phase of lab analysis, we finished individual identifications by analyzing 6 additional markers on samples that passed through the G10J prescreen. We did not attempt to assign individual identity to any sample that failed to produce strong, typical, diploid (i.e., not mixed) genotype profiles for all 7 markers. We believe that this strict rejection of all samples whose genotypes contained weak, missing, or suspect data (e.g., unbalanced peak heights) dramatically reduced genotyping error by eliminating the most error-prone samples.

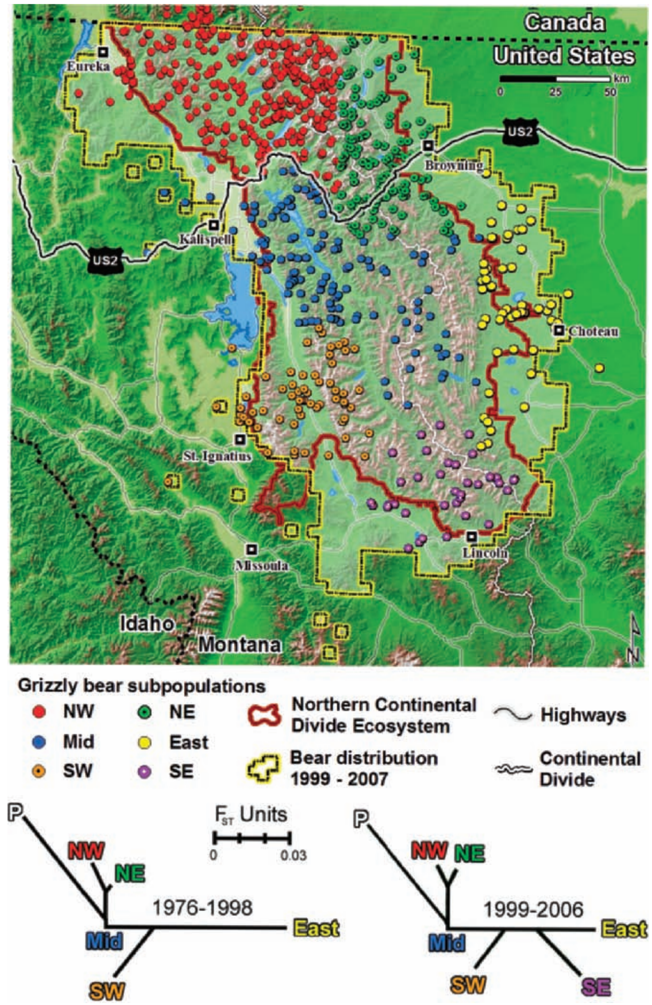


Figure 2. Change in genetic differentiation between regions within the Northern Continental Divide Ecosystem (NCDE) grizzly bear population, 1976–2006. (A) Map of region membership of grizzly bears with ≥13-locus genotypes within the NCDE as grouped by factorial correspondence analysis. Distribution of grizzly bears (1994–2007) in the NCDE study area based on records of grizzly bear presence; total population range = 33,475 km^2; Grizzly Bear Recovery Zone = 23,130 km^2. (B) Fitch tree of genetic distances within the NCDE population for 1976–1998 and 1999–2006. The small number of genotypes available for the SE region for 1976–1998 ($n = 2$) precluded inclusion in that time period. Genetic distance to the Prophet River (P), British Columbia, grizzly bear population 1,150 km north of the NCDE was included for comparison with within-NCDE population distances.

Genotyping errors that result in the creation of false individuals, such as allelic dropout and amplification error, can bias mark–recapture population estimates (Mills et al. 2000, Roon et al. 2005). We used selective reanalysis of similar genotypes to detect and eliminate errors. We replicated genotypes for all 1) individuals identified in a single sample, 2) pairs of individuals that differed at only 1 or 2 loci (1- and 2-mismatch pairs), 3) pairs of individuals that differed at 3 loci when those differences were consistent with allelic dropout (i.e., homozygous), and 4) individuals with samples geographically separated by large distances (Paetkau 2003, Roon et al. 2005, Kendall et al. 2008). We further minimized the risk of undetected genotyping error by replicating genetic data for all 17 markers (including gender) in $\geq$2 samples per individual or by repeating the analysis of all 17 markers in cases where just one sample was assigned to an individual. Whenever possible, we drew samples selected for reanalysis from a bear's 2 most distant capture points to potentially detect errors or true 0-mismatch pairs. We also made a photographic record of DNA liquid transfer steps to help determine the cause of handling errors when they occurred and to resolve them.

As part of our error-checking efforts, we submitted 748 blind control samples from 32 unique grizzly bears from throughout the NCDE to the laboratory. We constructed these samples to mimic the range of DNA quantity in hair samples collected in the field by varying the number of hairs with follicles per sample. Although lab personnel were aware that control samples would be randomly scattered among field samples, they were not aware of the number or identity of control samples. Genotyped bears for which sex was known from field data provided a similar opportunity to evaluate the accuracy of gender determinations. We also submitted 115 blind test samples that we created by mixing, in various proportions, hair from 2 individuals, mostly parent–offspring or full sibling pairs. As a final overall assessment of the reliability of our data, we contracted with Dr. Pierre Taberlet (Director of Research, National Centre for Scientific Research, Grenoble, France), an expert in issues of genotyping error in noninvasive samples (Taberlet et al. 1996, Abbott 2008), to conduct an independent assessment of our field, data entry, lab, and data exchange protocols. Among other tests, P. Taberlet examined the results of 100 randomly drawn and 406 blind samples for errors and then checked whether the data from the genetic analysis matched the database used for abundance estimates.

We replicated almost every genotype in the 17-locus data set, either between samples, by repeated analysis as positive controls, or during error-checking, which provided an outstanding opportunity to detect genotyping errors. We recorded an error each time a genotype was changed after being entered into the database as a high-confidence score (i.e., not flagged as requiring reanalysis to confirm a weak initial result). The extra measures we used to avoid the creation of spurious individuals, along with our large sample size, permitted us to evaluate the standard methods that formed the foundation of our genotyping protocol (Paetkau 2003). Before starting the analysis of supplemental markers (in duplicate, with emphasis on geographically distant samples), we generated a preliminary 7-locus results file using only the standard protocol of selective reanalysis of similar genotypes.

Estimating Abundance, Mortality, Distribution, and Genetic Population Structure

We developed an approach to abundance estimation that combined data from our 3 sampling methods (hair trap, bear rub, and physical capture) to construct individual bear encounter histories for use in Huggins–Pledger closed mark–recapture models (Huggins 1991, White and Burnham 1999, Pledger 2000, Boulanger et al. 2008*a*, Kendall et al. 2008). We performed all mark–recapture analyses in Program MARK (White and Burnham 1999; Pledger model updated May 2007). The Huggins model allows the use of individual covariates, in addition to group and temporal covariates, to model capture probability heterogeneity. Pledger (2000) mixture models use $\geq$2 capture probabilities to model heterogeneity by partitioning animals into groups with relatively homogenous capture probabilities. Our candidate models included gender, bear rub sampling effort (RSE), history of previous live capture (PrevCap), and distance to edge (DTE) covariates. Rub sampling effort was the number of days since the last survey summed for all bear rubs surveyed in a session. We considered a bear to have a history of live capture if it had been captured or handled, regardless of method, at any time before or during hair trap sampling. Distance to edge was the distance of the average capture location of each bear from the open (northern) boundary.

We used a stepwise a priori approach to mark–recapture model development. To determine the best structure for each data type, we initially modeled hair trap and bear rub data separately. We pooled the other 2 data types and used them as the first sample occasion for each exercise. For example, in the hair trap models, we combined bear rub and physical capture detections as the first sample session followed by the 4 hair trap sessions. We then combined the most supported hair trap and bear rub models into a single analysis in which we constructed encounter histories for each of the 563 bears detected during 10 sampling occasions as follows: physical capture (1), detection during 4 hair trap sessions (2–5), and detection during 5 bear rub survey sessions (6–10).

We evaluated relative support for candidate models with the sample size-adjusted Akaike Information Criterion for small sample sizes (AIC_c). We obtained estimates of population size as a derived parameter of Huggins–Pledger closed mixture models in Program MARK (White and Burnham 1999, White et al. 2001). Calculation of 95% log-based confidence intervals about those estimates incorporated the minimum number of bears known to be alive on the study area (White et al. 2001). We averaged population estimates based on their support in the data, as indexed by AIC_c weights, to account for model selection uncertainty (Burnham and Anderson 2002).

We used our abundance estimate to calculate an estimate of the known, human-caused mortality rate in 2004 for comparison with mortality and abundance estimates generated using the Recovery Plan method (USFWS 1993). The Recovery Plan population estimate and the number of mortalities applied only to the Recovery Zone plus a 16.1-km buffer. Because our abundance estimate covered a larger area, we used the total number of mortalities for this area to calculate mortality rate.

To determine the current range of grizzly bears, we plotted confirmed records of grizzly bear presence from hair snaring, captures, telemetry, mortalities, and sightings from 1994 to 2007 on a 5-km grid. We defined the edge of current distribution as the outermost occupied cells adjacent to other occupied cells. We mapped an occupied cell as an outlier if it was separated from other cells with bears by >1 empty cell (Fig. 2A).

To investigate population genetic structure, we identified regional subpopulation boundaries using factorial correspondence analysis (FCA) conducted in GENETIX (Belkhir et al. 2004). We adjusted the number and location of geographic boundaries on an ad hoc basis to minimize overlap of geographically defined genetic clusters (Fig. 2A). We used F_{ST} (Weir and Cockerham 1984, Barluenga et al. 2006) to estimate genetic differentiation between regions and visualized these values with Fitch trees (Fitch and Margoliash 1967). To determine gene flow across United States Highway 2 and BNSF railroad, we divided the corridor into 3 segments and used assignment tests (Paetkau et al. 1995) to compare the 50 individuals nearest to the highway on either side of the western and eastern sections (data not shown for the middle section; Fig. 2A).

To examine change in genetic structure over time, we divided our data set into 347 animals first captured before 1999 and 600 animals first captured more recently. We based the choice of 1998 as the cut-off for the earlier period on available sample size, which increased considerably after 1998. We conducted all population genetics analyses using ≥13-locus genotypes. We used 15 of the 16 microsatellite markers used in the NCDE in the data sets for bear populations in Canada and Alaska to which we made comparisons of genetic variability and population structure. Genetic distance calculations between the Prophet River and NCDE populations used 15-locus genotypes provided by G. Mowat (British Columbia Ministry of Environment, Nelson, BC, Canada; Poole et al. 2001).

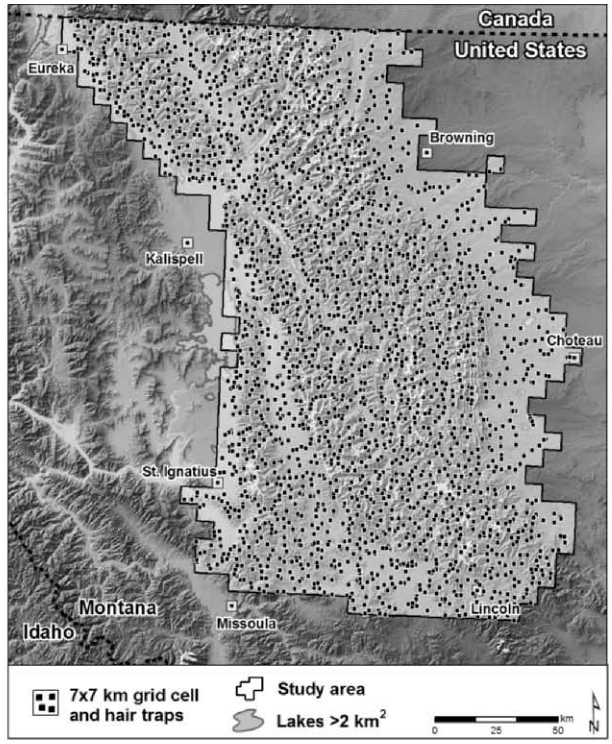
RESULTS

Sampling Effort

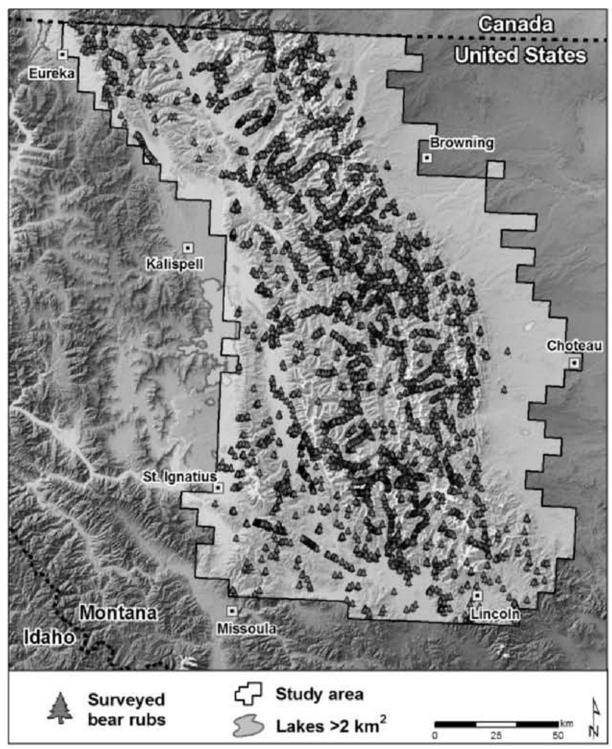
From 15 June to 18 August 2004, we collected 20,785 bear hair samples from 2,558 scent-baited hair traps (Fig. 3A; Table 1). We also collected 12,956 hair samples from 4,795 bear rubs (Fig. 3B; Table 2). We conducted 18,021 rub visits during our 15 June–15 September 2004 field season, for an average of 3.8 visits/rub (SD = 1.04; range 1–7; Table 2).

Genotyping Success, Marker Power, and Quality Control

We culled many of the 33,741 hair samples collected from hair traps and bear rubs before the first stage of analysis based on inadequate number of follicles (26.4%), obvious non–grizzly bear origin (2.3%), and subsampling criteria (2.1%). We attempted to genotype 23,325 (69.1%) samples. Genotyping success exceeded 70% with ≥3 guard hairs or ≥11 underfur follicles; success rates were similar for samples from hair traps and bear rubs. Of the samples we screened with the G10J marker, we set aside 17.3% after they failed twice and 51.2% identified as black bear (with 2 odd-



A



B

Figure 3. Location of grizzly bear hair snaring sites in the Northern Continental Divide Ecosystem, Montana, USA. (A) Location of bear hair traps (n = 2,558). We conducted hair trap sampling 15 June–18 August 2004. (B) Location of bear rubs (n = 4,795). We surveyed bear rubs on trails, forest roads, and power and fence lines during 15 June–15 September 2004.

Table 1. Grizzly bear hair trap results. We conducted hair trapping 15 June 2004–18 August 2004 in the Northern Continental Divide Ecosystem in northwestern Montana, USA, for 4 14-day sessions.[a]

Session	No. sites	% traps with ≥1 grizzly bear sample	Grizzly bear samples/trap[b]		Total no. grizzly bear samples	No. new bears		No. unique bears	
			$\bar{x}$	SD		F	M	F	M
1	640	19.4	4.3	4.0	535	70	60	70	60
2	637	15.5	5.8	6.4	570	44	40	50	55
3	638	20.2	6.2	6.8	796	83	39	111	55
4	643	19.7	6.4	6.8	810	69	43	114	76
$\bar{x}$	640	18.7	5.7	6.0	678	67	46	86	62
Total	2,558				2,711			266	182

[a] $\bar{x} = 13.98$ days, SD = 1.27.
[b] Of those hair traps that had ≥1 grizzly bear hair sample.

numbered alleles). We obtained complete 7-locus genotypes for 74.2% ($n = 4{,}218$) of the samples that passed the G10J prescreen. We encountered samples with hair from >1 bear infrequently; we classified 0.4% of hair trap and 0.8% of bear rub samples as mixed based on the appearance of ≥3 alleles at ≥3 markers. Of the 563 individual grizzly bears we used in our analyses, 560 had complete genotypes at 17 microsatellite loci and 542 were fully replicated at all 17 markers with ≥2 independent, high-confidence genotypes.

Mean observed heterozygosity across the 7 markers used to identify individuals was 0.73 (Table 3). The probability that 2 randomly drawn, unrelated individuals would share the same genotype (P_{ID}) was 9×10^{-8}, and the probability that full siblings would have identical genotypes (P_{SIB}) was 0.0017. Extrapolation from the mismatch distribution in our data set suggested approximately one pair of individuals with identical 7-locus genotypes. Expressed as a match probability, this equates to approximately 1/158,203, or 6×10^{-6}, midway between the estimates for siblings and unrelated bears (based on $563 \times 562/2 = 158{,}203$ pairs of individuals in the data set, and a predicted one pair of individuals with the same 7-locus genotype).

When we considered all available markers, all individual bears differed at ≥3 loci. All 563 individuals identified by the original 7-locus analysis also had unique multilocus genotypes for the supplemental microsatellite markers. Given the low rate of genotyping error documented during data duplication (above) and by blind control samples (below) there was effectively zero probability that a pair of samples from a given individual would contain undetected genotyping errors in both the original 7-locus and supplemental 9-locus genotype, so errors in the first 7 markers would be detected by discovery of matching genotypes at the supplemental markers.

As expected, some of the 748 blind control samples were of inadequate quality to obtain a reliable genotype. However, 100% of the 653 samples that we successfully genotyped were assigned to the correct individual, giving an estimated error rate for 7-locus genotypes of <1/653 (0.0015). As argued above, we believe that the actual number of false individuals is zero, but the blind controls provide an upper bound on the rate of error. Gender matched in all 514 cases for which we knew sex from field data. All of 115 deliberately mixed samples from 2 individuals were either assigned a genotype that matched 1 of the 2 source bears, failed to produce a clear genotype, or were correctly identified as mixed. In no case was a spurious individual recognized through mixing of alleles from 2 individuals' genotypes, presumably because of the strict exclusion of samples with atypical genotype profiles at even one marker. The independent assessment of field and laboratory protocols concluded that 1) all consistency checks strongly supported the reliability of the data, 2) no mechanism for systematic error was present, and 3) the error rate for the number of individual bears identified was ≤1%.

Factorial correspondence analysis (Kadwell et al. 2001, Belkhir et al. 2004) based on 6-locus genotypes (i.e., excluding G10J) provided unambiguous and independent

Table 2. Grizzly bear rub survey results. We conducted surveys 15 June 2004–15 September 2004 in the Northern Continental Divide Ecosystem in northwestern Montana, USA. We combined sessions with low sampling effort for mark–recapture analysis.

Session	No. bear rub visits	% bear rubs with grizzly bear hair	No. grizzly bear samples/rub[a]		Rub tree effort[b]	Total no. grizzly bear samples	No. new bears		No. unique bears	
			$\bar{x}$	SD			F	M	F	M
1–2	3,186	18.7	2.5	1.8	53,220	595	17	68	17	68
3	3,510	13.8	2.4	1.8	61,900	484	29	34	32	68
4	3,081	13.2	2.6	2.1	57,001	406	24	20	33	50
5	4,208	11.7	2.3	1.6	82,358	494	35	22	54	63
>6	4,036	10.4	2.2	1.5	63,999	380	15	11	39	50
$\bar{x}$	3,604	13.6	2.4	1.8	63,696	472	24	31	35	60
Total	18,021				318,478	2,359			120	155

[a] Of those bear rub visits that had at least one grizzly bear hair sample.
[b] Rub sampling effort (RSE) is the cumulative no. of days between successive hair collections for each rub sampled per session. For example, if we surveyed 3,000 rubs during session 3, each surveyed 20 days earlier, the RSE for session 3 would be $3{,}000 \times 20 = 60{,}000$.

Table 3. Variability of microsatellite markers used to determine individual identity of grizzly bears in the Northern Continental Divide Ecosystem in northwestern Montana, USA, in 2004.[a]

Marker	H_E	H_O	A	P_{ID}	P_{SIB}
G10J	0.76	0.72	6	0.10	0.40
G1A	0.72	0.73	7	0.11	0.42
G10B	0.77	0.74	9	0.08	0.38
G1D	0.79	0.80	11	0.07	0.37
G10H	0.68	0.65	11	0.13	0.44
G10M	0.71	0.69	9	0.14	0.43
G10P	0.77	0.75	7	0.08	0.39
$\bar{x}$	0.74	0.73	8.6		
Overall probability of identity				9E–08	0.0017

[a] H_E = expected heterozygosity; H_O = observed heterozygosity; A = no. of alleles; P_{ID} = probability of identity; P_{SIB} = probability of sibling identity.

Table 4. Total minimum counts and model-averaged estimates of grizzly bear population abundance in the Northern Continental Divide Ecosystem in northwestern Montana, USA, in 2004.

Parameter	Min. count	Estimate	SE	CV (%)	95% log-based CI	
					Lower	Upper
M	242	294.58	12.01	4.1	276	324
F	321	470.60	26.16	5.6	427	531
Pooled	563	765.18	29.27	3.8	715	831

species assignment for all individuals and confirmed that all individuals with ≥1 odd-numbered allele were black bears. The black bear genotypes that were closest to grizzly bears in the FCA had their genotypes extended to 16 microsatellite markers, as did genotypes that were homozygous for allele 94 at G10J. Subsequent 15-locus FCA analysis (excluding G10J) confirmed earlier 6-locus species assignments and identified 58 grizzly bears and 2 black bears that were homozygous for allele 94.

We estimated our rates of initial error (i.e., before error-checking) were 0.005 per locus per sample for the 7 microsatellites used on all samples, 0.002 for the 9 extra microsatellite markers, and 0.0007 for gender. Overall, we classified 67% of the 234 detected errors as human errors (e.g., inaccurate scoring), 18% as allelic dropout, and 15% as false or irreproducible amplifications.

Population Abundance, Mortality, Distribution, and Genetic Structure

Our model-averaged abundance estimate for the NCDE population in 2004 was $\hat{N} = 765$ (95% CI = 715–831; Table 4). Although this represents a superpopulation estimate (Crosbie and Manly 1985), we estimated from radio-telemetry and DNA captures that only 0.5% of the bears we sampled moved outside of the study area to the west or east, and 1% of bears crossed the northern boundary of our study area (12% of the perimeter) during our 2004 sample period. Total known, human-caused mortality when calculated using our abundance estimate was 4.6% (95% CI = 4.2–4.9%); the female mortality rate was double the maximum allowed by the Recovery Plan (Appendix; USFWS 1993).

Our data supported 10 models as indicated by ΔAIC_c values ≤2 (Burnham and Anderson 2002; Table 5). However, our stepwise model development process resulted in very similar candidate models in the final stages of the analysis. In fact, the only parameters that varied were the sex-specific DTE threshold values. Our joint (physical capture–hair trap–bear rub) models suggested that hair trap capture probabilities mainly varied by sex, time, and PrevCap (Table 5). Average per-session capture probabilities were similar across genders for hair traps ($\hat{\bar{p}}_M = 0.22$; $\hat{\bar{p}}_F = 0.19$), with both genders having the lowest capture probabilities in session 2 and the highest by session 4 (Fig. 4). Bears with a history of previous live capture were 58.4% (95% CI = 42–79%) less likely to be captured in hair traps than were bears with no known record of capture. Bear rub capture probabilities varied by sex, sex-specific temporal trends, and RSE (Table 5). Males had approximately 3-fold higher average capture probabilities than females, but males displayed slightly declining capture probabilities over time. Conversely, females showed a slight increasing trend in capture probabilities over time and were nearly equal with males in session 4 (Fig. 4). In addition, there was undefined heterogeneity present in the bear rub data as indicated by the support for mixture models with this data type (Table 5). The DTE threshold values for the most supported model was ≤15 km and 5 km for males and females, respectively, which is consistent with bear biology because males are expected to move greater distances than females. Generally, as DTE increased above those levels, model support declined (Table 5).

Spring molting and behavioral differences between males and females could cause variation in hair deposition rates, sometimes in opposing directions. Because this may have influenced DNA capture probabilities, we examined our data for seasonal and gender-based differences in the number of hair samples deposited. Our data showed no seasonal trend in the number of hair samples left by females and a slight decrease in the number of samples deposited by males over the course of hair sampling. Although male and female hair deposition rates differed by sampling type (hair trap or bear rubs), this did not result in variable detection rates because we needed only one sample from each individual per hair sampling site to document presence.

In total, we detected 545 unique bears with our joint hair snaring methods, or 71% of the estimated population. By comparing hair snaring captures to genotypes from 276 handled bears of known sex and age class, we estimated hair snaring detected 44% of cubs, 80% of yearlings, and 89% of adult females known to be, or potentially present (Table 6). From our live-captured bear data, we knew of 6 family groups detected at hair traps. Of the 17 instances when we detected one member of a family group, we failed to detect other family members 53% of the time. Bear rub data also showed variable detection within families; we detected multiple members of the same group together in only 31% of 16 opportunities.

We detected 321 unique females and estimated there were

Table 5. Model selection results from mark–recapture analysis of the grizzly bear population in the Northern Continental Divide Ecosystem in northwestern Montana, USA, in 2004, sampled using physical capture (occasion 1), hair traps (occasions 2–5), and bear rubs (occasions 6–10). We present only models with $\Delta AIC_c < 2$. Results from Program MARK, 25 November 2007 build.

Model[a]	AIC_c[b]	ΔAIC_c[c]	w_i[d]	Model likelihood	No. parameters	Deviance
Base model + DTE_{M15km}, DTE_{F5km}	5,012.216	0	0.116	1	21	4,970.051
Base model + DTE_{5km}	5,012.624	0.409	0.094	0.815	20	4,972.474
Base model + DTE_{M20km}, DTE_{F5km}	5,012.894	0.678	0.082	0.712	21	4,970.729
Base model + DTE_{15km}	5,012.947	0.731	0.080	0.694	20	4,972.797
Base model + DTE_{M25km}, DTE_{F5km}	5,013.084	0.868	0.075	0.648	21	4,970.919
Base model + DTE_{10km}	5,013.117	0.902	0.074	0.637	20	4,972.968
Base model + DTE_{M15km}, DTE_{F10km}	5,013.132	0.917	0.073	0.632	21	4,970.967
Base model + DTE_{M30km}, DTE_{F5km}	5,013.496	1.280	0.061	0.527	21	4,971.331
Base model + DTE_{M20km}, DTE_{F10km}	5,013.806	1.590	0.052	0.452	21	4,971.641
Base model + DTE_{M10km}, DTE_{F5km}	5,013.899	1.684	0.050	0.431	21	4,971.735

[a] Base model notation: PC (.) [HT: p(sex × t + PrevCap) RT: π (sex) $p_{1\&2}$ (× sex + sex × T + RSE)]. Base model description: Physical capture probability held constant. Hair trap: sex- and session-specific capture probabilities (p), with an effect of previous live capture (PrevCap), i.e., known to have a previous physical capture. Rub tree: sex-specific mixture probability (π). Capture probability is sex-specific with sex-specific linear trends (T), and an effect of rub sampling effort. Parameter definitions: PC = physical capture; HT = hair trap; RT = rub tree (includes all types of bear rubs). Mixture models only supported for RT data. RSE = rub sampling effort: cumulative no. of days between successive hair collections across all sampled rubs/session. For example, if we surveyed 2,000 rubs during session 2, each surveyed 20 days earlier, the RSE for session 2 would be 2,000 × 20 = 40,000. DTE = individual covariate of distance to northern edge of study area. Effects of distance to edge are limited to the thresholds specified in model notation, e.g., DTE_{M15km} means that only male bears with an average capture location ≤15 km from the northern edge are modeled with this covariate.

[b] Akaike's Information Criterion for small sample sizes.

[c] The difference in AIC_c value between the *i*th model and the model with the lowest AIC_c value.

[d] Akaike wt used in model averaging.

470 (95% CI = 427–531) in the NCDE population. We detected ≥1 (range 2–56) female in each of the 23 Bear Management Units defined in the Recovery Plan, as well as 12 females beyond the Recovery Zone boundary. Overall, population density declined along a north–south axis and toward the periphery of grizzly bear range (Fig. 5). Grizzly bears occupied 33,480 km^2 in the NCDE during 1994–2007, including 10,340 km^2 outside the Recovery Zone (Fig. 2A).

Factorial correspondence analysis identified 6 subpopulations in the NCDE (Fig. 2). In 4 of those subpopulations, genetic diversity approached levels found in undisturbed populations (15-locus mean H_E = 0.66–0.68). However, genetic variability was lower in the eastern ($H_E = 0.61$) and southeastern ($H_E = 0.62$) subpopulations.

Despite the general absence of geographically delimited genetic discontinuities, genetic differentiation between the northern NCDE and the southern and eastern periphery (F_{ST} = 0.05–0.09; 16–118 km apart) was similar to or greater than the value ($F_{ST} = 0.06$) observed between the northern NCDE and the Prophet River population in British Columbia, Canada, 1,150 km to the north (Fig. 2B; Table 7; Poole et al. 2001). When we compared population structure for animals first captured 1976–1998 with that of animals first captured 1999–2006, we found that the genetic distinctiveness of the eastern and southwestern periphery decreased over time (Fig. 2).

The only signal of population fragmentation that aligned with landscape features was across Highway 2 and the BNSF rail line (Figs. 2, 6). There was little discernible genetic differentiation across the eastern portion of the corridor ($F_{ST} = 0.01$), but at the western end, where human density and traffic volumes were higher, differentiation indicated reduced genetic interchange ($F_{ST} = 0.04$; Fig. 6).

DISCUSSION

Our study provides the first ecosystem-wide status assessment of the NCDE grizzly bear population. Our abundance estimate was 2.5 times larger than the recovery program estimate. However, density varied dramatically; we found the highest concentrations of grizzly bears in Glacier National Park but detected fewer bears in the southern portion of the ecosystem. Our results suggested that the population was growing in terms of abundance, occupied habitat, and connectivity in areas of historically low genetic interchange. Our results also suggested that the population has generally remained genetically integrated and connected to Canadian populations. Conversely, we detected incipient fragmentation along the major transportation corridor in the NCDE and caution that continued unmitigated development may lead to reduced gene flow within this population and reduced connectivity to adjacent populations. Our use of 3 data sources increased our sample coverage, resulting in improved estimate precision and greater resolution of genetic population structure. We demonstrated that our NGS detected bears of all sex–age classes; therefore, our derived estimates reflect total population abundance. Our assessment suggests that grizzly bear recovery efforts have generally been successful; however, our results also highlight the need for improved monitoring techniques and reinforce the need to reduce the human-caused female mortality rate.

Grizzly Bear Demography and Population Structure

Abundance and mortality.—Our abundance estimate was more than double the existing estimate (Appendix) and represents the first ecosystem-wide estimate of this population to include a measure of precision. Although our estimate reflects the superpopulation abundance, given the low rates of bear movement off our study area, we felt

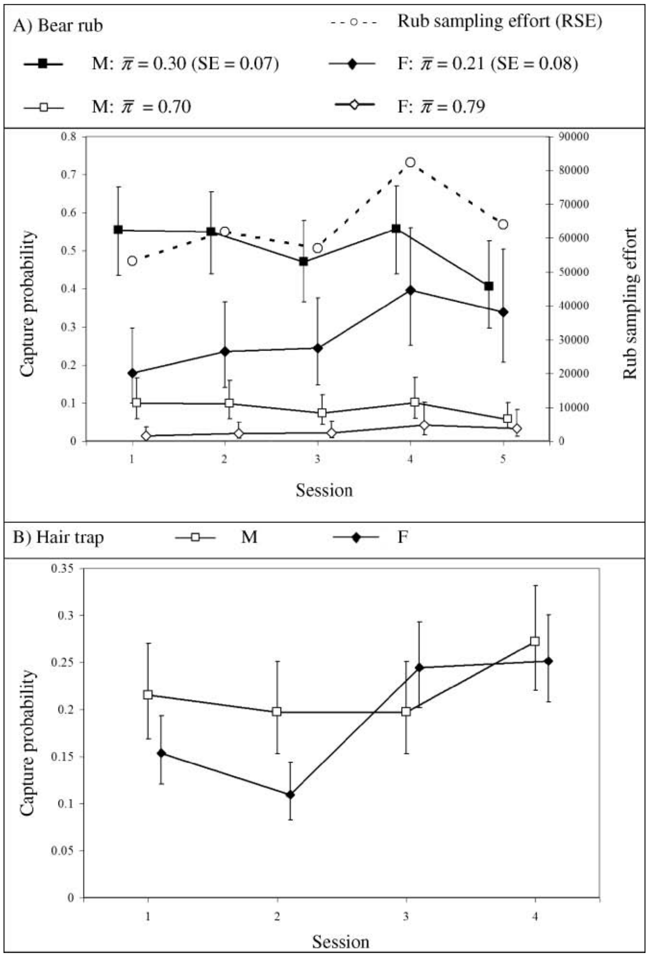


Figure 4. Gender-specific per session grizzly bear capture probability estimates from (A) bear rub surveys and (B) hair traps in the Northern Continental Divide Ecosystem, Montana, USA. Sampling sessions were 2 weeks long, beginning 15 June 2004. Pi (π) values represent the probability that an individual grizzly bear has 1 of 2 capture probabilities in the bear rub data. For example, in our data male bears had probability 0.30 of having the higher capture probabilities depicted in the top solid line. We derived estimates from the most selected models from Table 5. Rub sampling effort was the cumulative number of days between successive hair collections summed over all bear rubs sampled per session; values are presented on the secondary *y* axis.

correcting for closure violation was unnecessary and would not impact inferences on population status. The known, human-caused mortality rate in 2004 when calculated with our abundance estimate was slightly above the 4% level considered sustainable (USFWS 1993). However, the number of mortalities in 2004 ($n = 35$) was the highest on record, and the female mortality rate was double the level allowed in the Recovery Plan. This is noteworthy because female survival is the most important driver of population trend (Schwartz et al. 2006). Although the Recovery Plan thresholds account for unreported mortality, this rate is difficult to measure and may vary over time (Cherry et al. 2002).

Knowing the sex–age classes included in population estimates is vital for monitoring population trend and making meaningful comparisons of density among populations. For example, dependent offspring can constitute 30% of grizzly bear populations (Knight and Eberhardt 1985). Because an animal's age cannot be determined from hair, it has been unclear whether dependent offspring are sampled with hair snaring and included in abundance estimates derived from noninvasive sampling (Boulanger et al. 2004). Based on our large sample of bears ($n = 276$) for which sex and age were known, we found that hair snaring detected substantial proportions of the cubs and yearlings known to be present (Table 6). This represents the most conclusive evidence to date that bear population estimates derived from hair snaring include all sex–age classes. Our estimate of the DNA detection rate was likely conservative because 1) bears that have been previously live-captured may be less likely to be sampled in hair traps (Boulanger et al. 2008*a*); 2) some known bears may have ranged beyond the study area boundary during our sampling season, making them unavailable for DNA detection; and 3) unrecorded deaths could have occurred before DNA sampling.

Distribution.—Consistent with population expansion, we documented a substantial amount of habitat occupied by grizzlies beyond the Recovery Zone. Female grizzlies were well distributed and found in all bear management units. Although not all were of breeding age, the number and wide distribution of females detected suggest good reproductive potential. However, density varied substantially from high levels in Glacier National Park in the north to low levels in the south (Fig. 5). Several areas in the NCDE had few or no detections, including some that contained high-quality habitat, suggesting that there is still potential for population growth.

A single measure of bear density in a region as large and diverse as the NCDE would have little value and could be misleading compared with other populations. Climate, topography, vegetation, and land use were highly variable and likely influenced bear density patterns. Further complicating comparison with other populations, mammalian carnivore density estimates tend to vary inversely with study area size (Smallwood and Schonewald 1998).

Table 6. Number and proportion of grizzly bears that were present or potentially present that we detected with hair snaring in the Northern Continental Divide Ecosystem in northwestern Montana, USA, during the 2004 sampling period.

	Cub		Yearling		Subadult		Ad		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
F	11	36	7	100	11	55	118	89	147	83
M	5	60	8	63	20	75	96	94	129	88
Total	16	44	15	80	31	68	214	91	276	85

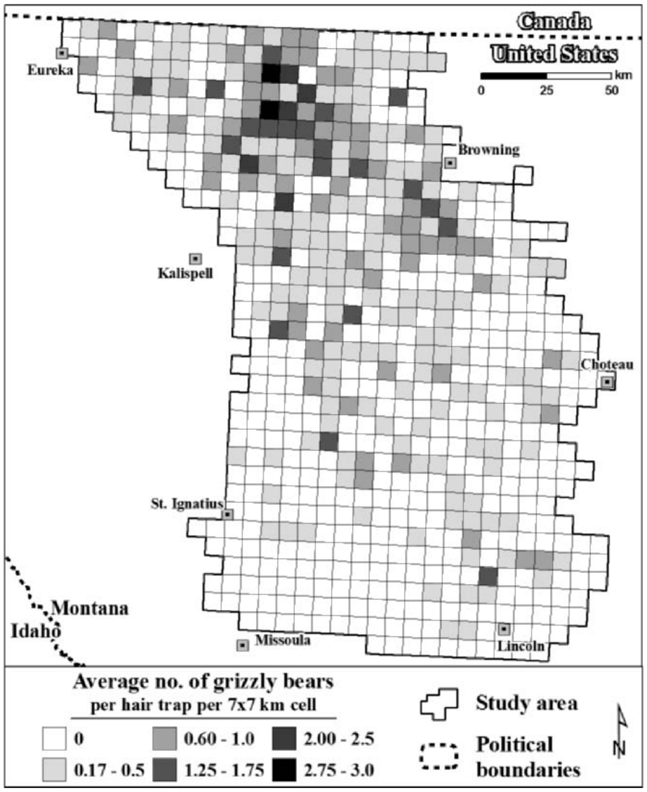


Figure 5. Relative density of grizzly bears in the 31,410-km^2 Northern Divide Grizzly Bear Project study area in northwestern Montana, USA. We conducted sampling 15 June–18 August 2004 at 2,558 hair traps systematically distributed on a 7 × 7-km grid. Because equal sampling effort was required for this analysis, we used only hair trap data.

Typically, larger study areas include more habitat heterogeneity, which is often associated with variation in animal abundance. Smaller areas include proportionally more animals with home ranges overlapping the study area boundary, which, if not corrected for, can result in positively biased abundance estimates (Miller et al. 1997, Boulanger and McLellan 2001). At 31,410 km^2, our study area was much larger than those of most other terrestrial wildlife abundance estimation studies.

Population structure.—Genetic diversity in the NCDE approached levels seen in relatively undisturbed populations in northern Canada and Alaska, USA (Paetkau et al. 1998). Our results suggest that this population had not experienced a severe genetic bottleneck and that connectivity within the population and with the Canadian Rocky Mountain populations remained largely intact. The apparent recent increase in gene flow with the eastern periphery of the study area was consistent with population recovery. The historically low levels of genetic interchange and subsequently reduced diversity in the eastern and southeastern areas were similar to levels observed along the edges of the Canadian grizzly bear distribution and did not align with any landscape features (Proctor et al. 2005). However, our observation of reduced connectivity at the more developed western end of the dominant transportation corridor in the NCDE may signal the need for management intervention to ensure gene flow across this corridor in the future (Proctor et al. 2005).

Data Sources, Analytical Methods, and Data Quality

Supplemental data sources.—Having access to information such as mortality records, familial relationships, and animal movement data allowed us to investigate central assumptions of NGS studies. Some studies have assumed that juvenile bears are not sampled with hair snaring (e.g., Dreher et al. 2007). Our data showed that our abundance estimate based on hair snaring included all cohorts in the population. Noninvasive genetic sampling studies that assume juvenile bears are not vulnerable to sampling may overestimate total population abundance. In the absence of data on the detection rate of cubs and yearlings for individual study designs, our data argue for assuming that they are sampled. We also used management records to document partial independence of detection probabilities of family members traveling together, thus easing concern that a lack of independence among individuals creates bias in variance estimates.

The management and research records we gathered on grizzly bears in this ecosystem previously resided with individual researchers and wildlife managers from 8 agencies in dozens of locations in the United States and Canada. In addition to the assumptions investigated above, we used these data to 1) increase sample coverage, extend encounter histories, and improve the precision of our abundance estimate; 2) produce a comprehensive map of grizzly bear occupied habitat in the NCDE; and 3) document the apparent decrease in genetic differentiation among population segments over time. Management responsibility for

Table 7. Changes in genetic differentiation (F_{ST}) between regions within the Northern Continental Divide Ecosystem (NCDE) grizzly bear population in northwestern Montana, USA. F_{ST} values for 1976–1998 are below the diagonal; 1999–2006 values are above the diagonal. The Prophet River, British Columbia, Canada, grizzly bear population 1,150 km north of the NCDE was included for comparison with within-NCDE population distances. Only 2 genotypes were available for the southeast region before 1999.

Region	Prophet	NW	NE	Mid	East	SW	SE
Prophet		0.07	0.07	0.05	0.10	0.09	0.10
NW	0.06		0.02	0.02	0.08	0.06	0.09
NE	0.06	0.02		0.02	0.07	0.05	0.07
Mid	0.05	0.02	0.01		0.05	0.03	0.05
East	0.12	0.10	0.08	0.06		0.05	0.04
SW	0.09	0.07	0.06	0.04	0.07		0.05
SE							

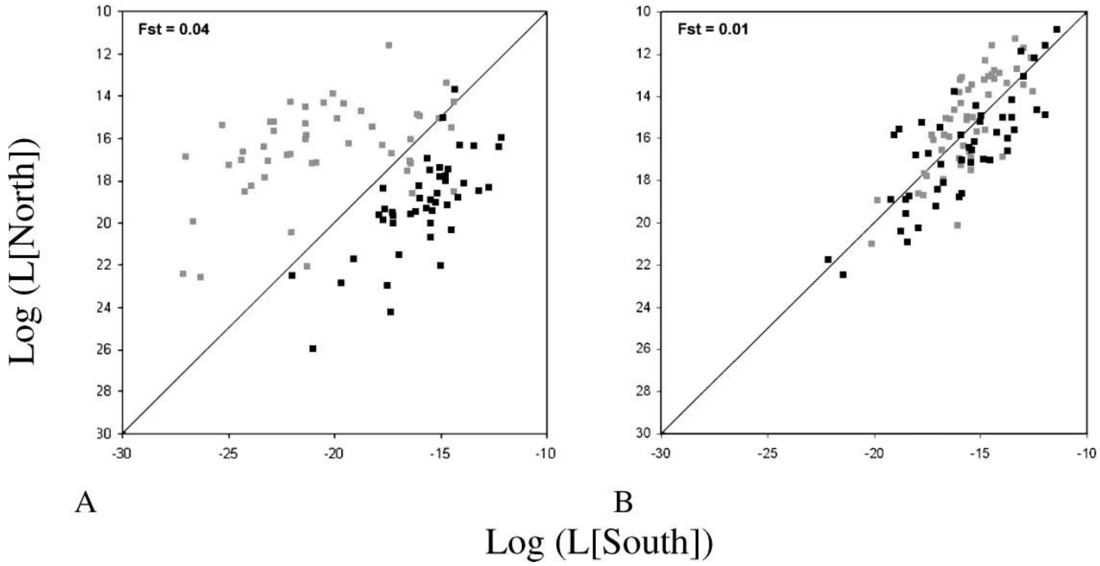


Figure 6. Genetic differentiation determined by assignment test between bears located on either side of the highway corridor for 2 segments of United States Highway 2, northwestern Montana, USA, 2004. Gray squares = bears north of highway; black squares = bears south of highway. (A) Western segment with higher traffic volume and human density. (B) Eastern segment with less traffic and development.

most populations of wide-ranging species is shared by multiple agencies. Centralized databases with standardized data and tissue sample repositories can be extremely useful and will become more valuable with time as analytical techniques are refined.

Mark–recapture methods.—Noninvasive genetic sampling has been widely used for estimating abundance of grizzly and black bear populations (Boulanger et al. 2002, Boersen et al. 2003), but estimates have often been imprecise (CV > 20%; Boulanger et al. 2002) and thus of limited use for detecting trends or guiding management policy, such as setting harvest rates. Factors that contributed to the precision of our estimate (CV = 3.8%) included the use of multiple sampling methods, the development of advanced mark–recapture modeling techniques (Boulanger et al. 2008*a*), and the large scale of our study. Combining detections from multiple data sources into single encounter histories yielded robust estimates with higher precision than a single–source approach (Boulanger et al. 2008*a*, Kendall et al. 2008). Mark–recapture models that can incorporate individual, group, and temporal covariates increase precision or reduce bias by more effectively modeling the heterogeneity in capture probabilities that is pervasive in wild populations (Huggins 1991, Pledger 2000, Boulanger et al. 2008*a*). Large study areas result in the larger sample sizes needed to model heterogeneity and reduce the effect of closure violation—a common source of capture probability variation. Our resulting population estimate was the most precise estimate obtained for a grizzly bear population using NGS.

Use of 3 sampling methods reduced estimate bias by increasing sample coverage; each method identified bears not sampled by the other methods (Table 8). Inclusion of physical capture data provided an opportunity to estimate capture probability for bears that were not detected using either hair snaring method and helped model heterogeneity in hair trap capture probabilities (Boulanger et al. 2008*a, b*).

An important assumption in mark–recapture analyses is the independence of capture probabilities among individuals. Family groups (parent–offspring and siblings traveling together) are the largest source of nonindependent movement in bear populations. Simulations suggested inclusion of dependent offspring causes minimal bias to population estimates but potentially a slight negative bias to variance estimates (Miller et al. 1997, Boulanger et al. 2004, Boulanger et al. 2008*b*). The magnitude of this phenomenon, however, has not been adequately explored with empirical data. Our evidence of partial independence of capture probabilities within family groups further suggested that this source of heterogeneity was unlikely to be a significant source of bias in our estimates.

Heterogeneity caused by lack of geographic closure is also a major challenge for DNA-based abundance estimation projects using closed models (Boulanger and McLellan 2001, Boulanger et al. 2004). The most effective ways to decrease this source of bias are to sample the entire

Table 8. Number and proportion of individual grizzly bears identified per sampling method during the Northern Divide Grizzly Bear Project, Montana, USA, 2004.

	M		F	
Sampling method	No.	%	No.	%
Hair trap only	83	35	187	61
Bear rub only	56	24	41	13
Both noninvasive genetic sampling (NGS) methods	99	42	79	26
Handled bears[a]	4	22	14	78
Total	242	43	321	57

[a] Of those bears detected in ≥1 NGS methods, 31 (18 M, 13 F) also had a record of physical capture.

population or minimize the ratio of open edge to area sampled. We sampled essentially all occupied grizzly bear habitat associated with the NCDE in the United States and used telemetry data to assess movement rates across study area boundaries. We found extremely low levels of closure violation; therefore, we did not correct our estimate of abundance for lack of closure but used DTE to account for expected lower capture probabilities for bears along the northern edge of the study area.

Individual heterogeneity in capture probabilities is the most difficult problem facing the estimation of animal abundance (Link 2003, Lukacs and Burnham 2005*b*). The physical captures used in our encounter histories were not the result of even sampling effort across the study area. However, their inclusion may have reduced heterogeneity-induced bias resulting from unknown sources, such as behavioral traits or age, neither of which are known from DNA data and therefore cannot be modeled (Boulanger et al. 2008*b*). We included the PrevCap covariate in hair trap models because Boulanger et al. (2008*b*) found that detection probabilities at hair traps can be lower for bears that have been live-captured due to caution associated with similar lure and human scents. This effect was not expected at bear rubs because rubbing is a natural behavior with no association with human encounters; therefore, we did not consider the PrevCap covariate in bear rub models. We included terms to model the effects of gender-specific heterogeneity and gender-specific temporal trends in capture probabilities for both hair trap (Boulanger et al. 2004) and bear rubs (Kendall et al. 2008). Our results were similar to those of Kendall et al. (2008), who found increasing capture probabilities for females in both sampling methods in the northern portion of the NCDE. Males showed less consistency in temporal trends in capture probabilities across projects; however, males showed higher capture probabilities than females in bear rub data across all years of sampling. Our results suggest that sampling later in the season results in greater capture probabilities, especially for females, and should result in more precise abundance estimates.

Data quality.—Some researchers advocate modeling genotyping error rates in mark–recapture analyses (Lukacs and Burnham 2005*a*). However, we not only used a protocol that has been shown capable of reducing error rates to a trivial level (Paetkau 2003), we also went beyond that protocol to duplicate all genotypes, whether or not they were similar to another genotype, and to confirm the authenticity of all 563 identified individuals using an independent set of microsatellite markers. This provided strong evidence that no spurious individuals were created through undetected genotyping error. Our data do not rule out the possibility that we sampled 2 individuals with the same 7-locus genotype, but do demonstrate that such events were exceedingly uncommon, if they occurred at all. The estimated error rate for the number of individual bears identified through genotyping was $\leq$1%. Errors of this magnitude do not bias mark–recapture population estimates, whereas addition of a parameter (error rate) to the population estimation model would reduce the precision of the estimate.

We used bar-coded sample numbers and scanners to help ensure that genetic results were associated with the correct field data by eliminating transcription and data entry errors in the field, office, and lab. We used data entry personnel with extensive experience in data quality control. Our database contained integrated error-checking queries that immediately identified questionable data and allowed us to resolve issues at the time of entry. We used GIS to verify the origin of samples, and we reviewed the detection history of each individual bear for inconsistencies. Furthermore, field crews received 9 days of training in protocols, project background, laboratory methods, bear ecology, GPS use, and other topics that contributed to successful execution of field duties. Our use of such rigorous quality control measures contributed to our confidence in our results.

Monitoring Populations with Noninvasive Genetic Sampling

Monitoring and recovery programs for threatened and endangered species are usually a compromise between the quality of data desired and the cost of obtaining it (Doak and Mills 1994, Miller et al. 2002) and are often woefully inadequate (Vucetich et al. 2006). Abundance estimates are the most common quantitative criterion in recovery plans (Gerber and Hatch 2002); however, they are often imprecise, error-ridden, or based on guesses (Holmes 2001, Campbell et al. 2002). In some cases, insufficient or erroneous data can directly influence how management efforts are prioritized and may result in misallocation of finite conservation resources (McKelvey et al. 2008). For example, inaccurate abundance estimates may result in misleading forecasts of population persistence because the magnitude of demographic stochasticity effects are a function of population size (Schwartz et al. 2006). Interpretation of per capita growth rate estimates may also be impacted by poor data, because growth rates can be affected by density-dependent demographic stochasticity (Drake 2005). For example, a monitoring program estimating trend would predict a flat or declining growth rate if the population was believed to be at or above carrying capacity (K). However, with inaccurate estimates of N or K, a declining growth rate could suggest that the population is experiencing a density-independent decline and elicit unnecessary management intervention.

To reliably monitor population trend, researchers must understand underlying patterns of variation in density and vital rates to guide stratified sampling, or sampling must be intensive enough to capture the variation. Measures of population trend such as those developed from projection matrices, commonly used for bears, may be insensitive to declines in some components of the population (Doak 1995). Using NGS methods for long-term monitoring therefore may be appealing when there is substantial heterogeneity in animal density and vital rates within a population, as with grizzly bears in the NCDE. Systematic

NGS of the entire study area may be able to detect changes in local density (Fig. 5), patch occupancy, and genetic structure (Fig. 2), as well as ecosystem-wide abundance and apparent survival. Low intensity or periodic genetic sampling, such as with bear rub surveys, could be an efficient complement to, or more effective than, sighting- and telemetry-based methods for monitoring dispersal, distribution, genetic structure, and population trend.

MANAGEMENT IMPLICATIONS

Our results indicate that the NCDE grizzly bear population is faring better than the USFWS monitoring program had indicated previously. However, it is likely that continued unmitigated development along the Highway 2 corridor will result in genetic fragmentation of the grizzly bear population in the NCDE. Increased traffic volume and development along the other highways in the NCDE carries similar risks. Any long-term management strategy for this population should include ways to facilitate continued genetic interchange across transportation corridors and the associated development that tends to grow along them.

The results of a 1-year study cannot measure population trend. Nonetheless, the recent decrease in genetic differentiation and apparent expanded distribution in the NCDE were consistent with population growth. In addition, the number and wide distribution of females we detected bodes well for the population. However, not all recovery criteria have been met. For example, even with our higher abundance estimate, the female mortality rate in 2004 was double the maximum allowed by the Recovery Plan. This suggests that, overall, management efforts have been effective in protecting this population but additional strategies are needed to reduce the female mortality rate, which is particularly important because the level of unreported mortality is difficult to assess. Clearly, a more intensive program should be considered to monitor population status and determine if mortality rates are sustainable. Based on our results, along with evidence of bear movement among populations and the recent initiation of a telemetry-based population trend study, the USFWS initiated a Status Review of threatened grizzly bear populations. This represents the first step in developing scientifically rigorous Recovery Plans for grizzly bears in the contiguous United States.

ACKNOWLEDGMENTS

W. Kendall and T. McDonald shared in developing our mark–recapture modeling approach. T. Graves assisted with model development and preliminary analyses. P. Cross, P. Lukacs, R. Mace, S. Miller, M. Schwartz, and an anonymous reviewer provided helpful comments on earlier drafts of this paper. We thank the hundreds of employees and volunteers who collected hair samples under difficult field conditions, entered reams of data, and processed thousands of hair samples. We also thank the following agencies that provided substantial logistical and in-kind support: Blackfeet Nation; Confederated Salish and Kootenai Tribes; Montana Department of Fish, Wildlife, and Parks; Montana Department of Natural Resources and Conservation; National Park Service; Northwest Connections; United States Bureau of Land Management; USFWS; and the University of Montana. Outstanding leadership by C. Barbouletos and M. Long helped make this project possible. Financial support was provided by the United States Geological Survey and United States Forest Service.

LITERATURE CITED

Abbott, R. 2008. Pierre Taberlet Recipient of 2007 Molecular Ecology Prize (editorial). Molecular Ecology 17:514–515.

Andelman, S. J., and W. F. Fagan. 2000. Umbrellas and flagships: efficient conservation surrogates or expensive mistakes? Proceedings of the National Academy of Sciences USA 97:5954–5959.

Barluenga, M., K. N. Stolting, W. Salzburger, M. Muschick, and A. Meyer. 2006. Sympatric speciation in Nicaraguan Crater Lake cichlid fish. Nature 439:719–723.

Belkhir, K., P. Borsa, L. Chikhi, N. Rafaste, and F. Bonhomme. 2004. GENETIX 4.05, logiciel sous Windows TM pour la génétique des populations. Laboratoire Génome, Populations, Interactions, CNRS UMR 5000, Université de Montpellier II, Montpellier, France. <http://www.genetix.univ-montp2.fr/genetix/genetix.htm>. Accessed 11 Apr 2007.

Boersen, M. R., J. D. Clark, and T. L. King. 2003. Estimating black bear population density and genetic diversity at Tensas River, Louisiana using microsatellite DNA markers. Wildlife Society Bulletin 31:197–207.

Boulanger, J., K. C. Kendall, J. B. Stetz, D. A. Roon, L. P. Waits, and D. Paetkau. 2008*a*. Multiple data sources improve DNA-based mark-recapture population estimates of grizzly bears. Ecological Applications 18:577–589.

Boulanger, J., and B. McLellan. 2001. Closure violation in DNA-based mark-recapture estimation of grizzly bear populations. Canadian Journal of Zoology 79:642–651.

Boulanger, J., B. N. McLellan, J. G. Woods, M. F. Proctor, and C. Strobeck. 2004. Sampling design and bias in DNA-based capture–mark–recapture population and density estimates of grizzly bears. Journal of Wildlife Management 68:457–469.

Boulanger, J., G. C. White, B. N. McLellan, J. Woods, M. Proctor, and S. Himmer. 2002. A meta-analysis of grizzly bear DNA mark-recapture projects in British Columbia, Canada. Ursus 13:137–152.

Boulanger, J., G. C. White, M. Proctor, G. Stenhouse, G. Machutchon, and S. Himmer. 2008*b*. Use of occupancy models to estimate the influence of previous live captures on DNA–based detection probabilities of grizzly bears. Journal of Wildlife Management 72:589–595.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Springer-Verlag, New York, New York, USA.

Campbell, S. P., J. A. Clark, L. H. Crampton, A. D. Guerry, L. T. Hatch, P. R. Hosseini, J. J. Lawler, and R. J. O'Connor. 2002. An assessment of monitoring efforts in endangered species recovery plans. Ecological Applications 12:674–681.

Cardillo, M., G. M. Mace, K. E. Jones, J. Bielby, O. R. P. Bininda-Emonds, W. Sechrest, C. D. Orme, and A. Purvis. 2005. Multiple causes of high extinction risk in large mammal species. Science 309:1239–1241.

Cherry, S., M. A. Haroldson, J. Ronbison-Cox, and C. C. Schwartz. 2002. Estimating total human-caused mortality from reported mortality using data from radio-instrumented grizzly bears. Ursus 13:175–184.

Crosbie, S. F., and B. F. J. Manly. 1985. Parsimonious modeling of capture-mark-recapture studies. Biometrics 41:385–398.

Doak, D. F. 1995. Source-sink models and the problem of habitat degradation: general models and applications to the Yellowstone grizzly. Conservation Biology 9:1370–1379.

Doak, D. F., and L. S. Mills. 1994. A useful role for theory in conservation. Ecology 75:615–626.

Drake, J. M. 2005. Density-dependent demographic variation determines extinction rate of experimental populations. PLoS Biology 3:1300–1304.

Dreher, B. P., S. R. Winterstein, K. T. Scribner, P. M. Lukacs, D. R. Etter, G. J. M. Rosa, V. A. Lopez, S. Libants, and K. B. Filcek. 2007. Noninvasive estimation of black bear abundance incorporating genotyping errors and harvested bears. Journal of Wildlife Management 71:2684–2693.
Ennis, S., and T. F. Gallagher. 1994. PCR based sex determination assay in cattle based on the bovine Amelogenin locus. Animal Genetics 25:425–427.
Fitch, W. M., and E. Margoliash. 1967. Construction of phylogenetic trees. Science 155:279–284.
Gerber, L. R., and L. T. Hatch. 2002. Are we recovering? An evaluation of recovery criteria under the U.S. Endangered Species Act. Ecological Applications 12:668–673.
Gibbons, A. 1992. Mission impossible: saving all endangered species. Science 256:1386.
Gittleman, J. L., and M. E. Gompper. 2001. Ecology and evolution. The risk of extinction—what you don't know will hurt you. Science 291:997–998.
Holmes, E. E. 2001. Estimating risks in declining populations with poor data. Proceedings of the National Academy of Sciences USA 98:5072–5077.
Huggins, R. M. 1991. Some practical aspects of a conditional likelihood approach to capture experiments. Biometrics 47:725–732.
Kadwell, M., M. Fernanadez, H. F. Stanley, R. Baldi, J. C. Wheeler, R. Rosadio, and M. W. Bruford. 2001. Genetic analysis reveals the wild ancestors of the llama and the alpaca. Proceedings of the Royal Society, London B 268:2575–2584.
Kendall, K. C., J. B. Stetz, D. A. Roon, L. P. Waits, J. B. Boulanger, and D. Paetkau. 2008. Grizzly Bear Density in Glacier National Park, Montana. Journal of Wildlife Management 72:1693–1705.
Knight, R. R., and L. L. Eberhardt. 1985. Population dynamics of Yellowstone grizzly bears. Ecology 66:323–334.
Link, W. A. 2003. Nonidentifiability of population size from capture-recapture data with heterogeneous detection probabilities. Biometrics 59: 1123–1130.
Lukacs, P. M., and K. P. Burnham. 2005*a*. Estimating population size from DNA-based closed capture–recapture data incorporating genotyping error. Journal of Wildlife Management 69:396–403.
Lukacs, P. M., and K. P. Burnham. 2005*b*. Review of capture-recapture methods applicable to noninvasive genetic sampling. Molecular Ecology 14:3909–3919.
McKelvey, K. S., K. B. Aubrey, and M. K. Schwartz. 2008. Using anecdotal occurrence data for rare or elusive species: the illusion of reality and a call for evidentiary standards. BioScience 58:549–555.
Miller, J. M. C., M. Scott, C. R. Miller, and L. P. Waits. 2002. Endangered Species Act: dollars and sense? BioScience 52:163–168.
Miller, S. D., G. C. White, R. A. Sellers, H. V. Reynolds, J. W. Schoen, K. Titus, V. G. Barnes, Jr., R. B. Smith, R. R. Nelson, W. B. Ballard, and C. C. Schwartz. 1997. Brown and black bear density estimation in Alaska using radiotelemetry and replicated mark–resight techniques. Wildlife Monographs 133.
Mills, L. S., J. J. Citta, K. P. Lair, M. K. Schwartz, and D. A. Tallmon. 2000. Estimating animal abundance using noninvasive DNA sampling: promise and pitfalls. Ecological Applications 10:283–294.
Paetkau, D. 2003. An empirical exploration of data quality in DNA-based population inventories. Molecular Ecology 12:1375–1387.
Paetkau, D., W. Calvert, I. Stirling, and C. Strobeck. 1995. Microsatellite analysis of population structure in Canadian polar bears. Molecular Ecology 4:347–354.
Paetkau, D., L. P. Waits, P. L. Clarkson, L. Craighead, E. Vyse, R. Ward, and C. Strobeck. 1998. Variation in genetic diversity across the range of North American brown bears. Conservation Biology 12:418–429.
Pledger, S. 2000. Unified maximum likelihood estimates for closed capture-recapture models using mixtures. Biometrics 56:434–442.
Poole, K. G., G. Mowat, and D. A. Fear. 2001. DNA-based population estimate for grizzly bears *Ursus arctos* in northeastern British Columbia, Canada. Wildlife Biology 7:105–115.
Proctor, M. F., B. N. McLellan, C. Strobeck, and R. M. R. Barclay. 2005. Genetic analysis reveals demographic fragmentation of grizzly bears yielding vulnerably small populations. Proceedings of the Royal Society Biology 272:2409–2416.
Roon, D. A., L. P. Waits, and K. C. Kendall. 2005. A simulation test of the effectiveness of several methods for error-checking non-invasive genetic data. Animal Conservation 8:203–215.
Schonewald-Cox, C., R. Azari, and S. Blume. 1991. Scale, variable density, and conservation planning for mammalian carnivores. Conservation Biology 5:491–495.
Schwartz, C. C., M. A. Haroldson, G. C. White, R. B. Harris, S. Cherry, K. A. Keating, D. Moody, and C. Servheen. 2006. Temporal, spatial, and environmental influences on the demographics of grizzly bears in the Greater Yellowstone Ecosystem. Wildlife Monographs 161.
Smallwood, K. S., and C. Schonewald. 1998. Study design and interpretation of mammalian carnivore density estimates. Oecologia 113:474–491.
Taberlet, P., S. Griffin, B. Goossens, S. Questiau, V. Manceau, N. Escaravage, L. P. Waits, and J. Bouvet. 1996. Reliable genotyping of samples with very low DNA quantities using PCR. Nucleic Acids Research 24:3189–3194.
U.S. Fish and Wildlife Service [USFWS]. 1993. Grizzly Bear Recovery Plan. U.S. Fish and Wildlife Service, Missoula, Montana, USA.
Vucetich, J. A., M. P. Nelson, and M. K. Phillips. 2006. The normative dimension and legal meaning of endangered and recovery in the U.S. Endangered Species Act. Conservation Biology 20:1383–1390.
Weir, P. S., and C. C. Cockerham. 1984. Estimating F-statistics for the analysis of population structure. Evolution 38:1358–1370.
White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study Supplement 46:120–138.
White, G. C., K. P. Burnham, and D. R. Anderson. 2001. Advanced features of Program Mark. Pages 368–377 *in* R. Field, R. J. Warren, H. Okarma, and P. R. Sievert, editors. Wildlife, land, and people: priorities for the 21st century. Proceedings of the second international wildlife management congress. The Wildlife Society, Bethesda, Maryland, USA.
Woods, J. G., D. Paetkau, D. Lewis, B. N. McLellan, M. Proctor, and C. Strobeck. 1999. Genetic tagging of free-ranging black and brown bears. Wildlife Society Bulletin 27:616–627.

Associate Editor: McCorquodale.

Appendix. Grizzly Bear Recovery Plan Monitoring Program metrics (U.S. Fish and Wildlife Service 1993) and molecular sampling results in 2004 in the Northern Continental Divide Ecosystem (NCDE) in Northwestern Montana, USA.[a]

Recovery criteria type	Recovery Plan targets: must be met for population to be considered recovered	Monitoring interval	2004 Recovery Plan monitoring results	2004 NCDE Hair Snare Project results: comparison with recovery criteria
Demographic and distribution: population size inside and outside GNP	≥10 FwC inside GNP and ≥12 outside GNP within 16 km of RZ, excluding Canada. Using the Recovery Plan method to derive population estimate from counts of FwC, total population needed = 391.	Running 6-yr average of FwC counted for use in estimating population size.	13 FwC inside and 8 FwC outside GNP. Using Recovery Plan method to derive population estimate from counts of FwC, total population = 304.	Min. count: 131 F and 98 M bears inside and 190 F and 144 M bears outside GNP. Total population estimate = 765 (471 F and 294 M). Note: direct estimate of population size and min. counts of bears inside and outside GNP can identify no. of F but not age or reproductive status.
Distribution: FwY-total	21 of 23 BMUs occupied by FwY; no 2 adjacent BMUs unoccupied.	Running 6-yr sum of observations.	All BMUs occupied; no. of FwC/BMU not available.	All BMUs occupied by F of unknown age. No. of F/BMU range 2–56. Total count of F, not just FwY.
Distribution: FwY-specific	Mission Mountains occupied by FwY.	Not stated.	Mission Mountains occupied; no. unique FwY not available.	Detected 12 unique F (reproductive status unknown).
Mortality: total	Known, human-caused mortality ≤4% of population estimate (based on 3-yr sum of FwC).	Cannot be exceeded for any 2 consecutive yr.	Total mortality = 10.5%; exceeds threshold.	Total mortality = 4.6%; slightly above threshold.
Mortality: F subquota	Of the above-mentioned 4%, ≤30% shall be F.	Cannot be exceeded for any 2 consecutive yr.	Allowable F morts ≤3. Recorded F morts = 18 (6× allowable level).	Allowable F morts ≤9 based on 2004 NCDE population estimate. Recorded F morts = 20 (2.2× allowable level).

[a] GNP = Glacier National Park; FwC = F with cubs; FwY = F with young of any age; RZ = Recovery Zone; morts = mortalities; BMU = Bear Management Unit.

BioOne RESEARCH EVOLVED

SYNTHESIS OF SURVIVAL RATES AND CAUSES OF MORTALITY IN NORTH AMERICAN WOLVERINES

Author(s): JOHN KREBS, ERIC LOFROTH, JEFFREY COPELAND, VIVIAN BANCI, DOROTHY COOLEY, HOWARD GOLDEN, AUDREY MAGOUN, ROBERT MULDERS, and BRAD SHULTS

Source: Journal of Wildlife Management, 68(3):493-502. 2004.
Published By: The Wildlife Society
DOI: http://dx.doi.org/10.2193/0022-541X(2004)068[0493:SOSRAC]2.0.CO;2
URL: http://www.bioone.org/doi/full/10.2193/0022-541X%282004%29068%5B0493%3ASOSRAC%5D2.0.CO%3B2

BioOne (www.bioone.org) is a nonprofit, online aggregation of core research in the biological, ecological, and environmental sciences. BioOne provides a sustainable online platform for over 170 journals and books published by nonprofit societies, associations, museums, institutions, and presses.

Your use of this PDF, the BioOne Web site, and all posted and associated content indicates your acceptance of BioOne's Terms of Use, available at www.bioone.org/page/terms_of_use.

Usage of BioOne content is strictly limited to personal, educational, and non-commercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

BioOne sees sustainable scholarly publishing as an inherently collaborative enterprise connecting authors, nonprofit publishers, academic institutions, research libraries, and research funders in the common goal of maximizing access to critical research.

SYNTHESIS OF SURVIVAL RATES AND CAUSES OF MORTALITY IN NORTH AMERICAN WOLVERINES

JOHN KREBS,[1] Columbia Basin Fish and Wildlife Compensation Program, 103-333 Victoria Street, Nelson, BC V1L 4K3, Canada
ERIC LOFROTH, Biodiversity Branch, Ministry of Water, Land and Air Protection, P.O. Box 9338, Station Provincial Government, Victoria, BC V8W 9M1, Canada
JEFFREY COPELAND, USDA Forest Service, Rocky Mountain Research Station, Box 8089, Missoula, MT 59807, USA
VIVIAN BANCI, V Banci Consulting Services, 21557 Campbell Avenue, Maple Ridge, BC V2X 3V6, Canada
DOROTHY COOLEY, Renewable Resources–Fish and Wildlife Branch, Northern Region, Box 600, Dawson City, YT Y0B 1G0, Canada
HOWARD GOLDEN, Alaska Department of Fish and Game, 333 Raspberry Road, Anchorage, AK 99518, USA
AUDREY MAGOUN, Wildlife Research and Management, 3680 Non Road, Fairbanks, AK 99709, USA
ROBERT MULDERS, Wildlife and Fisheries Division, Resources, Wildlife and Economic Development, Government of the NWT, 600, 5102-50th Avenue, Yellowknife, NT X1A 3S8, Canada
BRAD SHULTS, U.S. National Park Service, Western Arctic National Parklands, P.O. Box 1029, Kotzebue, AK 99752, USA

Abstract: Understanding population vital rates is fundamental to the evaluation of conservation options for wolverines (*Gulo gulo*). We estimated survival rates and causes of wolverine mortality in trapped and untrapped populations within montane, boreal, and tundra environments using data from 12 North American radiotelemetry studies conducted between 1972 and 2001. Rates were based on data for 62 mortalities of 239 radiomarked wolverines. Mortalities included 22 wolverines that were trapped or hunted, 3 road or rail killed, 11 that were predated, 18 that starved, and 8 deaths of unknown cause. Annual survivorship rates were estimated for sex and age class using Kaplan-Meier staggered-entry techniques. Survival was substantially lower in trapped (<0.75 for all age–sex classes) than in untrapped (>0.84 for all age–sex classes) populations. Human-caused mortality was mostly additive to natural mortality for wolverines in a management context. Logistic growth rate estimates indicated that trapped populations would decline ($\lambda \cong 0.88$) in the absence of immigration from untrapped populations ($\lambda \cong 1.06$). We recommend a system of spatial harvest controls in northern, continuous populations of wolverines and reduction of harvest along with more spatially explicit conservation measures in southern metapopulations.

JOURNAL OF WILDLIFE MANAGEMENT 68(3):493–502

Key words: *Gulo gulo*, harvest management, mortality sources, North America, refugia, survival rates, wolverine.

The wolverine is a wide-ranging mustelid existing at low densities throughout much of northern and western North America, Scandinavia, and Eurasia (Wilson 1982, Hash 1987, Banci 1994). In North America, wolverines occur in the northern boreal forest, taiga, and tundra from Labrador to Alaska and in the western mountains from Yukon south to Wyoming. Wolverines are classed as endangered in Quebec and Labrador and have protected status in Washington, Oregon, California, Colorado, Idaho, and Wyoming (Dauphine 1989, Banci 1994). In the remainder of their range, wolverines are classed as furbearers and are managed primarily through the timing of open trapping or hunting seasons.

Overexploitation through hunting and trapping, as well as predator poisoning programs, likely caused wolverine populations to contract in the eastern and southwestern portions of their historical range in North America since the early 1900s (Banci 1994). Declines in Scandinavia have been attributed to similar factors (Linden et al. 1994). Within the current range, extensive human activities including human settlement, highway and railway development, hunting and trapping, forest harvesting, mineral extraction, hydroelectric development, and backcountry recreation continue to pressure wolverine populations and habitat.

In exploited populations, age- and sex-specific mortality rates are key attributes used to determine sustainable harvests (Caughley 1977, Wolfe and Chapman 1987, Banci 1994). Coupled with reproductive rates and population sizes, quantitative estimates of population growth and sustainable harvest rates can be calculated. However, age- and sex-specific survival rates of wolverines are not available to parameterize population models. Wolverine population densities have been estimated as high as 15.4 animals/1,000 km^2 in Montana (Hornocker and Hash 1981), 4.7–5.2 animals/1,000 km^2 in south-central Alaska (Becker and Gardner 1992, Golden 1996), to as low as 1.3 animals/1,000 km^2 in southwestern Yukon (Banci 1987). At densities typically in the middle to low ranges and reproductive rates of <1 kit per

[1] E-mail: john.krebs@bchydro.bc.ca

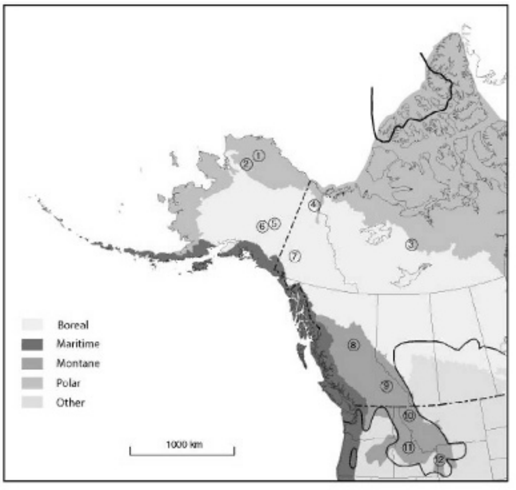


Fig. 1. Ecological zones and locations of wolverine radiotelemetry studies in western North America between 1972 and 2001. 1 = Magoun 1985; 2 = B. Shults, U.S. National Park Service, unpublished data; 3 = Mulders 2001; 4 = D. Cooley, Renewable Resources–Fish and Wildlife Branch, unpublished data; 5 = Gardner 1985; 6 = Golden 1993; 7 = Banci 1987; 8 = Lofroth 2001; 9 = Krebs and Lewis 2000; 10 = Hornocker and Hash 1981; 11 = Copeland 1996; 12 = Copeland 2000. Broad habitat categories were derived from Wiken (1986), Demarchi (1994), and Nowacki et al. (2001). Heavy black line indicates approximate wolverine distribution (based on Hash 1987). Numbers correspond to descriptions in Table 1.

adult female per year (post weaning; Magoun 1985, Copeland 1996), wolverine populations are vulnerable to human-caused mortality. The ability of wolverine populations to compensate (Wolfe and Chapman 1987) for human-caused mortality through reduced natural mortality and/or increased reproduction has not been examined.

In most of the current North American wolverine range, wolverine harvests are controlled through regulated seasons and bag limits. Management strategies in some areas have emphasized maintenance of untrapped "refugia" (Hatler 1989) within trapline areas. In other areas, authorities have enacted trapping season closures (e.g., Idaho, Washington, Wyoming, USA, and southwestern British Columbia, Canada). Little guidance is available regarding the importance of refugia size, habitat characteristics, and proximity of harvested areas to wolverine populations. An effective management strategy must consider population vital rates, home-range size, and dispersal characteristics. In addition to the effects of harvest, productivity of wolverine populations may vary depending on food distribution and abundance, competition with other species, and human-caused impacts such as roads, settlement, and land use (Banci 1994, Lyon et al. 1994, Weaver et al. 1996, Magoun and Copeland 1998). Because wolverines are logistically difficult and expensive to study, individual projects have been unable to collect sufficient information to estimate survival rates. Additionally, because management regimes and ecozones differed among studies, comparisons in population attributes were impractical. We synthesized available survival and mortality source data from 12 radiotelemetry studies carried out in western North America to compare survival rates among ecozones and management regimes. We also compared natural and human-caused mortalities in trapped and untrapped populations to assess potential compensation in survival rates. We considered lower natural mortality in trapped populations as support for survival-rate compensation.

STUDY AREA

We compiled data from 12 radiotelemetry studies of wolverines conducted in North America between 1972 and 2001 (Fig. 1). Study locations included polar and southern Arctic habitat in Alaska, USA, and Northwest Territories, Canada; taiga in northern Yukon, Canada; boreal forest in Alaska and Yukon; montane habitats in British Columbia, Canada, and Montana, USA; and Northern Rocky Mountain Forest in Idaho and Wyoming, USA (Table 1; Wiken 1986, Demarchi 1994, Nowacki et al. 2001). We classified study sites as tundra, boreal, or montane ecotypes.

Tundra study areas were dominated by treeless tussock tundra with shrubs in riparian areas. Northern Yukon taiga was included in this category. Climate in these areas was characterized by short, cool summers and long, cold winters. Average February snow depths were 35–49 cm (Brown et al. 2002). Elevations ranged from 360 to 1,800 m in the Alaska, Yukon, and Northwest Territories study areas. Migratory caribou (*Rangifer tarandus*) was the dominant ungulate food source for wolverines (Magoun 1985, Mulders 2001). Small mammals such as Arctic ground squirrel (*Spermophilus parryi*) also were important seasonal prey (Magoun 1987).

Boreal study areas were characterized by spruce (*Picea* spp.) forests intermixed with birch (*Betula* spp.), aspen (*Populus* spp.), and shrubs in low-elevation habitats. High-elevation habitats were dominated by alpine tundra vegetation. Elevations ranged from 275 to 2,360 m. Climate in these study areas was characterized by cool, dry

Table 1. Locations, ecological zones, and management characteristics of 12 wolverine studies conducted in North America between 1972 and 2001.

No.[a]	Location	Study area size (km^2)	Source	Ecological zone	Population management	Habitat management[b]
1	Northwest Alaska	2,400	Magoun 1985	Polar	Untrapped	HU
2	Northwest Alaska	22,000	Shults[c]	Polar	Trapped	HU
3	Central Northwest Territories	2,000	Mulders 2001	Southern Arctic	Untrapped	HU
4	Northern Yukon	6,000	Cooley[d]	Taiga Cordillera	Trapped	HU
5	South-central Alaska	7,700	Gardner 1985	Boreal Cordillera	Trapped	HS
6	South-central Alaska	4,000	Golden et al. 1993	Boreal Cordillera	Trapped	HU, RC
7	Southwest Yukon	1,590	Banci 1987	Boreal Cordillera	Trapped	PA
8	North-central British Columbia	8,900	Lofroth 2001	Montane Cordillera	Trapped	FL,TC,HS,MN
9	Southeast British Columbia	7,000	Krebs and Lewis 2000	Montane Cordillera	Trapped	FL,TC,RC,HS
10	Montana	1,300	Hornocker and Hash 1981	Montane Cordillera	Trapped	FL,TC,HS
11	Central Idaho	8,000	Copeland 1996	Northern Rocky Mountain Forest	Untrapped	PA,RC,HS
12	Wyoming	1,500	Copeland 2000	Northern Rocky Mountain Forest	Untrapped	PA,RC,HS

[a] Study numbers correspond to Fig. 1.
[b] Habitat management: FL = Forest harvesting; MN = Mineral extraction; RC = Backcountry recreation; TC = Major transportation corridor; HU = unpopulated; HS = sparsely populated; PA = protected area.
[c] B. Shults, U.S. National Park Service, unpublished data.
[d] D. Cooley, Renewable Resources–Fish and Wildlife Branch, unpublished data.

summers and cold, dry winters. Average February snow depths were 30–47 cm (Brown et al. 2002). Primary ungulate food sources for wolverines were moose (*Alces alces*), caribou, and Dall's sheep (*Ovis dalli*; Gardner 1985, Banci 1987). Arctic ground squirrels, snowshoe hare (*Lepus americanus*), and porcupine (*Erethizon dorsatum*) were identified as important diet items.

Montane study areas were characterized by relatively steep mountainous terrain, diverse forest habitats, alpine tundra at high elevations, cool winters, warm summers, and moderate to high precipitation. Average February snow depths were 100–140 cm (Brown et al. 2002). Elevations ranged from 460 to 3,280 m. Primary ungulate food sources for wolverines were moose and caribou in north-central British Columbia; moose, caribou, and mountain goats (*Oreamnos americanus*) in southeast British Columbia; and elk (*Cervus elaphus*), deer (*Odocoileus hemionus*, *O. virginianus*), and moose in Idaho, Montana, and Wyoming. Small-mammal prey, such as ground squirrels (*Spermophilus* spp.), porcupine, and hoary marmots (*Marmota caligata*), have been identified as seasonally important in some of these study areas (J. Krebs, unpublished data; E. Lofroth, unpublished data). As in tundra and boreal environments, the relative importance of other mammal and bird prey to wolverines in montane environments is not well described, especially for summer.

Wolverines were classed as a furbearer or game animal in 8 study areas and were trapped or hunted for their fur (Table 1). The southwest Yukon study was conducted in an area where trapping was not permitted. However, due to the small study-area size (1,590 km^2), trapping activity on the perimeter of the study area, and the relative level of harvest of the study population, this was effectively a "trapped" sample population (Banci 1987). The same was true for the Montana study (Hornocker and Hash 1981; M. Hornocker, Wildlife Conservation Society, unpublished data), where trapping was permitted during the first 2 years of the study and on the perimeter of this small area (1,300 km^2) for the duration of the study. Although the central Northwest Territories (Mulders 2001) and northwest Alaska (Magoun 1985) study areas had open trapping seasons, these areas were so remote that effectively no trapping occurred. Consequently, we classified these populations as "untrapped." The Idaho (Copeland 1996) and Wyoming (Copeland 2000) studies were conducted in untrapped wilderness areas.

METHODS

Capture

We captured wolverines using box traps (e.g., Copeland 1996, Krebs and Lewis 2000), barrel traps (Hornocker and Hash 1981, Banci 1987), or darting from a helicopter (e.g., Gardner 1985, Magoun 1985, Golden et al. 2002). We trapped or darted wolverines in areas where we believed captures were most likely to occur and areas that

Table 2. Wolverine mortalities from 12 radiotelemetry studies conducted in North America between 1972 and 2001. The number of wolverines includes all animals monitored for >10 days. Mortalities include natural and human-caused deaths of monitored wolverines. Excluded mortalities list wolverines that died after regular monitoring ceased.

Study area location	Ecotype	Management regime	No. of wolverines	Wolverine-years	Mortalities	Excluded mortalities
Northwest Alaska	Tundra	Untrapped	20	12.94	0	1
Central Northwest Territories	Tundra	Untrapped	28	24.66	1	3
Northwest Alaska	Tundra	Trapped	15	6.36	5	2
Northern Yukon	Tundra	Trapped	13	7.04	2	0
South-central Alaska	Boreal	Trapped	10	4.61	3	1
South-central Alaska	Boreal	Trapped	21	21.41	8	4
Southwest Yukon	Boreal	Trapped	9	5.45	6	1
North-central British Columbia	Montane	Trapped	40	30.96	11	2
Southeast British Columbia	Montane	Trapped	49	56.82	15	4
Montana	Montane	Trapped	15	5.92	4	0
Central Idaho	Montane	Untrapped	16	26.00	7	0
Wyoming	Montane	Untrapped	3	5.26	0	0
Total			239	207.43	62	18

were logistically accessible within the confines of project study areas. We immobilized wolverines using ketamine hydrochloride (HCl; e.g., Hash and Hornocker 1980, Copeland 1996) or with mixtures of tiletamine HCl and zolazepam HCl (e.g., Golden et al. 2002), phenylcyclidine and xylazine (e.g., Magoun 1985), or etorphine and xylazine (e.g., Gardner 1985) delivered via a pole syringe or tranquilizer dart. Wolverines were radiomarked with Telonics MOD315 or MOD335 radiocollars (Telonics, Inc., Mesa, Arizona, USA) or surgically implanted with Telonics IMP300 or IMP400 radiotransmitters by a veterinarian. Radiotransmitters were equipped with mortality sensors.

We classified wolverines as subadults (≤2 yr old) and adults (>2 yr old). Wolverines are reported as reproductively mature between age 2 and 3 (Banci 1994). Poole et al. (1994) reported difficulty in discriminating age of wolverines based on cementum annuli alone and found the proportion of pulp in tooth sections could accurately separate animals <16 months from those >16 months-of-age. Because wolverine parturition spanned the period of captures in our study (i.e., Jan–Apr; Magoun and Copeland 1998), we assigned age 1 (subadult) to wolverines on the basis of premolar or canine (postmortem) tooth-section characteristics and age 2+ (adult) based on tooth section and on tooth wear, the presence of cataracts, pelage appearance, or nipple and testes size (Magoun 1985). We chose 1 March as the birth date for all wolverines based on reported denning times for female wolverines (Magoun and Copeland 1998; J. Krebs, unpublished data; E. Lofroth, unpublished data). Juveniles (age ≤4 months) that were captured and radiomarked with their mother were considered as subadults in the analysis.

Monitoring

Radiomarked wolverines were relocated at least monthly via aircraft. Mortalities were investigated on the ground immediately following detection. Postmortem necropsies were conducted whenever possible. We broadly classified causes of death as natural (starvation, predation, unknown) or human caused (trapped–hunted, road–rail kill). We did not include in our analyses 18 deaths of radiomarked wolverines that occurred after they were no longer being regularly monitored (Table 2). Wolverine deaths (n = 7) attributed to research activities also were not included in analyses.

Statistical Analysis

We estimated annual survivorship rates for each age–sex class (adult female, subadult female, adult male, subadult male) by ecological zone (montane, boreal, tundra) and management regime (trapped, untrapped). We used a bootstrapped Kaplan-Meier technique (Pollock et al. 1989) following McLellan et al. (1999) to accommodate staggered entry of individuals into and out of the data set. We used retrospective 2-way analysis of variance (ANOVA) to compare bootstrapped survival rates among management regimes, habitats, and age–sex classes. A 3-way ANOVA was not possible because 1 cell ("boreal untrapped") of the design was empty. Two retrospective 2-way ANOVAs also were used to compare rates of mortality associated with natural and human-caused factors by age–sex, management regime, and ecological zone.

Table 3. Sources of wolverine mortality by age–sex class in trapped and untrapped study groups. Data were compiled from 12 radiotelemetry studies completed in western North America between 1972 and 2001. Wolverines were considered adults at 2 years-of-age.

		Mortality source				
Management		Natural			Human caused	
regime	Age–sex class	Predation	Starvation	Unknown	Trapped/Hunted	Road/Rail
Trapped	Adult female	0	4	1	5/0	0/0
	Adult male	2	5	0	6/0	0/0
	Subadult female	3	4	1	2/0	0/1
	Subadult male	4	3	2	8/1	2/0
Subtotal		9	16	4	21/1	2/1
Untrapped	Adult female	1	1	1	0	0
	Adult male	1	1	0	0	0
	Subadult female	0	0	3	0	0
	Subadult male	0	0	0	0	0
Subtotal		2	2	4	0	0
Total		11	18	8	22	3

Population Growth Simulations

To explore the effect of human-caused mortalities on population growth, we estimated lambda using our adult and subadult female survival rates bounded by their respective standard errors as well as 3 reproductive rates (0.25, 0.375, 0.5 females/adult female/yr) that bracket reported rates of 0.3 (Persson 2003), 0.345 (Magoun 1985), and 0.445 (Copeland 1996) from untrapped populations. We set age at first parturition at 3 years (Banci 1994, Copeland 1996, Magoun 1985, Persson 2003). Maximum age was set at 13 years for all simulations because this was the maximum age of carcass samples reported in Banci (1987) and Liskop et al. (1981). We did not vary reproductive rates by age or density because the relationship between these variables was unclear. Density-dependent compensation in reproduction is unlikely because unpredictable environmental conditions are likely far more influential in low-density populations (Taylor et al. 1987). Although we lack detailed demographic data from wolverine populations across a range of densities, recent work by Persson (2003) highlights the importance of winter food availability and reproductive status the previous year as determinants of reproductive success in wolverines. Because winter food availability (i.e., ungulate carrion) for wolverines is suggested to vary with environmental conditions (van zyll de Jong 1975), variation in reproductive rates is most likely driven by stochastic rather than density effects.

RESULTS

In the 12 studies, 239 wolverines (110 F, 129 M) were radiomarked and monitored for 207.4 radiotracking years (Table 2). Sixty-seven wolverines from 4 studies in Idaho, Wyoming, Alaska, and Northwest Territories were monitored in untrapped populations. The remaining 172 animals were from trapped populations in Montana, British Columbia, Yukon, and Alaska. Sixty-two (25.9%; 35 M, 27 F) wolverines died while being monitored (Table 3).

Human-caused mortality (22 trapping–hunting and 3 road–rail kills) accounted for 25 of 54 (46%) deaths in trapped populations and was not detected in untrapped populations (Table 3). Eleven of 25 human-caused mortalities were of subadult male wolverines. Starvation was the most common natural mortality source within trapped populations followed by predation and unknown (Table 3). Predation deaths included attacks from wolves (*Canis lupus*), mountain lions (*Felis concolor*), and conspecifics. In untrapped populations, numbers of wolverines dying from starvation, predation, and unknown natural mortalities were similar (Table 3).

Survival rates differed markedly between management regimes ($F_{1,281}$ = 12.86, $P < 0.001$) but were similar among age–sex class ($F_{3,281}$ = 2.50, P = 0.06; Table 4). The interaction between age–sex class and management regime was not significant ($F_{3,281}$ = 1.82, P = 0.143). Survival rates in untrapped populations were substantially higher than trapped populations (Table 4). Within age–sex classes, subadult males had the lowest survival.

We detected significant variation in survival among ecological zones ($F_{2,281}$ = 6.12, P = 0.003) and a nonsignificant age–sex effect ($F_{3,281}$ = 2.13, P = 0.097). The interaction between habitat and age–sex was not significant ($F_{6,281}$ = 0.78, P = 0.583). Survival estimates derived from tundra populations were higher than those in boreal and montane groups (Table 4). However, because survival

Table 4. Wolverine annual survival rates by ecological zone and management regime. Rates were estimated from 12 North American radiotelemetry studies conducted between 1972 and 2001. Wolverines were considered adults at 2 years-of-age. Standard errors were generated by bootstrap samples of survivorship data for each group. Groups represent pooled data among studies within the same ecological zone and/or management regime.

				Annual survival rate (±SE)			
Ecological zone	Management regime	Deaths	Wolverine-years	Adult female	Adult male	Subadult female	Subadult male
Tundra	Untrapped	1	37.60	1.0 (0)	1.0 (0)	0.92 (0.082)	1.0 (0)
Boreal	Untrapped	no data	no data	no data	no data	no data	no data
Montane	Untrapped	7	31.26	0.69 (0.149)	0.80 (0.129)	0.73 (0.167)	1.0 (0)
Tundra	Trapped	7	13.40	1.0 (0)	1.0 (0)	0.50 (0.382)	0.35 (0.195)
Boreal	Trapped	17	31.47	0.60 (0.167)	0.62 (0.155)	0.64 (0.141)	0.36 (0.181)
Montane	Trapped	30	93.70	0.78 (0.083)	0.73 (0.081)	0.72 (0.101)	0.55 (0.119)
Pooled	Trapped	54	138.57	0.73 (0.076)	0.74 (0.062)	0.69 (0.080)	0.45 (0.088)
Pooled	Untrapped	8	68.86	0.88 (0.065)	0.87 (0.095)	0.85 (0.082)	1.0 (0)
Tundra	Pooled	8	51.10	1.0 (0)	1.0 (0)	0.87 (0.089)	0.64 (0.121)
Boreal	Pooled	17	31.47	0.60 (0.161)	0.62 (0.155)	0.64 (0.141)	0.36 (0.181)
Montane	Pooled	37	124.96	0.76 (0.071)	0.74 (0.069)	0.72 (0.085)	0.70 (0.088)

rates of 1.0 are unachievable, tundra rates require larger sample sizes in several age–sex classes to detect mortalities. Survival data from untrapped boreal wolverine populations were not available.

Natural survivorship rates did not differ significantly among the combined management–ecological zone groups ($F_{4,273}$ = 2.22, P = 0.067; Table 5) or by age–sex ($F_{3,273}$ = 1.07, P = 0.364). We found no significant interaction between management–ecological zone and age–sex ($F_{12,273}$ = 1.26, P = 0.245).

Within trapped populations, survival rates associated with human-caused mortalities did not differ significantly by ecological zone ($F_{2,201}$ = 1.46, P = 0.235) or by age–sex class ($F_{3,201}$ = 2.31, P = 0.078). The interaction between habitat and age–sex class was not significant ($F_{6,201}$ = 0.62, P = 0.715; Table 6). Although subadult males experienced lower survival than other age–sex groups, human-caused mortalities were present in all age–sex groups.

DISCUSSION

Banci (1994) reported mortality percentages of radiomarked wolverines from trapped and untrapped populations to suggest annual mortality rates of 0.025 to 0.20 (mean = 0.106). However, Banci (1994) did not apply staggered-entry procedures (Pollock et al 1989) in estimating mortality rates, likely resulting in a significant negative bias. Further, Banci (1994) did not provide separate estimates for sex and age classes. Our data suggest that annual mortality rates (i.e., 1 – annual survival rate) in trapped populations are much higher (0.27 to 0.55 depending on age–sex class; pooled ecological zones Table 4), while mortality rates in untrapped areas were similar (0.0 to 0.15; pooled ecological zones Table 4) to those reported by Banci (1994).

The strength of the difference in survival between trapped and untrapped populations of wolverines in our study suggests that trapping had a significant effect on population demography. Nearly half of all wolverine mortalities recorded in trapped populations were human caused. These mortalities occurred across all age–sex classes but were most prevalent within subadult males. Greater encounter rates with human-caused mortality sources (traps, roads) for young, inexperi-

Table 5. Wolverine annual survivorship rates by management regime, ecological zone, and age–sex class based on natural mortalities only. Rates were estimated from 12 radiotelemetry studies completed in western North America between 1972 and 2001. Groups represent pooled data among studies within the same ecological zone and management regime. Wolverines were considered adults at 2 years-of-age. Standard errors (in parentheses) were generated by bootstrap samples of survivorship data for each group.

Management regime	Habitat	Adult female	Adult male	Subadult female	Subadult male
Trapped	Tundra	1.0 (0)	1.0 (0)	0.50 (0.377)	0.44 (0.232)
	Boreal	0.89 (0.107)	0.92 (0.075)	0.64 (0.144)	0.80 (0.196)
	Montane	0.87 (0.061)	0.83 (0.065)	0.86 (0.077)	0.82 (0.083)
Untrapped	Tundra	1.0 (0)	1.0 (0)	0.92 (0.082)	1.0 (0)
	Boreal	no data	no data	no data	no data
	Montane	0.69 (0.149)	0.80 (0.129)	0.73 (0.167)	1.0 (0)

Table 6. Wolverine annual survivorship rates based on human-caused mortalities only, by ecological zone and age–sex class in trapped populations. Rates were estimated from 8 radiotelemetry studies completed in western North America between 1972 and 2001. Groups represent pooled data among studies within the same ecological zone. Wolverines were considered adults at 2 years-of-age. Standard errors (in parentheses) were generated by bootstrap samples of survivorship data for each group.

Habitat	Adult female	Adult male	Subadult female	Subadult male
Tundra	1.0 (0)	1.0 (0)	1.0 (0)	0.80 (0.133)
Boreal	0.70 (0.152)	0.67 (0.162)	1.0 (0)	0.48 (0.194)
Montane	0.89 (0.073)	0.88 (0.071)	0.84 (0.089)	0.67 (0.128)

enced males during dispersal may explain this observation. We speculate that because natural mortalities occurred independent of management regime, harvest was additive mortality. Additional data, particularly from untrapped populations, would improve our ability to interpret this result. In simulations, McLellan et al. (1999) suggested that for grizzly bears (*Ursus arctos*), at least 42 animals in each age–sex class would be required to detect 5% differences in survival.

For trapped populations, estimates of λ clearly suggest potential population declines in all but the most favorable survival and reproductive rate scenarios (Table 7). The best estimate (using mean adult and subadult survival, reproductive rate = 0.375) suggests a 12.2% annual decline (λ = 0.878) in the absence of immigration from untrapped areas. In contrast, λ is increased in most of the scenarios modeled for untrapped populations (Table 7). Based on these simulations, untrapped populations are capable of increasing at 6.4% per year (λ = 1.064).

Table 7. Population growth rates for trapped and untrapped wolverine populations based on survivorship rates estimated from 12 North American radiotelemetry studies conducted between 1972 and 2001. Growth rates are modeled for the mean (±SE) of adult and subadult survivorship rates. Growth rates are modeled for 3 different reproductive rates (*R*; female kits/adult female/year). Maximum age in the model is estimated at 13; first age of parturition is estimated at 3.

Survivorship rates	Logistic rate of population growth (λ)		
	R = 0.25	*R* = 0.375	*R* = 0.5
Trapped populations			
Adult (+SE); Subadult (+SE)	0.914	0.972	1.020
Adult (mean); Subadult (mean)	0.825	0.878	0.920
Adult (–SE); Subadult (–SE)	0.736	0.783	0.821
Untrapped populations			
Adult (+SE); Subadult (+SE)	1.081	1.151	1.207
Adult (mean); Subadult (mean)	1.000	1.064	1.116
Adult (–SE); Subadult (–SE)	0.920	0.979	1.026

As with other low-density species, such as polar bear (*Ursus maritimus*; Taylor et al. 1987) and grizzly bear (Hovey and McLellan 1996), maintaining high annual survival (≥0.85) of adult female wolverines is central to sustaining populations and harvest (Eberhardt 1990). Because wolverine trapping techniques are nonselective with respect to sex and age, conservative harvest strategies are required. At harvest rates experienced during the timespan of this dataset, trapped populations likely were declining or being maintained via immigration from untrapped refugia. Because trapping occurs in most jurisdictions within the western North American range of the wolverine, the presence and spatial distribution of source populations within protected refugia may be critical to the persistence of wolverines in harvested areas. Resiliency of wolverine populations to harvest and fluctuations in food abundance is considered to be lower than grizzly bears (Weaver et al. 1996).

During the past century, wolverine distribution in North America has contracted substantially along the species' southern boundary (van zyll de Jong 1975). Factors proposed to explain reductions invariably include human exploitation and changes in prey distribution and abundance. Overexploitation of the wolverine in Scandinavia drove populations nearly to extirpation until protection was granted in Sweden and Norway (Landa et al. 1997). Our results confirm the strong potential effect of harvest on survival and therefore persistence of wolverines in North America.

We found significant differences in survival among habitats. However, because the boreal ecological-zone group did not include untrapped population data, we were unable to control for the effect of management regime on survival. Therefore, this result possibly is spurious. Additional survival data from untrapped tundra, and particularly untrapped boreal forest, would improve knowledge of baseline wolverine demography. However, statistical support for quantifying subtle differences in vital rates likely will continue to be weak since sample size requirements are considerable (McLellan et al. 1999). Maritime habitats, which extend from Alaska to Oregon along the Pacific coast, also are completely lacking in wolverine demographic data. Very limited reproductive rate data also hampers our understanding and conservation of North American wolverine populations.

MANAGEMENT IMPLICATIONS

Our data show sustained harvest of wolverine populations likely is maintained by dispersal from untrapped refugia. The ability of refugia to continue to support harvest in neighboring areas may be threatened by human activities that displace or diminish source populations or fragment habitat, particularly in the southern (southern British Columbia, Idaho, Montana, Wyoming) portion of their range. Even in the northern Arctic regions of Northwest Territories and Nunavut, which historically provided expansive refugia for wolverines, snowmobile-assisted access has changed the spatial distribution of the harvest. Since untrapped populations are potentially capable of increasing at 6.4% per year and trapped areas are potentially decreasing at 12.2% per year, refugia need to cover twice as much similarly productive wolverine habitat as harvested areas to support harvests that reflect our observed survivorship values. Protected areas that are targeted to include no more than 12% of the landbase (World Commission on Environment and Development 1987, British Columbia Commission on Resources and Environment 1994) cannot fulfill the role of refugia alone. Additional modeling will be needed to refine the size and distribution of a functional refugia system. Work on grizzly bears clearly suggests that population density and surrounding management context strongly influence reserve sizes (Wielgus 2002).

In continuous populations such as those in the boreal forest and tundra ecosystems of northern British Columbia, Yukon, Alaska, Nunavut, and Northwest Territories, a system employing spatial controls (McCullough 1996) of trapped and large untrapped areas might ensure long-term persistence of the wolverine. These untrapped refugia would need to encompass sufficient reproductive habitat to generate dispersers (Magoun and Copeland 1998).

In southern British Columbia, registered trapline tenures are too small (50–1,000 km^2) to contain viable refugia. Evidence from Banci (1987) and Hornocker and Hash (1981) demonstrate the futility of small (<1,600 km^2) trapping refuges. Within southern, fragmented populations—where dispersal ability among units may be impaired—conservative harvest strategies that include intensive management and monitoring may be necessary to conserve metapopulations (McCullough 1996). In some areas, harvest should be reduced to protect wolverine metapopulations and reduce subpopulation extirpation risk. Future harvest should be managed spatially, by defined metapopulation units. The continued functioning of dispersal linkages between and among southern British Columbia, Alberta, Montana, Idaho, and Washington is essential to long-term persistence of wolverines in the southern portion of their range.

ACKNOWLEDGMENTS

We thank the many field staff who assisted with capture, monitoring, and investigation of wolverine mortalities. F. Hovey provided expert analytical assistance. G. Nowacki and D. Demarchi provided assistance with ecological classification. I. Parfitt produced the study-area map. The following organizations provided funding and/or logistic support for these studies: Columbia Basin Fish and Wildlife Compensation Program, British Columbia Environment, British Columbia Habitat Conservation Trust Fund, Slocan Forest Products, Forest Renewal British Columbia, Peace-Williston Compensation Program, Parks Canada, British Columbia Forest Service, Columbia Basin Trust, Canadian Mountain Holidays, Idaho Fish and Game, U.S. Forest Service, U.S. Fish and Wildlife Service, Devlieg Foundation, National Fish and Wildlife Foundation, Alaska Fish and Game, Alaska Power Authority, Alaska Trappers Association, American Petroleum Institute, Pope and Young, Sigma XI, Wildlife Management Institute, U.S. National Parks Service, Turner Endangered Species Fund, Yukon Renewable Resources, Northwest Territories Renewable Resources, World Wildlife Fund, Department of Indian Affairs and Northern Development, Canadian Wildlife Service, Simon Fraser University, Natural Sciences and Engineering Research Council of Canada, Montana Fish Wildlife and Parks, National Science Foundation, National Geographic, National Wildlife Federation, National Audubon Society, New York Zoological Society, National Rifle Association, Boone and Crocket, and the University of Montana. This paper was prepared with support from Columbia Basin Fish and Wildlife Compensation Program and British Columbia Ministry of Water, Land,

and Air Protection. D. Heard, K. Kunkel, and 2 anonymous referees kindly reviewed earlier versions of this manuscript.

LITERATURE CITED

BANCI, V. 1987. Ecology and behaviour of wolverine in Yukon. Thesis, Simon Fraser University, Vancouver, British Columbia, Canada.

———. 1994. Wolverine. Pages 99–127 *in* L. F. Ruggiero, K. B. Aubry, S. W. Buskirk, L. J. Lyon, and W. J. Zielinski, editors. The scientific basis for conserving forest carnivores: American marten, fisher, lynx and wolverine in the western United States. U.S. Forest Service General Technical Report RM-254.

BECKER, E. F., AND C. L. GARDNER. 1992. Wolf and wolverine density estimation techniques. Research progress report. Alaska Department of Fish and Game, Juneau, Alaska, USA.

BRITISH COLUMBIA COMMISSION ON RESOURCES AND ENVIRONMENT. 1994. Finding common ground: a shared vision for land use in British Columbia. Province of British Columbia, Victoria, Canada.

BROWN, R., B. BRASNETT, AND D. ROBINSON. 2002. Development of a gridded North American monthly snow depth and snow water equivalent dataset for GCM validation. Proceedings of the 58th Eastern Snow Conference, Ottawa, Ontario, Canada.

CAUGHLEY, G. 1977. Analysis of vertebrate populations. John Wiley & Sons, New York, New York, USA.

COPELAND, J. P. 1996. Biology of the wolverine in central Idaho. Thesis, University of Idaho, Moscow, Idaho, USA.

———. 2000. Teton wolverine project. Annual progress report. Idaho Department of Fish and Game, Idaho Falls, Idaho, USA.

DAUPHINE, T. C. 1989. Updated status report on the wolverine (*Gulo gulo*) in Canada. Canadian Wildlife Service, Ottawa, Ontario, Canada.

DEMARCHI, D. A. 1994. Ecoprovinces of the central North American cordillera and adjacent plains. Pages 153–168 *in* L. F. Ruggiero, K. B. Aubry, S. W. Buskirk, L. J. Lyon, and W. J. Zielinski, editors. The scientific basis for conserving forest carnivores: American marten, fisher, lynx and wolverine in the western United States. U.S. Forest Service General Technical Report RM-254.

EBERHARDT, L. L. 1990. Survival rates to sustain bear populations. Journal of Wildlife Management 54:587–590.

GARDNER, C. L. 1985. The ecology of wolverines in southcentral Alaska. Thesis, University of Alaska, Fairbanks, Alaska, USA.

GOLDEN, H. N. 1996. Furbearer management technique development. Research progress report. Alaska Department of Fish and Game, Juneau, Alaska, USA.

———, W. T. ROUTE, AND E. F. BECKER. 1993. Wolverine demography and ecology in southcentral Alaska. Cooperative research project: project outline and phase 1 progress report. Alaska Department of Fish and Game and National Park Service, Juneau, Alaska, USA.

———, B. S. SHULTS, AND K. E. KUNKEL. 2002. Immobilization of wolverines with Telazol from a helicopter. Wildlife Society Bulletin 30:492–497.

HASH, H. S. 1987. Wolverine. Pages 574–585 *in* M. Novak, J. A. Baker, M. E. Obbard, and B. Malloch, editors. Wild furbearer management and conservation in North America. Ontario Ministry of Natural Resources, Toronto, Ontario, Canada.

———, AND M. G. HORNOCKER. 1980. Immobilizing wolverines with ketamine hydrochloride. Journal of Wildlife Management 44:713–715.

HATLER, D. F. 1989. A wolverine management strategy for British Columbia. British Columbia Ministry of Environment, Wildlife Branch, Wildlife Bulletin B-60.

HORNOCKER, M. G., AND H. S. HASH. 1981. Ecology of the wolverine in northwestern Montana. Canadian Journal of Zoology 59:1286–1301.

HOVEY, F. W., AND B. N. MCLELLAN. 1996. Estimating population growth of grizzly bears from the Flathead River drainage using computer simulations of reproduction and survival rates. Canadian Journal of Zoology 74:1409–1416.

KREBS, J. A., AND D. LEWIS. 2000. Wolverine ecology and habitat use in the North Columbia Mountains: progress report. Pages 695–703 *in* L. M. Darling, editor. Proceedings of a conference on the biology and management of species and habitats at risk. Volume 2. British Columbia Ministry of Environment, Lands, and Parks, Victoria, British Columbia, Canada, and University College of the Cariboo, Kamloops, British Columbia, Canada.

LANDA, A., O. STRAND, J. E. SWENSON, AND T. SKOGLUND. 1997. Wolverines and their prey in southern Norway. Canadian Journal of Zoology 75:1292–1299.

LINDEN, M., M. SANDELL, P. SEGERSTROM, AND J. LANTHA. 1994. The Swedish wolverine project—ecology and conservation. Progress report 1994. Swedish University of Agricultural Sciences, Umeå, Sweden.

LISKOP, K. S., R. M. F. S. SADLEIR, AND B. P. SAUNDERS. 1981. Reproduction and harvest of wolverine (*Gulo gulo* L.) in British Columbia. Pages 469–477 *in* J. A. Chapman and D. Pursley, editors. Proceedings of the Worldwide Furbearer Conference. Worldwide Furbearer Conference, Inc., Frostburg, Maryland, USA.

LOFROTH, E. C. 2001. Wolverine ecology in plateau and foothill landscapes. Northern Wolverine Project 2000/01Year End Report, 1996–2001. British Columbia Ministry Of Environment, Lands, and Parks, Victoria, British Columbia, Canada.

LYON, L. J., K. B. AUBRY, W. J. ZIELINSKI, S. W. BUSKIRK, AND L. F. RUGGIERO. 1994. The scientific basis for conserving forest carnivores: considerations for management. Pages 128–137 *in* L. F. Ruggiero, K. B. Aubry, S. W. Buskirk, L. J. Lyon, and W. J. Zielinski, editors. The scientific basis for conserving forest carnivores: American marten, fisher lynx and wolverine in the western United States. U.S. Forest Service General Technical Report RM-254.

MAGOUN, A. J. 1985. Population characteristics, ecology, and management of wolverine in northwestern Alaska. Dissertation, University of Alaska, Fairbanks, Alaska, USA.

———. 1987. Summer and winter diets of wolverines, *Gulo gulo*, in arctic Alaska. Canadian Field-Naturalist 101:392–397.

———, AND J. P. COPELAND. 1998. Characteristics of wolverine reproductive den sites. Journal of Wildlife Management 62:1313–1320.

MCCULLOUGH, D. R. 1996. Spatially structured populations and harvest theory. Journal of Wildlife Management 60:1–9.

McLELLAN, B. N., F. W. HOVEY, R. D. MACE, J. G. WOODS, D. W. CARNEY, M. L. GIBEAU, W. L. WAKKINEN, AND W. F. KASWORM. 1999. Rates and causes of grizzly bear mortality in the interior mountains of British Columbia, Alberta, Montana, Washington, and Idaho. Journal of Wildlife Management 63:911–920.

MULDERS, R. 2001. Wolverine ecology, distribution, and productivity in the Slave Geological Province. Final report. Government of the Northwest Territories, Yellowknife, Northwest Territories, Canada.

NOWACKI, G., P. SPENCER, T. BROCK, M. FLEMING, AND T. JORGENSON. 2001. Narrative descriptions for the ecoregions of Alaska and neighboring territories. U.S. Geological Survey Open File Report 02-297, Anchorage, Alaska, USA.

PERSSON, J. 2003. Population ecology of Scandinavian wolverines. Dissertation, Swedish University of Agricultural Sciences, Umeå, Sweden.

POLLOCK, K. H., S. R. WINTERSTEIN, C. M. BUNCK, AND P. D. CURTIS. 1989. Survival analysis in telemetry studies: the staggered entry design. Journal of Wildlife Management 53:7–15.

POOLE, K. G., J. LEE, AND A. GUNN. 1994. Use of canine pulp cavity size in separating juvenile and adult wolverines (*Gulo gulo*). Annales Zoologici Fennici 31:329–333.

TAYLOR, M. K., D. P. DEMASTER, F. L. BUNNELL, AND R. E. SCHWEINSBURG. 1987. Modeling the sustainable harvest of female polar bears. Journal of Wildlife Management 51:811–820.

VAN ZYLL DE JONG, C. G. 1975. The distribution and abundance of the wolverine (*Gulo gulo*) in Canada. Canadian Field-Naturalist 89:431–437.

WEAVER, J. L., P. C. PAQUET, AND L. F. RUGGIERO. 1996. Resilience and conservation of large carnivores in the Rocky Mountains. Conservation Biology 10:964–976.

WIELGUS, R. B. 2002. Minimum viable population and reserve sizes for naturally regulated grizzly bears in British Columbia. Biological Conservation 106:381–388.

WIKEN, E. B. 1986. Terrestrial EcoZones of Canada. Ecological Land Classification Series 19. Lands Directorate, Environment Canada, Ottawa, Ontario, Canada.

WILSON, D. E. 1982. Wolverine. Pages 644–652 *in* J. A. Chapman and G. A. Feldhamer, editors. Wild mammals of North America: biology, management, and economics. Johns Hopkins University Press, Baltimore, Maryland, USA.

WOLFE, M. L., AND J. A. CHAPMAN. 1987. Principles of furbearer management. Pages 101–112 *in* M. Novak, J. A. Baker, M. E. Obbard, and B. Malloch, editors. Wild furbearer management and conservation in North America. Ontario Ministry of Natural Resources, Toronto, Ontario, Canada.

WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT. 1987. Our common future. Oxford University Press, Oxford, England, United Kingdom.

Received 4 October 2002.
Accepted 22 March 2004.
Associate Editor: Gehrt.

MORTALITY OF LARGE MAMMALS ON RAILWAY TRACKS*

T. Kušta[1], M. Ježek[1], Z. Keken[2]

Czech University of Life Sciences, [1]Faculty of Forestry, Wildlife and Wood Sciences, [2]Faculty of Environmental Sciences, Prague Czech Republic

As linear structures, railways (rail corridors) significantly affect life in the wild, have negative impact on animal population levels, and affect the very form and structure of inhabited biotopes. This article analyses and quantifies mammal mortality on the Plzeň–Horažďovice suburban railway line. The research was conducted over the 12 months from 1 January 2009 to 31 December 2009. During this period total 60 animals were run down, among them, 60% of collisions were with roe deer (*Capreolus capreolus*), 17% with European hare (*Lepus europaeus*), 13% with pheasant (*Phasianus colchicus*), 5% with bird of prey, 3% with wild board (*Sus scrofa*) and 2% with and red fox *(Vulpes vulpes).* The aim of the research was to analyse in detail individual sections of the track, whose land cover, land use, migration rate and wildlife-train collisions vary. The outcome of this work is to evaluate and assess the overall animal mortality and to determine the most affected wildlife species. The aforementioned results show that rail transport is dangerous for wild mammals, and it can be clearly said that the most endangered species is roe deer (*Capreolus capreolus).*

game; migration; barrier effect; population; population fragmentation

INTRODUCTION

The issue of mammal mortality, often discussed in connection with road transport, is known only marginally in relation to railways. The length of railway lines in the Czech Republic was 9,430 km as at 31 December 2008, of which 3,078 km are electrified railways and 6,352 are non-electrified railways. On average, 9,000 passenger trains criss-cross the Czech Republic every 24 hours. Based on these facts, there is no doubt that with this intensity of rail traffic there are frequent wildlife-train collisions. There are, however, very few Czech studies that have focused on this issue. Foreign publications about the influence of rail transport on wildlife migration and mortality include, for example, Barry, Aitken (1991), Becker, Grauvogel (1991), Gundersen, Andreassen (1998), Rodriguez et al. (1996) and Selmić et al. (2010).

The frequency of wildlife crossing railway lines is influenced by a number of factors, the most significant of them are: (i) character of the surrounding landscape and concentration of mammals in the vicinity, (ii) grade level (height) of the railway in relation to the geomorphology of the surrounding terrain (large mammals run onto the railway particularly in those places where the grade level of the railroad is at the level of the surrounding terrain), (iii) age of the railway (mammals run more often onto newly constructed railways), and (iv) food and migration needs of mammals.

Generally, routes with high traffic create obstacles that are difficult for the mammals to overcome during their migration, and these are directly life-threatening for the mammals due to animal-vehicle collisions (Trocmé, 2003). For large mammals, routes are usually not an absolutely impermeable barrier. That is only the true in cases of high traffic density or fencing. Traffic density, speed of vehicles and overall technical design of routes are the main aspects influencing the extent of the barrier effect (Aanen et al., 1991; Iuell et al., 2003 etc.).

The phenomenon known as population fragmentation is thus becoming a serious and very complicated issue of environmental protection and can have catastrophic consequences for the future structure of ecocenoses, biotopes and consequently also entire ecosystems. Therefore, there are efforts to protect the integrity of valuable areas by means of various legislative instruments not only on the national but currently also on the European level (Hlaváč, Anděl, 2001; Iuell et al., 2003). Isolated locations gradually lose their ability to perform their natural functions as places for the existence of viable animal populations and where these populations are able to reproduce repeatedly.

Monitoring of traffic routes' impacts on wild mammals is described in Clevenger, Waltho (2005), Fahrig, Rytwinski (2009), Saeki, Macdonald (2004) and elsewhere. Mammals and birds tend to be very vulnerable to rail transport, as shown also by studies conducted in Spain, the Netherlands and Czech Republic (Brandjes, Smit, 1999; Van der Grift, 1999; Havlín, 1987,). Differences in mortality between species are well documented by the research of train-animal collisions on Spain's Madrid–Sevilla railway line. Along this railway, the annual mortality was estimated to be 36.5 run-down individuals/km (SCV, 1996). Around 57% of these victims were birds and 40% were mammals, while only 3% were reptiles and amphibians. European and North American studies show that many species of wild mammals are often killed by rail transport (Van

* This research was funded from the resources of the Internal Grant Agency of Czech University of Life Sciences Prague No. 43150/1312/3137.

T i g h e m , 1981; C h i l d , S t u a r t , 1987; B e l a n t , 1995; W e l l s , 1996).

An important issue, however, is what part of a population is actually affected by mortality on routes, or, more precisely, railways. The published data vary considerably depending on the specific research location. For example, I u e l l et al. (2003) and T r o c m é (2003) state that transportation kills some 5% of the population of common species (red fox, roe deer, wild boar). Swiss research (R i g h e t t i et al., 2003) focused on deaths of roe deer and red deer (data from 1999) points to the fact that mortality caused by traffic is clearly the most common cause of death for both species (49.3% for roe deer, 33.2% for red deer). The second most commonly stated cause of death of roe deer *(Capreolus capreolus)* is agricultural technology (19.8%), followed by other factors (9.1%), then age and diseases (7.1%). The second most common cause of death of red deer *(Cervus elaphus)* is other accidents (fall, avalanche, etc.), followed by other causes (14.7%), and then age and diseases (12.2%). The results show that the specific situation in a given territory must always be taken into account.

Species particularly sensitive to barrier effect and traffic mortality are: (i) rare species with small local populations and large individual territories, such as large carnivores (otter, lynx, etc.), (ii) species that migrate daily or seasonally between local biotopes (some ungulates use various environments during daytime and because of that they must cross roads and railways in most cases), (iii) species with long seasonal migrations from summer to winter territories, such as moose or reindeer (P f i s t e r , 1999; I u e l l et al., 2003).

According to H u i j s e r and M c G o w e n (2003), animal-vehicle collisions affect human beings' safety, their property and the animal population itself. In the USA, the total number of collisions with large ungulates has been estimated at more than 1 million a year.

Similar figures are available in Europe as well. In Europe (apart from Russia), more than a half million vehicle-ungulate collisions are recorded each year. These cause at least 300 human deaths, 30,000 human injuries, and property damage of more than EUR 1 billion (T r o c m é , 2003). These figures show an increasing trend. Some species of mammals have come to the brink of extinction due to collisions with vehicles and trains.

MATERIAL AND METHODS

The period of study was from January to December 2009 and was monitored section of the railway line between Plzeň and Horažďovice suburb is interwoven with 18 hunting districts: Horažďovice, Velký Bor, Třebomyslice, Pačejov, Milčice, Štírka Myslív, Nekvasovy, Mohelnice, Klášter, Srby Sedliště, Chejlava, Vlčice, Ždírec, Blovice, Zdemyslice, Žákava, Šťáhlavy and Starý Plzenec. Roe deer (*Capreolus capreolus*) populate all of those hunting districts named, and there are small numbers of common pheasant (*Phasianus colchicus*) and European hare *(Lepus europaeus)*. Moreover, wild boar (*Sus scrofa*) and red fox *(Vulpes vulpes)* regularly occur in all of the hunting districts. Mouflon *(Ovis musimon),* fallow deer *(Dama dama)* and red deer (*Cervus elaphus*) occur locally along the monitored railway. In the Velký Bor hunting district, rock partridge (*Alectoris graeca)* occurs as well.

Species of animals occurring in individual localities were obtained from individual gamekeepers or workers of municipal environmental departments. Along the railway line in the monitored section, fields and grasslands make up 84.2%, forest 10.1% and brush 5.7% of the represented biotopes. The railway line was monitored by train drivers who passed through this section within the monitored period. They recorded the numbers of run-down animals along the line and localized the surroundings of any site of collision (forest, field, brushwood). Data acquired in this way were continuously collected and recorded in a field diary. In addition, the precise kilometer mark of the finding was recorded for every run-down animal according to the track kilometer system of the Czech Railways, particularly to enable precise identification of the section of railway with the highest number of run-down animals and to exclude inaccuracies arising from the possibility that two train drivers would record the same run-down animal for a kilometer of track. Game species that was run down by the driver when driving was recorded, as well as wildlife that was seen along the track and had been already run down by another rail vehicle. During the entire period, several walking inspections along the track were carried out, whereby photo documentation was taken and the surroundings of the track were described in individual sections. Also a video record of the railway track on the line between Plzeň and Horažďovice suburb was made using a video camera placed behind the front window of the train as agreed with the train driver.

When calculating the number of collisions of the most affected animals the number of trains on the line between Plzeň and Horažďovice suburb was first determined according to the Czech Railways timetable for 2008/2009, with differentiation for weekdays, Saturdays, Sundays and public holidays. When calculating the animal-rail vehicle collision for each month separately, the procedure was such that the number of run-down individuals of the given species in individual months was divided by the number of train kilometers for each month, which gave the number of run-down individuals per 1 km of track. The data obtained were further examined to identify, in which biotope the animal-train collisions occurred.

The monitored section of the railway is traversed by 326 passenger trains per week. Moreover, it was necessary to add freight trains, which amounted to 126 according to the findings of the drivers. Daily average for the monitored section of the track is thus 65 passenger and freight trains.

Statistical analysis was carried out using Kruskal-Wallis ANOVA and basic statistical variables. Numbers of individual species of animals run down on the track were compared. This test also analysed in which locations (forest, field, brush) the collisions are most frequent. Furthermore, the measured data were analysed using chi-square test (observed vs. expected frequency). This test was used to determine whether the species of mammals are run down with the same regularity in individual months. The differences between run-down species of animals and between the localities where the collisions occur were graphically illustrated using cluster analysis.

RESULTS AND DISCUSSION

The data obtained were evaluated by a combination of several procedures on the basis of which we found that out of the total number of 60 wildlife-rail vehicle collisions 2 individuals were run down in January, 15 individuals in February, 4 in March, 5 in April, 4 in May, 3 in June, 4 in July, 5 in August, 5 in September, 4 in October, 4 in November, and 5 in December (Fig. 1).

By means of Kruskal-Wallis ANOVA, we recorded a statistically significant difference between the animals. [H (5, N = 72) = 40,89313 p = 0.0000) and Chi-square = 34,95201 sv = 5 p = 0.0000]

According to this test we recorded statistically significant difference in number of run down animals between roe deer (*Capreolus capreolus*) and pheasant (*Phasianus colchicus*) (p = 0.469), between roe deer (*Capreolus capreolus*) and wild board (*Sus scrofa*) (p = 0.0001), between roe deer (*Capreolus capreolus*) and red fox *(Vulpes vulpes)* (p = 0.0000), and between roe deer (*Capreolus capreolus*) and bird of prey (p = 0.0002).

When we examined the regularity of animal-train collisions in individual months in the monitored section of track using chi-square test (observed vs. expected frequency), we obtained these results:

- Roe Deer – chi-square = 12.66667, sv = 11, p = 0.315674
- Hare – chi-square = 6.800027, sv = 11, p = 0.815037
- Pheasant – chi-square = 1.000000, sv = 1, p = 0.317311

These results show that at the significance level of p = 0.05 there was no demonstration as to a statistically significant difference in animal-vehicle collisions between individual months.

Figs 2 and 3 indicate mortalities for individual species, which most often occur in places where there is a field or meadow. This can be explained by the fact that the landscape in the surroundings of the monitored track is mostly made up by fields or meadows (84.2%), where animals migrate to obtain food.

Fig. 4 clearly demonstrates how animal-vehicle collisions occur more frequently in fields and meadows, but Kruskal-Wallis ANOVA showed no statistically significant difference between the localities of the environments where these collisions occur [H (2, N = 18) = 4.012346,

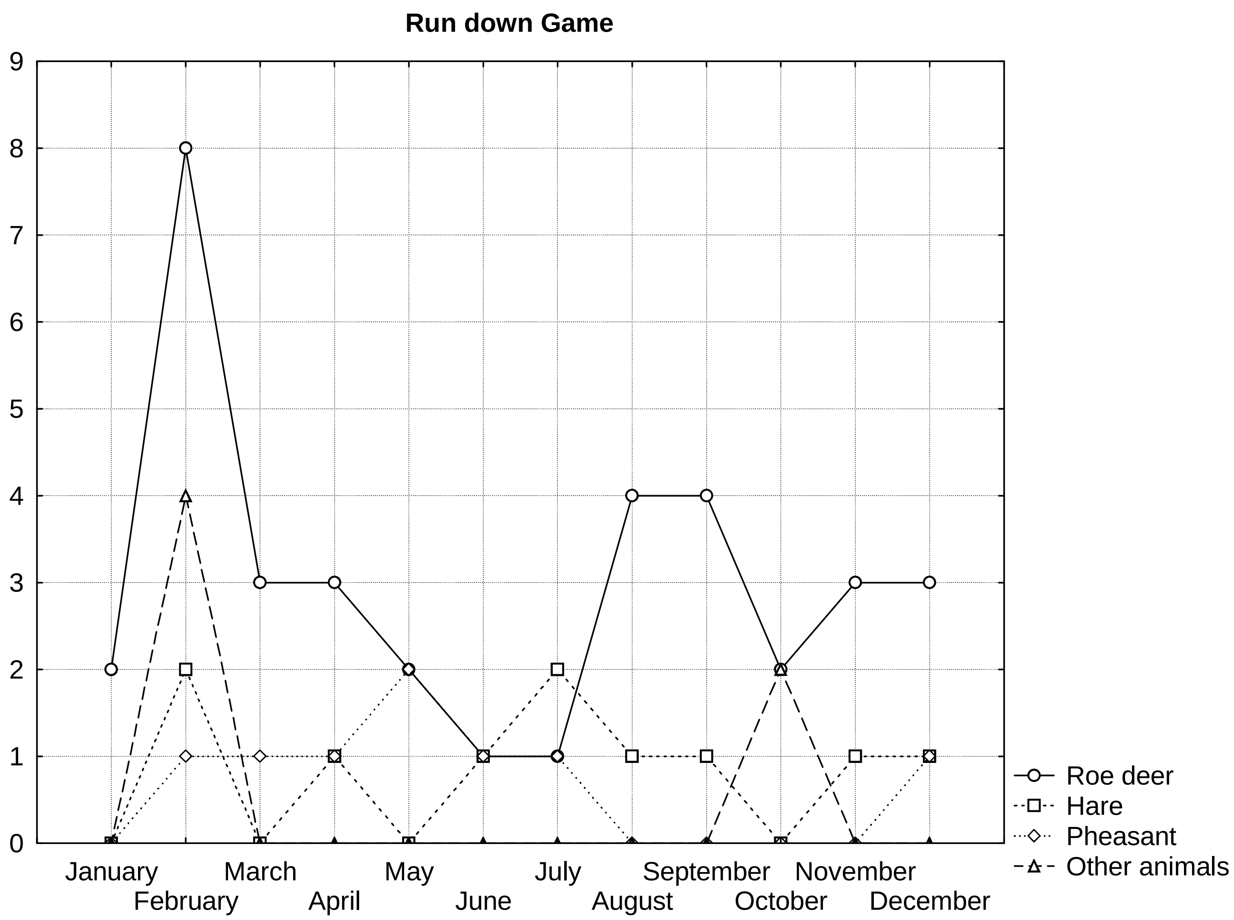
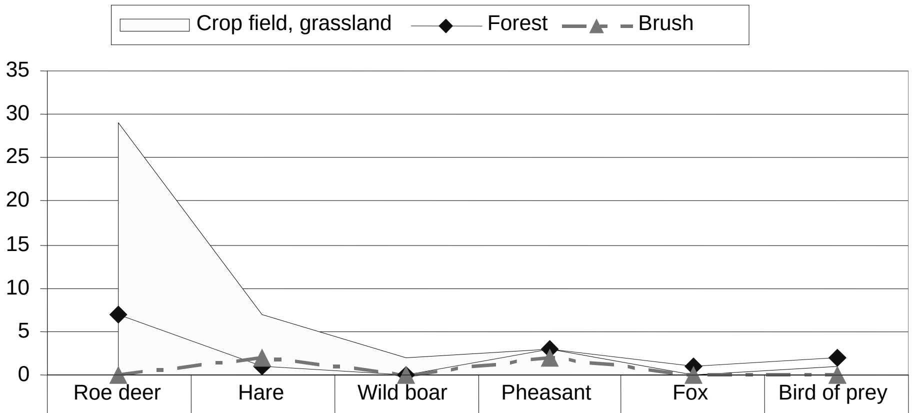


Fig. 1. Mortality of roe deer (*Capreolus capreolus*), European hare *(Lepus europaeus)* and common pheasant (*Phasianus colchicus*) and other animals in the monitored part of the railway



	Roe deer	Hare	Wild boar	Pheasant	Fox	Bird of prey
Crop field, grassland	29	7	2	3	0	1
Forest	7	1	0	3	1	2
Brush	0	2	0	2	0	0

Fig. 2. Mortality of animals in different types of environment

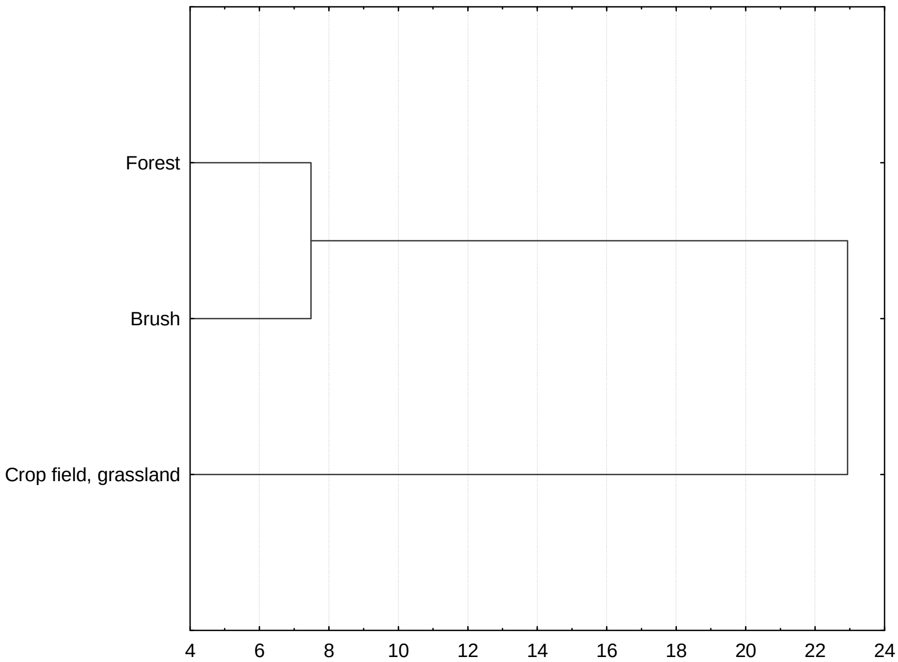


Fig. 3. Results of cluster analysis comparing animal mortality, depending on the type of environment

p = 0.1345 and chi-square = 1.333333 df = 2 *p* = 0.5134], and that was true also in relation to the different dimensions of individual areas that had not been taken into account.

At present, further research is known in the Czech Republic that is being conducted on the railway line between Trhový Štěpánov and Benešov u Prahy (Jankovský, Čech, 2001). It is a 33-km railway track, which crosses a number of very different biotopes and allows a more comprehensive view on the entire issue. The first research on this track was carried out in winter 1999–2000 and consisted of several walking examinations along the track and analyses of skeletal findings of animals run down by trains. The analysis showed that the most affected species mainly comprise roe deer (*Capreolus capreolus*) and European hare (*Lepus europaeus*). Leporids were run down in 32%, even-toed ungulates in 22% (roe deer in the absolute majority of cases), carnivores in 18%, birds in 10%, insectivora in 4% and reptiles in 2% of cases. Findings of body residues occurred in those sections where the line does not form a distinct height barrier, whether with its embankment or ditch. In these places, which are substantially elevated and often overgrown with brush, numerous carcasses of pheasants were found. Although there are several busy roe deer passages crossing the ditched railway, skeletal remains were never found at these intersections or in their vicinity. All killed individuals of roe deer *(Capreolus capreolus)* and European hare (*Lepus europaeus*) were found on open, flat sections of the track, in the vicinity of which the animals stayed over the long term. The most frequent animal-train collisions occur at night, according to Czech Railways personnel. In com-

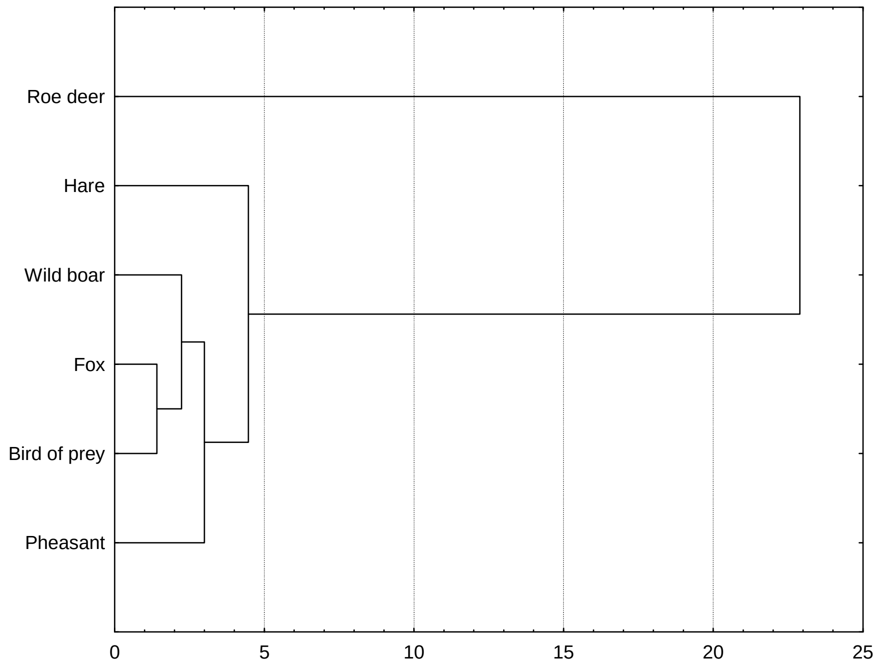


Fig. 4. Results of cluster analysis of comparing animal mortality in the monitored section of track

parison with our results can be found significant similarities, thus that the most affected kind of wildlife is roe deer (*Capreolus capreolus*) and hare (*Lepus europaeus*). The run down were frequently occurred in the open farmed landscape too like in our case study.

In May 2006, another research project on the railway line between Trhový Štěpánov and Benešov u Prahy was conducted. In analysing the second research, an increase in mortality of roe deer (*Capreolus capreolus*) was observed (Jankovský, Čech, 2008). In comparison with our results, this study indicates the fact that the high number of wildlife collisions with train occur in large forest complexes, too.

A 2008 research project from the Czech Moravian Highlands is known as well. In a 6-km section of the railway line (Dobrá voda u Pelhřimova – Hříběcí), an inventory of foot inspections performed on a regularly weekly basis had as its aim to quantify mortality of large mammals due to rail transport and to identify, which species are the most endangered due to this transport. Animals were searched for with the assistance of a trained blood-tracking dog. Almost the entire section passes through a forest complex. It is a line, which is used for regional trains only, and there is limited rail freight transport. Over the monitored interval (1 year), 10 dead roe deer (*Capreolus capreolus*), 3 European hares (*Lepus europaeus*) and one wild boar (*Sus scrofa*) were found (Kušta, Ježek, 2009).

Andreassen et al. (2005) analysed the efficiency of odour fencing, removal of vegetation along track and diversion feeding along a railway line in Norway. The research commenced in 1985 and ended in 1990, during which time 1,045 animal-vehicle collisions were recorded. Reduction of accidents by 46% was proven over the period when actions to reduce mammal mortality were taken on the track. Removal of vegetation and diversion feeding proved to be safe ways to reduce collisions. Noise barriers along the railway line are also very effective, although these create a complete barrier for most animals and significantly contribute to landscape fragmentation and significant increase of barrier effect. The effectiveness of odour fencing appeared to be very questionable in this research. According to the results of this study the most suitable mitigation measures recommended led to reduction of the number of wildlife collisions with train consist in removal of vegetation along the railway tracks.

By comparing this research to the aforementioned studies that have already been conducted, we can conclude that the most affected species due to linear structures in the Czech Republic is roe deer (*Capreolus capreolus*), followed by European hare *(Lepus europaeus)*. Mortality is probably the most visible impact of traffic on wild animal species. Millions of individuals are killed and injured every year by land transportation. It is believed that over the last 30 years transportation has become a major human activity causing mammal mortality and has thus overtaken even hunting.

CONCLUSIONS

During research on the 50-km Plzeň–Horažďovice suburb railway line (1 January 2009 – 31 December 2009), 60 animal individuals were run down. Among these, 60% of collisions were with roe deer (*Capreolus capreolus*), 17% with European hare (*Lepus europaeus*), 13% with pheasant (*Phasianus colchicus*), 5% with bird of prey, 3% with wild board (S*us scrofa*) and 2% with and red fox *(Vulpes vulpes)* (Mach, 2010). The data obtained also show that animal mortality on a single track (36 km long) is 52% and on a double track (24 km long) is 48%. Based on this finding, we cannot clearly agree with the statement that common single tracks are not a significant barrier for large mammals and that only multi-track lines are (Anděl et al., 2005). The aforementioned results clearly show that rail transport is a danger for wild animals. The species most endangered by animal-train collisions is the roe deer (*Capreolus capreolus*).

Fragmentation of animals' natural environments and fragmentation of natural ecosystems into smaller and smaller isolated biotopes is one of the greatest global threats to environmental protection and biological diversity (Broker, Vastenhout, 1995). Maintaining the migration potential of a landscape must be an integral objective of landscape planning policies and landscape planning itself. This assumption is one of the main theoretical bases for the concept of territorial systems of ecological stability. It must be taken into consideration in the case of large linear structures, which are a cause of both landscape fragmentation and decreased possibilities for animal migration (Sklenička, 2003).

The issue of ensuring migration permeability of the landscape (for species with large space requirements, like large ungulates and large carnivores) has for some time already been given great attention, particularly in relation to transportation structures, and there are currently specialized methodologies describing basic prerequisites and necessary measures (Anděl et al., 2006; Hlaváč, Anděl, 2001). Methodologies for evaluating fragmentation and migration permeability have been worked out for designing transportation structures. In practice, however, these methodological approaches are used very rarely. Detailed analysis in terms of fragmentation and migration permeability for linear structures is prepared only very rarely, and the implementation of necessary measures is itself also not very common.

REFERENCES

AANEN, P. – ALBERTS, W. – BROKER, G. J.: Nature engineering and civil engineering works. Wageningen, Pudoc Wageningen 1991. 138 pp.

ANDĚL, P. – HLAVÁČ, V. – LENNER, R.: Migration objects to find clearness of highways and routes for wild animals – TP 180. Liberec, EVERNIA 2006. 92 pp. (in Czech)

ANDĚL, P. – GORČICOVÁ, I. – HLAVÁČ, V. – MIKO, L. – ANDĚLOVÁ, H.: Evaluation of landscape fragmentation by traffic. Praha, Agentura ochrany přírody a krajiny 2005. 99 pp. (in Czech)

ANDREASSEN, H. P. – GUNDERSEN, H. – STORAAS, T.: The effect of scent-marking, forest clearing, and supplemental feeding on moose-train collisions. J. Wildlife Manage., *69*, 2005: 1125–1132.

BARRY, S. P. – AITKEN, D. A.: Moose mortality on highways and railways in British Columbia. Alces, *27*, 1991: 41–49.

BECKER, E. F. – GRAUVOGEL, C. A.: Relationship of reduced train speed on moose-train collisions in Alaska. Alces, *27*, 1991: 161–168.

BELANT, J. L.: Moose collisions with vehicles and trains in Northwestern Minnesota. Alces, *27*, 1995: 31–45.

BRANDJES, G. J. – SMIT, G. F. J.: Aangereden dieren langs spoorwegen. Report 99.74. Bureau Waardenburg, Culemborg 1999.

BROKER, H. – VASTENHOUT, M.: Nature across motorways. Ministry of Transport, Delft, Public Works and Water Management 1995. 103 pp.

CHILD, K. N. – STUART, K. M.: Vehicle and train collision fatalities of moose: some management and socio-economic considerations. Swed. Wildlife Res., *1*, 1987: 699–703.

CLEVENGER, A. P. – WALTHO, N.: Performance indices to identify attributes of highway crossing structures facilitating movement of large mammals. Biol. Conserv., *121*, 2005: 453–464.

FAHRIG, L. – RYTWINSKI, T.: Effects of Roads on Animal Abundance: an Empirical Review and Synthesis. Ecol. Soc., *14*, 2009: 21–22.

GUNDERSEN, H. – ANDREASSEN, H. P.: The risk of moose *Alces alces* collision: A predictive logistic model for moose-train accidents**.** Wildlife Biol., *4*, 1998: 103–110.

HAVLÍN, J.: On the importance of railway lines for the life of avifauna in agrocoenoses. Folia Zool., *36*, 1987: 345–358.

HLAVÁČ, V. – ANDĚL, P.: Methodological handbook for finding of motorways for wild animals. Praha, AOPK ČR 2001. 51 pp. (in Czech)

HUIJSER, M. P. – McGOWEN, P. T.: Overview of animal detection and animal warning systems in North America and Europe. Habitat Fragmentation due to Transportation Infrastructure – IENE, 2003: 47–48.

IUELL, B. et al.: Wildlife and Traffic: A European Handbook for Identifying Conflicts and Designing Solutions. Brusel, KNNV Publishers 2003. 169 pp.

JANKOVSKÝ, M. – ČECH, M.: Railway tracks as the place for collisions with animals. Živa, *1*, 2001: 39–40. (in Czech)

JANKOVSKÝ, M. – ČECH, M.: Railway transport and fauna near railway track. Živa, *3*, 2008: 136. (in Czech)

KUŠTA, T. – JEŽEK, M.: The effects of ground routes on population of bisulcate deer in model regions of the Czech Republic. COYOUS 2009 – Konference mladých vědeckých pracovníků, Česká zemědělská univerzita v Praze, Praha, 2009, pp. 222–231. (in Czech)

MACH, P.: The effects of traffic on game populations. [Bachelor's thesis.] ČZU Prague, 2010. 61 pp. (in Czech)

PFISTER, H. P.: Grünbrücken – ein Beitrag zur Verminderung straßenbedingter Trennwirkungen. Landschaftstagung, *30*, 1999: 96–100. In: Landschaftstagung 1997, Erfurt: Strassenbau und Umweltplanung.

RIGHETTI, A. – MALLI, H. – BERTHOLD, G. – GEORGII, B. – LEUZINGER, E. – SCHLUP, B.: Effect of unfenced (high-speed)-railway lines on wildlife. Habitat Fragmentation due to Transportation Infrastructure – IENE, 2003: 23–24.

RODRIGUEZ, A. – REMA, G. – DELIBES, M.: Use of non-wildlife passages across a high-speed railway by terrestrial vertebrates. J. Appl. Ecol., *33*, 1996: 1527–1540.

SAEKI, M. – MACDONALD, D. W.: The effects of traffic on the raccoon dog (*Nyctereutes procyonoides viverrinus*) and other mammals in Japan. Biol. Conserv., *118*, 2004: 559–571.

SCV 1996. Mortalidad de vertebrados en vías de ferrocarril. Documentos Técnicos de

Conservación, nº 1. Sociedad para la Conservación de los Vertebrados. Madrid. 23 págs.

SELMIĆ, M. – TEODOROVIC, D. – VUKADINOVIC, K.: Locating inspection facilities in traffic networks: an artificial intelligence approach. Transport. Plan. Techn., *33*, 2010: 481–493.

SKLENIČKA, P.: Fundamentals of landscape planning. Praha, Nakladatelství Naděžda Skleničková 2003. 321 pp. (in Czech)

TROCMÉ, M.: Habitat Fragmentation due to Transportation infrastructure – The European Review. European Commission, Directorate – General for Research, Luxembourg, 2003. 16 pp.

VAN DER GRIFT, E. A.: Mammals and railroads: impacts and management implications. Lutra, *42*, 1999: 77–98.

VAN TIGHEM, K.: Mortality of bighorn sheep on a railroad and highway in Jasper National Park, Canada. 1981.

WELLS, P.: Wildlife mortality on the Canadian Pacific Railway between Field and Revelstoke, BC. 1996.

Received for publication on October 14, 2010
Accepted for publication on December 10, 2010

KUŠTA, T. – JEŽEK, M. – KEKEN, Z. (Česká zemědělská univerzita, Fakulta lesnická a dřevařská, Fakulta životního prostředí, Praha, Česká republika):

Mortalita velkých savců způsobená železniční dopravou.

Scientia Agric. Bohem., *42*, 2011: 000–000.

Železniční tratě (koridory) jako liniové stavby podstatně ovlivňují život ve volné přírodě, negativně působí na populační stavy živočichů a ovlivňují samotnou podobu a strukturu obývaných biotopů. Článek analyzuje a kvantifikuje mortalitu savců na železniční trati Plzeň–Horažďovice předměstí. Průzkum byl prováděn po dobu 12 měsíců od 1. ledna 2009 do 31. prosince 2009. Během tohoto období bylo nalezeno 60 uhynulých zvířat. Nejvíce kolizí (60 %) bylo zjištěno u srnce obecného (*Capreolus capreolus*), 17 % u zajíce polního (*Lepus europaeus*), 13 % u bažanta obecného (*Phasianus colchicus*), 5 % u řádu dravců (*Falconiformes*), 3 % u divokých prasat (*Sus scrofa*) a 2 % kolizí u lišky obecné *(Vulpes vulpes)*. Cílem bylo podrobně zmapovat jednotlivé úseky tratě, které se liší krajinným typem (land cover), využitím krajiny (land use) a četností migrace a střetů živočichů s vlaky. Výstupem práce je vyhodnocení a posouzení celkové výše mortality zvěře a určení nejvíce ohrožených druhů živočichů. Z uvedených výsledků vyplývá, že železniční doprava je nebezpečím pro volně žijící savce, a jednoznačně lze říci, že nejohroženější zvěří je srnec obecný (*Capreolus capreolus)*.

zvěř; migrace; bariérový efekt; populace; fragmentace populace

Contact Address:

Ing. Tomáš Kušta, Česká zemědělská univerzita v Praze, Fakulta lesnická a dřevařská, Kamýcká 129, 165 00 Praha 6-Suchdol, Česká republika, tel.: +420 224 383 728, e-mail: kusta@fle.czu.cz

Turkish Journal of Zoology

http://journals.tubitak.gov.tr/zoology/

Research Article

Turk J Zool
(2014) 38: 479-485
© TÜBİTAK
doi:10.3906/zoo-1308-18

Deer on the railway line: spatiotemporal trends in mortality patterns of roe deer

Tomáš KUŠTA[1], Michaela HOLÁ[1,*], Zdeněk KEKEN[2], Miloš JEŽEK[1], Tomáš ZÍKA[1], Vlastimil HART[1]

[1]Department of Game Management and Wildlife Biology, Faculty of Forestry and Wood Sciences, Czech University of Life Sciences Prague, Prague, Czech Republic

[2]Department of Applied Ecology, Faculty of Environmental Sciences, Czech University of Life Sciences Prague, Prague, Czech Republic

Received: 07.08.2013 • **Accepted:** 16.02.2014 • **Published Online:** 20.05.2014 • **Printed:** 19.06.2014

Abstract: Traffic-related mortality of free-ranging animals is among the most commonly observed human–wildlife conflicts. These conflicts pose serious threats to human safety as well as having great economic consequences. Although considerable attention has been paid to the role of roads in affecting free-ranging animals, the effects of railways have been less studied. Our study provides initial insights into the spatial and temporal variability of the roe deer–train collisions at 4 selected railway sections in the Czech Republic. Using data on 69 roe deer–train collisions collected during 2009, we tested the effects of railway section length, train frequency, relative abundance of roe deer, and time of year (by month) on collision probability. The number of roe deer–train collisions was influenced by train frequency (i.e. the higher the number of trains passing through individual study sections, the higher the number of collisions) and the time of the year (i.e. the highest number of collisions occurred in winter, particularly in February). Future research efforts should focus on describing roe deer behavior and movement patterns along the railways as well as the mortality factors related to the accidents. Such findings will help to identify hotspots of future accidents and to design suitable mitigation measures.

Key words: Animal–train collisions, traffic mortality, Czech Republic

1. Introduction

To meet the demands of an increasing human population and resulting economic development, the volume of traffic has rapidly increased in past decades (Groot Bruinderink and Hazebroek, 1996; Frair et al., 2008). Simultaneously, better wildlife management and conservation measures have also led to an increase in the populations of large mammalian herbivores, both in density and distribution, throughout Europe (Apollonio et al., 2010). The increase in population size and density of these animals is now creating problems of human–wildlife conflict in various forms (Redpath et al., 2013). One widely occurring form of human–wildlife conflict is traffic-related mortality of ungulates, which is commonly observed throughout Europe (e.g., Rolandsen et al., 2011).

Populations of wild ungulates have been increasing throughout the Czech Republic over the last decades, and roe deer (*Capreolus capreolus*) is the most common, occupying open agricultural lands as well as forested areas (Červený, 2009). Considering the intensity and location of railway traffic and the high abundance and density of ungulates in the Czech Republic, frequent deer–train collisions are to be expected (Modafferi, 1991; http://www.cd.cz). Nonetheless, there is little existing research that has investigated the role of railways in affecting the populations of wild ungulates in the Czech Republic (Havlín, 1987; Jankovský and Čech, 2008; Kušta et al., 2011) and only a few studies have focused on this issue worldwide (e.g., Baofa et al., 2006). On the other hand, a large number of studies address the issue of mortality of wildlife due to road traffic (e.g., Langbein and Putman, 2005; Dussault et al., 2006; Gonzáles-Gallina et al., 2013).

Theoretically, roads and railways should have similar ecological impacts on wildlife (Canters et al., 1997; Joyce and Mahoney, 2001). Besides direct mortality of animals, roads and railways can affect wildlife in numerous different ways: by causing habitat loss and fragmentation, creating barriers to movement and behavioral modifications, increasing dispersal of exotic species, and, thereby, reducing long-term survival and population viability (Trombulak and Frisell, 2000). Animal–vehicle collisions also pose a serious threat to human safety and can have significant economic consequences as a result of medical costs and the costly measures adopted to prevent accidents, such as wildlife fences along roads (Groot Bruinderink and Hazebroek, 1996; Ascensão et. al., 2013). Although

* Correspondence: mhola@fld.czu.cz

collisions with trains may be less threatening to humans, they are certainly important from a wildlife management perspective and might even be more common than collisions on roads (Van der Grift, 1999).

In this primarily exploratory study, we aimed to examine the spatial and temporal patterns of roe deer–train collisions on 4 selected railway sections in the Czech Republic. We chose roe deer because it is the most numerous ungulate species and is important from a management perspective (both for hunting and habitat conservation). Specifically, we tested the effect of train frequency on roe deer–train collisions, assessed the temporal variability of collisions at each individual railway section, and, finally, determined the spatial variability of collisions across railway sections.

2. Materials and methods

2.1. Study area

The study was restricted to 4 selected railway sections in the Czech Republic with known occurrence of roe deer (Červený, 2009). The railway sections Plzeň–Horažďovice (hereinafter "section 1"; length: 60 km; 410 m a.s.l.) and Bělčice–Závišín (hereinafter "section 2"; length: 4.5 km; 520 m a.s.l.) run through the southwestern part of the Czech Republic. The sections Obrataň–Jindřichův Hradec (hereinafter "section 3"; length: 15.2 km; 660 m a.s.l.) and Dobrá Voda u Pelhřimova–Hříběcí (hereinafter "section 4"; length: 6 km; 650 m a.s.l.) are located in the south of the country (Figure 1).

2.2. Data collection

We calculated the train frequency (i.e. the number of trains passing per month through individual study sections) based on the Czech Railway's timetable for 2008–2009 (http://www.cd.cz/en/domestic-travel/timetable/line-timetables/index.php). We acquired the hunting statistics (http://eagri.cz/public/web/mze/lesy/myslivost/) on roe deer (i.e. animals killed per 100-ha area around the individual sections during 2009) as a proxy for the relative abundance of the species near the individual study sections. We used this dataset as it provides the most reliable indicator of roe

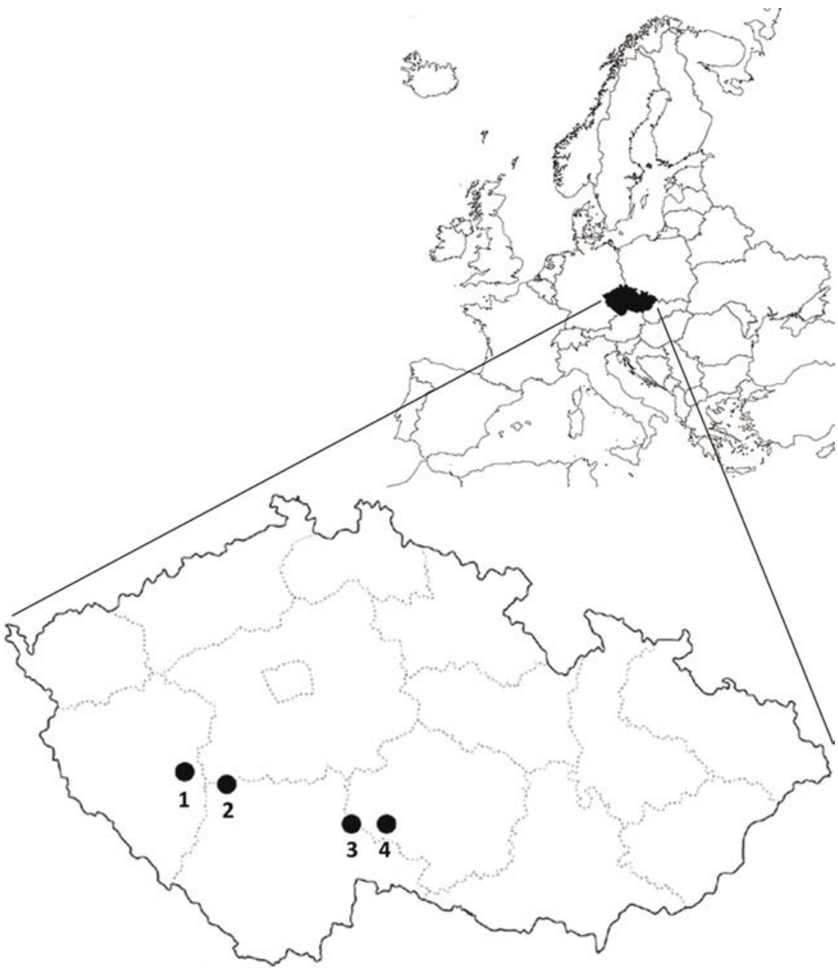


Figure 1. Location of 4 selected railway sections in the Czech Republic.

deer densities in the Czech Republic (Bartoš et al., 2010). Data on train kills were collected opportunistically during 2009 from train drivers who were required to record the locations and dates of the roe deer–train collisions while passing through the individual study sections. These locations were identified and marked based on the distance markers placed along tracks, which are used by the Czech Railway for distance indication. We also performed round trips along each study section twice per month throughout the study period in order to record any other roe deer–train collisions missed by the drivers and to map the surrounding habitats around each railway section. The habitats surrounding the collision locations were categorized as predominantly field/meadow, forests, or shrubland by section. The recorded locations were later checked for redundant duplication of recording, and only unique instances were selected for analyses.

2.3. Statistical analyses

We first estimated the relationship between the number of collisions and the spatial characteristics of individual study sections (i.e. section length, train frequency, and relative abundance of roe deer). We tested for correlations using Pearson's correlation coefficients (r) between each of these variables, in pairs. To test what predicts the probability of roe deer–train collision, we regressed train frequency per month in the individual study sections and months against number of collisions. We designated month as the temporal scale variation because the collision data and train frequency were collected and measured at this scale. However, we aimed to relate results by month to roe deer lifecycle and management measures. The winter season lasts from December to April, calving occurs from May to June, and rutting occurs during July and August. The hunting season lasts from May to September for bucks and from September to December for does and fawns. Deer are also given supplementary feed from September until April (Bartoš et al., 2010).

We used generalized linear mixed-effects models (GLMMs) with a Poisson error structure (Zuur et al., 2009) to identify the predictors of collision probability. Train frequency (i.e. number of trains passing per month through individual study sections) and month were treated as fixed effects and section identity as a random effect (to account for repeated measurements of roe deer–train collisions from the same railway sections). The models were fitted using the *glmer* function in R and estimated with the Laplace approximation. Model selection was performed using the ANOVA function and Akaike's information criterion (AIC) to compare the fit of individual and combined variables, with $\Delta AIC > 10$ indicating that the model was unlikely to perform better than the model with the lowest AIC (Burnham and Anderson, 2002). All statistical analyses were performed in R 3.0.2 statistical software (R Development Core Team, 2009) with the *lme4* (cran.r-project.org/package=lme4) package.

3. Results

3.1. Spatial trends

A total of 69 roe deer–train collisions were recorded across the 4 selected railway sections during 2009. The highest number of collisions was recorded at section 1 (n = 36), and 11 accidents were recorded at each of sections 2, 3, and 4.

The relative abundance of roe deer was highest at section 2 and lowest at section 4. Sections 1, 2, and 3 were predominantly field/meadow, whereas section 4 was mostly forested (Table 1). The number of collisions was positively correlated with the length of the railway section ($r^2 = 0.89$, $P < 0.04$) and the train frequency ($r^2 = 0.88$, $P < 0.04$), whereas the number of collisions and relative abundance of roe deer were not correlated ($r^2 = 0.313$, $P < 0.6$). The sections with a higher proportion of field/meadow habitats (sections 1, 2, and 3) were also the ones with a higher number of collisions, whereas section 4, dominated by forest, had fewer recorded collisions (Table 1).

A comparison of tested GLMMs, including AIC and ΔAIC values, is shown in Table 2. The best model (judged by the lowest AIC value) included train frequency as a fixed effect and section identity as a random effect. Nevertheless, the difference in AICs between this simpler model and a

Table 1. Spatial characteristics of individual railway sections surveyed for this study.

	Number of trains passing per week	Relative abundance of roe deer*	Surrounding habitats (%)		
			Field/meadow	Forest	Shrubland
Section 1	452	1.61	84	10	6
Section 2	170	2.17	85	5	10
Section 3	156	1.67	49	37	14
Section 4	132	1.06	23	69	8

*Animals killed per 100-ha area around the individual sections during 2009.

Table 2. Model comparison for factors potentially influencing the probability of roe deer–train collisions.

Model	Fixed effects	Random effects	AIC	ΔAIC
1	Train frequency	Railway section	144	0
2	Month + train frequency	Railway section	152	8
3	Month	Railway section	160	10

AIC: Akaike's information criterion; ΔAIC: $AIC_i - AIC_{min}$.

more complex model that also included month as a fixed effect was only 8 points, showing the simpler model to be only a slightly better relative fit than the more complex one (Table 2). Moreover, the ANOVA test did not show any significant difference between the 2 models ($P > 0.2779$). On this basis we decided to use the more complex model. The estimated coefficients and standard errors for the variables of the final model are shown in Table 3.

While accounting for the random variation due to railway section, the train frequency (i.e. number of trains passing per month through individual study sections) had a positive effect on the number of roe deer–train collisions (0.84 ± 0.00; $P < 0.0017$; Table 3).

Table 3. Results of the final generalized linear mixed effects model for the effects of month and train frequency on the occurrence of roe deer–train collisions.

	Estimate ± std. error
Fixed effects	
Intercept	–0.99 ± 0.64
May	0.36 ± 0.65
June	0.40 ± 0.64
July	0.36 ± 0.61
August	0.65 ± 0.61
September	0.69 ± 0.76
October	–0.33 ± 0.71
November	–0.25 ± 0.70
December	–0.38 ± 0.76
January	–0.33 ± 0.76
February	0.12 ± 0.58*
Train frequency	0.84 ± 0.00***
Random effect	Variance ± std. error
Segment	0.78 ± 0.47

*: Significant at 0.05; ***: Significant at 0.001.

3.2. Temporal trends

The number of collisions was highest in winter, especially in the month of February (Figure 2), and the month of February also emerged as significant in the final GLMM ($P < 0.0191$; Table 3). The effect of the remaining months was not significant (Table 3). However, this trend was not consistent over the sections as the collisions occurred throughout the year across sections and varied in number (Figure 2).

4. Discussion

We show that, even within a short sampling period, a large number of roe deer–train collisions were recorded. This finding in itself reemphasizes the importance of this issue and calls for more attention to be paid to wildlife–train collisions by researchers and wildlife management authorities. Our results suggest that the train frequency (i.e. number of trains passing through individual railway section per month) influences the probability of roe deer–train collisions. The effect of traffic frequency on the probability of accidents has already been shown in other studies (e.g., Seiler, 2004; Hussain et al., 2007; Danks and Porter, 2010). Our study concurs with these, as the number of roe deer–train collisions was positively correlated with the traffic frequency (Belant, 1995; Joyce and Mahoney, 2001). A higher train frequency for roe deer means that the deer encounter more trains per time unit, which would constantly agitate the animals, inciting flight and erratic movements and thus resulting in more collisions.

Our analyses revealed that the number of collisions was highest in winter and the most statistically significant month was February. Winter is generally the lean period in terms of food availability, and quality and presence of snow combined with scarcity of food affects the movement of ungulates (Marchand, 1996). Ungulates are forced to cover larger distances in winter in order to find food and snow-free areas or those with little snow where they can dig easily. Such areas can usually be found along roads and railways (Bowman et al., 2010; Rea et al., 2010). This could be an explanation for the increased frequency of deer–train collisions in our study areas, as deer may move more during winter months. February is one of the months when

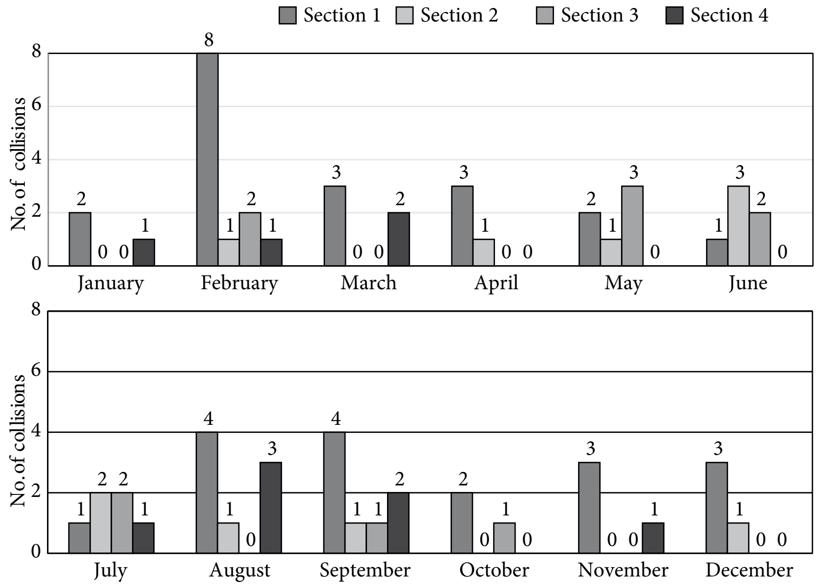


Figure 2. Bar plots showing spatial and temporal patterns of roe deer–train collisions between selected railway sections in the Czech Republic during 2009. The numbers above the bars represent the counts of collisions for each railway section during the particular month. Zero indicates that no collisions were recorded in that period.

deer are provided extensively with supplementary feed across the Czech Republic. Such practices are known to alter density and distribution of animals as well as increase direct and indirect interactions between individuals (Putman and Staines, 2003). Consequently, reactions to supplementary feeding could explain the higher number of collisions during winter, especially if feeding sites are close to railways and supplementary feeding increases direct competitive interactions between individuals.

An increase in deer–vehicle collisions in winter has also been observed for other deer species such as red deer (*Cervus elaphus*) and moose (*Alces alces*) in Norway (Gundersen and Andreassen, 1998; Meisingset et al., 2013) and mule deer (*Odocoileus heminonus heminonus*) in the United States (Myers et al., 2008). Studies from British Columbia in Canada (Child et al., 1991), northern Sweden (Lavsund and Sandegren, 1991), and Finland (Haikonen and Summala, 2001) also reported a peak in deer–vehicle accidents in midwinter. However, in other studies, collisions have been observed to peak in summer, e.g., roe deer in Slovenia (Pokorny, 2006) and moose in Quebec (Dussault et al., 2006) and Newfoundland (Joyce and Mahoney, 2001). This indicates that local factors and species biology likely affect the probability of accidents.

There are other factors that are known to affect the likelihood of deer–vehicle collisions, such as habitat characteristics around the traffic infrastructure (Seiler, 2003). Habitat features are known to determine the habitat selection patterns of ungulates, and roe deer are known to prefer open agricultural landscapes (Cederlund et al., 1980). In our study areas, railway sections with a high proportion of open fields (i.e. 1, 2, and 3) had higher roe deer density and frequent collisions. A high proportion of fields in sections 1, 2, and 3 corresponded with higher human population density, which, in turn, corresponded to higher train frequency in these sections.

Overall, human inhabitation and resulting changes in the landscape affect the likelihood of collisions (Cederlund et al., 1980; Nielsen et al., 2003). Our study provides an initial but crucial insight on the issue, but additional information is clearly needed. More sampling is required across railway sections to get a broader picture of the issue over time. In addition, studies on roe deer movement and behavior around the railway tracks are also needed to understand the causes and patterns of collisions in more detail. Countrywide studies are required in order to develop a nationwide policy of mitigation measures to minimize deer–train collisions. More accurate information building on our study would contribute to making sure that these policies, such as train speed limits in areas with higher train frequency stretching across different habitat types, are both appropriate and effective.

Acknowledgment
This study was supported by the Ministry of Agriculture of the Czech Republic, Grant No. QJ1220314.

References

Apollonio M, Andersen R, Putman R (2010). European Ungulates and Their Management in the 21st Century. Cambridge, UK: Cambridge University Press.

Ascensão F, Clevenger A, Santos-Reis M, Urbano P, Jackson N (2013). Wildlife–vehicle collision mitigation: is partial fencing the answer? An agent-based model approach. Ecol Model 257: 36–43.

Baofa Y, Huyin H, Yili Z, Le Z, Wanhong W (2006). Influence of the Qinqhai-Tibetan railway and highway on the activities of wild animals. Acta Ecol Sin 26: 3917–3923.

Bartoš L, Kotrba R, Pintíř J (2010). Ungulates and their management in the Czech Republic. In: Apollonio M, Andersen R, Putman R, editors. European Ungulates and their Management in the 21st Century. Cambridge, UK: Cambridge University Press, pp. 243–262.

Belant JL (1995). Moose collisions with vehicles and trains in northeastern Minnesota. Alces 31: 1–8.

Bowman J, Ray JC, Magoun AJ, Johnson DS, Dawson FN (2010). Roads, logging, and the large-mammal community of an eastern Canadian boreal forest. Can J Zoolog 88: 454–467.

Burnham KP, Anderson DR (2002). Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach. 2nd ed. New York, NY, USA: Springer-Verlag.

Canters K, Piepers A, Hendriks-Heersma A (1997). Habitat fragmentation, infrastructure and the role of ecological engineering. In: Proceedings of the International Conference on Habitat Fragmentation and Infrastructure; 17–21 September 1995; Maastricht, The Hague, Delft, the Netherlands: Ministry of Transport, Public Works, and Water Management, Road and Hydraulic Engineering Division.

Cederlund G, Ljungquist H, Markgren G, Stålfelt F (1980). Foods of moose and roe deer at Grimsö in central Sweden: results of rumen content analysis. Swe Wildlife Res 11: 169–247.

Červený J (2009). Ottova encyklopedie Myslivost. Prague, Czech Republic: Ottovo nakladatelství (in Czech).

Child KN, Barry SP, Aitken DA (1991). Moose mortality on highways and railways in British Columbia. Alces 27: 41–49.

Danks ZD, Porter FP (2010). Temporal, spatial, and landscape habitat characteristics of moose-vehicle collisions in western Maine. J Wildlife Manage 74: 1229–1241.

Dussault C, Poulin M, Courtois R, Ouellet JP (2006). Temporal and spatial distribution of moose-vehicle accidents in the Laurentides Wildlife Reserve, Quebec, Canada. Wildlife Biol 12: 415–425.

Frair JL, Merrill EH, Beyer HL, Morales JM (2008). Thresholds in landscape connectivity and mortality risks in response to growing road networks. J Appl Ecol 45: 1504–1513.

González-Gallina A, Benítez-Badillo G, Rojas-Soto OR, Hidalgo-Mihart MG (2013). The small, the forgotten and the dead: highway impact on vertebrates and its implications for mitigation strategies. Biodivers Conserv 22: 325–342.

Groot Bruinderink GWTA, Hazebroek E (1996). Ungulate traffic collisions in Europe. Conserv Biol 10: 1059–1067.

Gundersen H, Andreassen HP (1998). The risk of moose (*Alces alces*) collision: a predictive logistic model for moose-train accidents. Wildlife Biol 4: 103–110.

Haikonen H, Summala H (2001). Deer-vehicle crashes: extensive peak at 1 hour after sunset. Am J Prev Med 21: 209–213.

Havlín J (1987). On the importance of railway lines for the life of avifauna in agrocoenoses. Folia Zool 36: 345–358.

Hussain A, Armstrong JB, Brown DB, Hogland J (2007). Land-use pattern, urbanization, and deer-vehicle collisions in Alabama. Human-Wildlife Conflicts 1: 89–96.

Jankovský M, Čech M (2008). Železniční doprava a fauna v okolí tratě. Živa 3: 136 (in Czech).

Joyce TL, Mahoney SP (2001). Spatial and temporal distributions of moose-vehicle collisions in Newfoundland. Wildlife Soc Bul 29: 281–291.

Kušta T, Ježek M, Keken Z (2011). Mortality of large mammals on railway tracks. Scientia Agriculturae Bohemica 42: 12–18.

Langbein J, Putman R (2005). Deer-vehicle collisions in Britain – a nationwide issue. Ecology and Environmental Management - In Practice 47: 1–7.

Lavsund S, Sandegren F (1991). Moose-vehicle relations in Sweden: a review. Alces 27: 118–126.

Marchand PJ (1996). Life in the Cold: An Introduction to Winter Ecology. Hanover, NH, USA: University Press of New England.

Meisingset EL, Loe LE, Brejkum Ø, Moorter B, Mysterud A (2013). Red deer habitat selection and movements in relation to roads. J Wildlife Manage 77: 181–191.

Modafferi RD (1991). Train moose-kill in Alaska: characteristics and relationship with snowpack depth and moose distribution in lower Susitna Valley. Alces 27: 193–207.

Myers WL, Chang WY, Germaine SS, Vander Haegen WM, Owens TE (2008). An Analysis of Deer and Elk-Vehicle Collision Sites along State Highways in Washington State. Completion Report. Olympia, WA, USA: Washington Department of Fish and Wildlife.

Nielsen CK, Anderson RG, Grund MD (2003). Landscape influences on deer–vehicle accident areas in an urban environment. J Wildlife Manage 67:46–51.

Pokorny B (2006). Roe deer-vehicle collisions in Slovenia: situation, mitigation strategy and countermeasures. Vet Arhiv 76: 177–187.

Putman RJ, Staines BW (2003). Supplementary Feeding of Deer; A Review of Direct and Indirect Supplementary Feeding of Red Deer in Scotland: Reasons for Feeding, Feeding Practice and Effectiveness. Report to the Deer Commission for Scotland, Inverness.

Rea RV, Child KN, Spata DP, MacDonald D (2010). Road and rail side vegetation management implications of habitat use by moose relative to brush cutting season. Environ Manage 46: 101–109.

Redpath SM, Young J, Evely A, Adams WM, Sutherland WJ, Whitehouse A, Amar A, Lambert RA, Linnell JDC, Watt A et al. (2013). Understanding and managing conservation conflicts. Trends Ecol Evol 28: 100–109.

Rolandsen CM, Solberg EJ, Van Moorter B, Sæther BE (2011). Large-scale spatiotemporal variation in road mortality of moose: is it all about population density? Ecosphere 2: 113.

Seiler A (2003). The toll of the automobile: wildlife and roads in Sweden. PhD, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Seiler A (2004). Trends and spatial patterns in ungulate-vehicle collisions in Sweden. Wildlife Biol 10: 301–313.

Trombulak SC, Frisell CA (2000). Review of ecological effects of roads on terrestrial and aquatic communities. Conserv Biol 14: 18–30.

Van der Grift EA (1999). Mammals and railroads: impacts and management implications. Lutra 42: 77–98.

Zuur AF, Ieno EN, Walker N, Saveliev AA, Smith GM (2009). Mixed Effects Models and Extensions in Ecology with R. New York, NY, USA: Springer.

TRAIN MOOSE-KILL IN ALASKA: CHARACTERISTICS AND RELATIONSHIP WITH SNOWPACK DEPTH AND MOOSE DISTRIBUTION IN LOWER SUSITNA VALLEY

Ronald D. Modafferi

Alaska Department of Fish and Game, 1800 Glenn Highway, Suite 4, Palmer, Alaska 99645

ABSTRACT: Trends in moose (*Alces alces*) mortality (n = 3,054) due to train collisions along 756 km of railway in Alaska from 1963-90 are presented. Annual (May-April) mortality ranged from 9 to 725 moose. Winter (November-April) mortality varied from 7 to 705 moose, with more than 73% occurring from January through March. Mortality was greatest in sections of the railway transecting winter range. During the 1989-90 winter, 50 % (352 moose) of the train moose-kills occurred in a 64 km section of railway (8.5% of the railway length) in the lower Susitna Valley. There was a positive correlation among snowpack depth and train moose-kill, and moose numbers on winter range for the years when I studied the relationship. There was an inverse relationship between snowpack depth and moose density in alpine habitat, and between alpine density and train moose-kill for the years the relationship was studied. There was a relationship between the timing of deep snow and timing of moose occurrence on winter range, and timing of train moose-kill in two winters with greatly dissimilar patterns of snow accumulation. My results emphasize the importance of understanding moose movements in assessing and resolving the train-moose problem. Findings also identify the importance of alpine postrut concentration areas as a component of moose habitat.

ALCES VOL. 27 (1991) pp.193-207

The Alaska railway passes through moose habitat in a 756 km route from Fairbanks, an interior location, to Seward, a marine port in south-central Alaska. Large numbers of moose are killed in train collisions during winter at specific locations in years with deep snow (Chatelain 1951, Rausch 1958). Losses of moose to train collisions are economically costly and socially unacceptable (Rausch 1958, Child 1983). The Alaska Railroad Corporation (ARC) and the Alaska Department of Fish and Game seek to mitigate train-moose conflicts. A first step in resolving the train-moose conflict is defining and understanding the nature of the problem.

The purpose of my study was to: (1) consolidate significant information on the train moose-kill, (2) describe characteristics of the train moose-kill and (3) explore relationships between snowpack depth, train moose-kill and moose distribution.

STUDY AREA

Railway

The Alaska Railroad railway goes between Seward (milemark = 0), a marine port on the east coast of the Kenai Peninsula in south-central Alaska, and Fairbanks (milemark = 470), a major city in the interior of the state (Fig. 1). The 756 km railway, passes through cities, towns, rural settlements, and vast expanses of unsettled land. The route traverses a variety of habitats including: coastal spruce-hemlock forests, closed spruce-hardwood forests, open low-growing spruce forests, shrub thickets and treeless bogs (Viereck and Little 1972). Elevation of the route changes from sea level in Seward to a high point of 700 m in Broad Pass (milemark = 297), on the south side of the Alaska Mountain Range, to 130 m at Fairbanks. The Alaska Mountain Range divides Alaska into interior and south-central geographical regions. In south-central Alaska, about 160 km of the railway runs near major lowland river drainages, extensive active floodplains and large tracts of

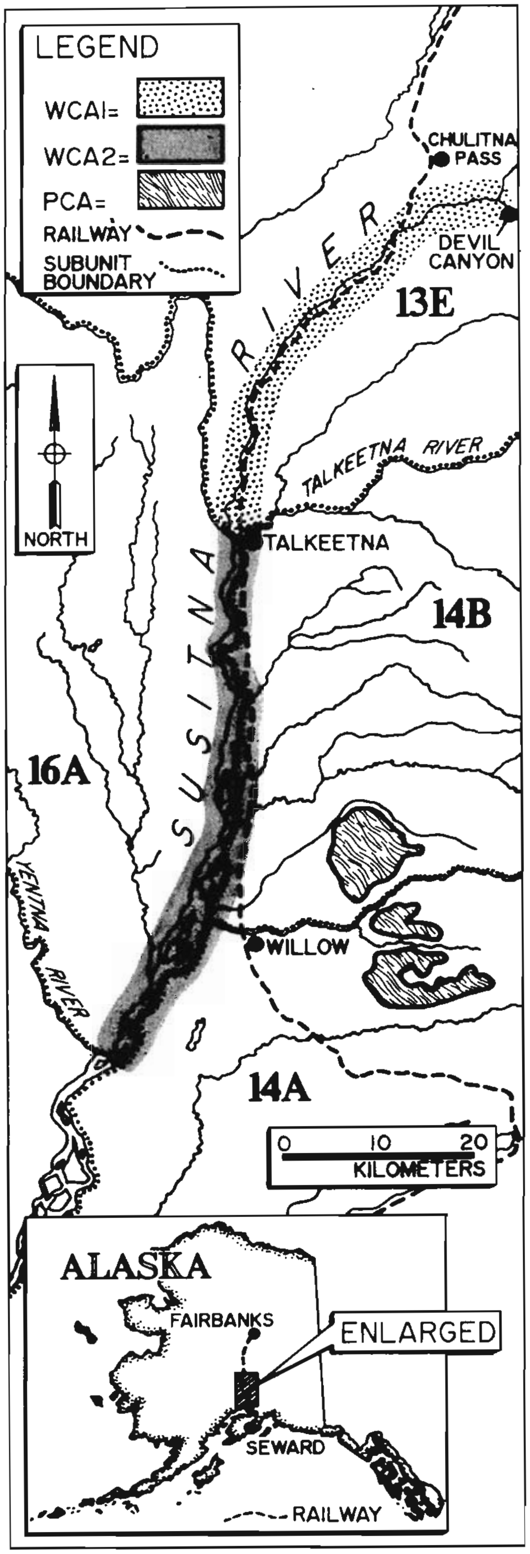


Fig. 1. Location of the 756 km railway between Seward (milemark 0) and Fairbanks (milemark 470) and the lower Susitna Valley study area in Alaska, showing game management subunits (14A, 14B, 16A and 13E), winter concentration areas (WCA1 and WCA2) and postrut concentration areas (PCA). Talkeetna and Willow were where snowpack depth was measured.

unmaintained old homestead land clearings. Forest vegetation along the route in the lower Susitna Valley include mixtures of old growth white spruce (*Picea glauca*), black spruce (*Picea mariana*), paper birch (*Betula papyrifera*), aspen (*Populus tremuloides*), balsam poplar (*Populus balsamifera*) and black cottonwood (*Populus trichocarpa*). Willows (*Salix* spp.), alders (*Alnus* spp.) and young deciduous tree species are particularly common at lower elevations in river drainages and in active floodplains. Early successional deciduous species dominate landscapes in settlements, unmaintained homesteads and the railway corridor where the ground surface has been disturbed by man. Willows and young deciduous tree species are preferred winter moose browse in south-central Alaska (Spencer and Chatelain 1953). Consequently, in winter, large numbers of migratory moose concentrate in locations along the railway in south-central Alaska where local conditions favor growth of early successional deciduous browse species.

Regional Conditions in Lower Susitna Valley

Winter climate in the lower Susitna Valley region is more variable and inclement away from the maritime influence of Cook Inlet and at higher elevations. Mean monthly temperatures vary from about 16 C in July to -13 C in January; maximum and minimum temperatures of 25 and -35 C are common. Total annual precipitation varies from about 40 cm in the south to over 86 cm in the north and west.

Snow accumulation varies with location, elevation, and site characteristics. Maximum snow depth can vary from <20 cm in the south to >200 cm in the north and west. Snow depth is generally deeper at higher elevations. Strong northerly winds often redistribute snow in exposed alpine sites and open floodplains. Snow accumulation in river channels varies depending on where and when ice forms over open water. Avalanches redistribute snow that accumulates on steep slopes.

Elevations within the region range from sea level to rugged mountain peaks well above 1500 m. Moose seldom use areas above 1100 m. Dominant habitat and canopy types in the region are characterized as: (1) floodplains dominated by willows, alders and poplars; (2) lowlands dominated by a mixture of wet bogs and closed or open mixed conifer-deciduous forests of paper birch, white spruce, black spruce, aspen; (3) mid-elevations dominated by mixed or pure stands of aspen, paper birch and white spruce; (4) higher elevations dominated by alder, willow, and birch shrub thickets (*Betula spp.*) or grasslands (*Calamagrostis spp.*); and (5) alpine tundras dominated by sedge (*Carex spp.*), ericaceous shrubs, prostrate willows, and dwarf herbs (Viereck and Little 1972).

METHODS

Train Moose-Kills

The ARC provided location and date for each moose-killed by the train on the railway between Seward and Fairbanks from October, 1963 through April, 1990. Accuracy in reporting train moose-kills in Alaska has greatly improved since 1980. Before which, numbers of were underreported (Rausch 1958). Data on train moose-kills before 1980 probably reflected month-to-month and year-to-year variations. Train moose-kill data for milemarks 0 to 470 were tabulated by year, season, month and location.

Train moose-kills were clustered in the section of the railway in the lower Susitna Valley. I explored relationships between snowpack depth, train moose-kill and moose distribution in a 145 km section of railway in the lower Susitna Valley from milemark 185 to 275. The high kill section of railway was divided into 2 segments. The train moose-kill on the segment extending from milemark 225 near Talkeetna to milemark 275 near Chulitna Pass was compared to moose counts in WCA1 and snowpack depth at Talkeetna. The train moose-kill on the segment extending from milemark 185 near Willow to milemark 225 was compared to moose counts in PCA and snowpack depth at Willow. The train moose-kill on the segment extending from milemark 185 to 275 was compared to moose counts in WCA1 + WCA2 and snowpack depth at Talkeetna.

Aerial Surveys

Numbers of moose were counted on aerial surveys in postrut concentration areas (postrut areas) and winter range in the lower Susitna Valley (Fig. 1). Survey areas were selected near railway sections with a high moose-kill.

Postrut areas (PCA) were located in the western foothills of the Talkeetna Mountains in Alaska Game Management Subunits 14A and 14B. This 240 km^2 area ranging in elevation from 600 to 1,200 m included 3 neighboring parcels of alpine habitat separated by lower elevation forested river drainages. This survey area was situated about 7 km east of the railway. In certain winters, moose were not found at higher elevations in the survey area. The area included portions of Bald Mountain Ridge, Moss Mountain and Willow Mountain.

Moose on winter range were surveyed in 2 areas of the Susitna River floodplain. One area was in Subunit 13E (WCA1); the other was in Subunit 16A (WCA2). The survey area in Subunit 13E was in the Susitna River floodplain between the Talkeetna River and Devil Canyon. This area encompassed 80 km of floodplain habitat ranging in elevation from 100 m at the Talkeetna River to 300 m at Devil

Canyon. Here, the floodplain was mostly <0.5 km wide with a scattering of islands. The railway from milemark 225-263 was mostly within 0.5 km of this survey area.

The survey area in Subunit 16A was located in the Susitna River floodplain between the Talkeetna River and the Yentna River. This area encompassed about 95 km of floodplain habitat ranging in elevation from 15 m at the Yentna River to 100 m at the Talkeetna River. In the survey area, the Susitna River floodplain was frequently >3 km wide where the river braids extensively around many small and large islands. The railway from milemark 185 to 225 was mostly within 2 km of this area.

Aerial surveys were conducted in winter, when snowcover was sufficient to observe moose, at 2- to 3-week intervals weather permitting. Surveys were conducted in WCA1 in 1981-85, WCA2 in 1982-84 and PCA in 1985-90. Survey flights were flown in Piper PA-18 aircraft at a search intensity of about 2.3 min per km^2. Low vegetative cover and good snow conditions in survey areas led to very high observability of moose.

Snowpack Depth

Snow depth data were obtained from Alaska Climatological Data Reports, U.S. Department of Commerce, NOAA, National Environmental Satellite, Data and Information Service, National Climate Data Center, Asheville, North Carolina. Snow depth data from Talkeetna were used as an index of snowpack depth in WCA1 and along the railway segment from milemark 225 to 275 in 1981-85, in WCA1+WCA2 and along the railway segment from milemark 185 to 275 in 1982-84, and along the railway segments from milemark 185 to 275 and milemark 225 to 275 in 1985-90. Snow depth data from Willow were used as an index of snowpack depth in PCA in 1985-90 and along the railway segment from milemark 185 to 225 in 1981-90. I presented the maximum snow depth recorded in each of 3, 10-day intervals (DIs) (1-10, 11-20 and 21-31 days) for each month. There were 21, DIs from October through April.

Snowpack depth was compared in relation to snowpack depth = 40 cm. Onset of fall-winter migrations of moose in Sweden (Sandegren *et al.* 1985) and Alaska (Van Ballenburghe 1977) were linked to snowpack depth of 42 and 40 cm, respectively.

Relationship Between Snowpack Depth, Moose Distribution and Train Moose-kill

To explore the relationship between snowpack depth, moose numbers on winter range, and train moose-kills, I used the Pearson correlation coefficient (Snedecor and Cochran 1980) to compare: (1) the maximum snowpack depth at Talkeetna (MSD-T) with the maximum number of moose counted in WCA1 (MMC-W) in 1981-85; (2) the MMC-W with the number of train moose-kills between milemarks 225 and 275 (TMK-T) in 1981-85; (3) the MSD-T with the TMK-T in 1981-85; and (4) the MSD-T with the TMK-T in 1981-90. Statistical significance was set at the 0.05 alpha level for all analyses in this papter.

To explore relationship between snowpack depth, moose numbers on winter range, and train moose-kills in 2 winters (1982-84) that differed greatly in the timing of snow accumulation, I used the Pearson correlation coefficient to compare: (1) the number of moose counted in WCA1 + WCA2 in each month (averaged by the number of counts per month) (AMC) with the number of train moose-kills between milemarks 185 and 275 in each month from November through March in the 1982-84 winters and (2) the AMC with the monthly maximum snowpack depth from November through March in the 1982-84 winters. I used a Chi-square analysis to compare the monthly number of train moose-kills between milemarks 185 and 275 from November through April in the winters, 1982-84. I used a Chi-square analysis with a Yates correction factor to compare the number of DIs with maximum snowpack depth <40 cm, and >40 cm in the 1982-83 and 1983-84 winters.

To explore the relationship between snowpack depth, moose numbers in postrut concentration areas and train moose-kills I used the Pearson correlation coefficient to compare: (1) the number of the DI when snowpack exceeded 40 cm at Willow (MIS-W) with the number of the DI when moose numbers in the PCA decreased by >75% in 1985-90; (2) the MIS-W with the number of train-moose kills between milemarks 185 and 225 (TMK-W) in 1985-90; (3) the number of the DI when moose numbers in the PCA decreased by >75% with the TMK-W in 1985-90; and (4) the maximum snowpack depth at Willow with the TMK-W in 1981-90.

RESULTS

Characteristics of the Train Moose-Kill

The ARC documented mortality of 3054 moose in train collisions in 756 km of railway between Seward and Fairbanks from May 1963 through April 1990. Numbers of train moose-kills ranged from 9 to 725 annually, May-April (Fig. 2). Numbers of train moose-kills ranged from 7 to 705 in winter. More than 93% of the train moose-kills were between Nov through Apr; 73.3% were in Jan through Mar (Fig. 3). Although only 3.5% and 4.4% of the annual train moose-kill occurred in November or April, it was 2.5-3.1 times greater than in any month from May through October.

In the 4 winters with the largest reported number of train moose-kills (1984-85 and 1987-90), kill locations were clusted in in Subunits 14A, 14B and 13E (Fig. 4). Kills were particularly numerous along a 193 km section of railway between milemarks 160 and 280 in the lower Susitna Valley. Other sections of the railway had few or no moose killed by trains. During the winters of 1984-85, and 1987-90, 204, 178, 88 and 352 moose were killed along a 64 km section of railway between milemarks 185 and 225. During these winters, 55, 56, 35 and 50 percent of the train moose-kills, respectively, occurred along 8.5

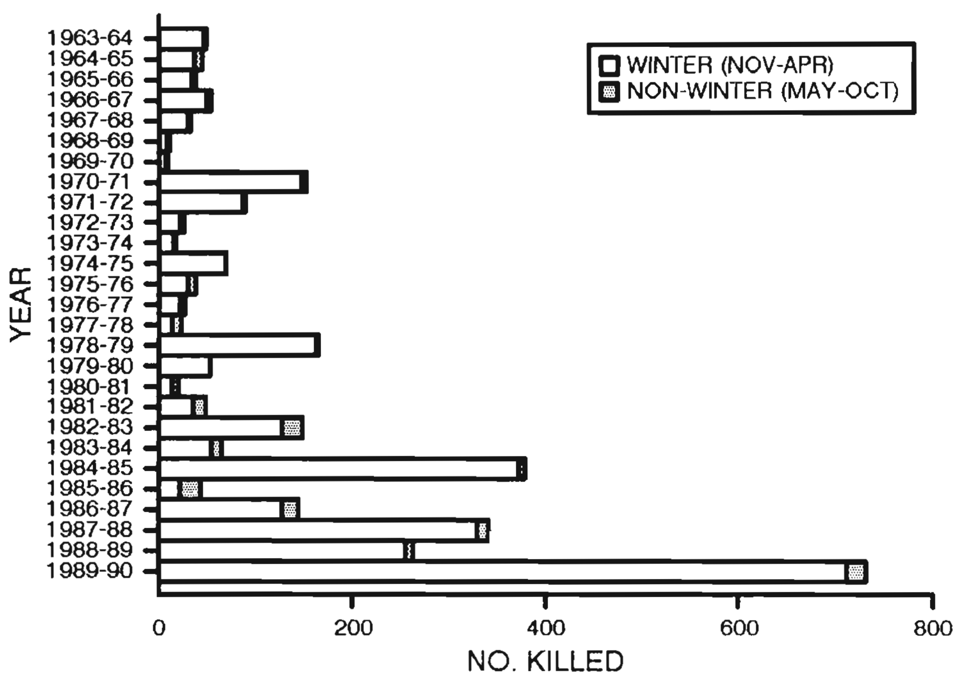


Fig. 2. Annual numbers of moose killed in train collisions May-April (n = 3054) and numbers killed in winter, November-April (n = 2851) and non-winter May-October (n = 203) in Alaska, 1963-90.

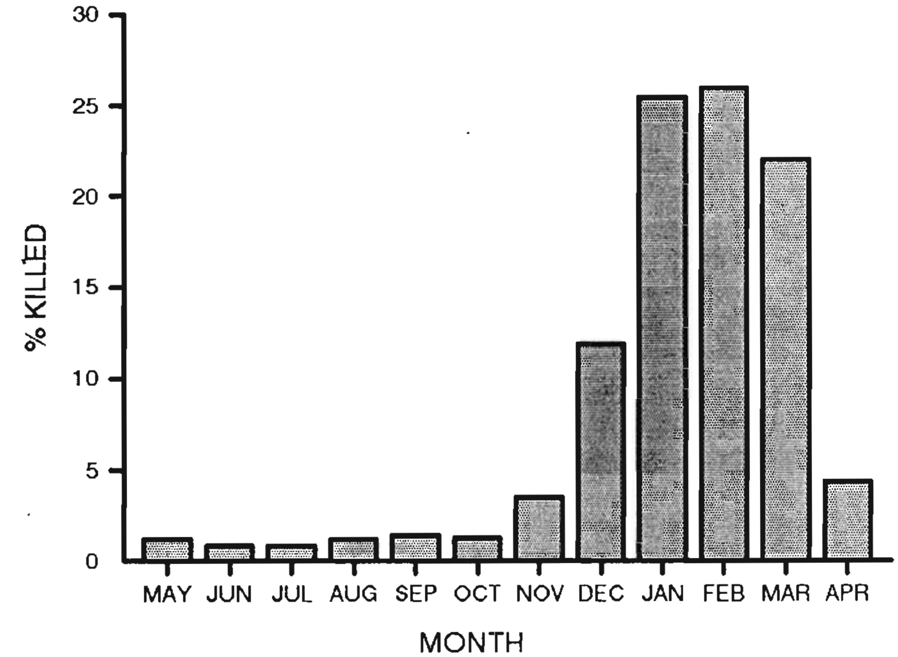


Fig. 3. Distribution of train moose-kills (n = 3054) by month in Alaska, 1963-90.

percent (64 km) of the railway.

Snowpack Depth, Moose Counts in Winter Concentration Areas, and Train Moose-Kills

Snowpack depth at Talkeetna, numbers of moose in winter concentration areas and numbers of train moose-kills varied greatly during 4 winters, 1981-85 (Fig. 5). Peak snowpack at Talkeetna, varied from 46 to 157 cm during these 4 winters. Snowpack generally increased from October through January, peaking in February or mid-March, and melting in late April. Thirty-four moose surveys were completed in WCA1 between November, 1981 and April, 1985, whereas 16 surveys were completed in WCA2 between November, 1982 and February, 1984. Thirty-seven surveys were conducted in PCA between October 1985 and March 1990.

The greatest number of moose counted in WCA1, in 34 surveys ranged from 36 to 132 during the 4 winters, 1981-85 (Fig. 5). Maximum numbers of moose counted was positively correlated with maximum snowpack depth during years 1981-85 ($r=0.976, P=0.024, n=4$). Thus the magnitude of moose meovement to winter range was related to snowpack depth.The fewest number of moose counted before and after the winter peak was 7 and 4, respectively. Moose numbers increased during November and December, peaking in January to mid-February, and then decreasing to low levels in March to mid-April. Numbers of train moose-kills between railway milemarks 225 and 275 ranged from 0-87 during the winters of 1981-85. There was a high non-significant positive correlation between train moose-kills and maximum moose counts during the winters 1981-85 ($r=0.887, P=0.113, n=4$). Train moose-kills were high when moose concentrated in winter areas near the railways.

Number of train moose-kills (1984-85) and the peak moose count was greatest when snowpack depth was greatest (Fig. 5). Train moose-kills (1981-82) and peak moose count was lowest when snowpack depth was lowest. There was a high non-significant positive correlation between greatest snowpack depth and train moose-kills during the 1981-85 win-

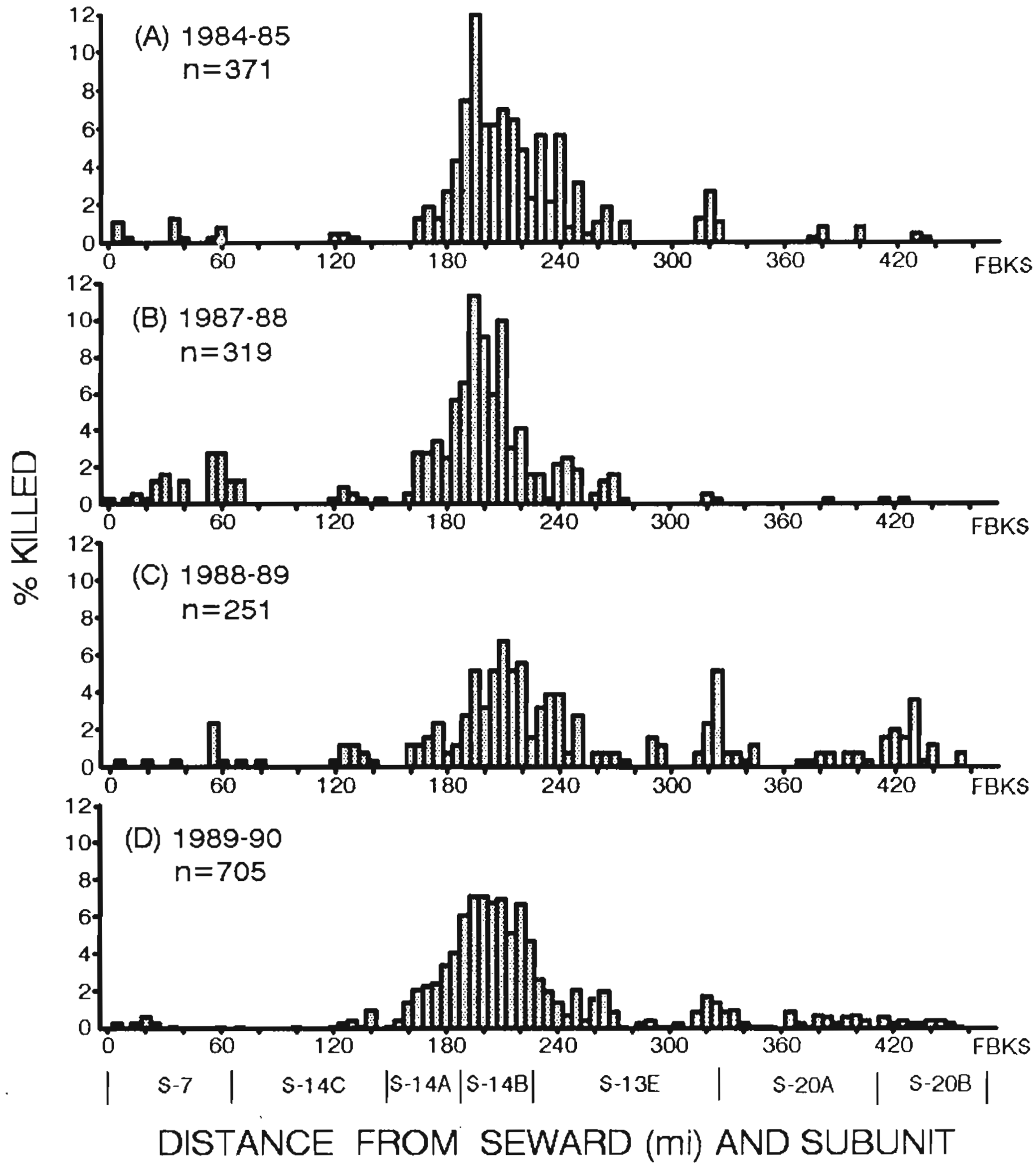


Fig. 4. Distribution of train moose-kills during winter, for 8-km sections along the railway from Seward (mi 0) to Fairbanks (mi 470), Alaska, during years, 1984, and 1987-89. Vertical lines below x-axis indicate milemark locations of Game Management Subunit (S-) boundaries. FBKS=Fairbanks.

ters (r=0.901,P=0.099,n=4). However, when the database was expanded including data from the 1985-90 winters, there was a significant positive correlation between snowpack depth and train moose-kills (r=0.962, P=0.0001, n=9). The train moose-kill was high when deep snow forced moose to migrate to winter concentration areas. Snowpack depth was bimodal in 1981-82, 1982-83 and 1984-85 (Fig. 5). Moose numbers in the WCA varied with this bimodal trend in snowpack depth (Fig. 5).

Snowpack depth, moose counts, and train moose-kills peaked earlier in 1982-83 than 1983-84 (Fig. 6). Snowpack depth increased from 23 to 81 cm between October and mid-January in 1982-83. During 1982-83, snowpack depth exceeded 40 cm by late Oc-

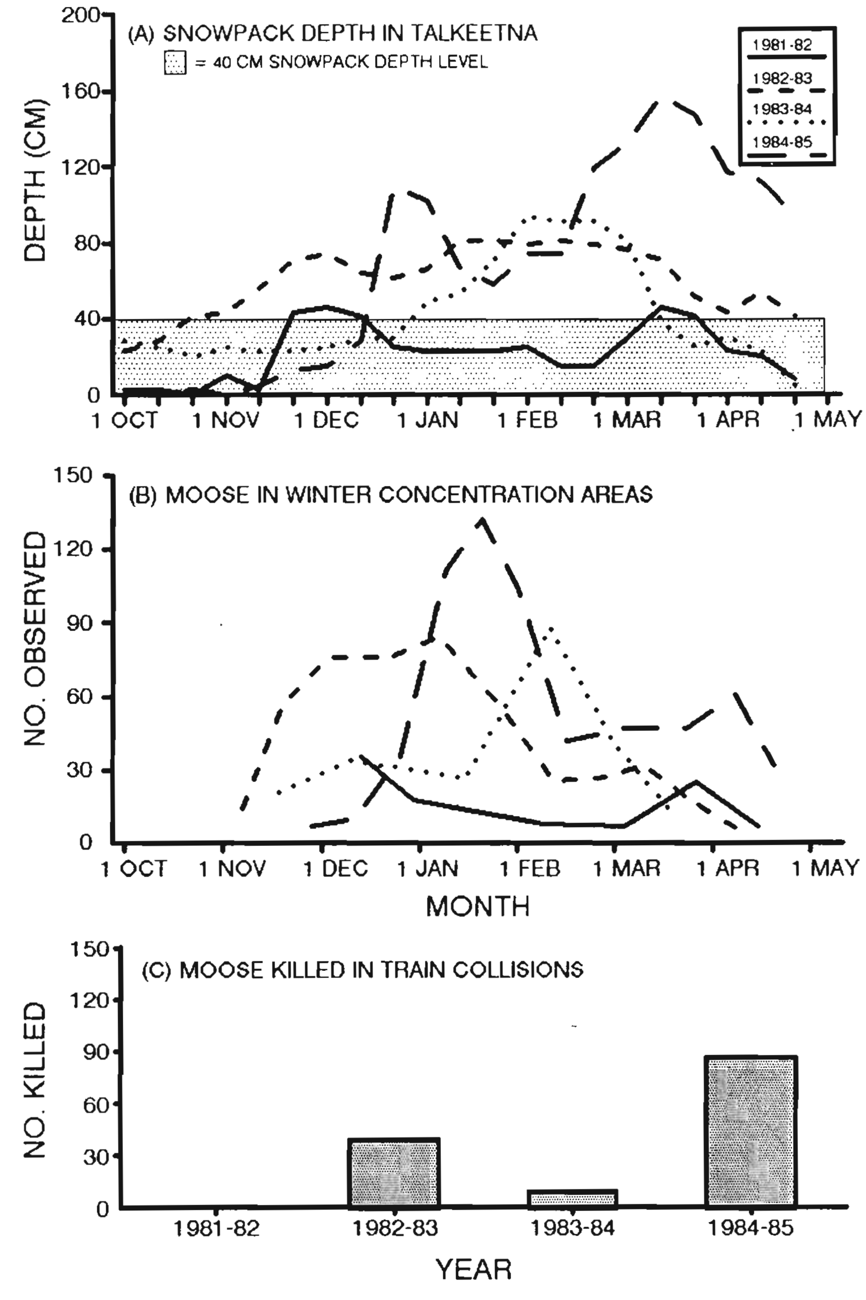


Fig. 5. Trimonthly maximum snowpack depth at Talkeetna (A), numbers of moose counted on aerial surveys in lowland winter concentration areas in the Susitna River floodplain between the Talkeetna River and Devil Canyon (B), and numbers of train moose-kills between railway milemarks 225 and 275, November-April (C), 1981-85, south-central Alaska. In other studies, onset of moose fall-winter migration coincided with snowpack depth = 40 cm.

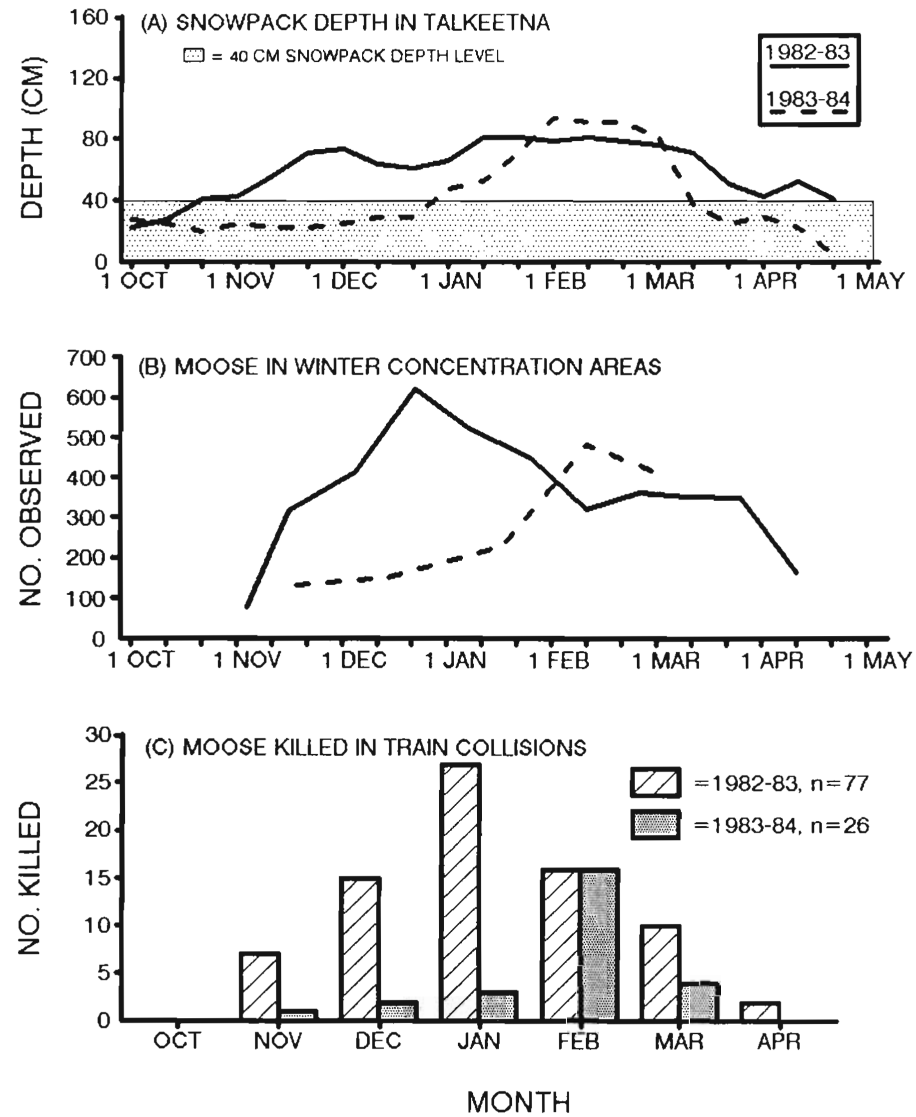


Fig. 6. Trimonthly maximum snowpack depth at Talkeetna (A), numbers of moose counted on aerial surveys in lowland winter concentration areas in the Susitna floodplain between the Yentna River and the Talkeetna River (B), and monthly number of train moose-kills between railway milemarks 185 and 275, October-April (C), 1982-84, south-central Alaska. In other studies,onset of moose fall-winter migration coincided with snowpack depth = 40 cm.

tober. In the 1983-84 winter, snowpack depth ranged from 5 to 94 cm. Snowpack depth exceeded 40 cm in early January, and peaked at 94 cm in early February. Snowpack depth exceeded 40 cm earlier and was >40 cm for a longer time in 1982-83 than 1983-84 ($X^2$12.22,df=1,P=0.005). Trends in numbers of moose counted in WCA1 + WCA2 differed between 1982-83 and 1983-84 (Fig. 6B). In 1982-83, numbers of moose ranged from 78 to 622 and peaked in late December, 1982. In 1983-84, numbers of moose ranged from 132 to 481, and peaked in early February. Monthly numbers of moose counted (AMC) were correlated with monthly maximum snowpack depth during November through March (r=0.764, P=0.016,n=9). Monthly numbers of train moose-kills were different between the 1982-83 and 1983-84 winters (Fig. 6) (X^2=17.17,df=5, P=0.0042). In 1982-83, train moose-kills peaked in January and 64 percent occurred before February. In 1983-84, train moose-kills peaked in February and 78 percent occurred after January. Monthly numbers of train-moose-kills were positively correlated with monthly numbers of moose counted (AMC) (r=0.815, P=0.008,n=9). The timing of snowpack accumulation influenced the timing of moose movements to winter concentration areas, and the timing of train moose kills.

Snowpack Depth, Moose Counts in Postrut Concentration Areas, and Train Moose-Kills

Snowpack depth at Willow, numbers of moose in postrut areas and numbers of train moose-kills varied among years 1985-90 (Fig. 7). Peak snowpack depth ranged from 43 to 234 cm. The greatest numbers of moose counted ranged from 626 to 938 moose, whereas the fewest number of moose counted before and after a winter peak was 42 and 12 moose, respectively. Numbers of moose counted in postrut concentration areas generally increased during October, peaked between late October and early December, and decreased from late December and mid-April.

In winter 1985-86, numbers of moose in postrut areas decreased by less than 50 percent between the peak count in early December and a count in late March. Snowpack depth first exceeded 40 cm in late March. In 1989-90, numbers of moose decreased precipitously in late October and early November, when 1989-90, snowpack depth first exceeded 40 cm in late October. Few moose were counted in late December, 1990, the year snowpack depth was greatest. During the winter of 1986-87, numbers of moose declined in December; snowpack exceeded 40 cm in early January. In the winters of 1987-89, moose numbers declined in mid-November to mid-December; snowpack depth exceeded 40 cm in late November.

The number of the DI when snowpack exceeded 40 cm was correlated positively with the number of the DI when numbers of moose counted in the PCA decreased to <75% of the peak count during the years 1985-90 (r=0.928, P=0.023,n=5). Moose dispersed from postrut concentration areas when snowpack exceeded 40 cm.

Numbers of train moose-kills between milemarks 185 and 225 ranged from 4 to 352 for the 1985-90 winters. Numbers of train moose-kills in winter were lowest in 1985-86, highest in 1989-90, and intermediate in 1986-89. Kills varied among the 3 winters with intermediate numbers of train moose-kills. Train moose-kills were twice as common in 1987-88 than 1988-89, and 2.4 times more numerous in 1988-89 than 1986-87. In 1986-87, snowpack depth exceeded 40 cm in early January, whereas in 1987-89 it exceeded 40 cm in late November. Snowpack depth in 1987-88 exceeded snowpack depth 1988-89 from mid-December through April. The numbers of the DI when snowpack exceeded 40 cm was not significantly correlated with the number of moose-kills 1985-90 (r=-0.793, P=0.109,n=5). The numbers of the DI when numbers of moose counted in the PCA were <75% of the peak count were not signficantly correlated with the numbers of moose-kills (r=-0.704,P=0.185,n=5). However, when the database was expanded including the 1981-85 winters, there was a significant positive correlation between maximum snowpack depth and train moose-kills ((r=0.815,P=0.007, n=9). The timing and depth of snow influenced dispersal of moose from postrut areas, and both correlated with train moose-kills. Maximum snowpack depth was an important factor influencing the number of train moose-kills. Perhaps, timing and magnitude of moose migrations from the PCA, which are influenced by snowpack depth, were weekly correlated with train moose-kills

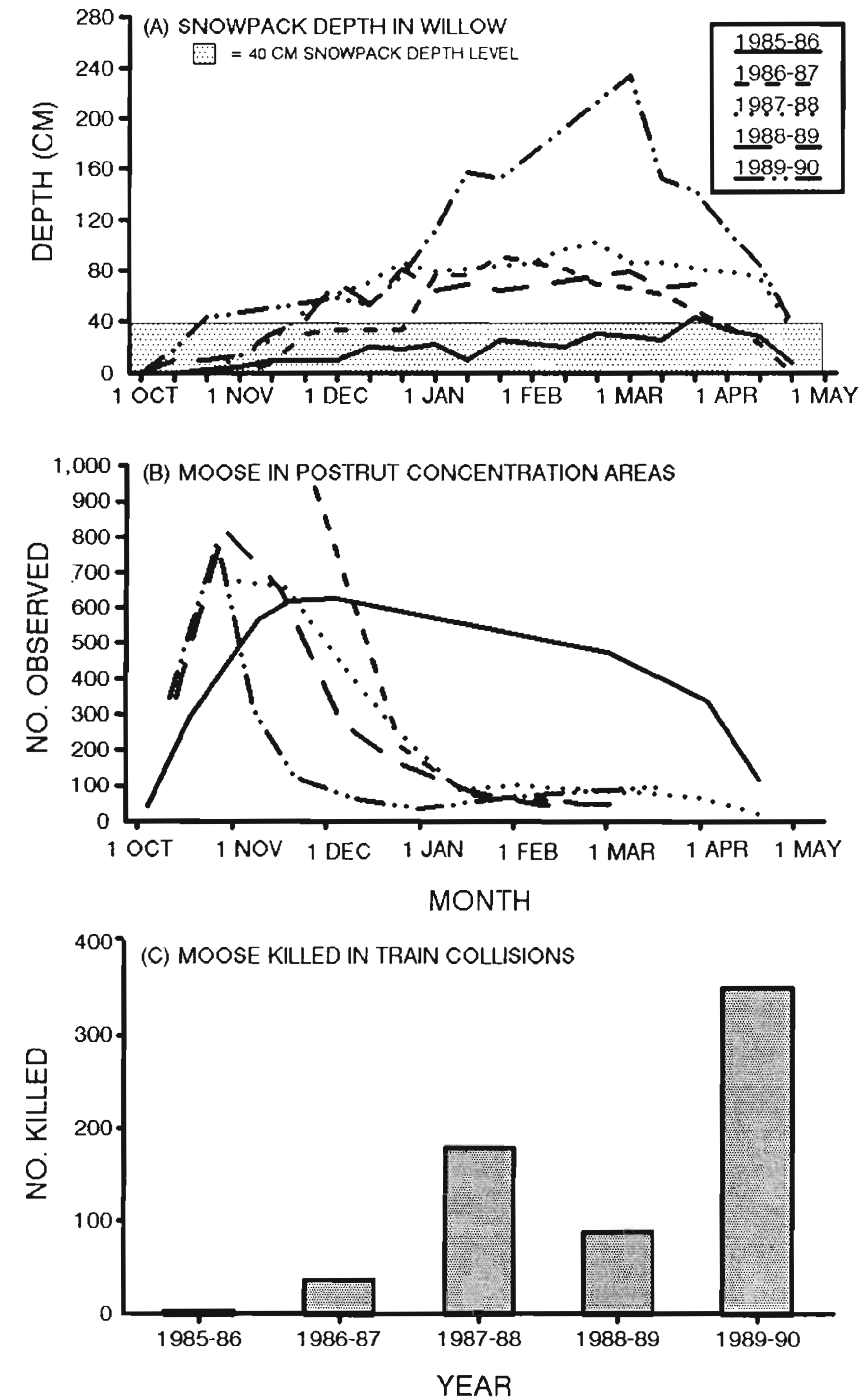


Fig. 7. Trimonthly maximum snowpack depth at Willow, numbers of moose counted on aerial surveys in alpine postrut concentration areas in the western foothills of the Talkeetna Mountains (B) and numbers of train moose-kills between railway milemarks 185 and 225, November-April (C), 1985-90, south-central Alaska. In other studies, onset of moose fall-winter migration coincided with snowpack depth = 40 cm.

because moose in the PCA migrate to winter range that is not near the railway.

DISCUSSION

A large number of moose were killed in train collisions in Alaska each year. This kill occurred mainly from November through April. Kills were clustered in certain segments of the railway, and more numerous in deep-snow winters. Kills were few in low-snow winters. These data agree with findings of others (Rausch 1958, Child 1983, Hatler 1983, Andersen *et al.* 1991). However, in southern Norway, <50% of the yearly train moose-kill occurred in winter (Jaren *et al.* 1991), and in Ontario and Manitoba, train-moose collisions were most frequent in June and July shortly after calving season (Child and Stuart 1987).

Train moose-kills increased when migratory moose moved to winter concentration areas near the railway. Kills were clustered in sections of the railway transecting migration routes and winter range. Kills were more numerous in deep-snow winters than in low-snow winters. In deep-snow winters, most moose in alpine postrut concentration areas dispersed to lowland winter range near the railway. In low-snow winters, many moose stayed in alpine habitat. The peak in train moose-kills occurred earlier in winter in an early-snow winter than in a late-snow winter because most moose migrated to winter range in response to snow accumulation. These findings were consistent with findings previously reported (Rausch 1958, Coady 1974, Van Ballenburghe 1977, Thompson *et al.* 1981, Child 1983, Sandegren *et al.* 1985). Although train moose-kills were numerous in deep-snow winters when large numbers of moose were near the railway, the additional affect of plowed snow along the railway likely affected behavior of moose increasing their vulnerability to train collisions (Rausch 1958, Child 1983, Hatler 1983, Andersen *et al.* 1991).

Loss of large numbers of moose in train collisions can have considerable consequences on management of local moose populations (Rausch 1958, Child 1983). More than 350 moose were killed in train collisions in Subunit 14B in the winter of 1989-90. However, in addition to moose resident in Subunit 14B, migratory moose from 2 neighboring Subunits were vulnerable to train collisions in Subunit 14B (R. Modafferi pers. comm.). Consequently, losses must be allocated among moose populations in 3 Subunits, and managers must understand movements of moose in the railway.

Plans to mitigate or resolve problems of train-moose collisions frequently include measures to manage habitat and moose populations along railways (Rausch 1958, Child 1983, Jaren *et al.* 1991). One option is to decrease numbers of moose near the railway. Forage along railways can be eliminated so moose are not attracted to the rail corridor. Habitat away from railways can be managed to attract moose and keep them distant from the rail corridor. Winter harvest quotas can be established near the railway. Fall harvest quotas can be increased in these Subunits overlapping the railway. However, findings in this study and another (R. Modafferi pers. comm.) suggest that these measures must be implemented at certain times and places to affect target moose populations.

In some moose management jurisdictions, railway corporations fail to provide wildlife managers with an accurate account of train moose-kills (Rausch 1958, Child and Stuart 1987). In Alaska, railway managers have cooperated with wildlife managers in collecting information on train-moose conflicts and in testing measures to help resolve the problem.

My findings indicate that moose distribution and numbers on winter range were related to snow accumulation throughout the winter. These findings agree with observations of Edwards and Ritcey (1956) who noted that snow depth was a major factor influencing timing and extent of moose migrations and yearly differences in moose distribution. Van Ballenburghe (1977) found that snow conditions caused moose to break from traditional migratory patterns during a seasonal cycle. Crete (1980) showed that moose did not winter in the same forest stands during consecutive winters; snow conditions were not assessed. Modafferi (pers. comm.) indicated that some individual radio-marked moose in the lower Susitna Valley migrated differently and were located in different areas in a low-snow winter versus a series of average- to deep-snow winters. In contrast, Sweanor and Sandegren (1987) reported that moose fall-winter migration patterns were consistent each year. However, in all years of their study, snow depth exceeded 40 cm, the threshold snow depth that initiated onset of migrations in moose (Sandegren *et al.* 1985). In this study, timing, magnitude and extent of moose migrations were correlated with snowpack depth. My findings suggested that not all moose migrated in response to the same threshold of snowpack depth, and that snow depth influenced the final destination of migrations of moose.

There is considerable information on movements of moose to winter concentration areas and the importance of winter concentration areas to moose (Stevens 1970, Telfer 1970, Brassard *et al.* 1974, Coady 1974, LeResche 1974, Peek 1974, Van Ballenburghe 1977, Crete and Jordan 1982, Sandegen *et al.* 1985, Lavsund 1987, Danell and Bergstrom 1989, Hundertmark *et al.* 1990). There is less data available on movements of moose to postrut concentration areas and the importance of postrut areas in moose ecology (LeResche 1972, Lynch 1975, Thompson *et al.* 1981). Like winter concentration areas, importance of postrut concentration areas, is suggested by the traditional use by large numbers of moose. Moose left surrounding habitats to move to these postrut areas in early winter before deep snowpack forced them to move to winter range (Coady 1974, Telfer 1978). Thompson et al. (1981) suggested that quantity and quality of browse in moose early winter concentration areas was superior to browse in surrounding habitats. Weight and body condition of moose entering winter determines survival and influences productivity the following spring (Saether 1987, Schwartz *et al.* 1988). During the postrut period, moose increase food intake (Schwartz *et al.* 1984) and gain weight (Schwartz *et al.* 1987). Quality of range in these postrut concentration areas likely influenced moose movements to them.

My observations indicated moose winter range has two components, alpine postrut concentration areas and lowland winter concentration areas. Snowpack depth affected timing, duration and magnitude of moose use of each component. When deep snowpack occurred early, moose dispersed from postrut areas in November to winter ranges. During winters with low snowpack many moose stayed in alpine postrut concentration areas. This extended use of postrut areas reduced the impact of browsing on forage in lowland winter concentration areas. These findings suggest that moose postrut concentration areas were an intergral component of moose habitat that deserve protection and further study.

ACKNOWLEDGEMENTS

Many persons deserve special thanks for contributing to various aspects of this study. I extend special thanks to my supervisor, K. B. Schneider, Alaska Department of Fish and Game (ADF&G), for providing support and helpful suggestions throughout this study, for reviewing drafts of this manuscript, and for willingly providing assistance in administration procedures. I am grateful to J. Swiss, John Swiss and Family, Big Game Guiding, Outfitting and Air Charter Service, and W. D. Wiederkehr, Wiederkehr Air Inc., for ability and safety in piloting and navigating PA-18 aircraft on the numerous aerial moose surveys, for enthusiasm in spotting moose and for willingness to complete surveys under less than ideal conditions. I thank J. C. Didrickson, C. A. Grauvogel, H. J. Griese,and M. W. Masteller, Area Management Biologists, ADF&G, for providing local support, useful suggestions on many aspects of the study, and for sharing their experiences and knowledge about moose. K. K. Koenen extracted train moose-kill information from railway dispatch records archived in the ARC headquarters. M. W. Masteller updated and organized parts of the train moose-kill database file. D. C. McAllister, ADF&G, provided logistic assistance and drafted Fig. 1. S. R. Peterson and other staff at ADF&G, Juneau, provided advice and many valuable comments on a previous version of this manuscript which greatly improved it's quality. E. F. Becker, ADF&G, is greatfully acknowledged for statistical treatment of data in this manuscript. I thank C. C. Schwartz and an anonymous reviewer for extensive critical reviews of this manuscript. I thank C. C. Schwartz and T. Timmermann for encouraging me to prepare and submit this paper. This study is a contribution of Fed. Aid Wildl. Restor., Proj. W-23.

REFERENCES

ANDERSEN, R., B. WISETH, P. H. PEDERSEN, and V. JAREN. 1991. Moose-train collisions: Effects of environmental conditions. Alces 27:79-84.

BRASSARD, J. M., E. AUDY, M. CRETE, and P. GRENIER. 1974. Distribution and winter habitat of moose in Quebec. Naturaliste can. 101:67-80.

CHATELAIN, E. F. 1951. Winter range problems of moose in the Susitna Valley. Proc. Alaska Sci. Conf. 2:343-347.

CHILD, K. N. 1983. Railways and moose in the Central Interior of British Columbia: A recurrent management problem. Alces 19:118-135.

_______, and K. M. STUART. 1987. Vehicle and train collision fatalities of moose: Some management and socio-economic considerations. Swedish Wildl. Res., Suppl. 1:699-703.

COADY, J. 1974. Influence of snow on behavior of moose. Naturaliste can. 101:417-436.

CRETE, M. 1980. Failure of moose to use the same stands in consecutive winters. Alces 16:482-488.

_______, and P. A. JORDAN. 1982. Population consequences of winter forage resources for moose, *Alces alces*, in southwestern Quebec. Can. Field Nat. 96:467-475.

DANELL, K., and R. BERGSTROM. 1989. Winter browsing by moose on two birch species: impact on food resources. Oikos. 54:11-18.

EDWARDS, R. Y., and R. W. RITCEY. 1956. The migrations of a moose herd. J. Mammal. 37:486-494.

HATLER, D. F. 1983. Concerns for ungulate collision mortality along New Surface Route. MacLaren Plansearch Corporation, Vancouver. 47 pp.

HUNDERTMARK, K. J., W. L. EBERHARDT, and R. E. BALL. 1990. Winter habitat use by moose in southeastern Alaska: Implications for forest management. Alces 26:108-114.

JAREN, V., R. ANDERSEN, M. ULLEBERG, P. H. PEDERSEN, and B. WISETH. 1991. Moose-train collisions: The effects of vegetation removal with a cost-benefit analysis. Alces 27: 93-110.

LAVSUND, S. 1987. Moose relationships to forestry in Finland, Norway and Sweden. Swedish Wildl. Res., Suppl. 1:229-244.

LERESCHE, R.E. 1974. Moose migrations in North America. Naturaliste can. 101:393-415.

_______. 1972. Migrations and population mixing of moose on the Kenai Peninsula (Alaska). Proc. N. Am. Moose Conf. Workshop 8:182-207.

LYNCH, G. M. 1975. Best timing of moose surveys in Alberta. Proc. N. Am. Moose Conf. Workshop 1:141-153.

PEEK, J. 1974. On the nature of winter habitats of Shiras moose. Naturaliste can. 101:131-141.

RAUSCH, R. A. 1958. The problem of railroad-moose conflicts in the Susitna Valley. Alaska Dep. of Fish and Game, Fed. Aid Wildl. Rest. Final Rep., Proj. W-3-R. 116pp.

SAETHER, B-E. 1987. Patterns and processes in the population dynamics of the Scandinavian moose (*Alces alces*): Some suggestions. Swedish Wildl. Res. Suppl. 1:525-537.

SANDEGREN, F., R. BERGSTROM, and P. Y. SWEANOR. 1985. Seasonal moose migration related to snow in Sweden. Alces 21:321-338.

SCHWARTZ, C. C., W. L. REGELIN, and A. W. FRANZMANN. 1984. Seasonal dynamics of food intake in moose. Alces 20:233-244.

_______, W. L. REGELIN, and A. W. FRANZMANN. 1987. Seasonal weight dynamics of moose. Swedish Wildl. Res. Suppl. 1:301-310.

_______, M. E. HUBBERT, and A. W. FRANZMANN. 1988. Energy requirements of adult moose for winter maintenance. J. Wildl. Manage. 52:26-33.

SNEDECOR, G. W. and W. C. COCHRAN. 1980. Statistical Methods. 7th edition. The Iowa Univ. Press, Ames, Iowa. 507pp.

SPENCER. D. L. and E. F. CHATELAIN. 1953. Progress in the management of the moose of south central Alaska. Trans. N. Am. Wildl. Conf. 18: 539-552.

STEVENS, D. R. 1970. Winter ecology of moose in the Gallatin Mountains, Montana. J. Wildl. Manage. 34:37-46.

SWEANOR, P. Y., and F. SANDEGREN. 1987. Migratory behavior of related moose. IV:59-65. in P. Y. Sweanor. Winter ecology of a Swedish moose population: Social behavior, migration and dispersal. MSc. Thesis. Swedish Univ. Agricult. Sci. Rept. 13. Uppsala. pp.94.

TELFER, E. S. 1970. Winter habitat selection by moose and white-tailed deer. J. Wildl. Manage. 34:553-559.

_______, 1978. Cervid distribution, browse and snow cover in Alberta. J. Wildl. Manage. 42:352-361.

THOMPSON, I. D., D. A. WELSH, and M. K. VUKELICH. 1981. Traditional use of early winter concentration areas by moose in northwestern Ontario. Alces 17:1-14.

VAN BALLENBURGHE, V. 1977. Migratory behavior of moose in southcentral Alaska. Pages 103-109 *in* 13th Int. Cong. of Game Bio. Atlanta, Ga.

VIERECK, L. A., and E. L. LITTLE, JR. 1972. Alaska trees and shrubs. U.S. Dept. Agric. Forest Serv. Handbook No. 410. 265pp.

Downloaded from http://rspb.royalsocietypublishing.org/ on November 24, 2014

PROCEEDINGS OF THE ROYAL SOCIETY B

rspb.royalsocietypublishing.org

Review

Cite this article: Morley EL, Jones G, Radford AN. 2014 The importance of invertebrates when considering the impacts of anthropogenic noise. *Proc. R. Soc. B* **281**: 20132683. http://dx.doi.org/10.1098/rspb.2013.2683

Received: 15 October 2013
Accepted: 20 November 2013

Subject Areas:
environmental science

Keywords:
environmental change, fitness, hearing, insect, noise quantification, pollution

Author for correspondence:
Andrew N. Radford
e-mail: andy.radford@bristol.ac.uk

Electronic supplementary material is available at http://dx.doi.org/10.1098/rspb.2013.2683 or via http://rspb.royalsocietypublishing.org.

Royal Society Publishing

The importance of invertebrates when considering the impacts of anthropogenic noise

Erica L. Morley[1,2], Gareth Jones[1] and Andrew N. Radford[1]

[1]School of Biological Sciences, University of Bristol, Woodland Road, Bristol BS8 1UG, UK
[2]Department of Biological Sciences, University of Toronto Scarborough, 1265 Military Trail, Scarborough, Toronto, Ontario, Canada M1C 1A4

Anthropogenic noise is now recognized as a major global pollutant. Rapidly burgeoning research has identified impacts on individual behaviour and physiology through to community disruption. To date, however, there has been an almost exclusive focus on vertebrates. Not only does their central role in food webs and in fulfilling ecosystem services make imperative our understanding of how invertebrates are impacted by all aspects of environmental change, but also many of their inherent characteristics provide opportunities to overcome common issues with the current anthropogenic noise literature. Here, we begin by explaining why invertebrates are likely to be affected by anthropogenic noise, briefly reviewing their capacity for hearing and providing evidence that they are capable of evolutionary adaptation and behavioural plasticity in response to natural noise sources. We then discuss the importance of quantifying accurately and fully both auditory ability and noise content, emphasizing considerations of direct relevance to how invertebrates detect sounds. We showcase how studying invertebrates can help with the behavioural bias in the literature, the difficulties in drawing strong, ecologically valid conclusions and the need for studies on fitness impacts. Finally, we suggest avenues of future research using invertebrates that would advance our understanding of the impact of anthropogenic noise.

1. Introduction

The ever-expanding urban world has made anthropogenic (man-made) noise almost ubiquitous across the globe. Noise-generating human activities have increased considerably since the Industrial Revolution, leading to substantial changes in the acoustic landscape both on land and underwater. The prevalence of transportation networks, resource extraction and urban development in terrestrial environments is much greater today than in the past [1,2], while shipping, recreational boating, seismic exploration, sonar and pile-driving are widespread and occur with increasing frequency in aquatic environments [3]. Moreover, the sound generated by human activities is often very different from that arising from natural sources, both in terms of its prominent frequencies and in such acoustic characteristics as constancy, rise time, duty cycle and impulsiveness [4]. Anthropogenic noise therefore presents a very real, and often novel, challenge to animals including ourselves.

In humans, anthropogenic noise causes physiological, neurological and endocrinological problems, increased risk of coronary disease, cognitive impairment and sleep disruption [5,6]. These impacts can be severe and legislation is therefore in place to monitor and manage noise exposure in daily life [7]. Over the last decade, there has also been a growing awareness of the potential impact of anthropogenic noise on non-human animals, with studies on a number of different taxonomic groups demonstrating effects ranging from behavioural and physiological adjustments of individuals to changes at the population and community level [1,3,8–10]. Consequently, anthropogenic noise is now recognized as a major component of environmental change in the twenty-first century and a pollutant of international concern, featuring prominently on international directives and agendas (e.g. inclusion in the United States National Environment Policy Act

© 2013 The Author(s) Published by the Royal Society. All rights reserved.

Downloaded from http://rspb.royalsocietypublishing.org/ on November 24, 2014

and the European Commission Marine Strategy Framework Directive, and as a permanent item on the agenda of the International Maritime Organisation).

A comprehensive search of the peer-reviewed literature published on terrestrial species by the end of 2012 (see the electronic supplementary material) highlights a number of trends and issues (see also [11]); we focus here on terrestrial species for brevity, although similar conclusions can be made for aquatic organisms. One striking trend is that only two of the 83 papers considered an invertebrate species. Shieh *et al.* [12] compared the calling behaviour of the cicada *Cryptotympana takasagona* in noisy and quiet urban parks, finding positive correlations between noise levels and both call frequency and chorusing. Lampe *et al.* [13] found that male bow-winged grasshoppers (*Chorthippus biguttulus*) collected from noisy roadsides sang with a greater low-frequency component than males collected from paired quiet areas nearby. As male singing was recorded in the absence of noise stimuli in anechoic chambers, the differences are unlikely to be the consequence of behavioural plasticity, but instead may result from longer term adaptation. In both studies, modification of call frequency is presented as a mechanism for avoiding masking, although further investigation is needed to determine whether that is indeed achieved and whether the vocal adjustments generate associated costs [14].

The paucity of research on invertebrates does not reflect their general importance, the likelihood that anthropogenic noise will affect them or the potential for such investigations to advance our understanding of this issue. Invertebrates are hugely diverse, constituting the vast majority of species on the Earth and with a large proportion yet to be identified [15]. They are crucial components of food webs and fulfil many ecosystems services, such as pollination, decomposition and nutrient release [16]. Removal of invertebrate species can lead to changes in diversity and modification to ecosystem function [17]. Consequently, our understanding of community structure and resilience, as well as the pressing need for food security, makes it imperative that we study how invertebrates are impacted by environmental change [18], especially as it is clear that they are indeed vulnerable. For example, artificial light can alter invertebrate community composition [19], heavy metals can cause decreased immunity [20], slower development and reduced survival and fecundity [21], and climate change can result in shifts in geographical distribution, population size, phenology, behaviour and genetic composition [16]. As many invertebrates have a proven ability to hear, to use sound for a variety of reasons and to communicate acoustically [22], they are also likely to be affected by the noise introduced into the environment by the activities of humans. Moreover, many inherent characteristics of invertebrates (e.g. their relatively small sizes, short life cycles and ease of study in both laboratory and field conditions) provide the potential to overcome a number of the current issues that can hamper research into the impacts of anthropogenic noise (see [11] and below).

Here, we begin by explaining why invertebrates are likely to be affected by anthropogenic noise—we briefly review their capacity for hearing and provide evidence that they are capable of evolutionary adaptation and behavioural plasticity in response to natural noise sources, such as wind and the chorusing of other organisms. We then discuss the importance of quantifying accurately and fully both auditory ability and noise content, and emphasize considerations of direct

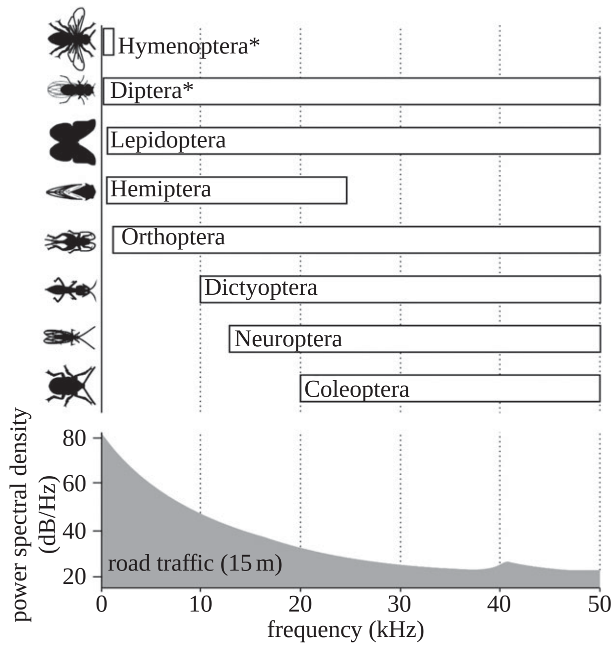


Figure 1. Approximate hearing ranges of insect orders and noise spectrum of road traffic recorded at 15 m. Noise spectra taken from Schaub *et al.* [28]. Asterisk indicates that species sensitive to particle velocity are also included.

relevance to how invertebrates detect sounds. We highlight some current issues identified by our review of the anthropogenic noise literature—a behavioural bias, the difficulty in drawing strong, ecologically valid conclusions, and a need for studies on fitness impacts—and consider whether studying invertebrates can help to resolve them. Finally, we suggest major avenues of future research relating to anthropogenic noise and how invertebrates can be used to advance our understanding of this pervasive global pollutant.

2. Why invertebrates are likely to be affected by anthropogenic noise

There is a considerable body of work on the auditory capabilities of invertebrates and their responses to abiotic and biotic environmental noise, which combined suggest that they have the potential to be impacted by noise sources in an urban environment.

(a) Audition in invertebrates

Although audition is currently documented in detail in relatively few invertebrate species [22,23], the ability to detect sound has evolved multiple times in the insects alone, resulting in a diversity of auditory structures that can be found on nearly any segment of the body and with sensitivities anywhere between 10s of Hz to over 100 kHz [24,25]. Moreover, invertebrate species are known to produce sounds for a variety of reasons, in the same contexts as vertebrates: for example, aggression (e.g. *Drosophila*, Orthoptera, Coleoptera, Trichoptera; [22]), mate location, attraction and courtship (e.g. *Drosophila*, mosquitoes, Orthoptera, Hemiptera, Coleoptera; [22]), predator avoidance (e.g. Lepidoptera; [26]) and detection of parasite host species (e.g. tachinid flies; [27]). As many invertebrates rely on communication at frequencies below 10 kHz [24] and are capable of hearing within the main frequency spectrum of much anthropogenic noise (figure 1), their vulnerability to this pollutant is clear.

Downloaded from http://rspb.royalsocietypublishing.org/ on November 24, 2014

The ability to hear typically refers to the detection of pressure waves; that is, oscillating compressions and rarefactions of the medium (usually air or water). Pressure waves are detected and produced by animals with tympanal ears: thin membranes coupled to mechanosensory cells that transduce the membrane vibration into electrical impulses. Humans, along with other vertebrates and many invertebrates, including the most conspicuously acoustic species, Orthoptera (crickets, katydids, grasshoppers) and cicadas, use tympanal ears [24]; recent work has demonstrated a remarkable example of convergent evolution between the ears of some insects and mammals [29]. As pressure waves dominate the sound field far from the source (greater than 1 wavelength (λ)), animals detecting sound pressure can communicate over considerable distances, but this also makes them vulnerable to noise originating further away. It is this component of sound that has been measured in all anthropogenic noise studies considering terrestrial animals to date.

There is a second distinct component to a sound wave, particle velocity, which comprises the oscillatory motion of particles back and forth within a propagating wave. As particle velocity is not detected by humans, it can be easy to overlook. However, many invertebrates detect this sound element using flagellar mechanosensory structures, such as hairs or antennae, that project into the oscillatory flow [25]. Particle velocity receivers sensitive to air-borne sound have been best characterized in two-winged flies (Diptera), where hair-like flagellar ears are sensitive to low frequencies (less than 1 kHz) [25,30,31]. The particle velocity component of sound attenuates rapidly and dominates only the sound field close to the source (less than 1 λ; for 10 Hz, $\lambda = 34$ m; for 1 kHz, $\lambda = 0.34$ m) [32]. Animals detecting just particle velocity may therefore be more robust than sound-pressure detectors to the impacts of anthropogenic noise. It must be noted, though, that the mechanosensory cells of both mosquitoes (*Toxorhynchites brevipalpis* [30]) and fruit flies (*Drosophila melanogaster* [31]), known to be sensitive to particle velocity, actively amplify quiet stimuli. This may effectively increase their sensitivity to distant sounds and, at the same time, their vulnerability to the effects of noise when compared with those species using a passive receiver system.

Vibrational communication through substrates, such as plants, spider webs and the ground, is also widespread in invertebrates [23]. While the sensory receivers for detecting substrate-borne vibrations are usually distinct from those of audition [22], acoustic stimuli can transmit into and be propagated in substrates, and hence acoustic noise also has the potential to impair vibratory communication. Recent work indicates that vibratory communication in the spider *Schizocosa ocreata*, for instance, is impacted by air-borne noise [33]. Vibratory communication is used in courtship in this species and when air-borne white noise (0–4 kHz) was played back, signal transmission and mating success in *S. ocreata* were decreased. The impact of anthropogenic noise on vibratory signals has received little direct attention (see [34] with an exception in Stephen's kangaroo rat (*Dipodomys stephensi*)) but as this modality is used by many different species both within and beyond the invertebrates, consideration of detrimental effects is important.

(b) Evidence for changes in response to noise

Many abiotic and biotic sound sources, such as wind, rain, running water and the choruses of other animals, can result in naturally noisy environments. To survive and reproduce in these conditions, invertebrates have evolved different mechanisms to cope with noise, incorporating adaptation over evolutionary time-scales and short-term behavioural plasticity.

Changes in auditory tuning mediated by both long-term physiological alterations and short-term behavioural modification are known in crickets and katydids. In noisy rainforests, where acoustic competition levels are high, the cricket *Paroecanthus podagrosus* has an auditory sensitivity that is relatively sharply tuned to conspecific song [35]. This contrasts with the broader auditory tuning of two species of European cricket, *Gryllus bimaculatus* and *Gryllus campestris*, which share their best frequency (the frequency of highest auditory sensitivity) with *P. podagrosus*, but live in quieter environments. The sharper tuning of *P. podagrosus* filters out background noise more effectively than in the broadly tuned species, but this may limit the detection of other environmental sounds that fall outside this narrow frequency range, for example those generated by approaching predators. Modifications in auditory tuning are also seen in the Australian bushcricket (*Sciarasaga quadrata* [36]). This species is able to close down the tracheal system, a system of air-filled tubes linking bilateral ears, to filter out much of the background noise generated by heterospecifics and tune the ear to the lower frequencies used by singing conspecific males. By maintaining a broad auditory sensitivity, these katydids may have a better ability to detect predators, while their flexible auditory response allows tuning into species-specific calls, and thus escape from acoustic competition.

There are also examples where species have evolved robust ways of communicating information even under noisy conditions. In bow-winged grasshoppers, calls include characteristics that allow attractiveness to be assessed even when subjected to high levels of white noise; noise does not appear to impair female choice in this species [37]. In other species, behavioural responses to noise are apparent, both in terms of sound production and recipient response. Römer *et al.* [38] found modifications to the temporal calling patterns in two sympatric katydid species, *Hemisaga dendiculata* and *Mygalopsis marki*, that almost completely overlap in call frequency, with *H. dendiculata* song suppressed in the presence of calling *M. marki*. In another species, *Mecopoda elongata*, which sings in choruses, levels of synchrony were reduced with increasing nocturnal rainforest noise [39]. Background noise can also induce changes in phonotaxis (the ability to move in an orientation with respect to a sound source). The playback of heterospecific calls or random noise interferes with female short-winged meadow katydid (*Conocephalus brevipennis*) movement towards conspecific male calls [40], while male grey bushcrickets (*Platycleis albopunctata*) move away from calling *M. marki* individuals, resulting in a separation of two sympatric species competing for acoustic space [41].

3. Receiver and noise source characterizations

To maximize the usefulness of research into the impact of anthropogenic noise, studies must suitably characterize the particular auditory receiver and noise source under consideration; it is common in the current literature to find that either or both are not done sufficiently to justify the conclusions drawn [11]. In this section, we highlight important general considerations in this regard (see also [10]), with particular

Downloaded from http://rspb.royalsocietypublishing.org/ on November 24, 2014

reference to aspects of invertebrate sound detection that differ from most vertebrate hearing (see above).

(a) Auditory sensitivities

Determination of whether a given noise stimulus falls within the auditory capabilities of an organism is vital to assess correctly any apparent lack of effect. Characterization of invertebrate hearing should include appropriate consideration of pressure or particle velocity components of sound, as well as potential nonlinear auditory responses (where the sensory system does not respond linearly with input amplitude). Auditory nonlinearities have been demonstrated in mosquitoes [30], fruit flies [42] and the tree cricket *Oecanthus henryi* [43]; the latter represents the first evidence of nonlinear audition from a tympanal hearing insect. In these systems, the total sound level across frequencies can impact the sensitivity and tuning of the ear, indicating that even noise which does not overlap with the best frequency of the auditory system (frequency of highest sensitivity) may still generate signal masking and impede signal differentiation from the background.

Characterization of the mechanical properties of the ear and of auditory responses and physiological measurement of auditory thresholds are relatively simple to obtain in invertebrates owing to the peripheral location of many auditory structures and ease of access to auditory neurons [22]. This is true for invertebrates sensitive to pressure and particle velocity; for each of these types of receiver, there are good examples of auditory characterization at the mechanical and physiological level (see [29,31,42–44]). Moreover, neurophysiological methods have been developed to measure auditory thresholds both in the laboratory and the field in Orthoptera [45]. Natural habitats have sound fields that are far more complex than laboratory conditions, generating differences in the thresholds of what is perceived by the animal, which makes it important to put laboratory work into an ecologically relevant context.

(b) Noise quantification

To avoid erroneous conclusions, it is critical to quantify the noise source using tools that best reflect the auditory capabilities of the study animal. However, most readily available, and commonly used, audio equipment is designed for human aural sensitivities, and thus studies have often restricted recording and playback to frequencies audible to us (20 Hz–20 kHz) and employed recording filters that emulate human hearing (e.g. A-weighting filter (dBA)). While this approach has been deemed acceptable for birds, which hear in a similar frequency range to us and on which the majority of terrestrial work has so far been conducted, noise quantification ideally needs to cover broad bandwidths extending beyond audible frequencies using unweighted, flat-response recording equipment. A study by Schaub *et al.* [28] on bat foraging sets a robust standard for quantification of anthropogenic noise in a way relevant to the study species: they measured road traffic noise between 0 and 50 kHz with a flat-response microphone, showing the majority of energy concentrated below 5 kHz. Moreover, Schaub *et al.* quantified the number of vehicles, vehicle type and distance from the noise source; as the same type of noise source can produce highly variable sounds and the frequency content and amplitude are dependent on the distance from the source, including these factors adds valuable information. In general, studies should ideally report a range of relevant acoustic metrics (e.g. dB, weighting function, maximum power, integration time and order statistics); making high-quality audio recordings of the noise source being studied available for alternative spectral filtering and acoustic analysis would potentially represent the best practice and allow the greatest opportunity for comparative work and generalization (for further details see [10,46]).

For the study of some invertebrates, recording particle velocity or substrate vibration generated by anthropogenic noise, and mimicking these components in playbacks, should be a crucial element of the work. To date, there has been little attempt to quantify these components of terrestrial anthropogenic noise or their impact on animals sensitive to such stimuli (but see [34]), not least because the majority of studies have been conducted on organisms (i.e. vertebrates) for which these considerations are not important. The pressure component of a sound wave, the quantification of which is discussed above, can differ considerably from particle velocity [32] and measuring particle velocity or substrate vibration presents technological challenges. The majority of available microphones are pressure sensitive, but some do detect the pressure gradient, which combined with the use of integrating amplifiers output the particle velocity of a signal. These tools have been used successfully to record particle velocity in studies examining audition, communication and mate location in insects [42]. Likewise, the measurement of substrate vibration is frequently carried out in other contexts by employing accelerometers or non-contact laser Doppler vibrometry [33]. Thus, there is the capacity to measure these aspects of a noise source that are relevant to some invertebrate hearing.

4. Can invertebrates provide model systems to investigate the impact of anthropogenic noise?

Our review of the current anthropogenic noise literature has identified three key issues that we believe need resolving (see [11]): a behavioural bias, the difficulty in drawing strong, ecologically valid conclusions and a need to determine the effects on individual fitness. In this section, we outline these issues and then consider whether invertebrates can help with their resolution.

(a) Behavioural bias

The majority of studies (60 out of 83) investigating the impact of anthropogenic noise on terrestrial species have considered behavioural responses (see the electronic supplementary material). The most commonly researched behaviour is acoustic communication and particularly ways in which animals might minimize the risk that their auditory signals are masked; masking occurs when there is an increase in the threshold for detection or discrimination of one sound in the presence of another. Loss of clear and efficient transmission of acoustic information can create potential fitness costs, including those related to mate attraction and territory defence if song is masked, increased predation risk if detection of alarm calls is impaired and reduced reproductive success if parent–offspring or parent–parent communication is disrupted (see [14]). Consequently, anthropogenic noise has resulted in alterations to the vocal parameters (frequency, amplitude, rate and duration) or the timing of signalling in many birds

Downloaded from http://rspb.royalsocietypublishing.org/ on November 24, 2014

and anurans, either through behavioural plasticity or evolutionary adaptation [14,47,48]. Some studies have also considered the impact of masking on adventitious signals [28,49]. For instance, greater mouse-eared bats (*Myotis myotis*), which listen for prey-generated sounds to locate food, avoid foraging when exposed to playback of road traffic noise and exhibit reduced foraging efficiency when noise is unavoidable. There is also some evidence that noise can mimic communicatory signals [34] and that vigilance behaviour is modified [50].

In contrast to behavioural adaptations, relatively little research has considered how anthropogenic noise impacts physiology ([8]; but see [51,52]), and there have been virtually no investigations with respect to development, neurobiology or genetics. Assessing how noise affects processes in addition to behaviour is vital for a full understanding of both proximate and ultimate impacts on fitness [8]. There is a long history of studying such fundamental processes in invertebrates in other contexts [53,54]. For example, by using genetic techniques and physiological and mechanical measurement, the molecular genetic and neural components required for an ear to receive and actively amplify sounds are being pieced together in *Drosophila* (see [53]). Moreover, there are good examples where invertebrate physiology, development and genetics have been studied with respect to global changes other than anthropogenic noise. For instance, considerable research has focused on the potential impacts of climate change on development in insects [55,56], as well as genetic effects in mosquitoes and fruit flies (for an overview see [57]). Physiological responses to climate change have also been measured in many invertebrates (for discussion see [58]). Such approaches should be equally applicable to studies examining the impact of anthropogenic noise.

(b) Difficulties in drawing strong, ecologically valid conclusions

Strong conclusions about the impact of anthropogenic noise are often not possible because suitable controls are lacking [11]. For example, roads are noisy, but they also have high levels of disturbance, chemical pollution and light, and provide an edge habitat. Studies comparing the responses of animals near a noisy road with those in a control area, either a quieter road or a site at a greater distance from the road, do not allow any differences to be conclusively attributed to noise. An experimental approach where noise is the only factor that differs is ideally required to tease out the direct effect of noise from potentially confounding factors.

Studies by Francis *et al.* [59] and Bayne *et al.* [60], for example, have highlighted that it is possible to provide strong evidence for the impact of noise using natural experiments: they have taken advantage of areas containing gas wells that either have or do not have noisy compressors to show that anthropogenic noise affects birds at both the species and community level. As the wells are comparable in both structure and surrounding habitat, and thus differ only in noise production, this system provides an excellent test of the impact of anthropogenic noise under field conditions. Such natural experimental situations may be rare, however, and manipulations are usually required. Careful controls are often the easiest in laboratory experiments, where more detailed data collection than in the wild is also potentially feasible [28,49,61], but care must be taken when extrapolating results to meaningful implications for free-ranging animals in natural conditions; the ecological validity of laboratory-based work can be questioned. Field experiments are becoming more common (e.g. [62,63]), but can be logistically more difficult, with the same level of control and detailed data collection harder to achieve than that in the laboratory, and characterization of some responses (e.g. neurological) particularly challenging. Studies that pair different types of work in different settings [48,64] offer the best solution, allowing the benefits of each approach to be used.

Invertebrates are amenable to a combined laboratory and field approach; they are small enough to be kept in large numbers in captivity and they can be manipulated in the wild. Römer *et al.* [38] provide an excellent example of this in their work with katydids, examining the influence of the acoustic environment on signal transmission. Investigating responses to masking by heterospecific noise, this study pairs both behavioural and neurophysiological measurements of auditory neurons in the field and laboratory settings, providing ecological validation for the laboratory work and technical controls for any confounding variables in the fieldwork. Further examples of experiments conducted in both the field and laboratory can be found in other orthopteran species. Schmidt & Römer [45] investigated neurophysiological detection thresholds for conspecific song in tropical crickets under noisy conditions, while studies of directional sensitivity in grasshopper audition [65] and katydid discrimination between background noise and calls of approaching predators [66] also used this paired laboratory and field approach.

(c) Need to evaluate effects of noise on individual fitness

Ultimately what is needed for successful policy-making and mitigation is consideration of how anthropogenic noise impacts individual survival and reproductive success, and consequently population and community structure. However, the vast majority of experimental studies to date have considered relatively short-term effects (see the electronic supplementary material), which do not necessarily have clear implications for fitness; at best, most of the current literature reports fitness proxies (see [11]). Some short-term effects (e.g. increased predation risk) can be translated relatively easily into ultimate consequences. However, others (e.g. foraging behaviour, signalling characteristics, movement patterns) need more careful consideration because animals may be able to compensate in quieter periods, the implications of the behavioural change are unclear or there may be costs associated with the noise-induced adjustment [14], and thus there may be no direct link between short-term effects and long-term consequences (see [67]). That is not to say changes in fitness do not result, but rather that the experiments required to determine them have rarely been carried out (but see [59,64,68,69]). A multiyear study by Francis *et al.* [59] demonstrated that some species might actually gain from additional noise if, for instance, potential predators avoid the area, and thus implications for individual fitness and community structure are not necessarily easy to predict.

As the life cycle of invertebrates is relatively short, it enables individual fitness and population viability to be assessed directly in a way that is logistically difficult in many vertebrates. Research into climate change provides good examples of how potential impacts of environmental modification on insects can be developed [70]. For example, an intergenerational

Downloaded from http://rspb.royalsocietypublishing.org/ on November 24, 2014

study on the pitcher-plant mosquito (*Wyeomyia smithii*) has revealed large decreases in fitness in response to changes in photoperiod and climate over evolutionary time-scales [71]. In a tropical butterfly (*Bicyclus anynana*), resource availability and temperature were found to modify fitness-related traits, with implications for the impacts of climate change on this species [72].

It is also possible to use data on individual fitness consequences to parametrize theoretical models making predictions about outcomes at a population level. Such agent-based modelling has previously been applied to environmental resource management, and to ecological and conservation issues [73]. If modelling such as this can be introduced to anthropogenic noise research, individual-based fitness studies would be able to indicate conservation priorities without the immediate requirement for long-term data that are not likely to become available in the near future. However, validation of such models is a crucial element of the process, and this step is also feasible with short-lived invertebrate species: successive generations, with appropriate controls, could be bred under different noise conditions.

5. The future

In addition to the suggestions inherent in the previous sections, there are three main areas that we consider are in need of particular attention if research into anthropogenic noise is to move forward substantially. First, experimental studies to date have concentrated efforts on the impact of a single, acute noise exposure in isolation (e.g. [63,74]; but see [52,59,60,62]). While this is understandable from a logistical perspective, organisms in most natural situations are likely to experience either chronic or repeated exposure to noise, which might lead to changes in response through such processes as sensitization, habituation or tolerance [75]. Moreover, it is currently unclear precisely how the impacts of anthropogenic noise are affected by simultaneous exposure to such situations as high disturbance or light and chemical pollution; potential synergistic effects arising from the combination of noise with other stressors require investigation.

Second, the majority of (experimental) studies to date have tackled the simple, but important question: is there an immediate impact of noise? It is clear from the rapidly expanding literature that this is indeed the case across a range of taxa (see the electronic supplementary material). What is required now is consideration of additional issues that build on this knowledge. For example, what is the spatial scale of impact and the dose-dependent relationship between noise and responses? What characteristics of anthropogenic noises are most problematic; it is unlikely that it is simply the amplitude that matters, but do such aspects as predictability, rise time, and frequency range and modulation also play a key role? How quickly do animals recover to pre-exposure levels and do they show compensation for any noise-induced responses? How are different members of the same species affected by the same noise; are there, for example, age-, sex-, size- and condition-dependent responses?

Third, it is clear that the same noise may not affect different species in the same way. Such variation in impact could have consequences at the dyadic level (i.e. when two species interact). For example, if a predator is affected in a more detrimental manner than its prey [49], the reproductive success of the latter may be enhanced in noisy environments. There could also be consequences in terms of community structure. Francis *et al.* [59] have found, for instance, that the nest success of certain bird species increased at noisy treatment sites compared with a quiet control, owing to a decrease in the abundance of predators. To date, there have been relatively few attempts to consider how anthropogenic noise affects biodiversity *per se* (but see [59,60,76]) and findings are mixed and potentially taxon specific. For instance, Herrera-Montez & Aide [76] found that although avian biodiversity declined in noisy areas, anuran biodiversity was not significantly affected. Finally, recent work has provided, to our knowledge, the first evidence that anthropogenic noise could affect ecosystem services: Francis *et al.* [77] showed that noise could influence pollination and seed dispersal. Interactions at the community and ecosystem level are clearly more complex than when considering single species, but are crucial for a full understanding of the potential impact of anthropogenic noise.

Although the issues outlined above can potentially be addressed using vertebrates, intergenerational studies considering the impacts of chronic or repeated exposure, as well as the possibilities for recovery and compensation, are achievable within relatively short time-frames using invertebrates. Likewise, their small size and the relative ease of maintaining populations in the laboratory make it possible to examine the impacts of complex interactions with other stressors, dose- and condition-dependence and intrapopulation differences in response. Moreover, as invertebrates can be good bioindicators of impacts of environmental change [78], they offer an ideal opportunity to track the impact of anthropogenic noise on wildlife in natural habitats. Not only are invertebrates useful as models and indicators, but their ubiquity in ecosystems throughout the world makes it important to assess how noise is affecting them *per se* together with their interactions with other species within the ecosystem.

6. Conclusion

Anthropogenic noise is an issue of international concern and studies of its potential impacts are important and becoming more prevalent. For brevity, this review has focused on terrestrial species, but there is also increasing awareness of the effects of such noise in aquatic environments [3,9]. Little direct work has so far investigated how invertebrates, despite their probable vulnerability, are impacted (but see [12,13,79,80]). One potential reason for this is that regulators and policymakers are intrinsically more interested in how noise affects charismatic vertebrates. However, research on invertebrates is not only important (invertebrates are critical elements of all ecosystems, not least in providing the food for most vertebrates), but also has the potential both to assist with some of the current issues apparent in the literature and to drive the field forward, thus establishing the full impact of this global pollutant. Unlike, for example, climate change and ocean acidification, where studies are considering future predicted changes, anthropogenic noise is an issue in the present day. Advancing our knowledge of its impacts and developing mitigation measures is therefore of pressing importance, and we argue that the study of invertebrates, perhaps within the valuable framework recently outlined by Francis & Barber [10], can play a crucial, yet currently underused role.

Acknowledgements. We are grateful to Martin McVay, Hilary Notley and the Bristol Bioacoustics and Behavioural Ecology research group for

Downloaded from http://rspb.royalsocietypublishing.org/ on November 24, 2014

valuable discussions, and to Jesse Barber and two anonymous referees for helpful comments on the manuscript.

Funding statement. We are grateful to Defra, who funded the initial literature search and assessment.

References

1. Barber JR, Crooks KR, Fristrup KM. 2010 The costs of chronic noise exposure for terrestrial organisms. *Trends Ecol. Evol.* **25**, 180–189. (doi:10.1016/j.tree.2009.08.002)
2. Watts RD, Compton RW, McCammon JH, Rich CL, Wright SM, Owens T, Ouren DS. 2007 Roadless space of the conterminous United States. *Science* **316**, 736–738. (doi:10.1126/science.1138141)
3. Slabbekoorn H, Bouton N, van Opzeeland I, Coers A, ten Cate C, Popper AN. 2010 A noisy spring: the impact of globally rising underwater sound levels on fish. *Trends Ecol. Evol.* **25**, 419–427. (doi:10.1016/j.tree.2010.04.005)
4. Hildebrand J. 2009 Anthropogenic and natural sources of ambient noise in the ocean. *Mar. Ecol. Progr. Ser.* **395**, 5–20. (doi:10.3354/meps08353)
5. Le Prell CG, Henderson D, Fay RR, Popper AN. (eds) 2012 *Noise-induced hearing loss: scientific advances*. New York, NY: Springer.
6. World Health Organisation 2011 *Burden of disease from environmental noise: quantification of healthy life years lost in Europe*. Geneva, Switzerland: World Health Organisation Regional Office for Europe.
7. European Parliament 2002 Directive 2002/49/EC of the European Parliament and of the Council. *Official J. Eur. Communities L* **189**, 12–26.
8. Kight CR, Swaddle JP. 2011 How and why environmental noise impacts animals: an integrative, mechanistic review. *Ecol. Lett.* **14**, 1052–1061. (doi:10.1111/j.1461-0248.2011.01664.x)
9. Tyack PL. 2008 Implications for marine mammals of large-scale changes in the marine acoustic environment. *J. Mammol.* **89**, 549–558. (doi:10.1644/07-MAMM-S-307R.1)
10. Francis CD, Barber JR. 2013 A framework for understanding noise impacts on wildlife: an urgent conservation priority. *Front. Ecol. Environ.* **11**, 305–313. (doi:10.1890/120183)
11. Radford AN, Jones G, Morley EL. 2012 The effects of noise on biodiversity. Defra Report NO0235.
12. Shieh B-S, Liang S-H, Chen C-C, Loa H-H, Liao C-Y. 2012 Acoustic adaptations to anthropogenic noise in the cicada *Cryptotympana takasagona* Kato (Hemiptera: Cicadidae). *Acta Ethol.* **15**, 33–38. (doi:10.1007/s10211-011-0105-x)
13. Lampe U, Schmoll T, Franzke A, Reinhold K. 2012 Staying tuned: grasshoppers from noisy roadside habitats produce courtship signals with elevated frequency components. *Funct. Ecol.* **26**, 1348–1354. (doi:10.1111/1365-2435.12000)
14. Read J, Jones G, Radford AN. In press. Fitness costs as well as benefits are important when considering responses to anthropogenic noise. *Behav. Ecol.* (doi:10.1093/beheco/art102)
15. Mora C, Tittensor DP, Adl S, Simpson AGB, Worm B. 2011 How many species are there on Earth and in the ocean? *PLoS Biol.* **9**, e1001127. (doi:10.1371/journal.pbio.1001127)
16. Prather CM *et al*. 2012 Invertebrates, ecosystem services and climate change. *Biol. Rev.* **88**, 328–348. (doi:10.1111/brv.12002)
17. Mulder CPH, Koricheva J, Huss-Danell K, Högberg P, Joshi J. 1999 Insects affect relationships between plant species richness and ecosystem processes. *Ecol. Lett.* **2**, 237–246. (doi:10.1046/j.1461-0248.1999.00070.x)
18. Losey JE, Vaughan M. 2006 The economic value of ecological services provided by insects. *BioScience* **56**, 311–323. (doi:10.1641/0006-3568(2006)56[311:TEVOES]2.0.CO;2)
19. Davies TW, Bennie J, Gaston KJ. 2012 Street lighting changes the composition of invertebrate communities. *Biol. Lett.* **8**, 764–767. (doi:10.1098/rsbl.2012.0216)
20. Sorvari J, Rantala LM, Rantala MJ, Hakkarainen H, Eeva T. 2007 Heavy metal pollution disturbs immune response in wild ant populations. *Environ. Pollut.* **145**, 324–328. (doi:10.1016/j.envpol.2006.03.004)
21. Moe SJ, Stenseth NC, Smith RH. 2001 Effects of a toxicant on population growth rates: sublethal and delayed responses in blowfly populations. *Funct. Ecol.* **15**, 712–721. (doi:10.1046/j.0269-8463.2001.00575.x)
22. Ewing AW. 1989 *Arthropod bioacoustics: neurobiology and behaviour*. Ithaca, NY: Cornell University Press.
23. Hill PSM. 2009 How do animals use substrate-borne vibrations as an information source? *Naturwissenschaften* **96**, 1355–1371. (doi:10.1007/s00114-009-0588-8)
24. Hoy RR, Robert D. 1996 Tympanal hearing in insects. *Annu. Rev. Entomol.* **41**, 433–450. (doi:10.1146/annurev.en.41.010196.002245)
25. Tautz J. 1979 Reception of particle oscillation in a medium: an unorthodox sensory capacity. *Naturwissenschaften* **66**, 452–461. (doi:10.1007/BF00399002)
26. Spangler HG. 1988 Moth hearing, defense and communication. *Annu. Rev. Entomol.* **33**, 59–81. (doi:10.1146/annurev.en.33.010188.000423)
27. Hoy RR, Popper AN, Fay RR. 1998 *Comparative hearing: insects*. New York, NY: Springer.
28. Schaub A, Ostwald J, Siemers BM. 2009 Foraging bats avoid noise. *J. Exp. Biol.* **211**, 3174–3180. (doi:10.1242/jeb.022863)
29. Montealegre-Z F, Jonsson T, Robson-Brown KA, Postles M, Robert D. 2012 Convergent evolution between insect and mammalian audition. *Science* **338**, 968–971. (doi:10.1126/science.1225271)
30. Göpfert MC, Robert D. 2001 Active auditory mechanics in mosquitoes. *Proc. R. Soc. Lond. B* **268**, 333–339. (doi:10.1098/rspb.2000.1376)
31. Göpfert MC, Humphris ADL, Albert JT, Robert D, Hendrich O. 2005 Power gain exhibited by motile mechanosensory neurons in *Drosophila* ears. *Proc. Natl Acad. Sci. USA* **102**, 325–330. (doi:10.1073/pnas.0405741102)
32. Rossing TD. (eds) 2007 *Springer handbook of acoustics*. New York, NY: Springer.
33. Gordon SD, Uetz GW. 2012 Environmental interference: impact of acoustic noise on seismic communication and mating success. *Behav. Ecol.* **23**, 707–714. (doi:10.1093/beheco/ars016)
34. Shier DM, Lea AJ, Owen MA. 2012 Beyond masking: endangered Stephen's kangaroo rats respond to traffic noise with footdrumming. *Biol. Conserv.* **150**, 53–58. (doi:10.1016/j.biocon.2012.03.007)
35. Schmidt AKD, Riede K, Römer H. 2011 High background noise shapes selective auditory filters in a tropical cricket. *J. Exp. Biol.* **214**, 1754–1762. (doi:10.1242/jeb.053819)
36. Römer H, Bailey W. 1998 Strategies for hearing in noise: peripheral control over auditory sensitivity in the bushcricket *Sciarasaga quadrata* (Austrosaginae: Tettigoniidae). *J. Exp. Biol.* **201**, 1023–1033.
37. Einhaupl A, Stange N, Hennig RM, Ronacher B. 2011 Attractiveness of grasshopper songs correlates with their robustness against noise. *Behav. Ecol.* **22**, 791–799. (doi:10.1093/beheco/arr064)
38. Römer H, Bailey W, Dadour I. 1989 Insect hearing in the field. III. Masking by noise. *J. Comp. Physiol. A* **164**, 609–620. (doi:10.1007/BF00614503)
39. Hartbauer M, Siegert ME, Fertschai I, Römer H. 2012 Acoustic signal perception in a noisy habitat: lessons from synchronising insects. *J. Comp. Physiol. A* **198**, 397–409. (doi:10.1007/s00359-012-0718-1)
40. Bailey WJ, Morris GK. 2010 Confusion of phonotaxis by masking sounds in the bushcricket *Conocephalus brevipennis* (Tettigoniidae: Conocephalinae). *Ethology* **73**, 19–28. (doi:10.1111/j.1439-0310.1986.tb00996.x)
41. Latimer W. 1981 Acoustic competition in bush crickets. *Ecol. Entomol.* **6**, 35–45. (doi:10.1111/j.1365-2311.1981.tb00970.x)
42. Göpfert MC, Robert D. 2002 The mechanical basis of *Drosophila* audition. *J. Exp. Biol.* **205**, 1199–208.
43. Mhatre N, Robert D. 2013 A tympanal insect ear exploits a critical oscillator for active amplification and tuning. *Curr. Biol.* **23**, 1952–1957. (doi:10.1016/j.cub.2013.08.028)
44. Kostarakos K, Römer H. 2010 Sound transmission and directional hearing in field crickets: neurophysiological studies outdoors. *J. Comp. Physiol. A* **196**, 669–681. (doi:10.1007/s00359-010-0557-x)
45. Schmidt AKD, Römer H. 2011 Solutions to the cocktail party problem in insects: selective filters, spatial release from masking and gain control in

Downloaded from http://rspb.royalsocietypublishing.org/ on November 24, 2014

tropical crickets. *PLoS ONE* **6**, e28593. (doi:10.1371/journal.pone.0028593)

46. Pater LL, Grubb TG, Delaney DK. 2009 Recommendations for improved assessment of noise impacts on wildlife. *J. Wildl. Manage.* **73**, 788–795. (doi:10.2193/2006-235)
47. Brumm H, Slabbekoorn H. 2005 Acoustic communication in noise. *Adv. Stud. Behav.* **35**, 151–209.
48. Cunnington GM, Fahrig L. 2010 Plasticity in the vocalizations of anurans in response to traffic noise. *Acta Oecol.* **36**, 463–470. (doi:10.1016/j.actao.2010.06.002)
49. Siemers BM, Schaub A. 2011 Hunting at the highway: traffic noise reduces foraging efficiency in acoustic predators. *Proc. R. Soc. B* **278**, 1646–1652. (doi:10.1098/rspb.2010.2262)
50. Rabin L, Coss R, Owings D. 2006 The effects of wind turbines on antipredator behavior in California ground squirrels (*Spermophilus beecheyi*). *Biol. Conserv.* **131**, 410–420. (doi:10.1016/j.biocon.2006.02.016)
51. Payne CJ, Jessop TS, Guay P-J, Johnstone M, Feore M, Mulder RA. 2012 Population, behavioural and physiological responses of an urban population of black swans to an intense annual noise event. *PLoS ONE* **7**, e45014. (doi:10.1371/journal.pone.0045014)
52. Blickley JL, Word KR, Krakauer AH, Phillips JL, Sells SN, Taff CC, Wingfield JC, Patricelli GL. 2012 Experimental chronic noise is related to elevated fecal corticosteroid metabolites in lekking male greater sage-grouse (*Centrocercus urophasianus*). *PLoS ONE* **7**, e50462. (doi:10.1371/journal.pone.0050462)
53. Lu Q, Senthilan PR, Effertz T, Nadrowski B, Göpfert MC. 2009 Using *Drosophila* for studying fundamental processes in hearing. *Integr. Comp. Biol.* **49**, 674–680. (doi:10.1093/icb/icp072)
54. Scharrer B. 1987 Insects as models in neuroendocrine research. *Annu. Rev. Entomol.* **32**, 1–16. (doi:10.1146/annurev.en.32.010187.000245)
55. Piyaphongkul J, Pritchard J, Bale J. 2012 Heat stress impedes development and lowers fecundity of the brown planthopper *Nilaparvata lugens* (Stål). *PLoS ONE* **7**, e47413. (doi:10.1371/journal.pone.0047413)
56. Régnière J, St-Amant R, Duval P. 2010 Predicting insect distributions under climate change from physiological responses: spruce budworm as an example. *Biol. Invasions* **14**, 1571–1586. (doi:10.1007/s10530-010-9918-1)
57. Bradshaw WE, Holzapfel CM. 2008 Genetic response to rapid climate change: it's seasonal timing that matters. *Mol. Ecol.* **17**, 157–166. (doi:10.1111/j.1365-294X.2007.03509.x)
58. Chown SL, Terblanche JS. 2006 Physiological diversity in insects: ecological and evolutionary contexts. *Adv. Insect Physiol.* **33**, 50–152. (doi:10.1016/S0065-2806(06)33002-0)
59. Francis CD, Ortega CP, Cruz A. 2009 Noise pollution changes avian communities and species interactions. *Curr. Biol.* **19**, 1415–1419. (doi:10.1016/j.cub.2009.06.052)
60. Bayne EM, Habib L, Boutin S. 2008 Impacts of chronic anthropogenic noise from energy-sector activity on abundance of songbirds in the boreal forest. *Conserv. Biol.* **22**, 1186–1193. (doi:10.1111/j.1523-1739.2008.00973.x)
61. Bee MA, Swanson EM. 2007 Auditory masking of anuran advertisement calls by road traffic noise. *Anim. Behav.* **74**, 1765–1776. (doi:10.1016/j.anbehav.2007.03.019)
62. Blickley JL, Blackwood D, Patricelli GL. 2012 Experimental evidence for the effects of chronic anthropogenic noise on abundance of greater sage-grouse at leks. *Conserv. Biol.* **26**, 461–471. (doi:10.1111/j.1523-1739.2012.01840.x)
63. McLaughlin KE, Kunc HP. 2013 Experimentally increased noise levels change spatial and singing behaviour. *Biol. Lett.* **9**, 20120771. (doi:10.1098/rsbl.2012.0771)
64. Halfwerk W, Bot S, Buikx J, van der Velde M, Komdeur J, ten Cate C, Slabbekoorn H. 2011 Low-frequency songs lose their potency in noisy urban conditions. *Proc. Natl Acad. Sci. USA* **108**, 14 549–14 554. (doi:10.1073/pnas.1109091108)
65. Gilbert F, Elsner N. 2000 Directional hearing of a grasshopper in the field. *J. Exp. Biol.* **203**, 983–993.
66. Hartbauer M, Radspieler G, Römer H. 2010 Reliable detection of predator cues in afferent spike trains of a katydid under high background noise levels. *J. Exp. Biol.* **213**, 3036–3046. (doi:10.1242/jeb.042432)
67. Bejder L *et al*. 2006 Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. *Conserv. Biol.* **20**, 1791–1798. (doi:10.1111/j.1523-1739.2006.00540.x)
68. Francis CD, Paritsis J, Ortega CP, Cruz A. 2011 Landscape patterns of avian habitat use and nest success are affected by chronic gas well compressor noise. *Landscape Ecol.* **26**, 1269–1280. (doi:10.1007/s10980-011-9609-z)
69. Kight CR, Saha MS, Swaddle JP. 2012 Anthropogenic noise is associated with reductions in the productivity of breeding eastern bluebirds (*Sialia sialis*). *Ecol. Appl.* **22**, 1989–1996. (doi:10.1890/12-0133.1)
70. Bradshaw WE, Holzapfel CM. 2006 Evolutionary response to rapid climate change. *Science* **312**, 1477–1478. (doi:10.1126/science.1127000)
71. Bradshaw WE, Zani PA, Holzapfel CM. 2004 Adaptation to temperate climates. *Evolution* **58**, 1748–1762.
72. Karl I, Stoks R, De Block M, Janowitz SA, Fischer K. 2011 Temperature extremes and butterfly fitness: conflicting evidence from life history and immune function. *Glob. Change Biol.* **17**, 676–687. (doi:10.1111/j.1365-2486.2010.02277.x)
73. McLane AJ, Semeniuk C, McDermid GJ, Marceau DJ. 2011 The role of agent-based models in wildlife ecology and management. *Ecol. Model.* **222**, 1544–1556. (doi:10.1016/j.ecolmodel.2011.01.020)
74. Halfwerk W, Slabbekoorn H. 2009 A behavioural mechanism explaining noise-dependent frequency use in urban birdsong. *Anim. Behav.* **78**, 1301–1307. (doi:10.1016/j.anbehav.2009.09.015)
75. Bejder L, Samuels A, Whitehead H, Finn H, Allen S. 2009 Impact assessment research: use and misuse of habituation, sensitisation and tolerance in describing wildlife responses to anthropogenic stimuli. *Mar. Ecol. Progr. Ser.* **395**, 177–185. (doi:10.3354/meps07979)
76. Herrera-Montes MI, Aide TM. 2011 Impacts of traffic noise on anuran and bird communities. *Urban Ecosyst.* **14**, 415–427. (doi:10.1007/s11252-011-0158-7)
77. Francis CD, Kleist NJ, Ortega CP, Cruz A. 2012 Noise pollution alters ecological services: enhanced pollination and disrupted seed dispersal. *Proc. R. Soc. B* **279**, 2727–2735. (doi:10.1098/rspb.2012.0230)
78. Jennings N, Pocock MJO. 2009 Relationships between sensitivity to agricultural intensification and ecological traits of insectivorous mammals and arthropods. *Conserv. Biol.* **23**, 1195–1203. (doi:10.1111/j.1523-1739.2009.01208.x)
79. Wale MA, Simpson SD, Radford AN. 2013 Size-dependent physiological responses of shore crabs to single and repeated playback of ship noise. *Biol. Lett.* **9**, 20121194. (doi:10.1098/rsbl.2012.1194)
80. Wale MA, Simpson SD, Radford AN. 2013 Noise negatively affects foraging and antipredator behaviour in shore crabs. *Anim. Behav.* **86**, 111–118. (doi:10.1016/j.anbehav.2013.05.001)

Journal of Wildlife Diseases, 41(2), 2005, pp. 298–303
© Wildlife Disease Association 2005

DISEASES AND MORTALITY IN FREE-RANGING BROWN BEAR (*URSUS ARCTOS*), GRAY WOLF (*CANIS LUPUS*), AND WOLVERINE (*GULO GULO*) IN SWEDEN

Torsten Mörner,[1,5] Hanna Eriksson,[2] Caroline Bröjer,[1] Kristina Nilsson,[1] Henrik Uhlhorn,[1] Erik Ågren,[3] Carl Hård af Segerstad,[3] Désirée S. Jansson,[4] and Dolores Gavier-Widén[1]

[1] Department of Wildlife, National Veterinary Institute, SE-751 89 Uppsala, Sweden
[2] Åkervägen 24E, SE-952 62 Kalix, Sweden
[3] Department of Pathology, National Veterinary Institute, SE-751 89 Uppsala, Sweden
[4] Department of Poultry, National Veterinary Institute, SE-751 89 Uppsala, Sweden
[5] Corresponding author (email: torsten.morner@sva.se)

ABSTRACT: Ninety-eight brown bears (*Ursus arctos*), 20 gray wolves (*Canis lupus*), and 27 wolverines (*Gulo gulo*), all free-ranging, were submitted to the National Veterinary Institute, Uppsala, Sweden, during 1987–2001 for investigation of diseases and causes of mortality. The most common cause of natural death in brown bears was infanticide. Infanticide also was observed in wolverines but not in wolves. Traumatic injuries, originating from road or railway accidents, were the most common cause of death in wolves and occurred occasionally in brown bears. Most wolverines were submitted as forensic cases in which illegal hunting/poaching was suspected. Sarcoptic mange was observed in several wolves but not in brown bears or wolverines. Sarcoptic mange most likely was acquired from infected red foxes (*Vulpes vulpes*) that were killed by wolves. Other parasites and infectious diseases were only found sporadically.
Key words: Brown bear, *Canis lupus,* diseases, forensic medicine, *Gulo gulo,* infanticide, mange, mortality, pathology, *Sarcoptes scabiei,* trauma, *Ursus arctos,* wolf, wolverine.

INTRODUCTION

Free-ranging populations of brown bear (*Ursus arctos*) and gray wolf (*Canis lupus*) have increased on the Scandinavian Peninsula during the last two decades, whereas wolverine (*Gulo gulo*) numbers have slowly declined. The brown bear population in Sweden was estimated at approximately 1,000 animals in the year 2001; the most recent estimate of the wolverine population was 250 animals (Anonymous, 1999). Approximately 25 yr ago, the wolf population included less than five individuals, but during the last 20 yr, it has increased to more than 100 animals (Anonymous, 1999). Sweden has a hunting season for brown bears, and approximately 50–60 are harvested annually. General county permits issued by the Swedish Environmental Protection Board regulate this hunting, and a limited number of permits are issued to each county. Permits to capture or kill wolverines (usually two–five animals) are issued by the Swedish Environmental Protection Board for protecting semidomestic herds of reindeer (*Rangifer tarandus*) in northern parts of Sweden. The wolf is almost completely protected by national legislation, and only a limited number of permits for killing individual problem wolves have been issued.

Brown bears, wolves, and wolverines that are found dead in nature, that die during research, or that are shot with permission from the Swedish Environmental Protection Board or county authorities are, according to Swedish legislation, the property of the Swedish state. Dead animals of these species must be reported to the local police and, thereafter, submitted to the National Veterinary Institute (NVI) or the Swedish Natural History Museum for examination and preservation. Because it is responsible for forensic cases, the NVI receives a majority of these animals when natural mortality because of disease is suspected and when the cause of death is not obvious. Animals that die in conjunction with wildlife research projects also are submitted to the NVI.

General knowledge about diseases and natural mortality among free-ranging bears, wolves, and wolverines in Sweden is sparse, mainly because of the depressed populations during recent decades and limited submissions for diagnostic evaluation. This information is important, because excessive natural mortality can have negative impacts on management success for these species. With recent increases of large-predator populations in Sweden, increasing numbers of animals are available for diagnostic evaluation at the NVI every year. The present study summarizes diseases and causes of death of brown bears, wolves, and wolverines examined at the NVI from 1987 to 2001.

MATERIALS AND METHODS

Ninety-eight free-ranging brown bears, 20 wolves, and 27 wolverines examined at the NVI between 1987 and 2001 were included in the present study. Necropsies were conducted on all animals according to a standard protocol, with special attention given to forensic cases. For cases in which poaching was suspected, as well as in most forensic cases, the whole animal was radiographed to detect fragments of bullets or lead pellets. Animals were aged according to body size, weight, and dental development and were classified as juvenile (<1 yr), young (1–2 yr), or old (≥3 yr).

Specimens from liver, spleen, kidney, heart, and lung, as well as any tissue with signs of disease, were fixed in 10% neutral buffered formalin, sectioned at 4 μ, and examined histologically. When bacterial infections were suspected, liver and spleen or tissues with lesions were cultured for bacterial growth. In cases when parasitic infections were suspected, macroscopic examinations of the stomach, intestine, and lungs as well as fecal floatation and washing tissue through a sieve were used to recover parasites for identification. Samples of diaphragm or cheek muscle were routinely evaluated for *Trichinella* spp. by trichinoscopy or a digestion method (Roneus and Christensson, 1979).

RESULTS

Brown bear

Causes of mortality in brown bears are shown in Table 1. The most frequent cause of natural death was traumatic injury; 16 bears (16% of total submissions) were killed by other bears. All but one of these cases were young bears, and based on supporting observations from the field, these were classified as infanticide. Nine of these bears were less than 1 yr old, and six were 1–2 yr old. Eight were females, and seven were males. One bear was an adult female, and in this case, a male bear killed both cub and sow. Road accidents were the cause of mortality in five bears (5%). Three bears (3%), all younger than 1 yr, died from starvation.

TABLE 1. Causes of mortality in brown bears (*Ursus arctos*) examined at the National Veterinary Institute, Sweden, in the years 1987–2001.

Cause of mortality	No. of animals (%)
Killed by bear	16 (16)
Vehicular collision	5 (5)
Emaciation	3 (3)
Circulatory collapse	2 (2)
Septicemia	1 (1)
Forensic cases[a]	41 (42)
Euthanized[b]	12 (13)
Wildlife research[c]	9 (9)
Unknown	7 (7)
Total	98 (100)

[a] Killed by hunters in self-defense or suspected to be illegally shot
[b] Killed because either repeatedly killing domestic animals or appearing in villages and/or eating out of garbage bins or bee houses
[c] Died in conjunction with immobilization

Most forensic cases involved bears killed by hunters in self-defense during moose hunting. Seven bears were killed with special permission, because they were repeatedly appearing inside villages and/or eating from garbage bins.

Nine and 41 bears were examined for intestinal parasites and *Trichinella* spp., respectively. No parasites were detected.

Wolf

Causes of mortality in wolves are shown in Table 2. The most common cause of death in wolves (seven animals, 35% of total) was traumatic injuries associated with vehicular collisions.

One wolf, a young female, was killed as a result of a broken skull. Presumably, this injury was inflicted by a moose, as determined by supporting field evidence (observed tracks) that indicated a fight had

TABLE 2. Causes of mortality in wolves (*Canis lupus*) examined in the National Veterinary Institute, Sweden, in the years 1987–2001.

Cause of mortality	No. of animals (%)
Sarcoptic mange	4 (20)
Traffic collision	7 (35)
Killed by moose	1 (5)
Septicemia	1 (5)
Malformation	1 (5)
Forensic cases[a]	4 (20)
Euthanized[b]	1 (5)
Unknown	1 (5)
Total	20 (100)

[a] Killed by hunters in self-defense or suspected to be illegally shot

[b] Killed because either repeatedly killing domestic animals or appearing in villages and/or eating out of garbage bins or bee houses

TABLE 3. Causes of mortality in wolverines (*Gulo gulo*) examined in the National Veterinary Institute, Sweden, in the years 1987–2001.

Cause of mortality	No. of animals (%)
Predator/other wolverine	11 (41)
Nephritis	1 (4)
Forensic cases[a]	9 (33)
Wildlife research[b]	3 (11)
Unknown	3 (11)
Total	27 (100)

[a] Killed by hunters in self-defense or suspected to be illegally shot

[b] Died in conjunction with immobilization

taken place between a moose and wolves. Sarcoptic mange, most likely acquired from affected red foxes (*Vulpes vulpes*), was the primary mortality factor in four wolves. Three of the four cases of sarcoptic mange occurred in the year 2001 in a family group; one 1-yr-old animal and two 1.5-yr-old animals were affected. Septicemia, caused by *Pasteurella multocida,* was observed in one wolf.

Malformation of the spinal cord was observed in a 6-yr-old male with hemivertebra of the seventh thoracic vertebra. Increasingly debilitating clinical signs were observed by volunteers tracking this animal approximately 3 wk before it was killed. The animal was finally paralyzed in the hind legs and was incontinent.

One female was killed because of increasing interactions with male dogs. Concern existed that cross-breeding might occur, and she had repeatedly killed hunting dogs. Four wolves were examined as forensic cases, and all four animals were killed illegally (either shot or run over by snowmobile).

Seven animals were investigated for intestinal parasites and nine for *Trichinella* spp. Of these, one wolf was infected with *Taenia hydatigena* and another with *Uncinaria stenocephala.*

Wolverine

Causes of mortality in wolverines are shown in Table 3. The most common cause of death (11 animals, 41% of submissions) was traumatic injuries inflicted by other predators or wolverines. Other wolverines were identified as the source of this trauma in four cases; the source was uncertain in the remaining seven cases. Chronic nephritis was the primary cause of death in an old and emaciated male. Nine wolverines were examined as forensic cases, and all were found to have been either shot or killed in an illegal activity, such as being run over by a snowmobile and killed by a head trauma.

DISCUSSION

The present study was restricted to animals submitted to the NVI, and the results may not accurately represent all causes of natural mortality among these species in Sweden. For example, very young animals will be underrepresented in such submissions because of the den-related behavior of these species. These results, however, do provide information about causes of death associated with animals likely to be detected and reported by both the public and wildlife professionals. Many of the submitted animals were radiocollared as part of unrelated scientific studies. This was particularly true for wolves, because a large proportion of the existing population in Sweden is radiocollared and most adults are found after death. This should provide very complete and accurate information regarding adult wolf mortality in the future.

Overall, the most common cause of death in brown bears, wolves, and wolverines was traumatic injuries, and in wolves, these injuries were associated with vehicles. This may reflect the natural habit of wolves to move long distances from forests in the west and north of Sweden into more populated and road-dense areas in the east and south. Only five brown bears (5%) and none of the wolverines died from vehicle-related injuries, reflecting that these animals live in sparsely populated mountain and forest areas in the north and west of Sweden; both areas have few major roads. This contrasts with the results reported for black bears (*Ursus americanus*) in Florida, USA, where accidents related to vehicles caused more than 50% of reported mortality (Dunbar et al., 1998). This difference may be explained by the fact that Florida has a road-dense area.

In brown bears and wolverines, intraspecies killing (infanticide) was the most common cause of natural mortality. Infanticide often could be verified with supportive field evidence of fighting, because animals were radiocollared or being tracked. Infanticide is believed to relate to limited resources, social pathology, parental manipulation, predation, and/or sexual selection (Hausfater and Hrdy, 1984), and it has been reported in a large number of animal species and humans (Hrdy, 1979; Hausfater and Hrdy, 1984; Dunn et al., 2002). Infanticide has been reported previously among brown bears in Sweden (Swenson et al., 1997). Intraspecific fighting among wolverines also has been reported previously in northern Scandinavia and was the most important cause of juvenile mortality (Person et al., 2003). Infanticide in brown bears probably is associated most commonly with territorial males (Swenson et al., 1997). As indicated by one observed case in which both an adult female and her cub were killed, such mortality also may occur in adults while presumably defending their young.

Several ongoing wildlife research programs in Sweden involve large predators, and a large number of the brown bears, wolves, and wolverines are currently fitted with radiocollars or intra-abdominal radiotransmitters. These animals are easily found when dead; this allows accurate estimates of illegal hunting, which unfortunately still occurs in Sweden (World Wildlife Fund Sweden, 2001).

Mortality caused by infectious diseases in free-ranging brown bears appears to be uncommon. Captive brown bears reportedly have died from Aujeszky's disease (Banks et al., 1999), but this disease has not been observed in free-ranging animals, even in areas where wild boar (*Sus scrofa*) are infected (Capua et al., 1997). Mortality caused by infectious diseases, with the exception of sarcoptic mange, also seems to be rare in free-ranging wolves in Sweden. We found one case of septicemia caused by *P. multocida* but no indications of mortality associated with any other infectious disease. Reports on infectious diseases in free-ranging wolves include canine parvovirus infection (Mech and Sagar, 1993; Johnson et al., 1994), rabies (Rupprecht et al., 2001), canine distemper (Johnson et al., 1994), and leptospirosis (Khan, 1991). Mortality among wolf pups has been reported as a possible result of canine parvovirus or canine distemper infection in wild wolf packs in the USA (Johnson et al., 1994; Mech et al., 1997). Both the presence and potential impact of viral infections in Swedish wolves are unknown, and to our knowledge, no serologic data are available. Because the causes of mortality among wolf pups in Sweden are also unknown, obtaining more information regarding viral or bacterial diseases that occur in the wolf population may be warranted. The potential impact of sarcoptic mange, which was found in several wolves of the present study, also deserves attention, especially given the social behavior of this species and the potential for introduction by other domestic or wildlife species.

Information related to diseases and mortality in wolverines is sparse. Addison and Boles (1978) as well as Wilson and Zarnke (1985) reported on parasites in wolverines, and with the exception of a serologic survey of orthopoxviruses in carnivores in Scandinavia (Tryland et al., 1998), we could find no other reports of infectious diseases in wolverines.

Endoparasites were uncommon in all species included in the present study. This is in contrast to results for these species reported from North America (Addison and Boles, 1978; Phillips and Scheck, 1991) and Belarus (Shimalov and Shimalov, 2000), where endoparasites appear to occur more frequently. *Trichinella* spp. is reported in wolves from many parts of the world (Dick and Pozio, 2001) and in grizzly bears from Alaska (Zarnke et al., 1997). This parasite is quite common in red foxes in Sweden, and it has been found previously in large predators in Sweden (Mörner, 1992). The reason we did not detect *Trichinella* spp. in brown bears in the present study is not understood but may relate to food habits. Brown bears do not normally feed on red foxes or badgers (*Meles meles*) (Dahle, 1996; Sandegren and Swenson, 1997), which represent the main reservoirs of *Trichinella* spp. in Sweden. *Trichinella* spp. also was not found in 20 brown bears examined during the 1970s in Sweden (Roneus and Christensson, 1979) but was reported to be present in 9% of brown bears and 33% of the wolves examined in Finland from 1996 to 1998 (Oivanen et al., 2002). The high prevalence among wolves in Finland could be related to the high infection rate (38%) of *Trichinella* spp. in the raccoon dog (*Nyctereutes procyonides*), which is not present in Sweden (Oivanen et al., 2002). In Finland, the infection rates in brown bears and wolves were highest in the southwestern part of the country, where the raccoon dog is common.

Malformation of the spinal cords was observed in one 6-yr-old male wolf. This male is believed to have sired two litters. If hereditary, this malformation might be important in the future wolf population, as has been described in dogs (Kramer et al., 1982). However, no more cases of spinal cord malformations have been observed during the last 3 yr.

Swedish brown bear and wolf populations currently are increasing, and the animals generally are in good condition. The present report demonstrates that infectious diseases, possibly with the exception of sarcoptic mange in wolves, do not seem to be a factor that is negatively impacting these populations. Illegal killing and mortality associated with other human activity, however, are problems that could potentially impact future management of these species, especially in the case of the wolf population. The cause of the negative trend in wolverine numbers is unknown, but results suggest that it may relate to illegal killing.

ACKNOWLEDGMENTS

We gratefully acknowledge Ewa Backman, Helene Gustafsson, Hans Kanbjer, Stern Lundin, and Johan Karevik for excellent technical assistance. We also acknowledge Marie-Pierre Ryser-Degiorgis and Arne Söderberg for valuable discussions.

LITERATURE CITED

ADDISON, E. M., AND B. BOLES. 1978. Helminth parasites of wolverine, *Gulo gulo,* from the District of Mackenzie, Northwest Territories. Canadian Journal of Zoology 56: 2241–2242.

ANONYMOUS. 1999. Sammanhållen rovdjurspolitik, Slutbetänkande av rovdjurs-utredningen SOU 1999:146, 348 pp. [Report to the Swedish Government. In Swedish.]

BANKS, M., L. S. TORRACA, A. G. GREENWOOD, AND D. C. TAYLOR. 1999. Aujeszky's disease in captive bears. Veterinary Record 145: 362–365.

CAPUA, I., R. FICO, M. BANKS, M. TAMBA, AND G. GAZETTA. 1997. Isolation and characterization of an Aujeszk's disease virus naturally infecting wild boar (*Sus scrofa*). Veterinary Microbiology 55: 141–146.

DAHLE, B. 1996. Nutritional ecology of brown bears (*Ursus arctos*) in Scandinavia with special reference to moose (*Alces alces*). MS Thesis, Norwegian University of Science and Technology, Trondheim, Norway, 33 pp.

DICK, T. A., AND E. POZIO. 2001. *Trichinella* spp. and Trichinellosis. *In* Parasitic diseases of wild mammals, W. M. Samuel, M. J. Pybus, and A. A. Kocan (eds). Iowa University Press, Ames, Iowa, pp. 380–396.

DUNBAR, M. R., M. W. CUNNINGHAM, AND J. C. ROOF. 1998. Seroprevalence of selected disease agents from free-ranging black bears in Florida. Journal of Wildlife Diseases 34: 612–619.

DUNN, D. G., S. G. BARCO, D. A. PABST, AND W. A. MCLELLAN. 2002. Evidence for infanticide in bottlenose dolphins of the western north Atlantic. Journal of Wildlife Diseases 38: 505–510.

HAUSFATER, G., AND S. B. HRDY. 1984. Comparative and evolutionary perspectives on infanticide: Introduction and overview. *In* Infanticide: Comparative and evolutionary perspectives, G. Hausfater and S. B. Hrdy (eds.). Aldine Publishing Company, Hawthorne, New York, pp. xiii–xxxv.

HRDY, S. B. 1979. Infanticide among animals: A review, classification, and examination of the implication for the reproductive strategies of females. Ethology and Sociobiology 1: 13–40.

JOHNSON, M. R., D. K. BOYD, AND D. H. PLETSCHER. 1994. Serological investigations of canine parvovirus and canine distemper in relation to wolf (*Canis lupus*) pup mortalities. Journal of Wildlife Diseases 30: 270–273

KHAN, A. M., S. M. GOYAL, S. L. DIESCH, L. D. MECH, AND S. H. FRITTS. 1991. Seroepidemiology of leptospirosis in Minnesota wolves. Journal of Wildlife Diseases 27: 248–253.

KRAMER, J. W., S. P. SCHIFFER, R. D. SANDE, AND E. K. WHITENER. 1982. Characterization of heritable thoracic hemivertebra of German shorthaired pointer. Journal of the American Veterinary Medical Association 181: 814–815.

MECH, L. D., AND M. G. SAGAR. 1993. Canine parvovirus effect on wolf population change and pup survival. Journal of Wildlife Diseases 29: 330–333.

———, H. J. KURTZ, AND S. GOYAL. 1997. Death of a wild wolf from canine parvoviral enteritis. Journal of Wildlife Diseases 33: 321–322.

MÖRNER, T. 1992. Liv och död bland vilda djur. Sellin & Partner, Stockholm. 170 pp. [In Swedish.]

OIVANEN, L., C. M. O. KAPEL, E. POZIO, G. LA ROSA, T. MIKKONEN, AND A. SUKURA. 2002. Associations between *Trichinella* species and host species in Finland. Journal of Parasitology 88: 84–88.

PERSON, J., T. WILLEBRAND, A. LANDA, R. ANDERSEN, AND P. SEGERSTRÖM. 2003. The role of intraspecific predation in the survival of juvenile wolverines. Wildlife Biology 9: 21–28.

PHILLIPS, M. K., AND J. SCHECK. 1991. Parasitism in captive and reintroduced red wolves. Journal of Wildlife Diseases 27: 498–501.

RONEUS, O., AND D. CHRISTENSSON. 1979. Presence of *Trichinella spiralis* in free-living red foxes (*Vulpes vulpes*) in Sweden related to *Trichinella* infection in swine and man. Acta Veterinaria Scandinavia 20: 583–594.

RUPPRECHT, C. E., K. STÖHR, AND C. MEREDITH. 2001. Rabies. *In* Infectious diseases of wild mammals, E. S. Williams and I. K. Barker (eds). Iowa University Press, Ames, Iowa, pp. 3–37.

SANDEGREN, F., AND J. SWENSON. 1997. Björnen—Viltet, ekologin och människan. Svenska Jägareförbundet, Stockholm, Sweden, 70 pp. [The brown bear—The animal, ecology, and man; in Swedish.]

SHIMALOV, V. V., AND V. T. SHIMALOV. 2000. Helminth fauna of the wolf (*Canis lupus* Linnaeus, 1758) in Belorussian Polesie. Parasitology Research 86: 163–164.

SWENSON, J. E., F. SANDEGREN, A. SÖDERBERG, A. BJÄRVALL, R. FRANZÉN, AND P. WABACKEN. 1997. Infanticide caused by hunting of male bears. Nature 386: 450–451.

TRYLAND, M., T. SANDVIK, J. M. ARNEMO, G. STUVE, Ø. OLSVIK, AND T. TRAAVIK. 1998. Antibodies against orthopoxviruses in wild carnivores from Fennoscandia. Journal of Wildlife Diseases 34: 443–450.

WILSON, N., AND R. L. ZARNKE. 1985. Occurrence of the ear canker mite, *Otodectes cynotis* (Hering), on the wolverine, *Gulo gulo* (L.). Journal of Wildlife Diseases 21: 180.

WORLD WILDLIFE FUND SWEDEN. 2001, Rapport från vargsymposiet Vålådalen Mars 2001, 150 pp. [In Swedish.]

ZARNKE, R. L., R. GAMBLE, R. A. HECKERT, AND J. VER HOF. 1997. Serologic survey for *Trichinella* spp. in grizzly bears from Alaska. Journal of Wildlife Diseases 33: 474–479.

Received for publication 13 November 2002.

Home Ranges and Movements of Pronghorn in Northern Arizona

Richard A. Ockenfels
William K. Carrel

Arizona Game and Fish Department
Research Branch
2221 W. Greenway Road
Phoenix, Arizona 85023-4312

Charles van Riper III

U.S. Geological Survey
Biological Resources Division
Colorado Plateau Research Station
P. O. Box 5614
Flagstaff, Arizona 86011-5614

Abstract. During October 1992, we captured 17 adult pronghorn (*Antilocapra americana*) within the environs of Wupatki National Monument (NM), Arizona, and 20 adults in or near Petrified Forest National Park (NP), Arizona. Each animal was relocated over the next two years to determine home-range sizes, movement patterns, and movement barriers. The greatest distance between any two consecutive locations was the only variable having a substantial effect on home-range size; neither animal gender or mean distance between locations added to the predictive ability. Multiple core use areas were more evident for females and their home ranges were significantly larger in Wupatki NM than in the Petrified Forest NP environs. Unfenced, 2-lane paved roads did not restrict pronghorn movements within either park, and no peak crossing periods were discernible. However, fenced, paved 2-lane roads and fenced, divided 4-lane highways outside of the parks constituted movement barriers. Furthermore, fenced railroad rights-of-way were barriers and influenced shapes of pronghorn home ranges. Pronghorn populations in northern Arizona can, therefore, be partially defined by highway and railroad barriers. These barriers could be modified to facilitate pronghorn interchange by either: (1) removing fencing; (2) expanding rights-of-way dimensions, then modifying fences; or (3) relocating rights-of-way out of pronghorn habitat. Knowledge of pronghorn home ranges and movements can be used to better manage populations, plan land uses, and mitigate human-related activities.

Key words: Antelope, *Antilocapra americana*, fences, geographic information systems, highways, home ranges, movements, Petrified Forest National Park, pronghorn, railroads, rights-of-way, Wupatki National Monument.

Pronghorn (*Antilocapra americana*) are a species of special concern in Arizona and intensified management is necessary to ensure that adequate populations are maintained throughout the state. Knowledge of pronghorn movement patterns is needed for effective land-use planning, mitigating effects of human-related activities, and practicing sensible game management (e.g., harvest rates).

In managing pronghorn, human-related activities are of concern because they can lower habitat quality (Neff 1986). With increased knowledge of pronghorn movements, land planners and managers can improve the design of developments, better place livestock water sources, and improve the design of fence placement. Pronghorn herd management strategies in Arizona are accomplished through hunt structures based on game management units (GMUs). Although natural landscape features are sometimes used to define GMU boundaries, more often boundaries are major roads.

In some areas, it is believed that highway and railroad fenced rights-of-way fragment pronghorn habitat and restrict movements, thereby isolating populations or preventing movements to seasonal ranges (Buechner 1950, O'Gara and Yoakum 1992, Ockenfels et al. 1994). Pronghorn are generally considered a nomadic animal, moving within habitats in response to changing conditions due to drought, winter storms, human disturbances, forage changes, and water availability (O'Gara and Yoakum 1992, Ockenfels et al. 1994). With increased habitat fragmentation, fewer pronghorn populations can respond to perturbations and maintain traditional migratory behavior (O'Gara and Yoakum 1992). Determining if highways and railroads are movement barriers can assist in better management of pronghorn populations.

This study was initiated to examine home ranges and movement patterns of pronghorn in two study areas in northern Arizona. Our objectives were to: (1) document pronghorn movement patterns; (2) determine home-range sizes for female and male adult pronghorn; (3) determine whether interchange occurred among neighboring herds; and (4) identify what types of barriers isolated pronghorn.

Study Areas

We chose two locations in northern Arizona, each delineated by a GMU and also centered around a national park. Our northeastern study area was most of GMU 2A that encompassed Petrified Forest National Park (NP) (Fig. 1). The north-central study area contained Wupatki and Sunset Crater National Monuments (NM) and encompassed most of GMU 7E (Fig. 2).

Northeastern Study Area

We centered our efforts south of I-40, in or near Petrified Forest NP, excluding lands administered by the Navajo Nation. Most of this area was

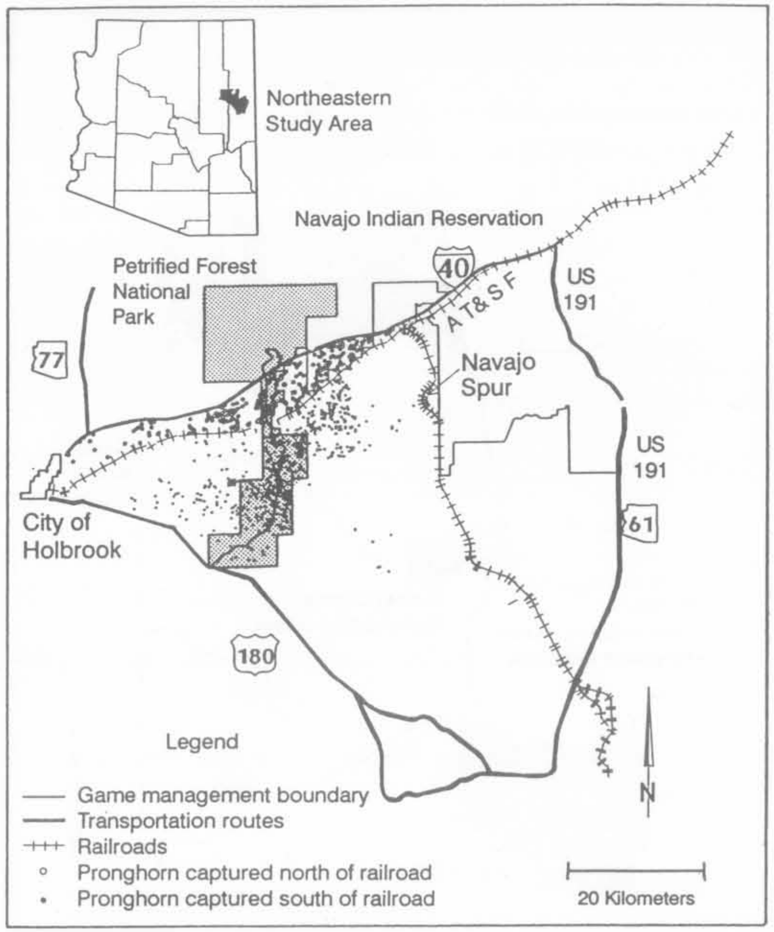


Fig. 1. Locations of radio-equipped adult pronghorn sightings, from 1992–94, within our northeastern Arizona study area. The study area was bounded by Game Management Unit 2A and centered on Petrified Forest National Park.

undulating terrain with rugged mesas or hills throughout, and numerous gullies extending from highly-eroded cliffs. Elevation ranged from 1,650 to 1,800 m. The Puerco River was the only major waterway but was not deeply incised.

This study area contained four sub-areas based on highways and railroads: (1) the area north of I-40 to the Navajo Indian Reservation; (2) the area between I-40 and north of the fenced Atchison, Topeka, and Santa Fe (AT&SF) railroad right-of-way; (3) the area south of the AT&SF right-of-way to U.S. 180 and east to the Navajo railroad spur line; and (4) the area east of the Navajo spur line (Fig. 1).

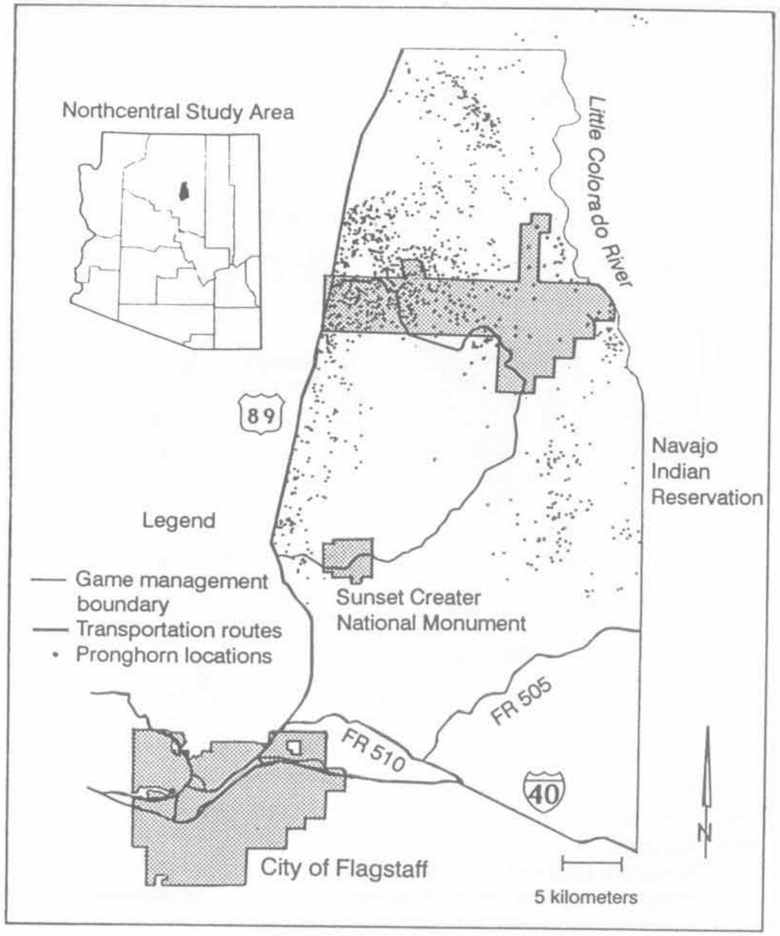


Fig. 2. Locations of radio-equipped adult pronghorn sightings, from 1992–1994, within our north-central Arizona study area. The study area, bounded by Game Management Unit 7E, was centered on Wupatki-Sunset Crater National Monuments.

Yearly precipitation was low (1941–1970: $\bar{x}$ = 18.7 cm), with over one-half of the rainfall occurring during brief thunderstorms in July–September (Sellers and Hill 1974). Average snowfall was only 12.4 cm, and snow seldom remained on the ground more than a few days.

Great Basin grassland (Brown 1994) and juniper (*Juniperus* spp.) woodland dominated the landscape. Blue grama (*Bouteloua gracilis*) and alkali-sacaton (*Sporobulus airoides*) were the predominant grasses. Sagebrush (*Artemisia* spp.), saltbush (*Atriplex* spp.), rabbitbrush (*Chrysothamnus* spp.), and Mormon-tea (*Ephedra* spp.) were scattered throughout, often forming small thickets. Snake-weed (*Gutierrezia* spp.) was abundant in localized poorer-condition sites. Plant nomenclature follows Kearney and Peebles (1960).

North-central Study Area

We selected this study area east of U.S. 89 (Fig. 2). Elevation ranged from 1,350 m along the Little Colorado River to 2,700 m at Sunset Crater NM. Undulating terrain throughout the area was broken by volcanic cinder hills and lava flows.

Because of the wide elevational range, climate in this area varied considerably. In the low-elevation northern portion, precipitation was low (1956–1962: $\bar{x}$ = 13.1 cm), with some December–January snowfall ($\bar{x}$ = 21.8 cm). Because of the presence of the nearby San Francisco Peaks, snowfall in the southern portion was substantially greater, resulting in extensive snow cover. Summer (July–September) rainfall in the southern portion was more consistent than in the northern portion, and year-round precipitation was greater (Flagstaff 1950–1970: $\bar{x}$ = 50.3 cm).

A short-grass prairie of *Hilaria* spp. and alkali-sacaton predominated the northern portion of this study area (Brown 1994). The southern portion was predominantly Rocky Mountain Coniferous Forest (Brown 1994), which was comprised almost entirely of ponderosa pine (*Pinus ponderosa*). Juniper woodlands occupied most of the eastern edge, as well as a band between the pine forest and short-grass prairie. Localized, dense stands of cliffrose (*Cowania mexicana*) and Apache plume (*Fallugia paradoxa*) occurred in the juniper woodlands.

Methods

Capture and Location

Using a net-gun fired from a helicopter (Firchow et al. 1986), we captured adult pronghorn in mid-October 1992. All animals were radio-equipped, ear-tagged, and released at their capture sites. In the northeastern study area, we captured pronghorn on and near Petrified Forest NP, but only in sub-areas south of I-40 and west of the Navajo spur line (Fig. 1). At our north-central study location, we captured pronghorn on or near Wupatki NM, all east of U.S. 89 and north of U.S. Forest Service roads (FR) 510 and 505.

We aerially located pronghorn two to three times per month, between October 1992 and September 1994, from various modified, high-wing, single engine aircraft. Each aircraft had a forward-phased, twin-Yagi antenna array mounted to the wing struts for signal detection and general signal direction, and a rotatable, belly-mounted, two-element antenna used to pinpoint pronghorn locations (Carrel 1972a,b). During flights, we plotted animal locations on U.S. Geological Survey (USGS) 7.5-min topographic maps. After each flight, Universal Transverse Mercator (UTM) coordinates for each location were defined to the nearest 0.1 km.

We also located pronghorn one to two times per month on the ground using a handheld two-element antenna. The UTM coordinates were derived to the nearest 0.1 km from USGS 7.5-min maps; we also used a Global Positioning System (GPS) receiver to calculate coordinates. After encoding and verifying the data, we merged ground and aerial locations, then transferred the UTM-coordinate files into a Geographic Information System (GIS).

Data Analysis

Statistical significance was set at alpha = 0.10. We decreased chances of accepting a false null hypothesis (Type II error) by choosing 0.10 instead of 0.05, but increased the probability of rejecting the null when it was indeed true (Type I error; Zar 1984). To provide management recommendations, with anticipated small sample sizes, we deemed Type II errors more important than Type I. Statistical tests were performed with SPSS/PC+ software (Norusis 1990).

Movements

Using features in HOME RANGE (Ackerman et al. 1990), we calculated (in km) the distance between consecutive locations and mean distance for each animal (which we defined as a movement). For each animal, we counted the number of movements ≥ 10 km and ≥ 20 km, and also recorded the largest movement and date (month, day, year) of that completed move.

Frequency distributions of movement variables ($\bar{x}$ distance, ≥ 10 km, ≥ 20 km, greatest distance) were assessed for normality with Kolmogorov-Smirnov (K-S) one-sample tests (Zar 1984). For descriptive purposes, we calculated gender-specific descriptive statistics ($\bar{x}$, SD, range) for normally-distributed variables in each study site, then pooled data and calculated descriptives for all adult pronghorn.

We tested for study site or gender-related differences, as well as site x gender interactions, in mean distance and greatest distance moved with 2 x 2 analysis-of-variances (ANOVAs). ANOVA was used because we were simultaneously testing >2 categories of normally distributed variables. Within study sites, we used *t*-tests for gender comparisons.

A Mann-Whitney (M-W) comparison was utilized for gender-related differences in long distance movements. The numbers of movements ≥ 10 km were not normally distributed, so a 2-group rank test had to be used. We also used a M-W comparison to test if site affected the number of movements ≥ 10 km made by females.

Rights-of-way Crossings

To determine if pronghorn crossed unfenced roads and highway or railroad rights-of-way, using GIS, each study area was subdivided by fenced rights-of-way and park roads. We then overlaid locations on this sub-area cover to match each location. Lastly, we sorted the file by animal identification and date, counting movements between appropriate sub-areas. For each study area, we summed the crossings by gender for each month from October 1992 to September 1994.

The 100% minimum-convex polygon method was selected as our estimate of home-range size, using a 50% convex polygon as the estimate of core (high use) areas (Ackerman et al. 1990). For each site, we calculated gender-specific descriptive statistics ($\bar{x}$, SD, range) for home-range and core use sizes, and assessed frequency distributions of home-range and core area size for normality with K-S one-sample tests. We then pooled the data and calculated descriptives for all adult pronghorn. We tested for site or gender-related differences, as well as site x gender interactions, in home-range and core use size with 2 x 2 ANOVAs. As with movement data, we used *t*-tests within each site for gender-related comparisons.

To determine significant factors affecting home-range size, we plotted all variables against each other, ran a correlation matrix, then used forward, step-wise regression.

Results

Capture and Location

In our northeastern study area, we captured, radio-collared, and ear-tagged 20 (15F, 5M) pronghorn. Four does were captured north and the remaining 16 pronghorn south of the AT&SF right-of-way. These animals were relocated 1,736 times (Fig. 1). Most locations were during daylight, between 0500 and 2000 Mountain Standard Time (MST).

We captured, radio-collared, and ear-tagged 17 (13F, 4M) adult pronghorn in the north-central study area. Five animals (4F, 1M) were captured within Wupatki NM, the rest captured to the north. We relocated these animals 1,671 times over the next two years, mostly between 0500 and 2000 MST (Fig. 2).

General Movements

Normality tests indicated that long distance movements were not normally distributed, whereas mean distance and greatest distance between any two consecutive locations were likely sampled from normally-distributed populations (Table 1).

Table 1. Movement and home-range characteristics of adult pronghorn in two areas of northern Arizona, 1992–1994.

Variable	Northeastern study area		North-central study area		Overall
	Females	Males	Females	Males	
n	15	5	13	4	37
Mean distance[a]	3.3	2.7	3.4	3.1	3.2
SD	0.6	0.4	0.5	0.5	0.6
Range	2.5–4.4	2.0–2.9	2.5-4.0	2.4–3.6	2.0–4.4
Number of movements ≥10 km[b]	36	7	66	4	113
Number of movements ≥20 km[b]	3	0	5	2	10
Mean of greatest distance[a]	14.4	9.0	16.8	13.2	14.4
SD	8.0	2.0	6.4	7.1	7.0
Range	6.0–35.0	6.5–10.6	7.6–33.7	7.8–22.8	6.0–35.0
Mean home-range size (km^2)[c]	124.0	81.7	195.2	135.6	144.6
SD	59.6	40.9	130.1	59.4	95.7
Range	56.5–243.2	44.4–140.0	80.5-552.0	72.8–211.1	44.4–552.0
Mean core use area (km^2)[c]	21.2	9.2	36.7	27.7	25.7
SD	5.4	7.4	25.4	31.9	20.2
Range	9.7-28.1	2.1-20.6	16.1-104.7	7.7–75.0	2.1–104.7

[a] Km between two consecutive locations for each animal as calculated by HOME RANGE (Ackerman et al. 1990), then averaged for mean distance.

[b] Distance between two consecutive locations.

[c] Home-range size using 100% minimum convex polygon and core use area using 50% minimum convex polygon from HOME RANGE (Ackerman et al. 1990).

Mean movements did not differ (F = 1.01; df = 1,36; P = 0.321) by site, but did (F = 5.34; df = 1,36; P = 0.027) by gender (Table 1); females ($\bar{x}$ = 3.3 km, SD = 0.5, n = 28) tended to move more in their home ranges than did males ($\bar{x}$ = 2.9 km, SD = 0.5, n = 9). No site x gender interactions were observed (F = 0.72; df = 1,36; P = 0.404). Much of the gender-related difference can be explained by a correlation (r = 0.64, n = 37, P <0.001) between mean movements and greatest movements.

We found no difference (F = 1.54; df = 1,36; P = 0.224) in greatest movements for the two study sites, but greatest movements differed (F = 3.03; df = 1,36; P = 0.091) by gender (Table 1); females ($\bar{x}$ = 15.5 km, SD = 7.3) had larger maximum movements than males ($\bar{x}$ = 10.9 km, SD = 5.1). As with mean movement, there was no site x gender interaction (F = 1.59; df = 1,36; P = 0.719).

Females had more (M-W Z = -2.01, P = 0.045) movements ≥10 km than males. Few females or males had movements ≥20 km. Females in the north-central site had more (M-W Z = -1.95, P = 0.051) movements ≥10 km than females in the northeastern site.

Specific Movements Within Study Areas

For the 20 adult pronghorn captured in the northeastern site, females tended to move more (t = 2.26, df = 18, P = 0.036) than males, and greatest movements of females were more variable and exceeded (t = 2.41, df = 17.63, P = 0.027) those of males (Table 1). Most (65%) pronghorn made some movements ≥10 km, however, only 15% made infrequent movements ≥20 km.

The greatest single movement was 35.0 km, made between 10 and 17 May 1993, by a doe north of the AT&SF railroad right-of-way. Overall, this doe ranged east-west from the community of Navajo nearly to Holbrook (Fig. 1). A doe south of the right-of-way moved 28.3 km (prior to 5 May 1993).

Of the 17 adult pronghorn in the north-central site, females did not (t = 0.93, df = 15, P = 0.393) move about more than males, nor did female greatest movements exceed (t = 0.94, df = 15, P = 0.363) those of the males (Table 1). Most (76%) pronghorn exhibited at least some movements ≥10 km. Only 3 (17.6%) had movements ≥20 km, and these were infrequent (only 2–3 times). Unlike the northeastern location, where only females (n = 3) moved long distances, one male and two females in the north-central location had movements ≥20 km. One female moved 33.7 km between 31 March and 3 April 1993.

Rights-of-way Crossings

Crossings, by both females and males, of the paved but unfenced road in Petrified Forest NP occurred throughout the two years of this study (Fig. 3).

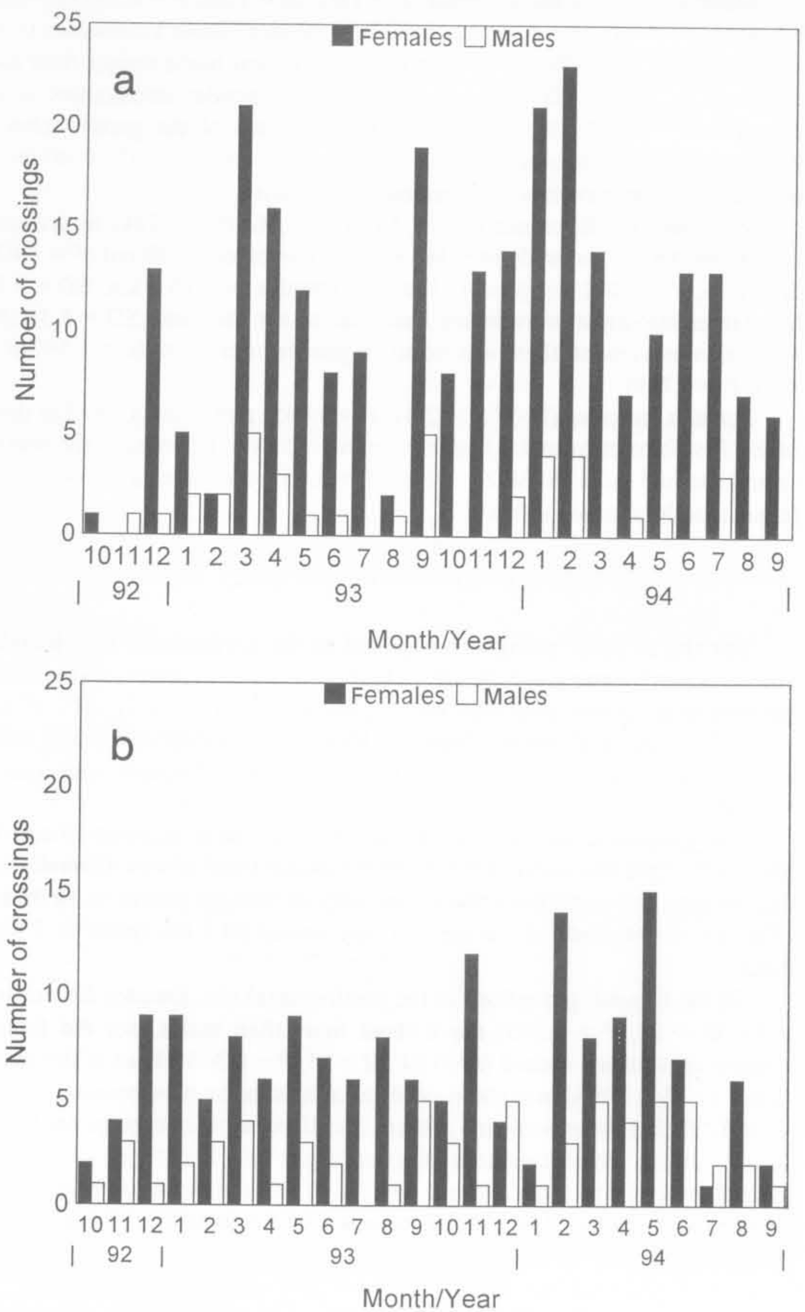


Fig. 3. Number of crossings during 1992–1994, by adult radio-equipped pronghorn, of unfenced, paved roads at (a) Petrified Forest National Park and (b) Wupatki National Monument.

No discernible crossing peak by either females or males was evident. Relative to the number captured, neither females or males seemed to cross more readily. Only two of the 15 females never crossed the road; one always stayed to the east, the other to the west. During the two years of this study, no females or males in the northeastern site crossed paved highways that were fenced (Fig. 1). Many pronghorn locations were within one km of I-40, US 191/AZ 61 and US 180; but no animals crossed. In fact, some of the home ranges seemed bounded by the roads. In addition, no crossings of the AT&SF or Navajo spur railroad rights-of-way were recorded (Fig. 1). For example, pronghorn captured north of the AT&SF had home ranges bounded by the railroad right-of-way and I-40, resulting in linear shapes, while those captured south of the railroad had non-linear home range shapes.

In our north-central study area, we documented 165 crossings of the paved, unfenced Wupatki NM road by females during the two years (Fig. 3b). One doe crossed a minimum of 46 times, including at least once in 21 of 24 months. Crossings occurred during all months and seemed to peak in winter and early spring of 93–94. For males, crossings ($n = 65$) occurred throughout the study by two of four bucks; one buck crossed a minimum of 44 times. One doe crossed the Little Colorado River, twice moving in the early spring onto the Navajo Indian Reservation to fawn (Fig. 2). No crossings of US 89 were documented, although numerous pronghorn locations were within 1 km of the fenced highway (Fig. 2).

Home Ranges and Core Use Areas

Home-range sizes clustered in the 75–125 km^2 range (Fig. 4). Few home ranges encompassed <50 km^2, and the three home ranges >250 km^2 were for females that had made large-scale seasonal movements. Core use areas were much smaller (Fig. 4). Home range and core use distributions were sampled from normal distributions (Table 1).

Home-range sizes varied by study site ($F = 5.05$; df = 1,36; $P = 0.031$), but not by gender ($F = 2.09$; df = 1,36; $P = 0.158$). Home-range sizes and variability were larger ($t = 2.15$, df = 22.32, $P = 0.042$) in the north-central study area than in the northeastern site (Table 1). There was no ($F = 0.06$; df = 1,36; $P = 0.805$) site x gender interaction in home-range size.

Similarly, core size varied by site ($F = 7.02$; df = 1,36; $P = 0.012$), but not by gender ($F = 2.23$; df = 1,36; $P = 0.145$). As with home-range size, core size and variability were larger ($t = 2.48$, df = 18.42, $P = 0.023$) in the north-central site than in the northeastern site (Table 1). There was no ($F = 0.04$; df = 1,36; $P = 0.844$) site x gender interaction.

The correlation between core and home-range size was only moderate ($r = 0.56$, $n = 37$, $P < 0.001$). Apparently other factors were influencing home-range size in our study areas. A forward, step-wise regression ($F = 71.98$; df = 1,35; $P < 0.001$) indicated that the greatest movement value was the only substantial variable affecting home-range size ($r^2 = 0.67$). Neither

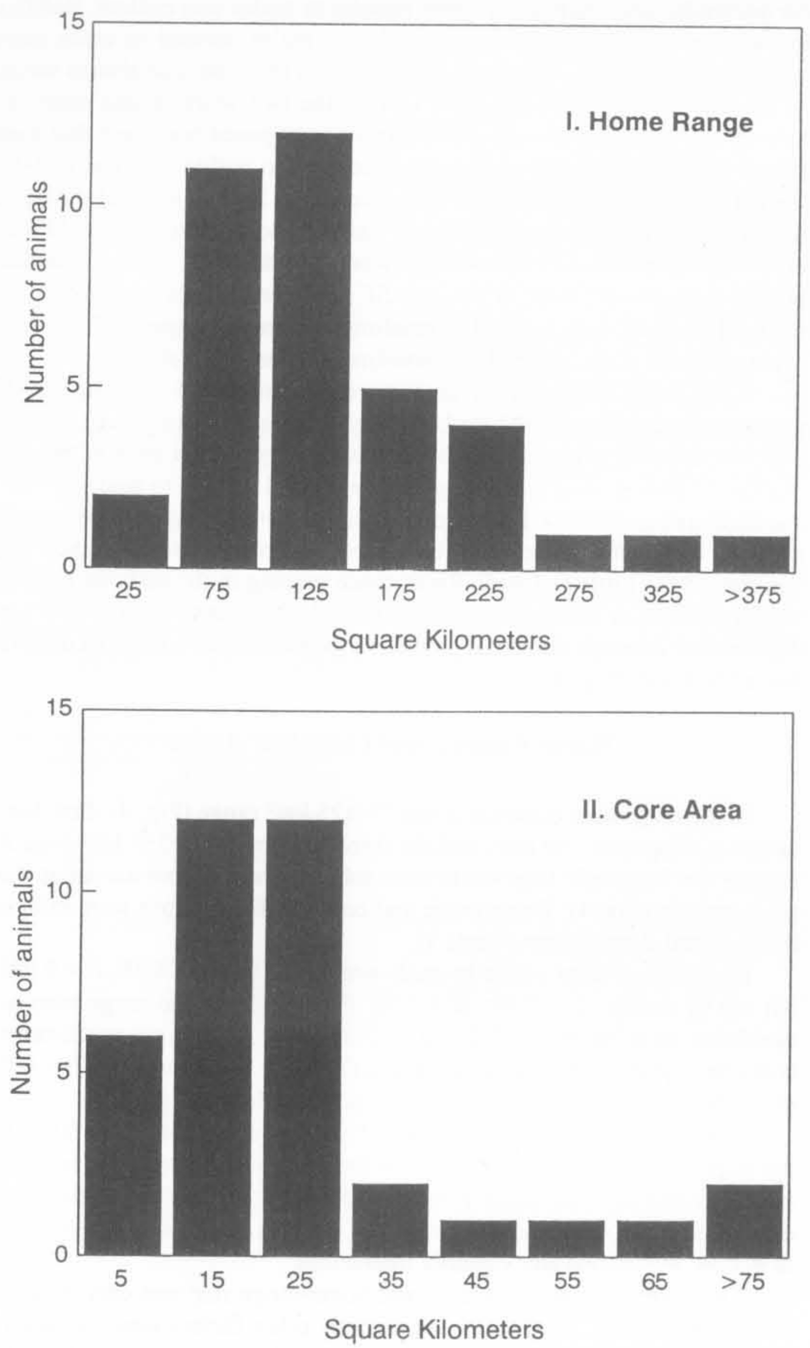


Fig. 4. Adult pronghorn (I) home-range and (II) core area sizes, in the northeastern and north-central Arizona study areas, 1992–1994.

the number of locations or gender added to r^2 nor did the mean distance between locations. However, when home range boundaries delineated by HOME RANGE, were overlaid with locations, most suggested fairly uniform movements throughout the home ranges.

The greatest influence on home range shapes of the pronghorn at both study areas was human-related development, particularly fenced highways and railroad rights-of-way.

Discussion

In our discussion we will deal with three major topics. First, we compare movements and home ranges between our study animals, then with findings from other areas of Arizona and the western United States. Secondly, we discuss what did, or did not, constitute a movement barrier. The third topic will deal with management actions that can be taken from the results of our research.

Movement and Home Range Comparisons

Movements

Mean pronghorn movements were not significantly different between our study sites. Furthermore, Ockenfels et al. (1994) found similar movement distances of pronghorn in central Arizona. There is nothing in the literature to indicate that mean movements (between relocation) in Arizona were different from pronghorn elsewhere. The nature of the species likely dictates at least a certain amount of movement to obtain daily requirements. These requirements should not differ substantially because of area if habitat conditions are reasonable.

Some of the differences in movements that we found between sites and gender can be accounted for by climatic influences. Pronghorn in our north-central study area were exposed to a regime of more variable precipitation and snowfall. Therefore, those pronghorn would sometimes have to move seasonally to prevent winter kill. This situation did not occur in our northeastern site, nor in central Arizona (Ockenfels et al. 1994). Historically, pronghorn in the north-central site used the higher elevations near Flagstaff for fawning and summer range. With human encroachment in many high elevation parks and meadows, suitable summer range areas have been reduced east of US 89. Recruitment into this pronghorn population could, therefore, be adversely affected by the loss of quality fawning and summer range.

The older age of pronghorn males captured in this study, particularly at the northeastern site, could be a significant factor in why gender-related movement differences were observed. Similar to central Arizona, young males tend to move more than mature, territorial individuals (Ockenfels et al. 1994).

Young males are often found in doe bands, and thus their movements are similar. Particularly during the breeding season, mature males move very little. With older males radio-collared in our study, one would expect less movement of this sex because of territorial constraints.

One other factor that contributed to movement differences between sites was the availability of permanent water sources. At our northeastern study site, the Puerco River provided permanent water throughout the year, especially within Petrified Forest NP. However, at the north-central site, there was no permanent water within Wupatki NM and pronghorn had to leave the park for livestock water sources to the north.

Home Range Comparisons

Pronghorn in our north-central study area had significantly larger home ranges than the northeastern animals. Weather certainly had an influence, as many of the north-central animals summered at higher elevations. However, lack of permanent water in the middle of our north-central study area (i.e, Wupatki NM), was probably a major contributing factor to the increase in home-range sizes. Ockenfels et al. (1994) showed that in central Arizona, water played a role in pronghorn home-range sizes. In fact, water in the West has a profound seasonal effect on the distribution of pronghorn (O'Gara and Yoakum 1992, Clemente et al. 1995).

Movement Barriers

Fenced Highway Rights-of-way

Buechner (1950), working in Texas, observed the negative effect highway rights-of-way fences had on pronghorn movements. White (1969) demonstrated that fenced highways blocked the movements of pronghorn in northern Arizona during a severe winter storm, resulting in losses of as much as 80% of some herds. In central Arizona, Ockenfels et al. (1994) provided further evidence of substantial fragmentation of pronghorn habitat and isolation of pronghorn herds by fenced highways.

After observing similar fragmentation in our study in northern Arizona, we are left to believe that rights-of-way fences are the major factor affecting pronghorn movements across their range.

Fenced Railroad Rights-of-way

Two transcontinental railroads traverse the entire width of Arizona. The AT&SF roughly follows the 35th parallel of northern Arizona, crossing much suitable pronghorn habitat. In addition to the two transcontinental lines, Arizona has many local rail lines, some of which could be in pronghorn habitat. In our northeastern study area, we demonstrated that pronghorn were isolated into two populations by the AT&SF. Similar fragmentation probably occurs in many other areas in the state and throughout the West, particularly if the tracks are tightly fenced on both sides.

Unfenced Rights-of-way

Although considerable traffic occurred seasonally on Petrified Forest NP and Wupatki NM roads, these unfenced paved roads did not adversely affect the movement patterns of pronghorn during the two years of our study. Ockenfels et al. (1994) observed similar patterns relative to certain roads (e.g., Dugas Road) in central Arizona. Thus, for management purposes, mitigation efforts should concentrate on fenced rights-of-way. Nonetheless, preventing any fencing of unfenced roads, highways, and railroads should also be of paramount concern for resource managers.

Management Implications

Fragmentation of habitat by fenced rights-of-way impairs movement of pronghorn in northern Arizona and probably affects survival and genetics of those herds. To facilitate movement and interchange among herds, it is imperative to reduce the effect of fenced rights-of-way on pronghorn populations. The pronghorn can then freely move as perturbations occur. Survival rates and genetic flow likely would increase. Winter kills, as a result of fenced rights-of-way blocking seasonal movements from severe storms (e.g., White 1969), could be mitigated with reasonable intervention.

Possible mitigation features could be: (1) removing fences along rights-of-way; (2) expanding rights-of-way dimensions by placing fences further away from the road or railroad, then modifying the fences to permit better movement of pronghorn between fenced areas (O'Gara and Yoakum 1992, Ockenfels et al. 1994); or (3) relocating rights-of-way out of pronghorn habitat. The use of underpasses has been found not to be an effective pronghorn management tool (Ward et al. 1980). In some areas, emergency plans could be established to remove fences during periods of severe weather to allow movement to and back from lower elevation habitats. To do so effectively, however, would require extensive knowledge of pronghorn movement corridors.

Arizona's current survey and harvest management program for pronghorn is designed around GMUs, most of which have been in existence since 1958. Many of the boundaries delineating these GMUs were based on highway rights-of-way. Because of the absence of movement across fenced right-of-ways observed during our study, some GMUs contain multiple pronghorn populations because of multiple fenced highway rights-of-ways within their boundaries. For example, GMU 7 is divided into 7E and 7W (by US 89) for some hunts, but typically not for pronghorn. Yet our results point out that animals do not interchange between 7E and 7W. Thus, isolated populations occur and combined survey and harvest data would not accurately reflect true pronghorn populations. Similar situations probably occur in other areas of the state, and perhaps throughout the West. If GIS methodology could be used to estimate the extent of the problem, pronghorn management strategies could be modified to better accommodate such fragmentation.

Acknowledgments

We thank D. M. Conrad and J. J. Hervert, along with pilots from Southwest Helicopter, for their expertise in capturing pronghorn. Pilots D. W. Hunt, W. H. David, S. A. Sunde, and B. D. Coffman were key components to the study, providing aerial, fixed-wing support for captures and location efforts. We appreciate A. Alexander's expertise as a backup for aerial location and J. L. Bright for the many ground locations. J. A. Wennerlund provided GIS support. The cooperation of NPS staffs at Wupatki-Sunset Crater National Monuments and Petrified Forest National Park was integral in completing the study. This cooperative research effort was supported by funds from the Federal Aid to Wildlife Restoration Act, administered by the Arizona Game and Fish Department, and funds from the U.S. National Park Service.

Literature Cited

Ackerman, B. B., F. A. Leban, M. D. Samuel, and E. O. Garton. 1990. User's manual for program home range. University of Idaho Forestry, Wildlife, and Range Experimental Station Technical Report 15, Moscow. 80 pp + ix.

Brown, D. E., editor. 1994. Biotic communities: southwestern United States and northwestern Mexico. University of Utah Press, Salt Lake City. 342 pp.

Buechner, H. K. 1950. Life history, ecology, and range use of the pronghorn antelope in Trans-Pecos Texas. American Midland Naturalist 43:257–355.

Carrel, W. 1972a. Forward phased twin-yagi antenna array. International Association of Natural Resource Pilots Handbook. Unpublished mimeo.

Carrel, W. 1972b. Removable rotary antenna handle for aerial radio-tracking. International Association of Natural Resource Pilots Handbook. Unpublished mimeo.

Clemente, F., R. Valdez, J. L. Holechek, P. J. Swank, and M. Cardenas. 1995. Pronghorn home range relative to permanent water in southern New Mexico. Southwestern Naturalist 40:38–41.

Firchow, K. M., M. R. Vaughan, and W. R. Mytton. 1986. Evaluation of the hand-held net gun for capturing pronghorns. Journal of Wildlife Management 50:320–322.

Kearney, T. H., and R. H. Peebles. 1960. Arizona flora. University of California Press, Berkeley. 850 pp + viii + 1.

Neff, D. J. 1986. Pronghorn habitat description and evaluation: a problem analysis report. Arizona Game and Fish Department Federal Aid Project W-78-R Report, Phoenix. 15 pp.

Norusis, M. J. 1990. SPSS/PC+ 4.0 base manual and statistics 4.0 manual. SPSS, Inc., Chicago, Ill.

Ockenfels, R. A., A. Alexander, C. L. Dorothy Ticer, and W. K. Carrel. 1994. Home ranges, movement patterns, and habitat selection of pronghorn in central Arizona. Arizona Game and Fish Department Technical Report 13, Phoenix. 80 pp + vi.

O'Gara, B. W., and J. D. Yoakum, editors. 1992. Pronghorn management guides. Proceedings of the Pronghorn Antelope Workshop 15 (Supplement). 101 pp v.

Sellers, W. D., and R. H. Hill. 1974. Arizona climate: 1931–1972. University of Arizona Press, Tucson. 616 pp + viii.

Ward, A. L., N. E. Farnwalt, S. E. Henry, and R. A. Hodorff. 1980. Effects of highway operation practices and facilities on elk, mule deer, and pronghorn antelope. Federal Highway Administration Report FHWA-RD-79-143, Washington, D.C. 48 pp.

White, R. W. 1969. Antelope winter kill, Arizona style. Proceedings of the Western Association of Game and Fish Agencies 49:251–254.

Zar, J. H. 1984. Biostatistical analysis. 2nd ed. Prentice-Hall, Englewood Cliffs, N.J. 718 pp + xiv.

Sources and Patterns of Black Bear Mortality in Louisiana

Richard M. Pace, III,[1] *U.S. Geological Survey, Biological Resources Division, Louisiana Cooperative Fish and Wildlife Research Unit, Louisiana State University, Baton Rouge, LA 70803–6202*

Donald R. Anderson, *U.S. Fish and Wildlife Service, Tensas River National Wildlife Refuge, Rt. 2, Box 295, Tallulah, LA 71282*

Steve Shively, *Louisiana Department of Wildlife and Fisheries, P. O. Box 98000, Baton Rouge, LA 70898*

Abstract: Louisiana black bears *(Ursus americanus luteolus)* are protected under the Endangered Species Act and live in 3 isolated geographic areas thought to encompass nearly all breeding individuals for that subspecies. Management strategies to recover these bears continue to evolve without knowledge of any differences in demographic patterns among these populations. We summarized data on Louisiana black bear deaths to see if any evidence existed for differences in mortality patterns among the 3 subpopulations. Since June 1992, 34 of 75 (45±6 [SE]%) verified losses (72 deaths plus 3 live removals) were caused by vehicular collisions, including road kills (27), farm equipment (5), and train (2), which was the most common cause of death. Although this bear subspecies has been protected under the Endangered Species Act since 1992, at least 12 (16±4%) have been illegally shot. Nearly two-thirds of verified deaths have come from the coastal population, which is not believed to be as abundant as the population in northeast Louisiana. Also, mortalities in the coastal population were predominantly adult females, whereas subadult males dominated mortalities in northeast Louisiana. Given the frequency with which adult females have been lost from the coastal population, the geographic limits of suitable bear habitat, and increasing development, long-term viability of this population is precarious. Patterns of observed mortalities alone suggest that conservation agencies must develop area-specific management strategies for these 3 isolated populations.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 54:365–373

In the Coastal Plain of the southeastern United States, several relatively isolated black bear populations exist which differ by geographic extent and availability of

1. Present address: Northeast Fisheries Science Center, 166 Water Street, Woods Hole, MA 02543.

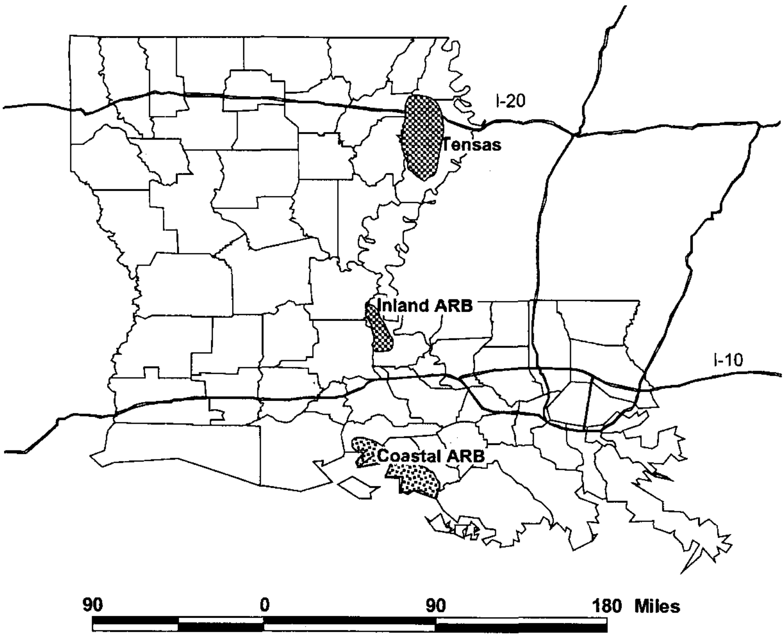


Figure 1. Louisiana black bear populations study areas designated for the analysis of mortality patterns.

habitat and are imperiled in the region primarily because of habitat loss (Wooding et al. 1994). Therefore, habitat enhancement and protection actions should dominate recovery or maintenance strategies offered for regional and state-wide bear populations. However, demographic patterns may affect short-term stability of local populations. Reproductive outputs vary within and among black bear populations, but this variability is generally thought to be a consequence of food availability and habitat quality (Pelton 1982, Bunnell and Tait 1981). Even if reproduction, which is generally difficult to monitor in unharvested bear populations, could be quickly enhanced through management, increased reproductive output does not always produce recruitment (Garshelis 1994). Conversely, differing mortality patterns may be a useful short-term indicator that new management emphases may benefit a local bear population. Evaluations of mortality patterns, in particular road kills, have been published for other coastal southeastern coastal plain bears, including North Carolina (Warburton et al. 1993), Florida (Wooding and Brady 1987) and the Great Dismal Swamp in Virginia (Hellgren and Vaughan 1989). We examined mortality sources and patterns for 3 relatively isolated black bear populations in Louisiana to determine if differences emerged among these populations or with other published reports that suggested differing management emphases were warranted.

Because all of Louisiana lies within the historic range of *U. a. luteolus* (Hall 1981), all Louisiana bears are protected by similarity of appearance and listed as threatened under the Endangered Species Act of 1973 (Fed. Reg. 57[4]:588:595).

Three relatively isolated geographic areas encompass all the known black bear breeding populations in Louisiana (Fig. 1). Probably the most numerous bear population located is in northeast Louisiana and is composed of 2 subpopulations with minimum interchange due to their separation by U.S. Interstate 20 (Pace et al. in press). The Inland Atchafalaya River population is considerably smaller than the other 2 populations (Pace et al. in press). All 3 populations have been subjects of continuous capture and tagging efforts since 1992 (Pace et al. in press) and researchers, together with the various responsible wildlife managment agencies, have placed a high priority on investigating and reporting bear deaths. However, no attempt had been made to summarize these data and assess their usefulness for setting management strategies.

We are grateful to many biologists, agents, mangers, technicians, and students who spent many field hours helping acquire these data. Research efforts have been supported by a wide array of public and private funding arrangements including considerable support from the U.S. Fish and Wildlife Service and the Louisiana Department of Wildlife and Fisheries. We are also grateful to an increasingly knowledgeable and responsive public in Louisiana who reported many of the otherwise unverifiable bear deaths or who otherwise aided our agencies' efforts. We thank D. Hightower, M. Vaughan, R. Wagner, and an anonymous referee for their reviews of our manuscript.

Methods

The 3 areas in Louisiana with occupied bear range are: 1) the Tensas River Basin (Tensas) on lands within, surrounding, and north of Tensas River National Wildlife Refuge (TRNWR), 2) the upper Atchafalaya River Basin (Inland ARB), especially the northwestern two-thirds of Point Coupee Parish, and 3) the coastal area west of the Atchafalaya River Delta (Coastal ARB), primarily south of U.S. Hwy. 90 in St. Mary and Iberia parishes. Considered part of the Tensas bear population, but north of and separated from TRNWR by U.S. Interstate 20 (I−20), are a number of bears living in small fragmented forest tracts owned by Deltic Timber Corporation. Tensas bears south of I-20 rarely encounter high-to-moderate traffic roads, whereas those north of I−20 are often forced to cross such roads to move among fragmented forest patches (Anderson 1997, Marchinton 1995). Road distribution and traffic volumes relative to bear habitat may be roughly comparable between Tensas north of I-20 and Inland ARB. In contrast, bear habitat in Coastal ARB is dissected by more well-traveled, paved, 2-lane roads. Row-crop agriculture is a common land use in all 3 geographic areas, but sugarcane farming is commonly practiced in Coastal ARB, occurs on the fringe of Inland ARB, and is absent in Tensas.

We pooled information from data bases held by 3 agencies to construct a list of verified bear mortalities. Verified mortalities were distinguished among reported mortalities by having filed reports demonstrating that agency personnel or bear researchers had examined the carcass. Dead bears were identified to study area, sex, age class (adult [>3], subadult, and cub of the year [<1]), whether or not the bear was tagged (ear tag and/or radio collar), probable cause of death, and date of death.

Dates of deaths varied in precision due to decomposition states of carcasses and were recorded as the first of the month if only month was reported.

We graphically explored data for patterns in timing of death (by year or month). We used loglinear models (Fienberg 1977) to examine associations between counts of deaths and sex, age (adult or subadult [included cubs of the year]), and area. Using a subset that excluded management and research-related losses, pooling among types of vehicular deaths and pooling other deaths, we used Fisher's exact test to examine if mortality counts by type (open situation vs. secluded situation) was independent of whether or not bears were tagged. This later test was performed to address whether or not inclusion of bears without radios would bias frequency of mortality causes toward vehicular deaths.

Results

Between 1 June 1992 and 31 May 2000, at least 75 bear (72) deaths plus live removals (3) occurred in Tensas (18), Inland ARB (8), and Coastal ARB (49) (Table 1). These 75 losses were attributed to road kills (27), unknown causes (15), shootings (12), management takes (8), sugarcane harvesting equipment (5), natural (4), research takes (2), and trains (2). Losses resulting from management actions included takes of 7 nuisance bears and 1 orphaned cub. Two management actions were live removals of nuisance bears from the population and their placement in zoos. The orphaned cub was moved from Coastal ARB to a rehabilitation center and later released at Tensas on 12 December 1997. It was radio-tagged at release and known to have left Tensas; its whereabouts are at present unknown. Management takes represented losses only to Coastal ARB (7) and Inland ARB (1). The 2 research takes were from deaths related to trapping efforts. Only 8 losses were observed for the Inland ARB population, and 4 of these were from illegal shooting. Mortalities were distributed somewhat uniformly among years (Fig. 2), but unevenly among months (Fig. 3). Relatively few deaths were

Table 1. Verified Louisiana black bear deaths (72) and live removals (3) from 3 areas arranged by probable source summed over years for the period 1 June 1992–31 May 2000.

Source	Coastal ARB	Inland ARB	Tensas	Total
Road kill	17		10	27
Poaching	6	4	2	12
Unknown	10	1	4	15
Management take[a]	7	1		8
Cane harvester	5		5	
Natural	2		2	4
Train	1	1		2
Research take	1	1		2
Totals	49	8	18	75

a. Includes 3 live removals. Two animals were placed in zoos. The third was moved from Coastal ARB to a rehabilitation center and later released at Tensas on 12 December 1997. It was radio tagged at release and known to have left Tensas; its whereabouts are at present unknown.

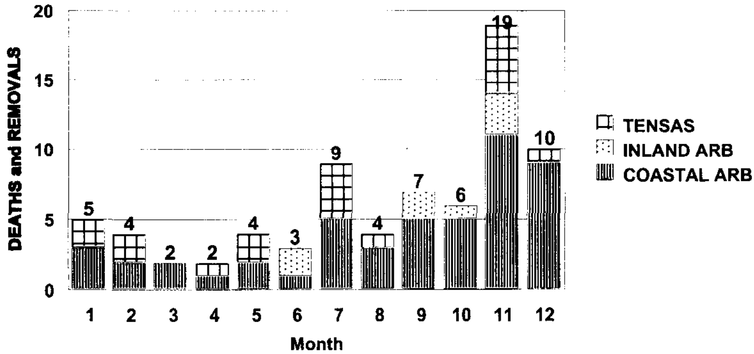


Figure 2. Verified bear deaths (72) and live removals (3) by year for the period 1 June 1992–31 May 2000 combined for 3 areas of Louisiana.

observed in the months of March through June (12±4%), whereas 25±5% occurred in November (Fig. 3). Road kills of males were nearly equal between January–June vs. July–December (6 vs. 8), whereas all 13 road kills of female bears occurred July–December (Fisher's exact test $P=0.016$). Mortality counts by source were nearly identical between sexes (all areas pooled) except for management takes (6M: 2F).

Despite small sample sizes, we had statistical evidence that mortalities ($N=65$), excluding research and management takes, were distributed disproportionately across areas by sex and age class (subadult and adult) ($\chi^2=9.18$, df=3, $P=0.03$). Adult female bears (42%) comprised the majority of deaths in Coastal ARB, whereas 9 of 18 Tensas bear deaths were subadult males (Table 2). During 8 years of observation, 8.5 times as many adult female bear deaths were recorded from Coastal ARB than Tensas. We observed 7 deaths of cubs of the year, all of which occurred in Coastal ARB.

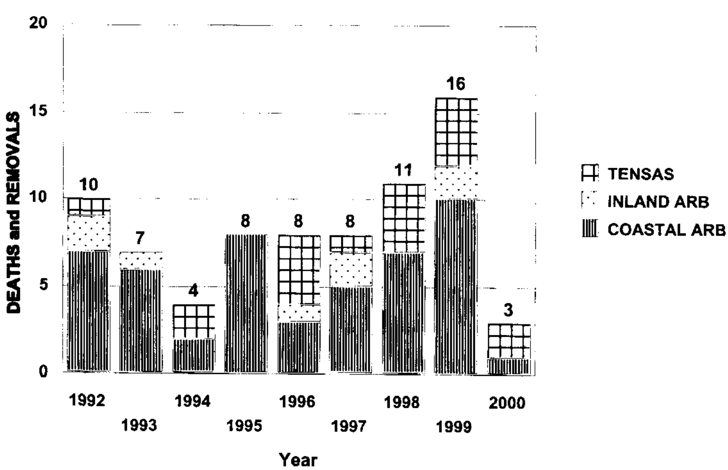


Figure 3. Verified bear deaths (72) and live removals (3) by month combined over the period 1 June 1992–31 May 2000 and over 3 areas of Louisiana.

Table 2. Verified bear deaths (72) plus live removals (3) arranged by sex, age, and area, and summed over years for the period 1 June–31 May 2000.

	Male		Female		
Area	Subadult	Adult	Subadult	Adult	Total
Coastal ARB	11	10	7	17	49[a]
Tensas	9	5	2	2	18
Inland ARB	2	1	1	3	8[b]
Totals	22	16	10	22	75

a. Total includes 4 bears of unknown sex and/or age.
b. Total includes 1 bear of unknown age.

Over all, 35% of dead bears (excluding research and management takes) were wearing radio collars and the proportion was the same for Tensas and Coastal ARB. We had no statistical evidence to suggest that the proportion of bears wearing radio collars differed between deaths in relatively open settings (road kills, sugarcane harvesting equipment, and trains) and deaths in relatively secluded settings (shootings, natural, and unknown) (Fisher's exact test $P=0.426$). Neither did proportions differ for open-setting deaths among radio tagged, ear tagged only, and untagged bears (Fisher's exact test $P=0.294$). These results suggest that including unmarked bears did not strongly bias the observed distribution of deaths among causes of mortality.

Discussion

Based upon habitat availability, trapping success, and associated observations during 1988–1998, the expert opinions of biologists have remained constant and place the combined or statewide bear population at 200–300 animals (excluding cubs of the year), with the population distributed according to Tensas > Coastal ARB >> Inland ARB. At such low population abundance, moderate levels of anthropogenic mortality will depress bear population growth rates, especially if adult females constitute many of the deaths. Hence, the larger number of deaths observed and the high proportion of adult females lost from Coastal ARB and Inland ARB were especially disconcerting. An analysis of mark-recapture data gathered during 1992–2000 (R. M. Pace, La. Coop. Fish and Wildl. Unit, Baton Rouge, La., unpubl. data) provided evidence for lower adult female survival in Coastal ARB ($75.8\pm8.6\%$) than in Inland ARB ($94.0\pm8.2\%$) which was more indicative of an unexploited bear population (Bunnell and Tait 1981).

Road kills are a common source of non-hunting mortality in bear populations (Pelton 1982). Evaluations of road kills have been published for other coastal southeastern coastal plain bears, including North Carolina (Warburton et al. 1993), Florida (Wooding and Brady 1987), and the Great Dismal Swamp in Virginia (Hellgren and Vaughan 1989). In general, young males are the most common group of bears in road kill statistics (Wooding and Brady 1987, Warburton et al., 1993), especially during summer. As in North Carolina and Florida, road kills of female bears were more common in fall, which is at least partly explained by female home range and habitat use shifts in fall (Hellgren and Vaughan 1989, Nyland 1995, Wagner 1995). In Coastal ARB, many bears use sugar cane fields in fall (Nyland 1995), which places them near roads more often during summer than winter.

We continue to be amazed by the number of illegal shootings of bears in Louisiana. Some of these undoubtedly occurred as the result of nuisance situations in rural settings. Some were linked to perpetrators ostensibly engaged in legal hunting, and for whatever reason decided to shoot a bear. Although agencies and non-governmental groups have been engaged in a public information campaign and nuisance abatement program for several years, these takes do not seem to have slowed.

We are somewhat surprised by our lack of evidence that the proportion of bears wearing radio collars was different among mortality causes. Because of the relatively dense understory and forbidding terrain of areas occupied by bears in Louisiana, it would be extremely difficult to locate bears that died from poaching, unknown, or natural causes without a radio tag on or near the carcass. We believe that our considerable ongoing efforts to trap, tag, and monitor bears coupled with aid from landowners interested in our work, led us to many dead but uncollared bears. Concomitantly, radio tags probably allowed us to find some bears that were struck by vehicles and wandered away from the road (open setting mortality) to secluded sites. The net result is that we believe our tabulation of mortality sources is less biased than a study without any radio-tagged animals, but may be somewhat biased relative to a study based solely on radio-tagged animals.

Management Recommendations

Antropogenic causes of mortality are taking a relatively large toll on the Coastal ARB population, both in terms of absolute numbers and because adult females represent a high proportion of the take. Similarly, female losses in Inland ARB are unacceptably high if that small population is to recover. Conversely, the mortality pattern observed in Tensas was predictable from life history and behavioral knowledge of black bears: young male bears tend to disperse and face greater hazards (Wooding and Maddrey 1994). The Coastal ARB population represents a challenge if management goals include the long term maintenance or enhancement of this population. Wildlife conservation agencies can do little to slow increasing human population growth and development in the area. The U.S. Fish and Wildlife Service has begun acquisition of land for a refuge featuring bears within Coastal ARB. Agencies have already joined with academic and non-governmental groups to work toward Louisiana black bear restoration (Bullock 1992), but the education and public awareness efforts need to be increased. Because poaching appears to be a relatively substantial cause of mortality in Coastal ARB and possibly Inland ARB, any increase in enforcement activities should be directed to those areas.

Management plans include repatriation of native bears to suitable vacant habitat within the historic range of Louisiana black bears (U.S. Fish and Wildl. Serv. 1995).

An effective method for repatriation appears to be winter translocation of female bears with their cubs of the year. Repatriation actions require selections of source populations from which adult females would be taken. Our mortality data represent the first comparative demographic information upon which to base a selection of a source population. In an analysis of mark recapture data spanning the same 8 years for Coastal ARB and Inland ARB, Pace (La. Coop. Fish and Wildl. Unit, Baton Rouge, unpubl. data) estimated annual survival of adult females at 75.8±8.6% and 94.0±8.2%, respectively. The already relatively low apparent survival and the disturbingly disproportionate number of mortalities of adult females in Coastal ARB seem to disqualify Coastal ARB as a potential source population until a more complete analysis of the impact of these removals on the long-term viability of this population can be completed.

Literature Cited

Anderson, D. R. 1997. Corridor use, feeding ecology, and habitat relationships of black bears in a fragmented landscape in Louisiana. M.S. Thesis, Univ. Tenn., Knoxville. 124pp.

Bullock, J. F., Jr. 1992. The Black Bear Conservation Committee. Miss. For. Assn. Tree Talk 14(1):4–6, 20.

Bunnell, F. L. and D. E. N. Tait. 1981. Population dynamics of Bears—implications. Pages 75–98 *in* C. W. Fowler and T. D. Smith, eds. Dynamics of large mammal populations. John Wiley & Sons, New York, N.Y.

Eastridge, R. 2000. Experimental repatriation of black bears to the Big South Fork area of Kentucky and Tennessee. M.S. Thesis, Univ. Tenn., Knoxville. 228pp.

Feinberg, S. E. 1977. The analysis of cross-classified categorical data. MIT Press. Cambridge, Mass. 151pp.

Hall, E. R. 1981. The mammals of North America. John Wiley & Sons, New York, 2 vols.

Hellgren, E. C. and M. R. Vaughan. 1989. Demographic analysis of a black bear population in the Great Dismal Swamp. J. Wildl. Manage. 53:969–977.

Garshelis, D. L. 1994. Density-dependent population regulation of black bears. Pages 3–14 *in* M. Taylor, ed. Density-dependent population regulation of black, brown, and polar bears. Internatl. Conf. Bear Res. Manage. Monogr. Series No. 3. 43pp.

Marchinton, F. B. 1995. Movement ecology of black bears in a fragmented bottomland hardwood habitat in Louisiana. M.S. Thesis, Univ. Tenn., Knoxville. 107pp.

Nyland, P. D. 1995. Black bear habitat relationships in coastal Louisiana. M.S. Thesis. Loiusiana State Univ., Baton Rouge, La. 76pp.

Pace, R. M., III, D. R. Anderson, and T. E. Rabot. In press. Louisiana Status Report. *In:* Proc. 15th Eastern Black Bear Workshop, Lennox, Mass.

Pelton, M. R. 1982. Black bear *(Ursus americanus).* Pages 504–514 *in* J. A. Chapman and G. A. Feldhamer, eds. Wild mammals of North America: biology, management, and economics. Johns Hopkins Press, Baltimore, Md.

U.S. Fish and Wildlife Service. 1995. Louisiana black bear recovery plan. Jackson, Miss. 52pp.

Wagner, R. O. 1995. Movement patterns of black bears in south central Louisiana. M.S. Thesis, La. State Univ., Baton Rouge. 57pp.

Warburton, G. S., R. C. Maddrey, and D. W. Rowe. 1993. Characteristics of black bear mortality on the coastal plain of North Carolina. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 47:276–286.

Wooding, J. B. and J. R. Brady. 1987. Black bear road kills in Florida. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 41:438–442.

———, J. R. Cox, and M. R. Pelton. 1994. Distribution of black bears in the southeastern coastal plain. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 48:270–275.

——— and R. C. Maddrey. 1994. Impacts of roads on bears. East. Workshop Black Bear Res. and Manage. 12:124–129.

Road Ecology Center
UC Davis

Title:
Trains, Grains, and Grizzly Bears: Reducing Wildlife Mortality on Railway Tracks in Banff National Park

Author:
Pissot, Jim, Defenders of Wildlife Canada

Publication Date:
05-20-2007

Series:
Recent Work

Publication Info:
Road Ecology Center

Permalink:
http://escholarship.org/uc/item/8sf4b0jr

Additional Info:
Pissot Jim. “Trains, Grains, and Grizzly Bears: Reducing Wildlife Mortality on Railway Tracks in Banff National Park”. In Proceedings of the 2007 International Conference on Ecology and Transportation, edited by C. Leroy Irwin, Debra Nelson, and K.P. McDermott. Raleigh, NC: Center for Transportation and the Environment, North Carolina State University, 2007. pp. 64-67.

Keywords:
grizzly bear mortality, train-wildlife collisions, inhibit wildlife movement

Abstract:
Between 2000 and 2007, the Canadian Pacific Railway emerged as the leading human-related cause of grizzly bear mortality in Banff National Park. Seven grizzlies were struck by CPR trains, and none of the five cubs orphaned by these collisions survived within the park. Other wildlife also have been struck and killed. Spilled grain, track-side attractants, and preference of animals for open travel corridors are cited as contributing to these collisions. CPR’s rail lines bisect the Canadian Rockies and, along with other factors, inhibit wildlife movement and genetic connectivity. Ecologists and conservations seek to implement measures to ensure continued ecological connectivity across these man-made barriers. Railways have adopted various methods to reduce wildlife mortality, including more efficient sealing of grain cars, vacuum cars to recover spilled grain, and warnings that alert wildlife of approaching trains. Fencing and crossing structures, such as those assisting wildlife to cross highways, also are being considered. We discuss the causes of train-wildlife collisions, steps taken to reduce the number of collisions, propose further opportunities to reduce the likelihood of collisions.

Copyright Information:
All rights reserved unless otherwise indicated. Contact the author or original publisher for any necessary permissions. eScholarship is not the copyright owner for deposited works. Learn more at http://www.escholarship.org/help_copyright.html#reuse

eScholarship
University of California

eScholarship provides open access, scholarly publishing services to the University of California and delivers a dynamic research platform to scholars worldwide.

Trains, Grains, and Grizzly Bears: Reducing Wildlife Mortality on Railway Tracks in Banff National Park

Jim Pissot (403-678-0016, jpissot@defenders.org), Executive Director, Defenders of Wildlife Canada, P.O. Box 40001, Canmore, Alberta T1W 3H9 Canada

Abstract: Between 2000 and 2007, the Canadian Pacific Railway emerged as the leading human-related cause of grizzly bear mortality in Banff National Park. Seven grizzlies were struck by CPR trains, and none of the five cubs orphaned by these collisions survived within the park. Other wildlife also have been struck and killed. Spilled grain, track-side attractants, and preference of animals for open travel corridors are cited as contributing to these collisions. CPR's rail lines bisect the Canadian Rockies and, along with other factors, inhibit wildlife movement and genetic connectivity. Ecologists and conservations seek to implement measures to ensure continued ecological connectivity across these man-made barriers. Railways have adopted various methods to reduce wildlife mortality, including more efficient sealing of grain cars, vacuum cars to recover spilled grain, and warnings that alert wildlife of approaching trains. Fencing and crossing structures, such as those assisting wildlife to cross highways, also are being considered. We discuss the causes of train-wildlife collisions, steps taken to reduce the number of collisions, propose further opportunities to reduce the likelihood of collisions.

Introduction

Connectivity, at a range of scales, is critical to the survival of wildlife populations. In Banff National Park in the Rocky Mountains of western Canada, Canada's main east-west highway, a principal rail line, and other natural and man-made barriers divide wildlife populations. Measures have been taken to mitigate the busy traffic on the Trans-Canada Highway, including fencing to increase motorist safety and reduce wildlife mortality, and under- and over-passes to promote safe wildlife movement. Speed limits and access are reduced on other roadways to conserve wildlife.

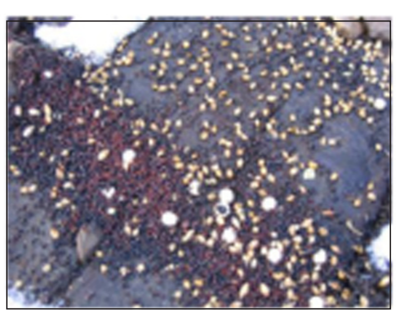
Since 2000, the Canadian Pacific Railway has emerged as "the number one known source of human-caused mortality" of grizzly bears in Banff National Park. Grizzlies and other animals are attracted to grain spilled from passing railway cars. Twelve grizzlies have been killed directly by trains or lost permanently to Banff National Park over the past seven years. This total includes four breeding age females and their seven cubs of the year. In 2006 alone, four black bears were killed. Necropsies by Parks Canada staff found grain in the stomachs of two of the black bears. More than a decade of efforts by the Railway has not meaningfully reduced the amount of grain on the tracks nor the number of animals struck and killed.

Spilled Grain

Grain spilled by rail cars has been identified by Parks Canada staff as the principal attraction that draws bears to their deaths between the rails in Canada's mountain parks. There are four major sources of spilled grain:

1. Derailments and other significant events that spill large amounts of grain;
2. Faulty, leaking, or improperly closed grain car discharge gates that spill small amounts of grain along the tracks, particularly along sections of tracks where cars are shaken in any way;
3. The temporary siding, stopping, or parking of grain trains, allowing leaking cars to spill larger amounts of grain in a single spot between the rails; and
4. The spillage of excess grain that has fallen onto flat surfaces of grain cars at the loading terminals and subsequently falls to the ground as the train moves along.

The Railway and government agencies respond promptly to derailments and larger spills, and usually take measures to prohibit bears and other wildlife from feeding on the spilled grain. Fencing, 24-hour human presence, Karelian bear dogs and other deterrents have been used until all grain has been cleaned. Similarly, minor spills from stopped or sided cars generally receive prompt attention, although some reported spills have remained on the tracks for more than 36 hours.



Smaller spills—with potentially more negative impacts on wild animals within Banff National Park—occur when small amounts of grain trickle along the tracks as loaded trains move west. Grain falls from hopper car discharge gates at the bottom of grain cars that are defective, worn or not closed properly. Of course, these are the same gates that spill larger amounts of grain when the cars move more slowly or with more jerky motions, or when the train is stopped.

The second source of trickled grain originates at terminals where grain hopper cars are loaded. Careless loading causes grain to fall outside of the hopper cars and collect on virtually every flat surface, including the tops of the cars and flat decks on either end of the cars. In turn, grain falls off these surfaces as trains move along. More than 10 cm of sprouting grain, spilled grain and detritus has been observed on hopper car end decks.

In 1990, the Canadian Pacific Railway introduced a specially designed self-powered vacuum truck to remove grain spilled on the tracks. The vacuum has proven effective on larger spills, but nearly useless on the constant streams of grain that trickles from leaking discharge gates and flat surfaces.

The Canadian Pacific Railway reports increased shipments of grain each year. Tracks were recently modified to accommodate even longer trains—up to two miles in length. So, there is increasing potential for grain spillage. Parks Canada wardens noted in 2006, “this is one of the heaviest years we've seen [for grain on the tracks].” Supervisors reported to the media, “our wardens are saying they're seeing more grain on the tracks.”

It has been said that some leaking grain cars arrive at the Vancouver terminal completely empty. Grain can be found scattered along the tracks, heavier in locations where cars move more slowly or are jostled along the way. In some sections, spilled grain sprouts to a thick green carpet. The Farmer Rail car coalition estimates that up to Cdn $10 million worth of grain and pulse are spilled annually from leaking hopper cars hauled by the Canadian Pacific Railway.

The Canadian Pacific Railway leases bout 6,300 grain hopper cars that are owned by the Canadian federal government. These cars have been in service for 30 to 40 years, and carry a variety of discharge gate designs. New loading and unloading equipment used at terminals is more powerful, likely stressing older discharge gates. Most cars owned by the Railway are of newer design, compatible with powerful and high-speed terminal equipment. Anecdotal evidence suggests that some of the older designs may be the most troublesome—worn or damaged, and failing to close securely.

<u>Grain and Dead Grizzlies</u>

According to senior Parks Canada officials, “bears frequent the tracks because they get the reward of grain.” Dr. Stephen Herrero of the University of Calgary, one of Canada's most respected grizzly bear experts, concluded that Canadian Pacific Railway trains “are the number one known source of human caused mortality” of grizzly bears in Banff National Park.

Between the spring of 2000 and mid-summer 2007, Canadian Pacific Railway trains struck and killed seven grizzly bears in Banff National Park alone. Four of these bears were breeding age females. None of the five orphaned cubs of the year survived in the park without their mothers. In 2006 alone, four black bears were struck and killed in Banff and Yoho national parks. Grain was found in the stomachs of two of the bears.

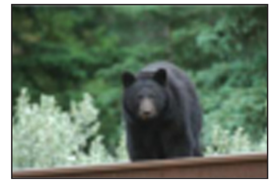
Bears and other wildlife are attracted to railway tracks for a variety of reasons—the promise of a meal between the rails, easy passage (particularly in the heavy snows of winter), and forage vegetation growing in open sunlight. In Canada's Mountain Parks, grain has proven to be the most fatal attraction.

According to Edward Abbott, manager of resource conservation of Parks Canada's Lake Louise, Yoho and Kootenay field unit, “bears frequent the tracks because they get the reward of grain. Over the years bears have a very good learning ability and they know where they get rewarded. And if they have been rewarded once, often they go back again just to check to make sure if there is anything there.”

We have observed and filmed a number of bears feeding between the rails and collected grain-filled bear scat along the tracks. More than a dozen bears have been seen in a single morning feeding at open railway tracks at Bath Creek Flats, near the border of Banff and Yoho national parks. When asked, some senior Parks Canada staff tell close friends and relatives that the best place to see grizzly bears in Banff National Park is along these tracks, as bears forage for grain. This is relatively open country, where the tracks offer no singular advantage of other forage or open travel. The bears are there because this is one of the very best dining areas along the “world's longest bird feeder.”

Bears aren't the only animals that seek grain and are killed between Canadian Pacific rails. According to Parks Canada figures, 564 elk, 9 moose, 51 deer were killed on CPR tracks between 1982 and 2001 in Banff and Yoho national parks. In turn, many of these carcasses attracted scavengers. During the same time period, 9 coyote and 9 wolves were killed by trains.

Management Responses by The Canadian Pacific Railway



The Railway conducted a wildlife mortality study in 1997. In 1999, the Canadian Pacific Railway, Parks Canada and other parties contributed to a seminal paper on railways and wildlife mortalities (Wells, P. et al. 1999, Wildlife mortalities on railways: monitoring methods and mitigation strategies. 11 pp. Unpublished.). The paper identified seven promising mitigation strategies: 1) concentrate mitigation strategies on identified problem areas; 2) instruct train crews to report wildlife incidents; 3) remove carcasses from right-of-way to reduce scavenging; 4) remove spilled attractants (e.g., grain) in a timely manner; 5) reduce chronic grain spills through car maintenance and loading/handling procedures; 6) reduce attractant vegetation on right-of-way; and, 7) share data among jurisdictions.

In the year this study was completed, the Canadian Pacific Railway put the industry's first vacuum truck into service, marking a major and innovative investment. The truck was designed to respond to reported spills and to clean spilled grain from the tracks. At the same time, the Railway instituted a program to train and encourage grain handlers at loading terminals. The intent was to reduce the amount of grain spilled on hopper car tops and end plates, and to ensure that discharge gates were fully closed and operating properly.

Prior to train departure, faulty discharge gates are to be noted and reported as "bad order cars." These cars are to be pulled from service and repaired. To date, the Canadian Pacific Railway has refused to release "bad order car" reports or to conduct public tests to document the spillage of grain or the effectiveness of its vacuum operations. And the Railway has declined to release the results of any tests it may have conducted.

The Railway has an agreement with Parks Canada to report grain spills and collisions with wildlife. Most reports are timely and adequate, but the process falls short on occasion. Parks Canada also agreed to allow the Railway to remove struck carcasses from the right-of-way onto park lands, reducing the likelihood that predators would be struck.

In a presentation to the American Association of Railroads in Urbana-Champaign, Illinois, USA in 2000, a representative of the Canadian Pacific Railway indicated that the company would carry out a number of measures to investigate and reduce the number of wildlife collisions, including trials of lights and sounds to alert wildlife, observations of wildlife behaviour, limited fencing, and programs to educate train crews and grain terminal operators. In addition, the Railway pointed to possible "future directions" including aversive conditioning, "science-based decision-making," "integrated research and planning" and crossing structures. The Railway has not reported any progress on these possible directions.

Under Canadian law, contracts and other agreements between government and private parties are governed by legal principles which consider the agreements as "privileged" in favour of the private party. As a result, the terms of the grain car lease, reports filed and other communications between the parties, and other documents are not—or in some cases, not easily—available to the public.

Media Responses by The Canadian Pacific Railway

Through most of this century, spokespersons for the Canadian Pacific Railway asserted the company was doing the best it could and that spilled grain was not a significant factor in the deaths of grizzly bears in the region. A sample of their responses, as recorded in local media, includes:

> "[The vacuum truck] does a good job of making the tracks as clean as possible so [the grain] is not evident. It has proven very effective." (August 5, 2004)
>
> "Look as a company at what we have tried to do to avoid contact with bears – we're trying our best." (Aug 25, 2005)
>
> "This is a bigger picture issue, not just a railway issue. It's the entire growth of human activity in that area. We're just one of the stakeholders. This is more of a community bear management issue." (Aug. 25, 2005)
>
> "But this is a bigger issue that just the railway..." (May 11, 2006)
>
> "I don't think grain is the issue here." (June 22, 2006)
>
> "We aren't a major contributor to bear mortality." (June 27, 2006)
>
> "We do have stringent measures in terms of our hopper maintenance and repair process that has been enhanced over the past year or two." (June 27, 2006)

The Big Breakthrough

On May 3, 2007, the Canadian Pacific Railway announced a new operating agreement with Canada's Ministry of Transport, Infrastructure and Community. The Railway's announcement read, in part (emphasis added):

> Under the agreement with Transport Canada, CP will, in addition to its normal maintenance practices, undertake over the next five years an extensive hopper car inspection and refurbishment program to ensure a quality fleet. **This will include the replacement of poor-performing discharge gates with technologically superior units as well as a general refurbishment program for the other gates on these cars.**

> "Canadian Pacific is pleased to have completed these extended negotiations with the federal government as it will ensure a secure hopper car supply for farmers and enhance operational fluidity," said Fred Green, President and CEO. **"This initiative will also strongly support our wildlife protection efforts by reducing grain and other wildlife attractants along our tracks."**

The refurbishment program on more than 6,300 hopper cars will take five years to complete at a cost of Cdn$20 million. The Railway expects to repair 70 percent of the cars by the end of 2010. The Canadian National Railway Company also agreed to invest Cdn$20 million in the 6,300 hopper cars it leases from the federal government.

Next Steps

Repairing leaking grain cars is a necessary—but not sufficient—step to reduce wildlife mortality on railway tracks. Animals will stray onto the tracks, even if grain is not present. And Banff's wild animals are habituated to finding grain on the tracks. As many as three generations of grizzly bears in Banff and Yoho national parks are accustomed to finding meals between the rails. For 15 years after open dumps were closed at Yellowstone National Park, bears returned looking for a meal. Additional steps will need to be taken as defective cars are repaired and as trains continue to move through Canada's premier national parks.

We suggest these steps to reduce wildlife collisions on CP Railway tracks:

1. Characterize sites where animals are struck, killed or frequently seen. The first step in understanding and reducing vehicle-wildlife collisions is to investigate the situations where animals are seen and struck. Was the incident on a straight or curved section? Does vegetation—particularly edible forage—grow close to the tracks? Is escape blocked by steep slopes, rivers, or embankments? Is there a known wildlife movement corridor in the vicinity?
2. Document wildlife incidents. Train crews should record location, time of day, weather conditions and speed of train. How far ahead of the train was the animal when spotted; what was it doing? How did the train crew respond (whistle, horn, lights, other)? How did the animal react and what was the outcome?
3. Test the effectiveness of lights to alert and deter bears and other wildlife. Train crews have reported that flashing lights appear to scare bears from the tracks.
4. Proceed as quickly as possible with the car repairs. "Bad order cars" should be pulled from service immediately. Measure the amounts of grain spilled at various locations to document the effectiveness of the repairs. In addition, measure the effectiveness of the vacuum truck.
5. Convene a workshop of wildlife managers, animal behaviour specialists, railway experts and others to address the causes and solutions to train-wildlife collisions.

While collisions with animals can have serious consequences for wildlife populations, relatively few trains strike wildlife on the tracks. To gather sufficient data for analysis, a larger data set likely will be needed. We suggest that the Canadian National Railway Company and the Burlington Northern Santa Fe Railway be engaged to contribute to the incident site characterizations and the collision incident reports.

Behavioral Ecology

The official journal of the ISBE
International Society for Behavioral Ecology

Behavioral Ecology (2014), 25(1), 4–7. doi:10.1093/beheco/art102

Invited Ideas

Fitness costs as well as benefits are important when considering responses to anthropogenic noise

Jade Read, Gareth Jones, and Andrew N. Radford
School of Biological Sciences, University of Bristol, Woodland Road, Bristol BS8 1UG, UK

Received 24 July 2013; revised 20 September 2013; accepted 2 October 2013; Advance Access publication 8 November 2013

Trade-offs lie at the heart of behavioral ecology, with our ultimate understanding of many behaviors reliant on an assessment of both fitness benefits and costs. However, the rapidly expanding research literature on the impacts of anthropogenic noise (a recently recognized global pollutant) tends to focus on the benefits likely to be accrued by any resulting behavioral adaptations or plasticity. In particular, although studies investigating acoustic communication (the topic receiving the most attention to date) invariably discuss, and occasionally attempt to measure, the perceived benefits in terms of reduced masking that might arise from vocal adjustments by signalers, only rarely are the potential fitness costs even mentioned. The bias toward benefits prevents a full understanding of the consequences of anthropogenic noise, including the implications for population viability and community structure. Here, we argue for a greater consideration of fitness costs, outline a number of specific examples (reduced transmission distances, increased risk of predation/parasitism, altered energy budgets, loss of vital information), make suggestions about how to move forward, and showcase why a balanced view is as crucial in this field as any other aspect of behavioral ecology.

Key words: **acoustic communication, anthropogenic noise, costs and benefits, fitness, trade-offs, vocalizations.**

INTRODUCTION

Noise-generating human activities, such as urban development, transportation, and the exploitation of energy sources, increased considerably in the last century and have led to substantial changes in the acoustic landscape in both terrestrial and aquatic ecosystems (e.g., McDonald et al. 2006; Watts et al. 2007). A burgeoning number of studies have demonstrated that anthropogenic (man-made) noise can affect animals in various ways (see Tyack 2008; Barber et al. 2009; Slabbekoorn et al. 2010; Kight and Swaddle 2011); however, the topic receiving by far the greatest attention has been acoustic communication (Radford et al. 2012; Morley EL, Jones G, Radford AN, unpublished data). The possibility that signalers might alter their acoustic output as a consequence of anthropogenic noise has been suggested by correlational studies on a variety of taxa (e.g., birds: Slabbekoorn and Peet 2003; marine mammals: Parks et al. 2011; anurans: Vargas-Salinas and Amezquita 2013; fish: Picciulin et al. 2012; invertebrates: Lampe et al. 2012), with the strongest body of experimental evidence coming from avian research (e.g., Halfwerk, Bot, et al. 2011; Halfwerk, Holleman, et al. 2011; McLaughlin and Kunc 2013; Montague et al. 2013); here, we focus on bird vocalizations to illustrate our argument.

Address correspondence to A.N. Radford. E-mail: andy.radford@bristol.ac.uk.

© The Author 2013. Published by Oxford University Press on behalf of the International Society for Behavioral Ecology. All rights reserved. For permissions, please e-mail: journals.permissions@oup.com

The most obvious way in which anthropogenic noise can disrupt acoustic communication is through masking, whereby there is an increase in the threshold for detection or discrimination of one sound in the presence of another (Brumm and Slabbekoorn 2005). Loss of clear and efficient transmission of acoustic information can create potential fitness costs, including those related to mate attraction and territory defense if song is masked (e.g., Halfwerk, Bot, et al. 2011), increased predation risk if detection of alarm calls is impaired (Lowry et al. 2012), and reduced reproductive success if parent–offspring or parent–parent communication is disrupted (Halfwerk et al. 2012; Leonard and Horn 2012). Consequently, adjustments resulting from both evolutionary adaptation (e.g., Luther and Baptista 2010) and behavioral plasticity (e.g., Gross et al. 2010) have been indicated in studies on a variety of avian species (Ortega 2012). For instance, evidence exists for anthropogenic noise–induced changes in vocal timing (Fuller et al. 2007), temporal structure (Halfwerk and Slabbekoorn 2009), amplitude (see Brumm and Zollinger 2011), frequency (see Slabbekoorn 2013), and complexity (Montague et al. 2013), and birds may also attempt to improve signal detection and discrimination by altering their choice of perch from which to vocalize (Halfwerk et al. 2012).

These vocal adjustments have often been described as adaptive in terms of a release from masking (Slabbekoorn and Ripmeester 2008), although there is some debate with respect to frequency

Downloaded from http://beheco.oxfordjournals.org/ at University of California, Santa Cruz on June 30, 2014

shifts (Nemeth and Brumm 2010). More recent work has begun to test these perceived *benefits*, by calculating the increases in potential communication distances (e.g., Nemeth and Brumm 2009) and assessing reproductive output (Halfwerk, Bot, et al. 2011). Although direct evidence of fitness benefits remains scarce (Slabbekoorn 2013), less attention has been paid to the potential fitness *costs* arising from vocal adjustments made in response to anthropogenic noise. This issue was raised by Patricelli and Blickley (2006), but the majority of the 50 studies investigating the impacts of anthropogenic noise on bird vocal communication published since then (unpublished data) do not even mention the possibility of costs (see Nemeth and Brumm 2010; Halfwerk, Bot, et al. 2011; Halfwerk, Holleman, et al. 2011; Luther and Derryberry 2012; Proppe et al. 2012 for exceptions). We argue that both sides of the trade-off need careful consideration if the true effects of noise are to be determined.

POTENTIAL FITNESS COSTS

Vocal adjustments could result in many direct or indirect fitness costs; we highlight 4 general examples here.

Reduced transmission distances

Signals are shaped over time by the acoustic environment in which they are emitted, the "acoustic adaptation hypothesis" (Morton 1975). Changes in vocal parameters may therefore affect the level of attenuation and degradation, potentially reducing transmission through vegetation or into and out of a nest (Slabbekoorn 2004). As a specific example, high-frequency signals—favored in urban areas (e.g., Slabbekoorn and Peet 2003)—attenuate faster and are degraded more easily than low-frequency signals (Wiley and Richards 1982). Adjustments in the timing of when vocalizations are produced may also come at a cost to transmission distances. For instance, because sound transmits further and more reliably at dawn than at other times of the day, due to lower wind noise and fewer atmospheric fluctuations (e.g., Brown and Handford 2003), birds that shift their singing away from the dawn chorus may suffer by communicating to a more localized audience.

Increased risk of predation or parasitism

The alarm calls of small passerines are often suggested to utilize high frequencies because this renders the signaler more difficult to detect or locate by birds of prey (Marler 1955; Klump and Shalter 1984). Changes in frequency may therefore result in the caller being more at risk; ultimately, this could lead to selection for a reduction in alarm calling, with consequences for subsequent generations that learn to give and utilize alarm calls from experienced adults (Hollén and Radford 2009). For all vocalizations, an increase in amplitude and the duration of vocalizing will make the signaler more conspicuous and potentially more vulnerable to predators. Similarly, noise-driven changes in perch choice, such as vocalizing from higher or more exposed positions (see Halfwerk et al. 2012), could increase predation risk. More time spent vocalizing and louder sound production could also enhance the likelihood of brood parasitism if host vocal activity is used as a cue by parasites to locate nests (see Banks and Martin 2001).

Altered energy budgets

There is some evidence that it is metabolically costly to vocalize for longer (Gillooly and Ophir 2010), to produce high-amplitude songs compared with those of lower amplitude (Oberweger and Goller 2001), and to shift songs to higher frequencies (Lambrechts 1996). Although the energy required for such vocal adjustments may not be as great as first assumed (see Ward et al. 2004; Zollinger et al. 2011), there could be consequences for growth, survival, and reproductive success if compensation does not occur. Moreover, spending more time foraging to compensate for increased energy consumption may itself increase predation risk (Lima and Dill 1990), enhance the likelihood of foraging errors (see Purser and Radford 2011), and reduce opportunities for other important activities such as preening (Tieleman and Williams 2002). If insectivorous birds sing at dawn because prey are hardest to detect at times of low light intensities and reduced invertebrate activity (Kacelnik and Krebs 1983), then a diel shift in singing may also result in foraging at less optimum times.

Loss of vital information

The auditory sensitivity of a species is often tightly tuned to the frequencies used in communication (e.g., Okanoya and Dooling 1988), and thus the efficacy of perception by receivers may be impaired by noise-induced vocal changes. Moreover, because mate choice and male–male competition are often based on assessments of song characteristics, with higher quality indicated by such aspects as high amplitude (Brumm and Ritschard 2011; but see Nemeth et al. 2012), low frequency (Halfwerk, Bot, et al. 2011; but see Eens et al. 2012), broad bandwidth (Ballentine et al. 2004), and large repertoire size (Krebs et al. 1978), changes to acoustic structure and output could have direct consequences for reproductive success. Alterations in one song component in response to changes in the acoustic environment could also restrict the elaboration of other characteristics, which are preferred by females (Gross et al. 2010), thus indirectly impacting fitness. For instance, singing more loudly may compromise the ability to generate a high song rate and longer song duration (Wasserman and Cigliano 1991), whereas an increase in minimum frequency could constrain song complexity (Montague et al. 2013). Misjudging quality during mate choice may result in rejection of high-quality mates and less time spent raising the offspring, with impacts on their success, if a low-quality mate is selected (Halfwerk, Holleman, et al. 2011). In male–male competition, signalers may be attacked more often if perceived as less aggressive, and receivers may mistakenly attack males that are stronger or have a higher motivation to fight than anticipated (Ripmeester et al. 2007). Song matching may also be an important aggressive signal in male–male competition (Krebs et al. 1981), and a male that drops low-frequency songs from his repertoire may not possess the song types required to match conspecific rivals.

These fitness costs introduce a series of trade-offs for individuals. For example, although low-frequency songs might be favored by sexual selection, anthropogenic noise could exert a natural selection pressure for high-frequency songs; there may be a choice between being heard by many or being perceived as high quality by a few (Halfwerk, Bot, et al. 2011). The preference could be molded by the fundamental need of females to mate, with a signal that is heard being at a selective advantage compared with one that is not heard, even if the quality communicated is lower. Other methods of assessment could then be developed, or other existing signals relied on to a greater extent, to restore the element of choice in the future.

Downloaded from http://beheco.oxfordjournals.org/ at University of California, Santa Cruz on June 30, 2014

POPULATION AND COMMUNITY CONSEQUENCES

All members of a population are unlikely to suffer the same costs associated with vocal adjustments. For instance, alterations that are energetically costly may be more easily borne by higher quality individuals (Zahavi 1975), which might give them further advantages in terms of female choice and male–male competition. However, if anthropogenic noise results in the loss of certain acoustic features that are used as honest indicators of quality, such as low-frequency song elements, then discrimination between different males becomes harder and lower quality males may be less easily dismissed. Ultimately, the exact nature of the cost will also depend on whether, and how quickly, a corresponding shift in assessment and preference by receivers occurs. Because females often have a preference for songs similar to those of their father or that were heard frequently during a learning period (Catchpole and Slater 2008), it is feasible that preference in this context at least could shift passively over a few generations simply through subadult experience.

In general, the effect of vocal adjustment on fitness will differ between species depending on 1) inherent vocal characteristics that vary the amount of adjustment needed, 2) the relevant sexual signals used that could be disrupted by adjustment, 3) the plasticity of song learning and corresponding plasticity in assessment, and 4) the inherent suitability of a species to persist in urban environments. For instance, there is a positive relationship between the existing vocal frequency range of a species and its response to noise (Hu and Cardoso 2010; Francis et al. 2011), and it is likely that naturally loud vocalizations also convey an advantage. Moreover, only a relatively small percentage of bird species are thought to be urban-adaptable (Johnston 2001). The different costs and benefits faced by different species in relation to anthropogenic noise will have consequences for community structure and functioning (Francis et al. 2009).

MOVING FORWARD

Ultimately, the assessment of fitness consequences requires measurement of reproductive success and survival. These are logistically challenging to determine, especially if the specific impact of a particular response, in this case vocal adjustments, is targeted. However, studies focusing on other, but related, questions have assessed such variables as pairing success (Habib et al. 2007; Gross et al. 2010), clutch size and fledging success (Francis et al. 2009; Halfwerk, Holleman, et al. 2011), and female fidelity (Halfwerk et al. 2012); care is needed to ensure that such effects are not the result of differential use of areas by individuals of different qualities (see Slabbekoorn 2013). Using playbacks at nests, or perhaps presentation of models, also offer opportunities to assess how different vocalizations affect predation or parasitism rates (see Haff and Magrath 2011).

If the fitness benefits and costs of responses to anthropogenic noise are to be determined, studies need to include several key elements (see also Slabbekoorn 2013). First, potential confounding factors must be ruled out; correlational work comparing, for instance, rural and urban areas or habitats at different distances from roads, cannot isolate noise as the reason for any differences found. Instead, naturally matched areas where only the noise differs (see Francis et al. 2009, 2011) or experimental manipulations (e.g., Halfwerk, Bot, et al. 2011; Halfwerk, Holleman, et al. 2011; McLaughlin and Kunc 2013; Montague et al. 2013) are required. Second, to assess cumulative effects and consider the possibility that responses change due to processes such as habituation, tolerance, and sensitization (Bejder et al. 2009), experiments over an extended period of time should ideally be conducted (e.g., Blickley et al. 2012), although they are more difficult to implement than short-term, acute exposures. Third, proper levels of replication are required; if strong conclusions are to be drawn about population-level consequences, then data from multiple sites, as well as multiple individuals, are needed (see Slabbekoorn 2013). In addition, to maximize the usefulness of studies investigating the impact of anthropogenic noise, the noise source should be characterized as fully as possible (reporting, for instance, dB, any weighting function, integration time and temporal variation, along with power spectra and spectrograms) and utilize equipment that best reflects the auditory capabilities of the study animal (see Schaub et al. 2009).

CONCLUSIONS

The human population is projected to increase by 2.3 billion between 2011 and 2050, with urban areas likely to absorb most of this growth (United Nations 2011). Noise pollution is thus both a pressing issue and one of ever-increasing concern. Ultimately, we need assessments of how anthropogenic noise affects individual fitness, population viability, and community structure. As with any aspect of behavioral ecology, this will only be possible if we consider both the benefits and costs arising from adjustments made in response to noise. Our aim is to stimulate a more balanced approach with respect to this trade-off; although we have illustrated our argument with reference to vocal signaling in birds, the principles apply across taxonomic groups and are relevant to all noise-induced behavioral changes.

We are grateful to S. Simpson, A. Goldsmith, and members of the Bristol Bioacoustics and Behavioural Ecology group for stimulating discussions and to H. Kunc and an anonymous referee for valuable comments on the manuscript.

Forum editor: Sue Healy

REFERENCES

Ballentine B, Hyman J, Nowicki S. 2004. Vocal performance influences female response to male bird song: an experimental test. Behav Ecol. 15:163–168.
Banks AJ, Martin TE. 2001. Host activity and the risk of nest parasitism by brown-headed cowbirds. Behav Ecol. 12:31–40.
Barber JR, Crooks KR, Fristrup KM. 2009. The costs of chronic noise exposure for terrestrial organisms. Trends Ecol Evol. 25:180–189.
Bejder L, Samuels A, Whitehead H, Finn H, Allen S. 2009. Impact assessment research: use and misuse of habituation, sensitisation and tolerance in describing wildlife responses to anthropogenic stimuli. Mar Ecol Prog Ser. 395:177–185.
Blickley JL, Blackwood D, Patricelli GL. 2012. Experimental evidence for the effects of chronic anthropogenic noise on abundance of Greater Sage-Grouse at leks. Conserv Biol. 26:461–471.
Brown TJ, Handford P. 2003. Why birds sing at dawn: the role of consistent song transmission. Ibis. 145:120–129.
Brumm H, Ritschard M. 2011. Song amplitude affects territorial aggression of male receivers in chaffinches. Behav Ecol. 22:310–316.
Brumm H, Slabbekoorn H. 2005. Acoustic communication in noise. Adv Study Behav. 35:151–209.
Brumm H, Zollinger SA. 2011. The evolution of the Lombard effect: 100 years of psychoacoustic research. Behaviour. 148:1173–1198.
Catchpole CK, Slater PJB. 2008. Bird song: biological themes and variations. Cambridge (MA): Cambridge University Press.
Eens M, Rivera-Gutierrez HF, Pinxten R. 2012. Are low-frequency songs sexually selected, and do they lose their potency in male–female interactions under noisy conditions? Proc Natl Acad Sci USA. 109:208.

Downloaded from http://beheco.oxfordjournals.org/ at University of California, Santa Cruz on June 30, 2014

Francis CD, Ortega CP, Cruz A. 2009. Noise pollution changes avian communities and species interactions. Curr Biol. 19:1415–1419.
Francis CD, Ortega CP, Cruz A. 2011. Noise pollution filters bird communities based on vocal frequency. PLoS One. 6:e27052.
Fuller RA, Warren PH, Gaston KJ. 2007. Daytime noise predicts nocturnal singing in urban robins. Biol Lett. 3:368–370.
Gillooly JF, Ophir AG. 2010. The energetic basis of acoustic communication. Proc R Soc Lond B. 277:1325–1331.
Gross K, Pasinelli G, Kunc HP. 2010. Behavioral plasticity allows short-term adjustment to a novel environment. Am Nat. 176:456–464.
Habib L, Bayne EM, Boutin S. 2007. Chronic industrial noise affects pairing success and age structure of ovenbirds *Seiurus aurocapilla*. J Appl Ecol. 44:176–184.
Haff TM, Magrath RD. 2011. Calling at a cost: elevated nestling calling attracts predators to active nests. Biol Lett. 7:493–495.
Halfwerk W, Bot S, Buikx J, van der Velde M, Komdeur J, ten Cate C, Slabbekoorn H. 2011. Low-frequency songs lose their potency in noisy urban conditions. Proc Natl Acad Sci USA. 35:14549–14554.
Halfwerk W, Bot S, Slabbekoorn H. 2012. Male great tit song perch selection in response to noise-dependent female feedback. Func Ecol. 26:1339–1347.
Halfwerk W, Holleman LJM, Lessells CM, Slabbekoorn H. 2011. Negative impact of traffic noise on avian reproductive success. J Appl Ecol. 28:210–219.
Halfwerk W, Slabbekoorn H. 2009. A behavioral mechanism explaining noise-dependent frequency use in urban birdsong. Anim Behav. 78:1301–1307.
Hollén LI, Radford AN. 2009. The development of alarm call behaviour in mammals and birds. Anim Behav. 78:791–800.
Hu Y, Cardoso GC. 2010. Which birds adjust the frequency of vocalizations in urban noise? Anim Behav. 79:863–867.
Johnston RF. 2001. Synanthropic birds of North America. In: Marzluff JM, Bowman R, Donnelly R, editors. Avian ecology in an urbanizing world. Norwell (MA): Kluwer Academic Publishers. p. 49–67.
Kacelnik A, Krebs JR. 1983. The dawn chorus in the great tit (*Parus major*): proximate and ultimate causes. Behaviour. 83:287–309.
Kight CR, Swaddle JP. 2011. How and why environmental noise impacts animals: an integrative, mechanistic review. Ecol Lett. 14:1052–1061.
Klump GM, Shalter MD. 1984. Acoustic behaviour of birds and mammals in the predator context: I. Factors affecting the structure of alarm signals. II. The functional significance of alarm signals and their evolution. Z Tierpsychol. 66:189–226.
Krebs JR, Ashcroft R, Van Orsdol K. 1981. Song matching in the great tit *Parus major*. Anim Behav. 29:918–923.
Krebs JR, Ashcroft R, Webber MI. 1978. Song repertoires and territory defence. Nature. 271:539–542.
Lambrechts MM. 1996. Organisation of birdsong and constraints on performance. In: Kroodsma DE, Miller EH, editors. Ecology and evolution of acoustic communication in birds. Ithaca (NY): Cornell University Press. p. 305–320.
Lampe U, Schmoll T, Franzke A, Reinhold K. 2012. Staying tuned: grasshoppers from noisy roadside habitats produce courtship signals with elevated frequency components. Funct Ecol. 26:1348–1354.
Leonard ML, Horn AG. 2012. Ambient noise increases missed detections in nestling birds. Biol Lett. 8:530–532.
Lima SL, Dill LM. 1990. Behavioural decisions made under the risk of predation—a review and prospectus. Can J Zool. 68:619–640.
Lowry H, Lill A, Wong BBM. 2012. How noisy does a noisy miner have to be? Amplitude adjustments of alarm calls in an avian urban 'adapter'. PLoS One. 7:e29960.
Luther D, Baptista L. 2010. Urban noise and the cultural evolution of bird songs. Proc R Soc Lond B. 277:469–473.
Luther DA, Derryberry EP. 2012. Birdsongs keep pace with city life: changes in song over time in an urban songbird affects communication. Anim Behav. 83:1059–1066.
Marler P. 1955. Characteristics of some animal calls. Nature. 176:68.
McDonald MA, Hildebrand JA, Wiggins SM. 2006. Increases in deep ocean ambient noise in the Northeast Pacific west of San Nicolas Island, California. J Acoust Soc Am. 120:711–718.
McLaughlin KE, Kunc HP. 2013. Experimentally increased noise levels change spatial and singing behaviour. Biol Lett. 9:20120771.
Montague MJ, Danek-Gontard M, Kunc HP. 2013. Phenotypic plasticity affects the response of a sexually selected trait to anthropogenic noise. Behav Ecol. 24:343–348.
Morton ES. 1975. Ecological sources of selection on avian sounds. Am Nat. 109:17–34.
Nemeth E, Brumm H. 2009. Blackbirds sing higher-pitched songs in cities: adaptation to habitat acoustics or side-effect of urbanization? Anim Behav. 78:637–641.
Nemeth E, Brumm H. 2010. Birds and anthropogenic noise: are urban songs adaptive? Am Nat. 176:465–475.
Nemeth E, Kempenaers B, Matessi G, Brumm H. 2012. Rock sparrow song reflects male age and reproductive success. PLoS One. 7:e43259.
Oberweger K, Goller F. 2001. The metabolic cost of birdsong production. J Exp Biol. 204:3379–3388.
Okanoya K, Dooling RJ. 1988. Hearing in the swamp sparrow *Melospiza georgiana*, and the song sparrow *Meospiza melodia*. Anim Behav. 36:726–732.
Ortega CP. 2012. Effects of noise pollution on birds: a brief review of our knowledge. Ornith Monogr. 74:6–22.
Parks SE, Johnson M, Nowacek D, Tyack PL. 2011. Individual right whales call louder in increased environmental noise. Biol Lett. 7:33–35.
Patricelli GL, Blickley JL. 2006. Avian communication in urban noise: causes and consequences of vocal adjustment. Auk. 123:639–649.
Picciulin M, Sebastianutto L, Codarin A, Calcagno G, Ferrero EA. 2012. Brown meagre vocalization rate increases during repetitive boat noise exposures: a possible case of vocal compensation. J Acoust Soc Am. 132:3118–3124.
Proppe DS, Avey MT, Hoeschele M, Moscicki MK, Farrell T, St Clair CC, Sturdy CB. 2012. Black-capped chickadees *Poecile atriapillus* sing at higher pitches with elevated anthropogenic noise, but not with decreasing canopy cover. J Avian Biol. 43:325–332.
Purser J, Radford AN. 2011. Acoustic noise induces attention shifts and reduces foraging performance in three-spined sticklebacks (*Gasterosteus aculeatus*). PLoS One. 6:e17478.
Radford AN, Morley EL, Jones G. 2012. The effects of noise on biodiversity. Defra Report NO0235 [cited 2013 September 19]. Available from: http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=O&ProjectID=18136.
Ripmeester EAP, Vries AM, Slabbekoorn H. 2007. Do blackbirds signal motivation to fight with their song? Ethology. 113:1021–1028.
Schaub A, Ostwald J, Siemers BM. 2009. Foraging bats avoid noise. J Exp Biol. 211:3174–3180.
Slabbekoorn H. 2004. Singing in the wild: the ecology of birdsong. In: Marler P, Slabbekoorn H, editors. Nature's music—the science of birdsong. San Diego (CA): Elsevier Academic Press. p. 178–205.
Slabbekoorn H. 2013. Songs of the city: noise-dependent spectral plasticity in the acoustic phenotype of urban birds. Anim Behav. 85:1089–1099.
Slabbekoorn H, Bouton N, van Opzeeland I, Coers A, ten Cate C, Popper AN. 2010. A noisy spring: the impact of globally rising underwater sound levels on fish. Trends Ecol Evol. 25:419–427.
Slabbekoorn H, Peet M. 2003. Birds sing at a higher pitch in urban noise. Nature. 424:267.
Slabbekoorn H, Ripmeester EAP. 2008. Birdsong and anthropogenic noise: implications and applications for conservation. Mol Ecol. 17:72–83.
Tieleman BI, Williams JB. 2002. Effects of food supplementation on behavioural decisions of hoopoe-larks in the Arabian Desert: balancing water, energy and thermoregulation. Anim Behav. 63:519–529.
Tyack PL. 2008. Implications for marine mammals of large-scale changes in the marine acoustic environment. J Mamm. 89:549–558.
United Nations. 2011. World urbanization prospects: the 2011 revision. New York: United Nations [cited 2013 September 19]. Available from: http://esa.un.org/unup/pdf/WUP2011_Highlights.pdf.
Vargas-Salinas F, Amezquita A. 2013. Traffic noise correlates with calling time but not spatial distribution in the threatened poison frog *Andinobates bombetes*. Behaviour. 150:569–584.
Ward S, Lampe HM, Slater PJB. 2004. Singing is not energetically demanding for pied flycatchers, *Ficedula hypoleuca*. Behav Ecol. 15:477–484.
Wasserman FE, Cigliano JA. 1991. Song output and stimulation of the female in white-throated sparrows. Behav Ecol Sociobiol. 29:55–59.
Watts RD, Compton RW, McCammon JH, Rich CL, Wright SM, Owens T, Ouren DS. 2007. Roadless space of the conterminous United States. Science. 316:736–738.
Wiley RH, Richards DG. 1982. Adaptations for acoustic communication in birds: sound propagation and signal detection. In: Kroodsma DE, Miller EH, editors. Acoustic communication in birds. Vol. 1. New York: Academic Press. p. 131–181.
Zahavi A. 1975. Mate selection: selection for a handicap. J Theor Biol. 53:205–214.
Zollinger SA, Goller F, Brumm H. 2011. Metabolic and respiratory costs of increasing song amplitude in zebra finches. PLoS One. 6:e23198.

Downloaded from http://beheco.oxfordjournals.org/ at University of California, Santa Cruz on June 30, 2014

Passerine Birds Breeding under Chronic Noise Experience Reduced Fitness

Julia Schroeder[1]*, Shinichi Nakagawa[1,2,3], Ian R. Cleasby[1], Terry Burke[1]

1 Department of Animal and Plant Sciences, University of Sheffield, Sheffield, United Kingdom, 2 Department of Zoology, University of Otago, Dunedin, New Zealand, 3 Evolutionary Genetics, Max Planck Institute for Ornithology, Seewiesen, Germany

Abstract

Background: Fitness in birds has been shown to be negatively associated with anthropogenic noise, but the underlying mechanisms remain obscure. It is however crucial to understand the mechanisms of how urban noise impinges on fitness to obtain a better understanding of the role of chronic noise in urban ecology. Here, we examine three hypotheses on how noise might reduce reproductive output in passerine birds: (H1) by impairing mate choice, (H2) by reducing territory quality and (H3) by impeding chick development.

Methodology/Principal Findings: We used long-term data from an island population of house sparrows, *Passer domesticus*, in which we can precisely estimate fitness. We found that nests in an area affected by the noise from large generators produced fewer young, of lower body mass, and fewer recruits, even when we corrected statistically for parental genetic quality using a cross-fostering set-up, supporting H3. Also, individual females provided their young with food less often when they bred in the noisy area compared to breeding attempts by the same females elsewhere. Furthermore, we show that females reacted flexibly to increased noise levels by adjusting their provisioning rate in the short term, which suggests that noise may be a causal factor that reduces reproductive output. We rejected H1 and H2 because nestbox occupancy, parental body mass, age and reproductive investment did not differ significantly between noisy and quiet areas.

Conclusions/Significance: Our results suggest a previously undescribed mechanism to explain how environmental noise can reduce fitness in passerine birds: by acoustically masking parent–offspring communication. More importantly, using a cross-fostering set-up, our results demonstrate that birds breeding in a noisy environment experience significant fitness costs. Chronic noise is omnipresent around human habitation and may produces similar fitness consequences in a wide range of urban bird species.

Citation: Schroeder J, Nakagawa S, Cleasby IR, Burke T (2012) Passerine Birds Breeding under Chronic Noise Experience Reduced Fitness. PLoS ONE 7(7): e39200. doi:10.1371/journal.pone.0039200

Editor: Tapio Mappes, University of Jyväskylä, Finland

Received December 7, 2011; **Accepted** May 21, 2012; **Published** July 11, 2012

Copyright: © 2012 Schroeder et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Funding: This work was funded by the grant NE/F00607/1 from NERC(Natural Environment Research Council) to TB, and SN was supported by a Humbolt Fellowship. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing Interests: The authors have declared that no competing interests exist.

* E-mail: julia.schroeder@gmail.com

Introduction

Anthropogenic noise can acoustically mask, and decrease, the efficacy of avian vocal communication. Warning calls, territorial defence and mating signals can be impaired, and this effect is often indicated by behavioural changes [1–6]. Communication impairment can have serious demographic consequences, as it has been shown to result in changes in bird abundance, community structure and predator–prey relationships [7–9]. More importantly, noise can also affect reproductive output. In a population of great tits (Parus major), for example, females laid smaller clutches in areas affected by traffic noise than in quieter areas; also, nests in noisy areas fledged fewer young [10]. The underlying mechanisms, however, remain unclear (but see [11]). Thus, while it is interesting to consider the effects of noise on specific behaviours, it is crucial to conservation efforts in urban environments to study the direct effects of environmental noise on reproductive success and recruitment [12].

Three, non-mutually exclusive, hypotheses have been suggested to explain why reproductive success is reduced in noisy areas [10]. H1, *impaired mate choice hypothesis*: Noise may interfere with the transmission of mate quality through bird song and a female's assessment of the quality of her mating partner may be impaired [10,11]. Under this hypothesis, females are expected to invest less, lay smaller clutches and solicit more extra-pair copulations when breeding in a noisy environment. H2, *reduced territory-quality hypothesis*: Noise may affect territory quality. If this is true, noisy areas are expected to be populated by less experienced or younger individuals of lower quality, or to be avoided in general [8,12,13]. H3, *impaired chick development hypothesis*: Noise can lead to poor chick development, by means of two different pathways. First, noise can induce physiological stress in chicks, which may lead to reduced growth [14]. Second, noise may mask acoustic communication between offspring and parents. Two potential mechanisms can operate: if chick begging is not audible, or is less audible, because it is acoustically masked by background noise, we expect chicks to increase the amplitude of their begging, or parents to provision less frequently [10]. Another possibility is that chicks may fail to notice their parents' arrival at the nestbox, resulting in them not begging for food [15].

These three hypotheses each predict reduced reproductive success in noisy environments. Here, we test these three hypotheses in an altricial passerine, the house sparrow (*Passer domesticus*). It is not usually possible to test for a within-individual effect of a noisy environment in a wild population, because this would usually require either the relocation of breeding individuals from a quiet to a noisy environment, and vice versa, or the experimental modification of the noise level around a group of breeding individuals [11]. The relocation of breeding birds is generally impractical. Changing the background noise level via loudspeakers would make it difficult to distinguish between the effects of the noise treatment *per se* and the effect of disturbance due to a change in the noise environment. Here, we take a different approach: we have a dataset of repeated measurements on individual sparrows who have bred in a noisy and three quiet environments, which, together with a cross-fostering set-up, allows us to statistically distinguish between among- and within-individual effects, as well as separating the effects of individual genetic quality and environmental noise. These data allow us to study the direct reactions of birds to the environmental noise that is part of their normal environment.

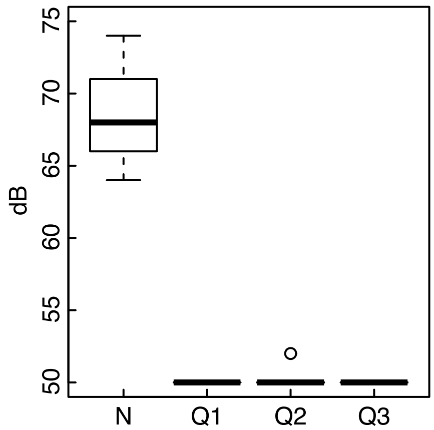


Figure 1. Mean noise levels at the four sites. Noise levels were assessed during the breeding season and measured at five random nestboxes at each site. We used a Silverline sound level meter, with A-weighting, with a range from 50–126 dB and an accuracy of ±2 dB.
doi:10.1371/journal.pone.0039200.g001

Methods

We used data from a long-term (2001–2008) study on a nestbox population of house sparrows on Lundy Island [16–21]. Low levels of migration to and from the island allow for accurate fitness and recruitment estimates; annual resighting probabilities of marked individuals are extraordinarily high (average 0.91, range: 0.72–1.00, [21]). The population has been systematically monitored since 2000; all nesting attempts are recorded from the moment the first egg is laid. Nearly all birds are individually marked as fledglings – therefore, we know their exact ages [17]. Cross-fostering of 2-day old hatchlings between nests has been routinely carried out between randomly chosen clutches of the same age, without changing clutch size, since 2000. Cross-fostering is a routine and systematic component of Lundy sparrow fieldwork and was not restricted to specific experiments (for more details on two small experiments please refer to [21] and references within). Birds were considered to have recruited into the breeding population if they started a brood.

Lundy Island is not connected to the power grid and electricity is generated on the island. Since March 2001, a set of generators (Cummins 6DTA5.9 and 6CTA8.3) has been run continuously between 06:00–12:00 h each day. These generators produce low-frequency noise that reverberates in the adjacent area (noisy environment, N), producing on average 68 dB(A) at the entrances of 29 nestboxes in the barn (Figs. 1, 2), as measured with a hand-held Silverline sound level meter. Another barn (quiet, Q1) harbours 46 boxes; 28 other nestboxes are attached to the outside of the buildings (Q2) and a further 27 nestboxes are located in a small wood (Q3). In Q1–Q3 the generator is only slightly audible. All areas but Q3 are similarly close to the main foraging area, the chicken run (Fig. 2).

The identities of parents at nestboxes were determined by visual identification of individual colour-ring combinations (viewed directly or with the help of video recordings), by catching parents at the nest box [17], and by using PIT-tags and corresponding nest-box antennae [21]. Since not all parents were caught at nestboxes the sample sizes for morphological measurements of parents differed from the sample sizes for parents of known age. Provisioning and incubation frequencies (measured as visits per hour), and incubation duration (in minutes) have been quantified since 2004 from video recordings (90 minutes long) taken at the nestboxes. The methodology is described in detail in [16]. Since sparrows are multi-brooded and, once in the breeding population, live on average for 3–4 years [17], we have repeated measures of provisioning by the same individuals within and between years, which allows us to test whether the same individuals changed their behaviour when they bred in the noisy area *vs* the quiet area. For the main analysis, we used provisioning frequencies collected at broods containing chicks that were 7 days old. We used Bayesian Markov-chain Monte Carlo (MCMC) methods to fit mixed models (BMM). We report effect sizes of the means of the posterior distribution. We considered fixed effects to be statistically significant if their 95% credibility interval (CI) did not include zero [22]. We used R 2.12.1 for statistical analyses.

Fitness Consequences of Noise

We first tested for the fitness consequences of being reared in a noisy location, independent of any potential mechanism. We only used cross-fostered chicks in this analysis. We compared the fate of chicks reared in the noisy environment, N (coded as 1), with those of birds breeding elsewhere, Q (all quiet areas pooled, coded as 0 = reference level). We used two binomial BMMs, with respectively survival from nestling to post-fledging and recruitment as the binomial response variables (survived = 1) and foster area (noisy versus quiet) as a fixed factor. We modelled year and natal area as random effects to correct for potential differences in parent quality. We modelled natal brood as a random effect to correct for chicks from the same nest being more alike than those from different nests.

Reproductive Investment (H1)

We tested if females invested differently in reproduction depending on whether or not they bred in the noisy environment. We tested for a difference in incubation visits and incubation time, whether broods in noisy areas contained fewer eggs and hatchlings, and whether the seasonal timing of breeding differed. We used data on genetic parentage [17] to test whether females breeding in the noisy area had more extra-pair offspring than those breeding in other areas.

Territory Quality (H2)

We tested whether sparrows avoided breeding in the noisy area by comparing annual occupancy rates between the areas. We then

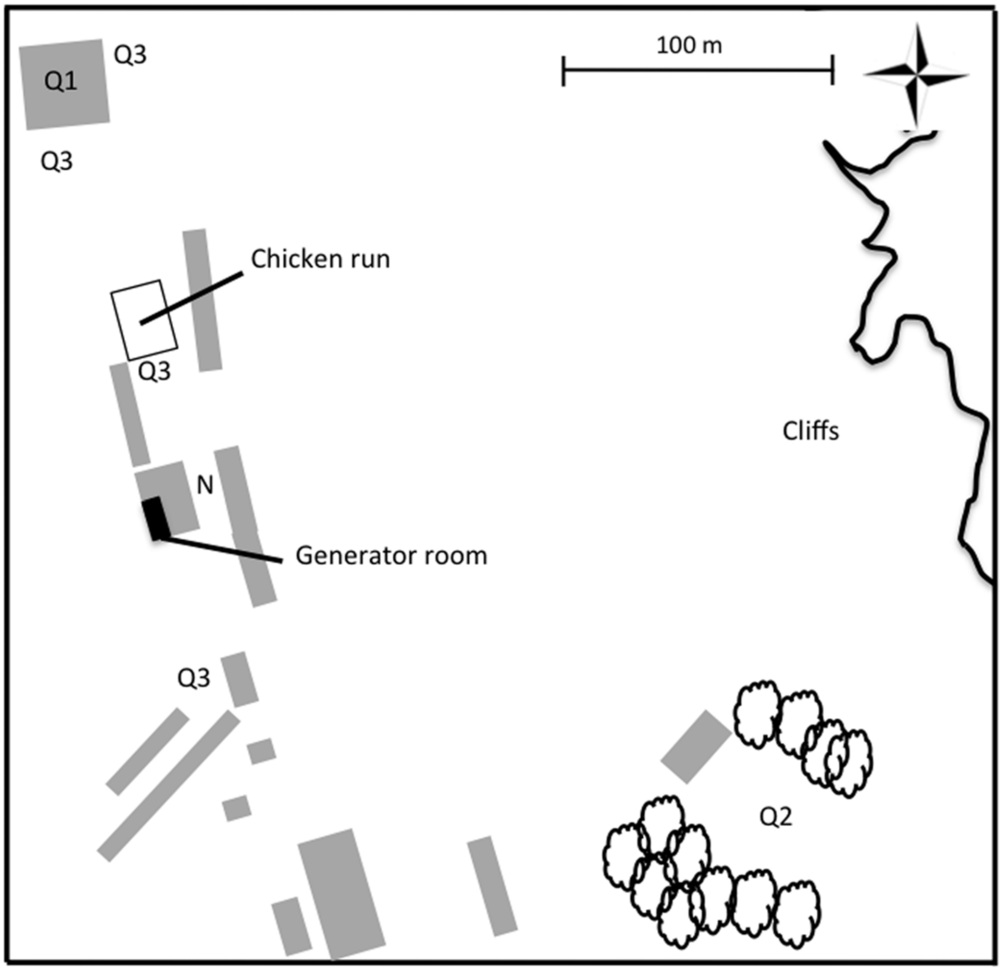


Figure 2. Locations of house sparrow nestboxes on Lundy Island. Grey boxes depict buildings.
doi:10.1371/journal.pone.0039200.g002

examined for the possibility that low-quality or less-experienced birds bred in noisy areas by comparing body mass and the age of parent birds breeding in different areas.

Chick Development (H3)

We first tested for the expectation that chicks that experienced noise grew more slowly, and tested for differences in body mass between fledglings from the noisy areas and elsewhere. We used only chicks that had been cross-fostered. We used a Gaussian BMM with brood, natal area and cohort as random effects to assess the effect of noise on chick body mass at day 12 after hatching. We corrected for time of day (morning or afternoon) as a fixed effect because chicks were lighter at the start of the morning before their parents started provisioning.

We then tested whether parents provided less to broods in a noisy environment than elsewhere. We carried out a cross-sectional analysis with Gaussian BMMs, where we compared the provisioning frequencies of sparrows breeding in the noisy environment with those breeding elsewhere in two models, one for each sex. We corrected for age of the parent and day of season by adding both variables as fixed effects to the model. Bird identity was modelled as a random effect on the intercept, as was year, to correct for annual variability. We then added identity of the partner as a random effect on the intercept, to correct for a potential bias resulting from the adjustments that individuals make, depending on the degree of parental investment by their partner [23].

Within-individual Effects of Noise on Provisioning

Using the same data, in which we have multiple records of individuals, we compared the provisioning by individual parents with those by the same individuals breeding in different areas (within-individual effects), using within-subject centring of variables in BMMs [24]. This model tests for the possibility that individual birds may display high provisioning frequencies when breeding in a quiet area, but low provisioning frequencies when breeding in a noisy area (either in the same or in subsequent years). We modelled the provisioning frequency of males and, respectively, females, as response variables. Our basic model structure was similar to the cross-sectional model, but did not include the non-significant effects of age, date of season, and identity of the partner. We added the number of chicks as a covariate, as individual birds may be able to flexibly adjust their provisioning frequency depending on the number of chicks they feed. We modelled bird identity as a random factor on the intercept, to account for potential heterogeneity among individuals. We used two new variables as fixed predictors: to eliminate any between-subject variation, we subtracted the mean location value (coded as: noisy = 1, quiet = 0) for each individual across all its broods from the value for the location of each individual brood.

Table 1. Results of a BMM with a logit link function modelling fledging and recruitment probability, of cross-fostered Lundy Island house sparrow chicks as response to noisy and quiet environments.

	Fledged		Recruited	
Effects	**Posterior mode**	**95% CI**	**Posterior mode**	**95% CI**
Fixed				
Intercept	1.02	0.48 – 1.39	−1.73	−2.30 – −1.08
Noisy environment	−0.55	−0.94 – −0.17	−0.49	−0.78 – −0.22
Random				
Brood	3.2	2.48–4.14	0.94	0.51–1.34
Natal location	0.01	0.00–0.12	0	0.00–0.02
Cohort	0.22	0.01–1.12	0.29	0.12–1.65
Residual	0	0.00–0.17	0.02	0.01–0.06

The quiet environment is the reference level. Statistically significant fixed effects are indicated in bold. N = 1474 chicks.
doi:10.1371/journal.pone.0039200.t001

That is, if a female bred once in the noisy environment and once elsewhere, it would get the value 0.5 for the datum when breeding in the noisy environment, and −0.5 for the other datum. This term estimates the within-subject variation component. We derived a second predictor variable to estimate the between-subject variation in provisioning, which is the mean area code for one individual [24].

To test whether within- and between-individual effects differed, we used a similar model, modelling the location (noisy or not) of each brood as a within-individual term and the mean location term from the first model, which represented the difference between the within- and between-individual effects. In both within-individual models, we also corrected for the number of hatchlings.

In order to test whether noise is the causal agent for the reduction of provisioning rate, we re-analysed the video recordings of two nests affected by the intermittent noise produced by a set of large industrial ventilators responsible for sucking in air to cool the power generators. When present, the noise level experienced at these separate nestboxes averaged 70 dB(A). The fans are turned on and off automatically as needed, at times of increased power consumption. Note that the nests are not affected by any airflow from these ventilators. We identified 22 video recordings of these nestboxes in which the ventilators either switched on or off; this was easily identified by listening to the audio track. The time when the fans went off or on was recorded. We calculated provisioning rate separately for the noisy and quiet sections of the videos, and tested whether birds responded directly to the noise levels. Provisioning frequency and fan use might be linked through a common correlate, such as outside temperature. In order to account for such a possibility, we used other videos taken at the same time, but at quiet nestboxes, as controls. This was possible because we usually used two or more cameras, and, therefore, matching videos were available for most cases. We partitioned the time in the same way as we partitioned the video data at the noisy locations. We then tested in the controls for a change in provisioning frequency during the times when the fans were on, even though those nests were not afflicted by the noise. For this analysis, we used data on provisioning frequencies across all chick ages to increase sample size.

This work was carried out under the permit from Natural England 20092529.

Results

Fitness Consequences of Noise

We compared the fate of cross-fostered house sparrow chicks reared in a noisy environment with those reared in other places (Figs 1, 2). Being reared in a noisy environment was associated with a significant drop in survival between hatching and fledging: When correcting for natal brood and area, the probability of fledging was 0.25 for nestlings reared in quiet environments ($N = 1093$) and 0.21 for chicks reared in the noisy environment ($N = 381$, Table 1, back-transformed coefficients from a binomial mixed linear model [23]). Chicks reared in the noisy environment also had a statistically significantly lower probability of recruiting into the population, compared to chicks from the other areas (Table 1, Fig. 3a).

Reproductive Investment (H1)

Broods in the noisy area did not differ from broods in quiet areas in the number of eggs (ANOVA with area (N, Q1–3) as a factor: $F_{3,1052} = 0.24$, $P = 0.87$), the number of hatchlings ($F_{3,967} = 1.12$, $P = 0.34$, Fig. 3b), or the laying date ($F_{3,1135} = 1.13$, $P = 0.34$). The number of incubation visits did not differ between noisy and quiet environments (Kruskal-Wallis test, Males: $\chi^2 = 1.13$, $df = 1$, $P = 0.29$, $N = 66$; Females: $\chi^2 = 2.06$, $df = 1$, $P = 0.15$, $N = 66$). Also, male and female house sparrows spent a similar amount of time incubating broods in the noisy environment as elsewhere (Males: $F_{1,65} = 0.02$, $P = 0.89$; Females: $F_{1,65} = 0.40$, $P = 0.53$). The proportion of clutches that contained extra-pair eggs did not differ between the noisy and the quiet environments (estimates from a binomial BMM with noisy or not as a fixed factor and year as a random effect: fixed effect: $b_{intercept} = -1.27$ (−5.46 to −0.45); $b_{noisy} = -0.54$ (−1.86 to 0.80), $u_{year} = 0.62$ (0.16 to 19.47), $e_{residual} = 0.22$ (0.08 to 39.12), $N = 953$ broods in 10 years). Also, the number of eggs per clutch sired by a male other than the social father did not differ among the four areas (Poisson BBM, fixed effect: $b_{intercept} = 0.10$ (0.05 to 0.16); $b_{noisy} = 0.002$ (−0.02 to 0.04), $u_{year} = 0.35$ (0.07 to 3.60), $e_{residual} = 0.48$ (0.33 to 0.79), $N = 953$ broods).

Territory Quality (H2)

Annual occupancy rates of nestboxes did not differ between the noisy area and elsewhere (ANOVA $F_{3,36} = 1.09$, $P = 0.37$). Body mass of sparrow parents was similar between quiet and noisy areas (females: $F_{3,584} = 0.15$, $P = 0.93$; males: $F_{3,520} = 0.98$, $P = 0.40$).

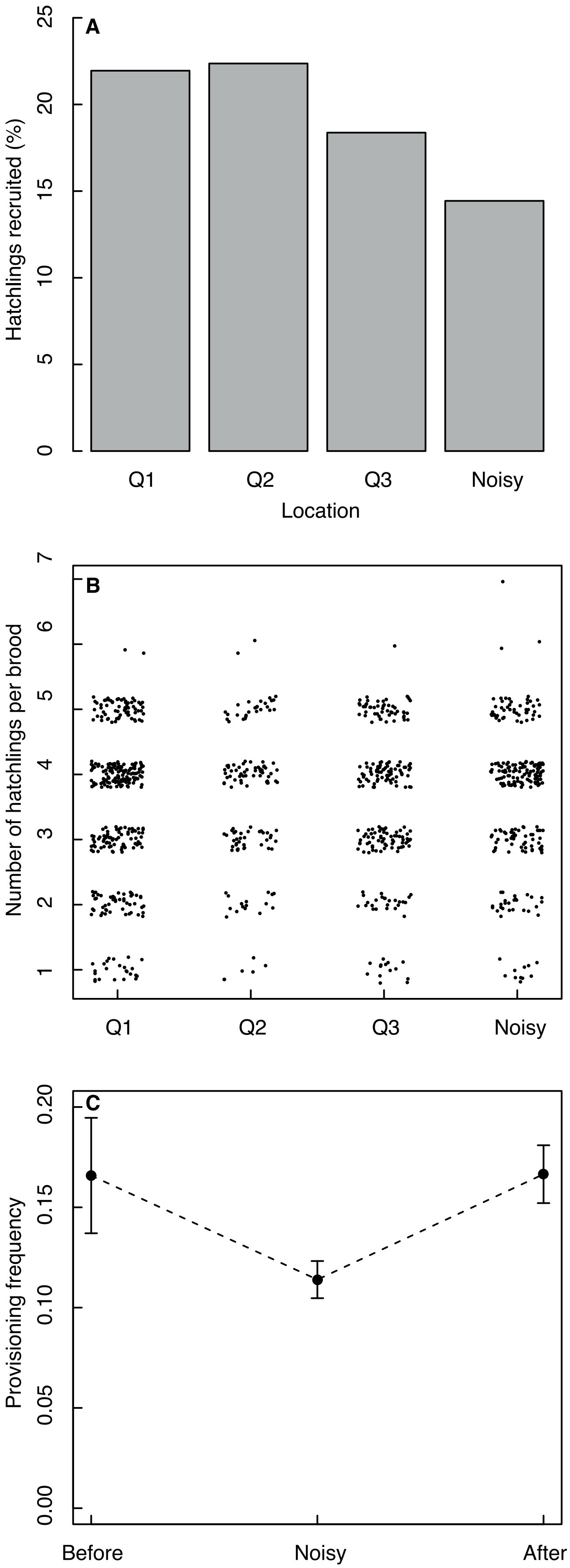


Figure 3. Reproductive success and provisioning frequency of Lundy island house sparrows breeding in nestboxes in the noisy area and elsewhere. (a) Percentage of house sparrow hatchlings that recruited to the breeding population, in relation to the environment in which they were raised (Q1–3 = quiet, N = noisy). These data are not corrected for natal brood and foster area. (b) Number of Lundy house sparrow hatchlings per brood in relation to brood area (jittered). (c) Provisioning frequency (visits per minute) within individual female house sparrows that bred in quiet environments before and after they bred, or both, in the noisy environment. *N* = 69 females switched between noisy and non-noisy locations between broods. Whiskers depict one standard error.
doi:10.1371/journal.pone.0039200.g003

Female age did not differ between noisy and quiet areas (Kruskal-Wallis test: $\chi^2 = 0.32$, $df = 1$, $P = 0.57$, $N = 962$) but males breeding at the noisy areas were older than those breeding elsewhere (Kruskal-Wallis test: $\chi^2 = 7.09$, $df = 1$, $P = 0.01$, $N = 954$).

Chick Development (H3)

We compared the fledging body mass of chicks reared in a noisy area with those reared elsewhere. We used the data from our cross-fostering experiment and corrected for the location of the natal brood. This was done to distinguish between the effect of low-quality parents, which might produce low-quality offspring, breeding more often in the noisy environment than elsewhere, from chicks suffering from being reared in the noisy environment. Chicks that were reared, but not necessarily born, in a noisy area had a significantly lower body mass when 12 days old than chicks reared in a quiet area (BMM, body mass at day 12 in grams: fixed effects: $b_{intercept} = 23.91$ (23.12 to 24.80); $b_{noisy} = -0.74$ (-1.39 to -0.02), $b_{time\ of\ day} = 1.58$ (0.77 to 2.24); random effects: $u_{brood} = 5.52$ (4.77 to 7.73), $u_{natal\ area} = 0.01$ (0 to 0.02), $u_{year} = 0.005$ (0 to 0.98), $e_{residual} = 7.49$ (6.82 to 8.55), $N = 922$).

Cross-sectional analysis. We then compared the provisioning frequencies of house sparrows breeding in the noisy environment with those of birds breeding elsewhere. Females, but not males, provisioned broods in the noisy environment significantly less often than in other areas (Table 2). Consistent with the previous observation that males are more repeatable in their parental care than females [16], we also found that males were individually more predictable caregivers than females (Table 2).

Within-individual effects of noise on provisioning. We used the same data to compare provisioning frequencies of individual parents breeding in the noisy area with the provisioning frequencies of the same individuals when they bred elsewhere (within-individual effects, see [24]). Individual females visited their broods less often per hour when breeding in the noisy environment (BMM parameter estimates (CI), fixed effects: $b_{intercept} = 6.52$, (4.93 to 8.01); $b_{within} = -1.09$ (-1.60 to -0.62); $b_{between} = -1.30$ (-2.41 to -0.29); $b_{clutchsize} = 0.40$ (0.02 to 0.78), random effects: $u_{ID} = 0.39$ (0 to 1.44), $u_{year} = 0.07$ (0–0.34), $e_{residual} = 16.61$ (14.3 to 19.46)). The within- and between-female effects of breeding in the noisy environment were not significantly different (BMM: fixed effects: $b_{intercept} = 7.86$ (6.10 to 9.56); $b_{within} = -2.59$ (-4.81 to -0.59); $b_{?\ between\text{-}within} = 0.21$ (-1.09 to 1.35); $b_{clutchsize} = 0.39$ (-0.01 to 0.75). We did not find a similar effect of noisy location on provisioning frequency in male house sparrows (BMM, fixed effects: $b_{intercept} = 6.82$ (4.32 to 9.47); $b_{within} = -0.88$ (-3.95 to 2.13); $b_{between} = -0.10$ (-1.82 to 1.80); $b_{clutchsize} = 0.61$ (0.19 to 1.14), random effects: $u_{ID} = 4.69$ (1.84 to 8.20), $u_{year} = 0.71$ (0 to 3.37), $e_{residual} = 24.13$ (20.91 to 28.29)).

We then used a subset of data that consisted only of those females that changed, within and between years, from or to the noisy area, and tested whether their provisioning frequency changed. We retained the information on whether or not females had bred previously in a quiet area and moved into a noisy environment, or *vice versa*. The same females provisioned their young more frequently before and after moving to the noisy environment ($N = 96$ broods, Figure 3c, linear model with area as factor: $F_1 = 11.48$, $P<0.001$; clutchsize: $F_1 = 0.24$, $P = 0.63$).

Finally, we also tested whether sparrow females reacted by adjusting their provisioning rate in response to short-term noise. When the noise was present, female sparrows had a reduced provisioning rate within a single brood, and an increased provisioning rate when the noise-producing ventilators were off independent of the sequence of events (Fig 4, Table 3). We used data from video recordings of provisioning taken at quiet locations but at approximately the same time as controls, because the fans' running time might have been correlated with some external variable that also affected provisioning. However, we found no change in provisioning rates at quiet nestboxes during the times when the fans were on (Fig. 4, Table 3).

Discussion

House sparrows reared in a noisy environment experienced reduced parental provisioning, lower fledging mass, and lower fledging and recruiting success. Our results support the impaired chick development hypothesis (H3). We observed a reduced provisioning frequency in the noisy environment, which is suggestive evidence for a novel mechanism of how noise may affect fitness of passerines: by masking parent–offspring communication. Our study has one caveat: We had only one location that was subjected to constant noise with sufficient data to measure fitness, and we can therefore not exclude the possibility that some other variable we did not account for caused the drop in fitness in the noisy area. We, however, do not believe that this is the case because the noisy location is similarly close to the main feeding grounds as most other nest sites and, therefore, birds should not have had a harder time foraging. If another environmental factor, such as exhaust pollution, caused the lowered condition of chicks then we would have also expected to see a similar effect in the physical condition of adults breeding in that area, which we did not find. Similarly, if another factor had led to a change in the visitation rate by birds to their nests, we would also have expected a difference in incubation visits between the noisy and quiet areas, which again we did not find. Furthermore, all nestboxes in all areas were built following a standard model [25], reducing environmental variability. We have found earlier that house sparrows on Lundy are consistent in their within-individual reproductive output between years, which indicates that deviations from this constancy may be due to changes in the environment, not changes in the adult [17]. Finally, the observation that females respond flexibly to the presence of noise within short periods of time supports the idea that a change in feeding rate, as a response to noise, might be the cause for the low fitness in the noisy area.

We did not find support for the impaired mate choice hypothesis (H1): females did not decrease reproductive investment other than provisioning behaviour when breeding in the noisy area: clutch size, breeding date and incubation behaviour did not differ between the noisy and quiet areas. Clutches in the noisy area did not contain an increased rate of extra-pair offspring (contradicting [11]). It is possible that females decreased provisioning rate in response to a potentially perceived low mate-quality, if mate quality in house sparrows is mainly signalled by song displays. Little is known about how song quality affects female choice in house sparrows. However, if coitus, and the decision to mate with a certain individual, take place away from the nest [26] and outside of the noisy environment in our study, it is likely that most females have the chance to sample their mate's song quality in a quiet area, unbiased by the noise. Furthermore, if females assume her mate is of lower quality it would be more prudent to reduce primary reproductive investment, i.e. in clutch size rather than reducing parental care after investing in costly eggs. The similar rates of extra-pair offspring between nests in noisy and quiet areas additionally suggest that mating decisions of females were not affected by the noise. We therefore assume that, in our study, acoustic masking of the communication between the adults probably did not affect the reduced reproductive fitness in the noisy environment.

We found no support for the impaired territory quality hypothesis (H2): Sparrows did not avoid breeding in the noisy area. Surprisingly, we found that older males, but not females, were more likely to breed in the noisy environment. Older house sparrows have a larger black bib, which signals social dominance [18,27]. The apparent preference of older males for the noisy area is difficult to explain, although it must be noted that the effect size was relatively small (0.3 years difference). However, assuming that

Table 2. Results of a BMM modelling Lundy island house sparrow provisioning frequencies (visits/hour) on day 7 in quiet and noisy environments. Statistically significant fixed effects are indicated in bold.

	Female provisioning frequency		Male provisioning frequency	
Effects	**Posterior mode**	**95% CI**	**Posterior mode**	**95% CI**
Fixed				
Intercept	8.91	5.77–10.63	7.24	4.49–11.03
Noisy environment	−2.31	−3.20– −1.51	−0.85	−2.31–0.27
Laying date	0.009	−0.01–0.02	0.004	−0.01–0.02
Age of Mother	0.23	−0.12–0.56	0.14	−0.21–0.61
Age of Social Father	−0.16	−0.43–0.14	−0.16	−0.50–0.35
Random				
Mother ID	0	0.00–0.74	0.002	0.00–0.75

Females: $N = 422$, with observations on 147 individuals; males: $N = 420$, with observations on 138 individuals.
doi:10.1371/journal.pone.0039200.t002

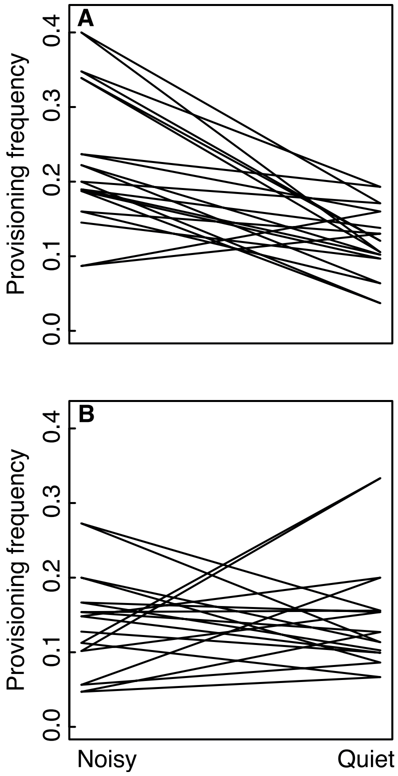


Figure 4. Frequency of provisioning (visits per minute) by female Lundy island house sparrows breeding in nestboxes affected by intermittent noise (top), and by those not affected by noise. Provisioning frequencies were calculated for the time period during which the noise was on and off in both groups. Lines represent changes in provisioning rate within individual females.
doi:10.1371/journal.pone.0039200.g004

older males are of higher quality, they would seem to consider the noisy area to be a desirable habitat.

Our results support the impaired chick development hypothesis (H3). Our study set-up does not allow us to distinguish between the effects of chronic stress and those of acoustic masking, and we discuss supporting evidence for or against both possible mechanisms. Chronic noise is known to induce stress-related changes along the hypothalamo–pituitary–adrenal axis [14], which might influence chick and parent physiology. We found twelve-day-old chicks to be of lower body mass when reared in the noisy environment, however, this seems as likely to be a consequence of the reduced provisioning frequency as a reaction to chronic stress. We found no evidence for an effect of stress in adults: body mass of adults did not differ between the noisy and quiet areas, which indicates that, at least for adults, the noise did not result in lowered condition due to stress. Stress could also affect adult behaviour and nest visitation rates. If this were the case, we would expect this stress response to similarly affect incubation behaviour, which was not the case. We cannot exclude that chronic noise and the associated stress has been the sole cause for the lowered chick condition, but given our results we consider it unlikely.

Provisioning rates were lower in the noisy environment than elsewhere. We have also shown that sparrow females respond flexibly to short-term, familiar environmental noise with an immediate reduction in provisioning frequency. The observation that sparrow females increase their provisioning rate during times with no noise is suggestive evidence for a causal mechanism to link provisioning behaviour with environmental noise. Parental birds

Table 3 Results of a BMM modelling Lundy island house sparrow female provisioning frequencies (visits/hour) at a location intermittently affected by noise and at control nestboxes during the same time periods (two-level factor with noise off as the reference level). Statistically significant fixed effects are indicated in bold.

Effects	**Effect size**	**95% CI**	**Effect size**	**95% CI**
	Intermittent noise		**Control**	
Fixed				
Intercept	13.73	10.54–16.60	8.27	5.44–10.90
Noise on	−6.54	−10.48– −2.61	0.25	−3.44–4.52
Random				
Bird ID	1.54	0.00–7.74	0.26	0.00–4.39
Residual	21.92	9.18–37.71	20.63	8.40–35.73

N_{noise} = 22 observation periods on five females, N_{quiet} = 20 observation periods on nine females.
doi:10.1371/journal.pone.0039200.t003

use the information communicated to them through begging from their chicks to adjust their provisioning frequency according to the chick's needs [28–33]. Offspring begging is an adaptive behaviour [33]; parent birds increase their provisioning rate when presented with increased begging [30]. Therefore, if noise masks begging vocalisations, parents will not respond appropriately. Another possibility is that offspring may not hear their parents arriving at the nestbox and therefore fail to beg for food [15].

We only found females to lower their provisioning rate in the noisy environment, not males. In house sparrows, males provide food to their young at a relatively constant rate while females are more flexible [16]. The most parsimonious explanation for the differences between the sexes is that males are unresponsive, while females may be more responsive to nuances in the chicks' begging vocalisations. We suggest that, in the noisy area on Lundy, female sparrows perceive they have less needy chicks because the acoustic communication with their chicks is intercepted by generator noise. The chicks of unresponsive parents are disadvantaged [29,32,33]. We suggest that acoustic masking of parent–offspring acoustic communication may be at least a partial explanation for the lowered parental provisioning in the noisy areas.

The strength of our study is that it suggests direct fitness consequences of chronic noise in wild birds. Fitness is generally difficult to measure in wild populations but, by using an island population, we can be relatively sure that the birds affected by noise had not simply dispersed. It is perhaps surprising that such a large fitness effect is found in house sparrows, a species thought to be well adapted to living in close association with humans, where chronic background noise is pervasive. Yet, insufficient reproductive output has been shown to be responsible for the decline of the sparrow from cities and rural areas [34]. Factors associated with urbanisation and food availability have been suggested as causes [35]. Our results point to the possibility that chronic noise might be a part of the explanation for the decline of the house sparrow in urban areas. Urban noise has been shown to interfere with acoustic communication between conspecifics in several bird species [9,36]. In order to assess which particular urban noises could be problematic we would need a comprehensive acoustic analysis of sound frequencies. The potential of urban noise to acoustically mask parent–offspring communication, as well as the physiological effects of urban noise, need to be investigated experimentally in order to validate the extent of these effects, and to understand the conservation implications [12].

Acknowledgments

We are grateful to the Lundy Company and their staff for allowing us to work on Lundy, and for their invaluable support in the field. We thank N. Ockendon, D. Gillespie and M. Karlsson for field data collection. H. Dugdale, M. Hinsch, A. Liker, R. Radersma, I. Winney, and two anonymous referees provided helpful comments on an earlier version of the manuscript.

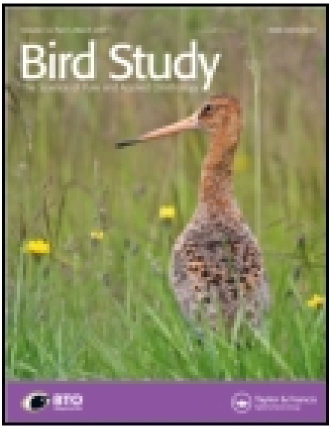
Author Contributions

Conceived and designed the experiments: JS SN IC TB. Performed the experiments: SN IC. Analyzed the data: JS. Contributed reagents/materials/analysis tools: TB SN. Wrote the paper: JS IC SN TB.

References

1. Slabbekoorn H, Peet M (2003) Birds sing at a higher pitch in urban noise. Nature 424: 267.
2. Brumm H (2004) The impact of environmental noise on song amplitude in a territorial bird. J Anim Ecol 73: 434–440.
3. Quinn J, Whittingham M, Butler S, Cresswell W (2006) Noise, predation risk compensation and vigilance in the chaffinch *Fringilla coelebs*. J Avian Biol 37: 601–608.
4. Swaddle J, Page L (2007) High levels of environmental noise erodes pair preferences in zebra finches: implications for noise pollution. Anim Behav 74: 363–368.
5. Francis CD, Ortega CP, Cruz A (2010) Vocal frequency change reflects different responses to anthropogenic noise in two suboscine tyrant flycatchers. Proc R Soc Lond B 278: 2025–2031.
6. Slabbekoorn H, den Boer-Visser A (2006) Cities change the songs of birds. Curr Biol 16: 2326–2331.
7. Rheindt FE (2003) The impact of roads on birds: Does song frequency play a role in determining susceptibility to noise pollution? J Ornithol 144: 295–306.
8. Habib L, Bayne EM, Boutin S (2007) Chronic industrial noise affects pairing success and age structure of ovenbirds *Seiurus aurocapilla*. J Appl Ecol 44: 176–184.
9. Francis CD, Ortega CP, Cruz A (2009) Noise pollution changes avian communities and species interactions. Curr Biol 19: 1415–1419.
10. Halfwerk W, Holleman LJM, Lessells CM, Slabbekoorn H (2011) Negative impact of traffic noise on avian reproductive success. J Appl Ecol 28: 210–219.
11. Halfwerk W, Bot S, Buikx J, van der Velde M, Komdeur J, et al. (2011) Low-frequency songs lose their potency in noisy urban conditions. Proc Natl Acad Sci USA 35: 14549–14554.
12. Slabbekoorn H, Ripmeester EAP (2008) Birdsong and anthropogenic noise: implications and applications for conservation. Mol Ecol 17: 72–83.
13. Reijnen R, Foppen R, Meeuwsen H. (1996) The effects of traffic on the density of breeding birds in Dutch agricultural grasslands. Biol Conserv 75: 255–260.
14. Cyr N, Earle K, Tam C, Romero L (2007) The effect of chronic psychological stress on corticosterone, plasma metabolites, and immune responsiveness in European starlings. Gen Comp Endocr 154: 59–66.
15. Leonard ML, Horn AG (2012) Ambient noise increases missed detections in nestling birds. Biol Lett doi:10.1098/rsbl.2012.0032.
16. Nakagawa S, Gillespie DOS, Hatchwell BJ, Burke T (2007) Predictable males and unpredictable females: sex difference in repeatability of parental care in a wild bird population. J Evol Biol 20:1674–1681.
17. Schroeder J, Burke T, Mannarelli M-E, Dawson DA, Nakagawa S (2012) Maternal effects and heritability of annual productivity. J Evol Biol 25: 149–156.
18. Nakagawa S, Burke T (2008) The mask of seniority? A neglected age indicator in house sparrows *Passer domesticus*. J Avian Biol 39: 222–225.
19. Ockendon N, Griffith SC, Burke T (2009) Extrapair paternity in an insular population of house sparrows after the experimental introduction of individuals from the mainland. Behav Ecol 20: 305–312.
20. Cleasby IR, Nakagawa S, Gillespie DOS, Burke T (2010) The influence of sex and body size on nestling survival and recruitment in the house sparrow. Biol J Linn Soc 101: 680–688.
21. Schroeder J, Cleasby I, Nakagawa S, Ockendon N, Burke T (2011) No evidence for adverse effects on fitness of fitting passive integrated transponders (PITs) in wild house sparrows *Passer domesticus*. J Avian Biol 42: 271–275.
22. Hadfield JD (2010) MCMC Methods for multi-response generalized linear mixed models: The MCMCglmm R package. J Stat Soft 33: 1–22.
23. Gelman A, Hill J (2007) Data Analysis Using Regression and Multilevel/Hierarchical Models. Cambridge: Cambridge University Press.
24. Van de Pol M, Wright J (2009) A simple method for distinguishing within-versus between-subject effects using mixed models. Anim Behav 77: 753–758.
25. Burke T (1984) The Ecological Genetics of Two Populations of the House Sparrow, *Passer domesticus*. PhD thesis, University of Nottingham.
26. Summers-Smith JD (1963) The House Sparrow. London: Collins.
27. Nakagawa S, Ockendon N, Gillespie DOS, Hatchwell BJ, Burke T (2007) Assessing the function of house sparrows' bib size using a flexible meta-analysis method. Behav Ecol 18: 831–840.
28. Burford J, Friedrich T, Yasukawa K (1998) Response to playback of nestling begging in the red-winged blackbird, *Agelaius phoeniceus*. Anim Behav 56: 555–561.
29. Price K (1998) Benefits of begging for yellow-headed blackbird nestlings. Anim Behav 56: 571–577.
30. Kilner R, Noble D, Davies NB (1999) Signals of need in parent–offspring communication and their exploitation by the common cuckoo. Nature 397: 667–672.
31. Leonard M, Horn A (2001) Begging calls and parental feeding decisions in tree swallows (*Tachycineta bicolor*). Behav Ecol Sociobiol 49: 170–175.
32. Leonard M, Horn A (2005) Ambient noise and the design of begging signals. Proc R Soc Lond B 272: 651–657.
33. Grodzinski U, Lotem A (2007) The adaptive value of parental responsiveness to nestling begging. Proc R Soc Lond B 274: 2449–2456.
34. Hole D, Whittingham M, Bradbury R, Anderson GQ, Lee PL, et al. (2002) Widespread local house-sparrow extinctions. Nature 418: 931–932.
35. Peach W, Vincent K, Fowler J, Grice P (2008) Reproductive success of house sparrows along an urban gradient. Anim Conserv 11: 493–503.
36. Hu Y, Cardoso GC (2010) Which birds adjust the frequency of vocalizations in urban noise? Anim Behav 79: 863–867.

This article was downloaded by: [University of California Santa Cruz]
On: 05 September 2014, At: 15:37
Publisher: Taylor & Francis
Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



Bird Study

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tbis20

Short Notes

H. Mayer-Gross [a], M. E. Greenhalgh [b] & K. G. Spencer [c]

[a] British Trust for Ornithology

[b] 173 Watling Street Road, Preston, Lancs

[c] 3 Landseer Close, off Carr Road, Burnley, Lancs

Published online: 04 Mar 2011.

To cite this article: H. Mayer-Gross, M. E. Greenhalgh & K. G. Spencer (1965) Short Notes, Bird Study, 12:3, 253-257, DOI: 10.1080/00063656509476103

To link to this article: http://dx.doi.org/10.1080/00063656509476103

PLEASE SCROLL DOWN FOR ARTICLE

Taylor & Francis makes every effort to ensure the accuracy of all the information (the “Content”) contained in the publications on our platform. However, Taylor & Francis, our agents, and our licensors make no representations or warranties whatsoever as to the accuracy, completeness, or suitability for any purpose of the Content. Any opinions and views expressed in this publication are the opinions and views of the authors, and are not the views of or endorsed by Taylor & Francis. The accuracy of the Content should not be relied upon and should be independently verified with primary sources of information. Taylor and Francis shall not be liable for any losses, actions, claims, proceedings, demands, costs, expenses, damages, and other liabilities whatsoever or howsoever caused arising directly or indirectly in connection with, in relation to or arising out of the use of the Content.

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden. Terms & Conditions of access and use can be found at http://www.tandfonline.com/page/terms-and-conditions

Downloaded by [University of California Santa Cruz] at 15:37 05 September 2014

Avian casualties on railways

In their paper 'Casualties among Birds along a selected Road in Wiltshire' (*Bird Study*, 11:168-182), Dunthorn & Errington mention the possible existence of 'black spots' at which exceptional numbers of birds are killed by motor traffic. In an attempt to determine whether such spots occur on railways, I have engaged myself in a certain amount of correspondence and research. The primary question remains unanswered, but the general facts which have come to light should, I think, be put on record.

Howe (*Field Naturalist*, 3:9, 24) lists a total of 75 birds killed on a 2¼ mile stretch of line in Cumberland during 1957 and the first two months of 1958. In correspondence, Messrs. D. Holding and G. W. Follows inform me of 30 birds being found dead in recent years along the 1¾ mile stretch from Glazebury to Astley in south Lancashire, and Mr. D. G. Lawson tells me of 11 casualties along the three miles of line from Farington Junction to Euxton Junction in mid-Lancashire between January and the end of April, 1965.

All the above victims (116) were specifically identified but some additional birds too decomposed for recognition were found. Moreover, as Messrs. Holding and Follows point out, it is likely that a number of victims are thrown well clear of the track, and thus escape notice.

Of the 116, 41 were Owls (27 Tawny, 12 Barn, 1 Long-eared, 1 Little), from which it is clear that those birds are particularly vulnerable. Partridges (24) and Pheasants (9) were next in the casualty order.

A letter of enquiry printed in *Rail News*, February 1965, elicited five replies which, though rather generalised in content, confirm the existence of a regrettably high mortality of birds along the railway: three of the five writers particularly stress the vulnerability of Partridges and Pheasants. Also noteworthy is one writer's mention of a high accident-rate among feral domestic Pigeons alongside a viaduct near Kidderminster.

I thank the several correspondents upon whose information this present communication is based. Their letters have been deposited at the Alexander Library, where they may be consulted by anyone wishing to pursue the subject further.

K. G. SPENCER,
3 Landseer Close,
off Carr Road,
Burnley,
Lancs.

Downloaded by [University of California Santa Cruz] at 15:37 05 September 2014

Lupinus nipomensis
(Nipomo Lupine)

5-Year Review:
Summary and Evaluation

©Dieter Wilken, Santa Barbara Botanic Garden 2005

U.S. Fish and Wildlife Service
Ventura Fish and Wildlife Office
Ventura, California

October 2009

5-YEAR REVIEW

Lupinus nipomensis (Nipomo Lupine)

I. GENERAL INFORMATION

Purpose of 5-Year Review:

The U.S. Fish and Wildlife Service (Service) is required by section 4(c)(2) of the Endangered Species Act (Act) to conduct a status review of each listed species at least once every 5 years. The purpose of a 5-year review is to evaluate whether or not the species' status has changed since it was listed (or since the most recent 5-year review). Based on the 5-year review, we recommend whether the species should be removed from the list of endangered and threatened species, be changed in status from endangered to threatened, or be changed in status from threatened to endangered. Our original listing of a species as endangered or threatened is based on the existence of threats attributable to one or more of the five threat factors described in section 4(a)(1) of the Act, and we must consider these same five factors in any subsequent consideration of reclassification or delisting of a species. In the 5-year review, we consider the best available scientific and commercial data on the species, and focus on new information available since the species was listed or last reviewed. If we recommend a change in listing status based on the results of the 5-year review, we must propose to do so through a separate rule-making process defined in the Act that includes public review and comment.

Species Overview:

Lupinus nipomensis (Nipomo lupine) is a small annual plant in the pea family (Fabaceae). Historically and currently, the species is known only from the southwestern corner of San Luis Obispo County, California, scattered over an area of approximately 2 miles wide and 2 miles long (3.2 by 3.2 kilometers (km)) (Figure 1). It is restricted to sandy soils associated with the Callender Dune Sheet (Cooper 1967). For purposes of this review, we are considering the entire extent of the species to comprise one population; however, the California Natural Diversity Database (CNDDB) has divided the population into approximately 10 occurrences for tracking purposes. Over the last 4 years, the total number of individuals has fluctuated between approximately 139 and 771, depending on winter and spring climatic conditions (Land Conservancy of San Luis Obispo County (Conservancy) 2009). Over time, the species' habitat has been fragmented by State Highway 1 and oil refinery facilities, and bounded on the eastern side by development and agriculture. The small size of the populations and their proximity to a variety of human activities makes it vulnerable to stochastic extinction.

Methodology Used to Complete the Review:

This review was prepared by the Ventura Fish and Wildlife Office (VFWO), following the Region 8 guidance issued in March 2008. We used survey information from experts who have been monitoring various localities of this species, and the CNDDB maintained by the California Department of Fish and Game. The recovery plan and personal communications with experts were our primary sources of information used to update the species' status and threats. This 5-

year review contains updated information on the species' biology and threats, and an assessment of that information compared to that known at the time of listing or since the last 5-year review. We focus on current threats to the species that are attributable to the Act's five listing factors. The review synthesizes all this information to evaluate the listing status of the species and provide an indication of its progress towards recovery. Finally, based on this synthesis and the threats identified in the five-factor analysis, we recommend a prioritized list of conservation actions to be completed or initiated within the next 5 years.

Contact Information:

Lead Regional Office: Diane Elam, Deputy Division Chief for Listing, Recovery, and Habitat Conservation Planning, and Jenness McBride, Fish and Wildlife Biologist, Region 8, Pacific Southwest; (916) 414-6464.

Lead Field Office: Connie Rutherford, Listing and Recovery Program Coordinator for Plants; Ventura Fish and Wildlife Office; (805) 644-1766 x 306.

Federal Register (FR) Notice Citation Announcing Initiation of This Review: A notice announcing initiation of the 5-year review of this taxon and the opening of a 60-day period to receive information from the public was published in the Federal Register on March 25, 2009 (74 FR 12878). No information was received in relation to this species.

Listing History:

Original Listing
FR Notice: 65 FR 14888
Date of Final Listing Rule: March 20, 2000
Entity Listed: *Lupinus nipomensis* (species)
Classification: Endangered

State Listing
Lupinus nipomensis was listed as endangered by the State of California in 1987.

Associated Rulemakings: N/A

Review History: N/A

Species' Recovery Priority Number at Start of 5-Year Review: The recovery priority number for *Lupinus nipomensis* is 5 according to the Service's 2008 Recovery Data Call for the Ventura Fish and Wildlife Office, based on a 1-18 ranking system where 1 is the highest-ranked recovery priority and 18 is the lowest (Endangered and Threatened Species Listing and Recovery Priority Guidelines, 48 FR 43098, September 21, 1983). This number indicates that the taxon is a species that faces a high degree of threat and has a low potential for recovery.

Recovery Plan or Outline: None

II. REVIEW ANALYSIS

Application of the 1996 Distinct Population Segment (DPS) Policy:

The Endangered Species Act defines species as including any subspecies of fish or wildlife or plants, and any distinct population segment (DPS) of any species of vertebrate wildlife. This definition limits listing as distinct population segments to vertebrate species of fish and wildlife. Because the species under review is a plant and the DPS policy is not applicable, the application of the DPS policy to the species' listing is not addressed further in this review.

Updated Information on Current Species Status, Biology, and Habitat:

<u>Species Biology and Life History</u>
Lupinus nipomensis is a small annual herb in the pea family (Fabaceae). The low-spreading individuals can reach 8 inches (20 centimeters) in height (Riggins 1993). Leaves are pinnately compound into five to seven leaflets. Up to 10 pinkish-purple flowers are borne on the ends of the inflorescences (flowering stems). Each flower produces a pod that contains three to four ovules (Riggins 1993), and one healthy plant can produce up to 10 inflorescences (Walters and Walters 1988). Potentially, seed production could reach on the order of 1,000 seeds; however, based on 2 years of sampling, observed seed production per plant ranged from 1 to over 200, with most plants producing less than 30 fruits (Walters and Walters 1988). Growth is indeterminate, with individuals aborting flowers on the central stems in favor of producing additional lateral branches and inflorescences when climatic conditions, particularly the timing of spring rains, are favorable (Walters and Walters 1988). Leaves and stems are succulent, and provide prolonged moisture for seed development. Flowers are self-compatible if manipulated; however, they may require insect visitation for full complements of seeds (Center for Plant Conservation (CPC) 2009). During their four-year study, no observations of pollinators were recorded by Walters and Walters (1988). While pollination ecology has not been specifically studied for *L. nipomensis*, other lupine taxa are known to be pollinated by butterflies and a variety of bee taxa, especially from the genera *Bombus*, *Osmia*, *Synhalonia*, and *Anthidium* (Moldenke 1976).

<u>Distribution</u>
According to records available through the CNDDB (2009) and the Consortium of California Herbaria (Consortium) (2009), all historical collections and unvouchered observations of *Lupinus nipomensis* are from one area in the southwestern corner of San Luis Obispo County. We estimate the total amount of potentially suitable habitat for *L. nipomensis* in contiguous portions of San Luis Obispo County is on the order of 1,000 acres (405 hectares (ha)), while the current footprint of the populations is on the order of 100 acres (40.5 ha).

At this time, *Lupinus nipomensis* is still known to be extant at one location in San Luis Obispo County, California (Appendix 1, figure 1). We consider all individuals at this site to comprise one population of approximately six occurrences (CNDDB 2009) or colonies scattered across a 2-mile (3.2-km) stretch of backdune habitat west of Highway 1 and between Black Lake Canyon to the north and Oso Flaco Lake to the south. All of the habitat for the species is privately owned, most by Conoco-Phillips Oil Company (CPOC), and smaller portions are owned by Pacific Gas and Electric Company, the Conservancy, and other private landowners. A portion of the habitat is within a California Department of Transportation right-of-way.

Abundance, Population Trends

Early survey data from the 1980s is incomplete. The first effort to conduct an annual census was initiated in 1984 and focused on the three colonies that comprise the "Callender" occurrences (CNDDB #2 in Table 2 below); 273 *Lupinus nipomensis* individuals were counted in that year. A large number of individuals (886) were counted during 1985; this number included 83 individuals located near Jack Lake (CNDDB #1 in Table 2 below). A small number of individuals (77) were located in 1986; however, the latter did not represent a complete census of the Jack Lake occurrence (Walters and Walters 1988). By 1987, four additional occurrences had also been located.

No complete surveys or censuses were conducted between 1987 and 2004. Census data taken since 2004 is more complete, but difficult to reconcile with earlier census efforts due to differing mapping methods. In 2003, annual surveys were resumed by the Conservancy. Census data for 2004 and 2005 are considered to be inaccurate due to confusion in differentiating between *Lupinus nipomensis* and another small annual lupine that occurs in the area (Daniel Bohlman, restoration ecologist, Conservancy, pers. comm. 2009). The most accurate census data are from years 2006 through 2009 (See Figure 2). During this 4-year time period, the number of individuals ranged between a high of 771 and a low of 139, prior to mortality due to pocket gopher damage (Conservancy in litt. 2009). For the 3 years from 2007 through 2009, between 28 to 31 percent of *L. nipomensis* individuals were consumed by pocket gophers on Conoco-Phillips property (Conservancy in litt. 2009). Relative to numbers of individuals for other annual plant species, these numbers are extremely low (Keith 1998).

Figure 2: Conservancy census results for *Lupinus nipomensis* at selected locations.

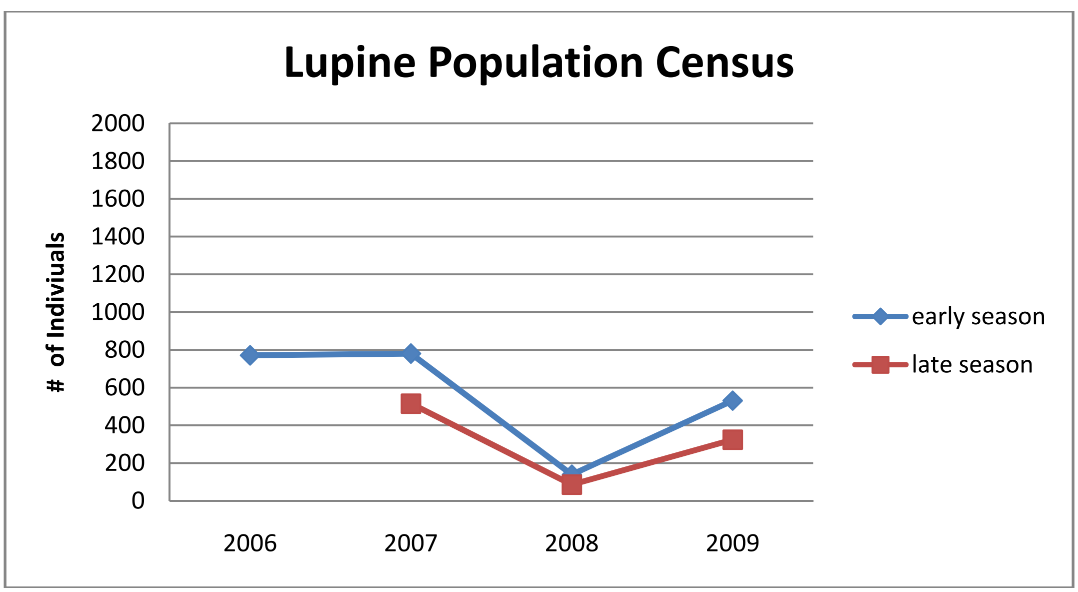


Table 1 below summarizes occurrence data from CNDDB; due to a difference in survey methodology, survey results from the Conservancy efforts (see Table 1) cannot be reconciled with CNDDB data, and therefore is not included in Table 1 below.

Table 1: Occurrence Records for *Lupinus nipomensis* Collated from the CNDDB (2009).

CNDDB #	Name (owner)	CNDDB Current trend	Year collected/observed	Pop size/Year surveyed	Reference
1	Southeast of Jack Lake (private)	presumed extant	Hoover #9365 (1965)	17 (1983) 83 (1985) 177 (1987) 276 (1988) 149 (1998)	CNDDB 2009
2	Callender switching station (CPOC and PG&E)	Presumed extant	Riggins #87204 (1987)	273 (1984) 803 (1985) 77 (1986) 317 (1987) 1035 (1988) 140 (2004)	CNDDB 2009
3	Near Black Lake and Highway 1 (Type locality) (Conservancy)	Presumed extirpated	Eastwood # 18929 (1940)	0 (1980) 0 (1981) 0 (1988)	CNDDB 2009
4	Southeast of main entrance of Unocal Oil Refinery (CPOC)	Presumed extant	--	50 (1987) 44 (1987) 636 (1988)	CNDDB 2009
7	0.8 mi SSW of jct of Highway 1and Willow Rd (private unknown)	Presumed extant	--	1300 (1988)	CNDDB 2009
8	Callender Dunes NE of Jack Lake (CPOC)	Presumed extant	--	80 (1998)	CNDDB 2009
9	Callender Dunes, 0.6 mi N of Jack Lake (CPOC)	Presumed extant	--	12 (1998)	CNDDB 2009

CNDDB identification # = element occurrence number assigned by the California Natural Diversity Database (CNDDB 2009).

Habitat or Ecosystem Conditions (e.g., amount and suitability)

Habitat for *Lupinus nipomensis* is comprised of stabilized back dunes supporting a central coastal dune scrub community. Dominant species include mock heather (*Ericameria ericoides*) and silver lupine (*Lupinus chamissonis*). Other frequent associated species include buckwheat (*Eriogonum parvifolium*), deerweed (*Lotus scoparius*), and horkelia (*Horkelia cuneata*), as well as a large variety of annual herbs interspersed in open areas between the shrubs (Howald 1988).

Walters and Walters (1988) described habitat for the species as either being of degraded quality due to disturbance (type 1) or better quality habitat that was less disturbed and more closely fits the description of coastal dune scrub above (type 2). The sites with disturbed or type 1 habitat are characterized by a lower diversity of species overall, a lower cover of shrubs, a higher percentage of bare sand, a higher cover of nonnative species, and, in most years, a lower density of *Lupinus nipomensis*. At some type 1 sites, the nonnative veldt grass (*Ehrharta calycina*) has become abundant and is crowding out native species.

Lupinus nipomensis needs open habitat to persist. Sandy soils along the coast typically undergo a certain amount of natural disturbance from coastal winds and from the activity of wildlife. However, over time, natural disturbance regimes have been altered by the planting of such species as European beach grass (*Ammophila arenaria*) and eucalyptus (*Eucalyptus* spp.), and human-caused disturbances, such as off-highway vehicle use, have increased. Although high densities of *L. nipomensis* may occur in disturbed habitat in certain years, predation of both seeds and plants is also known to be greater in areas of higher density *L. nipomensis* (Walters and Walters 1988), resulting in lower seed production or mortality. As a result, the occurrence of higher numbers of individuals in disturbed sites does not necessarily equate to a benefit to the species.

Changes in Taxonomic Classification or Nomenclature

No changes in taxonomy or nomenclature have been made since the time of listing.

Genetics

No new studies concerning the genetics of this taxon have been conducted since the time of listing.

Species-specific Research and/or Grant-supported Activities

In 2004, the Service contributed half of the funds necessary to establish a national endowment for the species through the CPC; a private donor contributed the rest of the funds. The endowment addresses activities related to seed collection, viability testing, long-term storage, and propagation if needed. The Santa Barbara Botanic Garden is a member of the CPC and has been undertaking this work (CPC 2009). Wilken (in litt. 2009) tested two batches of seed for viability. Seed that was at least 15 years old and not stored according to standard storage protocols exhibited no germination, while 1-year old seed and stored according to standard storage protocols exhibited 60 percent germination. Wilken also tested for self-compatibility and found that 100 percent (six out of six) of the individuals developed seed.

Five-Factor Analysis

FACTOR A: Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range

According to the California Department of Fish and Game (2005), three historical localities had been extirpated by the late 1990s. Plants have not been seen at the type locality, near Black Lake, since 1937; the location of the other two extirpated localities is unclear. All mapped occurrences, both historic and current, are found within the same small geographic area; therefore, we do not consider that there has been a reduction in the range of the species.

At the time of listing *Lupinus nipomensis* in 2000 (Service 2000), we discussed activities related to energy extraction and refinement (e.g., maintenance activities, hazardous waste cleanup) and development as threats to the species. Since the time of listing until the time of this review, we had not been aware that these activities have contributed to the alteration or loss of any habitat. However, during the course of this review, we became aware of a Notice of Preparation to expand refinery capabilities at the Conoco-Phillips plant (County of San Luis Obispo 2008). The Service has also recently received a notice regarding a proposal to construct a telecommunications facility less than 0.25 mile (0.4 km) away from EO #7 (C. Mehlberg, Service, in litt. 2009). The project proponent notes that the site was previously developed with agricultural fields; whether above-ground plants or a seed bank of *L. nipomensis* remains is unknown. In addition, it appears that several housing developments have been constructed within a mile of *L. nipomensis* habitat over the past 5 years (Google Earth 2009). The presence of a larger human population in the adjacent area is likely to introduce additional direct and indirect effects (such as trampling from recreational use, spread of invasive horticultural species used in landscaping, and loss of pollinator habitat) on the species as time goes on.

At the time of listing, we did not discuss under Factor A the role of sheep grazing, cattle grazing, or the spread of invasive veldt grass in the modification of habitat for *Lupinus nipomensis*. We typically discuss grazing impacts under Factor C (predation) and E (trampling), and competition with nonnative species under Factor E. However, because both these activities can play a role in modifying habitat for *L. nipomensis*, we are including them in Factor A in this review. Sheep grazing was terminated in the area sometime in the mid-1980s (Conservancy 2001). Since the time of listing, the number of cattle grazed on the Conoco-Phillips property has been reduced. In addition, the cattle are grazed between July 1 and December 1 of each year (Bohlman, pers. comm. 2009); because the timing of grazing is not during the active growing and flowering period for *L. nipomensis*, we believe that the direct impacts of grazing from trampling are less than they were at the time of listing.

Veldt grass was described as "rampant" in the area at least 25 years ago (McLeod and Walters 1987); its presence can cause a shift from scrub habitat to grassland habitat (Bossard et al. 2000, California Invasive Plant Council 2009). Since 2000, the Conservancy has been actively removing veldt grass from *Lupinus nipomensis* habitat. While these efforts may have slowed the conversion to a monoculture of veldt grass, it is likely that the habitat will have to be managed in perpetuity to maintain the open patches that is required by *L. nipomensis*. The Conservancy conducted grazing trials in the late 1990s to determine if cattle grazing would be useful in reducing the biomass of veldt grass in advance of treating the veldt grass with herbicides. They found that, although cattle grazing may be useful to reduce veldt grass biomass, it may not be effective in reducing the number of tufts (frequency) due to their pernicious root systems (Bossard et al. 2000, Conservancy 2001). In addition, they found that native shrubs experienced substantial damage from cattle trampling, and that veldt grass increased in areas where cattle grazing was reduced. The Conservancy concluded that the benefits of using cattle for removal of veldt grass biomass were outweighed by damage to native shrubs (Conservancy 2001). Long-term effects of cattle grazing may include altering biodiversity within the habitat and are not completely understood at this point in time.

Conservation

Conoco-Phillips is the primary landowner of habitat where *Lupinus nipomensis* remains extant. In the late 1980s, they entered into an agreement with California Department of Parks and Recreation for the latter to manage Conoco-Phillips lands that border Oceano Dunes State Vehicular Recreation Area. The designation of this land as a buffer zone decreased the amount of illegal off-highway vehicle activity in the area (R. Glick, in litt. 2009). In addition, Conoco-Phillips is working cooperatively with the Conservancy to continue veldt grass removal and to annually census *L. nipomensis* colonies on their lands (Bohlman in litt. 2009). In 1997, the Conservancy acquired a parcel that includes Black Lake and the surrounding area, which was the type locality for *L. nipomensis*. Although habitat is not currently suitable to support *L. nipomensis* due to heavy vegetation cover, it could possibly do so in the future. The

Conservancy has actively been managing for veldt grass, both on their own lands and in partnership with adjacent landowners.

In summary, oil refinery activities appear to be less of a threat than at the time of listing, but a proposal to expand refinery operations in the near future may alter or destroy suitable habitat for *Lupinus nipomensis.* Urban development activities may become more of a threat in the future with human population growth in the area. Overall, habitat is being more closely managed, and has resulted in several parcels falling under more protective management, including a reduction of illegal off-highway vehicle use, and the removal of veldt grass from *L. nipomensis* habitat. Little opportunity for population expansion is available adjacent to the existing populations because habitat has already been converted to other uses, including roads, facilities, agriculture, and housing. However, there may be some opportunity to enhance habitat at existing population sites. The presence of veldt grass continues to be the greatest long-term threat to *L. nipomensis* and its habitat.

FACTOR B: Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Overutilization for commercial, recreational, scientific, or educational purposes was not known to be a factor in the 2000 final listing rule (65 FR 14888). Overutilization for any purpose does not appear to be a threat at this time.

FACTOR C: Disease or Predation

Disease was not considered a threat at the time of listing in 2000. At that time, we identified that pocket gophers (*Thomomys bottae*) had consumed entire colonies of *Lupinus nipomensis*, as reported by Walters and Walters (1988). While pocket gophers are known to harvest seeds of many species in general (Martin et al. 1951), it is more likely that they consume the roots, stems, and leaves of *L. nipomensis*, and that seeds die prior to full maturation. However, seed that are able to complete maturation despite being excised from the plant may find suitable germination sites in the vacated gopher mounds the following winter season (Walters and Walters 1988). In addition, our listing rule stated that the presence of veldt grass increases the food source for pocket gophers and thus potentially increases their numbers and their potential harm to *L. nipomensis* (Walters and Walters 1988). Survey results for the 3 years from 2007 through 2009 indicate that from 28 to 31 percent of *L. nipomensis* individuals are consumed by pocket gophers on Conoco-Phillips property (Conservancy in litt. 2009); therefore, we continue to believe that pocket gophers continue to be a threat to the species.

Our listing rule stated that a variety of insects were variously foraging on the seeds, stems, or leaves of *L. nipomensis* and reducing its reproductive potential; insects include an anthomyid fly (*Hylemya lupini* Coquillette), the common painted lady butterfly (*Vanessa cardui*), a noctuid moth (family Pyridae), and a lupine blue butterfly (*Plebejus lupini monticola*). No data have been gathered to determine the extent of these threats on the long-term persistence of *L. nipomensis*.

At the time of listing, we were not aware of, and did not discuss, the potential impacts of cattle grazing on *Lupinus nipomensis*. In the early 2000s, the Conservancy worked with Conoco-Phillips to reduce the number of cattle grazed on their lands (Service in litt. 2005). In addition, the timing of grazing is such that it does not occur when *L. nipomensis* is growing and flowering. Therefore, we believe the effects of grazing due to consumption are small to none (see Factor A for a discussion of the effects of grazing on habitat).

FACTOR D: Inadequacy of Existing Regulatory Mechanisms

At the time of listing, regulatory mechanisms thought to have some potential to protect *Lupinus nipomensis* included: (1) listing under the California Endangered Species Act (CESA); (2) the California Environmental Quality Act (CEQA) and the National Environmental Policy Act (NEPA); (3) the California Coastal Act; and (4) local land use laws, regulations, and policies. The listing rule (65 FR 14888) provides an analysis of the level of protection that was anticipated from those regulatory mechanisms. For the most part, this analysis appears to remain valid. However, there may also be future federal and state involvement through the Environmental Protection Agency, the Water Quality Control Board, and the Air Quality Control Board, due to their regulatory authority over air quality, water quality, and hazardous waste management associated with oil refinery activities. In addition, the Federal Communications Commission may have regulatory authority over the installation and permitting of telecommunications facilities.

Lupinus nipomensis was listed as endangered by the State of California in 1987. As such, projects that would affect *L. nipomensis* are subject to CESA and CEQA requirements. Protection of listed species through CEQA is dependent upon the discretion of the lead agency involved. To the best of our knowledge, no projects have evaluated impacts to the species pursuant to CESA and CEQA since the species was listed. A Notice of Preparation was recently circulated by the County of San Luis Obispo for a proposed project to increase refinery capabilities by the Conoco-Phillips refinery by 12.5 percent (County of San Luis Obispo 2008). The project may include installation of a new pipeline from the refinery north to the San Francisco Bay area; if so, the pipeline would potentially alter or destroy habitat for *L. nipomensis*. This project would likely be subject to both state and federal agency regulations.

In summary, although there are both state and federal regulatory mechanisms that would potentially apply to projects within *Lupinus nipomensis* habitat, none of them have been invoked since the time of listing. We believe that pending and future projects will be subject to available regulatory mechanisms.

FACTOR E: Other Natural or Manmade Factors Affecting Its Continued Existence

At the time of listing, we discussed competition with nonnative species and stochastic extinction due to small size of populations and numbers as threats to *Lupinus nipomensis*. An analysis of these threats is contained in the final rule and appears to remain currently valid.

<u>Nonnative Species</u>
In general, invasion of this habitat by nonnative species (particularly veldt grass (see Bossard et

al. 2000)) is a threat to populations of native species because individuals cannot compete well for light, water, and resources (D'Antonio and Vitousek 1992). The expansion of veldt grass in *Lupinus nipomensis* habitat and its effects on the species were discussed in Factor A.

<u>Stochastic Extinction</u>
We continue to believe that the existence of less than 10 occurrences and the small number of individuals in the occurrences (Figure 1 and Table 1) place *Lupinus nipomensis* at risk of extinction from stochastic events. The conservation biology literature commonly notes the vulnerability of taxa known from one or very few locations and/or from small and highly variable populations (e.g., Shaffer 1981, 1987; Groom et al. 2006; Primack 2006). In particular, although the plants are apparently self-compatible and capable of self-fertilization, the small size of the population makes it difficult for this species to persist while sustaining the impacts of habitat alteration that favors nonnative plant species and the potential loss of pollinator habitat.

<u>Climate Change</u>
At the time of listing, we did not discuss the potential effects of climate change on the long-term persistence of *Lupinus nipomensis*. Current climate change predictions for terrestrial areas in the Northern Hemisphere indicate warmer air temperatures, more intense precipitation events, and increased summer continental drying (Field et al. 1999, Cayan et al. 2005, Intergovernmental Panel on Climate Change 2007). Recently, the potential impacts of climate change on the flora of California were discussed by Loarie et al. (2008). Based on modeling, they predicted that species' distributions will shift in response to climate change, specifically that the species will "move" or disperse to higher elevations and northward, depending on the ability of each species to do so. Species diversity will also shift in response to these changes with a general trend of increasing diversity shifting towards the coast and northwards with these areas becoming de facto future refugia. However, predictions of climatic conditions for smaller sub-regions such as California remain uncertain. It is unknown at this time if climate change in California will result in a warmer trend with localized drying, higher precipitation events, or other effects.

While we recognize that climate change is an important issue with potential effects to listed species and their habitats, we lack adequate information to make accurate predictions regarding its effects to *Lupinus nipomensis* at this time.

III. RECOVERY CRITERIA

Recovery plans provide guidance to the Service, States, and other partners on ways to minimize threats to listed species and on criteria that may be used to determine when recovery is achieved. There are many paths to accomplishing recovery of a species and recovery may be achieved without fully meeting all recovery plan criteria. For example, one or more criteria may have been exceeded while other criteria may not have been accomplished. In that instance, we may determine that, over all, the threats have been minimized sufficiently, and the species is robust enough, to reclassify the species from endangered to threatened or perhaps to delist it. In other cases, new recovery opportunities unknown at the time the recovery plan was finalized may be more appropriate. Likewise, new information may change the extent that criteria need to be met for recognizing recovery of the species. Overall, recovery is a dynamic process requiring adaptive management, and assessing a species' degree of recovery is likewise an adaptive process that may, or may not, fully follow the guidance provided in a recovery plan. We focus our evaluation of species status in this 5-year review on progress that has been made toward recovery since the species was listed (or since the most recent 5-year review) by eliminating or reducing the threats discussed in the five-factor analysis. In that context, progress towards fulfilling recovery criteria serves to indicate the extent to which threat factors have been reduced or eliminated.

A recovery plan for *Lupinus nipomensis* has not yet been developed; therefore no recovery criteria exist.

IV. SYNTHESIS

The status of *Lupinus nipomensis* does not appear to have changed substantially since the time of listing in 2000. Conservation measures have been undertaken to improve management of the habitat on several parcels. The Conservancy in partnership with adjacent landowners has been working to reduce the amount of veldt grass within *L. nipomensis* habitat. They have also been instrumental in carrying out an annual census of the species. Nevertheless, alteration of habitat due to the presence of veldt grass is a primary continuing threat to the species.

The most reliable census information from years 2006 through 2009 indicates that the total numbers of individuals of *Lupinus nipomensis* is very low and fluctuates annually. Pocket gopher predation has removed approximately 30 percent of the plants censused between 2007 and 2009. In addition, seed studies to date indicate that viable seed is being produced; however, germination rates in the wild appear to be lower than those in greenhouse studies. The combination of low numbers of individuals and the concentration of all occurrences in a small geographic area make this species vulnerable to stochastic extinction. We conclude that this taxon continues to be in danger of extinction throughout its currently known range and therefore meets the definition of endangered under the Federal Endangered Species Act; no status change is recommended at this time.

V. RESULTS

Recommended Classification:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist (indicate reasons for delisting per 50 CFR 424.11):
    ____ *Extinction*
    ____ *Recovery*
    ____ *Original data for classification in error*
__X__ No Change

New Recovery Priority Number and Brief Rationale: N/A

VI. RECOMMENDATIONS FOR FUTURE ACTIONS

1. Complete a Recovery Outline and Species Action Plan for *Lupinus nipomensis* as a first step in preparing a recovery plan for the species.

2. Work with Conoco-Phillips and California Department of Transportation to ensure that management of their lands and rights-of-way is consistent with the long-term persistence of *Lupinus nipomensis* at those sites. In addition, work with the County of San Luis Obispo to ensure that consideration is given to *L. nipomensis* during projects review and implementation.

3. In partnership with Santa Barbara Botanic Garden, continue with research on seed characteristics, particularly to determine the extent of the soil seed bank present, and whether there is a difference in seed viability between those produced from self-fertilization and those produced by cross-pollination to determine if lack of pollinators is a concern.

4. In partnership with Santa Barbara Botanic Garden and the Conservancy, experiment with establishment of new populations in other coastal dune scrub habitat in coastal San Luis Obispo County.

VII. REFERENCES

<u>Literature and *In litteris* cited</u>

Bohlman, Daniel. Restoration Ecologist, The Land Conservancy of San Luis Obispo. E-mail to Connie Rutherford, U.S. Fish and Wildlife Service, Ventura, California, regarding the management of Nipomo lupine on Conoco-Phillips parcel. June 24, 2009.

Bossard, C. C, J.M. Randall, and M.C. Hoshovsky. 2000. Invasive plants of California's wildlands. University of California Press, Los Angeles. Pp. 164-170.

California Climate Change Center. 2006. Projecting future sea level. California Energy Commission, Sacramento. 64 pp.

California Climate Change Center. 2009. Impacts of sea level rise on the California coast. California Energy Commission, Sacramento. P. 83.

California Coastal Commission. 2001. Overview of sea level rise and some implications for coastal California. San Francisco. 58 pp.

California Invasive Plant Council. 2009. Profile for *Ehrharta calycina*. Accessed online on June 1, 2009, at http://www.cal-ipc.org/.

California Department of Fish and Game. 2005. The status of rare, threatened, and endangered plants and animals of California 2000-2004. Sacramento. P. 465.

California Natural Diversity Data Base (CNDDB). 2009. Element occurrence reports for *Lupinus nipomensis*. California Department of Fish and Game, Sacramento, California.

Cayan, D., M. Dettinger, I. Stewart, and N. Knowles. 2005. Recent changes towards earlier springs: early signs of climate warming in western North America? U.S. Geological Survey, Scripps Institution of Oceanography, La Jolla, California.

Center for Plant Conservation. 2009. Species profile for *Lupinus nipomensis*. Accessed online at http://Centerforplantconservation.org on June 1, 2009.

Consortium of California Herbaria. 2009. Accessed records for *Lupinus nipomensis* online on March 1, 2009, at http://ucjeps.berkeley.edu/consortium.

Cooper, W.S. 1967. Coastal dunes of California. The Geological Society of America, mem. no. 104. Boulder, Colorado. Pp. 75-82.

County of San Luis Obispo. 2008. Notice of preparation of an environmental impact report. San Luis Obispo County Planning Department. Dated September 2008. 15 pp.

D'Antonio, C.M., and P.M. Vitousek. 1992. Biological invasions by exotic grasses, the grass/fire cycle, and global change. Annual Review of Ecology and Systematics 23: 63-87.

Field, C.B., G.C. Daily, F.W. Davis, S. Gaines, P.A. Matson, J. Melack, and N.L. Miller. 1999. Confronting climate change in California. Ecological impacts on the Golden State. A report of the Union of Concerned Scientists, Cambridge, Massachusetts, and the Ecological Society of America, Washington, DC.

Glick, R. 2009. Senior environmental scientist, Oceano Dunes District State, California Department of Parks and Recreation. E-mail to Connie Rutherford, U.S. Fish and Wildlife Service, Ventura, California, regarding the management of Conoco-Phillips lands adjacent to Oceano Dunes State Vehicle Recreation Area. September 11, 2009.

Google Earth. 2009. Images of the Black Lake Canyon-Nipomo Mesa area. Accessed online at http://earth.google.com on June 10, 2009.

Groom, M.J., G.K. Meffe, and C.R. Carroll. 2006. Principles of conservation biology, third edition. Sinauer Associates, Inc., Sunderland, Massachusetts.

Howald, A. 1988. Field survey forms for *Lupinus nipomensis* surveys, April 1-3, 1988, submitted to CNDDB. California Department of Fish and Game, Sacramento, California.

Intergovernmental Panel on Climate Change. 2007. Climate change 2007: the physical science basis. Summary for policymakers. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, IPCC Secretariat, World Meteorological Organization and United Nations Environment Programme, Geneva, Switzerland.

Keith D.A. 1998. An evaluation and modification of World Conservation Union Red List Criteria for classification of extinction risk in vascular plants. Conservation Biology, vol. 12, no. 5:1076-1090.

Land Conservancy of San Luis Obispo County. 1999. Tosco inland veldt grass grazing experiment. San Luis Obispo, California. 15 pp.

Land Conservancy of San Luis Obispo County. 2009. Monitoring data for *Lupinus nipomensis* for years 2004-2009. San Luis Obispo, California.

Loarie S.R., B.E. Carter, K. Haydoe, S. McMahon, R. Moe, C.A. Knight, D.D. Ackerly. 2008. Climate change and the future of California's endemic flora. Plos ONE 3(6): e2502 doi 10.1371/journal.pone 0002502.

Martin, A.C., H.S. Zim, and A.L. Nelson. 1951. American wildlife and plants: a guide to wildlife food habits. Dover Publications, Inc. New York. Pp. 255-256.

McLeod, M.G., and Walters, D.R. 1987. Status report on *Lupinus nipomensis*, 2nd draft. Prepared for U.S. Fish and Wildlife Service, Sacramento, California. San Luis Obispo. 8 pp.

Mehlberg, Colleen. 2009. Biologist, U.S. Fish and Wildlife Service, Ventura Office, Ventura, California. E-mail correspondence with Lacrissa Cook, Rincon Consultants, regarding the Hwy-1/Olivera Avenue Bechtel telecommunications facility project. Dated August 13, 2009.

Moldenke, A.R. 1976. California pollination ecology and vegetation types. Phytologia, vol. 34, no. 4. 56 pp.

Primack, R.B. 2006. Essentials of conservation biology (fourth edition). Sinauer Associates, Sunderland, Massachusetts.

Riggins, R. 1993. *Lupinus*. In: The Jepson manual; higher plants of California. University of California Press, Los Angeles. Pp. 622-636.

U.S. Fish and Wildlife Service (Service). 2005. Notes to the file: current status of listed "Dunes Trio" from coastal San Luis Obispo County. Submitted by Connie Rutherford, Listing and Recovery Coordinator for Plants, Ventura Fish and Wildlife Office, Ventura, California. September 2005.

Shaffer, M.L. 1981. Minimum population sizes for species conservation. Bioscience 31: 131-134.

Shaffer, M.L. 1987. Minimum viable populations: coping with uncertainty. Pp. 69-86. *In:* M.E. Soulé, (ed.) Viable populations for conservation. Cambridge University Press, New York, NY.

U.S. Fish and Wildlife Service (Service). 1983. Endangered and Threatened Species Listing and Recovery Priority Guidelines, 48 Federal Register 43098.

U.S. Fish and Wildlife Service (Service). 2000. Endangered and threatened wildlife and plants; final rule listing five plants from Monterey County, CA, as endangered or threatened. Federal Register 65 FR 14888.

U.S. Fish and Wildlife Service (Service). 2005. Notes to the file: current status of listed "Dunes Trio" from coastal San Luis Obispo County. Submitted by Connie Rutherford, Listing and Recovery Program Coordinator for Plants, Ventura Fish and Wildlife Office, Ventura, California. September 2005.

Walters, B., and D. Walters. 1988. Taxonomy, demography, and ecology of *Lupinus nipomensis* Eastwood. California Polytechnic State University, San Luis Obispo. 30 pp.

Wilken, Dieter. Vice President, Programs and Collections, Santa Barbara Botanic Garden. 2009. E-mail to Connie Rutherford, U.S. Fish and Wildlife Service, Ventura, California, regarding the results of seed trials for Nipomo lupine. Dated July 6, 2009.

Personal Communications Cited

Bohlman, Daniel. Restoration Ecologist, The Land Conservancy of San Luis Obispo. Conversation with Connie Rutherford, U.S. Fish and Wildlife Service, Ventura, California, regarding the status of Nipomo lupine. June 10, 2009.

U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of *Lupinus nipomensis* (Nipomo lupine)

Current Classification: Endangered

Recommendation Resulting from the 5-Year Review:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
__X_ No change needed

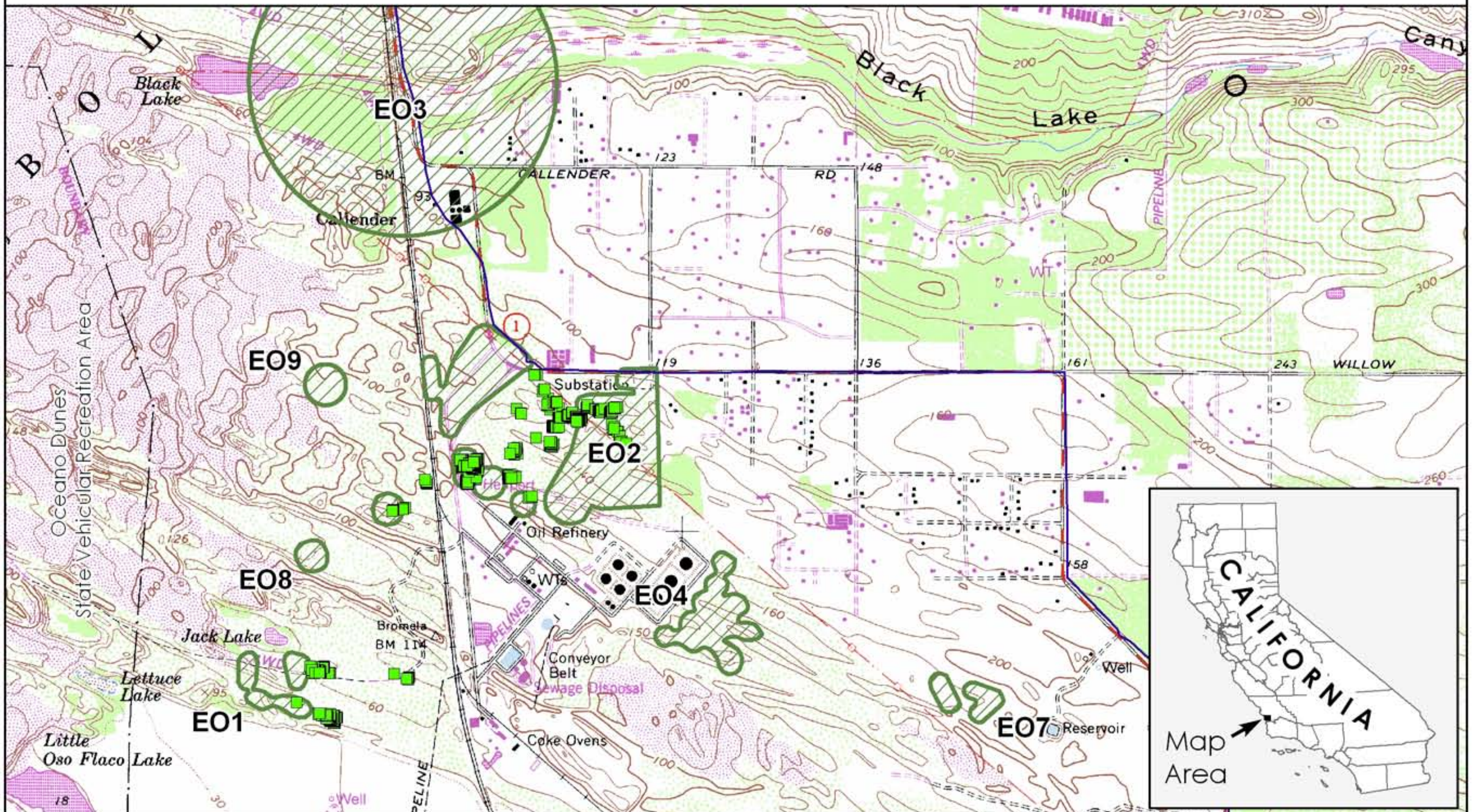
Review Conducted By: Connie Rutherford

FIELD OFFICE APPROVAL:

Field Supervisor, U.S. Fish and Wildlife Service

Approve Diane K. Noda Date 10/19/09

Appendix 1: Figure 1. Distribution of *Lupinus nipomensis* (Nipomo lupine), San Luis Obispo County, California



0 0.5 1 Kilometers

Prepared for the 5-year Review

Nipomo Lupine Records

- Conservancy Records 2007-2009
- CNDDB 2009 records

U.S. Fish & Wildlife Service
Ventura Fish & Wildlife Office
September, 2009

NCDE Grizzly Bear Conservation Strategy

---- DRAFT ---- DRAFT ---- DRAFT ----

April 2013

Photo by Rick Mace, Montana Fish Wildlife and Parks.

Draft NCDE Grizzly Bear Conservation Strategy

Table of Contents:

List of Tables

List of Figures

ACRONYMS USED IN THIS DOCUMENT

APD – Application for Permit to Drill
BE – Bitterroot Ecosystem
BIA – Bureau of Indian Affairs
BIR – Blackfeet Indian Reservation
BLM – Bureau of Land Management
BMU – Bear Management Unit
BNSF – Burlington Northern Santa Fe Railroad
CEM – Cumulative Effects Model
CYE – Cabinet Yaak Ecosystem
DNRC – Montana Department of Natural Resources and Conservation
DPS – Distinct Population Segment
EIS – Environmental Impact Statement
FIR – Flathead Indian Reservation
GIS – Geographic Information System
GNP – Glacier National Park
GYA – Greater Yellowstone Area
HCP – Habitat Conservation Plan
IGBC – Interagency Grizzly Bear Committee
IRA – Inventoried Roadless Area
MEPA – Montana Environmental Policy Act
MOU – Memorandum of Understanding
MVUM – motor vehicle use map
NCASC – North Cascades Ecosystem
NCDE – Northern Continental Divide Ecosystem
NEPA – National Environmental Policy Act
NF – National Forest
NPS – National Park Service
PCA – Primary Conservation Area
OMRD – Open Motorized Route Density
RSF – Resource Selection Function
SE – Selkirk Mountains Ecosystem
TMRD – Total Motorized Route Density
TNC – The Nature Conservancy
USFS – United States Forest Service
USFWS – United States Fish and Wildlife Service
USGS – United Stated Geological Survey
WMA – Wildlife Management Area

Executive Summary

Northern Continental Divide Ecosystem Grizzly Bear Conservation Strategy

CHAPTER 1 – INTRODUCTION AND BACKGROUND

This Conservation Strategy was developed by an interagency team of managers and scientists to describe the coordinated management and monitoring efforts necessary to maintain a recovered grizzly bear population in the NCDE and document the commitment of these agencies to this shared goal. This Conservation Strategy provides a cohesive umbrella for all signatories to operate under and reference but each signatory has their own legal process and authority to implement the Strategy. This Conservation Strategy would remain in effect beyond recovery, delisting, and the five year Monitoring period required by the Endangered Species Act (ESA). The agencies are committed to be responsive to the needs of the grizzly bear through adaptive management actions based on the results of detailed annual population and habitat monitoring.

The purposes of this Conservation Strategy are to:

- Describe and summarize the coordinated strategies, standards, and guidelines developed for managing the grizzly bear population, grizzly bear/human conflicts, and grizzly bear habitat to ensure their continued conservation in the NCDE.
- Document the regulatory mechanisms, legal authorities, policies, management documents, and monitoring programs that will maintain the recovered grizzly bear population.
- Document the commitments agreed to by the participating agencies.

Within the NCDE, the grizzly bear population and its habitat will be managed using an approach that identifies a Primary Conservation Area (PCA) and three additional management zones (Zone 1, Zone 2, and Zone 3: see Figure 1). The PCA is the area currently known as the NCDE Grizzly Bear Recovery Zone. This is where the most conservative habitat protections would remain, with habitat conditions that were compatible with the increasing grizzly bear population from 2004-2011 being maintained. Grizzly bears are also expected to occupy habitat outside the PCA in Zones 1 and 2 where they may serve as a source population to other grizzly bear ecosystems in the lower 48 States. Habitat and population protections would vary by management objective in these Zones with more protections in areas identified as "Demographic Connectivity Areas." While Management Zone 3 primarily consists of areas where grizzly bears do not have enough suitable habitat to support population growth, they were included in this Conservation Strategy because a bear living in Zone 3 most likely originated from the NCDE population. Grizzly bear occupancy will not be actively discouraged in Zone 3 and the management emphasis will be on conflict response.

Relationship to Other Plans

By integrating the Montana state plan into the Strategy, it was ensured that this plan and the Strategy are consistent and complementary. The state plan is formally incorporated in the Conservation Strategy as an Appendix. Relationships with national forest and national park plans are also mentioned throughout the Strategy. Our intent is to have signatories of this Conservation Strategy representing the land management agencies incorporate the habitat standards and guidelines described in this Conservation Strategy into their respective management plans.

CHAPTER 2 – DEMOGRAPHIC CRITERIA

To maintain a healthy (recovered) grizzly bear population in the NCDE, it is necessary to have adequate numbers of bears that are well distributed with a balance between reproduction and mortality. This section details the demographic criteria necessary to maintain and enhance a recovered grizzly bear population in the NCDE. The standards and monitoring protocol focus on the Recovery Zone and the area immediately around it identified in this Conservation Strategy as the NCDE Primary Conservation Area (PCA) and Management Zone 1 (Zone 1) respectively. Because grizzly bears are a difficult species to monitor, multiple criteria are identified to provide sufficient information upon which to base management decisions.

This Conservation Strategy sets an objective of maintaining a recovered grizzly bear population in the NCDE area sufficient to maintain a healthy population in biologically suitable habitats within the PCA and Zone 1. This Conservation Strategy sets both demographic *goals*, which may be difficult to quantify and demographic *standards*, which are objective and measurable criteria of population status and health. It is the goal of the agencies implementing this Conservation Strategy to maintain a genetically diverse NCDE grizzly bear population with at least 800 grizzly bears. We will achieve this goal by including specific standards to document a widely distributed population, a high adult female survival rate, and sustainable mortality limits that will not result in long-term population decline.

CHAPTER 3 – HABITAT MANAGEMENT AND MONITORING

The goal of habitat management on public lands is to maintain conditions compatible with a stable to increasing grizzly bear population in the NCDE. This Conservation Strategy identifies a Primary Conservation Area (PCA) and three additional management zones (Zone 1, Zone 2, and Zone 3: see Figure 1), each with varying levels of habitat protections depending on their relative importance to the NCDE grizzly bear population. Each management zone is a mosaic of land ownerships, with different types of habitat protections reflecting the mandates and interests of each agency or Tribal government. Our intent is to incorporate habitat standards into GNP's Superintendent's Compendium, and National Forest and BLM Land and Resource Management Plans. If adopted, these standards would replace existing regulatory standards included in those land management plans.

The **PCA** would have the most conservative habitat protections so it can be managed as a source area where the goal is continual occupancy by grizzly bears. Within the PCA, the overall goal for habitat management on public Federal lands is to maintain or improve habitat conditions that existed as of 2011, while maintaining options for resource management activities at approximately the same levels that existed in 2011. Here, secure habitat, road densities, developed sites, and livestock allotments would be maintained at levels known to be compatible with a stable to increasing grizzly bear population.

Management Zone 1 is similar in concept to the 10-mile buffer around the Recovery Zone within which population data were recorded while listed under the ESA. Population and mortality data will be collected in all of the PCA and Zone 1. On the northwest and southwest corners of Zone 1, there will be two **Demographic Connectivity Areas** (DCAs) with specific habitat measures to support female grizzly bear occupancy and eventual dispersal to other ecosystems in the lower 48 States (i.e., the Cabinet-Yaak and Bitterroot ecosystems). In these DCAs, habitat protections will focus on limiting miles of open road and managing current roadless areas as stepping stones to other ecosystems.

Management Zone 2 will be managed to provide the opportunity for grizzly bears, particularly males, to move between the NCDE and adjacent ecosystems (e.g., the GYA) via the multiple large blocks of habitat with motorized use restrictions that already exist as of 2011. Here, the management emphasis will be on conflict prevention and response.

Management Zone 3 does not have enough suitable habitat to contribute meaningfully to the long-term survival of the NCDE population but grizzly bears are sometimes found here. In contrast to Zones 1 and 2, Zone 3 does not lead grizzly bears to other suitable habitat or recovery ecosystems. It was included as part of this Conservation Strategy because any grizzly bear found in Zone 3 to date has originated from the NCDE and this will likely remain the case for the vast majority of Zone 3.

CHAPTER 4 – CONFLICT PREVENTION, RESPONSE, AND NUISANCE BEAR MANAGEMENT

For grizzly bear conservation to be successful, providing habitat on the landscape is not enough. For grizzly bears to survive, people must accept the grizzly as a cohabitant of the land. Tolerance can be maintained when the public has confidence in management agencies to respond quickly and appropriately to grizzly bear-human conflicts and the public is equipped with the knowledge to understand and avoid grizzly bear-human conflicts. The objective of conflict management is to maximize human safety and minimize property losses while maintaining a viable population of grizzly bears (Dood et al. 2006). When grizzly bear-human conflicts are not adequately addressed, there are negative consequences for the individual bear and the people involved, and support for grizzly bear management and conservation in the NCDE is undermined.

The emphasis of grizzly bear conflict management will be quick response by management authorities, removal of the source of the conflict where possible, and the use of non-lethal solutions. Depending on the circumstances of the conflict, appropriate responses may include:

- Removing or securing attractants,
- Public education and outreach,
- Discouraging the bear from visiting the site using non-lethal methods (e.g., **aversive conditioning**),
- Reactively or preemptively capturing and relocating a nuisance bear to a new area,
- **Removing** the bear from the wild, including lethal control.

The focus and intent of nuisance grizzly bear management inside and outside the PCA will be predicated on strategies and actions to prevent grizzly bear/human conflicts. Securing potential attractants is the single most effective way to prevent bears from becoming habituated or food conditioned, thereby limiting human-caused grizzly bear mortality, grizzly bear-human encounters, and other grizzly bear-human conflicts. Rules requiring attractants to be stored in a bear-resistant manner on most public lands already exist and will continue under this Conservation Strategy. The NCDE's existing I&E subcommittee will continue to coordinate outreach efforts in the NCDE to ensure the consistency of messages. All grizzly bear conflicts, relocations, and removals will be documented and reported annually in the NCDE Annual Report.

CHAPTER 5 – IMPLEMENTATION AND EVALUATION

Upon implementation of this Conservation Strategy, the NCDE Coordinating Committee will replace the current NCDE Grizzly Bear Subcommittee although its membership will remain largely the same. The Coordinating Committee will evaluate implementation of this Conservation Strategy, promote the exchange of data and information about the NCDE grizzly bear population among agencies and the public, and make recommendations to the management agencies regarding implementation of this Conservation Strategy. The NCDE Coordinating Committee will communicate with the IGBC about the NCDE grizzly bear population. The Coordinating Committee is not a decision-making body, although it may provide recommendations to member agencies from time to time. The Coordinating Committee does not supersede the authority of the management agencies beyond the specific actions agreed to as signatories to this Conservation Strategy.

Once adopted by the agencies, this Conservation Strategy's standards, guidelines, and/or monitoring procedures may only be changed through a clear demonstration of need based on biological data, the best available science, and/or new techniques. Any such amendments will be subject to public review and would be guided by and consistent with the agreements reached in this Strategy and its overall goal to maintain a recovered grizzly bear population in the NCDE and conserve its habitat.

The Coordinating Committee will be supported and informed by the NCDE Monitoring Team and Information and Education Team. The NCDE Monitoring Team will take the lead in preparing an annual monitoring report with staff support from the Coordinating Committee member agencies. Monitoring results and analysis will be provided to the Coordinating Committee and the public. If there are deviations from any of the population and/or habitat standards stipulated in this Conservation Strategy, a Biology and Management Review will be initiated. A Biology and Management Review examines management of habitat, populations, or efforts of participating agencies to complete their required monitoring. The NCDE Monitoring Team is not responsible for completing impact analyses for projects proposed by any agency; such analyses are the responsibility of the agency making the proposal. The Coordinating Committee will respond to the Biology and Monitoring Review with actions to address the deviations from the population or habitat standards. If desired population and habitat standards specified in this Conservation Strategy are not being met, and cannot be met in the opinion of the Coordinating Committee, then the Committee may petition the Fish and Wildlife Service for relisting.

CHAPTER 6 – REGULATORY AND CONSERVATION FRAMEWORK

The management of grizzly bears and the habitats they require for survival are dependent upon the laws, regulations, agreements, and management plans of the State, Tribal, and Federal agencies in the NCDE. This chapter documents the regulatory mechanisms and conservation framework that would continue to exist if/when they are removed from the Endangered Species Act's Federal List of Endangered and Threatened Wildlife. These laws, regulations, and agreements provide the legal basis for coordinating management, controlling mortality, providing secure habitats, managing grizzly bear/human conflicts, regulating hunters and hunting seasons, limiting motorized access where necessary, controlling livestock grazing, regulating oil and gas development, mitigating large scale mining operations, maintaining education and outreach programs to prevent conflicts, monitoring populations and habitats, and requesting management and petitions for relisting when necessary.

Memorandum of Understanding Detailing Agency Agreement to Implement this Conservation Strategy

The agencies signing this Conservation Strategy agree to use their authorities to maintain and enhance the recovered status of the grizzly bear in the Northern Continental Divide Area by implementing the regulatory mechanisms, interagency cooperation, population and habitat management and monitoring, and other provisions of the Conservation Strategy as per the details and responsibilities described in this document. All signatories recognize that each has statutory responsibilities that cannot be delegated and that this agreement does not and is not considered to abrogate any of their statutory responsibilities. This agreement is subject to and is intended to be consistent with all appropriate federal and state laws. Funding of this MOU is subject to approval and appropriations by state, tribal, and federal entities. All agencies will take appropriate steps to seek funding to implement this document. The adequacy of the regulatory mechanisms demonstrated by this Conservation Strategy are dependent upon funding being available to fully implement the management and monitoring actions detailed in this document. This Conservation Strategy does not go into effect until all agencies have signed this document and the final rule delisting the NCDE grizzly population has been published in the Federal Register.

Regional Forester — Date
U.S. Forest Service, Northern Region

Director — Date
Montana Fish, Wildlife & Parks

Director — Date
National Park Service, Intermountain Region

Regional Chief Biologist — Date
Central Region, USGS Biological Resources Division

State Director — Date
Bureau of Land Management Montana

State Director — Date
Montana Department of Natural Resources

Regional Director — Date
U.S. Fish and Wildlife Service, Region 6

Tribal Council Chairman Confederated Salish and Kootenai Tribes	Date
Tribal Business Council Chairman Blackfeet Nation	Date

Chapter 1 – Introduction and Background

THIS CONSERVATION STRATEGY

Development of the Conservation Strategy began in 2009, when representatives from the Montana Department of Fish, Wildlife and Parks (MFWP); the Montana Department of Natural Resources and Conservation (DNRC); the Blackfeet Nation; the Confederated Salish and Kootenai Tribes (CS&KT); Glacier National Park (GNP); the U.S. Forest Service (USFS); the U.S. Fish and Wildlife Service (USFWS); U.S. Geological Survey (USGS); and the Bureau of Land Management (BLM) were appointed by members of the NCDE subcommittee to the Interagency Conservation Strategy Team. These authorities will document their commitment to implementing the Strategy by signing a Memorandum of Understanding before it is finalized.

We (the signatories of this Conservation Strategy) envision the future management of the Northern Continental Divide Ecosystem (NCDE) grizzly bear population as one in which the grizzly and its habitat are conserved as functional and healthy parts of the ecosystem. This Conservation Strategy describes the management and monitoring direction to maintain a recovered grizzly bear population in the NCDE and documents the commitment of signatory agencies to implement these measures. It describes the regulatory framework for management and monitoring of the NCDE grizzly bear population and its habitat upon recovery and removal from the Endangered Species Act's Federal List of Endangered and Threatened Wildlife (i.e., delisting). Recovery of the grizzly bear population in the NCDE has been possible because of the partnerships between Federal and State agencies, multiple Tribes, county and city governments, educational institutions, numerous organizations, private landowners, and the public who live, work, and recreate in the NCDE and surrounding lands. We developed this Conservation Strategy because maintenance of a healthy, recovered grizzly population depends on the effective continuation of these partnerships to manage and conserve the NCDE grizzly bear population and its habitat.

This Conservation Strategy would remain in effect beyond recovery, delisting, and the five year Monitoring period required by the Endangered Species Act (ESA) as grizzly bears will always be a "conservation-reliant" species in the NCDE (Scott et al. 2005) and the need to coordinate management of the population across multiple land ownerships and jurisdictions will remain. The Strategy is a dynamic document. Given the Strategy's scope and expected duration, it is likely that management and monitoring will require adjustments as new information becomes available. Any adjustments will be based on the best available science and, where appropriate, public involvement.

The key to public support and successful management of grizzly bears is to balance multiple land uses, public safety, and careful consideration of grizzly bear needs. Human-caused mortality is the limiting factor for nearly all grizzly bear populations in the world and this Conservation Strategy aims to manage mortality at sustainable levels through habitat protections that minimize mortality risk while emphasizing conflict prevention, conflict response, and decisions grounded in scientific data and monitoring. On both public and private lands, public information and education efforts have played, and will continue to play, an integral role in minimizing grizzly bear/human conflicts. Similarly, the responsive management of nuisance grizzly bears that increased public support and tolerance while grizzly bears have been listed as a "threatened" species under the ESA, will continue. In a recovered, delisted population of grizzly bears, management as game animals is a valuable conservation tool that can increase public support among those living in grizzly bear habitat. As such, management may include regulated hunting when and where appropriate.

Within the NCDE, the grizzly bear population and its habitat will be managed using a management approach that identifies a Primary Conservation Area (PCA) and three additional management zones (Zone 1, Zone 2, and Zone 3: see Figure 1). This approach of differential protections in areas depending on their relative importance to the grizzly bear population is similar to the approach used in the NCDE while listed as "threatened" under the ESA. Different "Management Situations" and levels of flexibility were applied on different public lands based on their relative importance to the population and the sometimes competing needs of humans. The PCA is the area currently known as the NCDE Recovery Zone. Habitat protections in the PCA were compatible with an increasing population and this is where the most conservative habitat protections would remain. Grizzly bears are also expected to occupy habitat outside the PCA in Zones 1 and 2 where they may serve as a source population to other recovery ecosystems in the lower 48 States that remain "threatened" by small population size (e.g., the Cabinet-Yaak ecosystem) or other threats. In these adjacent management zones, habitat and population protections would vary by management objective. Our intent is to have signatories of this Conservation Strategy representing the land management agencies incorporate the habitat standards and guidelines described in this Conservation Strategy into their respective management plans. The USFWS will not approve and sign the Conservation Strategy's MOU until this process is complete. Upon implementation of this Conservation Strategy, management using the NCDE recovery zone line and grizzly bear Management Situations as described in the Interagency Grizzly Bear Guidelines (USFS 1986) would no longer be necessary and would no longer apply.

The Montana Grizzly Bear Management Plan for Western Montana (Dood et al. 2006), the Montana Grizzly Bear Management Plan for Southwestern Montana (MFWP 2002), Tribal grizzly bear management plans (Servheen et al. 1981; Blackfeet Nation, in process), Federal land and resource management plans, Tribal Forest management plans (CS&KT 2000; Blackfeet Nation 2008), State Habitat Conservation Plan (DNRC 2010), and other appropriate planning documents such as the Montana Comprehensive Fish and Wildlife Conservation Strategy (MFWP 2005) provide specific management direction both inside and outside the PCA and ensure implementation of and consistency with this Conservation Strategy. Ongoing review and evaluation of the effectiveness of this Conservation Strategy would be the responsibility of the State, Federal, and Tribal managers in the NCDE. This NCDE Conservation Strategy will be updated by the management agencies as necessary using the best available science, allowing for public comment in the updating process.

The purposes of this Conservation Strategy are to:

- Describe and summarize the coordinated strategies, standards, and guidelines developed for managing the grizzly bear population, grizzly bear/human conflicts, and grizzly bear habitat to ensure continued conservation in the NCDE.
- Document the regulatory mechanisms, legal authorities, policies, management documents, and monitoring programs that will maintain the recovered grizzly bear population.

- Document the commitments agreed to by the participating agencies.

Implementation of this Conservation Strategy requires continued cooperation between Federal, State, and Tribal agencies. To facilitate this cooperation, upon delisting, the NCDE Grizzly Coordinating Committee (hereafter referred to as the Coordinating Committee) will replace the NCDE Ecosystem Subcommittee (See Chapter 5 for more information about the activities of the Coordinating Committee). Because the NCDE is a dynamic environment, monitoring systems in this Conservation Strategy allow for adaptive management as environmental conditions change. The agencies are committed to being responsive to the needs of the grizzly bear through adaptive management actions based on the best available science and the results of detailed population and habitat monitoring.

Legal Framework for Habitat and Population Management

This Conservation Strategy provides a cohesive umbrella for all signatories to operate under but each signatory has their own legal process and authority to implement the Strategy. Any updates to the Conservation Strategy in the future will be governed by these same, agency-specific processes. The legal framework and authority to manage grizzly bear populations (i.e., establish population goals, hunting quotas, mortality limits, and respond to grizzly bear/human conflicts) within the state of Montana is given to Montana Fish Wildlife and Parks by Montana Code Annotated § 87-1-201(9)(a)(ii). Rangers and law enforcement personnel on public lands, National Forests and in Glacier National Park also have the authority to respond to and manage grizzly bear/human conflicts on lands under their management jurisdictions (see 36 CFC 1.7(B) 1.2 (d); 16 USC § 551, 553, and 559). The legal framework and authority to manage roads and other human activities in grizzly bear habitat is provided to GNP by the Glacier National Park Enabling Act (36 Stat., 354) and the National Park Service Organic Act (16 U.S.C. §1); to the USFS by the Forest and Rangeland Renewable Resources Act of 1974, and the National Forest Management Act of 1976 (36 CFR 219); to the BLM by the Federal Lands Policy and Management Act (43 U.S.C. §§ 1701-1777); to the CS&KT and Blackfeet Nation by the National Indian Forest Resources Management Act (25 USC Chapter 33); to Montana Fish Wildlife and Parks by Montana Code Annotated § 87-1-201(9)(b) and related Administrative rule (ARM 12.9.103); and to the Montana DNRC, by virtue of its status as the administrative arm of the Montana Board of Land Commissioners, by the Enabling Act of 1889, 25 Stat. 676, as amended, Article X, §§ 2 and 11 of the 1972 Montana Constitution, and Title 77 of the Montana Code Annotated, by the Executive Reorganization Act of 1971 (Chapter 272, Laws of Montana, 1971; Title 82A, R.C.M. 1947) and related Administrative Rules (ARM 36.11.401 – 36.11.471). In summary, this Conservation Strategy is the guiding document describing the concepts, principles, goals, requirements, and monitoring to maintain a recovered grizzly bear population in the NCDE, but the legal mechanisms and authority necessary to implement this Conservation Strategy are provided by numerous State, Federal, and Tribal laws (see Ch. 6 for more information about these regulatory mechanisms).

DESCRIPTION OF THE MANAGEMENT ZONES

The area within which grizzly bear management will be directed by this Conservation Strategy and associated management plans covers 27,338,696 acres (110,636 sq km) in central and western Montana. This large area is divided into a PCA and three management zones (Figure 1). In general, habitat management is implemented on public lands (State, Tribal, and/or Federal) whereas population management is implemented on all lands (State, Tribal, Federal, and/or private). Management direction for the PCA and adjacent management zones within the NCDE is described below:

- The **PCA** (*5,712,862 acres; 23,119 sq km*) will be managed as a source area where the objective is continual occupancy by grizzly bears and maintenance of habitat conditions that are compatible with a stable to increasing grizzly bear population. This is the area where the most conservative habitat protections apply. Here, large blocks of secure habitat would be maintained and no net increases in motorized route densities, developed sites, or livestock allotments would be allowed on Federal lands. Attractant storage rules would be implemented on Federal, Tribal, and most State lands.
- **Management Zone 1** (*4,808,719 acres; 19,460 sq km*) is similar in concept to the 10-mile buffer delineated around the Recovery Zone under listed status within which demographic recovery criteria apply. The objective in Zone 1 is continual occupancy by grizzly bears but at expected lower densities than inside the PCA. Here, habitat protections will focus on managing motorized route densities within levels specified in current Federal and Tribal land use plans because these are known to be compatible with a stable to increasing grizzly bear population. Attractant storage rules would be implemented on Federal, Tribal, and most State lands.
- The PCA and Zone 1 together (*10,521,581 acres; 42,579 sq km*) will be the area within which population data are collected and sustainable mortality limits apply. Regulated, sustainable grizzly bear hunting could be allowed and would be managed to promote social tolerance of grizzlies.
    - There will be two **Demographic Connectivity Areas** (DCAs) (*987,256 acres; 3,995 sq km*) on the western side of Zone 1 to benefit other grizzly bear populations within the lower 48 States that retain their "threatened" status (i.e., the Cabinet-Yaak and Bitterroot ecosystems) by supporting female occupancy and potential dispersal to these other populations. In these areas, habitat protections on Federal and Tribal lands will focus on limiting miles of open road and managing current roadless areas as stepping stones to other ecosystems. Hunting opportunities in these areas in the foreseeable future would be compatible with the objective of female occupancy.
- In **Management Zone 2** (*4,658,932 acres; 18,854 sq km*), the objective is to maintain existing resource management and recreational opportunities and allow agencies to respond to demonstrated conflicts (as defined in the nuisance bear management section) with appropriate management actions. Public lands in Zone 2 will be managed to provide the opportunity for grizzly bears, particularly males which are more likely to disperse long distances, to move between the NCDE and adjacent ecosystems (i.e., the Greater Yellowstone ecosystem or the Bitterroot ecosystem) via current direction in USFS and BLM Resource Management Plans. Here, the management emphasis will be on conflict prevention and response. Attractant

storage rules would be implemented on most Federal and State lands. Grizzly bears would not be captured and removed unless there are conflicts that can only be solved by capture and relocation or removal of the offending bear. MFWP would manage grizzly bear hunting opportunities in these areas in the foreseeable future to be compatible with grizzly bear occupancy, albeit at lower densities than in the PCA or Zone 1.

- **Management Zone 3** (*12,158,183 acres; 49,202 sq km*) primarily consists of areas where grizzly bears do not have enough suitable habitat for long-term survival and occupancy (see "GRIZZLY BEAR HABITAT MANAGEMENT" section below). Grizzly bear occupancy will not be actively discouraged. Management emphasis will be on conflict response. Grizzly bears will not be captured and removed just because they occur in Zone 3, nor will they be captured and removed from Zone 3 unless there are conflicts that can only be resolved by capture and relocation or removal of the offending bear. Regulated grizzly bear hunting would be allowed.

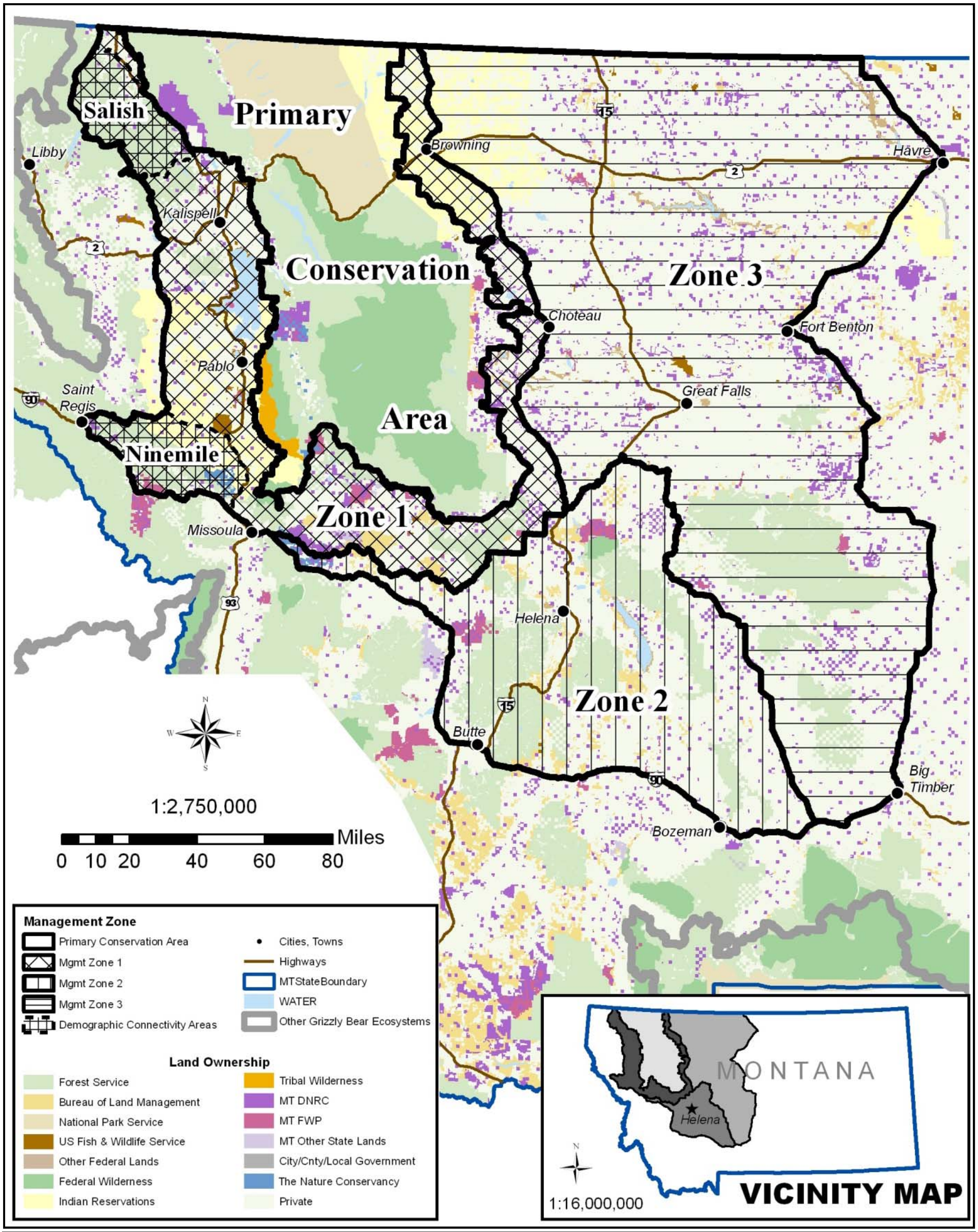


Figure 1. Grizzly bear management zones specified in this Conservation Strategy. The Salish and Ninemile Demographic Connectivity Areas within Zone 1 are delineated by cross-hatching.

GRIZZLY BEAR STATUS & ECOLOGY

Current Status

Thanks to the ongoing efforts of multiple agencies and partners, the grizzly bear population in the NCDE is strong, healthy, and recovered. Although numerous activities may impact individual grizzly bears, the management commitments contained in this Conservation Strategy ensure these will not threaten the population in the foreseeable future.

Using non-invasive sampling methods and capture-mark-recapture models, Kendall et al. (2009) estimated there were 765 grizzly bears in the NCDE in 2004. Between 2004 and 2009, Mace et al. (2012) radio-collared and monitored 83 different female grizzly bears in the NCDE to determine that the population was increasing at a rate of 3.06% per year during this time (95% CI = 0.928–1.102). This estimate of average annual population growth was re-calculated in 2012 using data through 2011 with a resulting rate of 3.03% per year across this time period (2004-2011). Applying this 3.03% rate of annual growth from Mace (2012, personal communication) to the 2004 DNA-based population estimate over the eight years from 2004 to 2011 yields a 2011 population estimate of 942 bears. The NCDE population of grizzly bears is contiguous with grizzly bears in Canada, resulting in high genetic diversity (Proctor et al. 2012). Grizzly bears are well distributed throughout the PCA and Zone 1 although density is higher inside the PCA (see Kendall et al. 2008, 2009; Mace and Roberts 2011). Further evidence of the wide distribution of grizzly bears across the NCDE is the documentation of females, or females with young, in at least 21 of 23 Bear Management Units (BMUs) between 1999 and 2010 (Dood et al. 2006; Kendall et al. 2009; Mace and Roberts 2011) (Figure 2). While the Recovery Plan (USFWS 1993, p. 62) identified sightings of females with cubs as a method to estimate minimum population size, it also recognized that "Because of the forested nature of much of the NCDE…the calculated minimum number of females with cubs will underestimate the actual number [population size]." Kendall et al.'s (2009) estimate of total population size was more than double the minimum population size estimate based on sighting of females with cubs, further corroborating the difficulty of using this parameter as an indicator of population size in this ecosystem. Therefore, since 2004, sightings of females with cubs have not been consistently collected, and this method is no longer used to estimate minimum population size. Instead, radio-telemetry, DNA samples, and mortalities are used to provide distribution data and annual population growth rates that are applied to Kendall et al.'s (2009) population size estimate to project an index of total population size since 2004.

Using the same data used to estimate trend, Mace et al. (2012) calculated dependent cub survival to be 0.612 (95% CI = 0.300–0.818); yearling survival to be 0.682 (95% CI = 0.258–0.898); subadult female survival to be 0.852 (95% CI = 0.628–0.951); and adult female survival to be 0.952 (95% CI = 0.892–0.980). These survival rates and Mace et al.'s (2012) estimate of trend indicate mortality was not only within sustainable limits between 2004 and 2009, but actually allowed an increasing population.

Grizzly bear densities within the NCDE vary but generally decrease toward the south and on the periphery of the ecosystem (Kendall et al. 2009). Grizzly bear population densities were highest inside Glacier National Park with approximately 30 bears per 1,000 sq km (247,105 acres) (Kendall et al. 2008). This is equivalent to approximately one bear per 33 sq km (8,154 acres). This estimate is similar to Mace et al.'s (1994) estimate of one bear per 25-30 sq km (6,177–7,413 acres) in the Swan Mountain Range in the west central portion of the NCDE.

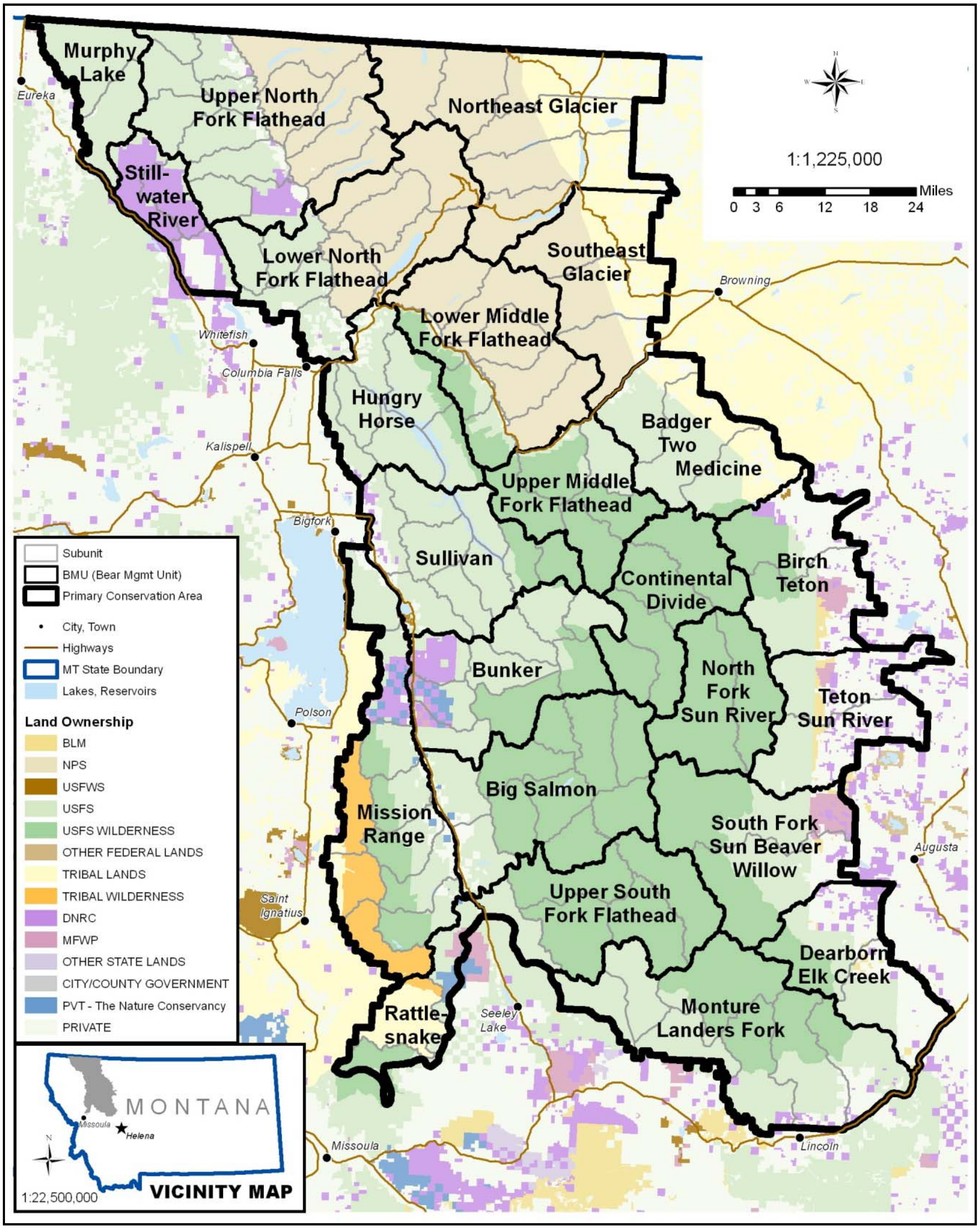


Figure 2. Bear Management Units (BMUs) in the NCDE Primary Conservation Area. BMU subunits are outlined in light gray.

Behavior & Life History

Adult grizzly bears are normally solitary except when females have dependent young (Nowak and Paradiso 1983) but they are not territorial and home ranges of adult bears frequently overlap (Mace and Waller 1997a Schwartz et al. 2003b). Home range size is affected by resource availability, sex, age, and reproductive status (LeFranc et al. 1987; Blanchard and Knight 1991; Mace and Waller 1997b). Generally, females with cubs-of-the-year or yearlings have the smallest home range sizes (Aune and Kasworm 1989; Blanchard and Knight 1991; Mace and Waller 1997b; Mace and Roberts 2011).

The annual home range of adult male grizzly bears in the NCDE ranges from 146–588 sq mi (377–1,522 sq km), while female ranges are typically smaller, between 26–94 sq mi (74-242 sq km) (Aune and Kasworm 1989; Mace and Waller 1997a; Waller 2005; Mace and Roberts 2011). Females inside GNP generally had smaller home range sizes than those outside the Park, which is likely due to the higher density of both bears and resources inside GNP (Mace and Roberts 2011). In the Swan Mountains of the NCDE, home range size was largest in the spring and smallest in the fall for both sexes, (Mace and Waller 1997a). The large home ranges of grizzly bears, particularly males, enhance genetic diversity in the population by enabling males to mate with numerous females (Blanchard and Knight 1991; Craighead et al. 1995).

Grizzly bears display a behavior called natal philopatry in which dispersing young establish home ranges within or overlapping their mother's (Waser and Jones 1983; Schwartz et al. 2003b). This type of movement makes dispersal across landscapes a slow process. Radio-telemetry and genetic data suggest females establish home ranges an average of 6.1 to 8.9 mi (9.8 to 14.3 km) away from the center of their mother's home range, whereas males generally disperse further, establishing home ranges roughly 29.9 to 42.0 km (18.6 to 26.0 mi) away from the center of their mother's (McLellan and Hovey 2001; Proctor et al. 2004).

Grizzly bears have a promiscuous mating system (Hornocker 1962; Craighead and Mitchell 1982; Schwartz et al. 2003b). Mating occurs from May through July with a peak in mid-June (Craighead and Mitchell 1982; Nowak and Paradiso 1983). Although females mate in spring and early summer, their fertilized embryos do not implant in their uterus until late fall. This delayed implantation only occurs if the female grizzly bear obtains enough fat over the summer and fall to survive the winter and nurse cubs for 2-3 months inside the den (Schwartz et al. 2003a; Schwartz et al. 2003b; Schwartz et al. 2006). Age of first reproduction and litter size may be related to nutritional state (Stringham 1990; McLellan 1994; Hilderbrand et al. 1999; Mattson 2000). Average age of first reproduction in the NCDE is 5.4 years old but can vary from 3-8 years of age (Mace et al. 2012). Mean litter size in the NCDE is 2.2 with a range from one to four cubs (Mace and Waller 1997b; Schwartz et al. 2003b). Cubs are born in the den in late January or early February and remain with the female for 1.5 to 2.5 years, making the average time between litters in the NCDE (i.e., the interbirth interval) 3.0 years (Mace and Waller 1997b; Schwartz et al. 2003b). Grizzly bears have one of the slowest reproductive rates among terrestrial mammals, resulting primarily from the reproductive factors described above: late age of first reproduction, small average litter size, and the long interval between litters (Nowak and Paradiso 1983; Schwartz et al. 2003b). Given the above factors, it may take a single female 10 years to replace herself in a population (USFWS 1993). Grizzly bear females cease reproducing some time in their mid- to late 20s (Aune et al. 1994; Schwartz et al. 2003a).

Grizzly bears usually dig dens on steep slopes where wind and topography cause an accumulation of deep snow and where the snow is unlikely to melt during warm periods. Grizzly bears in the NCDE occupy dens for 4-6 months each year, beginning in October or November (Mace and Waller 1997b; Linnell et al. 2000). Most of these dens are above 6,400 feet (> 1,942 m) in elevation (Mace and Waller 1997b). More than 29% (1,684,220 acres; 6,815 sq km) of the PCA is potential denning habitat so its availability is not considered a limiting factor for grizzly bears in the NCDE. Denning increases survival during periods of low food availability, deep snow, and low air temperature (Craighead and Craighead 1972). During this period, they do not eat, drink, urinate, or defecate (Folk et al. 1976; Nelson 1980). Hibernating grizzly bears exhibit a marked decline in heart and respiration rate, but only a slight drop in body temperature (Nowak and Paradiso 1983). Due to their relatively constant body temperature in the den, hibernating grizzly bears can be easily aroused and have been known to exit or re-locate dens when disturbed by seismic or mining activity (Harding and Nagy 1980) or other human activities (Swenson et al. 1997). Dens are rarely used twice by an individual although the same general area may be used multiple times (Schoen et al. 1987; Mace and Waller 1997b; Linnell et al. 2000). Females display stronger area fidelity than males and generally stay in their dens longer, depending on reproductive status (Judd et al. 1986; Schoen et al. 1987; Mace and Waller 1997b; Linnell et al. 2000). In the NCDE, females with new cubs typically emerge from their dens from early April to early May (Mace and Waller 1997b).

In preparation for hibernation, bears increase their food intake dramatically during a stage called hyperphagia (Craighead and Mitchell 1982). Hyperphagia is defined simply as eating in excess of daily metabolic demands and occurs throughout the 2-4 months prior to den entry (i.e., August – November). During hyperphagia, excess food is deposited as fat, and grizzly bears may gain as much as 1.65 kg/day (3.64 lb/day) (Craighead and Mitchell 1982). Grizzly bears must consume foods rich in protein and carbohydrates in order to build up fat reserves to survive denning and post denning periods (Rode and Robbins 2000). These layers of fat are crucial to the hibernating bear as they provide a source of energy and insulate the bear from cold temperatures, and are equally important in providing energy to the bear upon emergence from the den when food is still sparse relative to metabolic requirements (Craighead and Mitchell 1982).

Nutritional Ecology

The NCDE is a highly diverse landscape encompassing a wide array of habitat types and bear foods. Plant communities vary from short grass prairie and wheat fields on the eastern foothills to extensive conifer forests at mid-elevation and sub alpine and alpine meadows in the mountainous core. Although the digestive system of bears is essentially that of a carnivore, bears are successful omnivores, and in many areas of the NCDE are almost entirely herbivorous (Jacoby et al. 1999; Schwartz et al. 2003b). Grizzly bear diets are characterized by high variability among individuals, seasons, and years (Servheen 1981; Mattson et al. 1991a; Mattson et al. 1991b; Schwartz et al. 2003b; LeFranc et al. 1987; Felicetti et al. 2003; Felicetti et al. 2004). They opportunistically seek and consume the most nutritious plant and animal foods available to them. Grizzly bears will consume almost any food available including living or dead mammals or fish, insects, worms, plants, human-related foods, and garbage (Knight et al. 1988; Mattson et al. 1991a; Mattson et al. 1991b; Schwartz et al. 2003b). In areas where animal matter is less available, berries, grasses, roots, bulbs, tubers, seeds, and fungi are important in meeting protein and caloric requirements (LeFranc et al. 1987; Schwartz et al. 2003b).

Grizzly bears display great diet plasticity and switch food habits according to which foods are available (Servheen 1981; Kendall 1986; Mace and Jonkel 1986; Martinka and Kendall 1986; LeFranc et al. 1987; Aune and Kasworm 1989). Mattson et al. (1991a) hypothesized that grizzly bears are always sampling new foods in small quantities so that they have alternative options in years when preferred foods are scarce. In the GYA, Blanchard and Knight (1991) noted that, "After 10 years of food habits data collection, new feeding strategies continued to appear annually in this population."

Fecal analysis, direct observation, and stable isotope analyses have been used to determine diets of grizzly bears in the NCDE and nearby areas (Kendall 1986, Mace and Jonkel 1986; Martinka and Kendall 1986, Hamer and Herrero 1987; LeFranc et al. 1987; Aune and Kasworm 1989; Hilderbrand et al 1996; White et al. 1998; Robbins et al. 2004). Using scat analysis and direct observation, many studies have confirmed that NCDE grizzlies eat different foods in different seasons, depending on their availability (Servheen 1981; Kendall 1986; Mace and Jonkel 1986; Martinka and Kendall 1986; LeFranc et al. 1987; Aune and Kasworm 1989). Although scat analysis typically underestimates the contribution of animal matter in diets because it is more thoroughly digested, it allows direct comparison of other foods among seasons and individuals.

Using stable isotope analysis, Jacoby et al. (1999) investigated the proportion of meat and vegetation in grizzly bear diets in Glacier National Park and surrounding National Forest lands, concluding that males consume more meat than females or subadults. Adult female and subadults diets were 100% and 94% plant matter, respectively while adult male diets included 33% meat. Similarly, Mowat and Heard (2006) used stable isotope analysis to document that in the Swan Mountains, GNP, and the Canadian portion of the North Fork of the Flathead River, the amount of plant matter consumed when all age and sex classes were pooled ranged from 78-88%. On the Blackfeet and Flathead Indian Reservations, which flank the eastern and western edges of the mountainous core that characterizes the PCA, adult female diets consisted of 27% plant matter; adult male diets included 31% plant matter; and subadult males and females derived 34% of their diets from plant matter. The remaining proportions of diets were comprised of animal matter including insects, fish, livestock, wild ungulates, and other mammals. This increase in the amount of animal matter consumed when living within the foothills and prairies adjacent to mountainous areas is consistent with other studies of bear diet. Using fecal analysis, Aune and Kasworm (1989) found that meat was the 3rd most important food source during spring for grizzly bears on the Rocky Mountain Front (foothills) of the NCDE. Similarly, using fecal analysis, Munro et al. (2006) found that at the peak of meat consumption in early June in Alberta, the diets of foothills bears contained more than double the amount of meat (49%) than those of mountain bears (20%).

Upon den emergence, bears in the NCDE may search avalanche chutes for animal carcasses before descending to lower elevations seeking newly emerging vegetation. From den-emergence until early summer, grizzlies typically subsist on the roots of sweet vetches (*Hedysarum boreale* and *H. sulfurescens*), biscuit root (*Lomatium* species), glacier lilies (*Erythonium grandiflorum*) and western spring beauty (*Claytonia lanceolata*); berries from the previous year's crop of bearberry (*Arctostaphylos uva-ursi*); vegetation from grasses, sedges, cow parnsip (*Heracleum* species), and angelica (*Angelica* species); and ungulate meat (Servheen 1981; Kendall 1986; Mace and Jonkel 1986; Martinka and Kendall 1986; LeFranc et al. 1987; Aune and Kasworm 1989).

During summer, before berry crops are available, grizzlies in the NCDE may eat the roots of western spring beauty and glacier lilies and the vegetation of *Ligusticum* species, sweet cicely (*Osmorhiza* species), grasses, *Equisetum* species, cow parsnip, and *Angelica* species (LeFranc et al. 1987; Aune and Kasworm 1989; McLellan and Hovey 1995). Many grizzlies also begin to feed on army cutworm moths (*Euxoa auxiliaris*) in GNP from late June through mid-September (White et al. 1998). In the Mission Mountains, grizzlies may feed on army cutworm moths and ladybird beetles (*Coccinnella* species) from the beginning of July through the end of August (Chapman et al. 1955; Servheen 1983; Klaver et al. 1986). Grizzlies have also been observed feeding on army cutworm moths in the Scapegoat Wilderness (Sumner and Craighead 1973; Craighead et al. 1982) and the Rocky Mountain Front of Montana (Aune and Kasworm 1989). Once berries become available, grizzlies in the NCDE may consume huckleberries (*Vaccinium* species), soap berries (*Shepherdia canadensis*), service berries (*Amelanchier alnifolia*), hawthorn berries *(Crataegus douglasii*), and choke cherries (*Prunus* species); and to a lesser degree alderleaf buckthorn berries (*Rhamnus alnifolia)* and mountain ash (*Sorbus scopulina* and *S. sitchensis*) (Servheen 1981; Kendall 1986; Mace and Jonkel 1986; Martinka and Kendall 1986; LeFranc et al. 1987; McLellan and Hovey 1995). The amount and species of berries in bear diets vary annually based on annual fruit production and distributions (McLellan and Hovey 1995).

During late summer to fall, grizzlies in the NCDE may continue to eat berries but will also consume more meat (mostly from hunter gut piles and hunter wounded animals) and the roots/bulbs/corms of sweet vetches and biscuit roots (Kendall 1986; Mace and Jonkel 1986; Martinka and Kendall 1986; LeFranc et al. 1987; Aune and Kasworm 1989; McLellan and Hovey 1995). While the roots of sweet vetches are used by grizzly bear populations in Canada, Alaska, GNP and the northern reaches of the lower 48 States during spring and fall (Hamer and Herrero 1987; LeFranc et al. 1987; McLellan and Hovey 1995; Munro et al. 2006), where *Hedysarum* is less common in the southern and eastern edges of the PCA, grizzlies can consume biscuit roots and glacier lily bulbs instead (LeFranc et al. 1987; Aune and Kasworm 1989). Prior to the spread of whitepine blister rust (*Cronartium ribicola*) in the NCDE, grizzlies fed on whitebark pine seeds from late summer through fall when and where they were available, primarily in the Whitefish Mountain range and along the Rocky Mountain Front (Shaffer 1971; Mace and Jonkel 1986; Aune and Kasworm 1989; Kendall and Arno 1990). Whitebark pine mortality rates from the early to mid-1990s indicate that 42-58% of all trees surveyed within the NCDE were dead with 48-83% of trees surveyed showing signs of blister rust infection (Kendall and Keane 2001). Due to this widespread mortality from blister rust, whitebark pine seeds have been lost in the NCDE as a food source for bears. Despite this loss, the grizzly bear population is larger in size than once thought and increasing, a testament to the habitat diversity and flexibility of grizzly bear diets in the NCDE. In summary, the varying climate, topography, and vegetative conditions in the NCDE provide for a variety of habitats and foods for bears to consume.

Grizzly connectivity, genetic health, and population structure

Because grizzly bears live at relatively low population densities, disperse slowly, and are vulnerable to human-caused mortality, anthropogenic fragmentation of historically contiguous grizzly bear populations is common where grizzly bear populations occur in proximity to human population centers (Forman and Alexander 1996; Proctor et al. 2012; Lindenmayer and Fischer 2006). Small, isolated populations are vulnerable to extinction through genetic drift, demographic processes (e.g., human-caused mortality, decreased birth rates, etc.) and environmental processes (e.g., poor food years, climate change, habitat loss, etc.). It is widely accepted that extinction risk due to genetic drift is reduced even through minimal levels of connectivity (Soule 1987). For example, experimental and theoretical data suggest that one to two successful migrants per generation is an adequate level of gene flow to maintain or increase the level of genetic diversity in isolated populations (Mills and Allendorf 1996; Newman and Tallmon 2001; Miller and Waits 2003).

Genetic sampling and radio telemetry have been used to examine movements, genetic diversity, and population structure within the NCDE (see Kendall et al. 2008; Kendall et al. 2009; Mace et al. 2012; Proctor et al. 2012). Heterozygosity values are a useful, relative measure of genetic diversity. Higher values indicate greater genetic variation. Mean observed heterozygosity in the NCDE population was 0.73 in 2004, the year of sampling (Kendall et al. 2009). Similarly, Proctor et al. (2012) documented heterozygosity values of 0.67-0.68 for the NCDE for samples obtained between 1990 and 2004. These values approach levels found in relatively undisturbed grizzly bear populations in northern Canada and Alaska and indicate good genetic diversity.

Connectivity in grizzly bear populations should be examined in a genetic and demographic framework (Proctor et al. 2012). While male or female movements can enhance genetic diversity and reduce genetic fragmentation (i.e., provide genetic connectivity) (Miller and Waits 2003; Proctor et al. 2005), female movements are necessary to enhance a small population's growth rate (i.e., provide demographic connectivity) (Proctor et al. 2012). Proctor et al. (2012) used genetic assignment testing and movement data from radio-collared grizzly bears between 1979 and 2007 to assess fragmentation in grizzly bear populations in the U.S. and Canada. Both male and female grizzlies moved freely across the US/Canadian border on the northern edge of the NCDE. Proctor et al. (2012) documented 11 movements (10 males and 1 female) between the NCDE and grizzly bear populations north of Hwy. 3 in Canada, indicating the NCDE appears to be well connected to Canadian populations and its population size means there is currently little risk of significant reduction in the present high levels of genetic diversity.

Kendall et al. (2009) identified six subpopulations in the NCDE based on genetic analyses. However, the genetic differentiation values observed among the different areas within the NCDE was generally low. There are few geographical barriers thought capable of creating genetic discontinuities in the NCDE and generally the subpopulation boundaries did not coincide with natural or anthropogenic geographic features. Genetic differentiation between subpopulations decreased when genetic data from 1976-1998 was compared to data from 1999-2006, a finding consistent with demographic recovery of the population (Kendall et al. 2009). The only suggestion of human-caused fragmentation was on the western side of the U.S. Hwy. 2 / Burlington Northern Santa Fe (BNSF) rail line corridor between Glacier

National Park and National Forest lands where human-caused mortality is high. There was little genetic differentiation across the eastern portion of the corridor but at the western end where highway traffic volumes and human densities are three times higher, differentiation indicated reduced gene flow (Kendall et al. 2009). While this genetic differentiation north and south of the highway does not indicate complete absence of genetic interchange, it suggests fragmentation may be starting to occur. While managers remain vigilant about the possible fragmenting effects of the Hwy. 2 corridor, both male and female movements were documented across this corridor and the current state of fragmentation is within levels that ensure both demographic and genetic connectivity (Miller and Waits 2003; Waller and Servheen 2005).

Overall, the NCDE is well connected to Canadian populations genetically and its population size ensures demographic and genetic health. Accordingly, the NCDE should eventually serve as a source population for genetic and demographic rescue of other grizzly populations in the lower 48 States.

GRIZZLY BEAR POPULATION & HABITAT MANAGEMENT

In these sections, we provide background on the factors that need to be considered to successfully manage and conserve grizzly bears in the NCDE. These factors and their potential impacts to grizzlies provide the basis and logical framework for our population and habitat standards described in Chapters 2 and 3, respectively.

Grizzly Bear Population Management

Wildlife population managers are interested in a number of factors when gauging the status of a population including population size, trend (i.e., increasing, decreasing, or stable), density, distribution, levels of genetic diversity, reproductive rates, survival rates, and mortality causes. While population size is a well-known measure of population resilience, it is extremely challenging to obtain a reliable population estimate on an annual basis within the NCDE due to the difficulty of sighting individual bears and the high costs of more intensive methods. However, it is not necessary to estimate population size every year if its value at a given time is known and there is a reliable estimate of population trend. In the NCDE, we know the population consisted of 765 (95%CI = 715 – 831) individuals in 2004 and that it has been increasing approximately 3% annually since then (Kendall et al. 2009; Mace et al. 2012). This trend estimate incorporates all sources of mortality both known and unknown, and assures managers that grizzly bear mortality has been within sustainable levels.

Survival and reproduction are the two demographic vital rates driving whether the grizzly bear population increases, decreases, or remains stable (i.e., trend). Demographic parameters influencing trend include age-specific survival, sex-specific survival, age of first reproduction, average number of cubs per litter, the time between litters, age ratios, sex ratios, and immigration and emigration. These data are used to determine if and why the population is increasing or decreasing (Anderson 2002; Mills 2007; Mace et al. 2012).

Grizzly Bear Survival in the NCDE

Survival in the NCDE is influenced by age, sex, reproductive status, and home range location (i.e., proximity to humans and human activities). While grizzly bears in the NCDE die from natural causes on occasion, human-caused mortality is the driving force behind grizzly bear survival rates. Of 337 grizzly bear mortalities documented between 1998 and 2011 86% (290 of 337) were human-caused (Table 1). Despite these mortalities, the survival rate for adult females, the single most important cohort affecting population trend, is high: 0.952 (95% CI = 0.892–0.980) (Mace et al. 2012).

In the NCDE, the top three sources of human-caused mortality are: management removals (31%), illegal kills (21%), and defense of life (15%) (Table 1). Management removals of nuisance bears following grizzly bear/human conflicts are sometimes necessary. These removals benefit the conservation of grizzly bear populations by minimizing illegal killing of bears, providing an opportunity to educate the public about how to avoid conflicts, and promoting tolerance of grizzly bears by responding promptly and effectively when bears pose a threat to public safety. When making decisions about nuisance bears, this Conservation Strategy emphasizes consideration of the cause, severity, and location of the incident, the conflict history of the bear (if any), health, age, sex, and reproductive status of the bear, and the demographic standards regarding mortality limits. While removal of nuisance bears is sometimes necessary to protect the public, the ultimate source of the conflict that leads to nuisance bear behavior is usually manageable. The management agencies emphasize removal of the human cause of the conflict when possible and spend considerable time and money on outreach actions and materials teaching the public how to prevent conflicts before they occur.

The majority of management removals result from conflicts at sites associated with frequent or permanent human presence. Unsecured attractants such as garbage, human foods, pet/livestock foods, bird food, livestock carcasses, wildlife carcasses, barbeque grills, compost piles, orchard fruits, or vegetable gardens are usually the source of these conflicts and subsequent removals. Of the 89 management removals in the NCDE between 1998 and 2011, at least 57% (51 of 89) were related to attractants and may have been avoided if preventative measures had been taken. These conflicts involved food conditioned bears actively seeking out unsecured attractants or bears that were habituated to human presence seeking natural sources of food in areas near human structures or roads. While these mortalities are clearly related to human attractants, they are also related to attitudes and personal levels of knowledge about and tolerance toward grizzly bears. State, Tribal, and Federal agencies will continue to work with organizations such as the Swan Ecosystem Center and Blackfoot Challenge to prevent grizzly bear/human conflicts by educating the public and local governments about potential grizzly bear attractants, bear behavior, and bear ecology. The remaining management removals in the NCDE between 1998 and 2011 were related to bears depredating on livestock (23%; 21/89) or displaying unacceptable aggressive behavior (19%; 17/89).

Table 1. Grizzly bear mortalities and causes in the NCDE, 1998-2011. This table includes all known, probable, and possible mortalities for all age classes, including 99 dependent young (< 2 years old).

cause (all sources)	**# mortalities**	**avg. / year**	**% total**
natural	24	1.7	7%
unknown/undetermined	23	1.6	7%
human-caused	290	20.7	86%
total mortalities	**337**	**24.1**	
human-caused mortalities	**# mortalities**		**% human-caused**
augmentation*	6	0.4	2%
automobile collision	28	2.0	10%
capture related	15	1.1	5%
defense of life	43	3.1	15%
illegal	60	4.3	21%
management removal	89	6.4	31%
mistaken identification	18	1.3	6%
train	31	2.2	11%

* When bears are relocated from the NCDE to augment the Cabinet Yaak Ecosystem population, they are counted as mortalities in the NCDE.

Illegal killing of grizzly bears is a significant source of mortality in the NCDE (Table 1). People may kill grizzly bears for several reasons, including a general perception that grizzly bears in the area are dangerous, frustration over depredations of livestock, or to protest land use and road use restrictions associated with grizzly bear habitat management (Servheen et al. 2004). While we recognize illegal killings will never be eliminated entirely, reducing this source of human-caused mortality is worth pursuing. Ways to minimize illegal killings include a regulatory framework making them illegal and prosecutable under State law or Tribal law (i.e., designation as a game species), managing conflicts quickly and efficiently to increase assurance that conflicts will be properly addressed, and by using outreach and education to influence human attitudes and knowledge about grizzly bears and Federal regulation of public lands (Servheen et al. 2004). Additionally, we believe the flexible management provided in this Conservation Strategy and associated documents, including the use of regulated hunting, will help alleviate some of these illegal, malicious killings.

Humans kill grizzly bears unintentionally with vehicles or by mistaking them for black bears when hunting. From 1998 to 2011, 31% (92/290) of all human-caused grizzly bear mortalities in the NCDE were accidental or unintentional. This includes 28 mortalities due to collisions with vehicles, 31 from collisions with trains, 18 associated with mistaken identification, and 15 related to capturing and handling. Measures to reduce vehicle and train collisions with grizzly bears include removing wildlife carcasses from the road or tracks so that grizzly bears are not attracted to these areas (Servheen et al. 2004), keeping the tracks clean of spilled grain, constructing wildlife crossing structures over or under highways, and reducing human-caused mortality in nearby residential areas by providing bear resistant garbage containers where needed. All of these measures are already being implemented to varying degrees in different parts of the ecosystem.

Grizzly bear mortalities related to hunting accounted for 17 percent (50/290) of human-caused mortalities in the NCDE between 1998 and 2011. While many of these were related to people incorrectly identifying their targets during black bear or big game hunting seasons (18/290), the majority involved people shooting a grizzly bear in self-defense (28/290) while hunting other species (e.g., elk, pheasants, etc.). Mistaken identification is a preventable type of grizzly bear mortality. Many outreach programs are targeted at hunters to emphasize patience, awareness, and correct identification of targets so that grizzly bear mortalities from inexperienced black bear and ungulate hunters are reduced. The State of Montana requires all black bear hunters to pass a Bear Identification Test before receiving a black bear hunting license (see http://fwp.state.mt.us/bearid/). While it is more difficult to prevent grizzly bears being killed in self-defense during encounters with hunters, targeted outreach efforts may reduce this type of human-caused mortality. Montana includes grizzly bear encounter management as a core subject in basic hunter education courses (Dood et al. 2006) and in all big game hunting regulations, and encourages hunters to carry and know how to use bear spray.

To minimize grizzly bear mortality risk and increase human safety associated with bear capture and handling, managers and researchers adhere to the protocols first described by Jonkel (1993) when trapping grizzly bears. The latest veterinary medical research and anesthetic therapies are incorporated into these protocols annually and taught to trappers and field technicians at annual workshops with wildlife veterinarians. These protocols are designed to minimize restraint time, minimize capture-related stress, monitor the health of captured animals, administer appropriate levels of anesthesia, and minimize the duration of anesthesia through the use of appropriate antagonists. Additionally, new technologies that focus capture efforts (e.g. cameras), reduce non-target captures, and alert personnel when an animal has been captured (e.g. automatic text alerts) are incorporated as they become available.

Food Storage Orders

One of the most effective ways to prevent grizzly bear/human conflicts and increase grizzly bear survival on public lands is to require users and recreationists in grizzly habitat to store their food, garbage, and other bear attractants so that they are inaccessible to bears. Securing potential attractants can prevent bears from becoming food conditioned and displaying subsequent unacceptable aggressive behavior. Storing attractants in a manner that prevents bears from accessing them is effective in limiting grizzly bear mortality, grizzly bear/human encounters, and grizzly bear/human conflicts. Legally enforceable attractant storage requirements on public lands have been implemented or will be implemented on 87% of lands within the PCA. Attractant storage requirements for contractors or permitted activities occur on 91% of lands inside the PCA. These provisions will continue under this Conservation Strategy.

Grizzly Bear Habitat Management

Overview

Grizzly bears use a variety of habitats in the NCDE. In general, a grizzly bear's daily movements are largely driven by the search for food, mates, cover, security, and/or den sites. In the western portion of the ecosystem, Waller and Mace (1997) and Mace et al. (1997) demonstrated that avalanche chutes are important to bears during spring, summer, and autumn. Other open-canopied habitats such as shrub lands and places where timber has been harvested are also frequented by bears throughout the year. Mid- to high-elevation slabrock and meadow habitats possess many foods dug by bears. Grizzly bears use closed canopy forests less than expected during all seasons. Along the Rocky Mountain Front on the east side of the PCA, grizzly bears selected riparian zones during all seasons, up to 20 miles from the mountain front (Aune and Kasworm 1989), and occasionally over 50 miles (Mace and Roberts 2011). Shrub lands were important during autumn to bears in this area. As in other locales (e.g. McLellan and Shackleton 1988; 1989), grizzly bear habitat selection in the NCDE was negatively influenced by vehicular traffic (Mace et al. 1996; Waller and Servheen 2005) and at times non-motorized foot traffic (Mace and Waller 1996), both of which displaced grizzly bears.

Grizzly bears are long-lived opportunistic omnivores whose food and space requirements vary depending on a multitude of environmental and behavioral factors and on variation in the experience and knowledge of each individual bear. Grizzly bear home ranges overlap and change seasonally, annually, and with reproductive status. While these factors make the development of threshold habitat criteria difficult, habitat criteria may be established by assessing what habitat factors in the past were compatible with a stable to increasing grizzly population in the NCDE, and then using these habitat conditions as threshold values to be maintained to ensure a healthy population.

The available habitat for bears is determined largely by people and their activities. Human activities are the primary factor impacting habitat security. Human activities and the social structure and relationships among resident bears are the two major influences on the accessibility of available foods for bears. The question of how many grizzlies can live in any specific area is a function of overall habitat productivity (e.g., food distribution and abundance), the availability of habitat components (e.g., denning areas, cover types), the levels and types of human activities, grizzly bear social dynamics, learned behavior of individual grizzly bears, and stochasticity. Because carrying capacity in such an omnivorous and opportunistic species can vary annually and even day to day, there is no known way to calculate carrying capacity for grizzly bear populations. Therefore, controlling human-caused mortality, monitoring both population and habitat parameters, and responding when necessary with adaptive management (Walters and Holling 1990) are the best ways to ensure a healthy grizzly population. The USFWS defined adaptive management as "a method for examining alternative strategies for meeting measurable biological goals and objectives, and then, if necessary, adjusting future conservation management actions according to what is learned." This Conservation Strategy allows for modification of management practices in response to new or changing conditions.

Primary Conservation Area (PCA)

The PCA (known as the Grizzly Bear Recovery Zone while grizzlies are listed as threatened under the ESA) provides the habitat conditions necessary to accommodate a stable to increasing grizzly bear population in the NCDE. Between 2004 and 2011, the NCDE grizzly population was increasing at a rate of 3% per year (Mace et al. 2012; Mace 2012, personal communication). Due to this measured increasing population trend and the fact that motorized route density decreased between 2004 and 2011, 2011 was chosen as the baseline year for measuring levels of human activities. Decreases in motorized route density made between 2004 and 2011 were not reversed. While this approach contains some level of uncertainty related to how long changes in habitat translate into detectable changes in population parameters (i.e., lag time), it is the best option since we cannot calculate carrying capacity for such an omnivorous and opportunistic species. Furthermore, we are monitoring changes in multiple demographic rates other than population size, as recommended by Doak (1995). The PCA will continue to be managed and monitored carefully to maintain habitat conditions at 2011 levels through the management of motorized use, developed sites, and livestock allotments on most public lands. The 2011 habitat baseline values for secure habitat and motorized access route density are shown in Appendix 3; developed sites are in Appendix 4; and livestock allotments are shown in Table 7.

Management Zone 1

Outside of the PCA on the western side of Zone 1, two Demographic Connectivity Areas (DCAs) have been identified to provide opportunities for female grizzly bears to establish home ranges and exist at low densities: the Salish DCA and the Ninemile DCA (Figure 1). Males may also use these areas as part of their home ranges but are tangential to the main objective of these DCA's: to support female dispersal to other ecosystems within the lower 48 States that retain their threatened status (i.e., the Cabinet-Yaak and Bitterroot ecosystems). Unlike males who have large home range sizes, sometimes travel long distances, and establish home ranges nearly three times further away from their mother's home ranges than female offspring; female emigration to other ecosystems is a multi-generational process during which female offspring establish overlapping home ranges with their mothers. Females must be able to live year-round in an area to successfully reproduce and allow offspring to disperse into adjacent, unoccupied habitat. As such, habitat protections are more restrictive in the DCA's than in Zone 2 but still less rigorous than inside the PCA.

Management Zone 2

Grizzly bear occupancy within Zone 2 is not necessary to maintain the recovered status of the NCDE but it would be beneficial to other ecosystems if bears were able to occupy Zone 2 in low densities and successfully emigrate to these other ecosystems where grizzly bears remain "threatened." Because both male and female grizzly bears are already known to occur on occasion in Zone 2 without any protections specifically in place for grizzly bears, maintaining a healthy population in the PCA and Zone 1 while reducing the potential for conflicts in Zone 2 will be an effective way to ensure this continues in the foreseeable future. Because the objective in Zone 2 is not necessarily continual occupancy but instead, to have a few males (or females) move through this area into other ecosystems, less rigorous habitat protections are appropriate.

Management Zone 3

Due to the use of highways as easily described boundaries, some areas of habitat were included in this Conservation Strategy that will likely never support self-sustaining populations of grizzly bears in the foreseeable future. Specifically, much of the short-grass prairie on the east side of the Rocky Mountains within Zone 3 has been converted to agricultural land (Woods et al. 1999). Although lands east of Highway 89 were historically occupied, high densities of traditional food sources are no longer available due to land conversion and human occupancy of urban and rural lands. Traditional food sources such as bison and elk have been dramatically reduced and replaced with domestic livestock attractants such as cattle, sheep, chickens, goats, pigs, and bee hives, which can become anthropogenic sources of prey for grizzly bears. While food sources such as grasses and berries are abundant in some years in the riparian zones within which the bears travel, these are not reliable every year and can only support a small number of bears. These nutritional constraints and the potential for human-bear conflicts limit the potential for a self-sustaining population of grizzly bears to develop in the prairies, although we expect some grizzly bears to live in these areas. Grizzly bears in Zone 3 are not biologically necessary to the NCDE population. As such, habitat protections on Federal lands in Zone 3 are not necessary to maintain a recovered grizzly bear population in the NCDE. Grizzly bears in Zone 3 will likely always rely on the core population within the PCA of the NCDE to serve as a source for more bears, similar to the source-sink dynamic observed in Alberta between the mountain and prairie habitats along the Rocky Mountain Front (Proctor et al. 2012).

Secure Habitat

The negative impacts of humans on grizzly bear survival and habitat use are well documented (Harding and Nagy 1980; McLellan and Shackleton 1988; Aune and Kasworm 1989; McLellan 1989; McLellan and Shackleton 1989; Mattson 1990; Mattson and Knight 1991; Mattson *et al.* 1992; Mace *et al.* 1996; McLellan *et al.* 1999; White *et al.* 1999; Woodroffe 2000; Boyce *et al.* 2001; Johnson *et al.* 2004). These effects range from temporary displacement to actual mortality. History has demonstrated that grizzly bear populations survived where the frequency of contact with humans was very low (Mattson and Merrill 2002). Populations of grizzly bears persisted in those areas because the large expanses of relatively secure habitat without permanent human presence resulted in lower human-caused mortality. These areas are primarily associated with national parks, wilderness areas, and large blocks of public lands (Interagency Grizzly Bear Committee 1998). Maintaining habitat security is a major goal of this Conservation Strategy.

Motorized Access

The management of human use levels through motorized access route management is one of the most powerful tools available to balance the needs of grizzly bears with the needs and activities of humans. Open motorized route density is a predictor of grizzly bear survival on the landscape (Schwartz et al.

2010) and is useful in evaluating habitat potential for and mortality risk to grizzly bears (Mace et al. 1996).

Managing motorized access to maintain large blocks of secure habitat is important to the survival and reproductive success of grizzly bears, especially adult female grizzly bears (Mattson et al. 1987; Interagency Grizzly Bear Committee 1994; Schwartz et al. 2010). Managing motorized access (1) minimizes human interaction and reduces potential grizzly bear mortality; (2) minimizes displacement from important habitat; (3) minimizes habituation to humans; and (4) provides habitat where energetic requirements can be met with limited disturbance from humans (Mattson et al. 1987; McLellan and Shackleton 1988; McLellan 1989; Mace et al. 1996; Mattson et al. 1996).

Information and research specific to the NCDE indicated that 83% of documented locations of radio-collared females were in habitat that did not have motorized access (USFWS 1997). These areas were usually at least 2,200 acres in size. Additionally, approximately 62–64% of the composite home range of female grizzly bears studied in the South Fork of the Flathead River drainage was in habitat without motorized access (Mace and Waller 1997b). These values led National Forests west of the Continental Divide in the NCDE to manage most Bear Management Units (BMUs) so that at least 68% of each BMU was secure “core” habitat. In BMUs where the National Forests administered less than 75% of the lands and in National Forests east of the Continental Divide, BMUs were managed so that there was no net loss of secure “core” habitat. Core areas were defined at the time to include those areas more than 500 m (0.3 miles) from open or gated wheeled motorized access routes and high-use non-motorized trails, and at least 2,500 acres in size.

High Intensity Use Non-Motorized Trails

In 1994 and 1998, the IGBC task force charged with creating standard definitions and procedures for managing motorized access in grizzly bear recovery zones recommended that the impacts of “high intensity use” non-motorized trails be considered in calculations of “**core**” habitat (IGBC 1998, p. 4) but emphasized that “Motorized access is also one of the more influential parameters affecting habitat security” (IGBC 1998, p. 5). Because there were no data or literature available to determine what the threshold number of parties was that defined a “high intensity use” trail or how this number may relate to grizzly bear population parameters, the threshold value was determined by a panel of experts. In the NCDE, “high intensity use” non-motorized trails were defined as those receiving > 20 parties per week for at least one month during the non-denning season. Since 1995, National Forests in the NCDE have considered non-motorized trails meeting this definition of high intensity use as the equivalent of an open road. In other words, these high use non-motorized trails were buffered by 500 m (0.3 miles) and this area was not counted as core habitat.

The original recommendation to exclude areas within 500 m of high use non-motorized trails (e.g., foot or horse trails) from core area calculations was based on several untested assumptions regarding the potential impacts of such trails on grizzly bears. The approach is not clearly supported by the existing scientific literature. Multiple studies document displacement of individual grizzly bears from non-motorized trails to varying degrees (Schallenberger and Jonkel 1980; Jope 1985; McLellan and Shackleton 1989; Kasworm and Manley 1990; Mace and Waller 1996; White et al. 1999). However, none of these studies documented increased mortality risk from foot or horse trails or population level impacts to grizzly bears from displacement. For example, while Mace and Waller (1996) found that grizzly bears were further than expected (i.e., displaced) from high-use trails (90 visitors/day) in the Swan Mountains, they reported there were no historic or recent records of grizzly bear/human conflict in their study area. Similarly, while grizzlies in GNP are displaced to some degree by non-motorized trails (Jope 1985; White et al. 1999), conflicts and grizzly bear mortalities there are extremely low and related almost exclusively to campgrounds and other human-use areas. Furthermore, the recommendation that core blocks be a minimum of 2,500 acres in size was based on research regarding *road* density (see "Motorized Access" section immediately above) and did not address high intensity use non-motorized trails in the analyses. While we recognize that displacement merits concern because it can affect individual grizzlies through habitat loss and disrupted foraging or social behaviors, there are no data demonstrating that these impacts translate into detectable impacts to population-level variables such as grizzly bear survival or reproduction. Until such effects are documented, our primary concern with high-use trails is whether or not they are strongly associated with grizzly bear mortality, as motorized routes are. At this point, there are no data or research indicating non-motorized trail use results in disproportionate grizzly bear mortality or population declines.

In addition to the lack of data documenting a relationship between heavily used non-motorized trails and grizzly bear mortality, the difficulty of accurately measuring human use on non-motorized trails also undermines the usefulness of this habitat parameter when assessing habitat security for grizzly bears. Measuring human use on non-motorized trails is difficult for a number of reasons, including: (1) the high number of trails on the more than 5,000,000 acres (20,234 sq km) of public lands inside the PCA; (2) limited funding and personnel for monitoring trails; and (3) the need to address higher management priorities for grizzly bears, it is not feasible to directly measure human use on all non-motorized trails throughout the NCDE. Therefore, high intensity use trails are identified by on-the-ground land managers based on their expert opinion and professional familiarity. Because the amount of use on non-motorized trails is determined by the expert opinion of local USFS, GNP, or Tribal personnel, these decisions are affected by variations in annual use, changes in personnel, familiarity with an area, and personal judgment. The difficulty in obtaining actual data on use levels has led to the inconsistent assignment of use levels on the same trail in the past and highlights the subjectivity of this method.

Due to the lack of literature supporting the threshold value of 20 parties per week to define "high intensity use" in the NCDE, the subjectivity of quantifying use levels, and the lack of literature documenting population-level impacts from these heavily used non-motorized trails, we revised the definition of "core area" in this Conservation Strategy to remove consideration of high intensity use non-motorized trails. In other words, this Conservation Strategy considers the area surrounding non-motorized trails as "core" habitat. This Conservation Strategy uses the term "**Secure Core**" to represent this revised definition. Differences in the levels of Secure Core versus Core habitat in each BMU subunit are shown in Appendix 6.

- **Secure Core**: areas more than 500 m (0.3 miles) from an open or gated wheeled motorized access route, at least 2,500 acres in size, and in place for 10 years

This approach and revised definition are consistent with the decision reached by managers in the Greater Yellowstone ecosystem to treat high intensity use non-motorized trails as secure habitat: "Research addressing grizzly interactions with high use, non-motorized trails is very limited and has not identified impacts to grizzly bears, particularly when other management practices are employed to reduce conflicts i.e. food storage orders. …Further research is needed to address the potential impact of high use non-motorized trails…As such research information becomes available, an adaptive management approach will be used as necessary to incorporate any new information." (USFWS 2007). The increasing grizzly bear populations in both the GYA and NCDE during a time when recreational use of trails was also increasing lend further support to the decision to no longer count high intensity use non-motorized trails as the equivalent of an open road.

While growing human populations ensure that human use of non-motorized trails in the NCDE will continue to increase, the effects of these future increases will be adequately mitigated through motorized access and developed site standards, conflict prevention outreach and education, food storage orders, and continued presence of law enforcement and field staff as described in this Strategy. If research demonstrates that high intensity use non-motorized trails do significantly impact grizzly bear populations or that there are areas of significantly higher mortality risk near high intensity use non-motorized trails (as opposed to other trails or roads), this new information will be appropriately considered and incorporated through an adaptive management approach. Revisions to this Conservation Strategy will be made if necessary to conserve the NCDE grizzly bear population.

Snowmobiling

Snowmobiling has the potential to disturb bears while in their dens and after emergence from their dens in the spring. Because grizzly bears are easily awakened in the den (Schwartz et al. 2003b) and have been documented abandoning den sites after seismic disturbance (Reynolds et al. 1986), the potential impact from snowmobiling should be considered. We found no studies in the literature specifically addressing the effects of snowmobile use on any denning bear species and the information that is available is anecdotal in nature (USFWS 2002; Hegg et al. 2010).

Disturbance in the den could result in energetic costs (increased activity and heart rate inside the den) and possibly den abandonment which, in theory, could ultimately lead to a decline in physical condition of the individual or even cub mortality (Graves and Reams 2001). Although the potential for this type of disturbance while in the den certainly exists, Reynolds et al. (1986) found that grizzly bears denning within 1.4-1.6 km (0.9-1.0 mi) of active seismic exploration and detonations moved around inside their dens but did not leave them. Harding and Nagy (1980) documented two instances of den abandonment during fossil fuel extraction operations. One bear abandoned its den when a seismic vehicle drove directly over the den (Harding and Nagy 1980). The other bear abandoned its den when a gravel mining operation literally destroyed the den (Harding and Nagy 1980). Reynolds et al. (1986) also examined the effects of tracked vehicles and tractors pulling sledges. In 1978, there was a route for tractors and tracked vehicles within 100 meters (m) (328 feet (ft)) of a den inhabited by a male. This male was not disturbed by the activity nor did he abandon his den at any point. Reynolds et al. (1986) documented only one instance of *possible* den abandonment due to seismic testing (i.e., detonations) within 200 m of a den (Reynolds et al. 1986). This bear was not marked but an empty den was reported by seismic crews.

Swenson et al. (1997) monitored 13 different grizzly bears for at least five years each and documented 18 instances of den abandonment, 12 of which were related to human activities. Although many of these instances (n=4) were hunting related (i.e., gunshots fired within 100 m (328 ft) of the den), two occurred after “forestry activity *at* the den site,” one had moose and dog tracks within 10 m of a den, one had dog tracks *at* the den site, one had ski tracks within 80-90 m from a den, one had an excavation machine working within 75 m of a den, and two were categorized as “human related” without further details (Swenson et al. 1997). Swenson et al. (1997) found that 72% (13 of 18) of dens were abandoned between November and early January, before pregnant females give birth. After abandoning a den, bears moved an average of 5.1 km (3.2 mi) before establishing another den site, although 56% of bears moved ≤2 km (1.2 mi) (Swenson et al. 1997). Despite these relatively short distances, Swenson et al. (1997) found that 60% (n=5) of female bears that abandoned a den site before giving birth (i.e., in November or December) lost at least one cub in or near their new den site whereas only 6% (n=36) of pregnant females that did not abandon their dens during the season lost a cub in or near their den. In summary, the available data about the potential for disturbance while denning and den abandonment from nearby snowmobile use is extrapolated from studies examining the impacts of other human activities and is identified as “anecdotal” in nature (Swenson et al. 1997) with sample sizes so small they cannot be legitimately applied to assess population-level impacts (Harding and Nagy 1980, Reynolds et al. 1986; Hegg et al. 2010). The one documented observation of snowmobile use at a known den site in the lower 48 States found the bear did not abandon its den, even though snowmobiles were operating directly on top of it (Hegg et al. 2010). Again though, this is only an anecdotal observation because it is based on a sample size of one. There are no reports of litter abandonment by grizzlies in the lower 48 States due to snowmobiling activity (Hegg et al. 2010; Servheen 2010). Additionally, monitoring of den occupancy for three years on the Gallatin National Forest in Montana (2006) did not document any den abandonment (Gallatin National Forest 2006).

Our best information suggests that current levels of snowmobile use are not appreciably reducing the survival or recovery of grizzly bears. Yet, because the potential for disturbance exists, monitoring will continue to support adaptive management decisions about snowmobile use in areas where disturbance is documented or likely to occur.

Developed Sites on Public Lands

Developed sites refer to sites or facilities on public Federal lands with features that are intended to accommodate public use and recreation. Examples include, but are not limited to: campgrounds, trailheads, lodges, rental cabins and lookouts, summer homes, restaurants, visitor centers, and ski areas. Developed sites are generally associated with frequent, overnight or prolonged human use that may increase both the levels of bear attractants and grizzly bear mortality risk.

Developed sites can impact bears through temporary or permanent habitat loss and displacement but the primary concern regarding developed sites is direct bear mortality or removal from the ecosystem due to bear/human conflicts caused by unsecured bear attractants, habituation, and food conditioning (Mattson et al. 1987; Knight et al. 1988; Gunther et al. 2004; Servheen et al. 2004). **Habituation** occurs when grizzly bears encounter humans or developed sites frequently, and without negative consequences, so that the bears no longer avoid humans and areas of human activity (USFWS 1993). Habituation does not necessarily involve human-related food sources. **Food conditioning** occurs when grizzly bears receive human-related sources of food and thereafter seek out humans and human use areas as feeding sites (USFWS 1993). As discussed above, the majority of grizzly bears removed by management agencies were involved in conflicts at developed sites with unsecured attractants such as garbage, bird feeders, pet/livestock feed, and human foods. Although the majority of these mortalities occurred on private lands, this Conservation Strategy has no authority to regulate developed sites on private lands and applies only to public lands.

Livestock Allotments

Livestock operations can benefit the long-term conservation of grizzly bears through the maintenance of large blocks of open rangeland and habitats that support a variety of wildlife species (Dood et al. 2006). However, when grizzlies were listed in 1975, the USFWS identified "…livestock use of surrounding national forests" as detrimental to grizzly bears "…unless management measures favoring the species are enacted." (40 CFR 31734, p. 31734). Impacts to grizzly bears from livestock operations potentially include:

- direct mortality from control actions resulting from livestock depredation;
- direct mortality due to control actions resulting from grizzly bear habituation and/or learned use of bear attractants such as livestock carcasses and feed;
- increasing the chance of a grizzly bear livestock conflict;
- displacement due to livestock or related management activity;
- direct competition for preferred forage species.

Approximately 7% (21/290) of all human-caused grizzly bear mortalities in the NCDE between 1998 and 2011 were due to management removal actions associated with livestock depredations. This human-caused mortality is the main impact to grizzly bears in the NCDE associated with livestock. Most livestock-related grizzly bear mortalities occur on private lands or on the Blackfeet Indian Reservation (BIR) along the Rocky Mountain Front, east of the Continental Divide. The PCA in this area extends up to 18.5 miles east of Federal management boundaries and includes large areas of private ranchlands and Tribal grazing allotments. Indirect impacts on grizzly bears due to attractants can be effectively minimized with requirements to securely store and/or promptly remove attractants associated with livestock operations (e.g., livestock carcasses, livestock feed, etc.). Current levels of grazing intensity in forested environments are not displacing grizzly bears in significant ways and are not likely to affect vegetation structure enough to result in direct competition for forage species on public lands within the NCDE, as evidenced by the increasing population trend in the NCDE.

In the NCDE, most livestock depredations by grizzly bears occur on sheep or young cattle. While grizzly bears frequently coexist with large livestock such as adult cattle without preying on them, when grizzly bears encounter smaller animals such as calves, domestic sheep, goats, or chickens, they will often attack and kill them (Jonkel 1980; Knight and Judd 1983; Orme and Williams 1986; Anderson et al. 2002). Honeybees, classified as livestock in Montana (MCA 15-24-921), can also be attractants to some grizzly bears. If repeated depredations occur, managers may relocate bears or remove them from the population. As such, areas with domestic livestock have the potential to become population sinks (Knight et al. 1988). Because of the increased risk to grizzly bears posed by actions taken to protect sheep and other small livestock, the IGBC Guidelines emphasized the reduction of these types of allotments. In contrast, there are a number of permitted grazing operations for horses and mules in the NCDE, primarily on National Forest land and generally associated with outfitter and guide operations or Forest Service administrative use. There is no evidence of conflict with bears due to attractants, depredation, or forage competition related to these horse and mule permits.

A number of regulations and practices related to livestock allotments while grizzly bears are listed as threatened under the ESA promoted grizzly bear recovery through minimization of bear-livestock and related bear-human conflicts. These include but are not limited to:

- Forest Plan standards that require prioritization of wildlife concerns over other resource uses in grizzly bear habitat
- Clauses in grazing permits providing for the cancellation, suspension, or temporary cessation of activities if needed to resolve a grizzly conflict situation
- Reduction of the number of open and active sheep grazing allotments when opportunities with willing permittees arise
- Reduction in the potential for grizzly-human conflicts due to livestock food, carcasses, and poor or inadequate livestock management practices through implementation and enforcement of Attractant Storage rules, which require bear-resistant storage of all livestock food and reporting of all livestock carcasses within 24 hours of discovery.
- Use of the IGBC Guidelines to reduce livestock impacts to important grizzly bear habitats
- Use of the IGBC Guidelines for management of grizzly bear-livestock conflict situations
- Stratification of National Forest (NF) lands into Management Situations with specific recommendations for livestock conflict management

Most of these measures would carry forward either directly or indirectly under delisted status through this Conservation Strategy and associated management plans. Furthermore, it will be illegal for a member of the public to kill a grizzly bear to protect livestock unless it is “in the act” of attacking or killing livestock, as evidenced by an injured or dead animal.

Vegetation Management and Cover

Vegetation management occurs throughout the NCDE on lands managed by the US Forest Service, GNP, Montana DNRC, BLM, the Flathead Indian Reservation (FIR), the BIR, MFWP, and both corporate and small private lands. Vegetation management projects typically include timber harvest, thinning, prescribed fire, and salvage of burned, diseased, or insect-infested stands. Nearly 68% of the PCA is unavailable for general, commercial timber harvest through Federal or Tribal designations.

The relative importance of cover to grizzly bears was documented by Blanchard (1978) in a four-year study in the Greater Yellowstone ecosystem. Blanchard found grizzly bears needed an interspersion of open areas to be used as feeding sites and nearby areas with cover. Similarly, grizzlies in the NCDE thrive in landscapes with numerous different habitat types, including those with cover and those without (Aune and Kasworm 1989; Mace et al. 1997; Waller and Mace 1997), but generally prefer to forage in areas with some type of hiding cover nearby, particularly in daylight hours. If not implemented properly, vegetation management programs can negatively affect grizzly bears by (1) removing cover; (2) disturbing or displacing bears from habitat during the logging period; and (3) increasing human/grizzly bear conflicts or mortalities as a result of unsecured attractants; (4) increasing mortality risk or displacement due to new roads into previously roadless areas and/or increased vehicular use on existing restricted roads, especially if roads are open to the public after vegetation management is complete.

Conversely, vegetation management may result in positive effects on grizzly bear habitat once the project is complete, provided key habitats such as riparian areas and known food production areas are maintained or enhanced. For instance, tree removal for thinning or timber harvest and prescribed burning can result in localized increases in bear foods through increased growth of grasses, forbs and berry-producing shrubs (Zager et al. 1983; Kerns et al. 2004). Vegetation management may also benefit grizzly bear habitat by controlling undesirable invasive species, improving riparian management, and limiting livestock grazing in important food production areas.

Changes in the distribution, quantity, and quality of cover are not necessarily detrimental to grizzly bears as long as they are coordinated on a grizzly BMU or subunit scale to ensure that grizzly bear needs are addressed throughout the various projects occurring on multiple jurisdictions at any given time. Although there are known, usually temporary impacts to individual bears from timber management activities, these impacts have been managed acceptably using the IGBC Guidelines in place since 1986 (USFS 1986). Under these Guidelines, the grizzly bear population increased and recovered by following these two guiding principles: (1) maintain and improve habitat and (2) minimize the potential for grizzly bear/human conflict.

Mineral and Energy Development

Mineral and energy development have the potential to directly and indirectly affect grizzly bears and/or their habitat. For the purposes of this Conservation Strategy, mineral development refers to surface and underground hardrock mining and coal production whereas energy development refers to the production of oil and natural gas. As with vegetation management, the primary concerns are related to increased grizzly bear mortality risk from associated motorized use, habituation, and/or increased grizzly bear/human encounters and conflicts. Other impacts may include permanent habitat loss, habitat fragmentation, and displacement due to surface disturbance.

Mortality risk will be largely mitigated through motorized access standards, food storage requirements, and other habitat standards described in Chapter 3. Additionally, being designated a “sensitive species” on BLM, USFS, and DNRC lands ensures a higher level of scrutiny for future projects within the NCDE so that “viable populations” can be maintained “throughout their geographic ranges” (Forest Service

Manual 2672.32). To accomplish this objective, any project proposed on Forest Service, BLM, or DNRC lands would require a biological evaluation to analyze the effects on the population or habitat within the area of concern and the activity "must not result in loss of species viability or create significant trends toward Federal listing." (Forest Service Manual 2670-32).

While land management plans identify large areas considered "suitable" for oil and gas production, site-specific environmental analyses and mitigation measures occur at the project level. This environmental analysis involves two separate NEPA (or MEPA on State lands) processes. A NEPA process (or MEPA) is initiated when the decision is made to offer certain lands for leasing. Stipulations that would be required in order for leases to meet requirements of land and resource management plans, or to meet other policy or regulation, are identified when the decision is made to offer lands for lease. These stipulations remain with the lease even if it is sold, and would be placed on any leases issued for that area in the future. A second, site-specific NEPA analysis is completed if, and when, a lease holder submits an application for a permit to drill. At this point, site-specific mitigation measures are incorporated to address any environmental concerns associated with the surface use plan of operations. These mitigation measures may be incorporated as additional lease stipulations or as conditions of approval for the surface use plan. Until this application for a permit to drill is submitted, no exploration or development can occur.

In 1997, the Lewis and Clark National Forest decided to make the entire Rocky Mountain Ranger District unavailable for future leasing. In 2006, lands outside of Designated Wilderness Areas on the Rocky Mountain Ranger District, some areas of the Flathead National Forest, and BLM lands along the Rocky Mountain Front were withdrawn permanently from any future mineral, oil, natural gas, or geothermal leasing and all forms of location, entry and patent under mining laws, by Public Law 109-432, the Tax Relief and Health Care Act of 2006 (Figure 3). It was not necessary to withdraw lands inside Designated Wilderness Areas from future leasing because new leases are already prohibited by the Wilderness Act in these areas.

While Public Law 109-432 prohibited the establishment of new leases, it did not eliminate leases that existed at the time the law was passed. Many leases on Federal lands that existed at the time Public Law 109-432 was passed have been voluntarily retired. As of 2012, there were 247 oil and gas leases in the PCA and another 140 in Management Zone 1. Over 94% (365 of 387) of these leases are on USFS lands, with 88% (339 of 387) of them on the Flathead NF. Of the 247 existing leases inside the PCA, 235 are currently suspended, pending Forestwide leasing analyses (the first of two NEPA/MEPA processes described in the previous paragraph). Similarly, 87% (122 of 140) of the oil and gas leases in Zone 1 are on USFS lands, with 98% (119 of 122) currently suspended. Regional priorities for initiating the NEPA/MEPA process for these leases are based on available funding for analysis, public demand for action, and/or applications for permits to drill on existing leases.

Of the 247 oil and gas leases inside the PCA, nine lease holders have submitted Applications for Permit to Drill (APDs) to the BLM, one of which is on private lands. There have been 11 APDs submitted in Zone 1, only 3 of which are on USFS lands. The APDs include surface use plans of operation, which will require evaluation and analysis in compliance with NEPA and this Conservation Strategy. No action is currently being taken on these APDs pending decisions on funding and work priorities.

Stipulations included in existing leases would not be changed without agreement by lease holders, nor can additional stipulations be added to existing leases. Additional mitigations that may be needed to address environmental concerns, land and resource management plan requirements, or other policy or regulation would be included as conditions of approval of surface use plans of operation when permits to drill are issued. The majority of existing leases already contain stipulations that address maintaining grizzly bear security through such things as limits on timing or location of specific activities. When or if APDs are submitted on existing leases, the access standards as described in this document for the PCA would apply unless specific language in a lease superseded that requirement.

There have been several proposals before the Canadian government for large-scale industrial coal and gas developments in the upper North Fork Flathead River basin in British Columbia directly north of and upstream from Glacier National Park and the Flathead National Forest. If these proposals were fully implemented there could be significant impacts on grizzly bear connectivity between the NCDE and contiguous grizzly populations in Canada north of Canadian Highway 3. On February 18, 2010, the B.C. Premier announced that mining, oil, gas, and coal development were no longer permissible land uses in the Canadian portion of the North Fork Flathead River (British Columbia Office of the Premier 2010).

As with oil and gas, Public Law 109-432 made lands outside of Designated Wilderness Areas on the Rocky Mountain Ranger District of the Lewis and Clark National Forest, some areas of the Flathead National Forest, and BLM lands along the Rocky Mountain Front unavailable to future location and entry under the General Mining Act of 1872. While this law prohibited the establishment of new claims, it did not eliminate claims that existed at the time the law was passed. However, there are no Plans of Operation or Notices of Intent to explore or operate any commercial mines inside the PCA on National Forest or BLM lands, with one exception: the Cotter Mine on the Helena NF. There is some copper and silver exploration occurring at this mine but activity is low and mitigation measures to protect grizzly bears were included in the Plan of Operation (Shanley 2009). This Conservation Strategy ensures that appropriate mitigation measures will continue to be implemented in any future Plans of Operation inside the PCA.

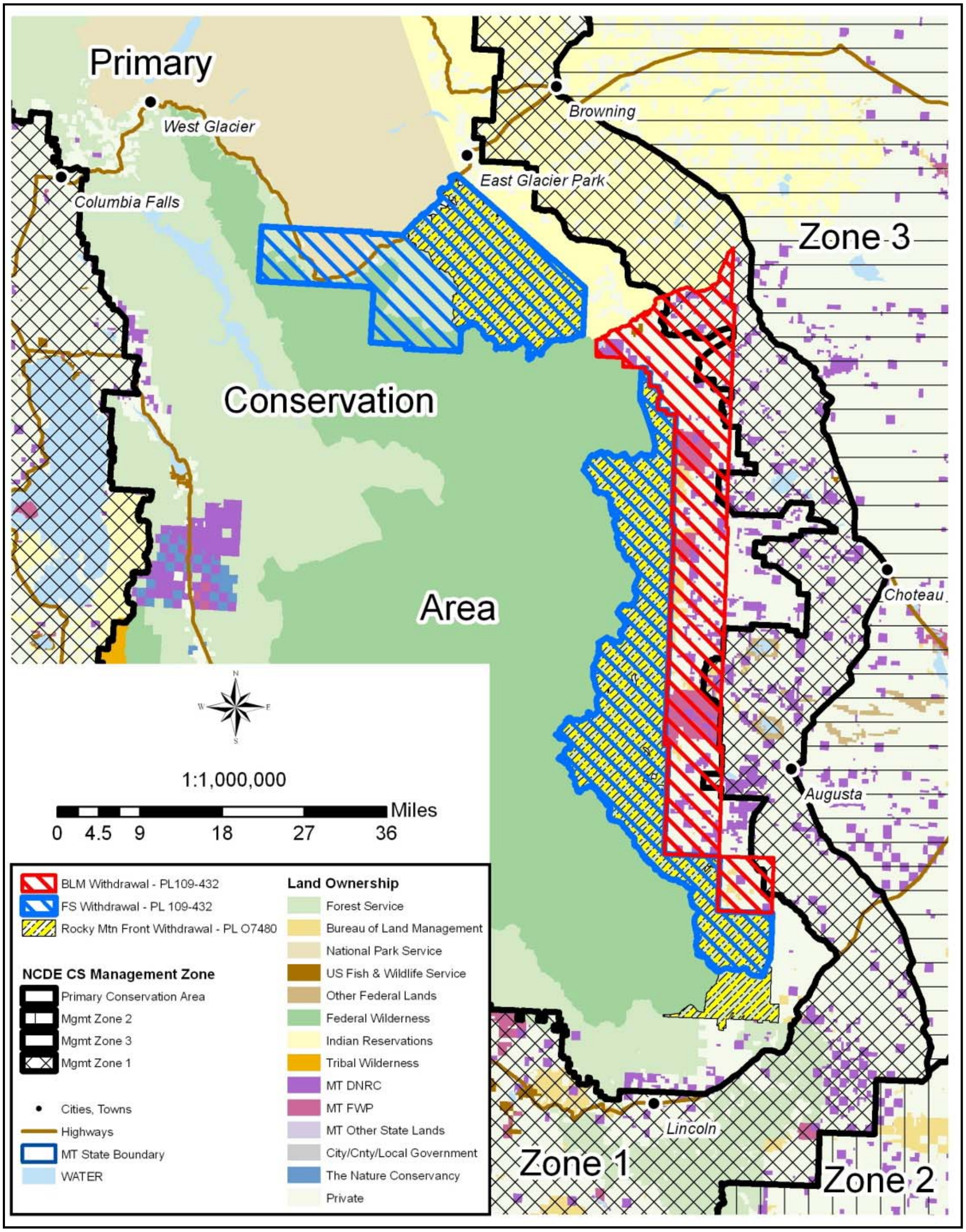


Figure 3. Rocky Mountain Front Mineral Withdrawal Area, where no new energy leases or mineral claims may be made on USFS or BLM managed lands.

Climate Change

Climate change may result in a number of changes to grizzly bear habitat, including a reduction in snowpack levels, shifts in denning times, shifts in the abundance and distribution of some natural food sources, and changes in fire regimes. Most grizzly bear biologists in the U.S. and Canada do not expect habitat changes predicted under climate change scenarios to directly threaten grizzly bears (Servheen and Cross 2010). These changes may even make habitat more suitable and food sources more abundant. However, these ecological changes may also affect the timing and frequency of grizzly bear/human interactions and conflicts (Servheen and Cross 2010). In this Conservation Strategy, the **denning season** is considered to be December 1- April 1 west of the continental divide and December 1- April 15 east of the continental divide. These dates will be adjusted if 10-year average den emergence data for females or females with offspring shows a shift of at least a week.

The hydrologic regime in the northern Rockies has changed with global climate change, and is projected to change further (Bartlein et al. 1997; Cayan et al. 2001; Leung et al. 2004; Stewart et al. 2004; Pederson et al. 2011). The western U.S. will likely experience milder, wetter winters with warmer, drier summers and an overall decrease in snowpack (Leung et al. 2004). While some climate models do not demonstrate significant changes in total annual precipitation for the western U.S. (Duffy et al. 2006), an increase in “rain on snow” events is expected (Leung et al. 2004; McWethy et al. 2010). The amount of snowpack and the timing of snowmelt may also change, with an earlier peak stream flow each spring (Cayan et al. 2001; Leung et al. 2004; Stewart et al. 2004). Although there is some disagreement about changes in the water content of snow under varying climate scenarios (Duffy et al. 2006), reduced runoff from decreased snowpack could translate into decreased soil moisture in the summer (Leung et al. 2004). However, Pederson et al. (2011) found that increased spring precipitation in the northern Rocky Mountains is buffering total annual stream flow thus far from these expected declines in snowpack.

Because timing of den entry and emergence is at least partially influenced by food availability and weather (Craighead and Craighead 1972; Van Daele et al. 1990), less snowpack would likely shorten the denning season as foods become available later in the fall and earlier in the spring. In the GYA, Haroldson et al. (2002) reported later den entry times for male grizzlies corresponding with increasing November temperatures from 1975 to 1999. This increased time outside of the den could increase the potential for conflicts with humans (Servheen and Cross 2010).

Climate change could create temporal and spatial shifts in grizzly bear food sources (Rodriguez et al. 2007). Changes in plant community distributions have already been documented, with species’ ranges shifting further north and higher in elevation due to environmental constraints (Walther et al. 2002; Walther 2003; Walther et al. 2005) or outbreaks of insects or disease (Bentz et al. 2010). Decreased snowpack could lead to fewer avalanches thereby reducing avalanche chutes, an important habitat component to grizzlies, across the landscape. However, increases in “rain on snow” events may decrease the stability of snowpack resulting in increases in avalanches. Changes in vegetative food distributions also may influence other mammal distributions, including potential prey species like ungulates. While the extent and rate to which individual plant species will be impacted is difficult to foresee with any level of confidence (Walther et al. 2002; Fagre et al. 2003), there is general consensus that grizzly bears are flexible enough in their dietary needs that they will not be impacted directly by ecological constraints such as shifts in food distributions and abundance (Servheen and Cross 2010).

Fire regimes can affect the abundance and distribution of some vegetative bear foods (e.g., grasses, berry producing shrubs) (LeFranc et al. 1987). For instance, fires can reduce canopy cover which usually increases berry production. However, on steep south or west aspects, excessive canopy removal due to fires or vegetation management may decrease berry production through subsequent moisture stress and exposure to sun, wind, and frost (Simonen 2000). Fire frequency and severity may increase with late summer droughts predicted under climate change scenarios (Nitschke and Innes 2008; McWethy et al. 2010). Increased fire frequency has the potential to improve grizzly bear habitat, with low to moderate severity fires being the best. For example, fire treatment most beneficial to huckleberry shrubs is that which results in damage to stems, but does little damage to rhizomes (Simonen 2000). High intensity fires may reduce grizzly bear habitat quality immediately afterwards by decreasing hiding cover and delaying regrowth of vegetation but Blanchard and Knight (1996) found that increased production of forb foliage and root crops in the years following the high intensity, widespread Yellowstone fires of 1988 benefited grizzly bears. We do not anticipate altered fire regimes will have significant negative impacts on grizzly bear survival or reproduction in the NCDE, despite its potential effects on vegetation.

Habitat Connectivity

One way to mitigate potential impacts from climate change is through well-connected populations of grizzly bears in the NCDE, Canada, and the lower-48 States. Connectivity among grizzly populations also mitigates genetic erosion and increases resiliency to demographic and environmental variation. This Conservation Strategy envisions the NCDE serving as a "source population" for grizzly bear populations in the Cabinet-Yaak, Bitterroot, and Greater Yellowstone ecosystems. Maintaining habitat connectivity between these areas would benefit multiple wildlife species and would be consistent with the USFWS Grizzly Bear Recovery Plan (USFWS 1993, pp. 24-25), the Grizzly Bear Management Plan for Western Montana (Dood et al. 2006, pp. 54-56), the Grizzly Bear Management Plan for Southwestern Montana (MFWP 2002, p. 44), the interagency statement of support for the concept of linkage zones signed by the state wildlife agencies in Montana, Washington, Idaho, and Wyoming and the USFS, USFWS, USGS, NPS, and BLM (IGBC 2001), and the Western Governors' Association Resolution 07-01 (2007). Although connectivity to the west and south would benefit other grizzly bear populations in the lower 48 States, it is not required for a healthy NCDE grizzly bear population because of this population's large size and connectivity with populations in Canada.

Based on existing data, sighting records, and the observations of current bear managers, we identified areas outside of the PCA already supporting low levels of grizzly bears to serve as connectivity areas to adjacent ecosystems. Two of these areas are within Management Zone 1 (the Salish and Ninemile DCAs) while the third area is all of Management Zone 2. The two DCAs in Zone 1 would be managed to allow female grizzly bear dispersal to other recovery ecosystems whereas Zone 2 would be managed to allow the dispersal of males (or females) to either the Greater Yellowstone or possibly the Bitterroot ecosystem.

Although lacking the large blocks of Wilderness Areas and National Parks that provide secure habitat to support dense populations of grizzly bears in the PCA, the DCAs will support lower densities of grizzly bears, and many reproductive females have already been documented in these areas. Because both DCA's contain human population centers and rural private lands, it is not expected, nor is it necessary, for grizzly bears to occupy these areas in high densities. As such, less rigorous habitat protections are appropriate. Therefore, management in the DCA's will focus on reducing risk of human-caused mortality and minimizing erosion of habitat security.

Similarly, Zone 2 will support lower densities of grizzly bears than the PCA because it lacks the large, contiguous Wilderness Areas and National Parks that support more dense populations in the PCA. Mortality risk in these areas will likely be higher due to greater human activities and presence than in the PCA but wary bears will be able to live in low densities in these areas, as demonstrated by the confirmed presence of several different males in Zone 2 already. Mortality risk and grizzly bear/human conflicts will be minimized through food storage orders on public lands and the current Forest Plan direction for managing the multiple Inventoried Roadless Areas, Wilderness Areas, and Wilderness Study Areas in Zone 2.

Private Land Development

Human population growth in Montana is expected to result in increased recreational use and increased residential development in important wildlife habitat adjacent to public lands. This increased human presence and residential development can result in loss of wildlife habitat, habitat fragmentation, and increases in grizzly bear/human conflicts, which can result in higher bear mortality rates. Activities associated with permanent human presence often result in management actions that adversely impact bears. Many of these activities occur on or are associated with private lands. Private lands account for a disproportionate number of bear deaths and conflicts.

The impacts of private land development on grizzly bears may be mitigated and minimized through appropriate residential planning, outreach and education about avoiding conflicts, tools and infrastructure that prevent conflicts (e.g., bear resistant trash containers and electric fencing for bee hives and chicken coops), and assistance in managing conflicts when they do occur. To assist counties and developers with residential development plans, MFWP developed a comprehensive GIS planning tool that identifies "Crucial Areas" for wildlife connectivity throughout the State. MFWP also developed the "Fish and Wildlife Recommendations for Subdivision Development in Montana: A Working Document" (MFWP 2012). This document describes how to mitigate the potential impacts of new private land development on wildlife, including bears. Management agencies have devoted significant efforts toward private landowner outreach programs to minimize grizzly bear/human conflicts and to manage bears and potential conflict situations on such sites, and are committed to continuing those efforts. MFWP, the Confederated Salish and Kootenai Tribes, and the Blackfeet Nation employ bear management specialists to manage and prevent grizzly bear/human conflicts on private lands. Similarly, the USDA Forest Service and National Park Service employ bear rangers, and recreation technicians to work with recreational users and owners of residences on the forests to minimize conflicts.

Chapter 2 – Demographic Criteria

To maintain a healthy (recovered) grizzly bear population in the NCDE, it is necessary to have adequate numbers of bears that are well distributed with a balance between reproduction and mortality. This section details the demographic criteria necessary to maintain and enhance a recovered grizzly bear population in the NCDE. The standards and monitoring protocol focus on the Recovery Zone and the area immediately around it identified in this Conservation Strategy as the NCDE Primary Conservation Area (PCA) and Management Zone 1 (Zone 1) respectively. Because grizzly bears are a difficult species to monitor, multiple criteria are identified to provide sufficient information upon which to base management decisions.

Intensive information has been generated in the NCDE about the status of the population. These data indicate that the demographic and distribution criteria, as outlined in the Revised *Grizzly Bear Recovery Plan* (USFWS 1993) have been greatly surpassed. Agencies responsible for management will continue their commitment to careful population monitoring and data collection to demonstrate that a healthy and biologically viable population is being maintained.

Under this Conservation Strategy, all known and probable human-caused mortalities, a calculated number of unknown/unreported mortalities, and all natural mortalities will be monitored and reported annually in the PCA and in all three Management Zones (see Figure 1), but the mortality standards will only apply in the PCA and Zone 1. All reports of females accompanied by young of any age will be reported in the PCA and Zone 1 but will only be used for the occupancy standard inside the PCA (currently the Recovery Zone).

COMMENTS ABOUT THE ISSUE OF UNCERTAINTY

All wildlife management and conservation entails recognizing and accommodating a certain level of uncertainty. In fact, uncertainty is pervasive through all management constructs, from uncertainty around identifying social and conservation desires, establishing population goals and objectives, to measuring population parameters. At each level, point estimates are accompanied by other possible values. Sometimes, uncertainty can be explicitly identified and measured, then incorporated into models. In other cases, we don't know what we don't know, but the uncertainty remains nonetheless. Despite our recognition that uncertainty exists, the need for action remains. Being unsure does not relieve us of responsibility to act to conserve and manage wildlife. Because grizzly bears are long-lived, slow-reproducing, and inherently rare, it is difficult to get enough data to accurately estimate population parameters. As data accumulates over time, estimates become more reliable, but this can take many decades. Key uncertainties in these demographic management standards are the wide confidence intervals around lambda[1] and survival. As of 2012, point estimates of lambda and survival indicate that the population is increasing 3% ($\lambda = 1.03$) annually, and that survival is over 95% for adult females. However, if one were to apply the lower or upper confidence limits around these estimates, the

[1] Lambda symbolized by the Greek letter λ denotes the long-term intrinsic growth rate of a population. Lambda greater than 1 indicates an increasing population, lambda = 1 indicates a stationary population, and lambda less than 1 indicates a decreasing population. Thus, lambda (λ) = 1.02 equates to a population growing at 2% per year while lambda (λ) = 0.97 equates to a population declining at 3% per year.

population would appear to be either catastrophically falling or wildly erupting. These are the limits of the confidence intervals because they are statistically less likely. The point estimates are the 'best approximation of reality' statistically, so that is what we plan to use to make management decisions. To further control for uncertainty, other lines of evidence are used to temper the limits of confidence. These other lines of evidence include monitoring the distribution of breeding females and female mortality across the landscape, measuring range expansion, and exploring and applying alternative methodologies, for example using DNA collected from bear rub trees. Convergent results from independent methodologies and observations improve confidence in predictions of future population performance.

Grizzly bear recovery in the NCDE has been achieved without any reliable method for measuring demographic performance. Only recently have we been able to measure population size and trend across the NCDE. The key population management element that allowed recovery was conservative habitat and mortality standards. The grizzly population has recovered to the point where managers can afford to be less conservative than in the past, however, in light of the uncertainty around population performance, standards will continue to be conservative. Under conservative management regimes, the population may decline over certain intervals of time, but not quickly, and observed declines will be balanced against periods of population increase.

Management Zones and Their Objectives

The area this Conservation Strategy applies to stretches from central Montana to the western edge of the NCDE, within which there are three different Management Zones outside of the PCA (Figure 1 – p. 6, Chapter 1).

The PCA and Zone 1 comprise the area within which habitat and population management will be most protective of grizzly bears. They are over 10.5 million acres (42,605 km^2; 16,450 mi^2) including 28% private, 42% USFS, 11% tribal, 9.4% GNP, 9.6% other).

Zone 2 is the area managed for genetic connectivity between the NCDE and the Yellowstone. It is over 4.5 million acres (18,855 km^2; 7,280 mi^2), and is predominantly privately owned (63% private; 25% USFS; and 12% other ownerships).

Zone 3 is the area where grizzly bear occupancy occurs. Grizzly bear occupancy will not be encouraged in this area, but bears that occur here will not be actively removed unless they are causing problems. This area is over 12 million acres (49,202 km^2; 18,997 mi^2), and is 78% private; 9% USFS; 4% Tribal; and 9% other ownerships.

The demographic standards for population trend, survival and mortality will be monitored and maintained within the PCA and Zone 1. Grizzly bear mortalities occurring in Zone 2 or Zone 3 will not be counted against the NCDE survival standards as these areas are not necessary to maintain a recovered grizzly bear population in the NCDE. Federal public lands within Zone 2 will be managed to provide the opportunity for grizzly bears to move between the NCDE and adjacent ecosystems (e.g., the Yellowstone) through implementing Food Storage Orders and emphasizing outreach and education, conflict response, and management when necessary. Zone 3 includes peripheral areas where the feasibility of long-term occupancy and viability of grizzly bears is less than in Zones 1 and 2 because of the large extent of private agricultural lands. It is expected that grizzly bears will occasionally use or occupy areas within Zone 3. Grizzly bear management in Zone 3 will consist of primarily minimizing bear/human conflicts.

While this Conservation Strategy aims to demonstrate a clear commitment to establish the NCDE as a source population to the Greater Yellowstone, Bitterroot, and Cabinet-Yaak grizzly bear recovery ecosystems, such connectivity is not required for the health or recovery of the NCDE population because of its large size and connectivity with Canadian populations. This Conservation Strategy allows the opportunity for movement between the NCDE and other ecosystems and in doing so, is consistent with the revised USFWS Grizzly Bear Recovery Plan (USFWS 1993), the Grizzly Bear Management Plan for Western Montana (Dood et al. 2006), and the Grizzly Bear Management Plan for Southwestern Montana (MFWP 2002).

POPULATION MANAGEMENT

Management and monitoring protocols for this population will focus on ensuring a recovered population is maintained and ensuring that demographic standards for the Conservation Strategy are being achieved. Additional monitoring or research may be conducted as determined by the NCDE Coordinating Committee.

Objectives of Population Management in this Conservation Strategy

This Conservation Strategy sets an objective of maintaining a recovered grizzly population in the NCDE area sufficient to maintain a healthy population in biologically suitable habitats within the PCA and Zone 1. This Conservation Strategy sets management goals, which may not necessarily be measurable. It includes demographic standards, which are objective and measurable criteria of population status and health.

Demographic and Genetic Management Goals:

- Maintain a population with genetic diversity. This can be accomplished by maintaining a minimum of 400 grizzly bears (400 is the population size required for an isolated grizzly population to maintain a minimal loss of genetic diversity over time (see Miller and Waits (2003)). Note that the NCDE population is not currently an isolated population.
- Maintain a demographic and genetic connection with Canada.

> Management Goals
> These are the overall desired outcomes of the management agencies regarding the status and distribution of the population. These goals are difficult to quantify because monitoring methods may be extremely expensive or invasive.

- Maintain a minimum of 800 grizzly bears in the PCA and Zone 1 to achieve dispersal and connectivity goals[2].
- Maintain demographic linkage opportunities to the west and south toward the Cabinet/Yaak and Bitterroot ecosystems.
- Maintain genetic linkage opportunities between the NCDE south toward Yellowstone with consistent grizzly bear presence in these intervening areas.

Demographic Standards:

Standard 1: Maintain a well-distributed population.

Adherence to this standard is determined by the presence of reproductive females in at least 21 of 23 BMUs at least once every six years (see Figure 2). A reproductive female is a bear accompanied by young (cubs, yearlings, or 2-year-old offspring). If this distribution standard is not met, then a management review[3] will be completed.

Demographic Standards
These are objective and measureable criteria that will be monitored and reported annually. If any demographic standard is not met, it requires a management review as described in the Implementation Chapter.

Standard 2: Manage for survival of independent females generally > 0.90 in the PCA and Zone 1.
Generally, independent females will be managed so that each of the consecutive 6-year estimates of their survival is ≥ 0.90. Survival of independent females will be calculated and reported annually using the most recent 6 years of survival data from known-fate monitoring (Appendix 1). If independent female survival estimates remain ≥ 0.90, no management review is warranted. If annual independent female survival estimates are between 0.89 and 0.90 for the 12 most recent annual (using the most recent 6 years of survival data from known-fate monitoring) estimates, then all discretionary mortality will be curtailed until a management review is completed. If independent female survival estimates are between 0.88 and 0.89 for the 10 most recent annual estimates (using the most recent 6 years of survival data from known-fate monitoring data), then all discretionary mortality will be curtailed until a management review is completed. If independent female survival estimates are between 0.87 and 0.88 for the eight most recent annual (using the most recent 6 years of survival data from known-fate monitoring data), then all discretionary mortality will be curtailed until a management review is completed. If independent female survival estimates are <0.87 for the five most recent annual estimates (using the most recent 6 years of survival data from known-fate monitoring) then all discretionary mortality will be curtailed until a management review is completed. Examples of the effects of different survival rates on population growth and the application of this standard can be seen in Tables 2 and 3.

[2] On the northwest and southwest corners of Zone 1, there would be 2 Demographic Connectivity Areas (DCAs) with specific habitat protection measures to support dispersal to other ecosystems in the lower 48 States (i.e., the Cabinet-Yaak and Bitterroot ecosystems) (see Figure 1).

[3] If there are deviations from any of the population or habitat standards stipulated in this Conservation Strategy, a Management Review will be completed by an interagency team of scientists and outside experts as necessary, appointed by the members of the Coordinating Committee. See Chapter 5 for details about this process.

Table 2. Examples of the effects of different survival levels on the rate of population growth. Confidence intervals are not reflected in this table. For more information, see Harris in Appendix 2, Section C.

Survival rates from 6-years of data	Management review response	Mean Lambda from Harris Table 9 in Appendix 2
.89-.90	After the 12th most recent 6-yr block (12 years)	1.002-1.009
.88-.89	After the 10th most recent 6-yr block (10 years)	0.992-1.002
.87-.88	After the 8th most recent 6-yr block (8 years)	0.983-0.992
<.87	After the 6th most recent 6-yr block (6 years)	<0.983

Table 3. The 6-year survival estimates and how they have already started and will be available to apply the management review trigger criteria as per Table 2. For example, in 2014, 6-year survival interval 1 is available; in 2015 6-year interval 2 is available, etc. As an example of the application of the management review triggers, if independent female survival was between .89 and .90 for 12 consecutive 6-year intervals such as 2014-2025, a management review would be triggered. If, for another example, independent female survival was less than .87 for 6 consecutive 6-year intervals such as 2016-2021, then a management review would be triggered.

Intervals	**Years 2009-2026**																	
	09	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**
1	X	X	X	X	X	**1**												
2		X	X	X	X	X	**2**											
3			X	X	X	X	X	**3**										
4				X	X	X	X	X	**4**									
5					X	X	X	X	X	**5**								
6						X	X	X	X	X	**6**							
7							X	X	X	X	X	**7**						
8								X	X	X	X	X	**8**					
9									X	X	X	X	X	**9**				
10										X	X	X	X	X	**10**			
11											X	X	X	X	X	**11**		
12												X	X	X	X	X	**12**	
13													X	X	X	X	X	**13**

Standard 3: Independent female mortality will not exceed 10% of the estimated number of independent females in either of the following two areas, whichever is reached first: 1) all independent females inside the PCA or Zone 1; and 2) all independent females excluding those whose annual home range is entirely within Glacier National Park (See Appendix 2, Section F). The average number of independent female mortalities from all causes, in the areas described above including grizzly bears dying from known and probable human-caused, natural, calculated unknown and unreported, and undetermined causes, will not exceed 10% of the projected population size of independent females estimated in either of the two areas described above whichever is reached first, as averaged over the most recent 6-year period (e.g.,

2006-2011, 2007-2012, and so on). Annual mortality reports will be used by population managers to determine maximum annual discretionary mortality.

Standard 4: Independent male mortality will not exceed 20% of the estimated number of independent males outside of Glacier National Park but inside the PCA or Zone 1 (see Appendix 2, Section D, Table 13). The average number of independent male mortalities outside of GNP but inside the PCA and Zone 1 from all causes, including grizzly bears dying from known and probable human-caused, natural, calculated unknown and unreported, and undetermined causes, will not exceed 20% of the projected population size of independent males outside GNP as averaged over the most recent 6-year period (e.g., 2006-2011, 2007-2012, and so on). Annual mortality reports will be used by population managers to determine maximum annual discretionary mortality.

Departure from Demographic Standards

Departure from any of the demographic standards will trigger a management review by a review team appointed by the NCDE Coordinating Committee. Who completes a management review; the specifications of a management review; and what happens to the resulting report are stated in the implementation chapter. If a management review recommends changes in monitoring or management techniques these recommended changes would be based on the best available science and subject to public review before they were implemented.

Monitoring Protocol for the Demographic Standards

Standard 1: Maintain a population well distributed with adult female reproduction documented in at least 21 of 23 BMUs (Figure 2) - Monitoring for distribution of family groups of grizzly bears will be accomplished by compiling verified sightings based on marked bears (radio-collared bears), aerial sightings from telemetry flights by MFWP grizzly bear specialists, verified sightings in Glacier National Park by Park staff, verified sightings by Tribal bear biologists and managers on the Confederated Salish and Kootenai and Blackfeet Indian Reservations, and records of bear/human conflicts. Additional occurrence records will be compiled through follow-up and validation of sighting and occurrence information from other non-agency sources when these can be validated. These records will be compiled and validation of occurrence information will be completed by MFWP. Validation of sightings will be done by evaluation of the credibility of each record and the origin of the record.

Standard 2: Manage for survival of independent females generally > 0.90 in the PCA and Zone 1. Generally, maintain a point estimate of independent female survival ≥ .90 averaged over the most recent 6-year period in the PCA and Zone 1. Independent female survival and population trajectory calculations will be accomplished annually using accumulated known fate radio telemetry data and the staggered-entry Kaplan–Meier method (Mace et al. 2012) or other appropriate methods. Radio-collared independent females will be distributed throughout the PCA and Zone 1. Survival and trajectory will be calculated for the most recent 6-year period to ensure adequate sample sizes for these estimates. The calculation of independent female survival will be done annually by the NCDE Monitoring Team led by

MFWP. The known fate monitoring system is described in Appendix 1. Background information specific to Standard 2 is given in Appendix 2.

Standards 3 and 4: Mortalities of independent females will be tallied and reported for the PCA and Zone 1, including Glacier National Park each year. Independent female mortalities will be reported for: 1) all independent females inside the PCA or Zone 1; and 2) all independent females excluding those whose annual home range is entirely within Glacier National Park (See Appendix 2, Section F). Independent male mortalities will be reported for: 1) all independent males inside the PCA and Zone 1; and 2) that portion of independent males outside of Glacier National Park but inside the PCA or Zone 1 (see Appendix 2, Section D, Table 13). Annual mortality reports of all bears (males and females) will include all mortalities from all causes including grizzly bears dying from known and probable human-caused, natural, calculated unknown and unreported, and undetermined causes. Mortalities of independent males and females will be tallied and reported for the entire Zone 1, including Glacier National Park each year. Mortality records will be collected and maintained by the NCDE Monitoring Team led by MFWP.

To calculate allowable male and female mortality, managers will use estimates of the population as extrapolated from estimates of lambda (λ). Lambda will be calculated for the entire population inside the PCA and Zone 1 using the most recent 6 years of cumulative independent female survival and reproduction data as a 6-year running average. The values of lambda (λ) for each successive 6-year time period will be estimated using standard deterministic demographic analyses of survival and reproduction, including estimates of sampling uncertainty. To ensure mortality doesn't exceed the male and female survival and mortality standards described above, annual discretionary mortality limitations will be developed using independent male and female mortality limits based on projected population size each year. These limits will be used by State and Tribal population managers when determining allowable discretionary mortality that will ensure the standards for survival and mortality are met. Background information specific to Standards 3 and 4 is given in Appendix 2.

Grizzly bears killed by collisions with vehicles on a highway completely within the Park (e.g., Going to the Sun Road) will be counted against the mortality limits inside GNP. If a bear is killed by a collision with a vehicle on a highway that is the boundary of GNP or Management Zone 1, it will be counted against the mortality limits outside GNP.

Hunting

Regulated hunting that reflects the best available science, is adaptable to changing factors, is established in a public process, and is consistent with meeting the demographic standards in this Conservation Strategy may be one of the tools used to manage the recovered NCDE grizzly bear population.

Chapter 3 – Habitat Management and Monitoring

HABITAT MANAGEMENT IN THE NCDE – OVERVIEW

The Northern Continental Divide Ecosystem (NCDE) and surrounding lands to which this Conservation Strategy apply are divided into four management zones, each with varying importance to the grizzly bear population (Figure 1). Each management zone is a mosaic of land ownerships, with different types of habitat protections reflecting the mandates and interests of each agency or Tribal government. In general, the goal of habitat management in this Conservation Strategy is to provide reasonable assurance to the USFWS that habitat on public lands will continue to be managed at levels present when there was a stable to increasing grizzly bear population in the NCDE. Consistent with habitat management while listed as "threatened" under the ESA, this means that rigorous habitat protections will be institutionalized on most public lands inside the PCA while less stringent protections will be adequate in other management zones. Additionally, all projects on Forest Service, BLM, and DNRC managed lands that could affect the grizzly bear will continue to consider potential impacts to grizzlies through project and site-specific analysis as required under the National Environmental Policy Act (NEPA) and the Montana Environmental Policy Act (MEPA) through designation of the grizzly bear as a "sensitive species" upon delisting.

The Primary Conservation Area (PCA) will be managed as a source area where the goal is continual occupancy by grizzly bears. This is the area where the most rigorous habitat protections apply. Management Zone 1 is similar in concept to the 10-mile buffer around the Recovery Zone within which population data were recorded while listed under the ESA. Population and mortality data will be collected in all of the PCA and Zone 1. On the northwest and southwest corners of Zone 1, there will be two Demographic Connectivity Areas (DCAs) with specific habitat measures to support female occupancy and eventual dispersal to other ecosystems in the lower 48 States (i.e., the Cabinet-Yaak and Bitterroot ecosystems). In these DCAs, habitat protections will focus on limiting miles of open road and managing current roadless areas as stepping stones to other ecosystems. Management Zone 2 will be managed to provide the opportunity for grizzly bears, particularly males, to move between the NCDE and adjacent ecosystems (e.g., the GYA) via the multiple large blocks of habitat with motorized use restrictions that already exist as of 2011. Here, the management emphasis will be on conflict prevention and response. Management Zone 3 does not have enough suitable habitat to contribute meaningfully to the long-term survival of the NCDE population but grizzly bears are sometimes found here (see "GRIZZLY BEAR HABITAT MANAGEMENT" section in Chapter 1 for more details). In contrast to Zones 1 and 2, Zone 3 does not lead grizzly bears to other suitable habitat or recovery ecosystems. It was included as part of this Conservation Strategy because any grizzly bear found in Zone 3 to date has originated from the NCDE and this will likely remain the case for the vast majority of Zone 3.

ORGANIZATION OF THIS CHAPTER & LAND OWNERSHIP TABLES

This chapter is organized by Management Zone, with a side header on each page indicating what zone the protections described on that page apply to: the PCA, Zone 1, Zone 2, or Zone 3. Within each management zone section, habitat features important to grizzly bears are listed, with protections from each agency or Tribal government provided afterwards. For Management Zones 2 and 3, land ownership tables are provided but there are no habitat standards specifically related to grizzly bears described because the objectives in these zones do not require them (see section "DESCRIPTION OF THE MANAGEMENT ZONES" and "GRIZZLY BEAR HABITAT MANAGEMENT" sections in Chapter 1). Many standards and guidelines in the current GNP General Management Plan, Forest Plans, and BLM Resource Land Management Plans benefit grizzly bears (see Appendices 10, 11), even though they are related to other resource concerns (e.g., elk habitat security, riparian health, etc.). Food storage orders on most public lands in Zone 2 will be adequate to allow for low densities of male and female grizzly bears and that is sufficient to facilitate connectivity with other ecosystems in this management zone.

Each section begins with a land ownership table for that management zone. Each land ownership table also contains information about how many acres in each management zone are considered "protected lands" due to a management classification that restricts road construction, motorized use, livestock allotments, hardrock mine development, and timber harvest, or some combination thereof. Altogether, 5,251,918 acres (21,254 sq km) of lands within the PCA, Zone 1, Zone 2, and Zone 3 are considered "protected lands" in ways that benefit grizzly bears (i.e., some restrictions on motorized access and/or new road construction) (Figure 4). These "protected lands" are reported in the land ownership tables in three categories: Congressionally Designated Wilderness, Other wilderness, and Other non-motorized areas.

Congressionally designated Wilderness Areas are part of the National Wilderness Preservation System that was established by the Wilderness Act of 1964 (16 U.S.C. 1131–1136). The Wilderness Act provides protections from road construction, permanent human habitation, increases in developed sites, new livestock allotments, new mining claims, and new oil and gas leases. There is no motorized use allowed in Wilderness Areas and these areas will not experience decreases in habitat security. While the Wilderness Act allows livestock allotments existing before the passage of the Wilderness Act and mining claims established before January 1, 1984, to persist within wilderness areas, no new grazing permits or mining claims are allowed. If pre-existing mining or oil and gas claims are pursued, the plans of operation are subject to Wilderness Act restrictions on road construction, permanent human habitation, and developed sites.

Additionally, there are thousands of acres in the NCDE that are managed similarly to wilderness areas based on relevant forest and resource management plans but have not been designated as Wilderness Areas by an Act of Congress. These areas are reported as "Other wilderness" in the land ownership tables. Generally, these areas (e.g., Recommended Wilderness, Proposed Wilderness, Wilderness Study Areas, Research Natural Areas, etc.) possess wilderness characteristics and individual National Forests, BLM Field Offices, National Parks, or Tribal governments manage these areas to maintain these characteristics until Congress decides to make them Designated Wilderness Areas. These areas are protected from new road construction and thereby safeguarded from decreases in habitat security. Wheeled, motorized use is not allowed. Activities such as timber harvest, mining, and oil and gas development are much less likely to occur in these areas because the road networks required for these activities are unavailable.

Other areas with motorized use restrictions include Inventoried Roadless Areas, Tribal roadless areas, Tribal Primitive Areas, & some National Recreation Areas, depending on their specific management direction. All of these classifications contain restrictions on motorized use, new road construction, and timber harvest to varying degrees. The 2001 Roadless Areas Conservation Rule prohibits road construction, road re-construction, and timber harvest in Inventoried Roadless Areas on National Forest lands (66 FR 3244–3273, January 12, 2001). This restriction on road building makes mining activities and oil and gas production much less likely because access to these resources becomes cost-prohibitive or impossible without new roads. Potential changes in the management of these areas are not anticipated, but are a possibility due to ongoing litigation regarding the 2001 Roadless Rule. The Flathead Indian Reservation (FIR) Forest Management Plan, in effect until 2030, designated several roadless and primitive areas that are unavailable to forest management activities completely or only allow helicopter timber harvest. Finally, when Forest Plans contain restrictions on road construction and motorized use in their National Recreation Areas, these were considered "protected lands" in ownership tables.

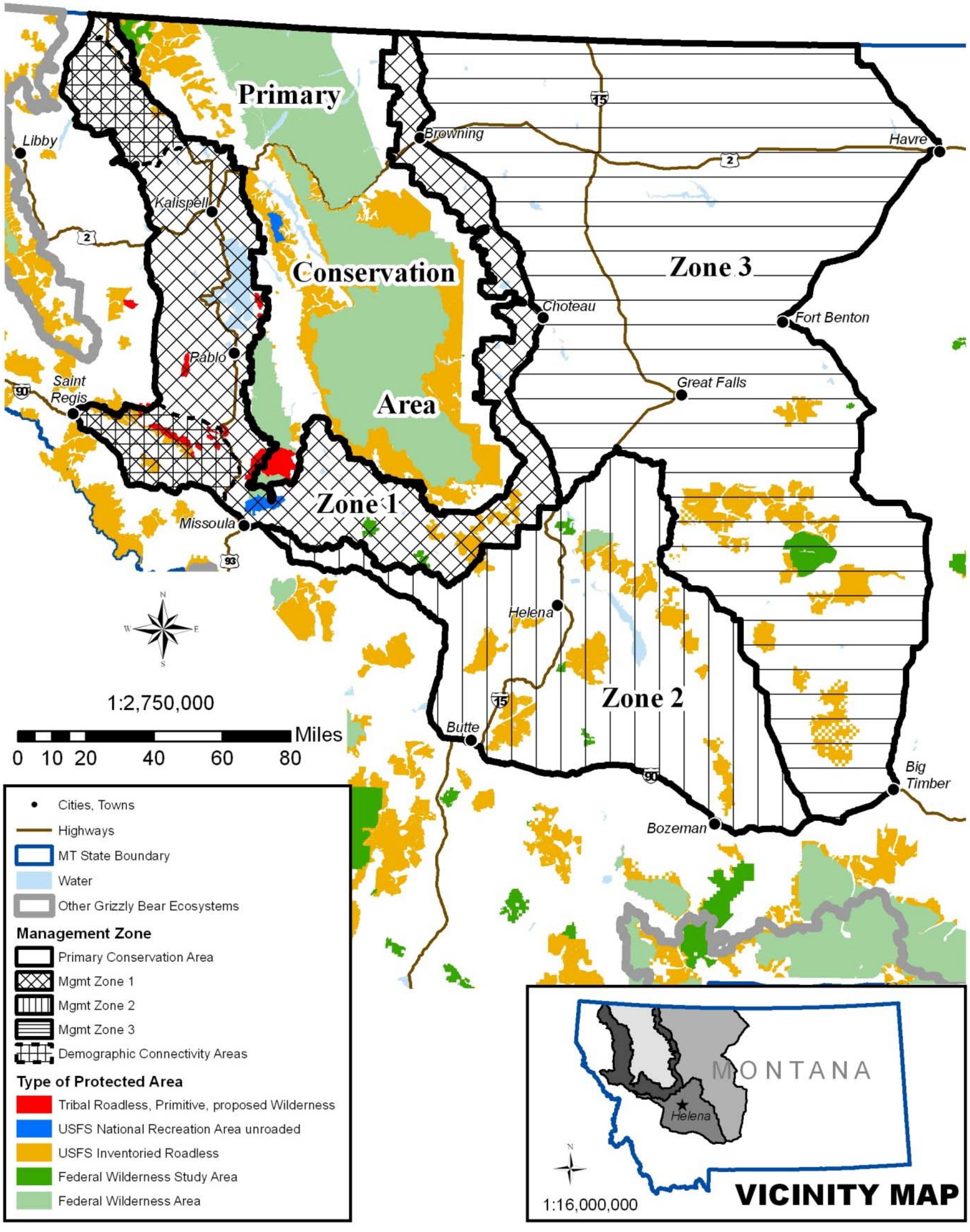


Figure 4. Map of "Protected areas" in the NCDE PCA and Management Zones

IMPLEMENTATION OF HABITAT STANDARDS

The intent is to have signatories of this Conservation Strategy representing the land management agencies incorporate the habitat standards and guidelines described in this chapter into their respective management plans. ***Standards*** refer to mandatory constraints on project and activity decision making whereas ***guidelines*** are constraints that allow for departure from their terms, so long as the purpose of the guideline is met. Guidelines in this Conservation Strategy serve to mitigate and minimize undesirable effects to grizzly bears or their habitat. The National Forest and BLM Resource Management Plans, the Glacier National Park Superintendent's Compendium, the Montana Department of Natural Resources (DNRC) Habitat Conservation Plan, and the Tribal Forest Management Plans largely dictate how grizzly bear habitat management will occur, and, in doing so, they serve to ensure against excessive grizzly bear mortality by minimizing human-caused mortality risk. Because amending or revising management plans will require an analysis under NEPA for some agencies, the USFWS will not sign the Conservation Strategy until this NEPA process is complete and satisfactory to ensure grizzly bear conservation in the foreseeable future. Implementation of this Conservation Strategy and any associated Amendments to land management plans would not occur until the USFWS signed the Conservation Strategy's MOU and determined the grizzly bear in the NCDE either (a) no longer meets the definition of threatened or endangered under the Endangered Species Act or (b) if the USFWS amended the Grizzly Bear Recovery Plan (USFWS 1993) with the management direction described in this Strategy for the NCDE.

While National Forest and BLM Resource Management Plans and National Park Superintendent Compendiums direct management on these Federal lands, habitat management on the FIR, Blackfeet Indian Reservation (BIR), and State lands is guided by other, legally enforceable management plans already in place. On the FIR, habitat management is directed by the Tribes' Forest Management Plan, as authorized by the Tribal Council and the Bureau of Indian Affairs. Of the 1,373,451 acres (5,558 sq km) of lands within the FIR, 459,408 acres (1,859 sq km) are forested with management directed by the Forest Management Plan. This Plan is in effect until 2030 and, in unison with this Conservation Strategy, establishes habitat management direction relevant to grizzly bears on the FIR. Management of forested grizzly bear habitat on Blackfeet Tribal lands is implemented through the Blackfeet Nation's Forest Management Plan, as authorized by the Tribal Business Council and the Bureau of Indian Affairs. Of the 1,525,691 acres (6,174 sq km) of lands within the BIR, there are 174,963 forested acres (708 sq km) whose management is directed by the Blackfeet Nation Forest Management Plan, nearly all of which occur within the PCA or Management Zone 1. This Plan is in effect until 2023 and establishes habitat management direction relevant to grizzly bears on the BIR.

On DNRC lands, management direction and policies are largely driven by a legal requirement to generate revenue to support state schools and educational institutions. In 1889, the United States Congress approved the Enabling Act, which granted lands to the State of Montana for support of common schools. Initially, sections 16 and 36 in every township within the state were set aside. Some parcels were consolidated by the State to address lands previously homesteaded, or situated within Indian reservations. DNRC lands can occur in large blocks or small, isolated parcels, surrounded by private or public lands. The acreage of State trust lands in Montana totals about 5.1 million acres.

Management actions on State Trust lands are carried out under the direction of the State Board of Land Commissioners, which consists of Montana's top elected officials. In cooperation with the State Board of Land Commissioners, DNRC's obligation for management of trust lands is to obtain the greatest monetary returns for beneficiaries. In 2011, DNRC entered into a habitat conservation plan (HCP) with the USFWS to clarify obligations under the Endangered Species Act, and to provide long-term certainty for their timber management program. Conservation measures contained in the HCP were designed to avoid, minimize, and/or mitigate the impacts of incidental take as a result of timber harvest and related activities to the maximum extent practicable. Measures contained in the HCP that pertain to conservation of grizzly bears address vegetation management, unnatural foods, information education, habitat displacement, habitat security, access management, habitat connectivity, den sites, foraging areas and monitoring. The DNRC HCP is in effect until 2061 and will guide management of grizzly bear habitat across forested State trust lands in western Montana during that time (DNRC 2010; USFWS 2011) (http://dnrc.mt.gov/HCP/Documents.asp).

Ultimately, the effectiveness of the commitments in this Conservation Strategy, including the habitat protections, will be demonstrated by the response of the grizzly bear population relative to predicted responses. Habitat protections in this Conservation Strategy may be subject to revision in the future, if appropriate, based on the best available science. Changes to the Strategy could be recommended to the agencies by the NCDE Coordinating Committee (see Chapter 5 – Implementation). Any such changes to habitat management on Federal lands would be evaluated through the NEPA process.

PRIMARY CONSERVATION AREA (PCA)

The primary land management entities responsible for habitat management in the PCA are the USFS, GNP, the Montana DNRC, the Blackfeet Nation on the BIR, and the Confederated Salish and Kootenai Tribes (CS&KT) on the FIR. Collectively, these entities manage 86% of lands within the PCA. Other resource management agencies in the PCA include the MFWP, the BLM, and the USFWS. By signing this Conservation Strategy, these entities have agreed to continue collectively managing grizzly bear habitat through ongoing actions and undertake the necessary processes to incorporate the habitat standards and monitoring items described herein into their respective management plans.

The most important issues in grizzly bear habitat management across a landscape are related to managing the types and levels of human activities. Human activities resulting in mortality were the main reasons the grizzly bear was listed as threatened in 1975. Since then, management of human activities has allowed the NCDE grizzly bear population to thrive. The key habitat features in the NCDE that are managed on the landscape to mitigate the impacts of human activities on grizzly bears are: (1) the amount and distribution of secure habitat, (2) motorized access route densities, (3) developed sites, (4) livestock allotments, (5) vegetation management practices, and (6) oil and gas and/or hardrock mining development. These are important features to consider because these activities can result in grizzly bear mortality and/or underuse of key habitat. For example, between 1998 and 2011, nearly 74% (157/213) of all known grizzly bear mortalities in the NCDE Recovery Zone occurred within 500m of a developed site or motorized route.

Of the more than 5.7 million acres (5,712,862 acres; 23,119 sq km) within the PCA, 61% is managed by the USFS across five different National Forests (the Flathead, Kootenai, Lewis and Clark, Helena, and Lolo National Forests); 17% is managed by Glacier National Park (GNP); 9% is privately owned or managed, and the remaining lands are managed by a variety of other agencies (Table 4). Nearly 68% of all lands inside the NCDE PCA are considered "Protected lands" in this Conservation Strategy because of their status as Congressionally designated Wilderness Areas (30%) or other non-motorized areas (38%) (Table 4, Figure 4).

Since 1986, the Interagency Grizzly Bear Guidelines (Guidelines) have shaped habitat management for grizzly bears on Federal lands in the PCA. These Guidelines (USFS 1986) focused on improving habitat quality and limiting human-caused mortality resulting from grizzly bear/human conflicts. The Guidelines used motorized access management as the primary habitat management tool and these restrictions were instrumental in recovery of the grizzly bear in the NCDE. To implement these Guidelines, Bear Management Units (BMUs) and subunits were identified to provide a basis for ensuring that adequate habitat for grizzly bears was well-distributed across the recovery zone (now known as the PCA). The recovery zone was divided into 23 BMUs and 126 BMU subunits (Figure 2). Because subunits are approximately the size of a female grizzly bear's home range, they provide a suitable scale at which to analyze and regulate impacts of human activities within grizzly bear habitat.

Table 4. Land ownership and management within the NCDE Primary Conservation Area (PCA)[1].

Ownership	Sub-category Acres	Acres	Sq Km	Percent of PCA
US Forest Service		3,480,415	14,085	60.9%
Flathead National Forest	2,133,638			
Helena National Forest	183,626			
Kootenai National Forest	118,538			
Lewis and Clark National Forest	776,096			
Lolo National Forest	268,516			
Glacier National Park		987,755	3,997	17.3%
Other federal [2]		22,973	93	0.4%
Blackfeet Indian Reservation		254,731	1,031	4.5%
Tribally managed lands [3]	111,094			
Individual allotments [4]	142,730			
Other government	907			
Flathead Indian Reservation, CS&KT		144,897	586	2.5%
Tribally managed lands [3]	143,750			
Individual allotments [4]	1,146			
DNRC		204,413	827	3.6%
MFWP		36,506	148	0.6%
Total Private lands		525,860	2,128	9.2%
Private land on the BIR	82,036			
Private land on the FIR	4,219			
All other Private lands	439,605			
Water		55,311	224	1.0%
	TOTALS	**5,712,862**	**23,119**	
PROTECTED AREAS WITHIN THE PCA				
Congressionally Designated Wilderness		*1,728,184*	6,994	*30.3%*
Other wilderness [5]		*1,014,408*	4,105	*17.8%*
Restricted motorized-use areas [6]		*1,125,291*	4,554	*19.7%*

[1] Acres are based on GIS layers from several Federal and State sources, dated 1 July 2012, at the 1:100,000 scale. When these layers were not in agreement, efforts were made to identify the correct owner but there may still be some discrepancies.
[2] Includes BLM (20,691 acres), Bureau of Reclamation (85 acres), and the USFWS (2,197 acres)
[3] Tribal lands managed by the respective Tribes through coordination with the BIA and Council approved management plans
[4] Allotted lands managed by individual Tribal members through coordination with the BIA
[5] Other Wilderness includes areas managed to maintain their wilderness traits such as Wilderness Study Areas, Proposed Wilderness (GNP), and CS&KT Wilderness outside the Mission Mountains Tribal Wilderness
[6] Restricted motorized-use areas include Inventoried Roadless Areas, Tribal roadless areas, Tribal Primitive Areas (limited to Tribal member use only), & the Jewel Basin and Rattlesnake National Recreation Areas; all of which contain restrictions on new motorized use, new road construction, and timber harvest.

SUMMARY OF HABITAT PROTECTIONS INSIDE THE PCA

Within the PCA, the overall goal for habitat management on public Federal lands is to maintain or improve habitat conditions that existed as of 2011, while maintaining options for resource management activities at approximately the same levels that existed in 2011. We propose using 2011 as the baseline year because the habitat conditions that existed on Federal lands in 2011 accommodated a grizzly bear population (approximately 942 animals) that was increasing at a rate of about 3% annually (Kendall et al. 2009; Mace et al. 2012; Mace 2012, personal communication). The habitat standards to maintain 2011 baseline values apply only to those lands under USFS, NPS, or BLM jurisdiction. Our intent would be to incorporate the following standards into GNP's Superintendent's Compendium, and National Forest and BLM Land and Resource Management Plans. If adopted, these standards would replace existing regulatory standards included in those land management plans.

<u>Habitat ***Standards*** on Public Federal lands in the PCA (78.6% of lands inside the PCA):</u>

- no net decrease in 2011 levels of Secure Core (Appendix 3)
- no net increase in 2011 levels of open motorized route densities (Appendix 3)
- no net increase in 2011 levels of total motorized route densities (Appendix 3)
- limit the number of developed sites in each BMU to 2011 levels or less (Appendix 4)
- limit the capacity of overnight developed sites in each BMU to 2011 levels or less (Appendix 4)
- no net increase in the number of livestock allotments from 2011 levels
- no net increases in the capacity of sheep allotments from 2011 levels

On other public lands within the PCA, the goal is to institutionalize habitat protections that benefit grizzly bears while maintaining opportunities for resource use and development. The long-term nature of the plans guiding grizzly bear habitat management on DNRC, Blackfeet Nation, and CS&KT lands increases our certainty about how these State and Tribal lands will be managed in the foreseeable future.

Habitat ***Standards*** on DNRC, Blackfeet Nation, and CS&KT lands in the PCA [4]:

- limits on net increases in open roads and/or road densities
- limits on net increases in total roads and/or road densities
- limits on the types and numbers of livestock allotments on DNRC & CS&KT lands

In addition to these habitat standards, there would be ***guidelines*** to minimize impacts to grizzly bears from vegetation management, grazing, and energy or mineral development on Federal and most State and Tribal lands. Trends in private land development and conservation easements would also be monitored. To assess the adequacy of food production and the types of foods grizzlies use across the landscape each year, we would monitor grizzly bear body condition and food habits using the most appropriate and available technology.

[4] Specific habitat protections on these different land ownerships vary but generally fall into the categories listed. Please see details in the Motorized Access Management, Livestock, and Vegetation Management sections below.

MOTORIZED ACCESS MANAGEMENT ON FEDERAL LANDS[5]

In 1994 and again in 1998, the Interagency Grizzly Bear Committee chartered a task force to evaluate State and Federal procedures for analyzing the effects of motorized access management on grizzly bears. The task force recommended that each recovery zone develop their own specific levels of acceptable (1) open motorized route densities (OMRD); (2) total motorized route densities (TMRD); and (3) core areas. These levels were based on female grizzly bears monitored in that recovery zone, other research results, and social or other management considerations. **OMRD** includes roads and trails that are open to wheeled motorized use without restriction. **TMRD** includes roads and trails open to motorized wheeled access and those with temporary restrictions, such as gates. OMRD is reported as the percentage of each BMU subunit that has more than 1 mi/sq mi of open routes and TMRD is reported as the percentage of each BMU subunit that has more than 2 mi/sq mi of total routes (e.g., 12% of the Bunker Creek subunit has OMRD values greater than 1 mi/sq mi and 4% of this subunit has TMRD values greater than 2 mi/sq mi). This Conservation Strategy defines **Secure Core** habitat as those areas more than 500 m (0.3 miles) from a motorized access route during the non-denning period and at least 2,500 acres in size. Secure Core is expressed as a percentage of the BMU subunit that meets this definition (e.g., 86% of the Bunker Creek subunit is Secure Core habitat). The habitat standards below address these three parameters. Following the description of each habitat standard for Federal lands, **Application Rules** specify how they will be implemented within the PCA.

Federal Motorized Access Habitat Standard 1. On National Park, National Forest, and BLM lands in the PCA, there will be no net decrease in the amount of Secure Core within each BMU subunit from levels that existed in 2011 (Appendix 3), unless temporarily decreased to allow projects according to the Application Rules.

Federal Motorized Access Habitat Standard 2. On National Park, National Forest, and BLM lands in the PCA, there will be no net increase in levels of open motorized route densities (OMRD) or total motorized route densities (TMRD) within each BMU subunit above 2011 baseline values (Appendix 3), unless increased temporarily to allow projects according to the Application Rules.

Appendix 3 documents the 2011 baseline values for the percent of Secure Core habitat, OMRD greater than one mi/sq mi, and TMRD greater than two mi/sq mi in each BMU subunit. Any changes since 2011 to on-the-ground conditions have been evaluated through the USFWS consultation process and were shown to be acceptable while grizzly bears were considered threatened under the ESA.

[5] The Federal lands these standards apply to comprise 78.6% (4,488,861 / 5,712,862 acres) of the PCA. These motorized access management standards would not apply to the subunits within the Swan Valley that are included in the Swan Valley Grizzly Bear Conservation Agreement or those involved in TNC fiber agreements. If the Swan Valley Grizzly Bear Conservation Agreement is dissolved at some point in the future, the USFS would continue to manage these affected subunits in accordance with Appendix 11.

Application Rules for Temporary Changes in Motorized Access on Federal Lands

While the grizzly bear was listed as threatened under the ESA, projects and activities on Federal lands occurred through compliance with standards and guidelines in land management plans. When projects could not meet existing standards and guidelines, site-specific amendments and mitigation measures to projects occurred through consultation with the USFWS. Consultation allowed for temporary modifications to existing standards and guidelines. To allow for activities and projects to continue at levels similar to those that occurred while the grizzly population was listed under the ESA, the following Application Rules were developed for temporary changes to motorized access management.

Table 6 provides a summary of the Application Rules for motorized access management in the PCA. The rule set in Table 6 will be used by the agencies in management and evaluation of projects and habitat management actions as appropriate under this Conservation Strategy. Appendix 5 provides additional information on definitions and Application Rules for implementation of standards.

These Application Rules are based on an analysis of six Federal land projects that were conducted while grizzly bears were listed as a threatened species under the ESA. This includes five projects that occurred on the Flathead NF and one on the Lolo NF, affecting 18 subunits. The projects were reviewed and allowed through consultation with the USFWS. They occurred between 2003 and 2010, a period during which the NCDE grizzly bear population is known to have been increasing (Kendall et al. 2009; Mace et al. 2012). Therefore, the duration of these projects and the associated increases in OMRD and TMRD are known to be compatible with an increasing grizzly bear population in the NCDE. Types of projects included salvage work, timber harvest, and road management. During the life of these six Federal projects, the OMRD temporarily increased an average of 5.4%, TMRD temporarily increased an average of 2.9%, and Secure Core fluctuated by 2%.

For the Application Rules, a **project** refers to any temporary activity requiring construction of new roads, reconstruction or opening of a restricted road, use of a restricted road above administrative levels allowed, or **recurring** helicopter flights at low elevations (< 500m above ground level). For helicopter use, we define "**recurring**" as multiple trips per day for more than two consecutive days (see Montana/Northern Idaho Biologists Team 2009). Approximately 79% of lands managed by the USFS and 99% of lands managed by GNP inside the PCA are protected areas (i.e., Wilderness Areas, Proposed Wilderness, Wilderness Study Areas, or Inventoried Roadless Areas) that preclude most projects requiring motorized access (Figure 4). Any proposed projects would require analyses of OMRD, TMRD, and Secure Core to ensure compliance with the habitat standards and with the following Application Rules. To provide evaluation of projects requiring temporary changes to the 2011 motorized access baseline, automated GIS programs and spreadsheets are available for use by affected agencies in each grizzly bear subunit (Appendix 5).

Temporary Changes in Motorized Access Route Density and Secure Core for Projects.

Temporary changes to 2011 baseline values for OMRD, TMRD, and Secure Core will be allowed for projects if the 10-year running averages for these parameters in each subunit do not exceed the following limits (see Table 5 below for an example of how these would be implemented):

- 5% temporary increase in OPEN Route Density (i.e., OMRD baseline plus 5%)
- 3% temporary increase in TOTAL Route Density (i.e., TMRD baseline plus 3%)
- 2% temporary decrease for Secure Core (i.e., Secure Core baseline minus 2%)

Additionally, the following conditions must be met for any temporary projects:

1) Secure Core and road density values must be restored within one year after completion of the project (i.e., when the road is no longer being used for project implementation beyond administrative levels).
2) Projects will be planned so that they do not exceed five years (with the exception of gravel pits). If extensions are necessary beyond five years, the reasons must be documented in writing and reviewed by the NCDE Coordinating Committee to recommend appropriate additional mitigation, if needed.
3) If a project cannot occur within administrative use levels (6 trips/week OR a 30-day window) on restricted routes, the temporary limits on increases for OMRD, TMRD, and Secure Core apply. If the project can occur completely within administrative use levels, the project will not count toward temporary allowable increases because it does not meet the definition of a "project" as defined in this Conservation Strategy (Table 6).

Motorized Access Management – PCA

Table 5. Hypothetical example of how temporary changes in OMRD, TMRD, and Secure Core would be implemented for a project. Part (A) shows the baseline values in a BMU subunit for OMRD, TMRD, and Secure Core from previous years and anticipated increases during the project (i.e., years 11 – 14). Part (B) uses the data from Part (A) to show the 10 year running averages for OMRD, TMRD, and Secure Core before, during, and after project completion, demonstrating that these 10-year running averages do not violate the Application Rules for Temporary Changes in Motorized Access. It should be noted that in this hypothetical example, another project in this subunit would not be possible until yr 24, unless that project did not require any changes in values for OMRD, TMRD, or Secure Core.

(A)

	BASELINE Value	Allowed Value for Project	yr 1	yr 2	yr 3	yr 4	yr 5	yr 6	yr 7	yr 8	yr 9	yr 10	project yr 11	project yr 12	project yr 13	project yr 14	yr 15	yr 16	yr 17
OMRD	19	24	19	19	19	19	19	19	19	19	19	19	31	31	31	31	19	19	19
TMRD	19	22	19	19	19	19	19	19	19	19	19	19	22	22	22	22	19	19	19
Secure Core	69	67	69	69	69	69	69	69	69	69	69	69	63	63	63	63	69	69	69

(B)

	BEFORE	DURING				AFTER		
	yr 1-10	yr 2-11	yr 3-12	yr 4-13	yr 5-14	yr 6-15	yr 7-16	yr 8-17
OMRD	19	20	21	23	24	24	24	24
TMRD	19	19	20	20	20	20	20	20
Secure Core	69	69	68	67	67	67	67	67

Changes in Secure Core	A project may mitigate its impact on Secure Core by providing replacement Secure Core habitat of equal size and similar quality (if possible) and function in the same grizzly subunit. The replacement habitat must either be in place before project initiation or be provided concurrently with project development as an integral part of the project plan. Alternatively, a project may also mitigate its impacts by adhering to the allowed levels of temporary changes summarized above and detailed in this Table.
Secure Core Habitat	More than 500 meters from an open motorized route (road or motorized trail), or helicopter flight line meeting the definition of "recurring." Must be greater than or equal to 2,500 acres in size. "Recurring" is defined as multiple trips per day for more than two consecutive days.
Open Motorized Route Density (OMRD)	Open motorized route density includes: all Federal, State, and Tribal roads and motorized trails that are open to public use for any part of the year and motorized routes closed by sign only. All roads are included in the database. However non-motorized trails, highway, county, private, decommissioned, or revegetated roads are not included in the calculations.
Total Motorized Route Density (TMRD)	Total motorized route density includes: all Federal, State, and Tribal roads and motorized trails, whether they are open or closed. All roads are included in the database. However, non-motorized trails, highway, county, private, decommissioned, or revegetated roads are not included in the calculations.
Motorized Access Routes in Database	All routes, regardless of ownership or jurisdiction, having motorized use or the potential for motorized use to exceed administrative use levels (restricted roads) including: motorized trails; highways; county/city, Federal, State, Tribal, corporate and private roads.
Lands in Database	All lands are included in database. However, large lakes (≥ 320 acres) and private lands are not included in calculations of Secure Core, OMRD, or TMRD.
Season Definitions	Denning season on the west side of the continental divide is from 1 December through 31 March. Denning season on the east side of the continental divide is from 1 December through 15 April. Wheeled motorized access standards do not apply during the denning season.
Project	A temporary activity requiring construction of new roads, reconstructing or opening a restricted road or recurring helicopter flights at low elevations (< 500m).
Activities Allowed in Secure Core	Activities that do not require road construction, reconstruction, opening a restricted road, or recurring, low-elevation helicopter flights. Aircraft used in emergency firefighting are allowed. Non-wheeled, over the snow use (i.e., snowmachines) allowed until research identifies a concern. Projects that remain within the limits established by the Application Rules for Temporary Changes in Motorized Access Management on Federal Lands.
Inclusions in Secure Core	Roads restricted with permanent physical barriers (not gates), decommissioned or obliterated roads, and/or non-motorized trails are allowed in Secure Core.
Administrative Use Levels	Motorized administrative use is permitted as either 6 trips (3 round trips) per week OR one 30-day unlimited use period during the non-denning season (Apr. 1 – Nov. 30).

ederal

Temporary Changes in Motorized Access Management	Temporary changes to baseline values for OMRD, TMRD, and Secure Core will be allowed for projects if the 10-year running averages for these parameters in each subunit do not exceed a 5% increase in OMRD, a 3% increase in TMRD, or a 2% decrease in Secure Core. During these projects, changes in OMRD, TMRD, and Secure Core may exceed these limits in individual years but the 10-year running average will not exceed these limits. Secure Core and road density values must be restored within one year after completion of the project (i.e., when the road is no longer being used for project implementation beyond administrative levels). On occasion, unforeseen events affecting thousands of acres (e.g., fires, long-term mine clean-up, insect or disease-killed trees, flooding, avalanches, mudslides, etc.) may require a response action that would not stay within these Application Rules for Temporary Changes in Motorized Access Management. In such cases, site-specific NEPA analysis would be completed and effects considered. Due to the nature of these events and the need to quickly and efficiently resolve the impacts of these disturbances to maintain project, recreational, and administrative opportunities, such circumstances would not be considered a violation of this Conservation Strategy's habitat standards. Any responses to these unforeseen events would, however, be considered when proposing other projects in affected subunits.
Gravel Pits	The Forest Service and National Park Service will use all available resources at existing gravel pits before constructing new pits.
Permanent Changes to OMRD, TMRD, and Secure Core Values	Permanent changes in OMRD, TMRD, or Secure Core may occur due to unforeseen circumstances, natural events, or other reasonable considerations. Such changes will change the baseline values but will not be considered a violation of the motorized access management habitat standards and will not require mitigation responses. Acceptable changes that may permanently change baseline values include the following: - the agency acquired better information or updated/improved the road information in their respective database(s) resulting in changed calculations without actual change on the ground; - technology or projections changed, resulting in changed calculations without actual change on the ground (e.g., a switch from NAD27 to NAD83); - the agency moved a road closure location a short distance (often <0.25 miles) to a better location for turn-arounds, less vandalism, or to improve enforcement of the road closure; - the agency acquired or sold land; - the agency built/opened a road for either handicapped access in a campground, or administrative site road; - the agency moved a road to increase human safety or to decrease resource damage - an adjacent, non-federal landowner made changes to their motorized access management which decreased Secure Core or increased motorized route densities on Federal lands.

Legacy Lands and Cooperative Habitat Management in the Swan Valley

The Montana Legacy Project was a cooperative effort with the Nature Conservancy, The Trust for Public Land, Plum Creek Timber, and multiple State and Federal partners throughout western Montana. The Legacy Project facilitated the purchase and transfer of over 310,000 acres (1,257 sq km; 485 sq mi) of private Plum Creek Timber Company lands into mostly public ownership. Although the Legacy Project was not specifically designed to conserve grizzly bear habitat, it benefits grizzly bears by consolidating land ownership patterns and management so that sustainable timber harvest, public access to these lands for recreation, and important wildlife habitat are maintained in public ownership while the possibility of private land development on these lands was largely eliminated.

The Nature Conservancy and The Trust for Public Land agreed to purchase the land from Plum Creek Timber Company initially, and then sell or donate these lands to Federal, State, and private owners. The vast majority of these lands have become Federal (USFS) or State (DNRC) owned and any lands that were sold to private owners have safeguards attached to them so that the integrity of wildlife habitat is maintained. There are still some lands owned and managed by the Nature Conservancy. Until transfer to other owners is completed, the actual number of acres continues to shift regularly as land is sold and traded to the described agencies.

As of May 2012, of the 310,585 acres of lands purchased from Plum Creek Timber Company, 203,994 acres are inside the NCDE Conservation Strategy Area while the remaining 106,591 acres are outside of the NCDE south of I-90. Of the 203,994 acres, 75,530 acres are inside the PCA; 101,097 acres are in Management Zone 1 of which 37,216 are within the Ninemile DCA; and 27,366 acres are within Management Zone 2. In the Swan Valley, the Flathead National Forest acquired 44,816 acres (181 sq km; 70 sq mi), the DNRC added 1,918 acres (8 sq km; 3 sq mi), and MFWP added 454 acres (1.8 sq km; 0.7 sq mi) to their land base. There are 18,160 acres yet to be transferred to federal or state land management agencies. There are also 63,721 acres that remain in private or transitory ownership but with conservation easements in place to maintain the integrity of wildlife habitat.

In the Swan Valley, the subunits affected by the Legacy Project are: the South Fork Lost Soup, Goat Creek, Lion Creek, Meadow Smith, Buck Holland, Porcupine Woodward, Piper Creek, Cold Jim, Hemlock Elk, Glacier Loon, and Beaver Creek subunits. Lands acquired by the National Forest system or MFWP require a 10-year fiber supply agreement in which timber will be sustainably harvested and sold to Plum Creek Timber Company. This fiber agreement requires the use of the road system as it currently exists and does not allow changes (reductions) until the terms of the fiber agreement have been satisfied. To fulfill the terms of the fiber agreement, management of these lands will continue to follow the terms of the Swan Valley Grizzly Bear Conservation Agreement (Appendix 7). The Swan Valley Conservation Agreement has coordinated timber harvest activities and associated road management across the multiple land ownerships in the Swan since 1997 and in doing so, contributed to the recovery of the grizzly bear. Once the 10-year term of fiber agreements end, DNRC may shift to management according to their HCP. If this occurs, the USFS would continue to manage its lands by the terms described in the Swan Valley Conservation Agreement.

MOTORIZED ACCESS MANAGEMENT ON TRIBAL LANDS IN THE PCA

Blackfeet Indian Reservation

On the 174,963 forested acres (708 sq km) of lands within the Blackfeet Indian Reservation managed under the Blackfeet Nation Forest Management Plan, no net increase in overall road density levels are allowed. If approved by the Tribal Business Council, the Blackfeet Nation would sign this Conservation Strategy, committing to monitor and maintain records of motorized routes on all of their lands and coordinate with other agencies to report and update these data annually.

Flathead Indian Reservation

Within the PCA, 91% of FIR lands are within the Mission Mountains Tribal Wilderness Area (91,368 acres) or the South Fork Jocko Primitive Area (44,684 acres), both of which are unavailable to commercial forest activities. In the Mission Mountains Tribal Wilderness, there will be no permanent increases in open or total road densities and there will be no permanent decreases in Secure Core. In the South Fork Jocko Primitive Area, there will be no net increase in open roads.

On the remaining 7,698 acres managed by the CS&KT in the PCA, habitat management is directed by their Forest Management Plan, as authorized by the Tribal Council and the BIA. On these lands, the following motorized access management direction applies:

- Open road densities shall not exceed 4 mi/sq mi.
- Total road miles shall remain at or below what existed in 1999.
- Total road densities will be reduced by removing 15% of road spurs in currently roaded areas over the life of the Plan (2000-2030).
- Roads in timber sale areas will be closed after the harvest is complete.

If approved by the Tribal Council, the CS&KT would sign this Conservation Strategy, committing to monitor and maintain records of motorized routes on all of their lands and coordinate with other agencies to report and update these data annually.

MOTORIZED ACCESS MANAGEMENT ON DNRC LANDS IN THE PCA

The DNRC will manage motorized access on the 145,589 acres of their forested lands within the PCA by their final Habitat Conservation Plan (HCP). DNRC lands within the PCA occur in either large blocks of State Forest or small, isolated parcels surrounded by other land ownerships. On all lands within the PCA, DNRC will:

- Minimize construction of new open roads, particularly in riparian areas, wetlands, and avalanche chutes.
- Inspect and repair all primary road closure devices annually.
- Suspend motorized activities within 1 km (0.6 mi) of a known, occupied den site.
- During the Spring Period, prohibit commercial activities and minimize motorized activities on restricted roads associated with low-intensity forest management activities.

On isolated parcels of DNRC lands inside the PCA, DNRC will not exceed baseline values for linear miles of open road at the administrative unit level.

On large blocks of DNRC land within the PCA on the Stillwater, Coal Creek, and Swan River State Forests (131,007 acres combined), DNRC will manage motorized access according to their HCP and approved transportation plans which remain in effect until 2061. These transportation plans cap the total miles of open and restricted road that can be constructed or re-opened for forest management activities over this time period. On the Swan River State Forest, there could be 70 miles of permanent new roads constructed, none of which would be open to the public for motorized use. There would be minimal net increase in linear open road miles in the Swan River State Forest. An additional 41.4 miles of road would become seasonally restricted to commercial forest management activities during the spring season (Apr. 1 – June 15) to provide grizzly bear security during this season. On the Stillwater and Coal Creek State Forests, 19.3 more miles of permanent road could be constructed and there will be a 15% reduction in the miles of roads that are open year-round (reduced from 125.3 miles to 107 miles). The HCP also identifies “subzones” on 59,100 acres of these State Forests where 4-year limits on commercial forest management activities followed by required 8-year rest periods apply (DNRC 2010). On the 19,400 acres of “subzones” identified on the Stillwater and Coal Creek State Forests, no new permanent roads will be constructed.

By signing on to this Conservation Strategy, the DNRC has committed to monitoring and maintaining records of motorized routes on all of their lands and coordinating with other agencies to report and update these data annually.

Monitoring Protocol in the PCA

Secure Core habitat, OMRD greater than 1 mi/sq mi, and TMRD greater than 2 mi/sq mi will be monitored using each individual land management agency’s Geographic Information System (GIS) database of motorized access routes, and reported biennially within each subunit in the NCDE Monitoring Team’s Annual Report. While an annual report would be prepared each year, motorized access will not be reported every year. Instead, it will be reported on a biennial basis. The reporting for OMRD, TMRD, and Secure Core will occur for odd-numbered years, beginning in 2011. The respective land management agencies would be responsible for maintaining their open motorized routes in a GIS database so that this information is available to run OMRD, TMRD, and Secure Core analyses, as needed.

DEVELOPED SITE MANAGEMENT ON FEDERAL LANDS

Developed sites refer to sites or facilities on public Federal lands with features that are intended to accommodate public use and recreation. Examples include, but are not limited to: campgrounds, trailheads, lodges, rental cabins, summer homes, restaurants, visitor centers, boat launches, and ski areas. Developed sites are generally associated with frequent and/or prolonged human use that may result in increased bear attractants and grizzly bear mortality risk. Improvements typical of developed sites include, but are not limited to: restrooms, fire rings, fresh water availability, picnic tables, horse loading areas, horse feed storage buildings, garbage storage, camp host presence, and/or a pavilion. There is general agreement that developed sites that support overnight use may pose higher risks to bears than day use sites since people spend more time at these areas, usually cook or eat meals, and produce garbage. In contrast to developed sites, **dispersed sites** have no permanent constructed features, are temporary in nature, have minimal to no site modifications, and have informal spacing, primitive roads, and/or informal interpretive services. These include many car camping sites along public roads, user-established camping areas accessible only by non-motorized means, and/or outfitter camps. Because dispersed sites do not contain permanently constructed features, they will not be subject to this developed site standard or count against the baseline for developed sites.
Administrative sites are sites or facilities constructed for use primarily by government employees to facilitate the administration and management of public lands. Examples include headquarters, ranger stations, dwellings, warehouses, guard stations, and Park entrances. For this Conservation Strategy, Federal, State, County, and municipal administrative sites are not subject to the developed site standards because agencies have direct control over the employees using these areas and can therefore minimize the presence of attractants and grizzly bear mortality risk. Nevertheless, increases in the number of administrative sites on Federal lands will be minimized and any proposed increases will be evaluated on a site-specific or individual basis. For this Conservation Strategy, we evaluate and report 2011 levels and types of developed sites on public Federal lands (Appendix 4) because we know these levels were compatible with an increasing grizzly bear population (Mace et al. 2012). This baseline does not include oil and gas wells, production wells, or large-scale hardrock mining operations because these types of permitted resource development do not involve public use or recreation and these activities will be regulated at the project level through separate requirements identified in this Conservation Strategy. Any changes in developed sites since 2011 have been determined acceptable through consultation with the USFWS while grizzly bears in the NCDE were listed under the ESA. While these changes in developed sites are minor, they allowed managers to actively respond to resource damage, safety, and attractant concerns, and modify problematic dispersed sites. Because the USFWS considered these changes in developed sites to be reasonable when grizzly bears were listed under the ESA, we modeled our Application Rules after them.

Developed Site Standards

The intent of the developed site standard is to not increase the number of developed sites or capacity at most overnight developed sites on public Federal lands within each BMU above levels known to have occurred at a time when there was a stable to increasing grizzly bear population. On USFS, GNP, and BLM lands inside the PCA:

- Within each BMU, the number of developed sites on USFS, GNP, and BLM lands will be maintained at or below levels known to have occurred at a time when there was a stable to increasing population.
- Within each BMU, the capacity at developed sites with overnight use campgrounds, guest lodges, cabin rentals, and hotels on USFS, GNP, and BLM lands will be maintained at or below levels known to have existed when the population was stable or increasing.
- While the NCDE grizzly bear population was listed as threatened under the ESA, there were occasional increases in developed sites that would not have met the Application Rules below but were approved through consultation with the USFWS. To allow a similar level of increase in developed site numbers or capacity that occurred under listed status, one increase in the capacity or number of developed sites would be allowed per BMU per 10 years, even if it did not meet the Application Rules below. Any such changes proposed to developed sites that did not meet the Application Rules below would be reviewed by the Coordinating Committee and a position statement issued (see chapter 5 – Implementation).

Application Rules

- If changes are proposed that increase, expand, or change use of developed sites beyond the baseline year in the PCA (Appendix 4), they will be analyzed by the agency proposing the change, and the potential detrimental and positive impacts documented through project evaluation or assessment. Such changes would be allowed if there is a corresponding reduction in the number and capacity at developed sites in that BMU through any of the following means: (1) equal reduction in capacity at another site; (2) closure of a developed site(s) within that BMU; or (3) consolidation and/or elimination of dispersed camping, when and where it can be enforced effectively and it is reasonably assured that new dispersed sites will not develop nearby
- When the elimination of other developed sites or reductions in their capacity is not feasible, other mitigation measures may be adequate to offset proposed increases in *capacity* at existing developed sites. Appropriate mitigation tools to offset increases in *capacity* at existing developed sites may include, but are not limited to:
    - increased information and education;
    - increased conflict prevention resources (e.g., improved sanitation, backcountry food-hanging poles, etc.); or
    - increased law enforcement and patrols.
- If mitigation is achieved through measures other than direct reduction in the capacity or number of existing developed sites, a member of the NCDE Coordinating Committee may request that the Coordinating Committee review the proposed mitigation measures and release a position statement about whether they are adequate.
- Mitigation measures allowing for changes in developed sites must be implemented within the same BMU as the changes are proposed.
- Mitigation measures will be in place before the initiation of the project or included as an integral component of the project, including required funding.

- If land managers reduce the number or capacity of developed sites below 2011 baseline levels, these reductions may be used at a future date to mitigate equivalent impacts of an increase, expansion, or change of use in developed sites within that BMU.
- Capacity at campgrounds will be measured as the number of sites available for public use.
- Capacity at overnight sites will be measured as the number of beds, rooms, cabins, or bunkhouses, depending on the type of overnight site.
- Increases in capacity at trailheads will be minimized.
- Maintenance to existing developed sites is allowed.
- Changes to the baseline values for the number and capacity of developed sites may occur due to a variety of reasonable circumstances listed below. Such changes could permanently increase the number or capacity of developed sites but would not require mitigation. Examples of allowed changes that may affect the developed site baseline include, but are not limited to, the following:
    1) the agency acquired better information or updated/improved information in its database(s);
    2) the agency acquired or sold land which contained developed sites;
    3) the agency complied with Federal laws (e.g., Americans With Disabilities Act);
    4) the agency modified an existing developed site or dispersed campsite to reduce resource damage, environmental impacts, or the potential for grizzly bear conflicts (e.g., installing a pit toilet at a heavily used dispersed site to avoid damage to water resources or installing a bear-resistant food storage structure to reduce conflicts);
    5) the agency modified an existing human use area to enhance human safety.
- Increases in the number and capacity of developed sites during the **denning season** are not counted against this standard.
- While increases in the number of administrative sites on Federal lands will be allowed, they will be minimized. Any proposed increases will be specifically evaluated for impacts and appropriate mitigation measures for grizzly bears will be implemented as necessary.
- Temporary work camps for major projects or wildland firefighting are exempt from human capacity mitigation if other viable alternatives are not available. Food storage facilities or attractant management plans must be in place to ensure food storage compliance (i.e., regulations established and enforced, camp monitors, hosts, permit administrators, etc.). All other factors resulting in potential detrimental impacts to grizzly bears will be mitigated as identified for other developed sites.
- Public community infrastructure sites, such as electronic sites, radio towers, gravel pits, utility corridors, and treatment plants are exempt from the developed site standard because these are not commonly associated with public use or grizzly bear attractants. The Forest Service and its Permittees will place additional towers, buildings, etc. at existing electronic sites before constructing new electronic sites
- Increases in the number or capacity of developed sites on private, State, or Tribal lands are not counted against this standard because Federal land management agencies have no authority over such developments.

Monitoring Protocol

The number and capacity of developed sites on Federal public lands in the PCA will be reported every two years and compared to the baseline in the Monitoring Team's annual report, which is publicly available. Developed sites will be reported for even-numbered years, starting in 2014. Developed sites are inventoried in existing GIS databases and placed into seven broad categories: (1) residences; (2) sites with overnight use; (3) campgrounds; (4) trailheads; (5) day-use only; and (6) administrative sites. While administrative sites are exempt from the developed site standard, increases are to be minimized so they will be tracked and reported with other developed sites. Appendix 4 displays the number of developed sites in the PCA in these six categories and will serve as the baseline. Changes in developed sites and subsequent mitigation measures on public Federal lands will be tracked and maintained in a database to facilitate coordination and compliance with this standard across the multiple Federal jurisdictions in the PCA (5 National Forests, GNP, and BLM).

LIVESTOCK ALLOTMENTS IN THE PCA

Levels of grazing on public lands inside the PCA in 2011 were compatible with an increasing grizzly bear population. The number and type of livestock allotments present in 2011 are reported in Table 7. These values will serve as the baseline values on Federal lands listed. Because there is no evidence of conflicts between grizzly bears and horse/mule allotments due to attractants, depredation, or forage competition, these types of allotments are not considered in this Strategy.

Table 7. Active cattle and/or sheep grazing allotments in the NCDE PCA, December 2011.

Land Manager	No. of Allotments	Type	AUMs*	Additional Info.
Flathead NF	3	Cattle	320	
Lewis and Clark NF	21	Cattle	9241	2 additional allotments are currently inactive – AUMs not included
Helena NF	3	Cattle	616	
	1	Sheep	133	
Lolo NF	1	Cattle	30	
Kootenai NF	1	Cattle	373	2 additional allotments are currently inactive – AUMs not included
Glacier NP	0	n/a	n/a	GNP does not permit commercial livestock grazing allotments within Park boundaries
BLM	23	Cattle	1942	
DNRC	128	Predominantly cattle	17,147	62,335 acres in grazing leases/licenses
MFWP	5	Cattle	2884	22,353 acres in grazing leases
FIR				no grazing in the PCA
BIR				BIR is fully allotted; numbers of allotments and AUMs not available

* AUM's (Animal Unit Months) are calculated by multiplying the permitted number of sheep or cow/calf pairs times the months of permitted use. Actual use by sheep or other livestock in many cases may have been less than the permitted numbers identified for 2011.

Livestock Allotment Standards in the PCA

On USFS, BLM, GNP, and FIR lands (81.1% of PCA):

- There will be no increases in the number of cattle allotments.

On USFS, BLM, GNP, DNRC, MFWP, and FIR lands (85.3% of PCA):

- There will be no increases in the number of sheep allotments or in permitted sheep AUM's, from the identified baseline (Table 7).
- Existing sheep allotments will be monitored, evaluated, and phased out as the opportunity arises with willing permittees.

- Apiaries permitted on State, Federal, or FIR lands must be enclosed within an approved and operating electric fence as defined in the National Forest Food Storage Order in the NCDE.
- New permits for use of small livestock (smaller than a cow, such as sheep, goats and llamas) for the purposes of weed control may occur but will follow existing Federal, State, or Tribal permitting processes. Such permits will stipulate that if the small livestock are subject to depredation by grizzly bears, consideration will be given to removing the small livestock from the area. Permits for the use of small livestock to control weeds will also stipulate that any grizzly bear(s) depredating on these small livestock will not necessarily be removed unless additional circumstances indicate removal is warranted (as described in the nuisance bear management chapter).
- Permits for existing livestock allotments will include requirements to store bear attractants in a bear-resistant manner, report livestock carcasses within 24 hours of discovery and work with the appropriate agencies to remove them, and establish bone yards in areas that will minimize the risk of habituating grizzly bears to human presence.
- Grazing permits will include clauses allowing for cancellation, suspension, or temporary cessation of activities if needed to resolve a grizzly conflict situation.

Application Rules

Allotments include both vacant and active commercial grazing allotments.

- Reissuance of permits for vacant cattle allotments may increase the number of permitted cattle, but the total number of allotments would remain the same as the indicated baseline.
- Combining or dividing existing allotments would be allowed as long as it does not result in grazing allotments in currently unallotted lands.
- Inactive allotments would not be increased from the allowable AUM included in the existing permit.
- Any use of vacant cattle allotments resulting in an increase in permitted cattle numbers will be allowed only after an analysis by the action agency to evaluate impacts on grizzly bears.
- Where chronic conflicts occur on cattle allotments inside the PCA, and an opportunity exists with a willing permittee, the permitting agency may consider phasing out cattle grazing or moving the cattle to a vacant allotment where there is less likelihood of conflict.
- Increases in allotment numbers on State or Federal lands in the PCA that result from land acquisitions or exchanges will be added into the baseline rather than being counted as deviations from the baseline.
- If depredations by grizzly bears occur to sheep during sheep trailing operations across public lands within the PCA, the grizzly bear(s) causing the depredation will not necessarily be removed unless additional circumstances indicate removal is warranted (as described in the nuisance bear management chapter).

<u>On BIR lands (4.4% of PCA):</u>

- All lands inside the PCA on the BIR are currently allotted for livestock grazing. Therefore there will be no increase in the number of permitted grazing allotments within the PCA on the BIR.

- One or more Bear Management Specialists on the BIR will continue to work with livestock producers to minimize and manage bear-livestock conflicts.
- Existing sheep allotments will be monitored, evaluated, and phased out if the opportunity arises with willing permittees.
- All provisions in the Blackfeet attractant storage order, (Blackfeet Fish and Wildlife Code Chapter 3, Section 17) including management of livestock carcasses, will be adhered to by grazing permittees, apiary permit holders, and their agents.

Monitoring Protocol

To ensure no increase from the 2011 baseline, numbers of commercial livestock grazing allotments and numbers of sheep AUM's within the PCA will be monitored and reported every two years by the permitting agencies on the same schedule as developed sites (i.e., reports for even-number years, starting in 2014).

VEGETATION MANAGEMENT ON NATIONAL FOREST LANDS INSIDE THE PCA

Although there are known impacts to individual bears from timber management activities, these impacts have been managed acceptably using the IGBC guidelines in place since 1986. These guidelines result in vegetation management projects that are compatible with the needs of grizzly bears. The two guiding principles are to (1) maintain and improve habitat and (2) minimize the potential for grizzly bear/human conflict.

Under this Conservation Strategy, vegetation management projects will be directed by the following guidelines, similar to those followed under listed status.

- All proposed vegetation management activities will be evaluated for their effects upon grizzlies and/or their habitat.
- Vegetation management prescriptions and contracts will include specific measures to protect, maintain and/or improve grizzly habitat and meet grizzly management goals and objectives. Timber sale contracts will include a clause providing for cancellation or temporary cessation of activities if needed to resolve a grizzly-human conflict situation. Contractors' full cooperation in meeting grizzly management goals and objectives will be a condition to their receiving and holding contracts.
- Vegetation and/or fire management activities that will have detrimental impacts on the grizzly bear population or their habitat, as determined in a project-specific environmental analysis, will not be permitted. Detrimental population effects are population reductions (as specified in the demographics section of this document) and/or grizzly bear food-conditioning.
- Grizzly habitat may be improved through vegetation manipulation. Silvicultural treatments such as tree harvest or thinning, sale area improvement and restoration, and prescribed burning are some of the methods by which grizzly bear habitat improvement can be accomplished. Detrimental habitat effects are permanent reductions in habitat quantity and/or quality and will not be permitted.
- Vegetation and fuels management activities should occur at a time or season when the area is of least biological importance to grizzlies, as determined by a biological evaluation or other environmental analysis. Winter logging is preferred, but it it is not feasible to complete activities during this time period, logging operations will be restricted in time and space to reduce significant disruptions of normal or expected grizzly activities. Logging is often restricted during the spring time period, to favor the needs of grizzly bears. Other forest management activities such as pre-commercial thinning, burning, weed spraying, and road best management practices may need to be completed during the spring time period in order to meet objectives (especially if needed to prevent resource damage), but may also be restricted in time or space, as determined by a biological evaluation.
- Silvicultural treatments in forested cover should provide a mosaic of all successional stages over the long term. Group selection cuts and irregularly shaped regeneration harvests, in which prescribed fire slash removal is used to mimic wildfire, are desirable for creating high grizzly food producing openings in some stand types and habitat types. Yarding methods should be designed to minimize soil disturbance, minimize weed invasion, and promote bear foods, where appropriate. Desirable regeneration harvest and slash disposal includes options such as: (1) methods to minimize the

distance to cover such as oblong or irregularly shaped harvest units or retention of one or more leave patches in units larger than 10 acres that won't be broadcast burned; (2) minimum soil scarification in habitat types where soil disturbance impedes the reestablishment of grizzly foods (consistent with Management Plans); (3) slash disposal by broadcast burning or whole-tree yarding to maintain or improve grizzly foods in suitable habitat types and terrain; and (4) protection of hydric stream bottoms, wet meadows, marshes, and bogs from soil disturbance and excessive cover removal (as specified in Design Criteria for Riparian Habitat Conservation Areas and Stream-side Management Zones).

- Sale Area Improvement Timber sale receipts, collected for post-sale area improvement (Knudsen-Vandenberg Act and other funds collected under Stewardship Contract projects) should be used, when practical, to enhance or restore the grizzly habitat quality of a logged area. Pre-commercial thinning can help maintain light to the forest floor and lengthen the time that bushes produce berries. Grizzly habitat enhancement through vegetation management is not recommended in or next to campgrounds and other developed sites frequented by people.
- All roads newly constructed for timber sales will be single purpose roads and will be closed to public motorized access not associated with timber sale operation and administration. Exceptions to this could include seasonal openings for other important resource uses or for short periods of time such as firewood gathering.
- Roads used for project implementation must comply with the Motorized Access Standards described elsewhere in this Conservation Strategy.
- Prior to beginning work, all contractors, operators and their employees will be informed of safe procedures for working and recreating in grizzly country.
- If contractors elect to camp on public Federal lands other than public campgrounds, written permission shall be obtained. Camp locations may be determined by appropriate site evaluation or other analysis. Contractors, operators and employees of contractors associated with fire camps must follow appropriate food storage orders.
- Cover will be maintained along meadows and other open feeding sites, riparian areas, past harvest units that do not yet provide hiding cover, and known travel corridors; as specified in a biological evaluation or other environmental document. Un-thinned strips or patches will be retained within harvest units and pre-commercial thinning units if needed for cover adjacent to open roads, as determined by a biological evaluation.

VEGETATION MANAGEMENT ON FORESTED TRIBAL LANDS

Blackfeet Indian Reservation

Of the 1,525,712 acres (6,174 sq km) of lands within the Blackfeet Indian Reservation, there are 174,963 forested acres (708 sq km) whose management is directed by the Blackfeet Nation Forest Management Plan. This Plan is in effect until 2023 and establishes the following habitat management direction for timber harvest relevant to grizzly bears:

- Timber harvesting activities will be limited to single drainages when possible
- Timber harvesting will be concentrated in one or two forest management units per year instead of being spread across the landscape

- No timber harvest or road construction will occur between April 1 and June 15 annually, allowing grizzlies secure access to spring foraging habitat
- Dense cover will be maintained adjacent to main roads
- All streams will be protected with Streamside Management Zones 100 feet in width on both sides of the stream with restrictions on how much vegetative cover and timber may be removed
- All workers on timber projects are prohibited from carrying firearms on or near the sale area
- All workers on timber projects are required to follow the attractant storage regulations described below (Blackfeet Fish and Wildlife Code Chapter 3, Section 17)

Flathead Indian Reservation

On the Flathead Indian Reservation, management of their 459,408 acres (1,859 sq km) of forested lands is directed by the Forest Management Plan, as authorized by the Tribal Council and the BIA. This Plan establishes the following habitat management direction relevant to grizzly bears:

- 36% (166,383 acres; 673 sq km) of these forested lands are unavailable to timber harvest
- 12% (57,011 acres; 231 sq km) contain restrictions on the locations and methods of harvest that may occur
- Hiding cover along major highways near identified crossing areas (e.g., Evaro, Hog Heaven, Ferry Basin, and the Ravalli Corridor) will be retained and managed to provide movement opportunities and promote population expansion along the western edges of the NCDE
- Adjacent drainages must remain undisturbed during the duration of a timber sale and for two years afterwards
- Roads in timber sale areas will be closed after the harvest is complete

VEGETATION MANAGEMENT ON DNRC LANDS

The DNRC will manage grizzly bear habitat within and outside the PCA according to their final HCP. For non-HCP lands, current administrative rules for forest management activities would apply, which would offer similar protections for grizzly bears. The DNRC HCP specifically establishes the following habitat management direction for timber harvest relevant to grizzly bears:

- DNRC shall consider grizzly bears during planning and environmental review on all forest management-related projects occurring on covered lands, and shall incorporate mitigation measures to minimize impacts to grizzly bears or their habitat to the extent possible;
- Development of site-specific mitigation measures to minimize the impacts to important grizzly bear habitat elements (berry fields, avalanche chutes, riparian areas, wetlands, WBP stands, and feeding/congregation areas);
- Retention of visual cover for grizzly bears in riparian and wetland areas by maintaining a 50 foot no-harvest buffer, and through additional measures restricting removal of trees within defined Riparian Management Zones;
- Retention of up to 100 feet of vegetation between open roads and clearcut or seed tree harvest units to provide **visual screening**;

- Must design regeneration harvest units to have no points in them that are >600 feet to visual screening cover;
- Restriction of commercial forest management activities during the spring period (Apr. 1-June 15) in spring habitat (lands < 5,200 feet in the Swan State Forest; < 4,900 feet on scattered parcels; areas associated with roads possessing restricted status during the spring period on the Stillwater State Forest);
- Prohibition of pre-commercial thinning and heavy equipment slash treatments during the spring period in spring habitat.

HARDROCK MINING & MINERAL DEVELOPMENT

Forty-seven percent (2,707,793 of 5,712,862 acres) of PCA lands are unavailable to new mining claims due to their status as Federally designated Wilderness, National Parks (i.e., Glacier National Park), or other special designations (see Figures 3 and 4). Mortality risk to grizzly bears from mineral development on Federal and DNRC lands outside of these protected areas will be largely mitigated through the motorized access standards described earlier in this chapter and food storage requirements, but additional mitigation measures that are project specific will also be implemented. The purpose of the guidelines described in this section is to avoid, minimize and mitigate environmental impacts to grizzly bears and their habitat from mining activities occurring on Federal (as authorized under the Mining Law of 1872) and State lands. The guidelines would be applied during review and approval of a site-specific *plan of operations* under 36 CFR 228A for locatable mineral activities on National Forest Lands, and under 43 CFR 3809 for locatable mineral activities on BLM-managed lands. Operating procedures, reclamation plans, or other mitigating measures necessary to meet the guidelines would be incorporated into the Operating Plan, or could become agency-imposed operating conditions, provided such measures were consistent with the rights provided for under applicable mining laws. All exploration, development production, mitigation measures, reclamation, and closure activities for locatable minerals on Federal, State and private lands are also under the regulatory permitting authority of the Montana Department of Environmental Quality (DEQ). The term “agencies” in this section refers to BLM/DEQ for BLM administered lands, FS/DEQ for National Forest lands and DNRC/DEQ for state lands. The agencies work cooperatively in the administration and management of mining operations. Mitigation measures may not conflict with the regulatory permitting authority of the DEQ. The following measures would apply to all new mining Plans of Operation on lands managed by the USFS, BLM, or DNRC in both the PCA and Zone 1.

Project Evaluation

The potential effects to grizzly bears and bear habitat, and the necessary mitigation measures will be determined at the project level by the authorizing or permitting agency through project review, an Environmental Assessment or Environmental Impact Statement. For projects with the potential to significantly, negatively affect grizzly bears or their habitat, operating plans, notices and permits will include a mitigation plan with measures to protect grizzly bears and minimize detrimental impacts to them during and after operations. Operators are required to comply with the mitigation plan through the agencies’ approval of the Operating Plan.

Mitigation plans will include specific measures to reasonably mitigate potential impacts to grizzly bears or their habitat from the following activities:

- Land surface and vegetation disturbance,
- Water table alterations,
- Construction, operation, and reclamation of mine-related facilities such as impoundments, rights of way, roads, pipelines, canals, transmission lines or other structures,
- Food storage and sanitation.

Performance of operating and reclamation measures, and site-specific mitigation measures used to protect grizzly bears or bear habitat will be enforced through the respective DEQ and Federal surface management regulations. Operators who fail to comply with mitigation measures for grizzly bear protection in the DEQ approved operating plan will be subject to a noncompliance order or notice issued by the DEQ, Forest Service, or BLM. Noncompliance orders specify the noncompliance and what is needed for the operator to come into compliance. Ultimately, the Forest Service or BLM may seek civil and/or criminal enforcement through the Federal Court system. The financial assurance (bond) for reclamation performance will be calculated and managed by the agencies. Bonding may include the cost of implementing the reclamation measures required to mitigate impacts to grizzly bears and bear habitat. The financial assurance instrument for reclamation performance will be held by the Montana DEQ for mining operations on private lands. For mining operations on mixed private/Federal lands or entirely on Federal lands, the agencies will develop joint financial assurance instruments that are frequently held by the Montana DEQ.

For operations where it is determined there is potential for significant impacts ("significance" as determined through environmental review and permitting) to the grizzly bear population or its habitat, a monitoring plan will be developed by the operator with approval by the DEQ or Federal regulatory permitting agency, and in close coordination with MFWP for the life of the project. The monitoring plan will outline how changes in habitat and disturbance to bears will be measured and include monitoring of reclamation measures. The plan will identify trigger levels or criteria to determine if direct research of local grizzly bears (i.e., capturing and radio-collaring bears) is warranted and to what extent the monitoring should be conducted.

Food and Attractants

For projects with the potential to significantly affect grizzly bears or their habitat, mitigation plans will include food storage/handling and garbage disposal measures and will incorporate any existing food storage measures for human occupancy. Mitigation plans for grizzly bears will include the following measures regarding food and attractants:

- Bear resistant food storage and garbage containers will be used at mine sites and at any campgrounds or dispersed sites where mining-related human occupancy is anticipated.
- Garbage will be removed in a timely manner.
- Road kills will be removed daily to a designated location determined in close coordination with and permitted by MFWP.
- The use of clover will be discouraged as part of any reclamation seed mixes used during mine construction, operation, or when reclamation activities are concurrent with operations. Native seed mixes will be promoted and used whenever practicable.
- No feeding of any wildlife will be allowed.

Implementation of the Food and Attractants measures is the sole responsibility of the operator. Compliance with these requirements will be evaluated during site inspections conducted by the authorizing agencies. The number and type of inspections as well as the mechanism for inspections will be identified through the planning process (MEPA or NEPA). Failure to comply with the measures will subject the operator to a noncompliance process as noted above.

Motorized Access

For projects with the potential to significantly affect grizzly bears or their habitat, mitigation plans will include the following measures regarding motorized access:

- New roads constructed for mineral exploration and/or development will be single-purpose roads only and will be closed to public use not associated with mineral activities.
- On USFS, NPS, and BLM managed lands inside the PCA, new roads or closed roads that are re-opened for mineral exploration will be consistent with this Conservation Strategy's motorized access standards
- A traffic management plan will be developed as part of any proposed activity to identify when and how mine roads will be used, maintained, and monitored, if required, and how roads will be closed after mineral activities have ended. The management agencies retain the right to impose speed limits on these roads if needed to prevent or reduce collisions with bears.
- On State lands only, roads constructed for mineral operations may be retained by the land management agency for use associated with other concurrent or future activities (such as timber sales or rights-of-ways). However, impacts associated with all uses of the road(s) must be analyzed in a MEPA environmental review, and impacts to grizzly bears minimized to the extent practicable.

Habitat

For projects with the potential to significantly affect grizzly bears or their habitat, Operating Plans will include the following mitigation measures regarding habitat:

- Mineral exploration and/or development activities will occur at a time or season when the area is of least biological importance to grizzlies. If timing restrictions are not practicable, reasonable and appropriate measures will be taken to mitigate negative impacts of mineral activity to grizzly bears.
- Reasonable and appropriate measures regarding the maintenance, rehabilitation, restoration or mitigation of functioning aquatic systems and riparian zones will be implemented. State and Federal regulatory permits may include reasonable and appropriate measures as part of a riparian reclamation plan identifying how reclamation will occur, vegetation species used in reclamation, a timeframe of when reclamation will be completed, and monitoring criteria.
- Reclamation and revegetation of roads, drilling pads, and other areas disturbed from mineral exploration and development activities will be completed as soon as practicable by the operator.

For projects with the potential to significantly affect grizzly bears or their habitat, the following tiered measures will be considered to mitigate impacts to grizzly bear habitat. Beginning at Step 1, any subsequent steps would be implemented only if the prior steps are not possible or achievable.

- Step 1: The operator should reclaim the affected area back to suitable bear habitat that has similar or improved characteristics and qualities as the original suitable habitat (such as the same native vegetation).
- Step 2: If Step 1 is not attainable, operators should either acquire a perpetual conservation easement (or easements) or purchase comparable or better replacement grizzly bear habitat in the PCA. Acquisition of habitat within connectivity corridors could also be considered for mitigation, when appropriate. Habitat acquired for mitigation may require a purchase rate of >1:1 on an acreage basis, depending on the quality of habitat degraded and habitat available for acquisition. The State or Federal land management agency and MFWP may provide input on the location of these habitats. Location of these habitats will be approved by the land management agency in close coordination with MFWP, and the easement/deeds will be transferred to the appropriate Federal or State agency or private conservation organization.
- Step 3: If Steps 1 or 2 are not achievable, the next option is to consider offsetting negative effects to bears and grizzly bear habitat with other appropriate types of actions. This could involve radio telemetry monitoring of grizzly bear movements in the affected area (in coordination with MFWP), other grizzly bear research (with MFWP involvement), funding a bear management specialist or enforcement officer or other appropriate actions as needed to develop site-specific mitigation.

Human Conflict

For projects with the potential to significantly affect grizzly bears or their habitat, the mitigation plan will include the following measures regarding human conflict:

- Firearms will be prohibited on site during operations except for security personnel and other designated persons. Carrying of bear spray will be recommended to the operator.
- The operator should require employees to attend training related to living near and working in grizzly bear habitat prior to starting work and on an annual basis thereafter.

OIL & GAS DEVELOPMENT

Forty-seven percent (2,707,793 of 5,712,862 acres) of PCA lands are unavailable to oil and gas leasing due to their status as Federally designated Wilderness, National Park, (i.e., Glacier National Park), or other special designations (see Figures 3 and 4). The only place where oil and gas development is currently being actively pursued in the PCA or Zone 1 is along the Rocky Mountain Front on the eastern side of the ecosystem on lands managed privately or by the Lewis and Clark NF, Helena NF, BLM, DNRC, or BIR (see "Mineral and Energy Development" section in Chapter 1; Portner 2003). For operations where it is determined there is potential for significant impacts ("significance" as determined through environmental review and regulatory permitting) to the grizzly bear population or its habitat, the following standards and guidelines apply to any future permits to drill issued on the Lolo, Flathead, Lewis and Clark, Kootenai and Helena National Forests in the PCA, and on BLM and DNRC managed lands in the PCA and Zone 1. The Blackfeet Nation is working directly with the Bureau of Indian Affairs, and the USFWS to create a management plan and mitigation package for oil and gas development on BIR lands. We have no authority over private lands.

DNRC

On all trust lands managed by the DNRC in the PCA, Montana Oil and Gas Stipulations will apply and measures related to grizzly bears and their habitat described in the "Interagency Rocky Mountain Front, Wildlife Monitoring/Evaluation Program, Management Guidelines for Selected Species" (Appendix 8) would be incorporated into mitigation plans.

BLM

On lands or oil and gas mineral estate managed by the BLM in the PCA, no new leases will be permitted in the Rocky Mountain Front Mineral Withdrawal Area (Public Law 109-432) (Figure 3). For new leases outside of this Mineral Withdrawal Area, no surface occupancy would be allowed in the PCA or Zone 1. Motorized access standards described previously in this Chapter would apply for the PCA. Exceptions could be granted if no detrimental impacts to grizzlies are determined through an environmental analysis. Additionally, the stipulation for no surface occupancy could be modified if the authorized officer, in consultation with MFWP determines the area is no longer important to grizzly bears.

USFS

Stipulations already included in existing leases on National Forest lands in the PCA would not be changed, nor would additional stipulations be added to existing leases, without the lease holder's agreement. The majority of existing leases already contain stipulations that address maintaining grizzly bear security through such things as limits on timing or location of specific activities. When or if APDs are submitted on existing leases, the motorized access standards and the following mitigation measures would be included in the permit and Surface Use Plan of Operations, unless specific language in a lease superseded that requirement.

The following standards would be incorporated as stipulations in new leases, and when possible as surface use criteria in any Surface Use Plans for proposed wells or operations, or as conditions in any permits for seismic activity.

USFS – Project Evaluation

The potential effects to grizzly bears and bear habitat, and the necessary mitigation measures will be determined at the project level by the authorizing or permitting agency through project review, an Environmental Assessment or Environmental Impact Statement. For projects with the potential to significantly, negatively affect grizzly bears or their habitat, permits will include a mitigation plan with measures to protect grizzly bears and minimize detrimental impacts to them during and after operations. Operators are required to comply with the mitigation plan through the agency's approval of the application for permit to drill.

In addition to a mitigation plan for operations where it is determined there is potential for significant impacts ("significance" as determined through environmental review and permitting) to the grizzly bear population or its habitat, a monitoring plan will also be developed in close coordination with MFWP for the life of the project. The monitoring plan will outline how changes in habitat and disturbance to bears will be measured (and include monitoring of reclamation measures). The plan will identify trigger levels or criteria for habitat parameters to determine if direct research of local grizzly bears (i.e., capturing and radio-collaring bears) is warranted and to what extent monitoring should be conducted.

USFS – Food and Attractants

For projects with the potential to significantly affect grizzly bears or their habitat, permits will include stipulations for food storage and garbage disposal measures and will incorporate existing food requirements for human occupancy. Mitigation plans for grizzly bears will include the following measures regarding food and attractants:

- Bear resistant food storage and garbage containers will be used at development sites and at any campgrounds or dispersed sites where exploration or production-related human occupancy is anticipated;
- Garbage will be removed in a timely manner;
- Road kills will be removed daily to a designated location determined in close coordination with MFWP;
- The use of clover will be discouraged as part of any reclamation seed mixes used during operations (i.e., construction, operation). Native seed mixes will be promoted and used whenever practicable;
- No feeding of any wildlife will be allowed;
- Any permits for seismic activity or drilling will include a clause providing for cancellation or temporary cessation of activities if such are needed to resolve a grizzly-human conflict situation;

- Analysis of potential impacts of work camps would be included in the site-specific Biological Evaluation, and locations of any work camps would be approved in advance of operations. Food storage requirements will be strictly adhered to in any work camps.

Implementation of the Food and Attractants measures is the sole responsibility of the operator. Compliance with these requirements will be evaluated during site inspections conducted by the authorizing agencies. The number and type of inspections as well as the mechanism for inspections will be identified through the planning process (NEPA). Failure to comply with the measures will subject the operator to the noncompliance process established in 36 CFR 228.112 thru .114.

USFS – Motorized Access

For projects with the potential to significantly affect grizzly bears or their habitat, permits will include the following mitigation measures regarding motorized access:

- New roads constructed for mineral exploration and/or development will be single-purpose roads only and will be closed to public use not associated with mineral activities;
- On USFS managed lands inside the PCA, new roads or closed roads that are re-opened for gas and oil/seismic will be consistent with this Conservation Strategy's motorized access standards;
- A traffic management plan will be developed as part of any proposed activity to identify when and how development roads will be used, maintained, and monitored, if required, and how roads will be closed after activities have ended;
- Helicopter use associated with seismic activity, exploration, drilling or development will follow an approved plan using criteria identified in the Application Rules below.

USFS – Habitat

For projects with the potential to significantly affect grizzly bears or their habitat, permits will include the following mitigation measures regarding motorized access:

- Mineral exploration and/or development activities will occur at a time or season when the area is of little or no biological importance to grizzlies. If timing restrictions are not practicable, reasonable and appropriate measures will be taken to mitigate negative impacts of mineral activity to the bear;
- Reasonable and appropriate measures regarding the maintenance, rehabilitation, restoration or mitigation of functioning aquatic systems and riparian zones will be implemented;
- Reclamation and revegetation of roads, drilling pads, and other areas disturbed from mineral exploration and development activities will be completed as soon as practicable by the operator;
- The leaseholder must appoint or designate a local agent who can be served notices and who has the authority to act for the leaseholder/permittee;

- Require notification of activities and proposals to deviate from operations plans, and regular activity logs documenting all surface activities.

USFS – Human Conflict

- Firearms will be prohibited on site during operations except for security personnel and other designated persons. Carrying of bear spray will be recommended to the operator;
- The operator should require employees to attend training related to living near and working in grizzly bear habitat prior to starting work and on an annual basis thereafter;
- Permits for seismic activity or drilling will include a clause providing for cancellation or temporary cessation of activities if such are needed to resolve a grizzly-human conflict situation.

USFS Application Rules

1. Mitigations, stipulations, and surface use criteria will include, as appropriate to the site and operating plan:
    a. Avoidance of ground-disturbance activity in identified grizzly bear spring habitat between 1 April and 30 June.
    b. No seismic activity in identified denning habitat from December 1 – April 1 (west of the Continental Divide) and from December 1 – April 15 (east of the Continental Divide).
    c. Timing restrictions to limit the cumulative impacts of multiple, concurrent seismic and/or drilling operations
2. Helicopter use plans will include:
    a. Recurring flights only at >500 feet above ground level
    b. Avoid construction of landing zones. If a landing zone is deemed necessary for safe implementation of the seismic or surface use plan or permit to drill, construct zones only in areas that have been analyzed and approved in the site-specific analysis and Biological Evaluation.
    c. Avoid establishing recurring flight lines or landing zones in spring habitats or other known important grizzly bear habitats or use areas.
3. Permits to Drill will include a clause stating that the leaseholder's and operator's full cooperation in meeting grizzly bear management goals and objectives will be a condition to their receiving and holding approved permits and plans.

In addition to the above standards, any new leases, and any proposed surface use plans or permits to conduct seismic exploration or to drill, should adhere to the following **guidelines**:

1. Wherever possible, use the best available noise-reduction technology on all equipment and motorized vehicles.
2. Maintain hiding cover at regular intervals along constructed roads, seismic corridors, and pipelines.

HABITAT CONDITION

Because of the wide variation in diets of NCDE grizzly bears and the spatial breadth of the ecosystem, it is infeasible to maintain on-the-ground monitoring of availability and use of individual foods. With sufficient sample sizes, it is possible to use ratios of stable isotopes in food items to infer assimilated diets (i.e., that which is digested and metabolically used) of grizzly bears (Robbins et al. 2004). As an example, ratios of ^{15}N to ^{14}N ($\delta^{15}N$) become higher with increasing trophic level, allowing distinction between a plant-based, animal-based, or mixed diet. Ratios of naturally occurring nitrogen, sulfur, and carbon isotopes will allow us to estimate the assimilated diet of grizzly bears in the NCDE.

Within the animal, metabolically active tissues (hair, blood components, etc.) incorporate material that reflects the isotopic ratio of the animals' diet. Hence, ratios of hair provide a catalogue of the assimilated diet during its growth period (approximately, summer to fall). Further, hairs can be segmented by length to assess changes in ingestion during the time of growth. In comparison, the turnover rate of blood components allows for shorter-term estimates of assimilated diet; ratios from blood plasma reflect the 1–2 weeks of digested diet prior to collection, while red blood cells reflect the recent 2–3 months of diet.

Habitat health and gross availability of high-quality foods can be measured indirectly by assessing the physiological condition of animals. Bioelectrical impedance analysis methods allow for direct estimation of fat content of captured grizzly bears (Farley and Robbins 1994, Hilderbrand et al. 1998). Ratios of lean body mass to fat mass vary widely from spring to fall, depending on available foods; these values provide insight into past nutrition of individual bears. Monitoring fat content and lean body mass to fat ratios in all bears captured will allow a better understanding of how body condition varies by sex and age of the bear, as well as season. Further, these estimates can provide information on whether females meet physiological requirements (primarily, high body fat content before denning, > 20%) for bearing offspring (Robbins et al. 2012).

Ideally, maintenance and accumulation of lean tissue and fat for all bears would occur when they are in secure habitat. In reality however, occasional scarcity of high-quality foods in secure areas or the seasonal availability of some habitats (i.e. low elevation areas free of snow in spring) may drive bears to seek foods found in lower elevations nearer human-development (Gunther et al. 2004). Ingested foods and body condition data will also allow managers to better understand, predict, and respond with management action or public information efforts when temporal and spatial changes in food availability may cause increased risk of human/bear conflicts. Further, continued monitoring of body condition in the future will assist in understanding possible changes in food availability as climate change continues.

Monitoring Protocol

Isotope ratio ($\delta^{15}N$ and $\delta^{34}S$) analysis – Existing monitoring efforts will be continued. Representative hair and blood samples from all captured bears, both research and management, will be analyzed annually. These isotope data will be analyzed to determine relative intake of plant matter and meat, then characterized by month, sex, age, reproductive status, area of capture, and management status.

Body condition – Bioelectrical impedance values will continue to be measured on all captured bears, both research and management. Body condition indices (body fat content, lean body mass to fat mass ratios) will be measured on all captured bears and will be characterized by sex, age, reproductive status, area of capture, and management status. .

Bioelectrical impedance analysis and stable isotope methods: 1) offer insight into the quality of habitat used by the sampled bear over a specific time period; and 2) estimate the proportions of digested foods. For example, if mean annual projections of October female body fat are greater than 1 standard error below baseline values, we can conclude that habitat and food base for the year was poor. Similarly, decreases in mean annual $\delta^{15}N$ isotope values for each region greater than 1 standard error below baseline regional averages would indicate a reduction in meat consumption, a high-quality food in certain regions.

Results of these analyses will be presented in the NCDE annual monitoring report. We will continue to monitor relationships between food use, management status, reproductive status, sex-age class, bear/human conflict rates, and body condition on a regional level, and report these findings annually in the NCDE annual monitoring report. We will monitor whether marked decreases in body condition, trophic level, or specific food sources are related to changes in numbers of human-caused mortality and females with dependent young, as well as other measureable population standards. These annual isotope and body condition data will be used in conjunction with demographic vital rate data to assess the health of the NCDE population. This monitoring program is designed to adapt to changing use and availability of foods and body conditions. Future monitoring will incorporate new techniques and knowledge as these become available.

PRIVATE LAND DEVELOPMENT

Federal land management and State wildlife agencies do not have management authority over private lands and these agencies do not have the ability to mitigate for private land development through management actions on their lands. As private lands are developed, State, Federal, and Tribal agencies will work together and with counties or other organizations to explore options that address impacts from private land development such as increased outreach efforts and proper storage of potential bear attractants. To this end, MFWP completed its "Fish and Wildlife Recommendations for Subdivision Development: A Working Document" in 2012. We encourage private land owners, counties and agencies to cite and use these recommendations when developing and reviewing subdivision applications and regulations. MFWP also developed a GIS planning tool for developers and counties to use that identifies "crucial areas" for wildlife connectivity. This GIS tool provides an easy-to-use and understandable way to plan for development and conserve land by including wildlife considerations from the beginning stages of planning and letting developers know in advance where to expect greater expense and potential mitigation costs.

Monitoring Protocol

As with monitoring developed sites on public Federal lands, tracking development on private lands can be valuable to indirectly assess potential risks to grizzly bears associated with displacement from habitat, habituation to human activities and attractants, and increased mortality risk. Every five years, MFWP will report changes in private land development and conservation easements on private lands within the PCA and compare these to 2011 conditions (Appendix 9). Specifically, MFWP will report the acres of conservation easements in place, and the number of residences, businesses, and miscellaneous structures on private lands within each BMU in 2011, then again in 2016, 2021, etc. This information will be gathered from various public sources such as Census Block data, county governments, and the Montana Natural Resource Information System (http://gis.mt.gov/). The quality and type of land parcel data varies greatly but will be useful in documenting relative changes and identifying areas where conflict prevention efforts should be directed. Private non-profits (e.g., Headwaters Economics) and other entities also gather data that can be used to categorize land development and these resources may be used to supplement county data.

Human-caused mortality related to private land conflicts will be monitored and must be controlled to meet the population/demographic standards in this Conservation Strategy. This requires ongoing efforts to limit grizzly bear/human conflicts on private lands inside and outside the PCA. As in the past, MFWP will continue to monitor and report annual human-caused mortality related to private land conflicts throughout the NCDE ecosystem (PCA + Zones 1, 2, and 3). Additionally, all bear-related conflicts in the PCA and Zone 1 will be reported annually. The entities responding to conflicts (MFWP, GNP, Blackfeet Nation, and Confederated Salish and Kootenai Tribes) will provide their raw data about conflicts to MFWP who will compile and report them annually. This information will be used to assess the efficacy of conflict reduction efforts and identify areas where conflicts are concentrated so preventative outreach can be directed there. MFWP, Confederated Salish and Kootenai Tribes, and the Blackfeet Nation will continue ongoing efforts to limit grizzly bear/human conflicts on private lands inside and outside the PCA in order to keep human-caused grizzly bear mortality within sustainable levels (see Chapter 4 – Conflict Prevention and Management). Upon request, MFWP and Federal agencies will continue to assist private non-profits and other entities to categorize and prioritize potential lands suitable for permanent conservation such as land exchanges, acquisitions, and conservation easements.

MANAGEMENT ZONE 1

In this section, we describe habitat management in the Demographic Connectivity Areas (DCAs), followed by a brief summary of draft measures the USFS, BLM, and DNRC would develop (or maintain) for grizzly bear habitat in the rest of Management Zone 1 (Figure 1). The primary land management entities responsible for habitat management in Zone 1 are the USFS, the BLM, DNRC, the Blackfeet Nation on the BIR, and the CS&KT on the FIR. Collectively, these entities manage 47% of the 2,240,663 acres (9,068 sq km) in Zone 1 (Table 8). Within Zone 1, another 47% of lands are privately managed. Approximately 5.7% of lands inside Zone 1 are considered "protected lands" because of their status as congressionally designated Wilderness Areas or other non-motorized areas (Table 8, Figure 4).

Management Zone 1 is similar in concept to the 10-mile buffer around the Recovery Zone within which population data are recorded while grizzly bears are listed as threatened under the ESA. The demographic standards and mortality limits described in Chapter 2 would be collected in all of the PCA and Zone 1. On the northwest and southwest corners of Zone 1, there would be two DCAs with specific habitat protection measures to support dispersal to other ecosystems in the lower 48 States (i.e., the Cabinet-Yaak and Bitterroot ecosystems) (see Figure 1). In these DCAs, habitat protections will focus on limiting miles of open road and maintaining current Roadless Areas as stepping stones to other ecosystems. Outside of these DCA's on USFS and BLM lands, there are either limits on open road miles and/or densities in current land management plans (Appendices 10, 11) or affected National Forests and BLM offices would incorporate motorized access management measures consistent with the intent of this Conservation Strategy when amending or revising their management plans. Similarly, on DNRC lands, the current HCP will provide conservation measures on 126,285 acres of forested trust lands (Appendix 12 provides a brief summary of these measures) and additional draft measures would be implemented on other trust lands not covered by the HCP (Appendix 13).

Of the five National Forests managing lands in Zone 1, four of them contain motorized access management standards in their current Forest Plans. On the **Flathead NF** in Zone 1, open motorized route densities are limited to maximum levels of 1.8 to 3.2 mi/sq mi, depending on the management unit. On the **Helena NF**, there are currently limits on open road densities during the general big game hunting season that are tiered to the availability of hiding cover (see Appendix 10). In areas with high amounts of hiding cover, open road densities may not exceed 2.4 mi/sq mi. In areas of lower amounts of hiding cover, open road densities cannot exceed 1.9, 1.2, or 0.1 mi/sq mi, depending on levels of hiding cover. Additionally, there is a forest-wide standard limiting open road densities to 0.55 mi/sq mi for areas of occupied grizzly habitat. Occupied grizzly habitat is defined as having verified grizzly bear observations over the last 6 of 10 years, including females with offspring in at least five of the last 10 years. On the **Kootenai NF**, linear miles of both open and total roads are limited to baseline values that have been compatible with successful occupancy by female grizzly bears with offspring. Because the **Lewis and Clark NF** manages only six acres in Zone 1, their motorized access management is not discussed here. While the **Lolo NF** currently has restrictions on open road densities of 1.1 mi/sq mi in "highly productive big game summer range," it does not have explicit language limiting open motorized routes or densities across Zone 1. Similarly, the **BLM** currently has guidelines to minimize new road construction and not allow increases above 1 mi/sq mi on many of their lands in Zone 1 but there are not uniform limits on open motorized routes across Zone 1.

Because we know current levels of open motorized routes on USFS and BLM lands in Zone 1 have not precluded an increasing grizzly bear population, our intent is to maintain these conditions on the landscape into the foreseeable future. By signing this Conservation Strategy, the USFS and BLM have committed to maintaining or establishing limits on motorized access routes in current and future management plans at levels guided by the agreements reached in this Strategy and consistent with the intent to maintain open motorized routes in Zone 1 at levels known to be compatible with a stable to increasing grizzly bear population in the NCDE. Changes to land management plans through future revisions will be guided by the agreements reached in this Strategy and will be consistent with this intent. In addition to standards and guidelines in current BLM management plans (Appendix 11), BLM developed draft standards and guidelines for management on large blocks of BLM lands in Zone 1 (Appendix 14). Similarly, DNRC has also developed specific measures to guide habitat management on non-HCP trust lands in portions of Zone 1 and Zone 2 (Appendix 13).

Table 8. Land ownership and management within NCDE Management Zone 1. [1]

Ownership	Sub-category Acres	Acres	Sq Km	Percent of Zone 1
US Forest Service		1,047,989	4,241	21.8%
Flathead National Forest	230,988			
Helena National Forest	149,095			
Kootenai National Forest	282,681			
Lewis and Clark National Forest	6			
Lolo National Forest	385,219			
BLM		109,720	444	2.3%
Other government [2]		65,594	265	1.3
Blackfeet Indian Reservation		268,858	1,088	5.6%
Tribally managed lands [3]	54,931			
Individual allotments [4]	213,927			
Flathead Indian Reservation, CS&KT		517,860	2,096	10.8%
Tribally managed lands [3]	492,495			
Individual allotments [4]	25,366			
DNRC		296,206	1199	6.2%
MFWP		57,919	234	1.2%
Total Private lands		2,283,668	9,242	47.5%
Private land on the BIR	125,715			
Private land on the FIR	362,988			
All other Private lands	1,794,965			
Water		160,905	651	3.3%
	TOTALS	**4,808,719**	19,460	
PROTECTED AREAS WITHIN MGMT ZONE 1				
Congressionally Designated Wilderness		15,804	64	0.3%
Other wilderness [5]		43,537	176	0.9%
Restricted motorized-use areas [6]		213,775	865	4.4%

[1] Acres are based on GIS layers from several Federal and State sources, dated 1 July 2012, at the 1:100,000 scale. When these layers were not in agreement, efforts were made to identify the correct owner but there may still be some discrepancies.

[2] includes the USFWS (31.808 acres), Bureau of Reclamation (7,819 acres), "other" government on the BIR (1,831 acres), US Government (291 acres), Dept. of Defense (45 acres), City government (40 acres), Montana State University System (23,760 acres).

[3] Tribal lands managed by the respective Tribes through coordination with the BIA and Council approved management plans

[4] Allotted lands managed by individual Tribal members through coordination with the BIA

[5] Other Wilderness includes areas managed to maintain their wilderness traits such as Wilderness Study Areas, Proposed Wilderness (GNP), and CS&KT Wilderness outside the Mission Mountains Tribal Wilderness

[6] Non-motorized areas include Inventoried Roadless Areas, Tribal roadless areas, Tribal Primitive Areas, & the Rattlesnake National Recreation Areas; all of which contain restrictions on new motorized use, new road construction, and commercial timber harvest.

HABITAT MANAGEMENT IN DEMOGRAPHIC CONNECTIVITY AREAS (DCAs)

Outside of the PCA on the western side of Zone 1, two DCA's have been identified to provide opportunities for female grizzly bears to establish home ranges and exist at low densities: the Salish DCA and the Ninemile DCA (Figure 1). In these areas, habitat protections will focus on limiting miles of open road and maintaining current IRAs as stepping stones to other ecosystems. Because the study areas of Kendall et al. (2009) and Mace et al. (2012) extended beyond the boundaries of the PCA and these are the data we base our demographic standards on, maintenance of current conditions in Zone 1 is a reasonable approach. From radio-collar data, we know that current levels of relatively high open road miles and low levels of secure habitat in the Salish DCA (compared to levels in the PCA) are adequate to support females with offspring. There have been at least eight different females with offspring documented here between 2001 and 2010 (Manley 2011, personal communication).

Salish Demographic Connectivity Area

Within the Salish DCA, 79.2% of lands (372,020/469,887 acres) are managed by the USFS. National Forest land management activities within this DCA will be regulated by the goals, objectives, and standards of the Kootenai and Flathead National Forest Plans.

Kootenai NF: On the 276,190 acres (1,118 sq km) managed by the Kootenai NF, the following protective measures to facilitate occupancy by female grizzly bears would apply:

1. There is one IRA (1,260 acres; 5 sq km) on the Kootenai NF in the Salish DCA. This IRA would be managed according to Forest Plan direction. Future management of this IRA will be guided by the agreements reached in this Strategy which are to maintain open motorized routes in Zone 1 at levels known to have been compatible with a stable to increasing grizzly bear population in the NCDE.
2. The majority of the Kootenai NF acres within the Salish DCA (266,947 acres of 276,190) will be managed according to the Kootenai National Forest's Motorized Access Amendment within the Selkirk and Cabinet-Yaak Grizzly Bear Recovery Zones (USFS 2011). Road management in this document states there would be no increases in permanent linear miles of open or total roads, with listed exceptions, as described in the Record of Decision for the Forest Plan Amendments for Motorized Access Management within the Selkirk and Cabinet-Yaak Grizzly Bear Recovery Zones (USFS 2011).
3. The remaining USFS acres within the KNF portion of the Salish DCA lies outside the area covered by the Access Amendment and will be managed according to Kootenai Forest Plan standards.

Flathead NF: On the 95,829 acres (388 sq km) managed by the Flathead NF, the following protective measures to facilitate occupancy by female grizzly bears would apply:

1. There is one Inventoried Roadless Area (5,443 acres; 22 sq km) on the Flathead NF in the Salish DCA. This IRA would be managed according to Forest Plan direction. Future management of this IRA will be guided by the agreements reached in this Strategy which are to maintain open motorized routes in Zone 1 at levels known to have been compatible with a stable to increasing grizzly bear population in the NCDE.

2. Road density standards in the current Forest Plan restrict open road densities to 1.3 – 2.2 mi/sq mi, depending on the geographic unit. Future management of road densities will be guided by the agreements reached in this Strategy which are to maintain open motorized routes in Zone 1 at levels known to have been compatible with a stable to increasing grizzly bear population in the NCDE.

Ninemile Demographic Connectivity Area

Within the Ninemile DCA, 70.2% of lands (363,351/517,369 acres) are managed by the USFS and the CS&KT. National Forest land management activities within this DCA will be regulated by the goals, objectives, and standards of the Lolo National Forest Plan while forested land management by the CS&KT will be regulated by their Forest Management Plan.

Lolo NF: On the 231,436 acres (937 sq km) managed by the Lolo NF, the following protective measures to facilitate occupancy by female grizzly bears would apply:

1. Within the Ninemile DCA, 22.5% of National Forest lands are in IRAs. These IRAs would be managed according to Forest Plan direction. Future management of these IRAs will be guided by the agreements reached in this Strategy which are to maintain open motorized routes in Zone 1 at levels known to have been compatible with a stable to increasing grizzly bear population in the NCDE. Four IRAs are located within the Ninemile DCA:
    a) Reservation Divide (16,865 acres; 68 sq km)
    b) Stark Mountain (12,559 acres; 51 sq km)
    c) North Siegel (9,197 acres; 37 sq km)
    d) South Siegel – South Cutoff (13,458 acres; 54 sq km)
2. There would be no net increase above 2011 baseline values in linear miles of permanent open roads allowed on National Forest System lands within this DCA, unless they are within the circumstances listed below. Permanent changes in linear miles of open roads may occur due to unforeseen circumstances, natural events, or other reasonable considerations. Such changes will not be considered a violation of this habitat standard and will not require mitigation responses. Acceptable changes that may permanently change linear miles of open road in the Ninemile DCA include the following:
    - the agency acquired better information or updated/improved the road information in their respective database(s) resulting in changed calculations without actual change on the ground;
    - technology or projections changed, resulting in changed calculations without actual change on the ground (e.g., recently a switch in the datum from NAD27 to NAD83 was required);
    - the agency moved a road closure location a short distinct (often <0.25 miles) to a better location for turn-arounds or less vandalism or to improve enforcement of the road closure;
    - the agency acquired or sold land;
    - the agency built/opened a road for handicapped access at an existing campground or day-use area;
    - the agency moved a road to address resource damage or human safety concerns.

3. Projects requiring high levels of administrative or commercial use of closed roads (i.e., greater than an average of ten round trips per day) will be designed to minimize adverse effects to the grizzly bear. Actions to minimize impacts may include restricting public use during project activities, establishing project subdivisions and scheduling project activities to allow alternative areas for bear dispersal and security, limiting seasons of use, and limiting project duration.
4. There would be no restrictions, except those defined in number three above, on the total number of miles of temporary roads (or trails) that are determined necessary for emergency operations or that are authorized by contract, permit, lease or other written authorization. Temporary roads and trails (defined in FSM 7505) are not considered part of or included in the forest transportation atlas (36 CFR 212.1).

Flathead Indian Reservation: On the 131,195 acres (531 sq km) managed by the CS&KT, the following protective measures to facilitate occupancy by grizzly bears would apply:

1. Tribally identified wilderness and roadless areas comprise 18.2% of Tribal lands within the Ninemile DCA. These areas would be managed according to Forest Plan direction. In general, these areas will be retained in their current, non-motorized condition. These include:
    a) Tribally designated wilderness area: Sleeping Woman (Ninemile Divide) (16,495 acres; 67 sq km)
    b) Tribally designated roadless area unavailable to logging or motorized use: Ravalli/Valley (Hewolf) Complex (7,841 acres; 32 sq km) and Burgess (1,750 acres; 7 sq km)
2. Open road densities shall not exceed 4 mi/sq mi;
3. Total road miles shall remain at or below what existed in 1999;
4. Hiding cover adjacent to Hwy. 93 at Evaro and the Ravalli Corridor will be retained and managed to provide movement corridors between ecosystems;
5. Roads in timber sale areas will be closed after the harvest is complete.

BRIEF SUMMARY OF HABITAT MANAGEMENT DIRECTION IN ZONE 1 ON BLM, USFS, & DNRC LANDS

Overview

Grizzlies will be classified as a "sensitive species" (or the equivalent legal term) by the DNRC, USFS, and BLM. This designation requires all proposed management activities to be evaluated for their effects on grizzlies and their habitat. For lands managed by the USFS, motorized access management in current plans is either adequate or will be modified to be consistent with the intent of this Conservation Strategy where motorized access is not formally incorporated into land management plans (i.e., the Lolo NF). The USFS would also incorporate habitat standards and guidelines regarding hardrock mining and oil and gas development. Measures consistent with the intent of this CS are summarized briefly in the sections below.

Motorized Access

BLM: There are roughly 92,500 acres (374 sq km) of BLM lands in Zone 1 that are large enough (i.e., > 2,500 acres) to provide Secure Core habitat. These blocks are found in four areas, all located within the Missoula Field Office:

(1) Chamberlain/Murray Douglas (42,500 acres; 172 sq km);
(2) Hoodoos (26,000 acres; 105 sq km);
(3) Lower Blackfoot Corridor (11,000 acres; 45 sq km); and
(4) the Marcum Mountain area (13,000 acres; 53 sq km).

In these four areas, there would be no decrease in current levels of Secure Core habitat and levels would be increased in the Marcum Mountain area. Additionally, open road densities would be maintained below 1 mi/sq mi in the first three areas and would be improved to be less than 2.5 mi/sq mi in the Marcum Mountain area.

DNRC: The HCP would regulate motorized access management on 126,285 acres (511 sq km) in Zone 1. On these lands, DNRC has agreed to minimize construction of new open roads and prohibit commercial forest activities during the spring period (April 1 – June 15) in identified spring habitat, and to suspend any motorized forest management activity within 0.6 miles of an active den site until May 31 or earlier if DNRC can confirm the bear has left the den site vicinity. On the remaining 169,921 acres (688 sq km) of other lands managed by DNRC in Zone 1, grizzly bears would be considered a sensitive species and administrative rules for management activities would be in place that would provide protective measures including minimization of new open motorized access routes.

USFS: Motorized access management in Zone 1 on lands managed by the USFS has been compatible with an increasing grizzly bear population. The Lolo is the only National Forest in Zone 1 that does not contain specific measures for motorized access to facilitate and maintain grizzly bear recovery in their Land Management Plan. Despite this, their motorized access management in Zone 1 has been compatible with an increasing grizzly bear population. This

National Forest would update their Forest Plan to include protective habitat measures for the Ninemile DCA and to institutionalize motorized access management in both the PCA and Zone 1.

Livestock Allotments/grazing

BLM: No new sheep allotments would be allowed in Zone 1. Additionally, no new livestock allotments of any kind would be created in Zone 1 with some minor exceptions for cows if new lands are acquired that previously allowed livestock grazing.

DNRC: On HCP lands in Zone 1, DNRC would discourage small livestock allotments and would allow them only if an adequate mitigation plan were developed and implemented. On all lands within Zone 1, grazing leases and licenses issued would require the following language:

- Re-locate livestock carcasses in areas with high risk of bringing grizzlies into conflict with humans within 24 hours of discovery to minimize risk of human/bear conflicts. Lessee shall cooperate with DNRC managers and FWP bear management specialists as necessary to address prompt removal of problem livestock carcasses.
- Bone yards that would promote habituation and frequent use by grizzly bears are prohibited.

Hardrock Mining

On lands managed by the USFS, BLM, and DNRC in Zone 1, habitat protections for mining projects are identical to those found in the PCA. Please see section earlier in this chapter (pp. 70-73) for more details.

Oil and Gas

Overview: Due to the low geological potential for occurrence in most of Zone 1 (Portner 2003), the only place where oil and gas development is currently being actively pursued is on the Rocky Mountain Front.

USFS Standards

1. Carry out site-specific analysis, including a Biological Evaluation, documenting potential impacts of proposed seismic or other activities on grizzly bears and grizzly bear habitat. Analysis will include potential impacts of proposed work camps or operation centers.
    a. Analyze the cumulative impacts to grizzly bears and grizzly bear habitat of concurrent seismic or other exploration or development activity proposed or occurring on the lease or adjacent leases.
    b. Where impacts to grizzly bears or grizzly bear habitat may occur, apply stipulations, or surface use criteria as described in the Application Rules below
2. All leaseholders and their agents, employees and contractors must adhere to all provisions of the Food Storage Order described elsewhere in this document.
3. Leaseholders and their agents, employees, and contractors will not be allowed to carry firearms while involved in activities associated with implementation of the operating plans or permits on NF lands.

4. Permits for seismic activity or drilling will include a clause providing for cancellation or temporary cessation of activities if such are needed to resolve a grizzly-human conflict situation.
5. The leaseholder must appoint or designate a local agent who can be served notices and who has the authority to act for the leaseholder/permittee
6. Require notification of activities and proposals to deviate from operations plans, and regular activity logs documenting all surface activities

USFS Application Rules

1. Mitigations, stipulations, and surface use criteria will include, as appropriate to the site and operating plan:
    a. Avoidance of ground-disturbance activity in identified grizzly bear spring habitat between April 1 and June 30.
    b. No seismic activity in identified denning habitat from December 1 – April 1 (west of the Continental Divide) and from December 1 – April 15 (east of the Continental Divide).
    c. Use timing restrictions to limit the cumulative impacts of multiple, concurrent seismic and/or drilling operations
2. Permits to Drill will include a clause stating that the leaseholder's and operator's full cooperation in meeting grizzly bear management goals and objectives will be a condition to their receiving and holding approved permits and plans.

BLM: On all lands managed by BLM in Zone 1, the mitigation measures for oil and gas would be identical to those described for the PCA earlier in this chapter (p. 74). These include a stipulation for no surface occupancy on all lands managed by the BLM or where the BLM owns the subsurface rights unless it is clearly demonstrated that the proposed action will not affect grizzly bears or their habitat.

DNRC: On all trust lands managed by DNRC in Zone 1, the mitigation measures for oil and gas would be identical to those described for the PCA (p. 74) earlier in this chapter.

LAND OWNERSHIP & MANAGEMENT IN ZONE 2

Because we know that management direction in current USFS and BLM land management plans in Zone 2 did not preclude male grizzly bears from occupying this area in low densities, existing direction will continue to apply. Land management plans on lands managed by the BLM or USFS contain numerous standards to benefit other species or resource values that will also benefit grizzly bears. Existing direction for USFS and BLM land management plans is summarized in Appendices 10 and 11. Measures in the DNRC HCP pertaining to food storage, retention of riparian cover, and minimization of open roads in riparian areas, would apply to most forested DNRC lands in Zone 2. These and additional measures for DNRC lands in Zone 2 that would require food storage and livestock carcass disposal clauses in future permits, leases, licenses, and operating plans are summarized in Appendix 13.

Table 9. Land ownership and management within NCDE Management Zone 2. [1]

Ownership	Sub-category Acres	Acres	Sq Km	Percent of Zone 2
US Bureau of Land Management		263,256	1,065	5.7%
US Forest Service		1,148,218	4,647	24.6%
Beaverhead-Deerlodge National Forest	417,893			
Gallatin National Forest	89,194			
Helena National Forest	641,092			
Lewis and Clark National Forest	2			
Lolo National Forest	38			
DNRC		217,769	881	4.7%
MFWP		56,541	229	1.2%
Other government [2]		19,474	79	0.4%
Private		2,909,571	11,775	62.5%
Water		44,102	178	0.9%
	TOTALS	**4,658,932**	**18,854**	
PROTECTED AREAS WITHIN MGMT ZONE 2				
Congressionally Designated Wilderness		*28,426*	*115*	0.6%
Wilderness Study Areas		*21,143*	*86*	0.5%
Inventoried Roadless Areas		*427,794*	*1,731*	9.2%

[1] Acres are based on GIS layers from several Federal and State sources, dated 1 July 2012, at the 1:100,000 scale. When these layers were not in agreement, efforts were made to identify the correct owner but there may still be some discrepancies.

[2] includes the USFWS (1,775 acres), Bureau of Reclamation (11,812 acres), other Federal US Govt. (106 acres), US Dept. of Defense (2,543 acres), the Montana State University System (793 acres), Montana Dept. of Transportation (31 acres), city government (1,922 acres), county government (483 acres), and other local government (8 acres)

LAND OWNERSHIP & MANAGEMENT ZONE 3

There are no habitat standards specifically related to grizzly bears here because Zone 3 does not have a goal of grizzly bear occupancy. However, land management plans on the roughly 10% of Zone 3 lands managed by the BLM or USFS contain numerous standards to benefit other species or resource values that will also benefit grizzly bears. Prevention of and response to grizzly bear/human conflicts will be emphasized in Zone 3.

Table 10. Land ownership and management within NCDE Management Zone 3.[1]

Ownership	Sub-category acres	Acres	Sq Km	Percent of Zone 3
US Bureau of Land Management		110,268	446	0.9%
US Bureau of Reclamation		82,541	334	0.7%
US Forest Service		1,088,625	4,406	8.9%
Gallatin National Forest	115,789			
Helena National Forest	5,790			
Lewis and Clark National Forest	967,047			
Other Government [2]		29,624	120	0.2%
Blackfeet Indian Reservation		432,882	1,752	3.6%
Tribally managed lands [3]	136,388			
Individual allotments [4]	296,494			
Rocky Boy's Indian Reservation		10,292	42	0.1%
DNRC		791,580	3,203	6.5%
MFWP		32,616	132	0.3%
Total Private Lands		9,547,023	38,635	78.5%
Private land on the BIR	355,484			
All other Private lands	9,191,539			
Water		32,733	132	0.3%
	TOTALS	**12,158,183**	**49,202**	
PROTECTED AREAS WITHIN MGMT ZONE 3				
Wilderness Study Areas		*82,984*	336	1%
Inventoried Roadless Areas		*550,571*	2,228	5%

[1] Acres are based on GIS layers from several Federal and State sources, dated 1 July 2012, at the 1:100,000 scale. When these layers were not in agreement, efforts were made to identify the correct owner but there may still be some discrepancies.
[2] includes USFWS (21,305 acres), "other" government on the BIR (4,154 acres), US Dept. of Defense (3,787 acres), other Federal US Govt. (19 acres), Montana Dept. of Transportation (251 acres), the Montana State University System (36acres), city government (29 acres), and county government (43 acres)
[3] Tribal lands managed by the respective Tribes through coordination with the BIA and Council approved management plans
[4] Allotted lands managed by individual Tribal members through coordination with the BIA

Chapter 4 – Conflict Prevention, Response, and Nuisance Bear Management

Grizzly bear-human conflicts are incidents in which bears either do or attempt to: injure people, damage property, kill or injure livestock, damage beehives, obtain anthropogenic foods, agricultural crops or other attractants. Most grizzly bear-human conflicts are the result of bears attempting to gain access to human-related attractants such as garbage, human foods, livestock or pet foods, hunter harvested deer or elk carcasses, orchards, compost piles, bird feeders, or vegetable gardens in areas of human presence. Although aggression towards people is uncommon, grizzly bears may occasionally injure or kill people when displaying natural defensive behavior or when they have become food-conditioned.

Within the NCDE, grizzly bear-human conflicts have increased as the frequency of bear-human encounters has gone up. This is a result of an increasing bear population with an expanding distribution in combination with increasing numbers and distribution of people living and recreating in grizzly bear habitat in western Montana. The Grizzly Bear Management Plan for Western Montana (Dood et al. 2006) addresses conflict management in the NCDE, and some of the language in this chapter is taken directly from that plan. Considering the many people who live, work, and recreate in the region, it is significant to note that levels of conflicts and grizzly bear mortalities since 2004 did not preclude an increasing grizzly bear population. Underlying attitudes toward grizzly bears are highly variable and relate to issues such as resident and recreationist safety concerns and economic impacts on local businesses and livestock producers. Local support for grizzlies on the landscape decreases if conflicts are not handled in an effective and timely manner.

The objective of conflict management is to maximize human safety and minimize property losses while maintaining a viable population of grizzly bears (Dood et al. 2006). This approach of balancing human needs with grizzly bear population considerations builds support and tolerance for grizzly bear conservation. For this approach to be effective, State, Tribal, and Federal agencies must respond to conflicts rapidly. When grizzly bear-human conflicts are not adequately addressed, there are negative consequences for the individual bear and the people involved, and support for grizzly bear management and conservation in the NCDE is undermined.

The emphasis of grizzly bear conflict management will be quick response by management authorities, removal of the source of the conflict where possible, and the use of non-lethal solutions. Depending on the circumstances of the conflict, appropriate responses may include:

- Removing or securing attractants,
- Public education and outreach,
- Discouraging the bear from visiting the site using non-lethal methods (e.g., **aversive conditioning**),
- Reactively or preemptively capturing and relocating a nuisance bear to a new area,
- **Removing** the bear from the wild, including lethal control.

Signatories to this Conservation Strategy will work to minimize the number of bears removed from the population as a result of conflict situations, recognizing that relocating or removing offending animals will be necessary to resolve some problems. Inside the PCA and Zone 1, **nuisance bear** status and response will be based on the Guidelines and Standards in this Conservation Strategy (see "Nuisance Bear Management" section in this chapter). In Management Zones 2 and 3, nuisance bear status and response will be based on relevant State or Tribal grizzly bear management plans.

Although there are a variety of situations that can result in a grizzly bear-human conflict, the primary causes are: (1) food **attractants** -- improper food storage or sanitation in either a backcountry situation (e.g., hunter camp, hiker or other backcountry recreationist), rural setting (e.g., farm/ranch, cabin, church camp, etc.) or urban setting (e.g., subdivision, town); (2) surprise encounters -- bears surprised at close range and acting defensively; (3) maternal defense -- females defending cubs; (4) natural food sources -- bears defending a kill/carcass etc.; (5) humans approaching a bear too closely (e.g., photographer, berry picker, hiker, hunter, etc.); or (6) bears responding to a noise attractant -- bears attracted to a hunter attempting to bugle or cow-call an elk, bears associating gunshots with a food source (carcass or gut pile).

The best ways to minimize these sources of conflicts are through education and outreach, food/attractant storage rules on public lands, and a variety of non-lethal methods that may be used directly by the public. In cases where Tribal, GNP, or State management authorities determine minimizing the sources of conflicts is ineffective or inadequate to address the specific circumstances of the conflict, relocation or removal of the nuisance bear is necessary and will be consistent with this Conservation Strategy and associated State and Tribal management plans.

EDUCATION AND OUTREACH

For grizzly bear conservation to be successful, providing habitat on the landscape is not enough. For grizzly bears to survive, people must accept the grizzly as a cohabitant of the land. Tolerance can be maintained when the public has confidence in management agencies to respond quickly and appropriately to grizzly bear-human conflicts and the public is equipped with the knowledge to understand and avoid grizzly bear-human conflicts. Education and outreach efforts are an essential component in building and maintaining this human tolerance of grizzlies. Other management strategies outlined in this Strategy are unlikely to succeed without useful, coordinated, adaptable outreach programs. Focused outreach messages must be communicated frequently and consistently, with emphasis on the importance of: (1) hunting safely in grizzly country, (2) keeping private property (including livestock and domestic pets) bear resistant, (3) appropriate food storage when camping or living in bear country, (4) hiking and camping safely in grizzly country, (5) being able to tell the difference between black bears and grizzly bears, (6) recognizing high-risk situations regarding grizzly bear habitat, (7) knowing grizzly bear biology and behavior.

Messages for all outreach efforts will be based on bear biology and behavior and be of a positive, non-alarmist nature. Custom messages targeted at specific audiences (e.g., hunters, hikers, recreationists, homeowners, livestock operators, rural communities, commercial entities, loggers, miners, resort operators, outfitters, etc.) have been identified and increase the efficiency of education and outreach efforts.

The following outreach actions in the NCDE are ongoing and will be continued:

- Outreach programs to local schools, businesses and community organizations;
- Lessons on human safety and conflict prevention while hunting in bear habitat presented to all hunter education classes;
- Online and in-person training to assist hunters with identification of black versus grizzly bears. MFWP implemented mandatory bear identification training for hunters purchasing black bear licenses in 2002;
- News releases and media (TV, radio and newspaper) messages, including information about helpful websites;
- Agency and partner-produced radio spots and Public Service Announcements;
- Web pages (on agency and Tribal websites) that are devoted to living and recreating in bear country;
- Dynamic websites (e.g., www.missoulabears.org) dedicated to reducing grizzly bear-human conflicts by disseminating information on current bear activity and how to keep neighborhood bear attractants minimized;
- Use of available tools, such as the “Bears and Bees” video to teach beekeepers about how to avoid conflicts with bears;
- Information and workshops on electric fencing to keep bears out of orchards, garbage, grain storage and bee yards;
- Meetings with homeowner groups and local communities about keeping bears out of garbage through bear-resistant garbage containers and electric fences;
- Day-to-day public contacts by agency and partner personnel during conflict situations with bears;
- Messages sent through online social networks (e.g., Facebook, Twitter, etc.);
- Bear rangers to talk with members of the public, make presentations, and post signage to proactively inform recreationists about bears and bear activity and reduce the potential for conflicts;
- Various bear safety brochures available at agency and partner offices, distributed by field personnel and given out at presentations;
- “Be Bear Aware” children’s handout/coloring book;
- Standardized “Hunters Know Your Bears” and “Food Storage” signs posted at campgrounds, trailheads, popular hunting areas, fishing access sites, etc. Public meetings to encourage citizen participation in land management decisions affecting grizzly bear habitat and management;
- Education and training of permanent and seasonal agency personnel.

Information & Education (I&E) Team

To ensure the consistency of messages presented across the multiple jurisdictions in this ecosystem, the NCDE’s existing I&E subcommittee, composed of State and Federal agency staff members and information and education professionals, will continue to coordinate outreach efforts in the NCDE. This team will identify and prioritize needed outreach efforts in the NCDE, ensure consistency and accuracy of information, facilitate partnerships with private land owners and non-profit organizations, identify and target specific audiences, identify and implement useful, new communication techniques, and adapt messages in response to public concerns. Chapter 5 contains details about the members of the I&E Team.

ATTRACTANT STORAGE RULES & REGULATIONS

Securing potential attractants is the single most effective way to prevent bears from becoming food conditioned and displaying subsequent unacceptable aggressive behavior. It is effective in limiting human-caused grizzly bear mortality, grizzly bear-human encounters, and other grizzly bear-human conflicts. These actions on public lands have been ongoing and will continue under this Conservation Strategy.

Federal Lands

The USFS has implemented and monitors compliance with food storage orders that require people using grizzly bear habitat to store food and other attractants properly on public lands so that bears cannot access them. Food storage orders apply to all lands within the PCA on the Flathead, Lolo, Helena, Lewis and Clark, and Kootenai National Forests. Food storage orders also apply to all of Zone 1 for the Flathead National Forest, Lolo National Forest, Kootenai National Forest, Rocky Mountain Ranger District of the Lewis and Clark national Forest and lands on the Lincoln Ranger District, Helena National Forest. The Helena National Forest and the Beaverhead-Deerlodge National Forest are in the process of developing and are committed to implementing a food storage order on all lands in Zone 1 and Zone 2. This would be effective before adoption of the Conservation Strategy.

<u>USFS:</u> Existing and future food storage orders on USFS lands are governed by direction of 36 CFR 261.50 and address: (1) Human, pet, and livestock food, toiletries, beverages, and garbage; (2) wildlife and domestic animal carcasses; (3) burnable attractants; and (4) reporting the death and location of livestock to a Forest Service official. Approved means and methods for the above are included in the special orders. Bear resistant food storage facilities are provided at some recreation sites.

> *Enforcement: Violations of these prohibitions are punishable by a fine of not more than $5,000 for an individual or $10,000 for an organization or imprisonment for not more than six months (16 U.S. C 551 and 18 U.S. C. 3559 and 3571).*

<u>GNP</u>**:** GNP enforces a food storage order governed by direction of 36 CFR 2.10 (d) which prohibits anyone from leaving food or garbage unattended or stored improperly where it could attract or otherwise be available to wildlife.

> *Enforcement: In general, citations are issued whenever there are violations of 36 CFR 2.10 (d) observed and the items left out would attract and provide a food reward to a bear or other wildlife. This includes such items as coolers containing food and/or beverages, packaged or cooked food, cooking equipment/utensils with food on them, and beverage containers with*

beverages in them. Campground managers remove any unsecured food or food coolers which may attract wildlife and provide a food reward. Only commissioned law enforcement officers may issue violation notices. In all cases it must be determined that the visitor(s) are, or have been, made aware of the food storage regulations prior to issuing a citation. If in doubt, a written warning is issued. Penalties for violations of 36 CFR 2.10 range from $50-$250 per violation.

USFWS: One National Wildlife Refuge exists in the PCA (Swan River) and another exists in Zone 1 (National Bison Range complex) of the NCDE. Other refuge lands and Waterfowl Production Areas, occur in Zone 1 in the Blackfoot Valley Conservation Area and the Rocky Mountain Front Conservation Area. All refuge lands are day-use only with no overnight camping allowed; visitors generally park and hike. All provide only parking areas and no garbage containers. Use of refuge lands operates under the pack-in/pack-out policy, which has been adequate for preventing grizzly bears from accessing human sources of food at day-use sites. To date, no conflicts with grizzly or black bears have been reported at any of these sites. Administrative and housing facilities are limited, and all attractants are stored in a bear-resistant manner.

Enforcement: Failure to comply with the pack-in/pack-out food and attractant policy results in violation of 50 CFR 27.94: Disposal of Waste - The littering, disposing, or dumping in any manner of garbage, refuse, sewage, sludge, earth, rocks or other debris on any national wildlife refuge except at points or locations designated by the refuge manager, or the draining or dumping of oil, acids, pesticide wastes, poisons, or any other types of chemicals wastes in, or otherwise polluting any waters, water holes, streams, or other areas within any national wildlife refuge is prohibited.

BLM: The BLM manages 20,691 acres within the PCA (<1% of total area). The BLM has drafted a food storage order for all BLM managed lands in the PCA, Zone 1, and Zone 2. Modeled after the Food Storage Orders on USFS lands in the NCDE, it will address: (1) Human, pet, and livestock food, and garbage; (2) wildlife carcasses; (3) burnable attractants; and (4) reporting the death and location of livestock to a BLM official. Currently, the proposed language for this food storage order includes some exceptions for specific campgrounds and developed recreation sites in Zone 2 but employs an adaptive management approach stating that if conflicts occurred at these sites, food storage orders would be implemented.

Enforcement: Failure to comply with food storage orders of special use permits result in the cancellation of the permit or denial of future permits. Contracts can be cancelled for failure to follow food storage orders. A Supplementary Rule will be pursued such that violations of any food storage regulations, except for provisions of 43 CFR 8365.1-7, would be punishable by a fine not to exceed $1,000 and/or imprisonment not to exceed 12 months (43 CFR 8364.1, 8365.1-6, 8360.07, and 18 USC 3559 and 3571 and FLPMA Section 303, 43 USC 1733).

State Lands

MFWP: The MFWP manages anthropogenic bear attractants on State owned Wildlife Management Areas (WMAs), fishing access sites, and State Parks through mandatory food storage requirements, pack in/pack out policies, and/or bear resistant containers. Attractant management varies by habitat, season, and bear activity. All WMAs in the PCA, Zone 1, and Zone 2 have mandatory food storage orders, including the Aunt Molly (1,184 acres), Blackfoot-Clearwater (43,761 acres), Kootenai Woods (1,417 acres), Marshall Creek (24,170 acres), Nevada Lake (740 acres), Sun River (19,771 acres), Ear Mountain (3,047 acres), and Blackleaf (10,397 acres) WMAs. MFWP employs an adaptive management approach stating that if conflicts occur at these sites, food storage orders would be implemented. Similarly, fishing access sites require that users pack out all garbage. At most State Parks within the NCDE, bear-resistant garbage bins are provided (Dood et al. 2006). Informational signage of other lands such as those enrolled in the Block Management Access program is encouraged to notify users of potential grizzly bear presence.

Enforcement: ARM 12.8.201 and 12.8.210 control the dumping, pollution or littering of lands or waters under the control, administration and jurisdiction of MFWP. The maximum penalty for a violation is $135. These rules are enforced by official Department staff such as wardens and park management staff.

DNRC: The Montana DNRC will rely on its HCP for forest management activities as the primary component of this Conservation Strategy for grizzly bears in the PCA and Zone 1 (DNRC HCP 2010). The HCP requires all DNRC personnel and contractors who conduct forest management activities or camp in the HCP area to store all human food, pet food, livestock feed, garbage and other attractants in a bear-resistant manner. Burnable attractants (such as food leftovers or bacon grease) shall not be buried, discarded, or burned in an open campfire. Additionally, inside the PCA, Zone 1, and Zone 2, all TLMD lease and license agreements that permit uses and/or activities that may involve the use or presence of bear attractants (e.g., leases/licenses for cabin and home sites, grazing, outfitting, group use licenses for camping, picnicking etc.) shall contain applicable clauses requiring unnatural bear foods and attractants to be contained and/or managed in a bear-resistant manner.

Enforcement: Violations of these orders are punishable by lease or license cancellation and a civil penalty of up to $1,000 for each day of violation. Pursuant to Montana Code Annotated § 77-1-804(8). In determining the amount of civil penalty, Administrative Rule 36.25.157 requires that DNRC consider the following factors: (1) number of previous violations, (2) severity of the infractions, and (3) whether the violation was intentional or unintentional.

Tribal Lands

BIR: The Blackfeet Nation implements and monitors compliance with attractant storage regulations in areas normally occupied by bears. This includes nearly all public BIR lands in the PCA and most public BIR lands in Zone 1. Blackfeet Fish and Wildlife Code Chapter 3, Section 17 requires all residents and visitors in "normally occupied" bear habitat to store food, garbage, livestock food, gut piles, big game carcasses and livestock carcasses in a bear-resistant manner. Chapter 3, Section 17 also applies to timber harvest activities within the Reservation. Purchasers, all employees, contractors and subcontractors must store trash in bear-resistant containers, remove trash on a daily basis, and refrain from feeding wildlife.

> *Enforcement: The penalty for violating this section shall be $100 per violation per day. The penalty for commercial food businesses violating food or garbage storage regulations shall be $500 per violation per day. Regulations are enforceable by Tribal wardens and Tribal police.*

FIR: The Confederated Salish and Kootenai Tribes implemented food storage regulations for campers and backcountry users on March 1, 2011. These regulations require that "all food, garbage, pet items or any attractants that may provide a reward to wildlife, must be stored in a bear resistant manner."

> *Enforcement: These regulations are enforceable by Tribal wardens and Tribal police. Fines for violations will range from $50 to $100.*

Other Lands

On private lands in Montana, Montana Code Annotated § 87-6-216 prohibits the feeding of certain wildlife including grizzly bears. A person may not provide supplemental feed attractants to animals by purposely or knowingly attracting any ungulates, bears, or mountain lions with supplemental feed attractants. A person who is engaged in the recreational feeding of birds is not subject to civil or criminal liability under this section unless, after having received a previous warning by the department, the person continues to feed birds in a manner that attracts ungulates or bears and that may contribute to the transmission of disease or constitute a threat to public safety.

> *Enforcement: MCA 87-6-216 is enforced by official MFWP employees with enforcement authority. The maximum penalty for a violation is $135.*

A technical working group coordinated by MFWP recently submitted recommendations to the Montana Department of Commerce Community Technical Assistance Program regarding a state-wide "rule set" for future subdivisions. These recommendations attempt to minimize the adverse impacts of subdivision development on wildlife and wildlife habitat. To minimize grizzly bear-human conflicts, MFWP recommended that if the proposed subdivision is located in an area of high or potentially high grizzly bear-human conflict in the opinion of the local MFWP biologist, the subdivision developer is required to provide adequate facilities for contained bear-resistant garbage collection.

Many counties and communities have improved their landfills and garbage collection systems to reduce or prevent conflicts with grizzly bears. Landfills have been made bear resistant with chain link or electric fence perimeters. Timing of garbage collection has been adjusted in some areas to limit the availability of attractants to grizzly bears. A number of private garbage disposal companies within the NCDE (e.g., Allied Waste Services) have replaced old dumpsters and cans with bear resistant containers in problem areas. Multiple non-government organizations as well as Federal, State and Tribal entities participate in grant programs that provide bear resistant containers to counties or other municipalities. For example, in 2012, the CS&KT used a Tribal Wildlife Grant from the USFWS to purchase 225 bear-resistant garbage cans to distribute to homeowners having problems with bears accessing their garbage.

NON-LETHAL CONFLICT MANAGEMENT & PREVENTION

Over the past few decades considerable effort has been directed toward the development of non-lethal techniques for preventing conflicts entirely or responding to them once they have occurred. These techniques, most of which are easily used by the general public, include the use of bear spray, electric fencing, and other **aversive conditioning** tools. The best available technologies and science will be used in the NCDE to aversively condition bears and minimize bear-human conflict when appropriate.

Bear spray is an effective way to stop a threatening or attacking bear. Electric fencing is an incredibly effective tool when properly maintained and monitored. It can prevent bears from accessing potential attractants such as chicken coops, pig pens, calving or lambing corrals, orchards, bee yards, compost piles, gardens, hunter-killed carcasses, and any anthropogenic attractant a bear should not be able to access. MFWP and Tribal bear management specialists work extensively with the public and non-profit organizations to make electric fencing as cheap and effective as possible for citizens. This is accomplished through cost-share programs, loaner kits for short-term attractants, demonstrations at local community events and farm and ranch stores, and a comprehensive guide produced by MFWP on "Bears and Electric Fencing" available online (http://fwp.mt.gov/fwpDoc.html?id=48893). Other tools that will **aversively condition** grizzly bears to humans with the goal of reducing or eliminating **habituation** include rubber bullets, cracker shells, plastic slugs, propane noise makers, and trained Karelian bear dogs.

NUISANCE BEAR GUIDELINES AND STANDARDS

Nuisance bears are bears that exhibit conflict behaviors which may place the public at undue risk. This includes any positively identified grizzly bear involved in a grizzly bear-human conflict that results in an agency management response activity (Dood et al. 2006). Examples of nuisance bears include, but are not limited to, grizzly bears that have become **food-conditioned**, that kill livestock or pets, damage property, or display **unacceptable aggressive behavior**. Some bears involved in conflicts that are resolved through preventive measures (i.e., removing or securing the human-related attractant) are not considered nuisance bears.

The Guidelines and Standards in this chapter of the Conservation Strategy apply to the PCA and Zone 1 only. For Zone 2 and Zone 3, relevant State and Tribal plans would guide decisions about nuisance bears and conflict response. However, grizzly bears in Zones 2 and 3 will not be captured and removed just because they are present, nor will they be captured and removed from these areas unless there are conflicts. MFWP, GNP, and Tribal management authorities make decisions regarding the appropriate management response within their respective jurisdictions. If the decision made by one of these management authorities is to relocate a bear, interagency communication and coordination will occur. The authority to manage and respond to grizzly bear-human conflicts is based upon existing State, Federal, and Tribal laws and regulations, as detailed in Chapter 6.

Within the PCA and Zone 1, decisions about nuisance bears will consider the following ***guidelines***:

- Location, cause of incident, severity of incident, history of the bear, health/age/sex of the bear, and demographic characteristics of animals involved will be considered in any decision about a nuisance bear (Dood et al. 2006)
- Recognizing that conservation of female bears is essential to maintenance of a grizzly population, removal of nuisance females will be minimized (Dood et al. 2006).
- Removal of nuisance bears will be carefully considered and consistent with mortality limits for the NCDE as described in Chapter 2 of this Conservation Strategy. While efforts will be made at all times to remain within sustainable mortality limits, nuisance grizzly bears must be removed if they pose a threat to human safety. If a decision to remove a nuisance bear violates the mortality limits, the reasons must be documented.
- Management of all nuisance bear situations will emphasize removal of the human cause of the conflict, when possible, and management and education actions to prevent future conflicts.
- Bears may be relocated as many times as judged prudent by management authorities.
- Bears may be preemptively moved when they are in areas where they are likely to come into conflict with humans if aversive conditioning and/or minimizing or removing attractant sources have failed to correct the bear's habituation. Such preemptive moves will not count against the bear when determining future management response actions or classifying that individual as a nuisance bear in the future.
- State and Tribal wildlife agencies, in coordination with the appropriate Federal agencies, will predetermine adequate and available sites for relocations. Relocation sites should be agreed upon before the need for relocation occurs. State and Tribal wildlife managers will coordinate with local Federal land managers on all relocations on Federal lands.

Within the PCA and Zone 1, the following ***standards*** apply to decisions about nuisance bears:

- No bear may be removed from the population for any offense, other than unacceptable aggression or a conflict resulting in a serious human injury or fatality, without at least one relocation, or documentation of the circumstances that warranted the removal decision.
- Bears displaying unacceptable aggression will be removed from the population.
- Bears displaying natural defensive behavior are not to be removed, unless management authorities judge that the particular circumstances warrant removal and document the circumstances that warranted the removal decision (e.g., the behavior resulted in a human fatality).
- State, Federal, and Tribal agencies will retain Grizzly Bear Management Specialists and law enforcement officers to rapidly respond to conflicts, perform public education, implement proactive sanitation measures such as fencing and livestock carcass redistribution, and assist with grizzly bear relocations and removals.
- Preemptive moves will not be used to stop distribution increases (Dood et al. 2006).
- To facilitate informed decisions about nuisance bears on adjacent jurisdictions, MFWP, CS&KT, the BIR, and GNP management authorities will communicate with each other to understand the origin and conflict history of any *marked bear* that is captured in a conflict situation within their respective jurisdictions, as appropriate.

Grizzly Bear Removals

Captured grizzly bears identified for removal may be given to public research institutions or accredited public/non-profit zoological parks for appropriate non-release educational or scientific purposes as per State and Federal regulations. Grizzly bears not suitable for release, research, or educational purposes will be euthanized by management authorities, as described in appropriate State and Tribal management plans or in compliance with National Park rules and regulations. Orphaned cubs of euthanized female bears will not automatically be classified as nuisance bears. Depending on the circumstances of the conflict and subsequent removal decision, they may be left in the wild, taken to the MFWP rehab facility in Helena, Montana for re-release to the wild, or removed from the population (see Dood et al. 2006, MFWP 2010 Policy on Intake, Rehabilitation, Holding, and Disposition of Wildlife). Outside of GNP, individual nuisance bears deemed appropriate for lethal removal could be killed by permitted citizens under certain circumstances and in compliance with rules and regulations promulgated by the appropriate State or Tribal authorities.

MONITORING PROTOCOL

MFWP will compile and report grizzly bear-human conflicts in all Management Zones across all jurisdictions. All reported conflicts and subsequent response actions, if any, will be documented and summarized annually. This reporting system will provide managers with a way to identify conflict "hot-spots" and compare trends in the frequency, location, cause, land ownership, and type of conflict so that conflict prevention efforts can be prioritized and directed at areas and user-groups more effectively.

Chapter 5 – Implementation and Evaluation

Upon implementation of this Conservation Strategy, the NCDE Coordinating Committee will replace the current NCDE Grizzly Bear Subcommittee. The Coordinating Committee will coordinate and evaluate implementation of this Conservation Strategy, promote the exchange of data and information about the NCDE grizzly bear population among agencies and the public, and make recommendations to the management agencies regarding implementation of this Conservation Strategy. The NCDE Coordinating Committee will inform the IGBC about the NCDE grizzly bear population. The Coordinating Committee is not a decision-making body, although it may provide recommendations to member agencies from time to time. This Coordinating Committee does not supersede the authority of the management agencies beyond the specific actions agreed to as signatories to this Conservation Strategy.

NCDE COORDINATING COMMITTEE MEMBERSHIP, ROLES, AND RESPONSBILITIES

NCDE Coordinating Committee membership will consist of representatives from the following entities:

Federal	National Park Service: Glacier National Park (one member) U.S. Forest Service: Flathead, Lewis and Clark, Helena, Lolo, and Kootenai National Forests. (two members total for the five National Forests) Bureau of Land Management: (Butte, Lewistown, and Missoula Field Offices. (one member total for the three Field Offices)
State of Montana	Montana Department of Fish, Wildlife & Parks (two members) Montana Department of Natural Resources and Conservation (one member) County representative appointed by the Montana Association of Counties (one member)
Tribes	Blackfeet Nation (one member) Confederated Salish & Kootenai Tribes (one member)

NCDE Coordinating Committee roles include:

- Establish meeting rules, committee procedures, and chairperson election rules including how the group comes to consensus on areas of disagreement.
- Seek funding to further the conservation of the NCDE grizzly bear by implementing this Conservation Strategy.
- Communicate with the public about management decisions and annual monitoring reports.
- Appoint members to the NCDE Monitoring Team and Information and Education Team.
- Appoint, as needed, science teams, task forces, or other sub-committees to analyze or make recommendations regarding specific grizzly bear management issues.

Primary NCDE Coordinating Committee activities include:

- Coordinate implementation of this Conservation Strategy across the numerous agency jurisdictions and Tribal governments within the NCDE.
- Ensure that population and habitat data are collected and reported, as agreed to in this Conservation Strategy, and evaluated to assess current status of the grizzly bear population
- Ensure annual monitoring reports are made publicly available.
- In a coordinated fashion, share information and implement management actions.
- Use adaptive management to recommend revisions or amendments to the Conservation Strategy standards, guidelines, and/or monitoring procedures based on biological data, the best available science, and/or new techniques. Any such amendments will be subject to public review and comment.
- Identify management, research, and financial needs and prioritize these to successfully implement the Conservation Strategy.
- In specific circumstances related to the developed site standard or if requested by a Coordinating Committee member, the Coordinating Committee will provide a "position statement." [6] A **position statement** would be a brief (e.g., 1-2 pages) assessment of the appropriateness of a proposed action relative to its impact on the entire NCDE population. If there is disagreement among Coordinating Committee members about the impacts to the grizzly bear population, the position statement would contain the viewpoints of both sides. While respective management agencies possess the sole authority to make decisions regarding grizzly bears within their jurisdictions, these position statements will communicate the NCDE Coordinating Committee's recommended course of action.

NCDE COORDINATING COMMITTEE – OPERATING PROCEDURES

Within 30 days of a final rule delisting the NCDE grizzly bear population, the signatories to this Conservation Strategy will name their agency representatives to the NCDE Coordinating Committee. This Committee does not supersede the authority of its member agencies.

The person serving as chairperson of the NCDE Subcommittee, if and when a final rule changing status is published, will call the first meeting of the NCDE Coordinating Committee.

- At the first meeting, the NCDE Coordinating Committee will elect a chairperson. Chairpersons will be elected at intervals determined by the members of the NCDE Coordinating Committee.
- The NCDE Coordinating Committee will meet at least one time each year, with additional meetings as needed and agreed to by a majority of the Committee. Public notification of these meetings will be made by the chairperson or her/his representative. The details on locations and times of meetings and other business issues associated with the functioning of the NCDE Coordinating Committee will be determined at the first meeting.
- Signatory agencies and Tribes will support the participation of their representatives.

[6] There are 2 circumstances that would lead to a position statement being issued by the NCDE Coordinating Committee: (1) if a proposed increase in the number of developed sites did not meet the Application Rules or (2) if a Coordinating Committee member requested a position statement for a specific project or proposal.

REVISING THIS CONSERVATION STRATEGY

Once adopted by the agencies, this Conservation Strategy's standards, guidelines, and/or monitoring procedures may only be changed through a clear demonstration of need based on biological data, the best available science, and/or new techniques. Any such amendments will be subject to public review and comment, must be in writing, and must be signed by each signatory to this Conservation Strategy. Ultimately, any such changes would be guided by and consistent with the agreements reached in this Strategy and its overall goal to maintain a recovered grizzly bear population in the NCDE and conserve its habitat.

NCDE COORDINATING COMMITTEE – IMPLEMENTATION STRUCTURE

The NCDE Monitoring Team

In order to understand the status of grizzly bears throughout the NCDE and formulate appropriate management strategies and decisions, there is a need for centralized responsibility to collect, manage, analyze, and distribute science-based information on grizzly bear trend, distribution, survival, mortality, conflicts, and habitat conditions. To meet this need, an NCDE Monitoring Team would be established to provide annual monitoring data to the Coordinating Committee as well as the USFWS (as required by Section 4(g)(1) of the ESA for the first five years after delisting any species). The NCDE Monitoring Team would consist of scientists representing GNP, USFS, BLM, MFWP, DNRC, the Blackfeet Nation, and the Confederated Salish and Kootenai Tribes. Other scientists can be added to the Monitoring Team with the agreement of the Coordinating Committee.

MFWP will oversee population monitoring, following procedures established since 2004. MFWP will house, manage, and share the grizzly bear population database within the structure defined by the Monitoring Team. The land management agencies (i.e., the USFS, BLM, or GNP) will house the maintained spatial GIS data to support analysis of the motorized access, developed site, and livestock habitat standards. These databases and GIS layers will be available to all participating agencies for analyzing impacts from proposed projects. An MFWP and a USFS representative will serve as co-chairs of the Monitoring Team and will call meetings as needed. Signatory agencies and Tribes will support the participation of their representatives.

MFWP will prepare an annual demographic monitoring report with staff support from participating agencies. This annual monitoring report will provide information about demographic monitoring efforts, mortality management, bear-human conflicts and conflict response efforts. The Monitoring Team will also produce an annual report on habitat standards and monitoring results for motorized access, developed sites, livestock allotments, and other habitat parameters on the schedules described in Ch. 3 of this Conservation Strategy. Agencies and Tribes responsible for monitoring major population and habitat parameters are listed in Appendix 15. Monitoring results and analyses will be presented by the Monitoring Team to the NCDE Coordinating Committee at their annual meeting.

To adequately assess habitat conditions, adherence to the habitat standards, and report on the habitat monitoring items identified in this Conservation Strategy, the use and intensive maintenance of GIS databases are required. Computer technology is constantly changing and assessment protocols must be updated as software and hardware are replaced. The GIS databases used to evaluate habitat parameters require continual updating, reevaluation, and testing. A coordinated approach to database maintenance and management is necessary for ongoing success. Members of the Monitoring Team will include identified biologists and GIS specialists from the signatory agencies and Tribes. All participating agencies would commit to seeking and sharing funding responsibilities for a GIS database manager position at levels similar to current levels.

As detailed in the monitoring sections of this Conservation Strategy, the NCDE Monitoring Team will:

- Coordinate grizzly bear data collection and analysis;
- Prepare annual monitoring reports with staff support from relevant agencies;
- Present monitoring results and analysis to the NCDE Coordinating Committee annually;
- Provide technical support to agencies and Tribes responsible for the immediate and long term management of grizzly bears in the NCDE to assist with project impact analyses.[7]
- Coordinate updates and maintenance of the motorized access, developed sites, and livestock allotments databases.
- Document and report any changes in motorized access route density, levels of Secure Core habitat, developed sites and their capacity, livestock allotments, and permitted sheep numbers biennially, according to the monitoring schedules described in Ch. 3 of this Conservation Strategy.
- Ensure that all cooperators have the tools and training to evaluate motorized access route density and Secure Core habitat for projects.
- Evaluate the need for updating or changing the methods used to evaluate habitat parameters and make recommendations to the NCDE Coordinating Committee on such changes, as necessary.
- Set and maintain standards, definitions, values, formats and processes for collecting and updating habitat data and assessment models consistently across jurisdictions.

The Information and Education Team

Successful maintenance of a recovered NCDE grizzly bear population requires joint understanding of issues, sharing of knowledge (including new science and results of monitoring), and open communication among agencies, Tribes, elected officials, non-governmental organizations, and the public. Members of the Information and Education Team will be appointed by the Coordinating Committee and will include information and education specialists from signatory agencies and Tribes.

The goals of the Information and Education Team are:

---

[7] The NCDE Monitoring Team is not responsible for completing impact analyses for projects proposed by any agency; such analyses are the responsibility of the agency making the proposal unless otherwise negotiated.

- Increase understanding of grizzly bears and their habitat.
- Increase public support for and compliance with agency management actions to maintain a secure NCDE grizzly bear population.
- Increase public knowledge about how to prevent encounters and conflicts.
- Increase public knowledge about the effectiveness and proper use of bear spray.
- Utilize all possible technology and media resources to help decrease grizzly bear/human conflicts while still maintaining maximum access to natural resources for humans and grizzly bears.
- Foster information sharing to ensure maximum resource, policy, and scientific informational exchange among agencies, Tribes, elected officials, interest groups, local residents, and the public.
- Provide for meaningful public involvement through a variety of methods to inform the public about agency decisions relating to grizzly bear habitat and population management activities and other management actions that may affect local residents, landowners, and other users.

EVALUATION AND CONSEQUENCES RELATED TO MONITORING RESULTS.

The evaluation of the effectiveness of grizzly bear conservation measures detailed in this Conservation Strategy will be an ongoing process shared by all members of the NCDE Coordinating Committee and based on the results presented in the Monitoring Team's annual reports. If there are deviations from any of the population or habitat standards stipulated in this Conservation Strategy, a **Management Review** will be completed by a team of scientists appointed by the members of the Coordinating Committee.

A Management Review will be triggered by any of the following criteria:

- failure to meet any of the demographic standards for female survival, distribution, or mortality limits;
- failure to meet any of the habitat standards for motorized route densities or Secure Core habitat, as specified in the Application Rules in Chapter 3;
- failure to meet the standards for developed sites or livestock allotments in any given year;
- failure by a participating agency to provide adequate habitat or population data from their jurisdiction to meaningfully assess adherence to the habitat or population standards in this Conservation Strategy.

Description of the Management Review

Under this Conservation Strategy, a Management Review is a process carried out by a team of scientists appointed by the NCDE Coordinating Committee. A Management Review examines management of habitat, populations, or efforts of participating agencies and Tribes to complete their required monitoring. The purposes of a Management Review are:

- To identify the reasons why particular demographic, habitat, or funding objectives were not achieved;

- To assess whether a deviation from demographic, habitat, or funding objectives constituted a biological threat to the grizzly bear population in the NCDE;
- To provide management recommendations to correct deviations from habitat or population standards, or to offset funding shortfalls (estimates of funding needs are shown in Appendix 16);
- To consider departures by one or more agencies or Tribes from the monitoring effort required under this Conservation Strategy and to develop plans to ensure that monitoring efforts be maintained as per the standards in this document, or;
- To consider and establish a scientific basis for changes/adaptations in management due to changed conditions in the ecosystem.

Management Reviews would normally be undertaken after the annual summary of monitoring information presented to the NCDE Coordinating Committee and in response to identified deviations from criteria listed above. Any NCDE Coordinating Committee member can request that a Management Review be initiated. This would be a topic for discussion by the NCDE Coordinating Committee and the review would be initiated based on their decision. The Management Review process would be completed within six months of initiation and the resulting written report presented to the NCDE Coordinating Committee and made available to the public.

Individual agencies on the NCDE Coordinating Committee will respond to the Management Review with actions that address the deviations from the population or habitat standards, if warranted and if possible.

Description of Petition for Relisting

Under Section 4 of the ESA, an individual or an organization can petition the USFWS to change the listed status of a species. If the petition were determined to be warranted, it would initiate a status review by the USFWS. A status review evaluates all factors affecting the population and results in a finding published in the Federal Register about whether protection under the ESA is warranted. For a petition to be considered warranted, it must present credible scientific information to support its conclusions. If the NCDE Coordinating Committee determines there are imminent threats to the NCDE grizzly bear population that threaten its long-term viability and cannot be managed adequately through the post-delisting management structure, it would petition the USFWS for relisting under the ESA. Because a petition from the NCDE Coordinating Committee would be accompanied by firsthand biological data regarding the population and its habitat, such a petition would trigger a status review by the USFWS. Alternatively, the USFWS can initiate a status review at any time to determine if the grizzly bear in the NCDE should be re-listed based on concerns about the population and/or its habitat.

If, as the result of the status review or a petition for relisting, the population is found to be warranted for listing, as per the criteria of the ESA in Section 4(a)(1), then the species could be immediately considered for relisting or could be relisted under emergency regulations, per Section 4(b)(7), if the threat were severe and immediate. The USFWS may also unilaterally consider emergency relisting at any time, without the completion of a status review. The ESA is very clear that relisting of a previously listed species shall be promptly undertaken if needed to prevent a significant risk to the well being of any recovered and delisted species (Section 4(g)(2)). Should such a situation exist, the relisting would be considered a high priority and would not be impacted by the listing backlog.

Criteria That Would Require the USFWS to Make a Decision about "Emergency Relisting"

In the event that unforeseen circumstances result in an unexpected, severe decline of the NCDE grizzly bear population, as defined by the criteria below, the USFWS will exercise its discretion to make an emergency re-listing decision within 30 days of receiving notification that any of these criteria have been met or exceeded. The USFWS retains all decision making discretion to determine if there is an emergency posing a significant risk to the well-being of the species and may determine that emergency re-listing is not warranted, but the USFWS will nevertheless make a decision within 30 days of notification. The USFWS also retains discretion to initiate a review of whether emergency listing is warranted based on factors other than the criteria identified below. If the USFWS determines that emergency re-listing is warranted, it will make prompt use of the ESA's emergency listing provisions. Biological criteria that would require the USFWS to make a decision about whether emergency re-listing is necessary are:

1) If a credible population estimate showed the population was less than 500[8] in the combined area of the PCA and Zone 1; or
2) If the most recent two 6-year pooled datasets showed independent female survival was less than 0.85 for two consecutive 6-year periods, as reported by the Monitoring Team; or
3) If the most recent three 6-year pooled datasets showed a declining population trend[9] of at least 5% for three consecutive time periods (e.g., 2005-2010, 2006-2011, 2007-2012), as reported by the Monitoring Team.

[8] Miller and Waits (2003) identified 400 as an adequate population size to minimize the chances that genetic factors will have a substantial effect on the viability of an isolated grizzly bear population for at least several decades. Because the NCDE grizzly bear population is well connected to Canadian populations, we used a conservative approach in identifying 500 as a criterion.

[9] Although population trend (i.e., lambda) is not included as a demographic standard, it will be reported annually using the methods of Mace et al. (2012) to pool together the previous 6 years of data, or other appropriate methods.

Chapter 6 – Regulatory and Conservation Framework

The management of grizzly bears and the habitats they require for survival are dependent upon the laws, regulations, agreements, and management plans of the State, Tribal, and Federal agencies in the NCDE. This chapter documents the regulatory mechanisms and conservation framework that will maintain a recovered grizzly bear population in the NCDE. These laws, regulations, and agreements provide the legal basis for coordinating management, controlling mortality, providing secure habitats, managing grizzly bear/human conflicts, regulating hunters and hunting seasons, limiting motorized access where necessary, controlling livestock grazing, regulating oil and gas development, mitigating large scale mining operations, maintaining education and outreach programs to prevent conflicts, monitoring populations and habitats, and requesting management and petitions for relisting when necessary.

Grizzly bear populations declined in part due to the lack of regulatory mechanisms to control take and protect habitat. Specifically, agencies could not develop effective management programs because they lacked data on population trends, habitat conditions, population size, annual mortality, and reproductive rates (40 FR 31734-31736, July 28, 1975). Delisting of the grizzly bear will remove the regulatory certainty provided by the ESA that prohibits the take of grizzly bears and the requirement that Federal agencies consult with the USFWS on projects that may affect grizzly bear habitat. In the absence of this regulatory framework, the USFWS must demonstrate that:

1) Adequate regulatory mechanisms are available for protecting grizzly bears after delisting;
2) These mechanisms will be effective in maintaining the recovered status of the grizzly bear; and
3) Any selected mechanisms will be carried forward into the foreseeable future with reasonable certainty.

This chapter documents the mechanisms to conserve grizzly bears in the NCDE that would continue to exist if/when they are removed from the ESA's Federal List of Endangered and Threatened Wildlife. Regulatory mechanisms relevant to grizzly bears consist primarily of Federal laws, regulations, USFS and BLM Resource Management Plans, GNP's Superintendent's Compendium, HCPs, and State laws. Other conservation mechanisms include Tribal and State grizzly bear management plans and other guidelines that coordinate management, population monitoring, and mortality control.

The National Forest and BLM Resource Management Plans, the Glacier National Park Superintendent's Compendium, the DNRC Habitat Conservation Plan, Tribal Forest Management Plans, Montana Code Annotated (MCA), and Administrative Rules of Montana (ARM) are regulatory mechanisms that are legally enforceable. These dictate how grizzly bear population and habitat management will occur, and, in doing so, they serve to ensure against excessive grizzly bear mortality by minimizing human-caused mortality risk. Our intent is to have signatories of this Conservation Strategy representing the land management agencies incorporate the habitat standards and guidelines described in this Conservation Strategy into their respective management plans. ***Standards*** are mandatory constraints on project and activity decision making whereas ***guidelines*** are constraints that allow for departure from their terms, so long as the purpose of the guideline is met (77 FR 21162, April 9, 2012). Guidelines in this Conservation Strategy serve to mitigate and minimize undesirable effects to grizzly bears or their habitat. Because amending or revising management plans will require an analysis under NEPA for some agencies, the USFWS will not sign the Conservation Strategy until this NEPA process is complete and satisfactory. Decisions will be made to ensure grizzly bear conservation in the foreseeable future. Conversely, implementation of this Conservation Strategy will be contingent on the USFWS determining the grizzly bear in the NCDE no longer meets the definition of threatened or endangered under the Endangered Species Act.

FEDERAL LAWS

Glacier National Park Enabling Act, 16 U.S.C. § 161 et seq. An Act of Congress on May 11, 1910 established Glacier National Park as a public park for the benefit and enjoyment of the people and for the preservation of the park in a state of nature and for the care and protection of the fish and game within its boundaries. GNP comprises 17.3% of the NCDE's PCA for grizzly bears.

> ***What it means to grizzly bears***: In an act that pre-dates the creation of the National Park Service, Congress created Glacier National Park in recognition of the unique scenic and natural values of the area. The Act directed the Secretary of Interior to promulgate such rules and regulations necessary to preserve these values for future generations. The Act clearly states that the park will be maintained in a natural state with its wildlife protected. Glacier National Park continues to work to fulfill this directive by implementing rigorous protection programs, as is evident by maintenance of a large population of grizzly bears for decades.

National Park Service Organic Act, 1916. The National Park Service...shall promote and regulate the use...by such means as... to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such a manner...as will leave them unimpaired for future generations. 16 U.S.C. §1

> ***What it means to grizzly bears***: This act created a National Park Service to administer National Parks. In this act Congress specifically directs the Park Service to conserve natural values and to prevent their impairment. Modern interpretations of the act assume that principles of ecosystem management will be applied. Such principles require the maintenance of fully functional ecological systems of which large predators like grizzly bears are integral components. This interpretation precludes the Park Service from engaging in any activity that would result in the loss or substantial diminishment of any native species in a National Park, including grizzly bears.

The Wilderness Act, 1964, 16 U.S.C. 1131- 1136. The Forest Service and National Park Service both manage lands designated or proposed as wilderness areas under the Wilderness Act of 1964 (16 U.S.C. 1131– 1136). Within these areas, the Wilderness Act states the following: (1) New or temporary roads cannot be built; (2) there can be no use of motor vehicles, motorized equipment, or motorboats; (3) there can be no landing of aircraft; (4) there can be no other form of mechanical transport; and (5) no structure or installation may be built. The Wilderness Act allows livestock allotments existing before the passage of the Wilderness Act and mining claims staked before January 1, 1984, to persist within Wilderness Areas, but no new grazing permits or mining claims can be established after these dates. If preexisting mining claims are pursued, the plans of operation are subject to Wilderness Act restrictions on road construction, permanent human habitation, and developed sites.

> ***<u>What it means to grizzly bears</u>***: Over 30% (1,728,184 acres; 6,994 sq km) of grizzly bear habitat inside the PCA is within Federal and Tribal Designated Wilderness Areas. As such, a large proportion of existing grizzly bear habitat is protected from direct loss or degradation by the prohibitions of the Wilderness Act. These Wilderness Areas are considered long-term secure habitat because they do not allow motorized access and are protected from new road construction, site developments, livestock allotments, mining claims, and energy development by Federal legislation.

Lacey Act, 16 U.S.C. § 3371 et seq. This Act makes it illegal to import, export, transport, sell, receive, acquire, or purchase any fish or wildlife or plant taken or possessed in violation of any law, treaty or regulation of the United States or in violation of any Indian Tribal law; and to import, export, transport, sell, receive, acquire, or purchase in interstate or foreign commerce any fish or wildlife taken, possessed, transported, or sold in violation of any law or regulation of any state or in violation of any foreign law. 18 U.S.C. §§42-43.

> ***<u>What it means to grizzly bears</u>***: The primary focus of the Lacey Act is the prohibition of interstate and international trafficking in protected wildlife. In the absence of ESA protection, other State, Federal, and Tribal laws remain that endeavor to protect grizzly bears or regulate hunting of the bears. Therefore, the species would continue to be protected by provisions specified under the Lacey Act because it is tied to the wildlife-related laws of Montana, Canada, and Tribal entities. Violators of the Lacey Act can face civil fines up to $10,000, forfeiture of wildlife and equipment, and criminal penalties up to five years' incarceration and maximum fines of $250,000 for individuals and $500,000 for organizations. There have been several instances of convictions in North America due to violations of the Lacey Act with regard to grizzly bears. These violations included illegal purchase of live bears, selling bear gall bladders, improper tagging of harvested bears, and illegal killing of bears. The Lacey Act will continue to apply to individuals or parties involved in such activities regardless of the status of grizzly bears under the ESA.

Fish and Wildlife Coordination Act, 16 U.S.C. §661-666c. This Act relates to wildlife associated with water resource development. This Act also authorizes that lands and waters may be acquired by Federal construction agencies for wildlife conservation to mitigate water projects in order to preserve and assure for the public benefit the wildlife potential of the particular water project area.

> ***<u>What it means to grizzly bears</u>***: The Fish and Wildlife Coordination Act requires that fish and wildlife conservation be given equal consideration with other aspects of water resource development. Consultation with USFWS is required if any modification of a stream or other water body is proposed by an agency under a Federal permit or license. In the absence of ESA protection, potential impacts to grizzly bears from a proposed project would still need to be evaluated. This Act also authorizes the preparation of plans to protect wildlife resources in the event that a water resource development project is undertaken. For example, mitigation plans

for hydroelectric projects within the range of the grizzly bear must consider potential impacts to the species and recommend mitigation measures. If any water resource development projects are proposed that have the potential to impact grizzly bears in the area, those impacts must be addressed.

National Wildlife Refuge Administration Act and 1997 Refuge Improvement Act. 16 U.S.C. §668dd et seq. The charter for the refuge system establishes a clear statutory goal of conservation, defined in ecological terms. The USFWS is directed by statutory mission to sustain, restore and enhance healthy populations of fish, wildlife, and plants on system lands. The USFWS may not permit uses to occur where they are incompatible with the conservation purpose of the system and economic uses must contribute to attaining the conservation mission. Statues require the USFWS to maintain "biological integrity, diversity, and environmental health" on the refuges.

What it means to grizzly bears: The mission of the refuge system is conservation, defined as being for animals, plants, and their habitats. This is in contrast to the more complex multiple-use, sustained yield missions that also seek to provide commodities extracted from other public lands. Further, by statue, the USFWS may not permit uses to occur where they are incompatible with conservation of wildlife and their habitat. These laws provide strong protections for grizzly bears and their habitat where they occur on refuge lands. In the PCA and Zone 1, the refuge system includes 22,072 acres of land.

Sikes Act, 16 U.S.C. §670g. The Secretaries of Agriculture and Interior and the State agencies will cooperate with the Department of Defense under this Act to plan, develop, maintain, and coordinate programs for the conservation and rehabilitation of wildlife, fish and game. These programs shall include, but not be limited to, specific habitat improvements projects and related activities and provide adequate protection for species considered threatened or endangered pursuant to Section 4 of the ESA.

What it means to grizzly bears: The Sikes Act requires the Department of Defense to develop and implement integrated natural resource management plans for U.S. military installations. Plans must consider fish, wildlife, and habitat needs; and are prepared in cooperation with the USFWS and state wildlife agencies. In the absence of ESA protection for the grizzly bear, requirements under the Sikes Act would still need to be met. The nearest major installations are Malmstrom Air Force Base in Great Falls, Montana and Fairchild Base near Spokane, Washington. Smaller facilities include Fort Missoula near Missoula, Montana and Fort William Henry Harrison near Helena, Montana. Resource plans for these installations that may have impacts on grizzly bears have been and will continue to be reviewed under the Sikes Act, post-delisting.

Multiple Use Sustained Yield Act, 16 U.S.C. §§528-531. It is the policy of the Congress that the National Forests are established and shall be administered for outdoor recreation, range, timber, watershed and wildlife and fish purposes. As used in this Act, "Multiple Use" means the management of all the various resources of the National Forests so that they are utilized in the combination that will best meet the needs of the American people. It requires National Forests to make the most judicious use of the land for some or all of these resources or related services over areas large enough to provide sufficient latitude for periodic adjustments in use to conform to changing needs and conditions. It allows for some land to be used for less than all of its resources while institutionalizing coordinated management of the various resources, without impairment of the productivity of the land, with consideration being given to the relative values of the various resources. It also allows management for multiple uses that may not necessarily provide the greatest dollar return or the greatest unit output.

> ***What it means to grizzly bears***: This means that while grizzly bear habitat will be managed according to the intent of this Conservation Strategy, the USFS must also balance the needs of grizzly bears with a combination of other, sometimes competing, land uses. The Multiple Use Sustained Yield Act applies to lands managed by the USFS, or approximately 60.9% (3,840,415 acres) of the PCA within the NCDE.

National Environmental Policy Act, 42 U.S.C. §§ 4321-4370(f) (NEPA). NEPA applies to federal agencies and requires those agencies to consider the environmental impacts of its decisions before taking federal actions. It requires agencies to take a "hard look" at the projected environmental impacts of a proposed action. The twin goals of NEPA are to provide for informed decision-making about the environmental effects of proposed actions and to make known those impacts to the public so that their views may be expressed. NEPA is a procedural statute. It does not dictate a result. Agencies must consider a range of alternatives to a proposed project, each with different levels of impacts. In addition to public review, NEPA requires federal agencies to coordinate or consult with each other prior to making decisions.

> ***What it means to grizzly bears***: NEPA ensures that any project occurring on federally managed lands, requiring Federal permits or involving expenditures of Federal funds will involve analysis and disclosure of potential environmental impacts. It uses a multidisciplinary approach to consider environmental effects in federal government agency decision making. It applies to a wide range of land use actions, including most land use plan revisions and amendments. It ensures that impacts to wildlife, including grizzly bears, from activities proposed on National Forest or other Federal lands will be analyzed in advance. It also ensures that decisions will be subject to some level of public review.

Endangered Species Act, 16 U.S.C. § 1531-1599. (**ESA**) The ESA requires the Secretary of the Interior to list species that are either endangered or threatened with extinction. The listing determination is based on the analysis of five factors. . If one or more of those criteria are met, it qualifies for listing as threatened or endangered. Listed species receive legal protection against "taking," which includes harassment, harm, hunting, killing and significant habitat modification or degradation. A major goal of the ESA is to recover endangered or threatened species to the point they can be removed from the list. In order to delist a species, the USFWS must review those same five factors to determine whether any one of them continues to threaten or endanger a species. Thus, the USFWS must find that: a) the species' habitat or range is not threatened with destruction, modification or curtailment, b) the species is not being over utilized for commercial, recreational, scientific or educational purposes, c) disease and predation are not significant problems, d) there are adequate regulatory mechanisms in place, and e) there are no significant other natural or manmade factors affecting the continued existence of the species. The USFWS must monitor recovered species for not less than five years after the species is delisted and no longer protected under the ESA. Both listing and delisting decisions must be based solely on the best available scientific and commercial information regarding a species' status, without reference to economic or other factors. The ESA authorizes a landowner to develop an HCP to minimize and mitigate, to the maximum extent practicable, any impact to threatened and endangered species while conducting lawful activities on their lands. An HCP may continue to apply even after a species is delisted. The USFWS has the authority to issue emergency regulations any time there is a significant risk to the well-being of an animal. Emergency rules may take effect immediately upon publication in the Federal Register. The emergency rule must explain in detail the reasons why such a regulation is necessary. The USFWS must withdraw the rule if it determines it is no longer necessary, based on the best scientific and commercial data available.

> ***What it means to grizzly bears***: The ESA governs the process for listing and delisting. If grizzly bears are removed from the Federal List of Threatened and Endangered Wildlife (i.e., "delisted"), the USFWS will continue to monitor the status of grizzly bears in the NCDE. Any HCP developed while grizzly bears were listed remains in effect for the life of the Plan, regardless of listed status. The USFWS must respond to any petitions for re-listing received and maintains the authority to emergency re-list at any other time if conditions warrant.

National Forest Management Act (NFMA) of 1976, 16 U.S.C. § 1600, et seq. NFMA provides the legal basis and direction for development of National Forest Resource Management Plans. It legally requires that standards in Forest Plans are met. NFMA specifies that the National Forest System be managed to provide for diversity of plant and animal communities to meet multiple use objectives. Subsequent regulations for planning land and resource management (36 CFR 219), adopted in 1982 and modified in 2012 (77 FR 21162, April 9, 2012), require the USFS to manage habitats to maintain viable populations of species of conservation concern. NFMA applies to lands managed by the USFS, or approximately 60.9% (3,840,415 acres) of the PCA within the NCDE.

> ***What it means to grizzly bears***: This directs the USFS to create legally binding Land Management Plans that can regulate human activities (i.e., motorized route densities, developed sites, livestock allotments) on National Forest lands. Limiting these activities is the crux of successful grizzly bear habitat management and directly reduces human-caused mortality.

Federal Land Policy and Management Act (FLPMA) of 1976. This law applies to BLM lands and states they will be managed in a manner that will protect the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resource, and archeological values...that will provide food and habitat for fish and wildlife and domestic animals, and that will provide for outdoor recreation and human occupancy and use. FLPMA is also the law that gives the BLM authority to designate "Wilderness Study Areas" on their lands and manage these areas "in a manner so as not to impair the suitability of such areas for preservation as wilderness." Similar to the Wilderness Act of 1964, FLPMA allows "the continuation of existing mining and grazing uses and mineral leasing" which were in existence on or before October 21, 1976. 43 U.S.C. §§ 1701-1777.

<u>What it means to grizzly bears</u>: Grizzly bears are a natural resource that fall under the FLPMA's umbrella of management guidelines which decrees that the resources required by grizzlies, and other species, will be provided for through appropriate management and with consideration for other land assets. The BLM will manage the natural elements that are necessary for grizzlies and other wildlife.

Fish and Wildlife Improvement Act, 16 U.S.C. § 742(a). This law authorizes the Secretaries of the Interior and Commerce to establish, conduct, and assist with national training programs for State fish and wildlife law enforcement personnel. It also authorized funding for research and development of new or improved methods to support fish and wildlife law enforcement. The law provides authority to the Secretaries to enter into law enforcement cooperative agreements with State or other Federal agencies, and authorizes the disposal of abandoned or forfeited items under the fish, wildlife, and plant jurisdictions of these Secretaries. It strengthens the law enforcement operational capability of the Service by authorizing the disbursement and use of funds to facilitate various types of investigative efforts. It expanded the use of fines, penalties and forfeiture funds received under the ESA and the Lacey Act to include the costs of shipping, storing and disposing of items. It specifically prohibits the sale of items whose sale is banned under other laws.

<u>What it means to grizzly bears</u>: Law enforcement cooperative agreements between Federal agencies, Montana and the Tribes will assist in efforts to control illegal activities directed at grizzly bears.

The National Parks Omnibus Management Act of 1998, 16 U.S.C. § 5901, et seq. This Act requires the Secretary of Interior to improve management, protection, interpretation and research of NPS resources. It also requires the Secretary to develop comprehensive training for NPS employees. It identifies the need to enhance management and protection of national park resources by providing clear authority and direction for the conduct of scientific study in the National Park system and to use the information gathered for management purposes.

<u>What it means to grizzly bears</u>: *This law provides further support for GNP to use scientific research to monitor and manage grizzlies within their boundaries*.

Tax Relief and Health Care Act of 2006, PL 109-432. This law withdrew lands on the Lewis and Clark National Forest and some areas of the Flathead National Forest from any future leasing under the mining laws and mineral leasing laws permanently. While this law prohibited the establishment of new leases, it did not eliminate leases that existed at the time the law was passed.

<u>What it means to grizzly bears</u>: This law means that nearly all USFS and BLM lands in the NCDE with a high potential for oil and gas development are legally unavailable to such development (Figure 3).

National Indian Forest Resource Management Act (25 U.S.C, Ch. 33). This Federal law requires a forest management plan for Indian forest lands to describe the manner in which policies of the Tribes and Secretary will be applied. It requires the silviculture plan to support the objectives of beneficial landowners and be based on the principle of sustained yield. It requires the approval of the Secretary of the Interior.

> ***<u>What it means to grizzly bears</u>***: Similar to NFMA for the USFS, this law provides authority for Indian Tribes to create management plans to regulate human activities such as livestock grazing (on forested lands) and road construction.

Clean Water Act, Safe Drinking Water Act, Clean Air Act, and Resource Conservation and Recovery Act

> ***<u>What it means to grizzly bears</u>***: Together, these environmental laws provide tangential benefits to grizzly bears by assuring minimum levels of environmental quality are maintained.

FEDERAL REGULATIONS

Roadless Areas Conservation Rule, 2001. The 2001 Roadless Areas Conservation Rule prohibits road construction, road re-construction, and timber harvest in Inventoried Roadless Areas (66 FR 3244-3273, January 12, 2001).

> ***<u>What it means to grizzly bears</u>***: As it stands at the time of writing, the Roadless Areas Conservation Rule (and subsequent Court decisions) effectively ensures that Inventoried Roadless Areas will be maintained in their current state in terms of road access. This means these areas will continue to serve as secure areas for grizzlies away from constant or prolonged human presence. This restriction on road building makes mining activities and oil and gas production much less likely because access to these resources becomes cost-prohibitive or impossible without new roads.

25 CFR 162.1 to .623. This Federal regulation describes the authorities, policies, and procedures governing the granting of leases on Indian reservations.

> ***<u>What it means to grizzly bears:</u>*** It affects grizzly bear conservation by providing for the regulation of the location and duration of leases of grazing units on land that contains grizzly bears and bear habitat.

25 CFR 166.1. This Federal regulation describes the authorities, policies, and procedures the Bureau of Indian Affairs uses to approve, grant, and administer permits for grazing livestock on Tribal land, individually-owned Indian land, or government land on Indian reservations.

> ***<u>What it means to grizzly bears</u>***: It affects grizzly bear conservation by regulating livestock grazing on land that contains grizzly bears and bear habitat.

36 CFR 1.2 (d). The regulations contained in 36 CFR parts 2 through 5, part 7, and part 13 of this section shall not be construed to prohibit administrative activities conducted by the National Park Service, or its agents, in accordance with approved general management and resource management plans, or in emergency operations involving threats to life, property, or park resources.

<u>What it means to grizzly bears</u>: Allows the NPS to manage grizzly bears and conduct research and management activities that would otherwise be prohibited.

36 CFR 1.5 (a)(1). Gives National Park Superintendents the authority to establish for all or a portion of a park area a reasonable schedule of visiting hours, impose public use limits, or close all or a portion of a park area to all public use or to a specific use or activity in order to protect natural resources or provide for human safety.

<u>What it means to grizzly bears</u>: Gives park superintendents the authority to limit specific activities, or human use of areas important to grizzly bears to prevent conflicts. 36 CFR 1.3 provides penalties for violations.

36 CFR 1.5 (a)(2). Gives National Park Superintendents the authority to designate areas for a specific use or activity, or impose conditions or restrictions on a use or activity.

<u>What it means to grizzly bears</u>: Allows superintendents to prohibit or restrict park uses that threaten grizzly bear security or other values, with penalties for violations.

36 CFR 1.7(b). National Park Service Superintendents shall publish in writing all designations, closures, permit requirements and other restrictions imposed under discretionary authority.

<u>What it means to grizzly bears</u>: This is the 'Superintendents Compendium' and is a legal record of Glacier National Park committing to management of grizzly bears by this Conservation Strategy.

36 CFR 2.2(a)(1). Prohibits the unauthorized taking of wildlife in National Parks.

<u>What it means to grizzly bears</u>: It protects grizzly bears by making it a Federal offense to kill them inside a National Park.

36 CFR 2.2(a)(2). Prohibits the feeding, touching, teasing, frightening, or intentional disturbing of wildlife in National Parks.

<u>What it means to grizzly bears</u>: This regulation is an effective way to minimize human-caused grizzly bear mortalities by making it illegal to contribute to their habituation or food-conditioning inside National Parks. This ultimately prevents conflicts and minimizes potential management removals.

36 CFR 2.10 (d). Gives the National Park Superintendents authority to designate all or a portion of a park area where food, lawfully taken fish or wildlife, garbage and equipment used to cook or store food must be kept to avoid bear/human conflicts. This restriction does not apply to food that is being transported, consumed, or prepared for consumption.

<u>What it means to grizzly bears</u>: This regulation provides National Parks the authority to implement and enforce food storage regulations. This important conflict prevention tool is widely applied throughout bear habitat and is strictly enforced.

36 CFR 219. This regulation specifies that the National Forest System be managed to provide for diversity of plant and animal communities to meet multiple use objectives. Subsections require that management prescriptions in Forest Land Management Plans provide for diversity of plant and animal communities while meeting multiple use objectives and maintaining viable populations of existing native and desired non-native vertebrate species in the planning area. A viable population is defined as one, which has the estimated numbers, and distribution of reproductive individuals to insure its continued existence is well distributed in the planning area.

> ***What it means to grizzly bears***: This regulation legally requires the USFS to design projects and include appropriate mitigation measures so that the viability of the grizzly bear population in the NCDE is not compromised.

36 CFR 261.50 (a) and (b). This regulation gives Forest Supervisors the authority to issue orders which close or restrict the use of described areas, or of any forest development road or trail within the area over which he has jurisdiction.

> ***What it means to grizzly bears***: This authority is used to close areas to minimize grizzly bear-human conflicts and to issue food storage, carcass storage and camping requirements.

36 CFR 261.53 (a) and (e). States that when provided for in an order authorized under 36 CFR 261.50 (a) and (b) it is prohibited to go into or be upon any area which is closed for the protection of: (a) threatened, endangered, rare, unique, or vanishing species of plants, animals, birds or fish or; (b) for public health or safety.

> ***What it means to grizzly bears***: This regulation provides the USFS with the authority to restrict human activities and entrance at specific times and/or locations to protect grizzly bears and provide for public safety, if it is deemed necessary.

36 CFR 261.58 (e) and (s) and (cc). States that when provided for in an order authorized under 36 CFR 261.50 (a) and (b) the following are prohibited. (a) Camping; (s) Possessing, storing, or transporting any bird, fish, or other animal or parts thereof as specified in the order; (cc) Possessing or storing any food or refuse, as specified in the order.

> ***What it means to grizzly bears***: This regulation provides for restricting certain human activities in order to minimize grizzly bear-human conflicts and provides for visitor safety

TRIBAL LAWS, RULES, & ORDINANCES

Blackfeet Indian Reservation

> **Tribal Ordinance 40(B)** – Timber Use Policy Statement with attached Timber Product Law. The Policy Statement is the driving document regulating the harvest of forest products on the Reservation. The Product Law specifies the enforcement procedures and penalties for failing to comply with Tribal regulations.

What it means to grizzly bears: This Ordinance provides Tribal authorities the authority to enforce conditions in their Forest Management Plans regarding road densities, food storage, and other provisions associated with individual projects. Ultimately, this reduces the potential for grizzly bear-human conflicts and therefore, human-caused grizzly bear mortality.

Constitution and By-Laws For the Blackfeet Tribe of the Blackfeet Indian Reservation of Montana, Article VI Section 1(p). This section of the Blackfeet Tribe's constitution grants the Blackfeet Tribal Business Council the power to promulgate rules and regulations governing hunting, fishing, and trapping on the Blackfeet Reservation

***What it means to grizzly bears*:** It is significant to grizzly bear conservation because it gives the Blackfeet Tribal Business Council the authority to govern hunting of grizzly bears on the Blackfeet Reservation. The constitution is enforced by the Blackfeet Tribe and recognized and approved by the Secretary of Interior.

Fish and Game Rules to Govern Fishing, Hunting, and Trapping on the Blackfeet Indian Reservation. This document describes how all wildlife on the Blackfeet Indian Reservation, including grizzly bears, are owned and managed by the Blackfeet Tribe. It describes the authority of the Blackfeet Tribe to manage wildlife and habitat on the reservation. It contains regulations regarding food storage and killing grizzly bears. It describes penalties and enforcement procedures. It is enforced by Blackfeet Tribal Game Wardens.

***What it means to grizzly bears*:** It applies to grizzly bear conservation by providing the legal basis to regulate and enforce the take of grizzly bears on the reservation and implementing a food storage order.

Flathead Indian Reservation

Tribal Ordinance 44D – Tribal Hunting and Fishing Conservation Ordinances

What it means to grizzly bears: This ordinance prohibits hunting of grizzly bears on the FIR by anyone except Tribal members. Hunts for religious, cultural or spiritual purposes that are otherwise prohibited by regulation may be engaged in if approved by the appropriate Tribal Culture Committee and/or the Tribal Council.

MONTANA STATE LAWS (MCAs) & ADMINISTRATIVE RULES (ARMs)

MCA § 87-1-217. Policy for management of large predators -- legislative intent.

(1) In managing large predators, the primary goals of the department, in the order of listed priority, are to:
   (a) protect humans, livestock, and pets;
   (b) preserve and enhance the safety of the public during outdoor recreational and livelihood activities; and
   (c) preserve citizens' opportunities to hunt large game species.

(2) As used in this section:
  (a) "large game species" means deer, elk, mountain sheep, moose, antelope, and mountain goats; and
  (b) "large predators" means bears, mountain lions, and wolves.

(3) With regard to large predators, it is the intent of the legislature that the specific provisions of this section concerning the management of large predators will control the general supervisory authority of the department regarding the management of all wildlife.

(4) The department shall ensure that county commissioners and tribal governments in areas that have identifiable populations of large predators have the opportunity for consultation and coordination with state and federal agencies prior to state and federal policy decisions involving large predators and large game species.

What it means to grizzly bears: This rule provides for local government involvement in large scale decision making relative to MFWP management of predators. Local support and tolerance of grizzly bears is critical to long term grizzly conservation.

MCA § 87-1-301. *(Effective March 1, 2012)* . Powers of the MFWP commission. The commission shall set the policies for the protection, preservation, management, and propagation of the wildlife, fish, game, furbearers, waterfowl, nongame species, and endangered species of the state and for the fulfillment of all other responsibilities of the department [MFWP] as provided by law. The commission shall also establish the hunting, fishing, and trapping rules of the department [MFWP] and review and approve the budget of the department prior to its transmittal to the budget office. The commission has the authority to establish wildlife refuges, bird, and game preserves and is responsible to establishing the rules of the department governing the use of lands owned or controlled by the department and waters under the jurisdiction of the department.

What it means to grizzly bears: Allows MFWP to manage grizzly bears as part of the suite of wildlife within the state with the goal of species protection and preservation.

MCA § 87-1-303. Rules for use of lands and waters. The commission may adopt and enforce rules governing uses of lands that are acquired or held under easement by the commission or lands that it operates under agreement with or in conjunction with a federal or state agency or private owner; adopt and enforce rules governing recreational uses of all public fishing reservoirs, public lakes, rivers, and streams that are legally accessible to the public or on reservoirs and lakes that it operates under agreement with or in conjunction with a federal or state agency or private owner. These rules must be adopted in the interest of public health, public safety, public welfare, and protection of property and public resources in regulating ….hunting, fishing, trapping….picnicking, camping, sanitation, and use of firearms.

What it means to grizzly bears: *Provides authority to the MFWP Commission to set mandatory food storage orders on state owned and/or managed lands in the interest of public safety, public welfare and protection of property.*

MCA § 87-1-304. *(Effective March 1, 2012)* . Fixing of seasons and bag and possession limits. Subject to the provisions of 87-5-302, the MFWP commission may:

(1) fix seasons, bag limits, possession limits, and season limits;
(2) open or close or shorten or lengthen seasons on any species of game, bird, fish, or fur-bearing animal as defined by 87-2-101;
(3) declare areas open to the hunting of deer, antelope, elk, moose, sheep, goat, mountain lion, bear, wild buffalo or bison, and wolf by persons holding an archery stamp and the required license, permit, or tag and designate times when only bows and arrows may be used to hunt deer, antelope, elk, moose, sheep, goat, mountain lion, bear, wild buffalo or bison, and wolf in those areas;
(4) subject to the provisions of 87-1-301(7), restrict areas and species to hunting with only specified hunting arms, including bow and arrow, for the reasons of safety or of providing diverse hunting opportunities and experiences; and
(5) declare areas open to special license holders only and issue special licenses in a limited number when the commission determines, after proper investigation, that a special season is necessary to ensure the maintenance of an adequate supply of game birds, fish, or animals or fur-bearing animals. The commission may declare a special season and issue special licenses when game birds, animals, or fur-bearing animals are causing damage to private property or when a written complaint of damage has been filed with the commission by the owner of that property. In determining to whom special licenses must be issued, the commission may, when more applications are received than the number of animals to be killed, award permits to those chosen under a drawing system. The procedures used for awarding the permits from the drawing system must be determined by the commission.
(6) The commission may adopt rules governing the use of livestock and vehicles by archers during special archery seasons.
(7) Subject to the provisions of 87-5-302, the commission may divide the state into fish and game districts and create fish, game, or fur-bearing animal districts throughout the state. The commission may declare a closed season for hunting, fishing, or trapping in any of those districts and later may open those districts to hunting, fishing, or trapping.
(8) The commission may declare a closed season on any species of game, fish, game birds, or fur-bearing animals threatened with undue depletion from any cause. The commission may close any area or district of any stream, public lake, or public water or portions thereof to hunting, trapping, or fishing for limited periods of time when necessary to protect a recently stocked area, district, water, spawning waters, spawn-taking waters, or spawn-taking stations or to prevent the undue depletion of fish, game, fur-bearing animals, game birds, and nongame birds. The commission may open the area or district upon consent of a majority of the property owners affected.
(9) The commission may authorize the director to open or close any special season upon 12 hours' notice to the public.

<u>What it means to grizzly bears</u>*:* This law provides authority to the MFWP commission to set rules and regulations for grizzly bear hunting. The MFWP commission has the authority to: fix, open, close, lengthen, or shorten hunting seasons; declare hunting arms specifications; set possession and bag limits; set tagging and license requirements; set shooting hours; open special areas, and issue special licenses to manage grizzly bears through sport harvest. The Commission process requires opportunity for public involvement.

MCA § Section 87-5-301. ***(Effective March 1, 2012)*****. Grizzly bear -- findings -- policy.** The legislature finds that: (a) grizzly bears are a recovered population and thrive under responsive cooperative management; (b) grizzly bear conservation is best served under state management and the local, state, tribal, and federal partnerships that fostered recovery; and (c) successful conflict management is key to maintaining public support for conservation of the grizzly bear. It is the policy of the state of Montana to: (a) manage the grizzly bear as a species in need of management to avoid conflicts with humans and livestock; and (b) use proactive management to control grizzly bear distribution and prevent conflicts, including trapping and lethal measures.

> ***<u>What it means to grizzly bears</u>****:* Allows state management of grizzlies as a classified species. Grizzly bears are currently dually classified in Montana as a game animal with no defined harvest season and as a 'species in need of management'. A 'species in need of management' classification implies the species is either in need of intense conservation or population management.

MCA § Section 87-5-302. ***(Effective March 1, 2012)*** **. Commission regulations on grizzly bears.** The commission has the authority to regulate the hunting of grizzly bears including establishing requirements: for the tagging of carcasses, skulls, and hides; for transportation, exportation, and importation. The commission shall establish hunting season quotas for grizzlies that will prevent the population of grizzly bears from decreasing below sustainable levels and with the intent to meet population objectives for elk, deer, and antelope. The provisions of this subsection do not affect the restriction provided in 87-2-702 that limits a person to the taking of only one grizzly bear in Montana per license.

> ***<u>What it means to grizzly bears</u>***: This law provides authority to the MFWP Commission to set rules and regulations for tagging, transportation, exportation, and importation of legally harvested grizzly bears and ensures that any hunting seasons set by the MFWP Commission will not contribute to the grizzly bear population decreasing below sustainable levels.

MCA § Section 87-2-101. **Definitions**. "Game animals" means deer, elk, moose, antelope, caribou, mountain sheep, mountain goat, mountain lion, bear, and wild buffalo.

> ***<u>What it means to grizzly bears</u>****:* Classifying grizzly bears as a game animal in Montana gives MFWP Commission the authority to implement a hunting season. Classification as a game animal also makes it illegal for private citizens to kill a grizzly bear without a license and outside the seasons set by the MFWP Commission. In other words, status as a game animal prevents unregulated take by citizens.

MCA § 87-6-202. Unlawful possession, shipping, or transportation of game fish, bird, game animal, or fur-bearing animal. A person may not possess, ship, or transport all or part of any game fish, bird, game animal, or fur-bearing animal that was unlawfully killed, captured, or taken, whether killed, captured, or taken in Montana or outside of Montana.

> ***What it means to grizzly bears**:* This law makes it illegal to possess any unlawfully obtained part of a grizzly bear.

MCA § 87-6-206. Unlawful sale of game fish, bird, game animal, or fur-bearing animal. A person may not purposely or knowingly sell, purchase, or exchange all or part of any game fish, bird, game animal, or fur-bearing animal..

> ***What it means to grizzly bears**:* This law makes it illegal to sell any unlawfully obtained part of a grizzly bear.

MCA § 87-6-106. Lawful taking to protect livestock or person. This law states that a citizen may kill a grizzly bear if it is "…attacking, killing, or threatening to kill a person." However, for purposes of protecting livestock, a person may not kill or attempt to kill a grizzly bear unless the grizzly bear is in the act of attacking or killing livestock." A person who takes wildlife based on this law shall notify the MFWP within 72 hours and shall surrender or arrange to surrender the wildlife to MFWP.

> ***What it means to grizzly bears**:* By making a distinction between grizzly bears and other wildlife which may kill livestock, the State of Montana has provided additional protection to grizzly bears. It makes this type of killing only allowed under extremely rare circumstances. Additionally, if a person kills a grizzly bear based on this law, there must be injured or dead livestock associated with it.

MCA § 87-6-216. Unlawful supplemental feeding.

(1) A person may not provide supplemental feed attractants to game animals by:
   a. purposely or knowingly attracting any cloven-hoofed ungulates, bears, or mountain lions with supplemental feed attractants;
   b. after having received a previous warning, negligently failing to properly store supplemental feed attractants and allowing any cloven-hoofed ungulates, bears, or mountain lions access to the supplemental feed attractants; or
   c. purposely or knowingly providing supplemental feed attractants in a manner that results in an artificial concentration of game animals that may potentially contribute to the transmission of disease or constitute a threat to public safety.

(2) A person is not subject to civil or criminal liability under this section if the person is engaged in:
   a. the normal feeding of livestock;
   b. a normal agricultural practice;
   c. cultivation of a lawn or garden;
   d. the commercial processing of garbage; or

e. recreational feeding of birds unless, after having received a previous warning by the department, the person continues to feed birds in a manner that attracts cloven-hoofed ungulates or bears and that may contribute to the transmission of disease or constitute a threat to public safety.

(3) This section does not apply to supplemental feeding activities conducted by the department for disease control purposes.

(4) A person convicted of a violation of this section shall be fined not less than $50 or more than $1,000 or be imprisoned in the county detention center for not more than 6 months, or both. In addition, the person, upon conviction or forfeiture of bond or bail, may be subject to forfeiture of any current hunting, fishing, or trapping license issued by this state and the privilege to hunt, fish, or trap in this state or to use state lands, as defined in 77-1-101, for recreational purposes for a period of time set by the court.

> ***<u>What it means to grizzly bears</u>****:* This law provides MFWP with a legal framework within which to regulate attractant storage on private lands. It means that MFWP has a legal basis to require landowners to store attractants in a manner in which bears cannot access them.

MCA § 87-2-702: **Restrictions on special licenses -- availability of bear and mountain lion licenses.** "A person who has killed or taken any game animal, except a deer, an elk, or an antelope, during the current license year is not permitted to receive a special license under this chapter to hunt or kill a second game animal of the same species. The [MFWP] commission may require applicants for special permits authorized by this chapter to obtain a valid big game license for that species for the current year prior to applying for a special permit. A person may take only one grizzly bear in Montana with a license authorized by 87-2-701."

> ***<u>What it means to grizzly bears</u>****:* Sport harvest is limited by rules set forth by the MFWP Commission. Legislative action would be required to change this restriction in any future season setting process.

MCA § Title 75, Chapter 1. Montana Environmental Policy Act. Establishes policy of the State of Montana to use all practicable means and measures to create and maintain conditions under which man and nature can coexist in productive harmony.

> ***<u>What it means to grizzly bears</u>***: This policy, similar to NEPA, is procedural in nature and assures that any project proposed by the state of Montana in grizzly bear habitat will consider, in detail, the impacts to grizzly bears. It establishes the requirement for the State of Montana to consider the environmental effects of each project and allow public input.

MCA § Title 77, Chapter 1. Administration of State Lands. Directs the State board of land commissioners to manage State lands to support education and for the attainment of other worthy objectives helpful to the well-being of the people of Montana. It further directs the board to manage State lands under the multiple use management concept to ensure: (1) they are utilized in that combination best meeting the needs of the people and the beneficiaries of the trust; and (2) harmonious and coordinated management of the various resources.

What it means to grizzly bears: This law means that lands managed by DNRC must be economically viable while balancing the needs of grizzly bears.

Administrative Rule of Montana (ARM) **12.9.103**. **Grizzly Bear Policy**. Whereas, the Montana Fish and Game Commission has management authority for the grizzly bear, a resident wildlife species, and is dedicated to the preservation of grizzly bear populations within the State of Montana; and
Whereas the secure habitat for the grizzly has been greatly reduced as a result of human development and population growth from 1850 through 1950 in the bear's traditional range in all western States; and
Whereas, a significant portion of the remaining grizzly bear habitat and population is located in Montana and these Montana populations occur in wildlands such as wilderness, primitive areas, de facto wilderness areas, national forests, national parks, Indian reservations, and seasonally, on adjacent private lands.
Now, therefore, in order to promote the preservation of the grizzly bear in its native habitat, the commission establishes the following policy guidelines for the Montana Department of Fish, Wildlife and Parks action when dealing with grizzly bear.

(a) Habitat. The department shall work to perpetuate and manage grizzly bear in suitable habitats of this State for the welfare of the bear and the enjoyment of the people of Montana and the nation. In performing this work the department should consider the following:
  (i) the commission has the responsibility for the welfare of the grizzly and advocates the protection of the bear's habitat;
  (ii) management of Montana's wildlands, including the grizzly bear habitat, is predominately, but not exclusively, a responsibility of various Federal agencies and private landowners;
  (iii) land use decisions made by these agencies and individuals affect grizzly bear habitat, thus cooperative programs with these agencies and individuals are essential to the management of this species;
  (iv) preservation of wildlands is critical to the protection of this species and the commission advocates wildland preservation in occupied grizzly bear habitat; and
  (v) while some logging may not be detrimental to grizzly habitat, each logging sale in areas inhabited by grizzly bear should be carefully reviewed and evaluated.

(b) Research. It is recognized by the commission that research on the habitat requirements and population characteristics of the grizzly bear is essential for the welfare of the species. Departmental research programs and proposals directed at defining those habitat requirements are encouraged and supported.

(c) Hunting and recreational use. The commission recognizes its responsibility to consider and provide for recreational opportunities as part of a grizzly bear management program. These opportunities shall include legal hunting, recreational experiences, aesthetics of natural ecosystems, and other uses consistent with the overall welfare of the species.
  (i) the department should consider the variability of values between individuals, groups, organizations, and agencies when management programs for various grizzly bear populations are developed.

(ii) sport hunting is considered the most desirable method of balancing grizzly bear numbers with their available habitat, minimizing depredations against private property within or adjacent to grizzly bear habitat, and minimizing grizzly bear attacks on humans.

(d) Depredations. Contacts between grizzly bear and humans, or property of humans, require delicate handling and consideration. When these contacts reach the stage for definite action, the following actions should be carried out:

(i) grizzly bear, in the process of threatening or endangering human life, shall be captured or dispatched immediately.

(ii) where no immediate threat to human life exists, individual bear encounters with humans shall be evaluated on a case by case basis and when the attack is abnormal or apparently unprovoked, the individual bear involved shall be captured or dispatched.

(iii) when the attack is normal (e.g., a female defending her cubs, any bear defending its food, or any bear defending itself) but the situation leads itself to no reasonable possibility of leaving the bear in place, then the bear should be removed.

(iv) grizzly bear committing depredations that do not directly endanger human life but that are causing property losses shall be evaluated on an individual case basis.

(v) where removal is determined to be the best resolution to the problem, depredating or nuisance bear shall be trapped, and if determined to be suitable for transplanting, shall be marked and released in suitable habitat previously approved with appropriate land management agencies.

(vi) reasonable efforts shall be made to inform the public of the transplant program, fully explaining the reasons for the capturing and locations of the release area. A bear 'relocation page' was created for the MFWP webpage in 2011 in the interest of public notification of all instances in which grizzly or black bears are captured and relocated. http://fwp.mt.gov/fishAndWildlife/livingWithWildlife/relocation/

(vii) upon request by an authorized scientific investigative agency or public zoological institution, a captured bear may be given to that agency or institution, for appropriate non release research purposes. A reasonable charge may be required to cover costs of handling.

(e) Depredating grizzly bear that are not suitable for release or research because of old age, acquired behavior, disease, or crippling, shall be killed and sent to the department's research facilities for investigation. The public shall be fully informed when these actions are taken and the reasons for these actions shall be fully explained

(f) Coordination. The department shall consult with appropriate Federal agencies and comply with applicable Federal rules and regulations in implementation of this policy. (History: Sec.87 1 301MCA, IMP, 87 1 201, 87 1 301 MCA; Eff. 12/31/72; AMD, 1977 MAR p.257, Eff. 8/26/77.)

<u>What it means to grizzly bears</u>: This policy guides decision making for grizzly bear conservation and management within the state of Montana with an overall goal to promote the preservation of the grizzly bear. It requires coordination with appropriate Tribal, Federal, State, and private entities and advocates protecting grizzly bear habitat.

Administrative Rule of Montana (**DNRC**) (ARM) 36.11.433 <u>GRIZZLY BEAR MANAGEMENT ON OTHER WESTERN MONTANA LANDS</u>. When conducting forest management activities on scattered lands administered by the Stillwater unit, Kalispell unit, Missoula unit and Clearwater unit, within the NCDE, and in Plains and Libby unit lands within the Cabinet-Yaak ecosystem, the department shall adhere to the following:

(a) Design projects to result in no permanent net increase of open road density on parcels that exceed an open road density of one mile per square mile using simple linear calculations. This shall apply only during the non-denning period. Temporary increases are permissible for up to two consecutive operating seasons. The department shall make efforts to reduce total road density when compatible with other agency goals and objectives.
(b) Retain cover that provides visual screening adjacent to open roads to the extent practicable.
(c) Maintain hiding cover where available along all riparian zones.
(d) Prohibit contractors and purchasers conducting contract operations from carrying firearms while operating.

Administrative Rule of Montana (**DNRC**) (ARM) 36.11.434 GRIZZLY BEAR MANAGEMENT ON EASTERN MONTANA LANDS. On Bozeman unit lands within the greater Yellowstone ecosystem, and Helena unit and Conrad unit lands within the NCDE, the department shall determine appropriate methods to comply with the Endangered Species Act, 16 U.S.C. Sections 1531 through 1544 and 77-5-116, MCA, on a project level basis. Factors to consider shall include, but not be limited to:

(a) cover retention;
(b) duration of activity;
(c) seasonal restrictions;
(d) hiding cover near riparian zones;
(e) food storage (where applicable); and
(f) road density.

What it means to grizzly bears: This policy requires that considerations and protective measures be incorporated into all forest management activities conducted on state trust lands in the areas specified. Affected lands occur in portions of the PCA, Zone 1 and Zone 2. These requirements supplement those contained in DNRC's habitat conservation plan and would be required for all applicable DNRC lands not covered under that agreement.

Montana Constitution. Article IX Environment and Natural Resources. Section 1 Protection and Improvement. The State and each person shall maintain and improve a clean and healthful environment in Montana for present and future generations.

What it means to grizzly bears: This Section provides tangential benefits to grizzly bears by assuring a minimal level of environmental quality on State lands and projects.

Montana Constitution. Article X, Section 2. Public school fund. The public school fund of the state shall consist of:
(1) Proceeds from the school lands which have been or may hereafter be granted by the United States,
(2) Lands granted in lieu thereof,
(3) Lands given or granted by any person or corporation under any law or grant of the United States,
(4) All other grants of land or money made from the United States for general educational purposes or

without special purpose,
(5) All interests in estates that escheat to the state,
(6) All unclaimed shares and dividends of any corporation incorporated in the state,
(7) All other grants, gifts, devises or bequests made to the state for general educational purposes.

> ***What it means to grizzly bears*:** This Section describes what lands belong to the State of Montana for management under Article X, Section 11 of the Constitution and the laws and administrative rules adopted there under.

Montana Constitution. Article X, Section 11. Public land trust, disposition. All lands of the state that have been or may be granted by congress, or acquired by gift or grant or devise from any person or corporation, shall be public lands of the state. They shall be held in trust for the people, to be disposed of as hereafter provided, for the respective purposes for which they have been or may be granted, donated or devised.
(2) No such land or any estate or interest therein shall ever be disposed of except in pursuance of general laws providing for such disposition, or until the full market value of the estate or interest disposed of, to be ascertained in such manner as may be provided by law, has been paid or safely secured to the state.
(3) No land which the state holds by grant from the United States which prescribes the manner of disposal and minimum price shall be disposed of except in the manner and for at least the price prescribed without the consent of the United States.
(4) All public land shall be classified by the board of land commissioners in a manner provided by law. Any public land may be exchanged for other land, public or private, which is equal in value and, as closely as possible, equal in area.

> ***What it means to grizzly bears*:** This Section requires that all State lands are held in trust and that full market payment must be made for any disposition of those lands. Thus, these considerations have the potential to influence land management policies of DNRC that may influence grizzly bears.

FEDERAL PLANS AND GUIDELINES

In addition to Federal and State laws and regulations, the following plans and guidelines provide both direction and guidance for grizzly bear population and/or habitat management.

National Park Service

> Glacier National Park released the **Bear Management Plan** and **Bear Management Guidelines** in May 2010 as guidance documents for managing grizzly bears. Sections in the Guidelines cover informing visitors and employees, preventive management actions, special bear management areas, preparing for management actions, and follow-up and evaluation of management actions.

> **NPS 77**, Natural Resource Management Guidelines, May 16, 1991. Guides National Park managers to perpetuate and prevent from harm (through human actions) wildlife populations as part of the natural ecosystems of parks.

Final Environmental Impact Statement, Grizzly Bear Management Program, Glacier National Park, July 1983:

- Identifies sanitation procedures designed to ensure that human foods and attractants are kept secured from bears. Garbage and other unnatural food attractants will be eliminated before control actions are required. The solid waste handling program will encompass use of trash containers of bear-resistant design, careful and frequent garbage pickup to prevent overflow and overnight accumulations.
- The Superintendent authorizes and approves the GNP Grizzly Bear Management Program that outlines the park's Bear Management Area Program. The Bear Management Area Program restricts recreational activity in areas with seasonal concentrations of grizzly bears. The goals of these restrictions include: (1) minimize bear/people interactions that may lead to habituation of bears to people (habituation can result in bears being removed from the population for human safety), (2) prevent human caused displacement of bears from prime food sources, and (3) decrease the risk of bear-caused human injury in areas with high levels of bear activity.
- Outlines Park bear monitoring program.
- Outlines Park bear research goals and objectives.
- Leaves open the possibility for supplemental feeding of grizzly bears, if deemed necessary.
- Identifies as an objective that public awareness of exposing bears to unnatural food sources may lead to human injury, or to the bears' destruction, or both. Requires an active information program be directed at both visitors and employees to inform them of policies and goals of bear management, and the reasons for these. Provides guidelines for the distribution of bear safety warning information through entrance stations, signs, visitor contacts, and literature.

U.S. Forest Service

If a change of status for the NCDE grizzly bear population under the ESA takes place, Forest Service Region 1 will classify the grizzly bear as a sensitive species in the NCDE area. Grizzly bears and their habitats will then be managed as sensitive on National Forest System lands in accordance with **Forest Service Manual 2670** (specifically 2670.22, 2670.32, and 2676.1 2676.17e). In addition, National Forests will continue to follow direction established in existing land management plans until amended or revised.

Beaverhead-Deerlodge Forest Land and Resource Management Plan (2009, with amendments)

Flathead Forest Land and Resource Management Plan (1986, with amendments)

Kootenai Forest Land and Resource Management Plan (1987, with amendments)

Lewis and Clark Forest Land and Resource Management Plan (1986, with amendments)

Helena Forest Land and Resource Management Plan (1986, with amendments)

Lolo Forest Land and Resource Management Plan (1986, with amendments)

Swan Valley Grizzly Bear Conservation Agreement is a collaborative document that guides management of multiple use lands owned by the USFS, the Nature Conservancy, and the DNRC in the upper Swan Valley that occur within USFWS identified linkage zones. It commits the signing parties to cooperatively manage motorized access and timber harvest on these lands so that there are not too many projects occurring simultaneously. Under ESA listed status, this Conservation Agreement was successfully implemented by all parties and all affected subunits met their criteria for motorized access management. The Conservation Agreement has a clause for automatic annual renewal and is still in place. These lands will continue to be managed to balance timber harvest with wildlife habitat security. Please see Ch. 3 ("Legacy Lands and Cooperative Habitat Management in the Swan Valley" section) or Appendix 7 (Swan Valley Grizzly Bear Conservation Agreement) for more detailed information about how this Conservation Agreement will continue to be implemented in the foreseeable future.

Bureau of Land Management

If a change of status for the NCDE grizzly bear population under the ESA takes place, the BLM will classify the grizzly bear as a sensitive species in the NCDE area. Currently, the Butte Field Office, Lewistown Field Office, and Missoula Field Office Resource Management Plans contain extensive guidelines that directly benefit grizzly bears and/or their habitat. While many of these are summarized in Ch. 3 (see the "Habitat Protections in Management Zone 1" or "Habitat Protections in Management Zone 2" sections), detailed descriptions are provided in Appendix 11 (Detailed summary of relevant BLM Management Plan direction for the Butte, Lewistown, and Missoula Field Offices).

STATE PLANS AND GUIDELINES

MFWP Grizzly Bear Management Plan for Western Montana. In 2006, MFWP released a management plan and final programmatic environmental impact statement (EIS) for grizzly bear management in 17 counties in western Montana that include the entire NCDE PCA, Zone 1, and Zone 2. The plan focuses on grizzly bear management in the Northern Continental Divide, Cabinet-Yaak, and Bitterroot Ecosystems, as well as intervening areas. The goal of this management plan is "To manage for a recovered grizzly bear population in western Montana and to provide for a continuing expansion of that population into areas that are biologically suitable and socially acceptable. This should allow MFWP to achieve and maintain population levels that support managing the bear as a game animal along with other species of native wildlife and provide some regulated hunting when and where appropriate." The Plan identifies management objectives, describes grizzly bear biology, provides strategies for reducing and responding to grizzly bear/human conflicts, and discusses both habitat and population monitoring needs.

DNRC State Forest Land Management Plan. The DNRC State Forest Land Management Plan was signed in May 1996 and provides specific resource management standards that apply to all forested state trust lands in Montana. The Plan contains specific standards that emphasize management of vegetation to promote biodiversity, and it includes habitat protection measures for endangered, threatened, and sensitive species. The resource management standards were codified in Forest Management Administrative Rules in September 2003.

DNRC Habitat Conservation Plan for Forested State Trust Lands. The DNRC released a final decision in 2011 to implement a Habitat Conservation Plan for forest management activities on most of its forested State lands throughout western Montana, including lands occupied by grizzly bears in the NCDE (DNRC 2010). This HCP will guide management of activities on 147,843 acres (598 sq km) of State lands within the NCDE PCA and an additional 72,875 acres (295 sq km) of occupied habitat outside the PCA (DNRC 2010). The DNRC developed their HCP and habitat mitigation measures in cooperation with the USFWS to address the needs of several listed species, including the grizzly bear. This HCP provides additional outreach focused on avoiding bear encounters and storing food properly, minimizes roads in key bear habitats (avalanche chutes and riparian areas), and suspends motorized activities within 1 km (0.6 mi) of a den site (DNRC 2010). On DNRC lands included in the HCP within the PCA, there will be no new grazing allotments for small livestock (i.e., sheep or goats). Additionally, in areas outside of PCA, new open road construction would be minimized, vegetative cover would be retained, there would be spring restrictions on forest management activities, and restrictions on livestock grazing to minimize bear/livestock conflicts would be incorporated into grazing permits (DNRC 2010).

Swan Valley Grizzly Bear Conservation Agreement is a collaborative document that guides management of multiple use lands owned by the USFS, the Nature Conservancy, and the DNRC in the upper Swan Valley. It is described immediately above in the “U.S. Forest Service” sub-section of the “Federal Plans and Guidelines” section. Its full language is also provided as an appendix (Appendix 7).

TRIBAL MANAGEMENT PLANS

Bear Management Plan and Guidelines for Bear Management on the Blackfeet Reservation. Pending adoption by the Blackfeet Tribal Business Council, this document describes the policies, goals, and methods for implementing bear management activities on the Blackfeet Indian Reservation. It describes how the Blackfeet Tribe will manage livestock depredations and other human/bear conflicts, what conflict preventative measures will be used, procedures for handling bears, and bear habitat protection measures. This document affects grizzly bear conservation because it directs the way grizzly bears are managed on the Blackfeet Indian Reservation. The Blackfeet Fish and Wildlife Department implements this plan.

Blackfeet Forest Management Plan, 2008. This document guides forest management activities on the Blackfeet Indian Reservation from 2009 to 2023. It is required by federal regulation and addresses timber harvesting, forest protection, forest development, and the organization of the forestry department. It describes special considerations for grizzly bear habitat in forest management activities. The plan is implemented by the Blackfeet Tribe with final oversight by the Bureau of Indian Affairs. It applies to grizzly bear conservation because it guides timber management, which affects the quality and quantity of grizzly bear habitat and how bears use it.

Flathead Indian Reservation Grizzly Bear Management Plan, 1981. A resolution by Tribal Council gave the plan its authority. It covers the Tribal Fish and Game Conservation Department, Wildland Recreation Department, and BIA Wildlife Branch. The overall goal is "to secure and/or maintain a viable, self-sustaining population [of grizzly bears] in critical habitat occupied in the Mission Mountains." It includes subgoals of managing the population for a "stable or slightly increasing" trend; maintaining sufficient grizzly bear habitat to support a "viable bear population;" minimizing human-bear competition; and managing "natural resources to minimize adverse effects and maximize benefits for grizzly bears while meeting the natural resource needs of the Confederated Tribes."

Flathead Indian Reservation Forest Management Plan, 2000 (with amendments). This plan, as authorized by the Tribal Council and the Bureau of Indian Affairs, is in effect from 2000 to 2030. It "…emphasizes restoration of the forest over the economic returns it could provide " by identifying timber harvest standards and providing legal descriptions and designations of roadless and wilderness areas where timber harvest and road construction is limited or not allowed. It also identifies areas where hiding cover should be maintained to facilitate movement across roads and restricts total road miles to levels at or below that number existing in 1999.

GLOSSARY OF TERMS

acceptable aggression – a bear defending its young, its food, itself, or during a surprise encounter

adaptive management – a model for conservation that uses and incorporates information from ongoing monitoring and research to direct appropriate management actions. Specifically, it is the integration of program design, management, and monitoring to systematically test assumptions in order to adapt management measures accordingly.

administrative sites – sites or facilities constructed for use primarily by government employees to facilitate the administration and management of public lands. Examples include headquarters, ranger stations, dwellings, warehouses, guard stations, and Park entrances.

attractants – human sources of food that may bring bears into an area including garbage, carcasses, bird seed, livestock feed, bee hives, pet food, garden vegetables, orchards, compost piles, and any other foods consumed or grown by humans

aversive conditioning – the use of non-lethal methods (e.g., rubber bullets, cracker shells, Karelian bear dogs, etc.) to teach bears to negatively associate humans and food

core habitat (former definition) – those areas at least 2,500 acres (hectares) in size and > 500m from an open road or high-use trail; this Conservation Strategy revises the definition of core habitat and changes the name of this revised term to "secure core habitat"

denning season – December 1- April 1 west of the continental divide and December 1- April 15 east of the continental divide; There are no restrictions on motorized use related to grizzly bears during this time.

developed site – sites or facilities on public Federal lands with features that are intended to accommodate public use and recreation. Examples include, but are not limited to: campgrounds, trailheads, lodges, summer homes, restaurants, visitor centers, and ski areas.

dispersed site –sites on public lands used frequently by the public but which have no permanent constructed features, are temporary in nature, have minimal to no site modifications, and have informal spacing, primitive roads, and/or informal interpretive services. These include many car camping sites along public roads, user-established camping areas accessible only by non-motorized means, and/or outfitter camps.

food conditioned – a bear that has received a significant amount of human foods such as garbage, camp food, pet food, livestock feed, or birdseed; and persistently seeks these foods

Food conditioned – bears that persistently seek anthropogenic foods or associate humans or their dwellings with food rewards

grizzly bear-human conflict – incidents in which bears either do or attempt to: injure people, damage property, kill or injure livestock, damage beehives, obtain anthropogenic foods, attractants, or agricultural crops

habituated – a bear that does not display avoidance behavior near humans or in human use areas such as camps, town sites, or within 100 meters of open roads due to repeated exposure to these circumstances.

high-use trail – those trails with an average of 20 or more partiers per week, based on expert opinion

lambda – a measure of annual population growth; a lambda value of 1.03 means that population of organisms is increasing at 3 percent annually

nuisance bear – bears that exhibit conflict behaviors which may place the public at undue risk. This includes any grizzly bear involved in a grizzly bear-human conflict that results in an agency management response action (Dood et al. 2006, p. 84).

position statement – a brief (e.g., 1-2 pages) document issued by the NCDE Coordinating Committee about the appropriateness of a proposed action relative to its impact on the entire NCDE population. If there is disagreement among Coordinating Committee members about the impacts to the grizzly bear population, the position statement would contain the viewpoints of both sides. While respective management agencies possess the sole authority to make decisions regarding grizzly bears within their jurisdictions, these position statements will communicate the NCDE Coordinating Committee's recommended course of action, based on the best available science. There are 2 circumstances that would lead to a position statement being issued by the NCDE Coordinating Committee: (1) if a proposed increase in the number of developed sites did not meet the Application Rules or (2) if a Coordinating Committee member requested a position statement for a specific project or proposal.

recurring helicopter flight – repeated (multiple trips/passes each day), low-altitude (< 500m above-ground-level) flights for periods longer than 48 hours

relocation – the capture and movement by management authorities of a bear involved in a conflict with humans or human-related foods, to a remote area away from the conflict site, usually after fitting the bear with a radio collar

removal – capture and placement of a bear in an authorized public zoological or research facility or destruction of that bear

resource selection function –

revegetated road – one that is not drivable by motorized vehicles; It is easier to walk on the side-hill than down the road

secure core habitat – those areas more than 500 meters (0.3) from a motorized access route during the non-denning period and at least 2,500 acres in size

stable isotope –

sustainable mortality – the amount of mortality a population can endure without reducing overall population growth. In other words, the number of deaths do not exceed the number of individuals born and surviving to reproductive age

unacceptable aggression – bear behavior that includes active predation on humans, approaching humans or human use areas in an aggressive way; aggressive behavior when the bear is unprovoked by self-defense, defense of young, defense of foods, or in a surprise encounter

visual screening – vegetation and/or topography providing visual obstruction capable of hiding a grizzly bear from view

LITERATURE CITED

Anderson, S H. 2002. Managing our wildlife resources. Prentice-Hall. Upper Saddle River, New Jersey. USA.

Anderson, C. R., Jr., M. A. Ternent, and D. S. Moody. 2002. Grizzly bear-cattle interactions on two grazing allotments in northwest Wyoming. Ursus 13:247-256.

Aune, K., and W. Kasworm. 1989. Final report East Front grizzly studies. Montana Department of Fish, Wildlife, and Parks, Helena, Montana, USA.

Aune, K. E., R. D. Mace, and D. W. Carney. 1994. The reproductive biology of female grizzly bears in the Northern Continental Divide Ecosystem with supplemental data from the Yellowstone Ecosystem. International Conference on Bear Research and Management 9:451-458.

Bartlein, P. J., C. Whitlock, and S. L. Shafer. 1997. Future climate in the Yellowstone National Park region and its potential impact on vegetation. Conservation Biology 11:782-792.

Bentz, B. J., J. Regniere, C. J. Fettig, E. M. Hansen, J. L. Hayes, J. A. Hicke, R. G. Kelsey, J. F. Negron, and S. J. Seybold. 2010. Climate change and bark beetles in the western United States and Canada: direct and indirect effects. Bioscience 60:602-613.

Blackfeet Nation. 2008. Blackfeet forest management plan, 2009-2023. Blackfeet Nation, Browning, Montana, USA.

Blanchard, B. 1978. Grizzly bear distribution in relation to habitat areas and recreational use: Cabin Creek-Hilgard Mountains. M.S. Thesis, Montana State University, Bozeman, Montana, USA.

Blanchard, B. M. and R. R. Knight. 1991. Movements of Yellowstone grizzly bears. Biological Conservation 58:41-67.

Blanchard, B. and R. R. Knight. 1996. Effects of wildfire on grizzly bear movements and food habits. Pages 117-122 *in* J.M. Greenlee, editor. The ecological implications of fire in Greater Yellowstone. Proceedings of the 2nd biennial conference on the Greater Yellowstone Ecosystem. 1993. Yellowstone National Park, Wyoming. International Association of Wildland Fire. Fairfield, Washington.

Boyce, M. S., B. M. Blanchard, R. R. Knight, and C. Servheen. 2001. Population viability for grizzly bears: a critical review. International Association for Bear Research and Management Monograph Series Number 4.

British Columbia Office of the Premier. 2010. British Columbia and Montana partner on environment and clean energy. News release, February 18, 2010.

Cayan, D. R., S. A. Kammerdiener, M. D. Dettinger, J. M. Caprio, and D. H. Peterson. 2001. Changes in the onset of spring in the western United States. Bulletin of the American Meteorological Society 82:399-415.

Chapman, J. A., J. I. Romer, and J. Stark. 1955. Ladybird beetles and army cutworm adults as food for grizzly bears in Montana. Ecology 36:156-158.

Confederated Salish and Kootenai Tribes. 2000. Flathead Indian Reservation forest management plan. Pablo, Montana, USA.

Craighead, F. C., Jr., and J. J. Craighead. 1972. Grizzly bear prehibernation and denning activities as determined by radiotracking. Wildlife Monographs 32:1-35.

Craighead, J. J., and J. A. Mitchell. 1982. Grizzly bear. Pages 515-556 *in* Wild mammals of North America: biology, management, and economics. The Johns Hopkins University Press, Baltimore, Maryland, USA.

Craighead, J. J., J. S. Sumner, and G. B. Scaggs. 1982. A definitive system for analysis of grizzly bear habitat and other wilderness resources. Monograph No. 1. Wildlife-Wildlands Institute, University of Montana Foundation, Missoula, Montana, USA.

Craighead, L., D. Paetkau, H.V. Reynolds, E.R. Vyse, and C. Strobeck. 1995. Microsatellite analysis of paternity and reproduction in arctic grizzly bears. The Journal of Heredity 86(4):255-261.

Doak, D.F. 1995. Source-sink models and the problem of habitat degradation: general models and applications to the Yellowstone grizzly. Conservation Biology 9:1370-1379.

Dood, A. R., S. J. Atkinson, and V. J. Boccadori. 2006. Grizzly bear management plan for western Montana: Final programmatic environmental impact statement 2006-2016. Montana Department of Fish, Wildlife and Parks, Helena, Montana, USA.

Duffy, P. B., R. W. Arritt, J. Coquard, W. Gutowski, J. Han, J. Iorio, J. Kim, L.-R. Leung, J. Roads, and E. Zeledon. 2006. Simulations of present and future climates in the western United States with four nested regional climate models. Journal of Climate 19:873-895.

Fagre, D. B., D. L. Peterson, and A. E. Hessl. 2003. Taking the pulse of mountains: Ecosystem responses to climatic variability. Climatic Change 59:263-282.

Farley, S.D., and C.T. Robbins. 1994. Development of two methods to estimate body composition of bears. Canadian Journal of Zoology 72:220–226.

Felicetti, L. A., C. C. Schwartz, R. O. Rye, K. A. Gunther, J. G. Crock, M. A. Haroldson, L. Waits, and C. T. Robbins. 2004. Use of naturally occurring mercury to determine the importance of cutthroat trout to Yellowstone grizzly bears. Canadian Journal of Zoology 82:493-501.

Felicetti, L. A., C. C. Schwartz, R. O. Rye, M. A. Haroldson, K. A. Gunther, D. L. Phillips, and C. T. Robbins. 2003. Use of sulfur and nitrogen stable isotopes to determine the importance of whitebark pine nuts to Yellowstone grizzly bears. Canadian Journal of Zoology 81:763-770.

Folk, G. E., Jr., A. Larson, and M. A. Folk. 1976. Physiology of hibernating bears. Pages 373-380 *in* Bears: their biology and management. Proceedings of the 3rd International Conference on Bear Research and Management, Binghamton, New York, USA.

Forman, R. T., and L. E. Alexander. 1996. Roads and their ecological effects. Annual Review of Ecology and Systematics 29:207-231.

Gallatin National Forest. 2006. Gallatin National Forest travel management plan – Record of decision and Final Environmental Impact Statement. Gallatin National Forest, Bozeman, MT, USA.

Graves, T., and V. Reams, editors. 2001. Record of the snowmobile effects on wildlife: Monitoring protocols workshop. April 10-12, 2001, Denver, CO, USA.

Gunther, K. A., M. A. Haroldson, K. Frey, S. L. Cain, J. Copeland, and C. C. Schwartz. 2004. Grizzly bear-human conflicts in the Greater Yellowstone ecosystem, 1992-2000. Ursus 15:10-22.

Hamer, D., and S. Herrero. 1987. Grizzly bear food and habitat in the front ranges of Banff National Park, Alberta. International Conference on Bear Research and Management 7:199-213.

Harding, L., and J. A. Nagy. 1980. Responses of grizzly bears to hydrocarbon exploration on Richards Island, Northwest Territories, Canada. Pages 277-280 *in* Bears: their Biology and Management. Proceedings of the 4th International Conference on Bear Research and Management, Kalispell, Montana, USA.

Haroldson, M. A., M. A. Ternent, K. A. Gunther, and C. C. Schwartz. 2002. Grizzly bear denning chronology and movements in the greater Yellowstone ecosystem. Ursus 13:29-37.

Hegg, S. J., K. Murphy, and D. Bjornlie. 2010. Grizzly bears and snowmobile use: a summary of monitoring a grizzly den on Togwotee Pass. Yellowstone Science 18:23-28.

Hilderbrand, G.V., S.D. Farley, C.T. Robbins, T.A. Hanley, K. Titus, and C. Servheen. 1996. Use of stable isotopes to determine diets of living and extinct bears. Canadian Journal of Zoology 74:2080-2088.

Hilderbrand, G. V., C. C. Schwartz, C. T. Robbins, M. E. Jacoby, T. A. Hanley, S. M. Arthur, and C. Servheen. 1999. The importance of meat, particularly salmon, to body size, population productivity, and conservation of North American brown bears. Canadian Journal of Zoology 77:132-138.

Hornocker, M. G. 1962. Population characteristics and social reproductive behavior of the grizzly bear in Yellowstone National Park. M.S. Thesis, Montana State University, Missoula, Montana, USA.

Interagency Grizzly Bear Committee. 1994. Interagency grizzly bear committee taskforce report: grizzly bear/motorized access management. Missoula, Montana, USA.

Interagency Grizzly Bear Committee. 1998. Interagency Grizzly Bear Committee Taskforce Report: Grizzly bear/motorized access management. Missoula, Montana, USA.

Interagency Grizzly Bear Committee. 2001. Support for the concept of linkage zones, signed memo.

Jacoby, M. E., G. V. Hilderbrand, C. Servheen, C. C. Schwartz, S. M. Arthur, T. A. Hanley, C. T. Robbins, and R. Michener. 1999. Trophic relations of brown and black bears in several western North American ecosystems. Journal of Wildlife Management 63:921-929.

Johnson, C. J., M. S. Boyce, C. C. Schwartz, and M. A. Haroldson. 2004. Modeling survival: application of the Andersen-Gill model to Yellowstone grizzly bears. Journal of Wildlife Management 68:966-978.

Jonkel, C. 1980. Grizzly bears and livestock. Western Wildlands 6:11-14.

Jonkel, J. J. 1993. A manual for handling bears for managers and researchers. U.S. Fish and Wildlife Service, Missoula, Montana, USA.

Jope, K. L. 1985. Implications of grizzly bear habituation to hikers. Wildlife Society Bulletin 13:32-37.

Judd, S. L., R. R. Knight, and B. M. Blanchard. 1986. Denning of grizzly bears in the Yellowstone National Park area. Pages 111-117 *in* Bears: their biology and management. Proceedings of the 6th International Conference on Bear Research and Management, Grand Canyon, Arizona, USA.

Kasworm, W. F., and T. L. Manley. 1990. Road and trail influences on grizzly bears and black bears in northwest Montana. International Conference on Bear Research and Management 8:79-84.

Kendall, K. C. 1986. Grizzly and black bear feeding ecology in Glacier National Park, Montana. Progress Report 1982-1985. USDI National Park Service, Glacier National Park, Montana, USA.

Kendall, K. C., and S. F. Arno. 1990. Whitebark pine – an important but endangered wildlife resource. Pages 264-273 *in* W. C. Schmidt and K. J. McDonald, compilers. Proceedings–Symposium on whitebark pine ecosystems: ecology and management of a high-mountain resource. USDA Forest Service, Intermountain Research Station, General Technical Report INT-270, Ogden, Utah, USA.

Kendall, K. C., and R. E. Keane. 2001. Whitebark pine decline: infection, mortality, and population trends. Pages 221-242 *in* D. F. Tomback, S. F. Arno, and R. E. Keane, editors. Whitebark pine communities: ecology and restoration. Island Press, Washington, D.C., USA.

Kendall, K. C., J. B. Stetz, J. Boulanger, A. C. Macleod, D. Paetkau, and G. C. White. 2009. Demography and genetic structure of a recovering grizzly bear population. Journal of Wildlife Management 73:3-17.

Kendall, K. C., J. B. Stetz, D. A. Roon, L. P. Waits, J. B. Boulanger, and D. Paetkau. 2008. Grizzly bear density in Glacier National Park, Montana. Journal of Wildlife Management 72:1693-1705.

Kerns, B. K., S. J. Alexander, and J. D. Bailey. 2004. Huckleberry abundance, stand conditions, and use in Western Oregon: Evaluating the role of forest management. Economic Botany 58:668-678.

Klaver, R. W., J. J. Claar, D. B. Rockwell, H. R. Mays, and C. F. Acevedo. 1986. Grizzly bears, insects, and people: Bear management in the McDonald Peak region, Montana. Pages 204-211 *in* G.P. Contreras and K.E. Evans, compilers. Proceedings—grizzly bear habitat symposium. U.S. Forest Service General Technical Report INT-207.

Knight, R. R., B. M. Blanchard, and L. L. Eberhardt. 1988. Mortality patterns and populations sinks for Yellowstone grizzly bears, 1973-1985. Wildlife Society Bulletin 16:121-125.

Knight, R. R., and S. L. Judd. 1983. Grizzly bears that kill livestock. Pages 186-190 *in* Bears: their biology and management. Proceedings of the 4th International Conference on Bear Research and Management, Kalispell, Montana, USA.

LeFranc, M. N., Jr., M. B. Moss, K. A. Patnode, and W. C. Sugg III, editors. 1987. Grizzly bear compendium. The National Wildlife Federation, Washington, D.C., USA.

Lindenmayer, D. B., and J. Fischer. 2006. Habitat fragmentation and landscape change: an ecological and conservation synthesis. Island Press, Washington, D.C., USA.

Leung, L. R., Y. Qian, X. Bian, W. M. Washington, J. Han, and J. O. Roads. 2004. Mid-century ensemble regional climate change scenarios for the western United States. Climatic Change 62:75-113.

Linnell, J. D. C., J. E. Swenson, R. Andersen, and B. Barnes. 2000. How vulnerable are denning bears to disturbance? Wildlife Society Bulletin 28:400-413.

Mace, R. D., D. W. Carney, T. Chilton-Radandt, S. A. Courville, M. A. Haroldson, R. B. Harris, J. Jonkel, B. McLellan, M. Madel, T. L. Manley, C. C. Schwartz, C. Servheen, G. Stenhouse, J. S. Waller, E. Wenum. 2012. Grizzly bear population vital rates and trend in the Northern Continental Divide Ecosystem, Montana. Journal of Wildlife Management 76:119-128.

Mace, R. D and C. J. Jonkel. 1986. Local food habits of the grizzly bear in Montana. International Conference on Bear Research and Management 6:105-110.

Mace, R. D., S. Minta, T. Manley, and K. Aune. 1994. Estimating grizzly bear population size using camera sightings. Wildlife Society Bulletin 22:74-83.

Mace, R. D. and L. Roberts. 2011. Northern continental divide ecosystem grizzly bear monitoring team annual report, 2009-2010. Montana Fish Wildlife and Parks, Kalispell, Montana, USA.

Mace, R. D. and J. S. Waller. 1996. Grizzly bear distribution and human conflicts in Jewel Basin Hiking Area, Swan Mountains, Montana. Wildlife Society Bulletin 24:461-467.

Mace, R. D. and J. S. Waller. 1997a. Final report: grizzly bear ecology in the Swan Mountains, Montana. Montana Fish, Wildlife and Parks, Helena, Montana, USA.

Mace, R. D. and J.S. Waller. 1997b. Spatial and temporal interaction of male and female grizzly bears in northwestern Montana. Journal of Wildlife Management 61:39-52.

Mace, R. D., J. S. Waller,T. L. Manley, K. Ake, and W. T. Wittinger. 1997. Landscape evaluation of grizzly bear habitat in western Montana. Conservation Biology 13:367-377.

Mace, R. D., J. S. Waller, T. L. Manley, L. J. Lyon, and H. Zuuring. 1996. Relationships among grizzly bears, roads and habitat in the Swan Mountains, Montana. Journal of Applied Ecology 33:1395-1404.

Martinka, C. J. and K. C. Kendall. 1986. Grizzly bear habitat research in Glacier National Park, Montana. Pages 19-23 *in* Proceedings of the Grizzly Bear Habitat Symposium, USDA Forest Service General Technical Report INT-207.

Mattson, D. J. 1990. Human impacts on bear habitat use. Pages 33-56 *in* Bears: their biology and management. Proceedings of the 8th International Conference on Bear Research and Management, Victoria, British Columbia, Canada.

Mattson, D. J. 2000. Causes and consequences of dietary differences among Yellowstone grizzly bears (*Ursus arctos*). Ph. D. Dissertation, University of Idaho, Moscow, USA.

Mattson, D. J., B. M. Blanchard, and R. R. Knight. 1991a. Food habits of Yellowstone grizzly bears, 1977-1987. Canadian Journal of Zoology 69:1619-1629.

Mattson, D.J., B.M. Blanchard, and R.R. Knight. 1992. Yellowstone grizzly bear mortality, human habituation, and whitebark pine seed crops. Journal of Wildlife Management 56:432-442.

Mattson, D. J., C. M. Gillin, S. A. Benson, and R. R. Knight. 1991b. Bear use of alpine insect aggregations in the Yellowstone ecosystem. Canadian Journal of Zoology 69:2430-2435.

Mattson, D. J., S. Herrero, R. G. Wright, and C. M. Pease. 1996. Science and management of Rocky Mountain grizzly bears. Conservation Biology 10:1013-1025.

Mattson, D. J., and R. R. Knight. 1991. Effects of access on human-caused mortality of Yellowstone grizzly bears. Interagency Grizzly Bear Study Team Report, Bozeman, Montana, USA.

Mattson, D. J., R. R. Knight, and B. M. Blanchard. 1987. The effects of developments and primary roads on grizzly bear habitat use in Yellowstone National Park, Wyoming. Pages 259-273 *in* Bears: their biology and management. Proceedings of the 7th International Conference on Bear Research and Management, Williamsburg, Virginia, USA.

Mattson, D. J., and T. Merrill. 2002. Extirpations of grizzly bears in the contiguous United States, 1850-2000. Conservation Biology 16:1123-1136.

McLellan, B. N. 1989. Dynamics of a grizzly bear population during a period of industrial resource extraction. II. Mortality rates and causes of death. Canadian Journal of Zoology 67:1861-1864.

McLellan, B. N. 1994. Density-dependent population regulation of brown bears. Pages 15-24 *in* M. Taylor, editor. Density-dependent population regulation of black, brown, and polar bears. 8th International Conference on Bear Research and Management, monograph series number 3.

McLellan, B. N., and F. W. Hovey. 1995. The diet of grizzly bears in the Flathead River drainage of southeastern British Columbia. Canadian Journal of Zoology 73:704-712.

McLellan, B. N., and F. W. Hovey. 2001. Natal dispersal of grizzly bears. Canadian Journal of Zoology 79:838-844.

McLellan, B. N., F. W. Hovey, R. D. Mace, J. G. Woods, D. W. Carney, M. L. Gibeau, W. L. Wakkinen, and W. F. Kasworm. 1999. Rates and causes of grizzly bear mortality in the interior mountains of British Columbia, Alberta, Montana, Washington, and Idaho. Journal of Wildlife Management 63:911-920.

McLellan, B. N., and D. M. Shackleton. 1988. Grizzly bears and resource-extraction industries: effects of roads on behaviour, habitat use and demography. Journal of Applied Ecology 25:451-460.

McLellan, B. N., and D. M. Shackleton. 1989. Grizzly bears and resource-extraction industries: habitat displacement in response to seismic exploration, timber harvesting and road maintenance. Journal of Applied Ecology 26:371-380.

McWethy, D. B., S. T. Gray, P. E. Higuera, J. S. Litell, G. T. Pederson, A. J. Ray, and C. Whitlock. 2010. Climate and terrestrial ecosystem change in the U.S. Rocky Mountains and Upper Columbia Basin: Historical and future perspectives for natural resource management. U.S. Department of the Interior, National Park Service Natural Resource Report NPS/GRYN/NRR–2010/260, Fort Collins, Colorado, USA.

Miller, C. R., and L. P. Waits. 2003. The history of effective population size and genetic diversity in the Yellowstone grizzly (*Ursus arctos*): Implications for conservation. Proceedings of the National Academy of Sciences 100:4334-4339.

Mills, L. S. 2007. Conservation of wildlife populations: Demography, genetics, and management. Blackwell Publishing, Malden, Massachusetts, USA.

Mills, L. S., and F. W. Allendorf. 1996. The one-migrant-per-generation-rule in conservation and management. Conservation Biology 10:1509-1518.

Montana Department of Natural Resources and Conservation (DNRC). 2010. Final Environmental Impact Statement for the Montana Department of Natural Resources and Conservation Forested Trust Lands Habitat Conservation Plan, Kalispell, Montana, USA.

Montana Fish, Wildlife and Parks (MFWP). 2002. Grizzly bear management plan for southwestern Montana 2002-2012. Helena, Montana, USA.

Montana Fish, Wildlife and Parks (MFWP). 2005. Montana comprehensive fish and wildlife conservation strategy. Helena, Montana, USA.

Montana Fish, Wildlife and Parks. 2012. Fish and Wildlife Recommendations for Subdivision Development in Montana: A Working Document. Montana Fish, Wildlife & Parks, Helena, Montana. 174 pp.

Mowat, G., and D. C. Heard. 2006. Major components of grizzly bear diet across North America. Canadian Journal of Zoology 84:473-489.

Munro, R. H. M., S. E. Nielsen, M. H. Price, G. B. Stenhouse, and M. S. Boyce. 2006. Seasonal and diel patterns of grizzly bear diet and activity in west-central Alberta. Journal of Mammalogy 87:1112-1121.

Nelson, R. A. 1980. Protein and fat metabolism in hibernating bears. Federation Proceedings 39:2955-2958.

Newman, D., and D. A. Tallmon. 2001. Experimental evidence for beneficial fitness effects of gene flow in recently isolated populations. Conservation Biology 15:1054-1063.

Nitschke, C. R., and J. L. Innes. 2008. Climatic change and fire potential in south-central British Columbia, Canada. Global Change Biology 14:841-855.

Nowak, R. M., and J. L. Paradiso. 1983. Walker's Mammals of the World, 4th edition. The Johns Hopkins University Press, Baltimore, Maryland, USA.

Orme, M. L., and R. G. Williams. 1986. Coordinating livestock and timber management with the grizzly bear in situation 1 habitat, Targhee National Forest. Pages 195-203 *in* G.P. Contreras and K.E. Evans, compilers. Proceedings—grizzly bear habitat symposium. U.S. Forest Service General Technical Report INT-207.

Pederson, G. T., S. T. Gray, T. Ault, W. Marsh, D. B. Fagre, A. G. Bunn, C. A. Woodhouse, and L. J. Graumlich. 2011. Climatic controls on the snowmelt hydrology of the northern Rocky Mountains. Journal of Climate 24:1666-1687.

Portner, R. 2003. Map: Oil and gas occurrence potential region 1. Missoula, MT, USA.

Proctor, M. F., B. N. McLellan, C. Strobeck, and R. M. R. Barclay. 2004. Gender-specific dispersal distances of grizzly bears estimated by genetic analysis. Canadian Journal of Zoology 1108-1118.

Proctor, M. F., B. N. McLellan, C. Strobeck, and R. M. R. Barclay. 2005. Genetic analysis reveals demographic fragmentation of grizzly bears yielding vulnerably small populations. Proceedings of the Royal Society, London 272:2409-2416.

Proctor, M. F., D. Paetkau, B. N. McLellan, G. B. Stenhouse, K. C. Kendall, R. D. Mace, W. F. Kasworm, C. Servheen, C. L. Lausen, M. L. Gibeau, W. L. Wakkinen, M. A. Haroldson, G. Mowat, C. D. Apps, L. M. Ciarniello, R. M. R. Barclay, M. S. Boyce, C. C. Swartz, C. Strobeck. 2012. Population fragmentation and inter-ecosystem movements of grizzly bears in western Canada and the northern United States. Wildlife Monographs 180:1-46.

Reynolds, P.E., H.V. Reynolds, and E.H. Follmann. 1986. Responses of grizzly bears to seismic surveys in northern Alaska. Pages 169-175 *in* Bears: their biology and management. Proceedings of the 6th International Conference on Bear Research and Management, Grand Canyon, AZ, USA.

Robbins, C. T., M. Ben-David, J. K. Fortin, and O. L. Nelson. 2012. Maternal condition determines birth date and growth of newborn bear cubs. Journal of Mammalogy 93:540–546.

Robbins, C. T., C. C. Schwartz, and L. A. Felicetti. 2004. Nutritional ecology of ursids: a review of newer methods and management implications. Ursus 15:161-171.

Rode, K. D., and C. T. Robbins. 2000. Why bears consume mixed diets during fruit abundance. Canadian Journal of Zoology 78:1640-1645.

Rodriguez, C., J. Naves, A. Fernandez-Gil, J. R. Obeso, and M. Delibes. 2007. Long-term trends in food habits of relict brown bear population in northern Spain: the influence of climate and local factors. Environmental Conservation 34:36-44.

Schallenberger, A., and C.J. Jonkel. 1980. Rocky Mountain east front grizzly studies, 1979. Annual report. Border Grizzly Project Special Report No. 39. Border Grizzly Project, Missoula, Montana, USA.

Schoen, J. W., L. R. Beier, J. W. Lentfer, and L. J. Johnson. 1987. Denning ecology of brown bears on Admiralty and Chichagof Islands. Pages 293-304 *in* Bears: their biology and management. Proceedings of the 7th International Conference on Bear Research and Management, Williamsburg, Virginia, USA.

Schwartz, C. C., M. A. Haroldson, and S. Cherry. 2006. Reproductive performance of grizzly bears in the Greater Yellowstone Ecosystem, 1983-2002. Pages 18-24 *in* C. C. Schwartz, M. A. Harolson, G. C. White, R. B. Harris, S. Cherry, K. A. Keating, D. Moody, and C. Servheen, eds. Temporal, spatial, and environmental influences on the demographics of grizzly bears in the Greater Yellowstone Ecosystem. Wildlife Monographs 161.

Schwartz, C. C., M. A. Haroldson, and G. C. White. 2010. Hazards affecting grizzly bear survival in the Greater Yellowstone Ecosystem. Journal of Wildlife Management 74:654-667.

Schwartz, C. C., K. A. Keating, H. V. Reynolds, III, V. G. Barnes, Jr., R. A. Sellers, J. E. Swenson, S. D. Miller, B. N. McLellan, J. Keay, R. McCann, M. Gibeau, W. F. Wakkinen, R. D. Mace, W. Kasworm, R. Smith, and S. Herrero. 2003a. Reproductive maturation and senescence in the female brown bear. Ursus 14:109-119.

Schwartz, C. C., S. D. Miller, and M. A. Haroldson. 2003b. Grizzly/brown bear. Pages 556-586 *in* G. Feldhamer, B. Thompson, and J. Chapman, editors. Wild mammals of North America: biology, management, and conservation. Johns Hopkins University Press, Baltimore, Maryland, USA.

Scott, J. M., D. D. Goble, J. A. Wiens, D. S. Wilcove, M. Bean, and T. Male. 2005. Recovery of imperiled species under the Endangered Species Act: the need for a new approach. Frontiers in Ecology and the Environment 3:383-389.

Servheen, C. 1981. Grizzly bear ecology and management in the Mission Mountains, Montana. Ph. D. dissertation. University of Montana, Missoula, Montana, USA.

Servheen, C. 1983. Grizzly bear food habits, movements, and habitat selection in the Mission Mountains, Montana. Journal of Wildlife Management 47:1026-1035.

Servheen, C. 2010. Email from Chris Servheen, U.S. Fish and Wildlife Service Grizzly Bear Recovery Coordinator to Rebecca Shoemaker, U.S. Fish and Wildlife Service Research Assistant.

Servheen, C., and M. Cross. 2010. Climate change impacts on grizzly bears and wolverines in the northern U.S. and transboundary Rockies: Strategies for conservation. Report on a workshop held September 13-15, 2010, in Fernie, British Columbia, Canada.

Servheen, C., M. Haroldson, K. Gunther, K. Barber, M. Brucino, M. Cherry, B. DeBolt, K. Frey, L. Hanauska-Brown, G. Losinski, C. Schwartz, and B. Summerfield. 2004. Yellowstone mortality and conflicts reduction report. Presented to the Yellowstone Ecosystem Subcommittee April 7, 2004.

Servheen, C., R. W. Klaver, and J. J. Claar. 1981. Flathead Indian Reservation Grizzly Bear Management Plan.

Shaffer, S. C. 1971. Some ecological relationships of grizzly bears and black bears of the Apgar Mountains in Glacier National Park, Montana. M. S. thesis, University of Montana, Missoula, Montana, USA.

Simonin, K. A. 2000. Vaccinium membranaceum. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis/ [2013, January 22].

Soule, M. E., editor. 1987. Viable populations for conservation. Cambridge University Press, New York, USA.

Stewart, I. T., D. R. Cayan, and M. D. Dettinger. 2004. Changes in snowmelt runoff timing in western North America under a ‘business as usual’ climate change scenario. Climatic Change 62:217-232.

Stringham, S. F. 1990. Grizzly bear reproductive rate relative to body size. Pages 433-443 *in* Bears: their biology and management. Proceedings of the 8th International Conference on Bear Research and Management, Victoria, British Columbia, Canada.

Sumner, J. and J.J. Craighead. 1973. Grizzly bear habitat survey in the Scapegoat Wilderness, Montana. Montana Cooperative Wildlife Research Unit, Missoula, Montana, USA.]

Swenson, J. E., F. Sandegren, S. Brunberg, and P. Wabakken. 1997. Winter den abandonment by brown bears, *Ursus arctos*: causes and consequences. Wildlife Biology 3:35-38.

U. S. Fish and Wildlife Service. 1993. Grizzly bear recovery plan. Missoula, Montana, USA.

U. S. Fish and Wildlife Service. 1997. Biological opinion on amendment 19 to the Flathead National Forest plan. U. S. Fish and Wildlife Service, Montana Field Office, Helena, Montana, USA.

U.S. Fish and Wildlife Service. 2002. Biological Opinion on greater Yellowstone ecosystem snowmobile use consultation. Helena, MT, USA.

U. S. Fish and Wildlife Service. 2007. Final conservation strategy for the grizzly bear in the Greater Yellowstone Area. Interagency Conservation Strategy Team.

U.S. Fish and Wildlife Service. 2011. Record of Decision. Proposed Issuance of a Permit to Montana Department of Natural Resources Conservation, Authorizing Incidental Take of Endangered and Threatened Species on Forested Trust Lands in Western Montana. Kalispell, Montana, USA.

U. S. Forest Service. 1986. Interagency grizzly bear guidelines. U.S. Forest Service, Washington, D.C., USA.

U.S. Forest Service. 2011. Final supplemental environmental impact statement, Forest plan amendments for access management within the Selkirk and Cabinet-Yaak grizzly bear recovery zones.

Van Daele, L. J., V. G. Barnes, and R. B. Smith. 1990. Denning characteristics of brown bears on Kodiak Island, Alaska. Pages 257-267 *in* Bears: their biology and management. Proceedings of the 8th International Conference on Bear Research and Management, Victoria, British Columbia, Canada.

Waller, J. S. 2005. Movements and habitat-use of grizzly bears along U. S. Highway 2 in northwestern Montana 1998-2001. Ph. D. dissertation. University of Montana, Missoula, Montana, USA.

Waller, J. S. and R. D. Mace. 1997. Grizzly bear habitat selection in the Swan Mountains, Montana. Journal of Wildlife Management 61:1032-1039.

Waller, J., and C. Servheen. 2005. Effects of Transportation Infrastructure on Grizzly Bears in Northwestern Montana. Journal of Wildlife Management 69(3):985-1000.

Walters, C. J. and C. S. Holling. 1990. Large-scale management experiments and learning by doing. Ecology 71:2060-2068.

Walther, G.-R. 2003. Plants in a warmer world. Perspectives in Plant Ecology, Evolution and Systematics 6:169-185.

Walther, G.-R., S. Berger, and M. T. Sykes. 2005. An ecological 'footprint' of climate change. Proceedings of the Royal Society B 272:1427-1432.

Walther, G.-R., E. Post, P. Convey, A. Menzel, C. Parmesan, T. J. C. Beebee, J.-M. Fromentin, O. Hoegh-Guldberg, and F. Bairlein. 2002. Ecological responses to recent climate change. Nature 416:389-395.

Waser, P. M., and W. T. Jones. 1983. Natal philopatry among solitary mammals. Quarterly Review of Biology 58:355-390.

White, D., Jr., K. C. Kendall, and H. D. Piction. 1998. Grizzly bear feeding activity at alpine army cutworm moth aggregation sites in northwest Montana. Canadian Journal of Zoology 76:221-227.

White, D., Jr., K. C. Kendall, and H. D. Picton. 1999. Potential energetic effects of mountain climbers on foraging grizzly bears. Wildlife Society Bulletin 27:146-151.

Woods, J. G., D. Paetkau, D. Lewis, B. N. McLellan, M. Proctor, and C. Strobeck. 1999. Genetic tagging of free-ranging black and brown bears. Wildlife Society Bulletin 27:616-627.

Woodroffe, R. 2000. Predators and people: using human densities to interpret declines in large carnivores. Animal Conservation 3:165-173.

Zager, P., C. Jonkel, and J. Habeck. 1983. Logging and wildfire influence on grizzly bear habitat in northwestern Montana. Pages 124-132 *in* Bears: their biology and management. Proceedings of the 5th International Conference on Bear Research and Management, Madison, Wisconsin, USA.

List of Appendices

Appendix 1

Methods to Calculate Trend and Other Vital Rates Using Known Fate Analysis

The survival rates, reproductive rates, and population trend of a wildlife population can be calculated using data collected from radio-collared females. This technique is termed “known-fate” monitoring because the fate (alive or dead) of each individual in generally known with certainty for each monitoring period (e.g. month, year). Known-fate monitoring has been employed as a monitoring tool for grizzly bears in the NCDE since 2004. The technique is generally described by Mace et al. (2005) and more recently in a publication of population trend by Mace et al. (2012).

Grizzly bears were captured using leg-hold snares and culvert traps, by helicopter darting, and in some instances, were darted and immobilized bears over baits. We chose specific capture sites within each capture zone while avoiding certain private properties. These properties were known to regularly attract grizzly bears seeking anthropogenic foods, and we suspected that survival rates of these bears would not be representative of the female population at large. All female bears were radio-collared, and each bear was tagged subcutaneously with passive transponder tags and pulled a pre-molar tooth for age determination. The sample of radio-collared females was distributed based on relative grizzly bear density across the NCDE, using the distribution of bears detected at DNA hair traps in 2004 (Kendall et al. 2009). A goal was established of monitoring a minimum of 25 females/year as possible. Female bears were categorized as either “research” bears or members of the “conflict-subsample.” Generally, population trend was calculated using only research bears. However, conflict bears could enter the dataset under certain circumstances (Schwartz et al. (2006).

Survival analyses were conducted on cubs and yearling of both sexes and for subadult and adult females. Survival of cubs and yearlings was determined form visual observations while monitoring their radioed mothers. Survival of independent subadult and adult females was estimated monthly using the staggered-entry Kaplan-Meier method within Program MARK using the logit scale. The reproductive status of each adult female was documented visually during telemetry sessions. Spring observation flights were conducted to ascertain which females had dependent offspring and the number of offspring per litter.

Population trend was estimated by computing the asymptotic rate of population growth (λ) using a standard, dynamic life table, solved iteratively for r (i.e., the intrinsic rate of growth). Approximate confidence intervals on λ were calculated by iterating life tables created using the empirical distribution of each rate in a Monte Carlo approach.

Appendix 2

Background Information for Demographic Standards 2-4.

Sections:

Section A: Methods to calculate sex and age class structure of the grizzly bear population in the NCDE.

The demographic standards in this Strategy require an estimate of the proportion of the male and female populations that are $\geq$ 2 years old (independent bears). Standards 3 and 4 fix a maximum mortality limit of 10% for independent females, and 20% for independent males. In the case of grizzly bears in the NCDE, the proportion of individuals of each age and sex cannot be ascertained directly from field data such as physical captures or from examination of genetics data from hair-traps or rub-trees. In the case of physical capture, as is used for population trend monitoring in the NCDE, age and sex classes are not captured in the same proportion as they exist in the population (Fig. 1). Cubs and yearlings are under-represented in the capture sample, and sub adults are over-represented relative to the stable state estimates. For genetic tagging data using hair samples collected at rub-trees or hair-trap (Kendall et al. (2009), it is not possible to determine the age of individuals.

There is a method to estimate the age structure of the population from vital population rates and population trend; the calculation of stable state population structure (Lotka and Sharpe 1911). A closed population that has experienced constant age-specific birth and death rates over a long period can be shown to also have a constant proportion of individuals in each age/sex class, thus a stable state (Seber 1982).

The stable age structure of grizzly bears in the NCDE was estimated in program RISKMAN (Taylor et al. 2001) using the vital reproductive rates, and cub and yearling female survival rates from Mace et al. (2012). Program RISKMAN uses a life-table approach to modeling structure. Specific input variables used in RISKMAN are given in Table 1. Independent male survival was set at 0.850 (Mace and Roberts 2012). The survival rates of independent sub-adult (2-4 years old) and adult (5+ years old) females were pooled at 0.936 for these analyses. For the entire male and female population, age-specific proportions are given in Table 2, and for each sex separately in Table 3. From these analyses, we estimated that 58.2% of the male population was independent bears, and 68.6% of the female population was independent-aged in the entire NCDE population (Table 3). These estimates of independent bears were used to calculate sustainable mortality levels of males and females.

Figure. 1. Comparison of female grizzly bear age structure from stable age distribution using program RISKMAN and from research female captures (2004-2012) in the NCDE whose age was known.

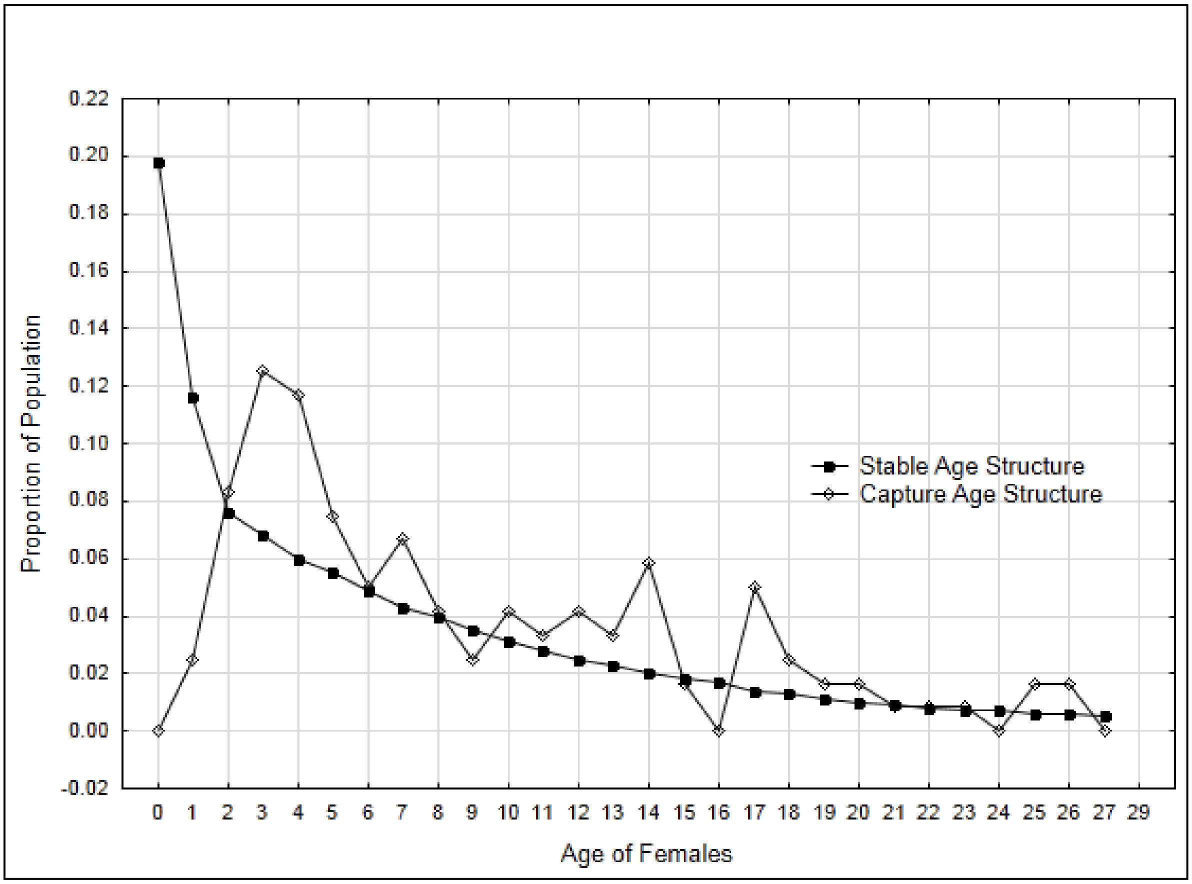


Table 1. Program RISKMAN input variables to estimate grizzly bear stable state population for the NCDE.

Program RISKMAN input variables	Value used to estimate stable state grizzly population
Preferences:	-Research/stochastic, trails = 1000 -no parameter/environmental uncertainty -normalize male and female structure
Species definition:	-annual -no hunting season -covariance of recruitment and survival rates -maximum age = 27 -age of 1st adulthood = 5 -maximum litter size = 3 -minimum age of 1st reproduction = 4 -maximum age of reproduction = 27
Individual survival rates; males	-age 0 = 0.612, se= 0.108 (Mace et al. 2012) -age 1 = 0.682, se= 0.132 (Mace et al. 2012) -age 2-27 = 0.850, se= 0.055 (Mace and Roberts 2012)
Individual survival rates; females	-age 0 = 0.612, se= 0.108 (Mace et al. 2012) -age 1 = 0.682, se= 0.132 (Mace et al. 2012) -age 2-27 = 0.936, se= 0.079 (Mace and Roberts 2012)
Recruitment:	-probability of 1 cub = 0.103[a] -probability of 2 cub = 0.524[a] -probability of 3 cub = 0.373[a] -mean litter size = 2.27, se = 0.18 (Mace et al. 2012) -proportion with litters = 0.322, se = 0.051 (Mace et al. 2012) -assume 50:50 M:F sex ratio for cubs at birth

[a] Proportions of 1, 2, and 3 cub litters varied somewhat from Mace et al. (2012) to achieve a mortality-adjusted cub litter size of 2.27.

Table 2. Stable state proportions of the grizzly bear population. Stable state proportions were based on a population of 1000 individuals using program RISKMAN.

Age	Age-specific proportion of entire population	
	Male	Female
0 (cub)	0.115	0.115
1	0.068	0.068
2	0.044	0.044
3	0.036	0.039
4	0.029	0.035
5	0.024	0.032
6	0.019	0.028
7	0.016	0.025
8	0.013	0.023
9	0.010	0.020
10	0.008	0.018
11	0.007	0.016
12	0.006	0.015
13	0.005	0.013
14	0.004	0.012
15	0.003	0.011
16	0.002	0.009
17	0.002	0.008
18	0.002	0.008
19	0.001	0.007
20	0.001	0.006
21	0.001	0.005
22	0.001	0.005
23	0.001	0.004
24	0.000	0.004
25	0.000	0.004
26	0.000	0.003
27	0.000	0.003

Table 3. Summary of grizzly bear stable population states for each sex separately as derived from program RISKMAN.

Age	Age-specific proportion of male population	Age-specific proportion of female population
0 (Cub)	0.276	0.198
1	0.162	0.116
2	0.105	0.076
3	0.086	0.068
4	0.07	0.06
5	0.057	0.055
6	0.046	0.049
7	0.038	0.043
8	0.031	0.04
9	0.025	0.035
10	0.02	0.031
11	0.016	0.028
12	0.013	0.025
13	0.011	0.023
14	0.009	0.02
15	0.007	0.018
16	0.006	0.017
17	0.005	0.014
18	0.004	0.013
19	0.003	0.011
20	0.003	0.01
21	0.002	0.009
22	0.002	0.008
23	0.001	0.007
24	0.001	0.007
25	0.001	0.006
26	0.001	0.006
27	0.001	0.005

Table 4. Comparison of grizzly bear population structure from three data sources.

Sex and age class of population	Data Source		
	Stable state structure from program RISKMAN[a]	Kendall et al. 2009	Mace et al. 2012
% females in population	58.2%	61.2%	na
% males in population	41.8%	38.8%	na
% of males 2+ years old (independent)	56.4%	na	na
% of females 2+ years old (independent)	68.6%	na	69%[b]

[a] Tabulated from Table 3.
[b] From Leslie-matrix projections to stable state projections using Microsoft Excel (Microsoft, Redmond Washington, USA) and the add-in PopTools (PopTools version 3.1, www.poptools.org, accessed 02 Feb 2010).

Section B: Sustainable Mortality Levels

Sustainable Rates For the entire grizzly bear population**.** Grizzly bear populations can sustain a certain level of mortality before populations decline (Bunnell and Tait 1980, Schwartz et al. 2003). Like other wildlife species, grizzly bears are subject to both natural and man-caused sources of mortality. Natural mortality rates vary by age and sex class. For adult males and females, natural mortality rates have been reported to be between 4 and 7 percent (McLoughlin 2003). Using estimates of mortality rates from radioed bears and their dependent offspring in the NCDE, it is estimated that on average, approximately 16% of the entire population, and 2.3% of the independent-aged bears die from natural causes each year (Table 5).

Table 5. Estimates of natural mortality levels in 2004 given an estimated population of 765 individuals and a stable age distribution.

Age	% of total stable age population[a]	# of bears out of 765[b]	Natural annual mortality rate[c] (n individuals)	# mortalities per year
Cubs	0.230	176	0.15 (n =73)	26
Yearlings	0.136	104	0.14 (n=48)	15
Independent-aged bears				
female	0.398	304	0.03 (n=102)	9
male	0.235	180	0.05 (n =52)	9
Total natural mortalities				59
% natural mortality of total population				59/765 = 7.7%
% of total population that				18/765 = 2.3%

are independent-aged				

[a] From stable state proportions.
[b] From estimate of total population size from Kendall et al. 2009.
[c] Natural rates of annual mortality from evaluation of survival rates of radio-collared research females and their dependent young; 2004-2011.

In addition to natural mortality, brown bears can sustain an additional man-caused mortality level for both sexes of between 2 and 5-6% (Miller 1989, McLoughlin 2003).

Sustainable Rate for independent male grizzly bears The fate of radio-collared male grizzly bears captured and instrumented during field efforts to capture females for population trend monitoring provided information on the current survival rate of independent males in the NCDE.

During the period 2004-2011 51 research males were monitored at population trend monitoring sites outside of Glacier National Park. Annual survival for independent males averaged either 0.844 (assuming 1 unresolved bear died) or 0.862 (assuming the 1 bear lived) (Table 6).

These survival data suggest a mean annual mortality rate for independent males of between 0.138 and 0.156 during a period when no legal hunting occurred. These independent male mortality rates were established during the same period that the population of grizzly bears in the NCDE was growing at a mean lambda of 1.0306, and where 71% of Monte Carlo simulations produced estimates of λ > 1.0 (Mace et al. (2012). Population trend is most influenced by female survival, not male survival (Hovey and McLellan 1986, Mace and Waller 1996, Harris et al. 2006.) An additional 5% man-caused mortality, above the 14-15% mortality currently observed, will not additionally influence population trend. The Interagency Grizzly Bear Study Team (2007) has stated that there are no quantitative tools to estimate the "sustainable" male mortality rate for grizzly bears unless the presence of males in some way influences female reproduction or survival, or if there are too few males to mate with available females. Rather the mortality rate for males affects the ratio of males to females in the population and at high levels could influence population viability.

Table 6. Survival rates of research male grizzly bears in the NCDE; 2004-2011.

Independent male sample	Survival parameter			
	Estimate	SE	-95 CI	+95 CI
Natural Survival	0.946	0.037	0.809	0.986
Natural plus man-caused: 1 individual whose fate was unresolved assumed to have lived	0.862	0.055	0.720	0.944
1 individual whose fate was unresolved assumed to have died	0.844	0.058	0.694	0.928

Sustainable mortality rate for independent female grizzly bears. Mace et al. (2012) calculated separate survival estimates for sub-adult (ages 2-4) and adult (ages 5+) females. Our estimates of sub-adult and adult female survival were 0.852 (95% CI = 0.628–0.951) and 0.952 (95% CI =

0.892–0.980) (Table 7). Coupled with other vital rates, Mace et al. (2012) estimated a mean lambda of 1.0306.

As an alternative to separate age classes, a survival rate was estimated for these categories combined ("independent female bears"). Analyses in program MARK found that this model (using this single, 2+ age-category) was within 0.3359 AIC units of the model than recognized both sub-adult and adult age-classes, suggesting that either model was similarly supported by available data. Results indicated an estimated survival rate of 0.936 (SE = 0.0216, and a 95% CI 0.878–0.968) for the period 2004-2009. This survival rate suggests a mean mortality rate of 0.064. Simulations (Section C) provided a similar but higher mean estimate of lambda of between 1.038 and 1.047 (Table 8).

A maximum 10% annual mortality (90% survival) threshold has been established as a population monitoring standard for independent females. Based on simulations by Harris (Section C), a 90% independent female survival rate would result in a mean lambda of 1.009 (Table 8). This population trajectory corresponds to an essentially stable population size. For a mean survival rate of 90%, 61% of the population simulations returned a value of lambda greater than 1.0 (stable) (Table 8). Twenty-eight percent of simulations at this benchmark rate indicated a population decline of $\geq$ 2%.

In the event that, for whatever reason, the survival of independent females should decline below 90% into the future, population management Standard #2 is in place to halt further declines until a management review is completed documenting and correcting, if possible, the reason behind the decline. The timing of the management review is based on the impact of female survival on population trend. If, through known-fate monitoring of radioed females, survival is determined to be between 0.89 and 0.90 for the most recent 12 year period, a review will take place. This equates to a mean population trend of between 1.002-1.009 (Table 8). Second, if survival is determined to be between 0.885 and 0.89 for the most recent 10 year period, a review will take place. This corresponds to a mean population trend of between >0.992 and 1.002 or a net change in the number of bears of -6 to +3 /bears year (Table 8). Third, if survival is determined to be between 0.875 and 0.885 for the most recent 8 year period, a review will take place. This corresponds to a mean population trend of >0.983 and $\leq$ 0.992 or a net change in the number of bears of -6 to -10/bears year (Table 8). And fourth, if survival is determined to be between $\leq$ 0.875 for the most recent 5 year period, a review will take place. This corresponds to a mean population trend of $\leq$ 0.982, or a net change of -13 bears/year (Table 8).

Table 7. Independent female survival rates from radio-collared bears in the NCDE.

Survival type	Estimate	SE	-95% CI	+95% CI
Natural survival (n = 2 deaths)[a]	0.989	0.008	0.956	0.997
Natural survival (n = 7 deaths)[b]	0.961	0.014	0.921	0.981
Natural and man-caused:				
1 unresolved assumed alive	0.940	0.018	0.895	0.966
1 unresolved assumed dead	0.934	0.018	0.888	0.962

[a] assumes bears with undetermined causes of death were not natural.

[b] assumes bears with undetermined causes of death were natural.

Table 8. Mean, SD, 95 confidence limits, and proportion of simulated λ values < 1.0, given reproductive and survival rates as estimated for the NCDE grizzly bear population 2004-09, and trial values of independent (age 2+) female survival. For all rates, distributions were generated using the desired mean, and variances that approximated the 95 confidence interval surrounding their empirical estimates.

Independent Female Survival	Mean λ	SD λ	Lower 95% λ	Upper 95% λ	Proportion λ < 1.0 (declining)	Proportion λ > 1.0 (increasing)	Proportion λ ≤ 0.98 (≥ 2% decline)
0.87	0.983	0.0347	0.9145	1.0489	68.6	31.4	46.3
0.88	0.992	0.0349	0.9213	1.0574	58.3	41.7	36.7
0.89	1.002	0.0349	0.9303	1.0673	47.1	52.9	22.5
0.90	1.009	0.0348	0.9399	1.0750	39.0	61.0	28.0
0.91	1.019	0.0349	0.9476	1.0848	27.8	72.2	16.4
0.92	1.028	0.0356	0.9562	1.0949	20.9	79.1	8.7
0.93	1.038	0.0363	0.9626	1.1046	15.5	84.5	2.4
0.94	1.047	0.0353	0.9754	1.1129	10.1	89.9	3.4
0.95	1.056	0.0359	0.9808	1.1212	6.8	93.2	2.3

Section C: Distributions of growth rates of grizzly bears in the Northern Continental Divide Ecosystem under various possible estimates of annual survival of independent bears.

Dr. Richard B. Harris
Department of Ecosystem and Conservation Sciences
University of Montana

I. Problem statement

Managers desire guidance on understanding the effects of various levels of mortalities on the grizzly bear population inhabiting the Northern Continental Divide Ecosystem (NCDE). Ideally, one would like to know how the number of mortalities that puts the population into a negative trajectory, so as to attempt to avoid having this many die. Calculating such a number with confidence is fraught with difficulty, for 2 reasons: 1) Although a precise estimate of total population size has been published, there is, at present, no protocol in place for updating this estimate; consequently, yearly population size of NCDE grizzly bears remains unknown; and 2) Considerably uncertainty surrounds both estimates of the number of bears dying, and the vital rates of the standing population.

Analyses conducted by Mace et al. (2012) suggest that the single best estimate of population growth (λ) during 2004-09 was1.0306 (i.e., roughly 3% increase yearly). However, largely because sample sizes were limited and the time period of this investigation spanned only 6 years, the 95% confidence limits around this estimate was 0.928–1.102. Thus, although the authors deem it highly likely that the population was increasing, available data do not allow this to be asserted with the conventional level of statistical certainty.

A possible option that managers may wish to consider in developing guidance regarding number of mortalities is to use what is known about the demographics of this population to explore how λ would vary if survival rates increased or decreased from the estimated value during 2004-09.

II. Objectives

The objectives of this exercise were to apply the level of uncertainty surrounding current estimates of vital rates for female grizzly bears to alternative future point estimates of the survival rate for independent female bears (defined here as age 2+), and from these, generate distributions of rates of growth (λ) that follow from these combinations. The results of this exercise are useful to someone asking the following question: "Given that reproduction and juvenile survival rates (as well as their uncertainty) are as best estimated during 2004-09, and given that uncertainty surrounding survival of independent female bears is similar to that estimated by Mace et al. (2012), what levels of annual female survival are consistent with a grizzly bear population that is unchanging in size?"

III. Methods

I projected λ from a series of life-tables of grizzly bear populations using PopTools (G. M. Hood, 2009; PopTools version 3.11). Each life table was produced from a sampling from the distributions of m_x (the mean number of female cubs/adult female/yr), for s_0 (female cub survival), and s_1 (female yearling survival) from the NCDE population, 2004-09 (Mace et al. 2012). I then used Monte Carlo methods (in PopTools) to sample from these distributions, each time recalculating λ. I then calculated means, standard deviations, and non-parametric 95% confidence limits of these simulated distributions (the latter by excluding the upper and lower 2.5% of simulated results). In all cases, n = 5,000 iterations.

To parameterize these life tables, I used the following means and standard errors from Mace et al. (2012): m_x: $\bar{X}$= 0.36685, SE = 0.0453; s_0: $\bar{X}$ = 0.6119, SE = 0.1077; s_1: $\bar{X}$ = 0.6820, SE = 0.1322. Note that this reproductive rate (0.36685) was an adjusted rate that accounted for cubs that were likely born but died prior to that year's first observation of her mother but still within the time period that the cub survival rate applied. Mace et al. (in press) calculated separate survival estimates for sub-adult (ages 2-4) and adult (ages 5+) females. To simplify calculations, I used a survival rate estimated for these categories combined ("independent female bears"), by Mark Haroldson (using the same data set): $\hat{S}_{F2+} = 0.936$, with a standard error, SE = 0.0216, and a 95% CI 0.878–0.968. Analyses in program MARK found that this model (using this single, 2+ age-category) was within 0.3359 AIC units of the model than recognized both subadult and adult age-classes, suggesting that either model was similarly supported by available data. I generated beta distributions that replicated the mean and 95% confidence interval of this survival rate. I then varied the desired mean survival in 0.01 increments (0.87-0.95), maintaining the same variance term in each case. Rates were modeled as independent of one another (i.e., no temporal correlation among rates).

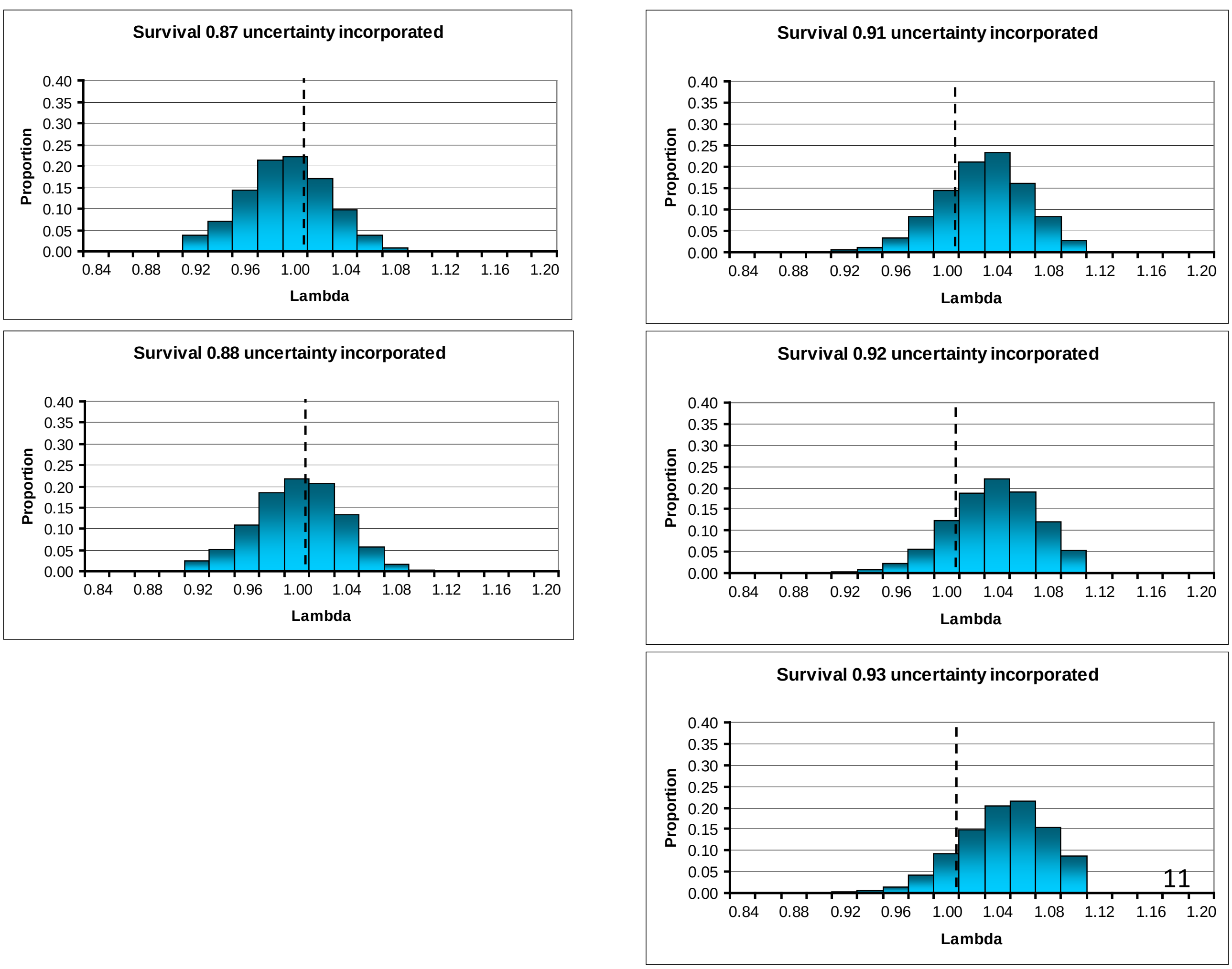
III. Results

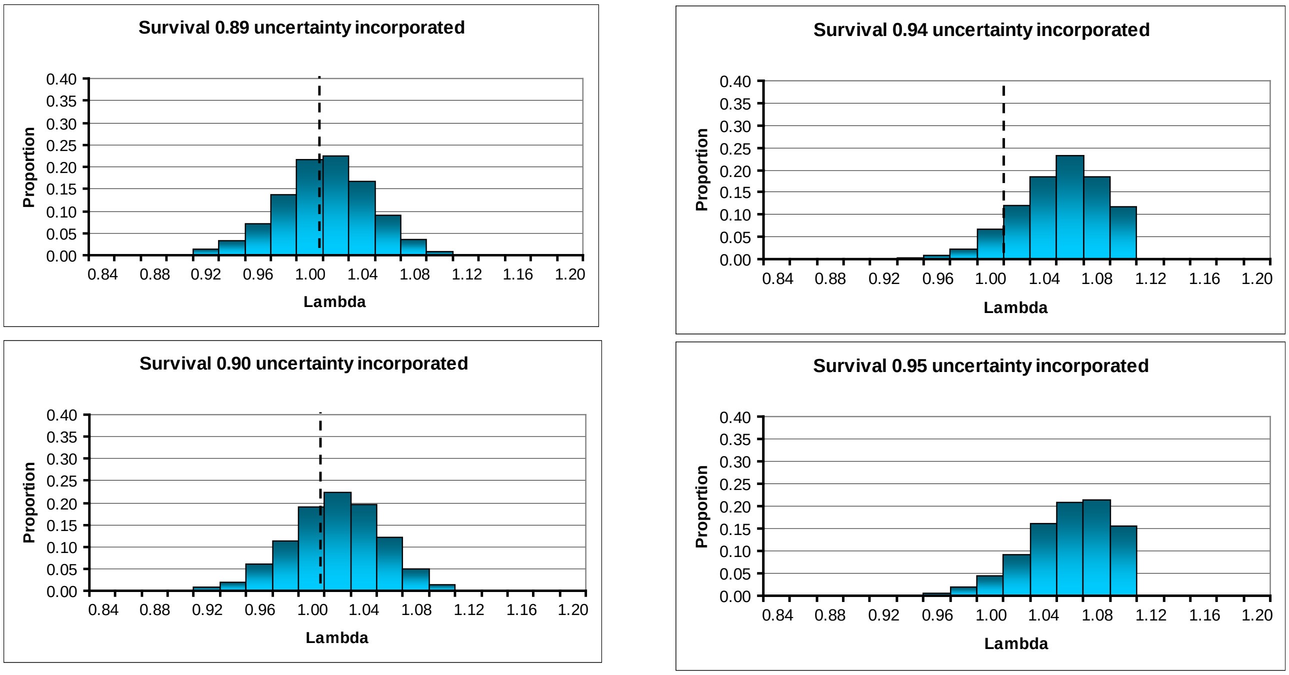
For each trial value of $S_{2+,}$ I report means, standard deviations, and upper and lower 95% confidence limits of λ in Table 1. Histograms of these distributions are shown in Figure 1. Mean values of λ and proportion of simulations < 1.0 are shown in Table 9.

Table 9. Mean, SD, 95% confidence limits, and proportion of simulated λ values < 1.0, given reproductive and survival rates as estimated for the NCDE grizzly bear population 2004-09, and trial values of independent (age 2+) female survival. For all rates, distributions were generated using the desired mean, and variances that approximated the 95% confidence interval surrounding their empirical estimates.

Independent Female Survival	Mean λ	SD λ	Lower 95% λ	Upper 95% λ	Proportion λ < 1.0 (declining)	Proportion λ > 1.0 (increasing)	Proportion λ ≤ 0.98 (≥ 2% decline)
0.87	0.983	0.0347	0.9145	1.0489	68.6	31.4	46.3
0.88	0.992	0.0349	0.9213	1.0574	58.3	41.7	36.7
0.89	1.002	0.0349	0.9303	1.0673	47.1	52.9	22.5
0.90	1.009	0.0348	0.9399	1.0750	39.0	61.0	28.0
0.91	1.019	0.0349	0.9476	1.0848	27.8	72.2	16.4
0.92	1.028	0.0356	0.9562	1.0949	20.9	79.1	8.7
0.93	1.038	0.0363	0.9626	1.1046	15.5	84.5	2.4
0.94	1.047	0.0353	0.9754	1.1129	10.1	89.9	3.4
0.95	1.056	0.0359	0.9808	1.1212	6.8	93.2	2.3

Fig. 2. Histograms of simulated λ given mean reproductive and juvenile female survival rates as estimated for the NCDE grizzly bear population 2004-09, and trial values of independent (age 2+) female survival. For cub survival (s_0), yearling survival (s_1), and independent female survival (s_{2+}), beta distributions were generated using the mean, and variances from their empirical estimates. For reproductive rate (m_x), a normal distribution was generated using the mean and variance from its empirical estimate (Mace et al. 2012).



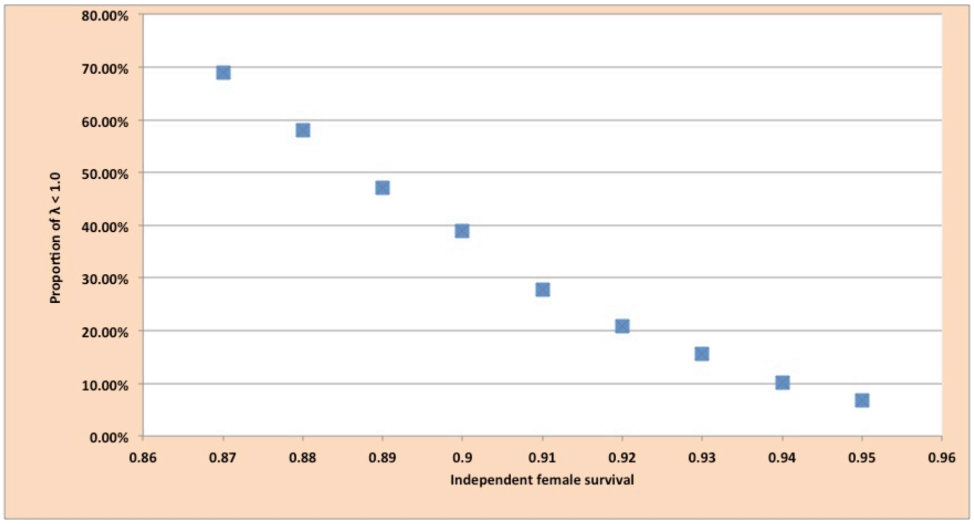


Discussion

Table 9 and Fig. 2 should be interpreted with the following information in mind. The magnitudes of variability surrounding each estimate of λ account for uncertainty of estimates for reproductive and survival rates but not for any possible covariance among these rates (although this is likely to be relatively unimportant). Projections of λ produced in this way also implicitly assume that mean reproductive and juvenile survival rates would remain unchanged under hypothetical survival rates of independent females, as well as with associated changes in density and distribution of grizzly bears.

To make an informed decision on the appropriate management goal for population management in the NCDE, managers need to consider Figure 3. Independent female survival is the vital rate that can be managed and carefully monitored to measure adherence to the management goal. Pervious sections of this report have detailed the methods available to measure independent female survival. The closer the management goal is to threshold management, the more uncertainty about the trajectory of the population increases.

Figure 3. The proportion of the 95% confidence interval around independent female survival in the NCDE that lies below λ = 1.0 for survival rates between 86% and 95%. λ = 1.0 is a stable population with no increase in size. The probability that the population is decreasing is represented by the Y axis (the proportion of the calculated □ < 1.0). Note that **decreases. For example, at survival = 0.91, 29% of the 95% confidence interval is below λ = 1.0. The larger the proportion of the 95% confidence interval below λ = 1.0, the greater the uncertainty that the population is stable to increasing.**



<u>Section D: Supporting Information for Demographic Standards 2-4</u>

<u>Standard 2. Maintain a point estimate of independent female (2+ years' old) survival of > 0.90 averaged over the most recent 6-year period in the PCA and Zone 1.</u>

Two estimates of independent female survival will be calculated and reported by the NCDE Monitoring Team each year: 1) independent female survival over the entire PCA and Zone 1, and 2) "All independent females excluding those whose annual home range is entirely within GNP" (See Section F).

The sample of radioed-females to use in survival analyses must meet the protocol of Mace et al. (2012) and Schwartz et al. (2006) as being "research females." For survival analysis #1 (above), all independent radioed-females throughout the PCA and Zone 1 in the sample will be used in the analysis including radioed female bears in Glacier National Park. For survival analysis #2 (above), all radioed females except those whose annual home range is entirely within the Park boundary will be used.

Independent female survival will be estimated annually using the staggered-entry Kaplan-Meier (known fate) method as in Mace et al. (2012) or other appropriate method. Survival will be calculated and averaged over the most recent 6-year period to ensure adequate sample sizes. Each year, females whose telemetry points are entirely within Glacier National Park will be excluded from survival analyses for the second estimate. The known fate method of calculating survival is described in Appendix 2-1.

Standard 3: Independent female mortality will not exceed 10% of the estimated number of independent females in the following two areas, whichever is reached first : 1) all independent females inside the PCA or Zone 1; and 2) all independent females excluding those whose annual home range is entirely within Glacier National Park. (See Appendix 2, Section F). The average number of independent female mortalities from all causes in the areas described above, including grizzly bears dying from known and probable human-caused, natural, calculated unknown and unreported, and undetermined causes, will not exceed 10% of the projected population size of independent females estimated in either of the two areas described above, whichever is reached first, as averaged over the most recent 6-year period (e.g., 2006-2011, 2007-2012, and so on). Annual mortality reports will be used by population managers to determine maximum annual discretionary mortality.

Standard 4: Independent male mortality will not exceed 20% of the estimated number of independent males outside of Glacier National Park but inside the PCA or Zone 1 (see Appendix 2, Section D, Table 13). The average number of independent male mortalities from all causes outside of GNP but inside the PCA and Zone 1, including grizzly bears dying from known and probable human-caused, natural, calculated unknown and unreported, and undetermined causes, will not exceed 20% of the projected population size of independent males outside GNP as averaged over the most recent 6-year period (e.g., 2006-2011, 2007-2012, and so on). Annual mortality reports will be used by population managers to determine maximum annual discretionary mortality.

Mortalities of independent females and males will be tallied and reported for the PCA and Zone 1, including Glacier National Park each year, and reported for the two areas described above. Annual mortality reports of all bears will include all mortalities from all causes including grizzly bears dying from known and probable human-caused, natural, calculated unknown and unreported, and undetermined causes. Levels of unreported mortality will be estimated and updated using the methods of Cherry et al. (2002) and as described in Section E. Few independent female mortalities occur within Glacier National Park (Table 10). Mortality records will be collected and maintained by the NCDE Monitoring Team led by MFWP.

Mortality limits will be used by State and Tribal population managers to determine allowable discretionary mortality that will ensure the standards for survival and mortality are met. To calculate annual allowable independent male and female mortality, managers will use estimates of the population size as extrapolated from population trend (λ). Two estimates of lambda will be calculated and reported by the NCDE Monitoring Team each year: 1) lambda over the entire PCA and Zone 1, and 2) lambda for that portion of the population (See Section F) that use habitats either entirely outside of Glacier National Park plus that portion of the population that straddles the Park boundary.

The 2 estimates of population trend will be calculated each year using the most recent 6 years of vital reproductive and survival rate data obtained from the sample of radio-collared independent females. All vital population rates and associated standard errors will be estimated using the method of Mace et al. (2012) or other appropriate methods. Population trend will be estimated using program RISKMAN or other appropriate model, including measures of uncertainty. Sub-adult and adult female survival rates will be pooled for analyses unless significant differences exist. Trends in all vital rates will be investigated annually.

Each year, a total mortality limit of 10% of independent females will be calculated for the both: a) the entire population in the PCA and Zone 1 and separately for: b) all females except those living entirely within Glacier National Park. These calculations are given in Table 11. Second, the number of known and probable non-hunting independent female mortalities outside GNP will be averaged over the most recent a 6-year period. This average non-hunting mortality number will then be subtracted from the total limit of 10% to ascertain the number of discretionary mortalities available per year. Between 1999 and 2011, an average of 11 independent females were known to die from non-hunting causes each year outside of Glacier National Park but within the PCA and Zone 1 but this number does not include the estimated unknown/unreported kills during that period (Table 12).

Each year, a total mortality limit of 20% of independent males will be calculated for the both: a) the entire population in the PCA and Zone 1 and b) separately for those independent males expected to be using habitats outside the Park and straddling the Park boundary. These calculations are given in Table 13. Second, the number of known and probable non-hunting independent male mortalities outside GNP will be averaged over the most recent a 6-year period. This average non-hunting mortality number will then be subtracted from the total limit of 20% to ascertain the number of discretionary mortalities available per year. Between 1999 and 2011, an average of 14 independent males were known to die from non-hunting causes each year outside of Glacier National Park but within the PCA and Zone 1 but this number does not include the estimated unknown/unreported kills during that period (Table 14).

Table 10. Annual known and probable grizzly bear mortalities in the PCA and Zone 1 that showing mortalities within and outside Glacier National Park. Data do not include an estimate of unreported mortality; 1999-2011.

Year	Percent of all known or probable grizzly mortalities inside GNP	Percent of independent female mortalities in the NCDE that occurred within GNP
1999	0.0	0.0
2000	0.0	0.0
2001	4.2	0.0
2002	7.1	0.0
2003	6.7	0.0
2004	0.0	0.0
2005	0.0	0.0
2006	21.4	20.0
2007	0.0	0.0
2008	7.1	0.0
2009	19.0	20.0

2010	0.0	0.0
2011	3.1	0.0
Mean	4.3%	3.1%

Table 11. Method to calculate annual sustainable mortality for independent females.

Area	Estimate of total number of females in given year (T_{Fpop})[a]	Proportion of independent females (2+ years old)[b]	Proportion of independent females using habitats outside GNP[c]	Independent female mortality limit (10%)
a)PCA and Zone 1	= (471)λ^z	0.69	na	$T_{Fpop)*0.69*0.10}$
b)Proportion of population using habitats outside GNP	= (471)λ^z	0.69	0.71	$T_{Fpop)*0.69*0.71*0.10}$
2015 example				
a) PCA and Zone 1	(471)1.03^{11} = 652	652*0.69=450	na	450*0.10 = 45
b)Proportion of population using habitats outside GNP	(471)1.03^{11} = 652	652*0.69=450	450*0.71=320	320*0.10 = 32

[a] estimate of 471 females in 2004 (Kendall et al. 2009),), and trend of 1.03 from Mace et al. (2012). "Z" is the number of year's post-2004.
[b] see Section A for estimation of proportion of independent females from stable age distribution.
[c] see Section F for estimated proportion of the population of grizzly bears that use habitats outside and straddling the boundary of Glacier National Park.

Table 12. Female mortality records for that portion of NCDE outside of Glacier Park.

		Mortality Cause					
Year	Est. independent female population outside of GNP[a]	Mgmt Removals	Public Discovery	Unreported Estimate	Telemetry Discovery	Total	% Mortality[b]
1999	209	0	4	5	0	9	3.2
2000	215	2	6	8	1	17	5.9
2001	221	2	5	7	0	14	4.7
2002	227	1	4	5	0	10	3.3
2003	234	1	1	1	0	3	1.0
2004	242	3	3	4	4	14	4.3
2005	248	5	1	1	1	8	2.4
2006	256	1	0	1	2	4	1.2
2007	263	0	6	8	1	15	4.2
2008	272	3	2	2	0	7	1.9
2009	280	0	5	7	2	14	4.0
2010	288	2	0	1	2	5	1.6
2011	296	2	7	9	0	18	4.5
Mean		1.77	3.38	4.54	1.08	10.77	3.2%

[a] Estimated number of females derived from Kendall et al.'s (2009) estimate of 471 total females in 2004. Seventy-five percent of the population is estimated to use habitats outside of Glacier National Park. Population grew at a lambda of 1.03 (Mace et al. 2012).
[b] Total mortality/population size.

Table 13. Method to calculate annual sustainable mortality for independent males.

Area	Estimate of total number of males in given year (T_{Fpop})[a]	Proportion of independent males (2+ years old)[b]	Proportion of independent males using habitats outside GNP[c]	Independent male mortality limit (20%)
a)PCA and MZ1	= (295)λ^z	0.56	na	$T_{Fpop)*0.56*0.20}$
b)Proportion of population using habitats outside GNP	= (295)λ^z	0.56	0.79	$T_{Fpop)*0.56*0.79*0.20}$
2015 example				

a) PCA and MZ1	$(295)1.03^{11} = 408$	408*0.56=228	na	237*0.20 = 47
b)Proportion of population using habitats outside GNP	$(295)1.03^{11} = 408$	408*0.56=228	228*0.79=180	180*0.20 = 36

[a] estimate of 295 males in 2004 (Kendall et al. 2009), and trend of 1.03 from Mace et al. (2012). "Z" is the number of year's post-2004.
[b] see Section A for estimation of proportion of independent males from stable age distribution.
[c] see Section F for estimated proportion of the population of grizzly bears that use habitats outside of Glacier National Park.

Table 14. Male mortality records for that portion of the PCA and Zone 1 outside of Glacier Park.

		Mortality Cause					
Year	Est. independent male population outside of GNP[a]	Mgmt Removals	Public Discovery	Unreported Estimate	Telemetry Discovery	Total	% Mortality[b]
1999	116	5	2	2	2	11	9.5
2000	120	3	1	1	0	5	4.2
2001	123	5	5	7	2	19	15.4
2002	127	3	4	5	0	12	9.4
2003	131	3	1	1	0	5	3.8
2004	135	1	6	8	0	15	11.1
2005	139	2	8	11	1	22	15.8
2006	143	2	1	1	1	5	3.5
2007	147	2	10	14	0	26	17.7
2008	152	1	4	5	0	10	6.6
2009	156	1	6	8	0	15	9.6
2010	161	7	3	4	0	14	8.7
2011	166	7	6	9	1	23	13.9
Mean		3.2	2.3	4.0	5.4	14	9.9%

[a] Estimated number of males derived from Kendall et al.'s (2009) estimate of 294 total males in 2004. Population grew at a lambda of 1.03 (Mace et al. 2012). Independent males are assumed to be 58% of total using stable state probabilities from program RISKMAN. Seventy-nine percent of the population is estimated to use habitats outside of Glacier National Park.
[b] Total mortality/population size.

Section E. Estimating the Level of Unreported Mortality for Grizzly Bears in the NCDE

Mace, R. and L. Roberts. 2011. Northern Continental Divide Ecosystem Grizzly Bear Monitoring Team Annual Report, 2009-2010. Montana Fish, Wildlife & Parks, 490 N. Meridian Road, Kalispell, MT 59901. Unpublished data.

Introduction

Grizzly bear mortalities in the NCDE are recorded annually. The number grizzly bear of deaths involving agency removals, and those that die while wearing functional radio collars are know with certainty. However, managers acknowledge that not all dead bears discovered by the public are reported to authorities. To more accurately estimate the total number of bear mortalities occurring each year requires an estimate of the level of these unreported mortalities. Although such estimates are available for the Greater Yellowstone Ecosystem, and are incorporated into annual total mortality tabulations no such estimates have been made for the NCDE. To more accurately estimate annual total mortality in the NCDE, we employed the methods of Cherry et al. (2002) using a sample of radio-instrumented bears.

Methods

Cherry et al. (2002) provided a method wherein radio-collared bears that died were used to estimate additional grizzly bear deaths that go undetected. Each death of an independent aged (2 + years old) radioed-instrumented bear, monitored between 1999 and 2010, was classified as being either reported by the public or unreported by the public. We defined a reported death as one where either a radioed or non-radioed bear that was reported to wildlife management authorities by the public without the aid of radio-telemetry. We defined an unreported death as the death of a radioed bear discovered by telemetry. Bears reported by employees of other state, federal, or tribal agencies were considered publicly reported deaths. Likewise, bear/train collisions reported by Burlington Northwestern personnel were considered to be public reportings.

We used a sample of independent-aged (2+ years old) grizzly bears radioed-monitored at time of death, 1999-2010. We considered deaths where bears were wearing a functional radio collar at time of death, and were radio-monitored within 2 months of death. Additionally, the death had to be either a known death (a carcass or other evidence) or a probable death (Strong evidence of death, but no carcass) (Cherry et al. 2002). We excluded radioed bears that were removed from the ecosystem due to conflicts with humans (management removals).

The number of reported and unreported deaths of radio bears was then used in the Bayesian method of Cherry et al. (2002), to estimate the number of grizzly bear deaths that go unreported each year. As per the Interagency Grizzly Bear Study Team document (2005), we used the median of the creditable interval for the estimated reported and unreported loss.

Results

We used data from 32 radio-collared bears to estimate the ratio of unreported to reported mortalities in the NCDE. We drew inference from 13 and 19 instrumented males and females, respectively. For males, 53.8% of the deaths were reported, while 31.5% of the female deaths were reported (Table 15). When sexes were combined, 40.6% of the deaths were reported, and 51.43% were unreported. The ratio of unreported to reported deaths for both sexes suggest that for every 1 reported death there are 1.43 deaths were not reported to management authorities.

The estimated total reported and unreported deaths per year is provided in Table 16 given the unreported rate of 1.43. To calculate total mortality of independent aged bears of each sex annually, sanctioned management removals, and removals of radio-collared bears must be add to this total.

Table 15. Cause of death for 32 radio-collared grizzly bears in the NCDE that were used to judge the level of unreported mortality; 1999-2010.

Cause of death	Reporting of Mortality by Sex				Total
	Male		Female		
	Reported by Public	Unreported by Public (due to telemetry)	Reported by Public	Unreported by Public (due to telemetry)	
Train collision	2	0	3	0	5
Automobile collision	2	0	0	0	2
Defense-of-life	0	0	1	0	1
Illegal	3	4	2	3	12

Undetermined	0	1	0	8	9
Natural	0	1	0	2	3
Total	7	6	6	13	32

Table 16. Estimated number of reported and unreported deaths of grizzly bears each year based on the ratio of unreported to reported deaths (1.43) of a test sample of radioed bears. These numbers should be used separately for male and female deaths.

Number of Publicly Reported Deaths per year[a]	Estimated Number of Unreported Deaths per year	Total Reported and Unreported Deaths per year[b]
0	*1*	*1*
1	*1*	*2*
2	*2*	*4*
3	*4*	*7*
4	*5*	*9*
5	*7*	*12*
6	*8*	*14*
7	*9*	*16*
8	*11*	*19*
9	*12*	*21*
10	*14*	*24*

[a] *the number of deaths in the official mortality records reported by the public.*
[b] *the median of the credible interval for reported and unreported mortalities (Cherry et al. 2002).*

Section F. Proportion of grizzly bear population using habitats outside of Glacier National Park: Where do the mortality standards apply

Prepared by: Richard Mace, John Waller, Dan Carney, Chris Servheen

Introduction

This chapter contains a description of management zones, and outlines proposed population management strategies. Management of independent male and female mortality limits is a central part of the Chapter. Within the PCA and Management Zone 1, there are 2 standards (3 and 4) which pertain to allowable mortality limits for independent males and females. It is necessary to determine where within the PCA, and what portion of the male and female population are subject to the mortality standards of 10% for independent females and 20% of independent males.

The PCA can be divided into 2 main areas regarding mortality standards; Glacier National Park where the use of discretionary mortality is very limited, and the remainder of the PCA where there is most discretionary mortality management would be applied. It is therefore necessary to determine the proportion of the total population of independent males and females that occupy habitats either wholly or partly outside of Glacier National Park.

Methods

To address this issue, we used home ranges from radio-instrumented female grizzly bears, and DNA detections at rub-trees for the period 2009-2011 (Kendall, USGS unpublished data; email to C. Servheen dated 5 July, 2012). Location data on these radioed females were obtained as a part of the NCDE Grizzly Bear Trend Monitoring Program (Mace et al. 2012).

For the radioed sample of females, we examined the home ranges of those individuals that lived within and directly adjacent to Glacier National Park. We did not include bears captured and radioed during human conflict situations. For each individual and year, we used the telemetry coordinates and calculated the standard radius (km) of each bears annual home range (Harrison 1958, Single and Roseberry 1989). The standard radius was calculated as $D_i = \sqrt{(x_2-x_1)^2+(y_2-y_1)^2}$. Using GIS, we then buffered the boundary of Glacier Park using this radius. Each female was categorized as having a home range that was 1) 100% within Glacier Park, 2) 100% outside of the park but within the buffer, or 3) bears whose home range straddled the Park. For these females, we determined the percentage of telemetry points within and outside Glacier Park. The percentage was assumed to be closely correlated with the amount of time bears spend in and out of the park.

We then evaluated the individual male and female grizzly bears that were detected at through DNA at rub-trees to ascertain the proportion of individuals in 3 geographic zones. These zones were: 1) a buffer zone that was the average home range radius extending outside the Park boundary plus a home range radius that extended inside the Park boundary, 2) the internal portion of GNP not within the buffer zone, and 3), the area of the NCDE outside the buffer surrounding the Park (Fig. 4). The proportions of males and females detected in each zone were then determined.

Results

<u>Home Range Location Relative to GNP</u>

We evaluated 76 home ranges of 34 females that lived in or adjacent to Glacier Park. Home ranges were developed for the period 2004-2011, and individual females had between 1 and 6 annual home ranges within the sample. Most home ranges (59%) straddled the Park boundary (Table 17). Home range diameters were, on average, smallest for bear that lived 100% within the Park, and largest (mean = 6.07 km) for females that straddled the Park boundary. For the pooled sample, the average home range radius was approximately 5 km. For the bears that straddled the Park, an average of 57.02% of their locations were within the Park (Table 18), while 42.98% were outside the Park. A sample of multi-annual female home ranges that straddle the GNP boundary is shown in Fig. 5.

<u>DNA Rub-tree Detections</u>

Comments by K. Kendall (USGS) regarding the results of the distribution grizzly bear detections at rub-trees are as follows. “The proportion of bears detected in each zone was similar for hair traps and bear rubs in 2004. The proportion of bears outside of GNP and the buffer was consistently higher 2009-2011 than in 2004. This is consistent with preliminary analysis of trend data from bear rub monitoring suggesting that the population inside GNP increased slightly or was stable 2004-2010 and the population outside GNP increased at a higher rate. We sampled all of habitat in the NCDE thought to be occupied by grizzlies in 2004, which extended beyond the Recovery Zone boundary. The proportions in the table do not include 21 individuals detected in 2004 and 16 individuals detected in 2009-2011 whose average locations were outside the Recovery Zone boundary. Obviously, if these bears were included, the proportion of the population occurring outside the park would be higher. We did not sample in Canada so we had no detections in the buffer north of the border."

For females, 75% of the individuals were detected in either the 12 km buffer around the Park or in the remainder of the NCDE (Table 18). This is the assumed proportion of the independent female population in the NCDE that either do not use the Park or move between the Park and non-park habitats.

For males, 79% of the individuals were detected in either the 12 km buffer around the Park or in the remainder of the NCDE (Table 18). This is the assumed proportion of the independent male population in the NCDE that either do not use the Park or move between the Park and non-park habitats.

Table 17. Home range radius size for bears living 100% outside GNP, 100% inside of GNP, and for those bears whose ranges straddled the Park boundary.

Female Home Range Relationship Relative to Glacier Park	Radius of Home Range (km)				
	Mean	**-95% CI**	**+95% CI**	***n***	**SE**
100% In GNP	2.799	2.289	3.308	21	0.244
100% Out Of GNP	4.645	3.515	5.775	10	0.499
Straddle Park Boundary	6.070	5.044	7.096	45	0.509
All Groups	4.979	4.273	5.684	76	0.354

Table 18. Proportion of males and females detected by DNA at rub-trees in different zones within the NCDE (Kendall, USGS, unpublished data).

Area of the NCDE	% of population detected at rub-trees in each zone
FEMALES	
GNP Core	24%
12 km buffer around GNP[a]	16%
Remainder of NCDE[b]	59%
a +b	75%
MALES	
GNP Core	22%
12 km buffer around GNP[a]	18%
Remainder of NCDE[b]	61%

a +b	79%

Figure 4. Location of 3 geographic zones used to judge the proportion of the male and female grizzly bear population that use non-park habitats; Core GNP, a 12 km wide buffer (6 km internal to park boundary, and 6 km outside the boundary), and the remainder of the NCDE.

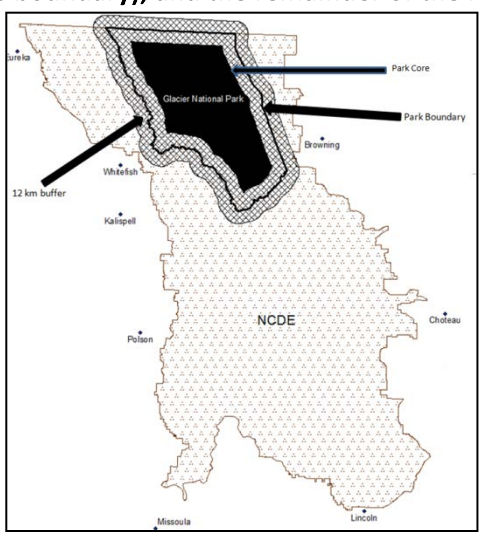
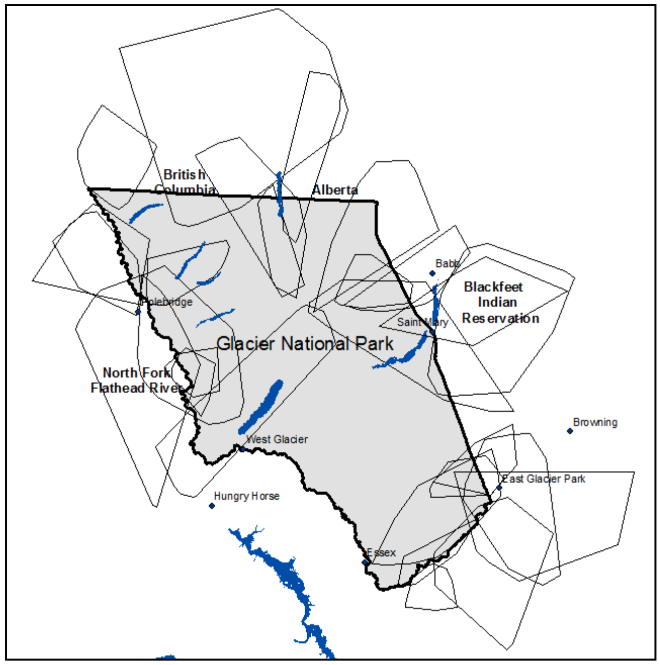


Figure 5. Female grizzly bear convex polygon home ranges (multi-annual) relative to Glacier National Park, for those females who used both Park and non-park habitats; 2004-2011.



Literature Cited

Bunnell, F. E., and D. E. N. Tait. 1980. Bear in models and reality. International Conference for Bear Research and Management. 4:15-23.

Cherry, S., M. A. Haroldson, J. Robinson-Cox, and C. C. Schwartz. 2002. Estimating total human-caused mortality from reported mortality using data from radio-instrumented grizzly bears. Ursus 13:175-184.

Cherry, S., G. C. White, K. A. Keating, M. A. Haroldson, and C. C. Schwartz. 2007. Evaluating estimators for numbers of females with cubs-of-the-year in the Yellowstone grizzly bear population. Journal of Agricultural, Biological, and Environmental Statistics. 12:195-215.

Harris, R. B., C. C. Schwartz, M. A. Haroldson, and G. C. White. 2006. Trajectory of the Yellowstone grizzly bear population under alternative survival rates. Pages 44-55 *in* C. C. Schwartz, M. A. Haroldson, G. C. White, R. B. Harris, S. Cherry, K. A. Keating, D. Moody, and C. Servheen, editors. Temporal, spatial, and environmental influences on the demographics of grizzly bears in the Greater Yellowstone Ecosystem. Wildlife Monographs 61.

Harris, R.B. 2011. Study design and sampling intensity for demographic analyses of bear populations. Ursus. 22:24-36.

Harris, R. B., G. C. White, C. C. Schwartz, and M. A. Haroldson. 2007. Population growth of Yellowstone grizzlies: uncertainty and future monitoring. Ursus. 18:168-178.

Harrison, J.L. 1958. Range of movement of some Malaysian rats. Journal of Mammalogy. 39:190-206.

Hovey, F. W., and B. N. McLellan. 1996. Estimating population growth of grizzly bears from the Flathead River Drainage using computer simulations of reproductive and survival rates. Canadian Journal of Zoology. 74:1409-1416.

Interagency Grizzly Bear Study Team. 2005. Reassessing methods to estimate population size and sustainable mortality limits for the Greater Yellowstone Ecosystem grizzly bear. Interagency Grizzly Bear Study Team, USGS Northern Rocky Mountain Science Center, Montana State University, Bozeman, Montana, USA.

Interagency Grizzly Bear Study Team. 2006. Supplement to Reassessing methods to estimate population size and sustainable mortality limits for the Greater Yellowstone Ecosystem grizzly bear. Interagency Grizzly Bear Study Team, USGS Northern Rocky Mountain Science Center, Montana State University, Bozeman, Montana, USA.

Interagency Grizzly Bear Study Team. 2007. Summary and explanation of methods to estimate population size and sustainable mortality of Yellowstone grizzly bears. Interagency Grizzly Bear Study Team, U.S. Geological Survey, Northern Rocky Mountain Science Center, Montana State University, Bozeman, Montana.

Keating, K.A., C.C. Schwartz, M.A. Haroldson, and D. Moody. 2002. Estimating numbers of females with cubs-of-the-year in the Yellowstone grizzly bear population. Ursus. 13:161-174.

Kendall, K. C., J. B. Stetz, J. Boulanger, A. C. McLeod, D. Paetkau, and G. C. White. 2009. Demography and genetic structure of a recovering grizzly bear population. Journal of Wildlife Management. 73:3-16.

Knight, R. R., B. M. Blanchard, and L. L. Eberhardt. 1995. Appraising status of the Yellowstone grizzly bear population by counting females with cubs-of-the-year. Wildlife Society Bulletin. 23:245-248.

Lande, R., B. Saether, and S. Engen. 1997. Threshold harvesting for sustainability of fluctuating resources. Ecology. 78:1341–1350.

Lotka, A., and F. Sharpe. 1911. A problem in age-distribution. Philosophical Magazine. *12*:435–438.

Mace, R.D. and J.S. Waller 1997. Demography and population trend of grizzly bears in the Swan Mountains, Montana. Conservation Biology. 12:1005-1016.

Mace, R. D., D. W, Carney, T. Chilton-Radandt, S.A. Courville, M.A. Haroldson, R.B. Harris, J. Jonkel, M. Madel, T.L Manley, C.C. Schwartz, C. Servheen, J.S. Waller, and E. Wenum. 2012. Grizzly bear population vital rates and trend in the Northern Continental Divide Ecosystem, Montana. Journal of Wildlife Management.76:119-128.

Mace, R. and L. Roberts. 2012. Northern Continental Divide Ecosystem Grizzly Bear Monitoring Team Annual Report, 2011. Montana Fish, Wildlife & Parks, 490 N. Meridian Road, Kalispell, MT 59901. Unpublished data.

McLoughlin, P.D. 2003. Managing risks of decline for hunted populations of grizzly bears given uncertainty in population parameters. Final report to the British Columbia Independent Scientific Panel on Grizzly Bears. Department of Biological Sciences, University of Alberta, Edmonton AB.

Miller, S.D. 1989. Population management of bears in North America. International Conference on Bear Research and Management. 8:357-373.

Miller, S. D., G. C. White, R. A. Sellers, H. V. Reynolds, J. W. Schoen, K. Titus, V. G. Barnes Jr, R. B. Smith, R. R. Nelson, W. B. Ballard, and C. C. Schwartz. 1997. Brown and black bear density estimation in Alaska using radiotelemetry and replicated mark-resight techniques. Wildlife Monographs. 133.

Single, J.R. and J. L. Roseberry. 1989. Clarification of circular home range probability zones based on standard diameters. 1989 Transactions of the Western Section of the Wildlife Society. 25:89-90.

Schwartz, C.C. 1999. Evaluation of a capture-mark-recapture estimator to determine grizzly bear numbers and density in the Greater Yellowstone Area. Pages 13-20 *in* C.C. Schwartz and M.A. Haroldson, editors. Yellowstone grizzly bear investigations: annual report of the Interagency Grizzly Bear Study Team, 1998. U.S. Geological Survey, Bozeman, Montana, USA.

Schwartz, C.C, S.D. Miller, and M.A. Haroldson. 2003. Grizzly bear. Pages 556-586 in G.A. Feldhamer, B.C. Thompson, and J.A. Chapman, eds. Wild Mammals of North America: Biology, Management, and Conservation. Second edition. Johns Hopkins Univ. Press. Baltimore, Maryland, USA.

Schwartz, C. C., M. A. Haroldson, and G. C. White. 2006. Survival of independent grizzly bears in the Greater Yellowstone Ecosystem, 1983–2002. Pages 33–42 *in* C. C. Schwartz, M. A. Haroldson, G. C. White, R. B. Harris, S. Cherry, D. Moody, and C. Servheen, authors. Temporal, spatial, and environmental influences on the demographics of the Yellowstone grizzly bear. Wildlife Monographs. 161.

Schwartz, C. C., M. A. Haroldson, S. Cherry, and K. A. Keating. 2008. Evaluation of rules to distinguish unique female grizzly bears with cubs in Yellowstone. Journal of Wildlife Management. 72:543–554.

Seber, G.A.F. 1982. The estimation of animal abundance and related parameters. Charles Griffin and Co. LTD. London.

Stetz, J.B., K. C. Kendall, and C. Servheen. 2010. Evaluation of rub tree surveys to monitor grizzly bear population trends. Journal of Wildlife Management. 74:860-870.

Taylor, M., Kuk, M., Obbard, M., Cluff, H.D., and Pond, B. 2001. RISKMAN: risk analysis for harvested populations of age structured, birth-pulse species. http://riskman.nrdpfc.ca/index.htm

United States Fish and Wildlife Service. 1993. Grizzly bear recovery plan. Missoula, Montana, USA.

United States Fish and Wildlife Service. 2007. Final Conservation Strategy for the Grizzly Bear in the Greater Yellowstone Area. Missoula, Montana, USA.

Walters, C. 1986. Adaptive management of renewable resources. MacMillian Publishing, New York. 386 pp.

White, G.C. and R.A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, Inc.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46, Supplement. 120-138.

White. 2010. Evaluation of Population Estimation with DNA Collected from Rub Tree. Unpublished report. 8 pp.

Woods, J. G., D. Paetkau, D. Lewis, B. N. McLellan, M. Proctor, and C. Strobeck. 1999. Genetic tagging of free-ranging black and brown bears. Wildlife Society Bulletin. 27:616-627.

Appendix 3

Habitat Baseline 2011 – Motorized Access in Each Bear Management Subunit

BMU	Subunit Name	Principal Agency	OMRD	TMRD	CORE
BATM	Badger	LCNF-Rocky Mtn Front RD	0	0	94
BATM	Heart Butte	LCNF-Rocky Mtn Front RD	1	0	81
BATM	Two Medicine	LCNF-Rocky Mtn Front RD	2	1	87
BGSM	Albino Pendant	FNF-Spotted Bear RD	0	0	100
BGSM	Big Salmon Holbrook	FNF-Spotted Bear RD	0	0	100
BGSM	Black Bear Mud	FNF-Spotted Bear RD	0	0	100
BGSM	Brushy Park	FNF-Spotted Bear RD	0	0	100
BGSM	Buck Holland	FNF-Swan Lake RD	24	41	49
BGSM	Burnt Bartlett	FNF-Spotted Bear RD	0	0	100
BGSM	Hungry Creek	FNF-Spotted Bear RD	0	0	100
BGSM	Little Salmon Creek	FNF-Spotted Bear RD	0	0	100
BGSM	Meadow Smith	FNF-Swan Lake RD	21	53	41
BGSM	White River	FNF, Spotted Bear RD	0	0	100
BITE	Birch	LCNF-Rocky Mtn Front RD	0	0	93
BITE	Teton	LCNF-Rocky Mtn Front RD	12	4	75
BNKR	Big Bill Shelf	FNF-Spotted Bear RD	11	2	87
BNKR	Bunker Creek	FNF-Spotted Bear RD	5	3	92
BNKR	Goat Creek	FNF-SLRD & MT DNRC	23	59	42
BNKR	Gorge Creek	FNF-Spotted Bear RD	0	0	100
BNKR	Harrison Mid	FNF, - Spotted Bear RD	1	0	99
BNKR	Jungle Addition	FNF-Spotted Bear RD	19	17	68
BNKR	Lion Creek	FNF-SLRD & MT DNRC	19	47	51
BNKR	South Fork Lost Soup	FNF-SLRD & MT DNRC	25	48	40
BNKR	Spotted Bear Mtn	FNF-Spotted Bear RD	20	18	68
CODV	Pentagon	FNF-Spotted Bear RD	0	0	100
CODV	Silvertip Wall	FNF-Spotted Bear RD	0	0	100
CODV	Strawberry Creek	FNF-Spotted Bear RD	0	0	100
CODV	Trilobite Peak	FNF-Spotted Bear RD	0	0	100
DELK	Falls Creek	LCNF-Rocky Mtn Front RD	0	0	85
DELK	Scapegoat	LCNF-Rocky Mtn Front RD	2	0	83
HGHS	Coram Lake Five	FNF-Hungry Horse RD	30	46	18
HGHS	Doris Lost Johnny	FNF-Hungry Horse RD	57	19	36
HGHS	Emery Firefighter	FNF-Hungry Horse RD	19	20	53
HGHS	Peters Ridge	FNF-HHRD & SLRD	52	25	34
HGHS	Riverside Paint	FNF-Hungry Horse RD	19	16	73
HGHS	Wounded Buck Clayton	FNF-Hungry Horse RD	28	28	65
LMFF	Dickey Java	FNF-Hungry Horse RD	9	0	85
LMFF	Lincoln Harrison	Glacier NP	0	0	98
LMFF	Moccasin Crystal	FNF-Hungry Horse RD	8	1	81
LMFF	Muir Park	Glacier NP	0	0	98

BMU	Subunit Name	Principal Agency	OMRD	TMRD	CORE
LMFF	Nyack Creek	Glacier NP	0	0	100
LMFF	Ole Bear	Glacier NP	0	0	94
LMFF	Pinchot Coal	Glacier NP	0	0	99
LMFF	Stanton Paola	FNF-Hungry Horse RD	8	3	83
LNFF	Anaconda Creek	Glacier NP	5	0	94
LNFF	Apgar Mountains	Glacier NP	15	4	81
LNFF	Canyon McGinnis	FNF-GVRD & FNF-TLRD	18	30	56
LNFF	Cedar Teakettle	FNF-Glacier View RD	35	32	24
LNFF	Dutch Camas	Glacier NP	6	0	93
LNFF	Lake McDonald	Glacier NP	13	5	85
LNFF	Lower Big Creek	FNF-Glacier View RD	18	20	66
LNFF	Upper McDonald Creek	Glacier NP	9	2	90
LNFF	Werner Creek	FNF-Glacier View RD	19	21	42
MSRG	Beaver Creek	FNF-Swan Lake RD	6	26	66
MSRG	Cold Jim	FNF-Swan Lake RD	18	56	43
MSRG	Crane Mtn	FNF-Swan Lake RD	28	56	38
MSRG	Crow	Flathead IR	6	3	92
MSRG	Glacier Loon	FNF-Swan Lake RD	22	43	45
MSRG	Hemlock Elk	FNF-Swan Lake RD	6	30	64
MSRG	Piper Creek	FNF-SLRD & MT DNRC	19	43	52
MSRG	Porcupine Woodward	FNF-SLRD & MT DNRC	28	72	15
MSRG	Post Creek	Flathead IR	10	5	87
MSRG	Saint Marys	Flathead IR	4	2	94
MLFK	Alice Creek	HNF-Lincoln RD	9	17	71
MLFK	Arrastra Mountain	HNF-Lincoln RD	15	19	75
MLFK	Monture	LNF-Seeley Lake RD	1	0	99
MLFK	Mor-Dun	LNF-Seeley Lake RD	17	17	78
MLFK	N-Scapegt	LNF-Seeley Lake RD	0	0	100
MLFK	Red Mountain	HNF-Lincoln RD	22	20	62
MLFK	S-Scapegt	LNF-Seeley Lake RD	10	14	79
MULK	Krinklehorn	KNF-Fortine RD	22	14	75
MULK	Therriault	KNF-Fortine RD	25	9	72
NFSR	Lick Rock	LCNF-Rocky Mtn Front RD	0	0	100
NFSR	Roule Biggs	LCNF-Rocky Mtn Front RD	0	0	100
NEGL	Belly River	Glacier NP	0	0	99
NEGL	Boulder Creek	Glacier NP & Blackfeet IR	18	13	76
NEGL	Chief Mtn	Glacier NP & Blackfeet IR	28	10	53
NEGL	Poia Duck	Glacier NP & Blackfeet IR	23	8	68
NEGL	Upper Saint Mary	Glacier NP	11	1	89
NEGL	Waterton	Glacier NP	0	0	100
RTSN	Mission	LNF-Seeley Lk RD & MFWP	23	57	33
RTSN	Rattlesnake	LNF-Missoula RD	3	13	86
RTSN	South Fork Jocko	Flathead IR	38	14	59
SUBW	South Fork Willow	LCNF-Rocky Mtn Front RD	8	2	88

BMU	Subunit Name	Principal Agency	OMRD	TMRD	CORE
SUBW	West Fork Beaver	LCNF-Rocky Mtn Front RD	12	4	84
SEGL	Divide Mtn	Glacier NP & Blackfeet IR	32	25	67
SEGL	Midvale	Glacier NP & Blackfeet IR	7	4	87
SEGL	Spot Mtn	Glacier NP & Blackfeet IR	10	3	79
STRV	Lazy Creek	MT DNRC	68	62	10
STRV	Stryker	MT DNRC	37	33	50
STRV	Upper Whitefish	MT DNRC	34	57	54
SLVN	Ball Branch	FNF-Spotted Bear RD	8	4	84
SLVN	Jewel Basin Graves	FNF-Hungry Horse RD	19	19	72
SLVN	Kah Soldier	FNF-Spotted Bear RD	19	18	69
SLVN	Logan Dry Park	FNF-HHRD & FNF-SBRD	30	33	54
SLVN	Lower Twin	FNF-Spotted Bear RD	9	2	91
SLVN	Noisy Red Owl	FNF-Swan Lake RD	22	14	59
SLVN	Swan Lake	FNF-Swan Lake RD	40	23	46
SLVN	Twin Creek	FNF-Spotted Bear RD	0	0	100
SLVN	Wheeler Quintonkon	FNF-HHRD & FNF-SBRD	25	17	66
TESR	Deep Creek	LCNF-Rocky Mtn Front RD	4	2	73
TESR	Pine Butte	LCNF-Rocky Mtn Front RD	6	2	71
UMFF	Flotilla Capitol	FNF-HHRD & FNF-SBRD	0	0	100
UMFF	Long Dirtyface	FNF-Hungry Horse RD	0	0	100
UMFF	Plume Mtn Lodgepole	FNF-HHRD & SBRD	0	0	100
UMFF	Skyland Challenge	FNF-Hungry Horse RD	20	17	63
UMFF	Tranquil Geifer	FNF-Hungry Horse RD	0	2	90
UNFF	Bowman Creek	Glacier NP	6	0	93
UNFF	Coal & South Coal	FNF-Glacier View RD	15	21	72
UNFF	Ford Akokala	Glacier NP	7	1	93
UNFF	Frozen Lake	FNF-Glacier View RD	10	4	86
UNFF	Hay Creek	FNF-Glacier View RD	24	13	55
UNFF	Ketchikan	FNF-Glacier View RD	16	3	72
UNFF	Kintla Creek	Glacier NP	3	0	96
UNFF	Logging Creek	Glacier NP	4	0	94
UNFF	Lower Whale	FNF-Glacier View RD	36	17	50
UNFF	Quartz Creek	Glacier NP	4	0	93
UNFF	Red Meadow Moose	FNF-Glacier View RD	25	17	55
UNFF	State Coal Cyclone	FNF-GVRD & MT DNRC	31	24	59
UNFF	Upper Trail	FNF-Glacier View RD	14	4	88
UNFF	Upper Whale Shorty	FNF-Glacier View RD	12	10	86
USFF	Basin Trident	FNF-Spotted Bear RD	0	0	100
USFF	Gordon Creek	FNF-Spotted Bear RD	0	0	100
USFF	Jumbo Foolhen	FNF-Spotted Bear RD	0	0	100
USFF	Swan	LNF-Seeley Lake RD	32	16	55
USFF	Youngs Creek	FNF-Spotted Bear RD	0	0	100

	Indicates subunit is ≥50% federal or tribal wilderness of all lands within subunit.

Appendix 4

Habitat Baseline 2011 – Developed sites in Each Bear Management Unit

BMU Name	Residences	Overnight Sites		Campgrounds	Day-Use	Trailheads	Admin.
		# sites	type of capacity				
Badger Two Medicine	-	-	-	1 (17)	1	7	2
Big Salmon	32	2	7 cabins; 9 rooms	4 (50)	5	8	12
Birch Teton	7	1	6 cabins; 1 room	3 (23)	3	8	1
Bunker	-	3	17 cabins; 2 rooms; 4 bunkhouses	7 (54)	6	26	5
Continental Divide	-	-	-	-	-	-	5
Dearborn Elk	1	-	-	-	1	3	2
Hungry Horse	-	-	-	11 (139)	20	39	6
Lower Middle Fork Flathead	10	-	-	12 (32)	7	16	12
Lower North Fork Flathead	82	9	54 cabins; 185 rooms; 2 bunkhouses; 362 emp. beds	19 (726)	35	60	24
Mission Range	1	1	1 cabin	1 (22)	5	17	-
Monture Landers Fork	-	1	1 cabin	4 (42)	11	28	8
Murphy Lake	-	5	5 cabins	8 (29)	12	41	1
Northeast Glacier	-	4	27 cabins; 350 rooms; 294 emp. beds	27 (429)	16	28	14
North Fork Sun River	-	-	-	-	-	-	5
Rattlesnake	-	1	1 cabin	1 (3)	-	6	-
Southeast Glacier	-	-	-	11 (143)	9	14	8
Sullivan	20	2	9 cabins; 1 room; 1 bunkhouse	8 (89)	9	30	6
Stillwater River	-	-	-	2 (3)	-	2	1
South Fork Sun Beaver Willow	74	4	19 cabins; 2 rooms; 3 bunkhouses; 3 RV	6 (65)	2	15	8
Teton Sun River	17	1	2 bunkhouses	2 (32)	2	10	4
Upper Middle Fork Flathead	-	2	2 cabins	2 (21)	3	12	4
Upper North Fork Flathead	7	7	7 cabins	24 (153)	6	36	21
Upper South Fork Flathead	-	1	1 cabin	-	3	5	6

Residences. These are full-time or seasonal recreational residences. We have no authority to limit increases in capacity at these sites so it is not reported for these essentially private residences. However, there will be no new residences allowed.

Overnight Sites. Cabin rentals, guest lodges with or without rooms and/or cabins, camps, etc. Capacity is the number of cabins, rooms, bunkhouses, employee beds (Glacier NP) and RV sites.

Campgrounds. List # of campgrounds with # of campsites in parentheses, i.e. "2 (32)" is two separate campgrounds with a total number of 32 sites. Campground development ranges from fully developed with all amenities to very minimal development. There are group sites included; however, the number accommodated at one group site is variable.

Day-Use. Site includes businesses, restaurants, river/lake access, picnic areas, points of interests, etc.

Trailheads. Trailheads range from fully developed to a turn-out at a road closure.

DRAFT

Admin.	Administrative sites include ranger stations, work centers, guard stations, active fire lookouts, etc. While these sites are not subject to the Developed Site standards, increases in the number of administrative sites on Federal lands will be minimized so they are reported here to provide transparency and accountability.

DRAFT

Appendix 5

Protocol Paper for Motorized Access Analyses Application Rule

EXECUTIVE SUMMARY

This Protocol Paper contains a descriptive explanation of the application rule for motorized access density and secure core analyses as well as key points for the components, input GIS layers, and actual processes. The paper is intended to provide the reader with both a general background for moving window route density and secure core analyses as well as specific information and requirements for the Northern Continental Divide Ecosystem (NCDE) Conservation Strategy (2012).

A moving window type of motorized access density analysis requires several components: 1) a road layer; 2) a trail layer; 3) analysis area(s); and 4) a good vector and raster-based GIS software package. The secure core area analysis involves buffering roads and trails a given distance, using GIS software. Either raster or vector GIS software will work for the secure core analysis, but vector is more commonly used.

There are five sections within the Protocol Paper:

1. BACKGROUND gives some history and rationale for methods of calculating road densities, and a general description of the moving window and security analyses.
2. ANALYSIS COMPONENTS describes the GIS software and individual GIS layers needed for the analyses.
3. GIS PROCESSES outlines and describes the procedures for the analyses, as non-technical as possible.
4. NCDE CONSERVATION STRATEGY ANALYSES gives the specifics for running the moving window and secure core procedures for grizzly bear analysis for programmatic and project level work within the NCDE.
5. LITERATURE CITED.

BACKGROUND

Until 1993, road density was calculated by dividing the total miles of roads by the square miles for a analysis area resulting in a linear average density. GIS technology has allowed the user to place buffers around roads or trails, create density contour maps, and calculate density. Traditionally, the analysis area has been about 5,000 to 15,000 acres (7.81 to 23.44 square miles). Currently, BMU Subunits are used for the analysis area, approximating the 50 square miles of a female grizzly bear home range.

For a moving window density, each pixel (square unit of land, 30 meters by 30 meters in size for the NCDE) is assigned an access route density value based upon the roads and trails within the specified surrounding window, where the window size is commonly 1 square mile or 1 square kilometer. The square mile or kilometer is the "window" surrounding a pixel. The "moving window" refers to the actual process that the GIS software program utilizes. Starting in the upper left corner, the first pixel is assigned an access route density value based upon its surrounding window; the program moves over 1 pixel and assigns this next pixel a density value based upon its surrounding window; move over 1 pixel and that pixel is assigned a density; etcetera until the entire file has been analyzed pixel by pixel. This can then be summarized as the proportion of the analysis area in various density classes.

As described in the Interagency Grizzly Bear Committee (IGBC) Motorized Access Management report (1994, 1998) and referenced in the NCDE Conservation Strategy (2012), the moving window analysis should be used for calculating the open road and motorized trail, and total motorized access route densities for a given analysis area. Moving window processes are used to create two access route density maps: 1) open motorized access (open roads and open motorized trails); and 2) total motorized access (motorized roads and motorized trails). The output for the analysis area is provided in percentages of one mile route density increment classes. Traditionally in linear average density, we might have stated that analysis area 'B' has 1.00 miles of total roads per square mile. The main benefit from the moving window density analysis is the spatial display of the access route density by one mile classes. The user can see where the density is high within the analysis area, rather than just the average density over the entire area. Instead of knowing the analysis area 'B' had 1.0 mile/sq mile, we would know that 33% of the area had greater than 3.0 mile/sq mile and 67% had 0.0 mile/sq mile density, and more importantly, where that high density occurs within the analysis area relative to secure habitat.

Secure habitat is defined as areas that do not have human access. Referred to as Core Areas in the IGBC Motorized Access Management report (1994, 1998), these areas are defined as being >0.3 miles (500 meters) from any open road, motorized road or trail, and high use road or trail. Per IGBC direction, core areas are to include seasonal habitats represented in proportion to that of the analysis area. And once established, core areas are to remain in place for at least ten years. The South Fork Grizzly Bear Study defined secure habitat as polygons greater than 2000 acres, farther than a mile from any road or trail. The NCDE Conservation Strategy defines Secure Core as areas more than 500m (0.3 miles) from open or gated wheeled motorized access routes, at least 2,500 acres in size, and in place for 10 years.

For the purposes of this protocol paper, the standards, prodecures, and analyses will follow those outlined in the NCDE Conservation Strategy for open route density (OMRD), total route density (TMRD), and Secure Habitat.

ANALYSIS COMPONENTS

GIS software

Raster GIS software packages generally have some sort of moving window program. This program systematically moves throughout the whole file, analyzing each pixel based upon the surrounding pixels (=window). For instance, a 3x3 window would analyze 3 rows by 3 columns of pixels, or 9 pixels. The center pixel would be the analysis pixel and would be assigned a new value based upon the class values of the 9 window pixels. The road density analysis utilizes a sum, or count, analysis of the window. As of August 2001, four GIS software packages have been used to run a moving window analysis: ERDAS, ARC/Info GRID, ArcGIS, or EPPL7. For the NCDE, Arc/Info GRID and ArcGIS are currently used. The problem does not seem to be the mechanics of the moving window, most raster-based GIS software packages have some sort of filtering routine. However, some software packages do not have the program set with a large enough window size to allow a one square mile moving window. At 50 meter pixels, it is 32 by 32 pixels for one square mile; at 30 meters, it is 54 by 54 pixels.

Due to differences between vector to raster algorithms and in actual moving window calculations, it is strongly recommended that the same software package, utlized to develop the standards, is utilized for all analyses. If this is not feasible, then extra steps in the analysis may be needed so that, using the same GIS coverages, the processes and software used to analyze will provide the same results as the processes and software used to develop the standards.

Analysis area layer

This refers to the area(s) for which the road density classes are evaluated. For grizzly bear analyses, the IGBC Motorized Access Management report recommends analysis areas that approximate a grizzly bear female home range, incorporate all seasonal habitats when possible, and generally follow watershed boundaries or other topographic features. These analysis areas have been delineated for the NCDE and are referred to as Bear Management Unit (BMU) subunits, or just subunits.

Due to motorized routes near enough to affect density or secure core within the analysis area(s), the BMU subunit(s) should be buffered at a distance to include any routes within the influence zone. For NCDE Conservation Strategy analyses, that distance is one mile (1609.344 meters), although the actual distance is 0.7072 miles (1138 meters) which is half the distance of the diagonal within the one mile square window. This buffered analysis area should be used for clipping all data as well as the area for the raster moving window analysis. If using a circular moving window, it is the radius of that circular window.

While BMU subunits are not needed to directly run the moving window or secure core analyses, it is required to summarize the results of the analyses. Moving window analyses may be used to look at road density for other purposes than grizzly bears. In those cases, it may be appropriate to use some other analysis area for summarizing the results.

Road layer

Each road which is applicable to the analysis should be uniquely identified. This allows the user to develop "what-if" scenarios. While it may be obvious to one person that several roads will always be included in all alternatives, someone else may wish to analyze the "what if those roads were decommissioned" situation. Regardless of whether or not each road is uniquely identified, roads should be attributed with their jurisdiction, road management, and, if applicable, type of closure device. Jurisdiction refers to what agency actually has jurisdiction on the road. This is not always the same as the landowner. For example, a State Department of Natural Resources & Conservation (DNRC) road crosses Forest Service land, the jurisdiction of the road is State, but the landowner is Forest Service. For the purposes of the motorized access analysis, it is a State road. Federal and state highways (primary and secondary only), county roads, and small private roads will need to be identified. Road management provides information on whether the road is open yearlong or seasonally, closed (=restricted) yearlong, etc. Seasonally open roads will need to have the dates of closure. If a road is closed for all or part of the year, the type of closure device will be required. Additionally, each road should be attributed for the following characteristics during the non-denning season (April 1 through November 30). Definitions are based upon the IGBC Motorized Access Management report with verbal clarification from individual committee members (see Flathead NF, Land Resource Management Plan, Amendment 19 project file).

ROAD

All created or evolved routes that are >500 feet long (minimum inventory standard for the Forest Service INFRA data base), which are or were reasonably and prudently driveable with a conventional passenger car or pickup.

OPEN ROAD

A road without legal restriction or physical obstructions on motorized vehicle use.

RESTRICTED ROAD

A road on which motorized vehicle use is legally restricted, or physically obstructed, seasonally or yearlong. The road requires physical obstruction (gate, berm, jersey barrier, etc.). As indicated above, restricted roads will need two attributes: duration of restriction/obstruction, and type of closure device. For duration of restriction/obstruction, assign yearlong or seasonal. If the latter, include dates of restriction. For closure device, provide the type, such as gate, berm, barrier, rock, natural vegetation, etcetera.

HISTORICAL ROAD

Sometimes referred to as a reclaimed or obliterated road, a historical road has been treated in such a manner so as to no longer function as a road or trail, and the road is no longer considered part of the agency's road system. This can be accomplished through one or a combination of several means including: recontouring to original slope, placement of logging, road, or forest debris, planting or shrubs or trees, etc. Culverts and bridges may or may not be pulled.

Trail layer

All trails which are applicable to the analysis should be identified. Each trail should be attributed with the following characteristic during the non-denning season (April 1 through November 30). Definitions are based upon the IGBC Motorized Access Management report with verbal clarification from individual committee members.

TRAIL

All created or evolved access routes that do not qualify as a "road". They are not reasonably and prudently driveable with a conventional passenger car of pickup. Generally, these routes are maintained and inventoried as part of the trail system.

OPEN MOTORIZED TRAIL

A trail without legal restriction, or physical obstruction, open for motorized use by motorized vehicles. For the purposes of these analyses, an open yearlong or open seasonally motorzied trail is considered open. Trails use by 4-wheeler, 4-wheel drive vehicles and motorized trail bikes are examples of this type of access route.

RESTRICTED MOTORIZED TRAIL
A trail on which motorized use is legally restricted yearlong.

NON-MOTORIZED TRAIL
Any trail that does not have legal motorized use yearlong.

Lake layer

For the NCDE, if the project area contains all or a portion of any large lake (≥320 acres), the lake acreage will need to be subtracted from the analysis acres. The subtraction occurs after the moving window procedure has been completed. Either within or 1 mile from the NCDE Primary Conservation Area (PCA), the following is a list of large lakes: Flathead, Upper Stillwater, Whitefish, Echo, Swan, Holland, Lindbergh, Gray Wolf, and Big Salmon Lakes, Lake Blaine, and Hungry Horse Reservoir (Flathead N.F.); Duck and Lower Saint Mary Lake (Blackfeet I.R.); Dickey Lake (Murphy Lake R.D.); Kicking Horse Reservoir (Flathead I.R.); Waterton, Upper Kintla, Kintla, Bowman, Quartz, Logging, Lower McDonald, Harrison, Saint Mary, Two Medicine, Lower Two Medicine Lakes, and Lake Sherburne (Glacier N.P.); Bynum, Eureka, Farmers, Gibson, Swift and Nilan Reservoirs (Rocky Mtn Front R.D.).

Large lakes are generally not considered as grizzly bear habitat, and therefore these large bodies of water should not be considered when calculating secure habitat or motorized access densities. The 320 acre (1/2 square mile) figure was agreed to by Tom Wittinger (Flathead NF Forest Wildlife Biologist), Nancy Warren (Flathead NF Wildlife Biologist), and Kathy Ake (Flathead NF GIS Specialist) in 1994, and has been used for all IGBC motorzied access analyses since 1994.

Land Ownership layer

This layer is required for projects occurring within the NCDE for grizzly bears. Current direction from the US FWS states that roads within small private land holdings are not to be considered in calculating the motorized access densities. Small-tract private lands are treated just like the large lakes, by subtracting from the analysis acres before calculating the percent road density. The subtraction occurs after the moving window procedure has been completed. Originally, Plum Creek Timber Company (PC) lands were not considered small-tract private lands. However since the Montana Legacy Project, in which most of the Plum Creek Timber Company lands were purchased and transferred to public ownership through a cooperative effort, the acreage of PC lands in the NCDE have dramatically decreased. For the Conservation Strategy, PC lands will be considered small-tract private lands.

GIS PROCESSES

This section provides a description of the processes and not actual GIS programs and steps. Nor does the section specify the requirements for motorized route access and secure core analyses in the NCDE Conservation Strategy.

Moving Window Road Density Analysis

The analysis entails having a moving 1 square mile window across the entire rasterized road/trail file. For a 1 square mile window, it is a 32x32 window size for 50 meter pixels, and 54x54 window size for 30 meter pixels. For a 'circular' 1 square mile window, it is a radius of 18 50 meter pixels and 31 30 meter pixels. If a 1 square kilometer (metric) window is required, it is 20x20 window size for 50 meter pixels, and 33x33 window size for 30 meter pixels. A circular 1 square kilomter window is 11 50 meter pixels and 19 30 meter pixels. The center pixel of the window is assigned the sum total number of road and trail pixel cells that fall within the window. Starting with the first pixel in the upper left corner, the program counts the total number of road and trail cells within the square mile window and assigns the value to the center pixel. Then the window moves over to the next pixel, counts the road and trail cells within the window and assigns the value to the center pixel. This process repeats itself until the entire file has been completed. Since the moving window uses a summation of the GIS values for each cell, the input GIS file for the actual moving window step needs to have value '1' for all roads and trails to be counted and value '0' for everything else. A ‘nodata’ or null pixel within the analysis area will not suffice; these cells need to be a value 0.

The output from the moving window program is a file where each pixel represents the number of road/trail cells within the surrounding window size. The next step is to recode the sum total values into one mile, or one kilometer, increments. To equate the sum totals to number of pixels for route density ranges, divide the mi/sq mi value by the miles/pixel value. This is based upon a 50 meter pixel equaling 0.03107 miles, and a 30 meter pixel equaling 0.018642 miles. Using a 50 meter pixel, for the 0.5 mi/sq mi break, divide 0.5 mi/sq mi by 0.03107 mi/pixel, and the number of pixels is 16. Thus, if the sum total value is between 1 and 16, the density is 0.1 to 0.5 miles per square mile. The following table is a breakdown for 50 meter and 30 meter pixel sizes for both English (miles) and metric (kilometer) windows. The number of pixels was rounded to the nearest whole number.

Table 1. Breakdown of Road Density Classes for Various Window and Pixel Cell Sizes.

Route Density Class Range	Number of pixels for 1 SQ MILE		Number of pixels for 1 SQ KM	
	At 30 meters	At 50 meters	At 30 meters	At 50 meters
0.0	0	0	0	0
0.1- 0.5	1-27	1-16	1-17	1-10
0.6 - 1.0	28-54	17-32	18-33	11-20
1.1 - 1.5	55-80	33-48	34-50	21-30
1.6 - 2.0	81-107	49-64	51-67	31-40
2.1 - 2.5	108-134	65-80	68-83	41-50
2.6 - 3.0	135-161	81-97	84-100	51-60
>3.0	162-last	98-last	101-last	61-last

Pixel cell sizes are not set in concrete. A 50 or 30 meter pixel size is not mandatory. The values just happen to be common pixel size. The smaller the pixel size the better the file approximates the actual width of a road, down to about a 10 meter file (approximately 32.8 feet). Changing a GIS layer to a smaller pixel size does not necessarily mean that the layer is more accurate. Accuracy level depends more upon the resolution and accuracy of the original map used to create the GIS layer.

Security Analysis

The analysis involves buffering by 500 meters specific roads and trails. While the total road and motorized trail density moving window analysis has a 0.0 route density category, this is not the same as areas over 500 meters (0.3 miles) from a motorized route. The user needs to execute a buffering routine to accurately calculate the security area.

Summaries and Displays

For each BMU subunit, or subunit, it is useful to have a summary table listing the following:

- percentage of each route density class for open route density
- percentage of each route density class for total route density
- percentage of secure core and non-core areas
- miles of roads and trails by their management class (open yearlong, closed yearlong by gate, etc.)

At minimum, the summary table should have the percentage >1.0 mi/sqmi for OMRD, the percentage >2.0 mi/sqmi for TMRD, and the percentage of Secure Core for each BMU subunit.

Maps will either show the open road density classes, total road density classes, or the secure core areas. Additional information should include the roads and trails by management, BMU subunit boundaries, and small-tract private or large lakes areas, if appropriate.

Cautions

It should be mentioned that the project window needs to be at least either half the distance of the diagonal of a square window, or the radius of a circular window, from the actual analysis area. A distance of 1 mile would cover all potential square mile or square kilometer window sizes, and 30 or 50 meter pixel sizes. If the analysis boundary line follows a ridge, then the project window needs to be another mile from the ridge line, so that the pixels on the boundary of the analysis area can be assigned the correct density value. If the area directly outside the analysis area is cut off, then those pixels just within the analysis area will not factor in any road or trail pixels that fall within 1 mile of the analysis area and influence the density values. This applies to the Secure Core analysis as well.

Additionally, all maps and outputs for the route density and security analyses should only display the analysis area with a buffer of a 1 mile. Nothing should be displayed beyond 1 mile from the analysis area. The user may or may not have the correct and/or updated information beyond their area of interest.

As different grizzly bear ecosystems develop standards for access management, it is very possible that slightly different steps, order of processes, pixel sizes, window shapes, and determinations of roads or trails required will occur. It is strongly suggested that the processes, parameters, and software package used to determine the standards are also used for running the analyses to measure compliance. For example, if the standard was developed using ERDAS software and their rasterization algorithm, measuring compliance using ARC/Info's rasterization algorithm would be inappropriate. ARC/Info results in approximately 18% more "road" pixels than the same vector coverage rasterized in ERDAS. If differences are unavoidable, then extra steps in the analysis may be needed so that, using the same GIS coverages, the processes and software used to analyze will provide the same results as the processes and software used to develop the standards.

General Outline of the Procedures

I. Open Motorized Route Density

a) Select required arcs from road layer
b) Select required arcs from trail layer
c) Combine required selected roads and trails
d) Rasterize vector dataset
e) Run the moving window
f) Recode raw density value to road density classes
g) Vectorize the road density raster layer
h) If appropriate or required, subtract out large lakes, and small private acreage
i) Summarize the percentage of each open route density class within the analysis areas
j) Create required maps

II. Total Motorized Route Density

a) Select required arcs from road layer
b) Select required arcs from trail layer
c) Combine required selected roads and trails
d) Rasterize vector dataset
e) Run the moving window
f) Recode raw density value to road density classes
g) Vectorize the road density raster layer
h) If appropriate or required, subtract out large lakes, and small private acreage
i) Summarize the percentage of each total route density class within the analysis areas
j) Create required maps

III. Secure Core Analysis

a) Select required arcs from road layer
b) Select required arcs from trail layer
c) Combine required selected roads and trails
d) Buffer combined roads/trails 500 meters
e) Recode output from buffer routine
f) If appropriate or required, subtract out large lakes, and small private acreage
g) Summarize the percentage of secure core areas within the analysis areas
h) Create required maps

DRAFT

NCDE CONSERVATION STRATEGY ANALYSES

These procedures apply to all Federal, Tribal and State land agencies within the NCDE Conservation Strategy's Primary Conservation Area (PCA).

Motorized access route density and security analyses will be applied to BMU subunits. These areas are meant to approximate a grizzly bear female home range, incorporate all seasonal habitats if possible, and generally follow watershed boundaries or other topographic features. BMU subunits have been delineated by biologists from US Forest Service, US Fish & Wildlife Service, US National Park Service, MT Dept. Natural Resource Conservation, MT Dept. Fish, Wildlife and Parks, Confederated Salish & Kootenai Tribes, and Blackfeet Tribe for the entire NCDE.

With the Conservation Strategy, it was decided to keep the same process utlitized when the grizzly bear was listed. From a historical perspective for both NCDE and Flathead N.F. Amendment 19, the access standards were developed using EPPL7 software, 30 and 50 meter pixel sizes, a square 1 square mile window, breakpoints between classes as listed in Table 1, and due to software limitations a 32x32 window size. The area was the South Fork Grizzly Bear Study Area and radio-collared female grizzly bears were used for telemetry points. The recommended NCDE procedures have two steps added to the process to account for differences between ARC/Info's rasterization algorithm and EPPL7's algorithm as well as any other differences in cell and/or window size. The GRID THIN function is used to mitigate for the rasterization algorithm. A regression equation is applied after the moving window step to mitigate for the remaining differences. The regression equation was developed by comparing results from EPPL7 and ARC/Info software using the same road and analysis area files.

During the analysis for Flathead N.F's Amendment 19, many questions regarding small tract private lands, definitions for roads and road management classification were resolved for the motorized access analyses for both the NCDE and Amendment 19.

Application Rules

Table 5 from Chapter 3 of this Conservation Strategy is repeated below to provide the rule set and definitions for motorized access management on USFS, GNP, and BLM lands inside the PCA (referred to as Table 2 in this Appendix).

DRAFT

Table 6. (p. 1 of 2). The rule set and definitions for motorized access management standards on Federal lands inside the PCA.

Changes in Secure Core	A project may mitigate its impact on Secure Core by providing replacement Secure Core habitat of equal size and similar quality (if possible) and function in the same grizzly subunit. The replacement habitat must either be in place before project initiation or be provided concurrently with project development as an integral part of the project plan. Alternatively, a project may also mitigate its impacts by adhering to the allowed levels of temporary changes summarized above and detailed in this Table.
Secure Core Habitat	More than 500 meters from an open motorized route (road or motorized trail), or helicopter flight line meeting the definition of "recurring." Must be greater than or equal to 2,500 acres in size. "Recurring" is defined as multiple trips per day for more than two consecutive days.
Open Motorized Route Density (OMRD)	Open motorized route density includes: all Federal, State, and Tribal roads and motorized trails that are open to public use for any part of the year and motorized routes closed by sign only. All roads are included in the database. However non-motorized trails, highway, county, private, decommissioned, or revegetated roads are not included in the calculations.
Total Motorized Route Density (TMRD)	Total motorized route density includes: all Federal, State, and Tribal roads and motorized trails, whether they are open or closed. All roads are included in the database. However, non-motorized trails, highway, county, private, decommissioned, or revegetated roads are not included in the calculations.
Motorized Access Routes in Database	All routes, regardless of ownership or jurisdiction, having motorized use or the potential for motorized use to exceed administrative use levels (restricted roads) including: motorized trails; highways; county/city, Federal, State, Tribal, corporate and private roads.
Lands in Database	All lands are included in database. However, large lakes (≥ 320 acres) and private lands are not included in calculations of Secure Core, OMRD, or TMRD.
Season Definitions	Denning season on the west side of the continental divide is from 1 December through 31 March. Denning season on the east side of the continental divide is from 1 December through 15 April. Wheeled motorized access standards do not apply during the denning season.
Project	A temporary activity requiring construction of new roads, reconstructing or opening a restricted road or recurring helicopter flights at low elevations (< 500m).
Activities Allowed in Secure Core	Activities that do not require road construction, reconstruction, opening a restricted road, or recurring, low-elevation helicopter flights. Aircraft used in emergency firefighting are allowed. Non-wheeled, over the snow use (i.e., snowmachines) allowed until research identifies a concern. Projects that remain within the limits established by the Application Rules for Temporary Changes in Motorized Access Management on Federal Lands.
Inclusions in Secure Core	Roads restricted with permanent physical barriers (not gates), decommissioned or obliterated roads, and/or non-motorized trails are allowed in Secure Core.
Administrative Use Levels	Motorized administrative use is permitted as either 6 trips (3 round trips) per week OR one 30-day unlimited use period during the non-denning season (Apr. 1 – Nov. 30).

DRAFT

Table 6. (p. 2 of 2). The rule set and definitions for motorized access management standards on Federal lands inside the PCA.

Temporary Changes in Motorized Access Management	Temporary changes to baseline values for OMRD, TMRD, and Secure Core will be allowed for projects if the 10-year running averages for these parameters in each subunit do not exceed a 5% increase in OMRD, a 3% increase in TMRD, or a 2% decrease in Secure Core. During these projects, changes in OMRD, TMRD, and Secure Core may exceed these limits in individual years but the 10-year running average will not exceed these limits. Secure Core and road density values must be restored within one year after completion of the project (i.e., when the road is no longer being used for project implementation beyond administrative levels). On occasion, unforeseen events affecting thousands of acres (e.g., fires, long-term mine clean-up, insect or disease-killed trees, flooding, avalanches, mudslides, etc.) may require a response action that would not stay within these Application Rules for Temporary Changes in Motorized Access Management. In such cases, site-specific NEPA analysis would be completed and effects considered. Due to the nature of these events and the need to quickly and efficiently resolve the impacts of these disturbances to maintain project, recreational, and administrative opportunities, such circumstances would not be considered a violation of this Conservation Strategy's habitat standards. Any responses to these unforeseen events would, however, be considered when proposing other projects in affected subunits.
Gravel Pits	The Forest Service and National Park Service will use all available resources at existing gravel pits before constructing new pits.
Permanent Changes to OMRD, TMRD, and Secure Core Values	Permanent changes in OMRD, TMRD, or Secure Core may occur due to unforeseen circumstances, natural events, or other reasonable considerations. Such changes will change the baseline values but will not be considered a violation of the motorized access management habitat standards and will not require mitigation responses. Acceptable changes that may permanently change baseline values include the following: - the agency acquired better information or updated/improved the road information in their respective database(s) resulting in changed calculations without actual change on the ground; - technology or projections changed, resulting in changed calculations without actual change on the ground (e.g., a switch from NAD27 to NAD83); - the agency moved a road closure location a short distance (often <0.25 miles) to a better location for turn-arounds, less vandalism, or to improve enforcement of the road closure; - the agency acquired or sold land; - the agency built/opened a road for either handicapped access in a campground, or administrative site road; - the agency moved a road to increase human safety or to decrease resource damage - an adjacent, non-federal landowner made changes to their motorized access management which decreased Secure Core or increased motorized route densities on Federal lands.

Python script requirements

To insure consistency across the NCDE, a Python script available through ArcToolBox will be used. Each agency unit will have a "master" grid to be used in the moving window routine. Through investigation, it has been discovered that the output values will vary even if slightly different extents are used for the moving window; therefore, a single "master" grid will be created for each agency's unit requiring a motorized access analysis. The script follows the steps from the General Outline of the Procedures in the GIS Processes section.

The remap table for converting the actual count of "road" cells in the one mile window to mile/square mile density classes has a specfic format. The table needs to be a text file with a '.txt' extension, and the specific values as shown in the last column below.

Table 3. Remap table for converting raw density values to mile/square mile classes.

Mile/Square Mile Density Class	# of "route" pixels	Output GRID Value	Remap Table
0.0 mile/squre mile	0	1	0 0:1
0.1 to 1.0 mile/square mile	>0 - ≤54	2	0 54:2
1.1 to 2.0 mile/square mile	>54 - ≤107	3	54 107:3
>2.0 mile/square mile	>107 - ≤5000	4	107 5000:4

DRAFT

The Python script requires specific values for road management, motorzied trails, ownership and large lakes. The following tables provide that information.

Table 4. Road mangement descriptions and attribute values used in OMRD and TMRD.

Road Management Description	Specific Value in Attribute for Script	Road Used in Analysis		
		OMRD	TMRD	CORE
Open yearlong roads, no restriction	OPEN yearlong	X	X	X
Open seasonally roads, has seasonal restriction	OPEN seasonally	X	X	X
Closed yearlong by sign closure	CLOSED yrlng sign	X	X	X
Closed yearlong by gate closure, but with high administrative use[1]	CLOSED yrlng ADH	X	X	X
Closed yearlong by gate closure	CLOSED yrlng gate		X	X
Closed yearlong by physical barrier, but should be closed by gate[2]	CLOSED yrlng BNC		X	X
Closed yearlong by physical barrier[3]	CLOSED yrlng berm		X	
Closed yearlong and naturally revegetated, but should be closed by gate[4]	CLOSED yrlng VEGNC		X	X
Primary or secondary federal/state highways	hwys, cnty/city road			X
County or city roads	hwys, cnty/city road			X
Small-tract private roads or federal special use permitted roads[5]	small PVT roads			X
Closed yearlong and is either naturally revegetated, entrance has been obliterated, or bridge/large <4ft culvert removed. Essentially, the road is completely impassable	CLOSED yrlng impass			
	historic roads			

[1] ADH – closed by gate but receives high administrative use (HH SB compounds). Has been specific to Flathead NF.

[2] BNC – closed by berm, but to be buffered for Security CORE. Barrier put in due to frequent damage to gate. Has been specific to Flathead NF.

[3] berm – refers to berms, rocks, jersey barriers, etcetera. Does not include roads closed by a bridge or large (<4ft) culvert being removed, obliterated entrances, and live vegetation. Any of these last three types make the road impassable (no standard vehicle or two-wheel motorized vehicle can pass). These roads are not included in any analyses. Has been incorporated this way since IGBC motorized access or Flathead NF's A19 started.

[4] VEGNC – refers to roads currently closed by live vegetation, but planning or project documents indicate that the road is to closed by gate. For the purposes of TOTAL route density and Security CORE, the road is to be included. Has been specific to Flathead NF.

[5] small PVT roads – Typcially the permitee of a Special Use permitted road does not have road management restrictions. As a result, the road could be open or closed according to the permittee, therefore the road is classified as "small PVT roads" for the analyses.

Roads that are decommissioned, labeled historic, and no longer on the system, are not included in the analyses, i.e. they do not count in OMRD or TMRD calculations, nor are they buffered in the Secure Core analysis.

Similar to historical roads, roads that are naturally revegetated, have the entrance obliterated for >0.1 miles, or have the bridge or large >4ft culvert removed are also not included in the analyses, i.e. they do not count in OMRD or TMRD calculations, nor are they buffered in the Secure Core analysis. These roads are to be impassable by any vehicle (passenger car, truck, 4WD vehicle, ATV, motorcycle, etcetera). These roads are still on the system. Revegetated roads defined as so grown-in that they are no longer drivable. The vegetation growth is such that it is easier to walk on the side-hill as opposed to down the center of the road bed. The caveat is: if any of these 3 types of road is bladed open, or the bridge/culvert repaired, it will be included in analyses based upon the closure device. If a physical barrier (berm, rock, etc.) is put in, the road will be included in TMRD calculations. If a gate is put in, the road will be included in TMRD calculations, and will also be buffered in Secure Core analysis. If no closure device is put in (i.e. the road is open), the route will be included in both OMRD and TMRD calculations, and will be buffered in Security CORE analysis.

Table 5. Motorized route attributes.

Motorized Route Description	Specific Value in Attribute for Script	Route Used in Analysis		
		OMRD	TMRD	CORE
Roads or trails legally open to motorized use anytime during the non-denning season.	M	X	X	X
Non-motorized routes	<blank>			

The trail or road is considered motorized if the route is legally open to two-wheeled motorized traffic (ATV, motorcycles, etcetera). These routes can either be included in the road dataset or separate. Either way, a specific text attribute as indicated above is required.

Table 6. Attributes for ownership, small private lands, and large lakes.

Land Ownership and Lake Descriptions	Specific Value in Attribute for Script
Federal, state, and tribal lands	FED STATE TRIBAL
Large lakes, >320 acres	large lakes
Small-tract private lands	small PVT lands

While State and Tribal lands do not have OMRD, TMRD, and Secure Core standards, their lands are included in the analyses run by federal land agencies. For tribal lands, only those lands designated as “tribal” and open for public use are included. Tribal allotments (land owned by tribal members) and tribal fee lands (owned or leased to private individuals) are to be considered “small PVT lands” for the purposes of the anlsyses. For private lands, these are small-tract, corporate, or Non-Governmental Organization (NGO) lands.

Typcially, agencies have ownership and lakes in separate GIS datasets. For the purposes of the Python script, they will need to be combined and attributed as indicated.

DRAFT

Standards

<u>Habitat Standards on Public Federal lands in the PCA:</u>

- maintain or decrease 2011 levels of open motorized route densities (OMRD)
- maintain or decrease 2011 levels of total motorized route densities (TMRD)
- maintain or increase 2011 levels of Secure Core
- temporary increases are allowed if the 10-year running average does not exceed a
  - 5% increase in OMRD and
  - 3% increase in TMRD and
  - 2% decrease in Secure Core

<u>Habitat Standards on DNRC, Blackfeet Nation, and CS&KT lands in the PCA:</u>

- limits on net increases in open roads and/or road densities
- limits on net increases in total roads and/or road densities

Analysis runs for NCDE reports and projects

OMRD, TMRD, and Secure Core will be measured biennially on odd number years starting in 2011. The status of each of the 126 BMU subunits will be reported in that year's annual report, even though the OMRD, TMRD, and Secure Core standards only apply to federal lands.

Individual projects on federal lands will be analyzed if the project requires construction of new roads, reconstruction or opening a restricted road, use of a restricted road above administrative levels allowed, or recurring helicopter flights at low elevations (< 500m). Any project meeting this definition will require analysis to determine the OMRD, TMRD and Secure Core for the route management situation during the project, i.e. all routes used for the project will be labeled as 'OPEN yearlong' for the analysis. Temporary changes to baseline values for OMRD, TMRD, and Secure Core will be allowed for projects if the 10-year running averages for these parameters in each subunit do not exceed a 5% increase in OMRD, a 3% increase in TMRD, or a 2% decrease in Secure Core. During these projects, changes in OMRD, TMRD, and Secure Core may exceed these limits in individual years but the 10-year running average will not exceed these limits. Each agency or agency's unit will have a spreadsheet set up to record and determine if the project(s) meeting these standards for those BMU subunits they manage.

Individual projects on State or Tribal lands do not have a 10-year running average requirement for OMRD, TMRD, or Secure Core.

Miscellaneous

The Swan Valley Grizzly Bear Conservation Agreement (SVGBCA) pertains to 11 BMU subunits in the Swan Valley: South Fork Lost Soup, Goat Creek, Lion Creek, Meadow Smith, Buck Holland, Porcupine Woodward, Piper Creek, Cold Jim, Hemlock Elk, Glacier Loon, and Beaver Creek. Plum Creek Timber Company is divesting all their lands in the Swan Valley, with a vast majority being transferred to Forest Service and State agencies through the MT Legacy Project. The Forest Service and State are still abiding by the agreement until the fiber agreement is complete. Once the fiber agreements end, DNRC may shift to management according to their HCP. If this occurs, the USFS would continue to manage its lands by the terms described in the Swan Valley Conservation Agreement, in perpetuity.

DRAFT

LITERATURE CITED

Interagency Grizzly Bear Committee. 1994. Task Force Report, Grizzly Bear/Motorized Access Management. 6pp. (Final Approved by IGBC July 21, 1994)

Interagency Grizzly Bear Committee. 1998. Task Force Report, Grizzly Bear/Motorized Access Management. 6pp. (Revision Approved by IGBC July 29, 1998)

U.S. Forest Service. 1985. Flathead National Forest Land and Resource Management Plan, Amendment 19. (Forest Plan was amended with Amendment 19 in February 1995).

Interagency Conservation Strategy Team. 2012. Draft Conservation Strategy for Grizzly Bears in the Northern Continental Divide Ecosystem. November 2012. Missoula, Montana, USA.

DRAFT

Appendix 6

Comparison Between NCDE Conservation Strategy Secure Core Levels and Current IGBC Security CORE Levels in Each Bear Management Subunit

BMU	Subunit Name	Principal Agency	Cons. Strategy Secure Core	Current Security CORE
BATM	Badger	LCNF-Rocky Mtn Front RD	94	94
BATM	Heart Butte	LCNF-Rocky Mtn Front RD	81	81
BATM	Two Medicine	LCNF-Rocky Mtn Front RD	87	87
BGSM	Albino Pendant	FNF-Spotted Bear RD	100	88
BGSM	Big Salmon Holbrook	FNF-Spotted Bear RD	100	87
BGSM	Black Bear Mud	FNF-Spotted Bear RD	100	84
BGSM	Brushy Park	FNF-Spotted Bear RD	100	84
BGSM	Buck Holland	FNF-Swan Lake RD	49	40
BGSM	Burnt Bartlett	FNF-Spotted Bear RD	100	92
BGSM	Hungry Creek	FNF-Spotted Bear RD	100	88
BGSM	Little Salmon Creek	FNF-Spotted Bear RD	100	98
BGSM	Meadow Smith	FNF-Swan Lake RD	41	41
BGSM	White River	FNF, Spotted Bear RD	100	74
BITE	Birch	LCNF-Rocky Mtn Front RD	93	93
BITE	Teton	LCNF-Rocky Mtn Front RD	75	75
BNKR	Big Bill Shelf	FNF-Spotted Bear RD	87	80
BNKR	Bunker Creek	FNF-Spotted Bear RD	92	92
BNKR	Goat Creek	FNF-SLRD & MT DNRC	42	39
BNKR	Gorge Creek	FNF-Spotted Bear RD	100	90
BNKR	Harrison Mid	FNF, - Spotted Bear RD	99	95
BNKR	Jungle Addition	FNF-Spotted Bear RD	68	68
BNKR	Lion Creek	FNF-SLRD & MT DNRC	51	41
BNKR	South Fork Lost Soup	FNF-SLRD & MT DNRC	40	40
BNKR	Spotted Bear Mtn	FNF-Spotted Bear RD	68	68
CODV	Pentagon	FNF-Spotted Bear RD	100	94
CODV	Silvertip Wall	FNF-Spotted Bear RD	100	97
CODV	Strawberry Creek	FNF-Spotted Bear RD	100	100
CODV	Trilobite Peak	FNF-Spotted Bear RD	100	100
DELK	Falls Creek	LCNF-Rocky Mtn Front RD	85	85
DELK	Scapegoat	LCNF-Rocky Mtn Front RD	83	83
HGHS	Coram Lake Five	FNF-Hungry Horse RD	18	14
HGHS	Doris Lost Johnny	FNF-Hungry Horse RD	36	36
HGHS	Emery Firefighter	FNF-Hungry Horse RD	53	53
HGHS	Peters Ridge	FNF-HHRD & SLRD	34	34
HGHS	Riverside Paint	FNF-Hungry Horse RD	73	72
HGHS	Wounded Buck Clayton	FNF-Hungry Horse RD	65	64
LMFF	Dickey Java	FNF-Hungry Horse RD	85	81

DRAFT

BMU	Subunit Name	Principal Agency	Cons. Strategy Secure Core	Current Security CORE
LMFF	Lincoln Harrison	Glacier NP	98	90
LMFF	Moccasin Crystal	FNF-Hungry Horse RD	81	81
LMFF	Muir Park	Glacier NP	98	97
LMFF	Nyack Creek	Glacier NP	100	98
LMFF	Ole Bear	Glacier NP	94	93
LMFF	Pinchot Coal	Glacier NP	99	99
LMFF	Stanton Paola	FNF-Hungry Horse RD	83	81
LNFF	Anaconda Creek	Glacier NP	94	94
LNFF	Apgar Mountains	Glacier NP	81	70
LNFF	Canyon McGinnis	FNF-GVRD & FNF-TLRD	56	51
LNFF	Cedar Teakettle	FNF-Glacier View RD	24	24
LNFF	Dutch Camas	Glacier NP	93	86
LNFF	Lake McDonald	Glacier NP	85	66
LNFF	Lower Big Creek	FNF-Glacier View RD	66	66
LNFF	Upper McDonald Creek	Glacier NP	90	76
LNFF	Werner Creek	FNF-Glacier View RD	42	42
MSRG	Beaver Creek	FNF-Swan Lake RD	66	66
MSRG	Cold Jim	FNF-Swan Lake RD	43	43
MSRG	Crane Mtn	FNF-Swan Lake RD	38	26
MSRG	Crow	Flathead IR	92	92
MSRG	Glacier Loon	FNF-Swan Lake RD	45	41
MSRG	Hemlock Elk	FNF-Swan Lake RD	64	64
MSRG	Piper Creek	FNF-SLRD & MT DNRC	52	52
MSRG	Porcupine Woodward	FNF-SLRD & MT DNRC	15	15
MSRG	Post Creek	Flathead IR	87	87
MSRG	Saint Marys	Flathead IR	94	94
MLFK	Alice Creek	HNF-Lincoln RD	71	70
MLFK	Arrastra Mountain	HNF-Lincoln RD	75	75
MLFK	Monture	LNF-Seeley Lake RD	99	99
MLFK	Mor-Dun	LNF-Seeley Lake RD	78	74
MLFK	N-Scapegt	LNF-Seeley Lake RD	100	94
MLFK	Red Mountain	HNF-Lincoln RD	62	59
MLFK	S-Scapegt	LNF-Seeley Lake RD	79	78
MULK	Krinklehorn	KNF-Fortine RD	75	75
MULK	Therriault	KNF-Fortine RD	72	72
NFSR	Lick Rock	LCNF-Rocky Mtn Front RD	100	91
NFSR	Roule Biggs	LCNF-Rocky Mtn Front RD	100	89
NEGL	Belly River	Glacier NP	99	79
NEGL	Boulder Creek	Glacier NP & Blackfeet IR	76	64
NEGL	Chief Mtn	Glacier NP & Blackfeet IR	53	51
NEGL	Poia Duck	Glacier NP & Blackfeet IR	68	51

DRAFT

NEGL	Upper Saint Mary	Glacier NP	89	68
NEGL	Waterton	Glacier NP	100	84
RTSN	Mission	LNF-Seeley Lk RD & MFWP	33	33
RTSN	Rattlesnake	LNF-Missoula RD	86	85
RTSN	South Fork Jocko	Flathead IR	59	59
SUBW	South Fork Willow	LCNF-Rocky Mtn Front RD	88	85

BMU	Subunit Name	Principal Agency	Cons. Strategy Secure Core	Current Security CORE
SUBW	West Fork Beaver	LCNF-Rocky Mtn Front RD	84	76
SEGL	Divide Mtn	Glacier NP & Blackfeet IR	67	59
SEGL	Midvale	Glacier NP & Blackfeet IR	87	78
SEGL	Spot Mtn	Glacier NP & Blackfeet IR	79	61
STRV	Lazy Creek	MT DNRC	10	5
STRV	Stryker	MT DNRC	50	50
STRV	Upper Whitefish	MT DNRC	54	54
SLVN	Ball Branch	FNF-Spotted Bear RD	84	84
SLVN	Jewel Basin Graves	FNF-Hungry Horse RD	72	65
SLVN	Kah Soldier	FNF-Spotted Bear RD	69	68
SLVN	Logan Dry Park	FNF-HHRD & FNF-SBRD	54	52
SLVN	Lower Twin	FNF-Spotted Bear RD	91	91
SLVN	Noisy Red Owl	FNF-Swan Lake RD	59	52
SLVN	Swan Lake	FNF-Swan Lake RD	46	45
SLVN	Twin Creek	FNF-Spotted Bear RD	100	100
SLVN	Wheeler Quintonkon	FNF-HHRD & FNF-SBRD	66	66
TESR	Deep Creek	LCNF-Rocky Mtn Front RD	73	70
TESR	Pine Butte	LCNF-Rocky Mtn Front RD	71	68
UMFF	Flotilla Capitol	FNF-HHRD & FNF-SBRD	100	99
UMFF	Long Dirtyface	FNF-Hungry Horse RD	100	100
UMFF	Plume Mtn Lodgepole	FNF-HHRD & SBRD	100	97
UMFF	Skyland Challenge	FNF-Hungry Horse RD	63	63
UMFF	Tranquil Geifer	FNF-Hungry Horse RD	90	85
UNFF	Bowman Creek	Glacier NP	93	70
UNFF	Coal & South Coal	FNF-Glacier View RD	72	72
UNFF	Ford Akokala	Glacier NP	93	92
UNFF	Frozen Lake	FNF-Glacier View RD	86	80
UNFF	Hay Creek	FNF-Glacier View RD	55	55
UNFF	Ketchikan	FNF-Glacier View RD	72	68
UNFF	Kintla Creek	Glacier NP	96	86
UNFF	Logging Creek	Glacier NP	94	94
UNFF	Lower Whale	FNF-Glacier View RD	50	49
UNFF	Quartz Creek	Glacier NP	93	86
UNFF	Red Meadow Moose	FNF-Glacier View RD	55	55
UNFF	State Coal Cyclone	FNF-GVRD & MT DNRC	59	59

DRAFT

UNFF	Upper Trail	FNF-Glacier View RD	88	88
UNFF	Upper Whale Shorty	FNF-Glacier View RD	86	86
USFF	Basin Trident	FNF-Spotted Bear RD	100	85
USFF	Gordon Creek	FNF-Spotted Bear RD	100	82
USFF	Jumbo Foolhen	FNF-Spotted Bear RD	100	94
USFF	Swan	LNF-Seeley Lake RD	55	55
USFF	Youngs Creek	FNF-Spotted Bear RD	100	92

	Indicates subunit is ≥50% federal or tribal wilderness of all lands within subunit.

The differences between the process under the Conservation Strategy and the current IGBC Motorized Access are listed in the following table.

NCDE Conservation Strategy Process	**Current IGBC Motorized Access Process**
Plum Creek Timber Company roads and lands are treated as "private" roads & lands. After the MT Legacy Project, Plum Creek Timber Company lands are a small percentage of the NCDE.	Plum Creek Timber Company roads and lands were treated like federal/state lands. Prior to the MT Legacy Project, Plum Creek Timber Company lands were a significant percentage in the NCDE.
Grizzly Bear Management Situation 3 (MS-3) is no longer used post delisting; therefore, these lands are now included in route density calculations.	Grizzly Bear Management Situation 3 (MS-3) lands were excluded from open & total route density calculations.
High Use (>20 parties/week for at least 25% of the non-denning season) trails are not used, i.e. they are not buffered when calculating Secure Core and do occur in Secure Core.	High Use (>20 parties/week for at least 25% of the non-denning season) trails were buffered when calculation Security CORE, i.e. high-use trails could not occur in Security CORE.

DRAFT

Appendix 7

Subunit Management Under the Swan Valley Conservation Agreement

Subunits Included (immediate subunit rotation for activity and past rotation):

	Mission BMU	Big Salmon BMU	Bunker BMU
1997-1999	Piper Ck Beaver Ck	Meadow-Smith	Lost Soup
2000-2002	Porcupine-Woodward Hemlock-Elk	Buck Holland	Lion Ck
2003-2005	Cold-Jim Glacier-Loon	Meadow-Smith	Goat Ck
2006-2008	Piper Ck Beaver Ck	Buck-Holland	Lost Soup
2009-2011	Porcupine-Woodward Hemlock-Elk	Meadow-Smith	Lion Ck
2012-2014	Cold-Jim Glacier-Loon	Buck-Holland	Goat Ck
2015-2017	Piper Ck Beaver Ck	Meadow-Smith	Lost Soup
2018-2020	Porcupine-Woodward Hemlock-Elk	Buck-Holland	Lion Ck
2021-2023	Cold-Jim Glacier-Loon	Meadow-Smith	Goat Ck
2024-2026	Piper Ck Beaver Ck	Buck-Holland	Lost Soup
2027-2029	Porcupine-Woodward Hemlock-Elk	Meadow-Smith	Lion Ck
2030-2032	Cold-Jim Glacier-Loon	Buck-Holland	Goat Ck
2033-2035	Piper Ck Beaver Ck	Meadow-Smith	Lost Soup

DRAFT

1. Definitions

This Agreement is consistent with the Flathead Land and Resource Management Plan, as amended (the "LRMP"). The Forest Service is bound by and/or accepts existing definitions found within the LRMP. The Forest Service will utilize existing definitions found in the LRMP, unless definitions found in this Agreement are more conservative in regard to the Bear, in which case, definitions found in this Agreement will be utilized.

"Active Subunit" shall mean those BMU Subunits in which the Parties are conducting Administrative and Commercial Use activities.

"Active Subunit Restricted Road" shall mean a gated or barriered road within an Active Subunit which is closed for all uses except Administrative Use and Commercial Use.

"Administrative Use" shall mean use by Forest Service (FS), or Department of Natural Resources (DNRC) associated with all land and resource management activities including, without limitation, timber sale layout, road location, pre-commercial thinning, road maintenance, tree planting, slash disposal and Salvage Harvest, but shall not include Commercial Use. Administrative Use also shall mean minor actions such as bough and post and pole harvest that are less than two consecutive weeks in duration.

"Bear" shall mean the grizzly bear (*Ursus arctos horribilis*).

"BMU Subunits" shall mean the female home range analysis areas specified on Attachment D hereto, which is hereby incorporated herein and made a part hereof.

"BMUs" shall mean Bear Management Units as set forth in Attachment A, which is hereby incorporated herein and made a part hereof.

"Commercial Use" shall mean major forest management activities by FS or DNRC including, without limitation, road construction, road reconstruction and timber harvest, but does not include Salvage Harvest.

"Conservation Area" shall mean certain National Forest and Department of Natural Resource lands set forth on Attachment B, which is hereby incorporated herein and made a part hereof, that lie within the Swan Valley in the Northern Continental Divide Ecosystem Grizzly Bear Recovery Zone.

"Core Areas" shall mean those areas as defined by the IGBC Access Task Force Report (July 1994) and set forth in Attachment C, which is hereby incorporated herein and made a part hereof.

DRAFT

"Cover" shall mean vegetation blocks having a minimum diameter of at least three Sight Distances, which on DNRC lands shall not be less than 300 feet.

"Denning Period" shall mean the period between November 16 and March 31.

"Even Age Cutting Unit" shall mean a harvest unit in which either a clearcut or seedtree silvicultural prescription is used or any other treatment that would result in openings of more than three (3) Sight Distances.

"Guidelines" shall mean the principles and guidelines for forest management set forth in Section 3 hereof, as the same may be amended from time to time.

"Inactive Subunit" shall mean those BMU Subunits in which the Parties are not conducting Commercial Use activities.

"Inactive Subunit Restricted Road" shall mean a gated or barriered road within an Inactive Subunit, which is closed for all uses except Administrative Use, and Commercial log haul when necessary.

"Linkage Zones" shall mean the areas necessary for linking populations of Bears specified on Attachment E, which is hereby incorporated herein and made a part hereof.

"Open Road" shall be any road on which there are no use restrictions. Open Road shall not mean Restricted Roads or highways, county roads, administrative site access roads and private residence access roads.

"Preferred Habitat" shall mean areas adjacent to streams and wetlands inside Linkage Zones as set forth in Attachment G, as the same may be changed from time to time by mutual agreement of the Parties based on field verification.

"Reclaimed Road" shall mean a road which (i) has been "put to bed" to address Bear security or to address watershed concerns by pulling culverts and revegetating with trees or grass; and (ii) is generally unusable for 4-wheeled vehicles due to physical obstructions such as "kelly humps" or other physical obstructions, rather than gates. Reclaimed Road shall also mean roads that are physically blocked using large cement blocks or equivalent barriers. A Reclaimed Road will not receive motorized Administrative or Commercial uses.

"Restricted Period" shall mean the non-denning period which runs between April 1 and November 15.

DRAFT

"Restricted Roads" shall mean Active Subunit Restricted Roads and Inactive Subunit Restricted Roads.

"Riparian Zone" shall mean a streamside management zone as defined on the date hereof in the Montana Streamside Management Zone Rules, a copy of which is attached hereto in Attachment F, which is hereby incorporated herein and made a part hereof.

"Salvage Harvest" shall mean short term activities to harvest dead or dying trees resulting from fire, disease, blowdown or the like and shall not continue for periods of more than two consecutive weeks or for more than 30 days in the aggregate during a given calendar year in the non-denning period (April 1 to November 15). Salvage activities that result from catastrophic fire or blowdown and that require more than two consecutive weeks to complete, will require special management considerations (refer to Section 3(b)(iv)).

"Sight Distance" shall mean the distance at which 90% of an animal is hidden from view, which on DNRC and National Forest lands is approximately 100 feet depending on the type of cover available.

“Spring Habitat” shall mean all areas within Linkage Zones below 5200 feet in elevation.

“Spring Period” shall mean period of time running from April 1 to June 15.

"Take" shall mean take of a species as contemplated under Section 9 of the Act.

"Visual Screening" shall mean a minimum of one Sight Distance.

1. Management Guidelines

DNRC, and the Forest Service agree to carry out forest management practices within the described subunits according to the practices and procedures that follow. In addition to the practices and procedures documented in this agreement, the Forest Service will continue to adhere to all Objectives, Standards and Guidelines found in the Flathead Forest LRMP, as amended

(a) Open Road Densities

(i) To minimize the risk of death or injury to Bears, the Parties will manage roads throughout the included subunits so that no more than 33% of any given BMU Subunit exceeds an Open Road density of one mile per square mile during the Restricted Period. This density will be achieved as soon as is practicable, but no later than five years after the termination of the Fiber Agreement that resulted from the sale of Plum Creek lands to FS and DNRC. (Planned to be 2018). This date may be extended if an additional fiber agreement is put in place to obtain additional Plum Creek properties by either the National Forest or the Department of Natural Resource Conservation. The long-term goal is that no more than 21% of a BMU Subunit shall exceed the Open Road density of one mile per square mile. The reduction from 33% to 21% will be done by voluntary road closures by the Parties.

(ii) The share of the allowable possible deviation from the 1 mi/sq mile standard will be apportioned among the Parties in approximate proportion to land ownership within the BMU Subunit, provided that no Party shall take advantage of road reductions made by another Party, except as mutually agreed to by all Parties. No Party will be required to close roads if the required open road density of 33% set forth in Section 3(a)(i) is otherwise being met.

(iii) Open road densities of lands owned or managed by the Parties within each BMU Subunit will be calculated using a GIS moving window technique.

(b) Operations and Uses

(i) The Parties agree to stop all management activities (other than replanting and non-motorized Administrative Use) during the Spring Period in Spring Habitat, provided that (x) Administrative Use and the hauling of harvested logs may occur on roads that are open to the public that are in such Spring Habitat and (y) road use associated with replanting and limited spring burning is permitted on all roads. Roads within Linkage Zones at low elevation that are open to all Administrative Uses between April 1 and June 15 are shown in Attachment H.

(ii) The Parties agree to limit the number of Active Subunits within the Conservation Area by concentrating Commercial Use during the Restricted Period in four (4) out of the eleven (11) BMU Subunits on a rotational basis, leaving the other seven (7) BMU Subunits as Inactive Subunits during the Restricted Period for a minimum of three (3) years. The rotational schedule as it is currently contemplated is governed by Attachment I attached to and hereby made a part of this Agreement. At no one time during the Restricted Period will more than: two BMU Subunits be Active Subunits within the Mission Range BMU; one BMU Subunit be an Active Subunit within the Big Salmon BMU; and one BMU Subunit be an Active Subunit within the Bunker BMU. The Parties will commence such rotation on the date set forth in Attachment I, but in any event not later than three years after the Effective Date. Periodically, as necessary, the Parties may agree to adjust or modify these seasonal and rotational concepts based on evolving science regarding the needs of the Bear. Insofar as possible, schedules will be developed 3 years in advance of the start of the Commercial Activity within a BMU Subunit.

(iii) Every effort will be made to minimize uses in Inactive Subunits, but when in the interests of local residents it may be possible to allow post and pole and bough collection in Inactive Subunits as long as the activity is less than two consecutive weeks in duration.

(iv) Salvage Harvests will not occur in Spring Habitat during the Spring Period. In Inactive Subunits, Salvage Harvests shall be conducted either: (x) between June 16 and August 31 as long as they do not exceed more than 30 days in the aggregate for a given Inactive Subunit within a given calendar year, or (y) during the Denning Period (November 16 to March 31). Salvage Harvests during the period June 16 to August 31 in Inactive Subunits resulting from extraordinary events such as catastrophic fire or blow-down that require more than two consecutive weeks or in the aggregate more than 30 days in a calendar year to complete, may require special management. The Parties agree to confer on a case-by-case basis with respect to such events to determine the special management opportunities that might compensate for any such Salvage Harvests.

(v) Although the Parties will attempt wherever feasible to avoid activities during the Spring Period in Spring Habitat outside of Preferred Habitat, they recognize that some Administrative and Commercial Use may need to occur in Active Subunits in such low elevation areas during such period. If a party wishes to conduct an activity within Spring Habitat (but outside of Preferred Habitat) during the Spring Period that is otherwise prohibited by subparagraphs (i) or (iv) above, such party may nevertheless conduct such activity provided that the activity complies with a plan prepared in accordance with this paragraph. Before conducting such activity, the Party proposing such activity agrees to confer with the Service on a disturbance avoidance plan to mitigate for such activity. Such plan, which shall be prepared by a wildlife biologist for the party proposing such activity after conferring with the Service, shall detail the steps that will be taken to avoid and/or minimize the impacts of the activity on Bears and be submitted to the Service for review at least four weeks prior to the commencement of the planned activity.

(c) Road Locations

(i) The Parties recognize the importance of Preferred Habitat and Riparian Zones to Bear security and the Service recognizes the Parties' need to access their lands. Accordingly, the Parties will limit the construction of new roads in Preferred Habitat and Riparian Zones to those roads that are essential to forest management. In addition, any roads built in these areas will be constructed in such a manner as to minimize the density/mileage of roads in such areas. Existing roads will be analyzed and those not required for short term management will be Reclaimed, and those roads needed for ongoing primary access will be relocated when reasonable.

(ii) Within the Conservation Area, harvest or new road construction will leave Visual Screening between roads that are outside of Even Age Cutting Units and the Unit itself, although exceptions may be required to accommodate some cable yarding harvest.

(d) Cover

(i) The Parties will evaluate Cover across all ownerships and will manage their lands so that a minimum of 40% of all land in each BMU Subunit in the Conservation Area is maintained in Cover. To the extent feasible, Cover will be distributed evenly throughout the Subunit. Each party will be responsible for maintaining cover, at a level adequate to meet the 40% objective, in proportion to its ownership within the Subunit.

(ii) Visual Screening retention will be the management objective in areas adjacent to all Open Roads. The Parties will leave Visual Screening adjacent to Open Roads, although exceptions may be required for such situations as cable yarding harvest and in some exceptional cases of insects, disease, or blow down. Even-age treatments adjacent to Open Roads will be no larger than one acre.

(iii) The Parties will lay out Even Age Cutting Units in the Conservation Area so that no point in the unit is more than 600 feet from Cover. The Parties will use their best efforts to leave Cover around natural open areas so that no point of such openings is more than 600 feet from Cover. Catastrophic events will be dealt with on a case-by-case basis.

(iv) In large Even Age Cutting Units (larger than 40 acres) the Parties will retain Cover to reduce line-of-sight distances.

(e) Riparian Zones

The Parties will use uneven-aged forest management practices in Riparian Zones located in the Conservation Area.

DRAFT

(f) Security

(i) The Parties acknowledge that Reclaimed Roads and Restricted Roads are important for providing security for Bears. The Parties agree to contribute to security, particularly within Linkage Zones, by reclaiming or restricting roads. DNRC may voluntarily elect to contribute to security, particularly within Linkage Zones, by reclaiming (as defined in this Agreement) some roads that are not essential to their respective management. The Forest Service hereby agrees not to take management actions that increase total road density or open road density or to decrease Core Areas on its ownership. DNRC will voluntarily agree to contribute those areas set forth in Attachment C as Core Areas. The Forest Service also agrees to reclaim roads to enhance use of preferred and other high quality habitats, and to complement adjacent areas of secure habitat. The Parties will cooperate in identifying roads on their lands within the Conservation Area that are grown-in and/or unnecessary for management and will make such roads Reclaimed Roads from April 1 to November 15 in order to increase security for bears. The Parties agree not to reclaim existing roads accessing the other Parties' lands without first ensuring that reasonable alternative access exists. DNRC agrees to work with the Forest Service to minimize the number and length of new roads that will go through Core Areas; provided, however, that the foregoing will not require DNRC to accept alternate access that would preclude reasonable use of their lands. The Forest Service agrees that if the only reasonable access is through Core Areas that it will provide replacement Core Areas, where feasible, so that such access by DNRC is possible.

(ii) Both the FS and DNRC will prohibit their contractors that are working under contract from carrying firearms while on duty.

(iii) DNRC will not be subject to a total road density standard. The Forest Service will not take management actions that increase total road density on its ownership except to the extent required by law to grant access to in-holders. The Forest Service agrees to reclaim roads to the extent necessary to meet its total road density obligations. DNRC agrees to work with the Forest Service to minimize the total road density impact on the Forest Service caused by their access requests; provided that the foregoing will not require DNRC to accept alternative access that would preclude reasonable use of their respective lands.

(iv) Nothing in this Section 3(f) shall be construed to change the obligation of the Forest Service to maintain existing easements and permits or to provide access to non-federal lands within the boundaries of the national forest, as required by law.

2. Monitoring and Coordination

(a) The Parties acknowledge that the principles of "adaptive management" should govern management within the Appendix __ subunits. As such, new information gained from monitoring and research, conducted either within or outside the appendix __ subunits, will be reviewed on an annual or more frequent basis, as necessary, to determine if changes in management direction are appropriate. The Parties may choose to support such research/monitoring by contributing to ongoing or future proposed Bear research projects.

(b) The Parties will cooperatively monitor the application and effectiveness of the Guidelines on an ongoing basis and provide the Service with the results thereof on an annual basis. Monitoring will include: (i) an analysis of open and total road densities, (ii) levels of Administrative Use in Inactive Subunits, (iii) levels of Administrative Use on Restricted Roads within Linkage zones during the Spring Period and fall period (September 1 to November 15).

(c) The Guidelines will be reviewed by the Parties annually and appropriately revised, pursuant to the procedures set forth in Section 10 hereof. Revisions will be commensurate with new research findings concerning Bear conservation practices and experience with the practicability of the strategies agreed to here.

(d) The Parties agree to develop strategies to inform the public about the needs of the Bear.

3. Application

The provisions of this Appendix have been tailored to protect Bears under the special conditions present within the Swan Valley of the Northern Continental Divide Ecosystem. The terms of this appendix apply only to the Subunits as defined in this Appendix.

4. Resources

Nothing in this Appendix shall require the DNRC or the Forest Service to expend funds that have not been lawfully appropriated and administratively allocated for such use.

DRAFT

DRAFT

Appendix 8

Interagency Rocky Mountain Front Management Guidelines for Selected SpecieS

Interagency

ROCKY MOUNTAIN FRONT

Wildlife Monitoring/Evaluation Program

Management Guidelines for Selected Species,
Rocky Mountain Front Studies.

Interagency Rocky Mountain Front
Wildlife Monitoring/Evaluation Program

Management Guidelines

Grizzly Bear	Elk
Mountain Goat	Mule Deer
Bighorn Sheep	Raptors

Approved By:

John D. Gorman, Forest Supervisor Lewis & Clark National Forest	SEP 1 1987 Date
Wayne Zinne, District Manager Bureau of Land Management, Lewistown District	SEP 1 1987 Date
Wayne Brewster, Field Supervisor U.S. Fish & Wildlife Service	SEP 1 1987 Date
Daniel Vincent, Regional Supervisor Montana Department Fish, Wildlife and Parks	SEP 1 1987 Date

INTRODUCTION

The Interagency Rocky Mountain Front Monitoring and Evaluation Program was initiated in 1980 in response to the collective needs of the participating agencies. These needs involved both the proactive management of the diverse wildlife resource as well as planning and evaluation of a multitude of human use activities and management of other natural resources. The guidelines developed from this coordinated interagency effort are best management practices to maintain or enhance selected wildlife species and their habitats. Application and monitoring of the guidelines will assist land and wildlife managers in meeting their wildlife and habitat objectives, will assist managers in coordinating multiple-use objectives with the biological requirements of these wildlife resources and will provide an analytical tool in evaluating effects of proposed activities.

It is recognized that all potential activities cannot be conducted simultaneously while maximizing outputs from all resource uses. Multiple-use involves both complimentary and competing activities at various times and locations and by definition may involve maximizing benefits from one resource use while precluding all or parts of the benefits of a competing use. The guidelines were not developed with the intent of precluding certain activities, but rather to assist in providing a balance of land uses while at the same time preserving the integrity and diversity of these wildlife resources. It is recognized that application of these guidelines in designing activities may require certain activities to be modified, restricted, or even precluded in order to conserve the diverse wildlife resources of the Rocky Mountain Front. On the other hand, they identify windows of opportunity where little or no competition exists, they identify opportunities for enhancement of these wildlife resources, and finally, they identify those instances where there is competitive overlap so more informed management decisions can be made, resulting in balanced stewardship of the broad array of national resources.

In the event that future efforts or information result in the need for a new guideline or the modification of an existing guideline, it can be submitted at anytime to an appropriately designated interagency committee for review and approval.

The following management guidelines are based on the best information currently available. They are a result of current or recently completed studies on selected wildlife species. Field investigators conducting the studies have completed extensive literature reviews on the various species considered. The guidelines which have been formulated and presented in this document are not only the result of the study findings and literature review, but incorporate the professional judgement of the technical personnel involved.

OBJECTIVES

The need for management is predicated on management concerns involving the effects of existing and proposed land uses and human activities upon various wildlife species and their habitat. The objective of the development and application of management guidelines is to avoid or minimize the following effects of human related activities which may adversely impact some or all of the selected wildlife species being considered:

A. Physical destruction of important wildlife habitat components.
B. Human disturbance that would displace various wildlife species from important seasonal use areas.
C. Increased direct human caused mortality.
D. Increased stress due to higher human activity levels.
E. Direct mortality or physical impairment resulting from environmental (chemical) contaminates.
F. Increased wildlife/human interaction resulting from habitat intrusion or displacement.

MANAGEMENT GUIDELINES

Management guidelines provide coordination measures designed to avoid or minimize the potential conflicts previously identified between human related activities and wildlife. Although many of the guidelines are applicable to a variety of human activities, some of them are specific to a single activity. Oil and gas exploration and development has received special emphasis due to the relatively high level of activity in recent years. As a result, some of the guidelines apply specifically to that activity.

The guidelines have not been submitted for interdisciplinary analysis, public comment, or NEPA review. Where they have been employed, they were exposed to this review as part of the public planning process. Decision makers for each agency involved will determine what is a reasonable and prudent application of these guidelines in each case. The resulting planning, evaluation, and decision process will conform to the NEPA process. Departure from the guidelines, the impacts resulting from that departure, and the justification for such departure will be displayed in the appropriate planning documents.

Approved management guidelines will be included in permits, contracts or other formal authorizations of human activities as applicable. Omissions or modifications of guidelines as they are applied to specific activities will be documented in compliance with NEPA.

MONITORING

A majority of the radio tracking and habitat survey data collected to date has been baseline information including the identification of seasonal ranges, reproduction areas, breeding areas and migration corridors. Future studies will place increasing emphasis on the monitoring of effects of increased human activity levels, particularly those associated with oil and gas exploration, on the wildlife species being studied. The management guidelines presented in this document are only partially based on monitoring information collected during the current studies on the Rocky Mountain Front. An important consideration in further monitoring efforts will be to test and validate the guidelines as to their effectiveness and applicability. Projects that may be proposed in the future should include as part of the cost of the project, funding to help assist in validating these guidelines.

PART A — GENERAL MANAGEMENT GUIDELINES

The following general management guidelines are applicable coordination measures that will be considered when evaluating the effects of existing and proposed human activities in identified seasonally important habitats for a variety of wildlife species:

1. Identify and evaluate for each project proposal the cumulative effects of all activities, both existing uses and other planned projects. Potential site specific effects of the project being analyzed are a part of the cumulative effects evaluation which will apply to all lands within a designated biological unit. A biological unit is an area of land which is ecologically similar and includes all of the yearlong habitat requirements for a sub-population of one or more selected wildlife species.

2. Evaluate human activities, combinations of activities, or the zones of influence of such activities that occur on seasonally important wildlife habitats and avoid those which may adversely impact the species or reduce habitat effectiveness.

3. Space concurrently active seismographic lines or line segments at least nine (9) air miles apart to allow an undisturbed corridor into which wildlife can move when displaced (Olson, G., 1981).

4. Establish helicopter flight patterns of not more than one-half (1/2) mile in width along all seismographic lines, between landing zones and the lines, and between landing zones and other operations, unless flying conditions dictate deviations due to safety factors.

5. Because helicopters produce a more pronounced behavioral reaction by big game and raptors than do fixed-wing aircraft, helicopters will maintain a minimum altitude of 600 feet (183 meters) above ground level when flying between landing zones and work areas where landing zones are not located on seismic lines, unless species specific guidelines recommend otherwise (Hinman, H., 1974; McCourt, K.H., et al. 1974; Klein, D.R., 1973; Miller, F.L. and A. Gunn, 1979).

6. Designate landing zones for helicopters in areas where helicopter traffic and associated human disturbances will have the minimum impact on wildlife populations. Adequate visual and/or topographic barriers should be located between landing zones and occupied seasonal use areas.

7. The use of helicopters instead of new road construction to accomplish energy exploration and development is encouraged.

8. Base road construction proposals on a completed transportation plan which considers important wildlife habitat components and seasonal use areas in relation to road location, construction period, road standards, seasons of heavy vehicle use, road management requirements, etc.

9. Use minimum road and site construction specifications based on projected transportation needs. Schedule construction times to avoid seasonal use periods for wildlife as designated in the species specific guidelines.

10. Locate roads, drill sites, landing zones, etc. to avoid important wildlife habitat components based on a site specific evaluation.

11. Insert "dog-legs" or visual barriers on pipelines and roads built through dense vegetative cover areas to prevent straight corridors exceeding one-fourth (1/4) mile where vegetation has been removed (Stubbs, C.W. and G.J. Markham, 1979).

12. Roads which are not compatible with area management objectives and are no longer needed for the purpose for which they were built will be closed and reclaimed. Native plant species will be used whenever possible to provide proper watershed protection on disturbed areas. Wildlife forage and/or cover species will be utilized in rehabilitation projects where deemed appropriate.

13. Keep roads which are in use during oil and gas exploration and development activity closed to unauthorized use. Place locked gates and/or road guards at strategic locations to deter unauthorized use when activities are occurring on key seasonal ranges.

14. Impose seasonal closures and/or vehicle restrictions based on wildlife or other resource needs on roads which remain open.

15. Bus crews to and from drill sites to reduce activity levels on roads. Shift changes should be scheduled to avoid morning and evening wildlife feeding periods.

16. Keep noise levels at a minimum by muffling such things as engines, generators and energy production facilities.

17. Prohibit dogs during work periods.

18. Prohibit firearms during work periods or in vehicles traveling to and from work locations.

19. Seismographic and exploration companies should keep a daily log of activities. Items such as shift changes, shut down/start up times, major changes in noises or activity levels, and the location on the line where seismic crews are working should be recorded.

GRIZZLY BEAR

The Interagency Grizzly Bear Committee approved the application of guidelines on National Forest System, Bureau of Land Management (BLM) and National Park System lands throughout grizzly bear ecosystems in the States of Idaho, Montana, Washington, and Wyoming. (November 26, 1986 Federal Register, Vol. 51, No. 228). These guidelines are known as the Interagency Grizzly Bear Guidelines (IGBG). The IGBG provide definition and management direction for grizzly bear Management Situations I, II, III, IV and V and further provide generalized guidelines on "how to coordinate various activities with the bear in the various management situations. Grizzly bear habitat along the Rocky Mountain Front has been stratified into grizzly bear management situations pursuant to the IGBG.

The Rocky Mountain Front Guidelines (RMFG) found in this document do not identify management situations or provide definitions or management directions of the stratification. The Management Situations designated on the Front pursuant to the IGBG identify where the emphasis on grizzly bear needs to be placed, and if there is a conflict, where the conflict should be resolved in favor of the bear. The RMFG represent best management practices for coordinating multiple use activities within the grizzly bear management situations delineated on the Front. The RMFG are detailed coordination measures for specific activities that will assist land managers in meeting the management direction provided in the IGBG. They are consistent with the IGBG and further refine the IGBG to specific habitat conditions on the Front.

Study results documented to date along the east Rocky Mountain Front are the basis for the development of management guidelines for grizzly bear and their habitat. During the period from 1977-1979, research was carried out by the Border Grizzly Project under a contract with the BLM.

Since 1980 the Montana Department of Fish, Wildlife and Parks has assumed the intensive grizzly bear monitoring work with funding continuing from the Interagency Rocky Mountain Front Task Force, private industry (ARCO, Mobil Oil Corporation, Shell Oil, American Petrofina, Williams Exploration, Sun Exploration) and the Nature Conservancy. In addition, a BLM funded livestock/ grizzly bear interaction study was conducted by a graduate student from Montana State University during the field seasons of 1985 and 1986.

These guidelines were developed as a direct result of grizzly bear monitoring conducted on the East Front. They represent guidelines that, when followed, will mitigate but not totally eliminate influences of human activities on grizzly bears and grizzly bear habitat. Human activities within grizzly bear range will have effects, however subtle, on grizzly bears.

All previously mentioned "general management guidelines" are applicable coordination measures that should be considered when evaluating human activities in grizzly bear habitat. The following are additional species specific guidelines.

1. Avoid human activities in identified grizzly bear habitat constituent elements or portions of constituent elements containing specific habitat values during the following seasonal use periods (see data summarization):

   A. Spring habitat (concentrated use areas) .... April 1 - June 30
   B. Alpine feeding sites .... July 1 - Sept. 15
   C. Subalpine fir/whitebark pine habitat types .... Aug. 1 - Nov. 30
   D. Denning habitat .... Oct. 15 - Apr. 15

2. Avoid human activities in grizzly bear habitat components which provide important food sources during spring and early summer, April 1 - July 15. These habitat components include riparian shrub types, *Populus* stands, wet meadows, sidehill parks, and avalanche chutes. Maintain an undisturbed zone of at least 1/2 mile between activities and the edge of these habitat components where many important bear foods occur.

3. Establish flight patterns in advance when activities require the use of helicopters. Flight patterns should be located to avoid seasonally important grizzly bear habitat constituent elements and habitat components during the designated seasonal use periods.

4. No seismic or exploratory drilling activities should be conducted within a minimum of one mile of den sites during the October 15 - April 15 period (Reynolds, P.E. et al, 1983).

5. Seismic permits should include a clause providing for cancellation or temporary cessation of activities, if necessary, to prevent grizzly/human conflicts.

6. Scheduling of well drilling on adjacent sites, within important grizzly bear use areas, should be staggered to provide a disturbance free area for displaced bears.

7. Pipeline construction required for the development of a gas or oil field should be condensed into the shortest time frame possible and subject to seasonal restrictions when conducted in important grizzly bear habitat.

8. Field operation centers associated with seismic or oil/gas exploration activities should be placed carefully to avoid seasonally important habitat components or constituent elements. Such placement of sites is necessary in order to avoid direct or potential conflicts between man and grizzly bear.

9. Retain frequent dense cover areas adjacent to roads for travel corridors and security cover necessary to protect important habitat components. Three sight distances are desirable to provide visual security for grizzlies. A sight distance is the average distance at which a grizzly or other large animal is essentially hidden from the view of an observer by vegetation cover. The same security cover guidelines also applies to timber harvest units.

10. No off-duty work camps will be allowed within occupied seasonally important constituent elements.

11. Incinerate garbage daily or store in bear proof containers and remove to local landfill dumps daily.

12. Commercial activities permitted on public land should be planned and coordinated to avoid conflicts with grizzly bear trapping operations being conducted under the monitoring program. General public use of areas where trapping operations are active will be controlled through appropriate administrative actions by the agencies involved.

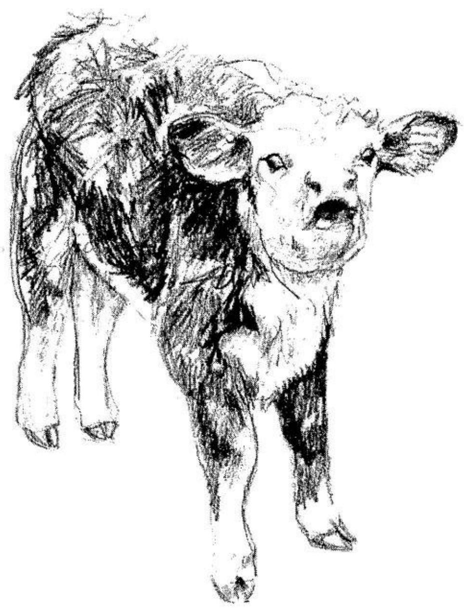
The following are grizzly bear management guidelines specifically oriented toward livestock grazing:

1. Livestock grazing on riparian plant communities should be deferred until after July 1.

2. In pastures grazed after July 1, cattle should be removed before the amount of the riparian forage base is reduced by 50 percent by either grazing or structural damage.

3. Exceptions to the July 1 entry date can be made when a pasture is part of a grazing system (for example, rest rotation or deferred rest rotation) that does not cause a decrease in the condition or size of the riparian plant communities.

4. In riparian habitats that receive high amounts of bear use, fencing to exclude livestock grazing and trampling may be necessary where livestock turn-out dates prior to July 1 are allowed.



5. Boneyards and livestock dumps are prevalent along the East Front and are frequented by grizzly bears. Ranchers and landowners should be encouraged to place carcasses of dead livestock and garbage on remote areas of their land. Dead cows and calves should be hauled a considerable distance from calving grounds to discourage bears from feeding on carion and newborn calves.

6. Options given in the IGBG for sheep allotments will be followed: "On sheep allotments where grizzly — livestock depredation has been authenticated, adjustments will be made for the primary purpose of grizzly bear conservation. The following options are available:

   (a) change the season of use, bedding practices, or grazing area to avoid known problem areas or other habitat important to grizzlies in time and space;

   (b) change the class of livestock from sheep to cattle if the range is suitable for cattle; or

   (c) remove all livestock and close the allotment. Vacant sheep allotments will not be restocked with sheep."

In addition to the guidelines listed above for livestock grazing practices, the following research/ management recommendations are presented; and will be considered as allotment management plans are updated.

1. The condition and trend of all riparian plant communities and their production of *Angelica arquta, Heracleum lanatum*, and *Osmorhiza occidentalis* need to be determined on all East Front public lands grazed by livestock.

2. For pastures where the condition of riparian plant communities needs improving, the construction of special use pastures is recommended. A special use pasture should be constructed where large areas of riparian vegetation are enclosed so an adequate forage base will be available to allow for stocking rates compatible with livestock operations. (Exclosures should be considered if riparian areas are too small.) These pastures should only be grazed after July 1, and the livestock should be removed before the utilization of the riparian forage base reaches 50% or the special use pastures should be incorporated into a deferred rest rotation grazing system similar to that described by Marlow (1985). Some other methods which may be used to reduce impacts to riparian include; development of alternate water sources, placement of salt away from riparian, and improved herding practices.

3. For riparian areas where the abundance of important plant species used by grizzlies for cover (*Populus tremuloides, Populus tricocarpa, Salix* spp., or *Betula* spp.,) or food (*Angelica arquta, Heracleum lanatum*, or *Osmorhiza occidentalis*) has been reduced, reestablishment should be attempted.

Appendix 9

Private Lands – 2011 Values Inside the PCA

BMU Name	miscellaneous businesses, day-use, etc.	residences & overnight use	unknown
Badger Two Medicine	10	79	
Big Salmon	26	390	5
Birch Teton	2	55	1
Bunker		42	
Dearborn Elk Creek		163	
Hungry Horse	1488	1515	14
Lower Middle Fork Flathead	119	305	4
Lower North Fork Flathead	179	379	
Mission Range	5	563	3
Monture Landers Fork	1	97	
Murphy Lake		10	
Northeast Glacier	89	271	1
Rattlesnake		6	
South Fork Sun Beaver Willow	1	34	
Southeast Glacier	83	245	1
Stillwater River	19	27	
Sullivan	111	674	9
Teton Sun River	1	97	2
Upper Middle Fork Flathead	21	76	5
Upper North Fork Flathead	177	331	3
Upper South Fork Flathead		5	
sub-totals	**2332**	**5364**	**48**

Spatial data used in this analysis:

Katherine Ake, NCDE Data Base Coordinator. USFS. Northern Continental Divide Ecosystem Bear Management Units (BMU) for GrizzlyBears. Kalispell, MT. 2008.

Montana Base Map Service Center/Montana State Library. Montana Structures Framework. Helena, MT. January 2, 2013.

Montana Base Map Service Center/Montana State Library. Public Lands (Cadastral Version). Helena, MT. November 13, 2012.

Data Analysis Notes:

Structures locations where value_ IS NULL or value_ = "Structure (abstract)" were not used in this analysis because these locations were generated from address data and are typically duplicate locations for the structures digitized using aerial imagery. Structures occurring on public lands were excluded from the analysis. Structure types were generalized into the classification descriptions as noted in the corresponding Structures Lookup worksheet in this spreadsheet file.

Appendix 10

Detailed Summary of Current USFS Management Plan Direction Relevant to Grizzly Bears in Management Zones 1 and 2

HABITAT MANAGEMENT – ZONE 1

Habitat Standards from Existing Forest Plans and/or Biological Assessments for Grizzly Bears

Programmatic Decisions or Actions beneficial for Grizzly Bears

- Regional INLAND Native Fish Strategy, 1996 – amends Forest plans (Flathead, Helena, Kootenai, Lolo and Deerlodge) in western Montana and provides direction in the form of riparian management objectives, standards and guidelines. Riparian direction provides consistent direction to maintain productivity of highly used bear habitat component.
- Off-Highway Vehicle Record of Decision for Montana, January 2001 – amends Forest Plans in Montana and establishes a new standard that restricts yearlong, wheeled motorized cross-country travel, where it is already not restricted, with specific exceptions. Restricting motorized cross-country travel would benefit all terrestrial species by reducing disturbance to wildlife and the soil (OHV FEIS)
- Roadless Area Conservation Strategy, 2001 – prohibits road construction, road reconstruction, and or timber cutting, sale or removal in inventoried roadless areas except under certain circumstances. Subsequent litigation resulted after this decision. On October 21, 2011 the US Court of Appeals for the Tenth Circuit unanimously ruled to restore the Roadless Rule, ending a 2008 national injunction. The Roadless Rule blocks road-building and commercial timber harvesting on expanses of National Forest roadless areas. This decision is likely to provide a vast area of secure habitat for terrestrial species.
- Northern Rockies Lynx Management Direction, 2007 – may beneficially affect grizzly bears by maintaining riparian habitat, reducing the disturbance associated with minerals and human uses, reducing habitat fragmentation and providing for animal movement.
- The Montana Legacy Project is a cooperative project of The Nature Conservancy, The Trust for Public Land and state, federal and private partners that have transferred ownership of about 310,000 of former Plum Creek lands to conserve vital wildlife habitat and water resources, maintain the forestland production and restoration opportunities that sustain both the land and local economies, and to conserve

traditional access for a broad variety of outdoor recreation activities. Many of these acres are located within current grizzly bear habitat and connectivity areas.

- Participation with other federal, state, county, and private partners in land management and conservation such as the Swan Valley Bear Resources and Forest Stewardship programs, the Blackfoot Challenge, and Vital Ground which promote programs and projects to reduce bear-human conflicts and promote habitat connectivity.

General Management Directions

Upon delisting the grizzly bear will be designated a Forest Service Sensitive Species.

- As part of the National Environmental Policy Act process, conduct analyses to review programs and activities, and determine their potential effect on sensitive species. The biological evaluation shall be conducted or reviewed by qualified persons as determined by the Forest Supervisor. Adverse impacts to sensitive species or their habitats should be avoided. If impacts cannot be avoided, the significance of potential adverse effects on the population or its habitat within the area of concern and on the species as a whole will be analyzed. Project decisions will not result in loss of species viability or create significant trends towards federal listing.

- To further minimize and avoid risks to species the proposed action will include the following additional clauses as conservation measures[1]. These clauses or provisions were selected from Forest Service Handbook 2709.11 – Special Uses Handbook Chapter 50 - Terms and Conditions, Section 52 - supplemental terms and conditions and the Region 1 Special Uses Handbook Supplement No. 2709.11-2000-1 for resource and improvement protection.

- <u>X-8</u>. <u>Protection of Habitat of Endangered, Threatened, and Sensitive Species</u>.

  Location of areas needing special measures for protection of plants or animals listed as threatened or endangered under the Endangered Species Act of 1973, as amended, or as sensitive by the Regional Forester under authority of FSM 2670, derived from ESA Section 7 consultation, may be shown on a separate map, hereby made a part of this authorization, or identified on the ground. Protective and mitigative measures specified by the authorized officer shall be the responsibility of the authorization holder. If protection measures prove inadequate, if other such areas are discovered, or if new

[1] **Conservation measures** - are actions to benefit or promote the recovery of listed species that are included by the Federal agency as an integral part of the proposed action. These actions will be taken by the Federal agency or applicant, and serve to minimize or compensate for, project effects on the species under review. These may include actions taken prior to the initiation of consultation, or actions which the Federal agency or applicant have committed to complete in a biological assessment or similar document.

species are listed as federally threatened or endangered or as sensitive by the Regional Forester, the authorized officer may specify additional protection regardless of when such facts become known. Discovery of such areas by either party shall be promptly reported to the other party.

- R1-X10 - Grizzly Bear Protection. Mandatory in all special-use authorizations within occupied grizzly bear habitat.

  This special-use authorization includes land which is part of the habitat of the grizzly bear. Therefore, in compliance with Forest Service responsibilities under the Endangered Species Act of 1973, 16 U.S.C. 1531, the following conditions apply to this special-use authorization:
  1. The authorized officer may order an immediate temporary suspension of all human activities permitted by this authorization and, if needed, revoke or terminate the special-use authorization when, in his/her judgment, such action is necessary in order to prevent confrontation or conflict between humans and grizzly bears. The holder shall immediately comply with such order. The United States shall not be liable for any consequences from such a suspension, revocation, or termination. Such suspension, revocation, or termination may be appealed to the next higher level as provided in 36 CFR 251, Subpart C *(For easements under Title V FLPMA, 43 U.S.C. 1761-1771, change authority to 7 CFR 1.130-1.151)*
  2. The holder, his/her agents, employees, contractors, and subcontractors will comply with the requirements of the attached Grizzly Bear Management and Protection Plan dated _________ in the conduct of any and all activities authorized. The authorized officer may review and revise the plan as needed. *(The Grizzly Bear Management and Protection Plan will, as a minimum, address the following: 1. Camp locations and period of time each location is to be used. 2. Areas to avoid or enter, by type of activities, schedule. 3. Seasonal or other human activity limitations. 4. Identify livestock and pets. a. By location, b. Numbers, c. Types (horses, dogs, and so forth), d. Treatment of carcasses. 5. Food storage. a. Livestock and pets, b. Human. 6. Food preparation and cleanup. 7. Garbage and refuse disposal. a. Livestock and pets, b. Human. 8. Storage of game meat, if applicable. 9. Suggestions for minimizing direct conflict. 10. Human safety. 11. Provisions for amendment or modification).*
  3. The holder assumes full responsibility and shall hold the United States harmless from any and all claims by him/her or by third parties for any damages to life or property arising from the activities authorized by this special-use authorization and encounters with grizzly bears, or from suspension, revocation or termination of activities authorized by this special-use authorization.
  4. Intentional or negligent acts by the holder, his/her agents, employees, contractors, and subcontractors that result in injury or death of a grizzly bear will be cause for revocation or termination of this authorization in whole or in part.
  5. Failure to comply with provisions 1, 2, or 3 may result in suspension, revocation, or termination of this authorization in whole or in part, and may cause criminal action to be taken against the holder under provisions of the Endangered Species Act of 1973, as amended, or other applicable authority.

DRAFT

B6.24 Protection Measures Needed for Plants, Animals, Cultural Resources, and Cave Resources.

- Locations of known areas needing special measures for the protection of plants, animals, cultural resources, and/or cave resources are shown on Sale Area Map and/or identified on the ground. Special protection measures needed to protect such known areas are identified in C6.24.

- In addition to any special protection measures noted, Purchaser has a general duty to protect all known and identified resources referenced in this Subsection from damage or removal during Purchaser's Operations. Discovery of additional areas, resources, or members of species needing special protection shall be promptly reported to the other party, and operations shall be delayed or interrupted at that location, under B8.33, if Contracting Officer determines there is risk of damage to such areas, resources, or species from continued operations.

- Wheeled or track-laying equipment shall not be operated in areas identified as needing special measures for the protection of cultural resources, except on roads, landings, tractor roads, or skid trails approved under B5.1 or B6.422. Unless agreed otherwise, trees will not be felled into such areas. Purchaser may be required to backblade skid trails and other ground disturbed by Purchaser's Operations within such areas in lieu of cross ditching required under B6.6.

- Purchaser shall immediately notify Forest Service if disturbance occurs to any area identified as needing special protection measures and shall immediately halt operations in the vicinity of the disturbance until Forest Service authorizes Purchaser to proceed. Purchaser shall bear costs of resource evaluation and restoration to identified sites. Such payment shall not relieve Purchaser from civil or criminal liability otherwise provided by law. Nothing in this Subsection shall be interpreted as creating any warranty that all locations and special measures for the protection of plants, animals, cultural resources, and cave resources have been described herein, elsewhere in the contract, or designated on the ground.

Standard Provisions for a Timber Sale Contract include:

B6.24 Protection Measures Needed for Plants, Animals, Cultural Resources, and Cave Resources.

- Locations of known areas needing special measures for the protection of plants, animals, cultural resources, and/or cave resources are shown on Sale Area Map and/or identified on the ground. Special protection measures needed to protect such known areas are identified in C6.24.

- In addition to any special protection measures noted, Purchaser has a general duty to protect all known and identified resources referenced in this Subsection from damage or removal during Purchaser's Operations. Discovery of additional areas, resources, or members of species needing special protection shall be promptly reported to the other party, and operations shall be delayed or interrupted at that location, under B8.33, if Contracting Officer determines there is risk of damage to such areas, resources, or species from continued operations.

- Wheeled or track-laying equipment shall not be operated in areas identified as needing special measures for the protection of cultural resources, except on roads, landings, tractor roads, or skid trails approved under B5.1 or B6.422. Unless agreed otherwise, trees will not be felled into such areas. Purchaser may be required to backblade skid trails and other ground disturbed by Purchaser's Operations within such areas in lieu of cross ditching required under B6.6.

- Purchaser shall immediately notify Forest Service if disturbance occurs to any area identified as needing special protection measures and shall immediately halt operations in the vicinity of the disturbance until Forest Service authorizes Purchaser to proceed. Purchaser shall bear costs of resource evaluation and restoration to identified sites. Such payment shall not relieve Purchaser from civil or criminal liability otherwise provided by law. Nothing in this Subsection shall be interpreted as creating any warranty that all locations and special measures for the protection of plants, animals, cultural resources, and cave resources have been described herein, elsewhere in the contract, or designated on the ground.

B8.33 Contract Suspension and Modification, (a) Contracting Officer may, by written order, delay or interrupt authorized operations under this contract or modify this contract, in whole or in part:

- To prevent environmental degradation or resource damage, including, but not limited to, harm to habitat, plants, animals, cultural resources, or cave resources;

- To ensure consistency with land and resource management plans or other documents prepared pursuant to the National Environmental Policy Act of 1969, 42 USC 4321-4347;

- To conduct environmental analysis, including, but not limited to, engaging in consultation pursuant to the Endangered Species Act of 1973, 16 USC 1531, *et seq.*; or …

<u>Food and Attractant Storage Special Orders</u>

The Kootenai, Flathead and Lolo have mandatory forest wide orders that were established in 2011. The Helena currently has orders for the NCDE recovery zone and the Lincoln RD. Orders are included in contracts and permits on a portion of the Helena RD. The Helena NF will be establishing a forestwide order in the near future.

Road Density Standards

Flathead LRMP Standards

- Miles of existing "open" roads on a yearlong or seasonal basis will generally not increase above current "open" mileage.
- To assure wildlife security needs within the different Geographic Units, unrestricted road density requirements have been established (refer to Table II-6). (Unrestricted roads do not have seasonal or yearlong closure to public motorized access; restricted roads are physically closed by a gate, berm, or revegetation.)

Table II-6. Geographic Unit Unrestricted Road Density Standards outside the NCDE recovery zone.

Geographic Unit	LRMP Road Density Requirement (Mi / mi²)
Olney-Martin Creek	1.3 to 1.8
Upper Good Creek	1.3 to 1.8
Sylvia Lake	1.3 to 1.8
Star Meadow-Logan Creek	1.8 to 2.2
Tally Lake-Round Meadow	1.8 to 2.2
Mountain Meadow-Rhodes Draw	1.8 to 2.2
Upper Griffin	2.0 to 3.2
Ashley Lake	2.0 to 3.2
Island Unit	2.0 to 3.2

Helena LRMP Standards

- Implement an aggressive road management program to maintain or improve big game security.
- Road management will be implemented to at least maintain big game habitat capability and hunting opportunity. To provide for a first week bull elk harvest that does not exceed 40% of the total bull harvest, roads will be managed during the general big game hunting season to maintain open road densities with the following limits.

Existing Percent Hiding Cover (according to FS definition of hiding cover[1]	Existing Percent Hiding Cover (according to MDFWP definition of hiding cover[2]	Max Open Road Density
56	80	2.4 mi / mi²
49	70	1.9 mi / mi²
42	60	1.2 mi / mi²
35	50	0.1 mi / mi²

[1]A timber stand which conceals 90% or more of a standing elk at 200 ft. [2]A stand of coniferous trees having a crown closure of greater than 40%.

- Unacceptable damage to soils, watershed, fish, wildlife, or historical/archaeological sites will be mitigated by road restrictions or other road management actions as necessary. Restrictions for wildlife reasons will be coordinated with the MDFWP.

- APPENDIX D Forest Plan Grizzly Bear Management Outside of Recovery Areas. Outside the recovery zone has a forest-wide standard of 0.55 miles/mile^2 of open road density for areas of occupied grizzly habitat. Grizzly bear habitat is identified by documentation of Biological Activity Centers which are verified grizzly bear observations over the last 6 years out of 10, which would include females with cubs or yearlings at least 5 of the 10 years.

- Populations of wildlife "indicator species" will be monitored t o measure the effect of management activities on representative wildlife habitats with the objective of ensuring that viable populations of exiting native and desirable non-native plant and animal species are maintained (the threatened and endangered species include grizzly bear, gray wolf, bald eagle and peregrine falcon;

Kootenai LRMP Forestwide Standards (*an access amendment was signed Nov 2011, and a draft revised forest plan 2012 is released for public review)*

- Developmental activities will be rigorously examined to insure that the minimum number and length of roads are constructed to the minimum standard necessary.

- Outside the recovery zone there is an open road density standard of 0.75 miles/mile^2 for big game emphasis management area 12 and an open road density standard of 3.0 miles/mile^2 for recreation and timber emphasis management areas 15 – 18.

- *The recently signed access amendment applies to seven grizzly bear recurring use areas (i.e., BORZ areas) located outside of the CY and NCDE Grizzly Bear Recovery Zones and will ensure no increases in permanent linear miles of open and total roads on National Forest System lands in any individual BORZ, above the baseline conditions identified within the sixth code watersheds comprising the BORZ. Listed exceptions are included in the Access Amendment and include but are not limited to ANILCA claims, and identification of RS24477 thoroughfares. Areas within the BORZ boundary can increase or decrease based on the criteria developed by the Level 1 consultation team representing the CYE.*

Lolo LRMP Forestwide Standards

- Motorized vehicles will be limited to system roads and trails which are designated open in the Lolo Forest Travel Plan.
- Lolo National Forest roads will be the minimum number and meet the minimum design standards possible while still meeting safety, user and resource needs.
- Manage Forest roads to provide for resource protection, wildlife needs, commodity removal, and a wide range of recreation opportunities.
- On highly productive big game summer range, open road densities of existing roads will be restricted to a maximum of 1.1 miles of road per section and all new roads, except arterials, will be closed year-round (average values calculated over designated herd-unit analysis areas).
- New roads will be closed to the public year-round in areas of moderate big game summer range, but roads now open (1984 Travel Plan) will remain open.
- Areas with high potential for walk-in hunting or fishing experiences will be considered for road closures.
- Roads within grizzly bear habitat may be closed seasonally if it is determined that an open road may be increasing the risk of human-caused bear mortality. Within designated Essential Habitat spring range, all non-arterial systems will be closed April 15 to June 15. On summer range, roads that bisect identified critical habitat components will be closed July 15 thru October 15.

<u>Vegetation Standards and Guidelines</u>
Flathead LRMP

- Maintain or restore existing old growth consistent with Wildlife and Fish objectives and standards.

- Elk summer habitat[*] will be given appropriate protection and managed in accordance with the following selected recommendations from the Coordinating Elk and Timber Management, Final Report of the Cooperative Elk-Logging Study, 1970-1985, January 1985.

Helena LRMP

- On important summer (see Glossary in Forest Plan) and winter range, adequate thermal and hiding cover will be maintained to support the habitat potential.

[*] Elk summer habitat, as defined above, encompasses some 30,000 acres of tentatively suitable timberland on the Flathead National Forest. Of the 30,000 acres, 6,500 are in riparian areas.

- An environmental analysis for project work will include a cover analysis. The cover analysis should be done on drainage or elk herd unit basis. (See Montana Cooperative Elk-Logging Study in Appendix C of the Forest Plan for recommendations and research findings on how to maintain adequate cover during project work.)

- Subject to hydrologic and other resource constraints, elk summer range will be maintained at 35 percent or greater hiding cover and areas of winter range will be maintained at 25 percent or greater thermal cover in drainages or elk herd units.

Kootenai LRMP

- The standard for evaluation of elk habitat quality and for formulation of the prescriptions for timber sales and road development projects is The Montana Cooperative Elk-Logging Study, January, 1985.

- Key habitat components (wallows, wet meadows, bogs, etc) will be avoided when constructing roads. As they are identified, those key components will be mapped and managed as riparian areas.

- Manage to provide habitat diversity including cover and forage areas in a ratio appropriate for the species being considered (see list of species in MA goals).

Lolo LRMP Forestwide Standards

- Wildlife features such as wallows, mineral licks and seeps will be protected……]
- A wildlife biologist will examine and recommend vegetative objectives for managing and protecting all winter range whenever activity is proposed within it.
- The document, "Coordinating Elk and Timber Management" (Final Report of the Montana Cooperative Elk-Logging Study, 1970-1985) which summarizes the results of 15 years of interagency elk/logging research will be used as a basic tool for assessing the affects of timber harvest upon elk habitat and for making decisions that affect the overall big game resource.
- When considering activities in lands with intermingled ownership, the effects of activities by all landowners on the big game resource will be analyzed.

<u>Livestock Grazing Standards and Guidelines</u>

Flathead LRMP

- Control livestock grazing in riparian areas to maintain water quality and fisheries habitat.

- Management of domestic livestock grazing allotments will be consistent with management area direction.

Helena LRMP

- Riparian condition within livestock allotments will be mapped and become part of the Allotment Management Plan
- Where analysis shows range resource damage, the cause will be identified and corrective action will be initiated through an allotment management plan.
- Best management practices will be used to minimize livestock damage to lakeside soils, streamsides, and other fragile areas.
- Allotment management plans will specify the utilization standards of key plant species needed to protect the soil and water quality.

Kootenai LRMP

- Management of domestic livestock grazing allotments will be consistent with Management Area direction.
- The soil and water conservation practices specified in FSH 2509.22 will be applied during Forest plan implementation to ensure that Forest water quality goals are met.

Lolo LRMP Forestwide Standards

- Conflicts between livestock and big game will be resolved so big game are allocated the forage required to meet their needs. Domestic livestock will be allowed to utilize any forage surplus not conflicting with the planned expansion of big-game populations. Reductions in livestock numbers will be avoided if possible, but will be acceptable to meet management goals.
- Allotments with no AUM's shown for the Proposed Action in Appendix B will be phased out unless the permittee is willing to make necessary investments in livestock management and structural improvement to maintain range condition at an acceptable level.
- 1995 Lolo Forest Plan amendment closed a number of livestock allotments and removed sheep grazing from the forest.

<u>Oil and Gas Leasing / Minerals Standards and Guidelines</u>

Flathead LRMP - In addition, to assist land managers in meeting established goals for the grizzly bear, the following guidelines have been developed.

- All oil and gas planning, leasing, and implementing activity on the Flathead National Forest will be in accordance with the EA (Environmental Assessment), Flathead National Forest, 1980, other NEPA documents covering the portions of the Forest not covered by the 1980 environmental assessment, or other NEPA documents or processes that may be required by the current litigation challenging that 1980 EA.

- Scheduling of mineral exploration and other development activities will be established so as to provide security areas immediately adjacent to project analysis areas.

- Temporary living facilities for exploration and/or development personnel may be onsite but with restrictions as necessary. Offsite camps will be encouraged. Approved camps will include restrictions on food storage, garbage disposal, firearms, and domestic pets.

- Avoid superimposing activities on seasonally important grizzly bear habitats which may adversely affect the species or reduce habitat effectiveness.

- Establish flight patterns (corridors) in advance when activities require the use of helicopters. Flight patterns should be located to avoid seasonally important grizzly bear habitat constituent elements and habitat components during bear-use periods. In some instances altitudinal restrictions could safeguard bears as well as flight corridors.

Helena LRMP - Amendment 3 and 13– Leasable Minerals. The Forest Plan does not make leasing recommendations. The Plan identifies where oil and gas leasing could potentially occur, where it would be compatible or incompatible with surface resource management direction and what stipulations may be applied to the leasing activity should it occur. Before any action is recommended on lease applications, site-specific analysis of environmental effects will be done in accordance with the NEPA process. Stipulations displayed in Appendix N which are based upon the EA for Oil and Gas Leasing on the Helena NF, 1981, will be recommended in accord with management area direction in Chapter III. Amendment 13 replaced Appendix N with a new Appendix N which contains lease notices and new stipulations for leases issued for available lands. The need to change the Forest Plan to incorporate the uniform format for the lease stipulations and the decisions resulting from the leasing analysis on the Helena NF based on the 1987 Oil and Gas Leasing Reform act.

- Contact the Forest Service to determine if a biological evaluation is required (FSM 2670.31-32). The Forest Service is responsible for ensuring that the leased land is examined through a biological evaluation, prior to undertaking any surface-disturbing activities, to determine effects upon any plant or animal species listed or proposed for listing as threatened, endangered, or sensitive.

- The lessee or operator may choose to conduct the evaluation on the leased lands at their discretion and cost. This biological evaluation must be done by or under the supervision of a qualified biologist/botanist approved by the Forest Service. An acceptable report must be provided to the Forest Service identifying the anticipated effects of a proposed action on threatened, endangered, or sensitive species. An acceptable biological evaluation is to be submitted to the Forest Service for review and approval no later than that time when an otherwise complete application for approval of drilling or subsequent surface-disturbing operation is submitted.

- Implement mitigation measures required by the Forest Service. Mitigation may include the relocation of proposed lease-related activities or other protective measures. The findings of the biological evaluation may result in some restrictions to the operator's plans or even disallow use and occupancy to comply with the 1973 Endangered Species Act (as amended), threatened and endangered regulations and Forest Service regulations.

- If threatened, endangered, or sensitive plant or animal species are discovered in the area after any required biological evaluation has concluded, an evaluation will be conducted to assess the effect of ongoing and proposed activities. Based on the conclusion drawn in the evaluation, additional restrictions or prohibitions may be imposed to protect the species or their habitats.

Kootenai LRMP

- Before recommendations are made on any lease applications, additional, site specific analysis of environmental effects will be made. Stipulations which are displayed in Appendix 10 will be recommended in accord with management direction in Chapter III. Stipulations are for erosion control, and controlled or limited surface use.

Lolo LRMP - Appendix F Oil and Gas Stipulations

- Over the entire study area, conduct biological evaluation and, if needed, initiate formal consultation with the FWS for all oil and gas activities found to result in a may affect situation as per FSM 2670.

- Prevent long-term or extensive disturbance within key T&E species habitat.

- No surface occupancy will be allowed in grizzly bear denning areas.

<u>Developed Sites Standards and Guidelines</u>

Flathead LRMP

- Retain the existing capacity of National Forest developed recreation sites on the Flathead National Forest during the next 10 years. The quality of the developed recreation opportunities available will be improved through "full-service" maintenance[2] or redesign and reconstruction of existing sites to better accommodate present and future needs. Some slight capacity changes may occur as a result of these improvements; however, the changes will provide a better service to the public.

---

[2] "Full Service" maintenance is specified in Forest Service standards and guidelines on Cleaning Recreation Sites, July 1980, USDA FS #80231801, pages 6-7.

- No expansion of campground capacity will be permitted if the expansion competes with campgrounds in the private sector.

- Subdivisions - District Rangers will work closely with city/County planning and zoning organizations when proposed subdivisions affect National Forest resources. Early input into development plans are needed to minimize potential problem areas such as: access, garbage disposal, utilities, water systems, sewage disposal, TV and/or radio antennas, boundary line accuracy, fencing, covenants, fire hazards, and visual problems. As subdivisions develop, requests for individual use will be discouraged in favor of group or community requests. Initial individual (developer) permits will be phased out and incorporated in community permits.

Helena LRMP

- New campgrounds and other developed recreation facilities, such as boat ramps or picnic areas, will generally not be constructed. Continue to maintain existing developed sites, but emphasize providing dispersed recreation opportunities. Removal of existing sites may be necessary in some cases, due to site deterioration or excessive maintenance cost.

- Subdivisions - District Rangers will work closely with city/County planning and zoning organizations when proposed subdivisions affect National Forest resources. Early input into development plans are needed to minimize potential problem areas such as: access, garbage disposal, utilities, water systems, sewage disposal, TV and/or radio antennas, boundary line accuracy, fencing, covenants, fire hazards, and visual problems. As subdivisions develop, requests for individual use will be discouraged in favor of group or community requests. Initial individual (developer) permits will be phased out and incorporated in community permits.

Kootenai LRMP

- Provide displays and information to make site users more aware of and informed about the area wildlife.

- New recreation sites will be located away from important wildlife habitat such as calving areas, meadows, winter range, etc. If the only available sites are on wildlife habitat, the recreation use season will be adjusted to avoid conflict with important wildlife use seasons.

Lolo LRMP Forestwide Standards

- The Forest will not significantly expand the capacity of developed recreation sites on the Lolo National Forest during the next 10-year period.

DRAFT

HABITAT MANAGEMENT – ZONE 2

Lewis and Clark National Forest – Jefferson Division

Portions of 3 Ranger Districts:

- Judith – northeast portion of the Little Belt Mountains
- White Sulphur Springs – western Little Belt Mountains, north Castle Mountains
- Musselshell – southeast portion of Little Belts, north Crazies

Access Management

- Some road density restrictions are in place based on Management Areas (MAs):
    - 19% of Division in 05.-1.5 mi/sq mi open road density (ORD)
    - 30% in 1.5-3 mi/sq mi ORD
    - 7% in 3+ mi/sq mi ORD (developed recreation areas and mining sites; corresponds with what would likely be MS-3 habitat)
- Some restrictions on road-building exist that do not involve specific road density numbers, in remaining MAs:
    - 19% of Division allows construction for harvest only within first mile from roads documented in 1983 inventory; these to remain closed to public except seasonal firewood cutting
    - 23% of Division specify no construction for surface uses, and roads built for subsurface minerals must be closed to public
- 1.4% does not allow any road construction except in small area for limited harvest; roads there must be obliterated and re-contoured
- Forest Plan does not address motorized trails
- Forest-wide big game standard establishes numeric standard for hiding cover, calculation of which includes road density component (methods to be based on MT Elk-Logging Study)
- Current motorized routes set by 2007 Travel Plan, part of which has been remanded in litigation and interim direction applied that increases motorized route density in specific areas (mainly WSAs) from what was reported in Travel Plan FEIS and ROD.
- Requires NEPA process to alter current Travel Plan (i.e. create additional open motorized routes)

BVRD - RECREATION AND TRAVEL MANAGEMENT

Table – Density of Roads and Trails Open to Summer Motorized Use by Landscape

Landscape	Desired Summer Open Motorized Road and Trail Density Mi/mi^2*	Food Storage Order Applies
Boulder River	1.9	
Clark Fork - Flints	1.9	
Jefferson River	1.6	
Upper Clark Fork	2.0	

**This does not include roads available for permitted or administrative use.*

Table – Hunting Season Open Motorized Road/Trail Densities by Hunting Unit

Hunting Unit	Desired Fall Open Motorized Road and Trail Density Mi/mi^2*
215	1.5
318	1.8
350	1.3
370	1.0

**This does not include roads available for permitted or administrative use.*

Outside the PCA in areas identified in state management plans as biologically suitable and socially acceptable for grizzly bear occupancy, accommodate grizzly bear populations with other land use activities, if feasible, but not to the extent of the exclusion of other uses. “Feasible” means one, which is compatible with (does not make unobtainable) major goals and objectives of other uses.

Food Storage

Currently, Food Storage Order in place only for campgrounds in Little Belt mountains.

<u>Helena National Forest</u>

Portions of 2 Ranger Districts:

- Helena – north Boulder Highlands, NW Elkhorns, N Big Belts
- Townsend – E Elkhorns, S Big Belts

Access Management

- Limited area (approx. 25,000 ac) specifically restricted to $\leq$ 2 mi/sq mi ORD in north Boulder/Highlands; no other specific density standards. January 2013 a site specific amendment is being intiated that modifies this to create less density and more security overall. This amendment will supercede this standard. As a result there will be specific areas that will have higher densities and others less.
- Forest-wide big game standard establishes numeric standard for hiding cover, calculation of which includes road density component (methods to be based on MT Elk-Logging Study). Specific open road densities are established for hunting season in order to achieve specific cover objectives.
- Forestwide standards include provisions to close/restrict roads in seasonally important wildlife habitats
- Access for minerals development is to be on case-by-case basis, with full analysis of impacts to all potentially affected resources
- No specific references to motorized trails (old Forest Plan, pre-dates most recreational ATV use)

Food Storage

No food storage in place anywhere except the portion of the Lincoln RD that is outside the PCA. We anticipate food storage orders being implemented in Zones 1 and 2 by 2014.

Sheep Grazing

DRAFT

- Townsend RD (Big Belts) has 2, with total of about 1200 sheep; no plans to phase out
- No sheep allotments on the Helena RD (Big Belts)
- Lincoln RD has 2

Gallatin National Forest

Portions of 3 Ranger Districts:

- Bozeman – Bridgers and Bangtails
- Livingston - West Crazies
- Big Timber – East Crazies

Access Management

- Travel Planning Decision in 2006 removed via Forest Plan Amendment specific standards for road density based on elk hiding cover
- Travel Plan also amended several MA standards out of the Plan that limited new road or trail construction based on Recreation Opportunity Spectrum; the purpose of amending them out was to allow the Travel Planning analysis process to determine appropriate and detailed goals, objectives, standards, and guidelines for individual geographic areas. Some MAs were retained that allow, limit, or prevent new road or trail construction, depending on MA goals and objectives.
- Detailed goals, objectives, standards, and guidelines are established in Travel Plans for individual geographic areas
- Travel Plan ROD states that roads can be built or re-opened for specific uses but that "it will be necessary however to effectively close these routes to public motorized use after completion of the activity unless theyare otherwise designated for such use through the Travel Plan."
- Travel Plan ROD and BO may provide further information about access management; also USFWS 1996 Biological Opinion (BO), Gallatin Forest Plan Amendment 19 (may apply only to occupied habitat), and the 2004 BO for the Forest Plan outside the recovery zone

Food Storage

The entire Gallatin National Forest is under a Food Storage Order

Sheep Grazing

There are no domestic sheep grazing allotments on the GNF

Beaverhead-Deerlodge National Forest

Portions of 6 Landscapes (planning areas) all in Boulder/Highlands mtns:

- Boulder River (N and NE of Butte)
- Elkhorn

DRAFT

- Jefferson River (E of Butte)
- possibly small portion of Upper Clark Fork (N of Butte)
- possibly small portion of Clark Fork-Flints (E of Deer Lodge)

Also includes SW portion of Elkhorns but defer mgmt. to Helena

Access Management

- Forest Plan states for wildlife secure areas and connectivity to "manage density of open motorized roads and trails by landscape year-round, except fall rifle big game season, to achieve levels at or below the following; if they exceed these densities, manage for no net increase:
    - Boulder River: 1.9 mi open motorized/sq mi
    - Jefferson River: 1.6 mi open motorized/sq mi
    - Upper Clark Fork: 2.0 mi open motorized/sq mi
    - Clark Fork-Flints: 1.9 mi open motorized/sq mi
- Plan established desired ORD for Fall by hunting district (all in the Boulder/Highlands mtn range; all at or lower than summer ORDs); if they exceed these densities, manage for no net increase
- Deferring update of management in Elkhorn Unit of B-D to Helena NF; currently no motorized use and none anticipated

Food Storage

No Food Storage requirements north/east of I-90 currently but anticipated by November 2014.

Sheep Grazing

No sheep allotments in the Boulder Highlands or Elkhorns ranges

BVRD - RECREATION AND TRAVEL MANAGEMENT

Table 13. Density of Roads and Trails Open to Summer Motorized Use by Landscape

Landscape	Desired Summer Open Motorized Road and Trail Density Mi/mi^2*	Food Storage Order Applies
Boulder River	1.9	
Clark Fork - Flints	1.9	
Jefferson River	1.6	
Upper Clark Fork	2.0	

**This does not include roads available for permitted or administrative use.*

Table 14. Hunting Season Open Motorized Road/Trail Densities by Hunting Unit

Hunting Unit	Desired Fall Open Motorized Road and Trail Density Mi/mi^2*
215	1.5
318	1.8
350	1.3
370	1.0

*This does not include roads available for permitted or administrative use.

Outside the PCA in areas identified in state management plans as biologically suitable and socially acceptable for grizzly bear occupancy, accommodate grizzly bear populations with other land use activities, if feasible, but not to the extent of the exclusion of other uses. “Feasible” means that which is compatible with (does not make unobtainable) major goals and objectives of other uses.

DRAFT

Appendix 11

Detailed Summary of Current BLM Management Plan Direction Relevant to Grizzly Bears in the PCA, Management Zone 1, and 2 for the Butte, Lewistown, and Missoula Field Offices

Butte Field Office Resource Management Plan

The Butte Field Office has 232,000 acres in Zones 1 and 2 (5,000 acres in the PCA). Management of BLM lands here occurs under the Butte Resource Management Plan 2009. The following management guidelines in the plan are relevant to grizzly bears and/or their habitat:

- Manage dry forest types to contain healthy, relatively open stands with reproducing site-appropriate, desired vegetation species.
- Manage moist forest types to contain healthy stands that combine into a diversity of age classes, densities, and structure (including dead and down material).
- Forest and woodland health assessments will be incorporated into Land Health Standards at the activity plan level to determine forest health conditions in project areas.
- Vegetation manipulation projects will be designed to minimize impacts to wildlife habitat and improve it when possible.
- New permanent and temporary road construction will be kept to a minimum. Temporary roads will be decommissioned (route will be closed and rehabilitated to eliminate resource impacts such as erosion, and rendered no longer useable for public or administrative uses) within one year of project completion. In addition, replacement, maintenance, or decommissioning of existing roads to meet transportation planning and management objectives may also occur as part of forest product removals or stewardship treatment projects.
- Firewood cutting will not be allowed within 100 feet of live (yearlong flow) streams or within 50 feet of intermittent streams.
- When salvage is proposed in dead and dying forests, contiguous acres of undisturbed standing and down woody material will be retained in adequate amounts for those wildlife species that depend on this type of habitat.
- The BLM will strive to maintain and/or restore stands with old forest structure within historic range of variability to maintain and/or enhance habitat for species dependent on this type of habitat. Existing and developing old forests will be retained and protected from uncharacteristically severe natural disturbances such as; stand replacing wildland fire, and insect and disease epidemics.
- Manage riparian and wetland communities to move toward or remain in proper functioning condition (appropriate vegetative species composition, density, and age structure for their specific area). Manage these communities to be sustainable and provide physical stability and adequate habitat for a wide range of aquatic and riparian dependent species.
- At the Field Office scale, management will maintain, protect, restore and/or improve riparian areas and wetlands. Riparian areas that are functioning at risk will be a high priority for restoration.

- Restorative treatments in riparian areas will focus on re-establishing willows, aspen, and cottonwood stands as well as other riparian vegetation, and to move towards pre-fire suppression stem densities in conifer stands.
- Where conifers are outcompeting or precluding regeneration of aspen, or preventing establishment of aspen or cottonwood stands, conifers will be removed (via mechanical methods and/or prescribed burning) to provide suitable habitat for expansion of these species.
- Forested riparian habitats will be managed to accelerate the development of mature forest communities to promote shade, bank stability, and down woody material recruitment. Late-successional riparian vegetation will be promoted in amounts and distribution similar to historic conditions.
- Grazing practices in riparian areas (accessibility of riparian areas to livestock, length of grazing season, stocking levels, timing of grazing, etc.) that retard or prevent attainment of riparian goals or proper functioning condition will be modified.
- Sufficient forage and cover will be provided for wildlife on seasonal habitat.
- BLM will develop and implement appropriate grazing strategies in grizzly bear management zones.
- BLM will continue to use a combination of cultural, physical, chemical, and biological treatments for weed control.
- BLM will encourage the development of weed management areas where the landowners and users are cooperatively working to manage noxious weeds within designated areas.
- BLM will focus prevention of weed spread along roads, trails, waterways, recreation sites, and disturbed sites associated with project implementation.
- Weed management prescriptions will be included in all new vegetation treatment projects and incorporated where possible in all existing contracts, agreements, and land use authorizations that would result in ground-disturbing activities.
- Weed seed free forage will be used on BLM lands. Forage subject to this rule will include hay, grains, cubes, pelletized feeds, straw, and mulch.
- The BLM will maintain an up-to-date record of the grizzly bear conflicts and management actions that occur on lands managed by the Butte Field Office.
- The BLM will manage habitat for sensitive terrestrial and aquatic species in a manner consistent with current and future restoration, conservation and recovery plans, and conservation agreements. Management activities will be designed and implemented consistent with adopted conservation strategies, including Montana's Comprehensive Fish and Wildlife Conservation Strategy (MFWP 2005), and current, accepted science for special status and priority species.
- The BLM will emphasize actions that promote conservation of special status wildlife species and the ecosystems on which they depend. BLM will also emphasize maintaining and supporting healthy, productive, and diverse populations and communities of native plants and animals (including big game species such as deer, elk, and bighorn sheep) appropriate to soil, climate, and landform.

- The BLM will maintain functional blocks of security habitat for big game species across BLM lands. Where minimum-size blocks of security habitat (250 acres), as defined by Hillis et al. (1991), are located, they will be addressed and retained in a suitable condition throughout project planning and implementation. Protection of larger blocks of security habitat will also be addressed during project or watershed level planning. Where security habitat is limited or fragmented across the landscape, the BLM will emphasize improving habitat through vegetation treatments and road closures (including seasonal closures) to increase security habitat for big game species.
- To minimize disturbance to big game and grizzly bears, there will be no net increase in permanent roads built in areas where open road densities are 1 mi/mi^2 or less in big game winter and calving ranges, and within the current distribution of grizzly bear unless this is not possible due to rights-of-way, leases, or permits. All practicable measures will be taken to assure that important habitats with low road densities remain in that condition. Open road densities in big game winter and calving ranges, and within the current distribution of grizzly bear will be reduced where they currently exceed 1 mi/mi^2.

Grazing:

BLM will include a clause in all new and revised grazing permits for the area within the grizzly bear distribution line requiring the permittee to properly treat or dispose of livestock carcasses as deemed necessary on a case-by-case basis by BLM in coordination with USFWS, so as to eliminate any potential attractant for bears. BLM will include guidance to permittees to contact MFWP if they need carcass disposal assistance.

Connectivity:
The BLM will participate in ongoing interagency efforts to identify, map and manage linkage habitats essential to grizzly bear movement between ecosystems.

The BLM will maintain suitable habitat conditions and minimize fragmentation in linkage corridors among habitats for priority species.

The BLM will continue to manage roads on BLM lands to achieve lower road densities in grizzly bear habitat.

Vegetation Management
- Where grizzly bear use is known or likely to occur and where practicable, the BLM will delay disturbing activities during the spring in spring habitats to minimize displacement of grizzly bears.
- There will be a focus on biological diversity by restoring vegetation cover types and structural stages that have declined substantially including dry, open forest habitats with low tree densities, meadow habitats, shrub and hardwood dominated riparian systems, as well as open grasslands and shrublands with low tree densities.

- As identified through project-level NEPA analyses, seasonal timing restrictions on projects that cause disturbance to wildlife will be applied where needed to minimize the impacts of human activities on important seasonal wildlife habitat including grizzly bear spring and summer range (4/1 to 9/1), and grizzly bear denning habitat (10/1 to 4/30). These dates may be revised when new data become available.

BLM will develop and implement human food storage regulations and guidelines in grizzly bear distribution zones in coordination with MFWP and other agencies.

Human food storage regulations will be developed and implemented for all recreation sites with high potential and/or known encounters between people and bears.

Oil and Gas StipulationsOil and gas stipulation - Timing Limitation. Activity is prohibited from April 1 to June 30 and from September 15 – October 15 in the Grizzly Bear Distribution Zone.

Lewiston Field Office Resource Management Plan (Revision potentially beginning in 2013)

Lewistown Field Office has a total of 16,000 acres within the PCA). BLM lands within the Conservation Strategy Management Area within the Lewistown Field Office are managed under the 1984 Headwaters Resource Management Plan. **The following management guidelines in the PCA would protect grizzly bear under this plan:**

1. Special guidance for oil and gas development along the Rocky Mountain Front – for federal mineral estate (includes both surface and sub-surface acres) 3,167 acres
2. Low priority for forest management (8,361 acres)
3. High priority for forest management (398 acres)
4. No disposal of BLM lands (4,119 acres)
5. Closed to motorcycles (3,131 acres) –
6. Closed to motorized use (0 acres).
7. Restricted motorized use (3,131 acres) –
8. Avoidance areas for utility and transmission corridors (3,131 acres)

Guidelines that could benefit the grizzly bear on all BLM Lewistown Field Office management lands in Zones 1 and 2 (19,000 acres) include:

- Habitat improvement projects will be implemented where necessary to stabilize and/or improve unsatisfactory or declining wildlife habitat condition.
- Seasonal restrictions – no activity in grizzly bear spring and summer range (4/1 through 9/1) and denning habitat (10/1 through 4/30)
- To the extent practicable, management actions within occupied grizzly bear habitat will be consistent with the goals and objectives contained in the Grizzly Bear Recovery Plan.
- Sufficient forage and cover will be provided for wildlife on seasonal habitat.

- Vegetative manipulation projects will be designed to minimize impact on wildlife habitat and to improve it whenever possible.
- Montana Fish, Wildlife and Parks will be consulted in advance on all vegetative manipulation projects, including timber harvest activities involving: the construction of new access into roadless elk summer/fall ranges; critical, crucial or essential wildlife habitat and sales over 250,000 board feet.
- Management actions within floodplains and wetlands will include measures to preserve, protect and, if necessary, restore their natural functions.
- Management techniques will be used to minimize the degradation of streambanks and the loss of riparian vegetation.
- Riparian habitat needs will be taken into consideration in developing livestock grazing systems and pasture designs.
- Manage public access to maintain the habitat effectiveness of security cover and key seasonal habitat (such as winter range and calving/nursery areas) for elk and deer.
- Maintain adequate untreated peripheral zones around important wet meadows, springs and riparian zones.
- Discourage thinning immediately adjacent to clearcuts.
- Use of new grizzly bear information acquired from current or future studies of the effects of oil and gas development on grizzly bear will be incorporated into activity decisions affecting the species (from FWS BO).

Missoula Field Office Resource Management Plan (1986, with amendments; revision potentially beginning in 2014)

The most recent RMP under which Missoula FO has been operation does not address grizzly management in the original document. In 2006, Backlog Consultation as conducted with FWS to amend the RMP. FWS issued a Biological Opinion with terms and conditions to address effects to grizzlies from livestock and roads.

The Missoula Field Office has **129,956 acres** in Zone 1 and 2 (no acres in the PCA). BLM lands within the Conservation Strategy Management Area within the Missoula Field Office are managed under the Garnet Resource Area Resource Management Plan 1986. **The following management guidelines would protect grizzly bear under this plan:**

Riparian Protection Zones (411 acres) - where the emphasis is on maintaining or enhancing riparian values while providing elements of old-growth or mature forest for wildlife habitat and providing opportunities for other uses. Utility corridors will not be permitted. Timber management activities will be prohibited. These lands will remain in public ownership.

Elk Summer and Fall Habitat Components (9,605 acres) - where the emphasis is on maintaining or improving elk summer and fall habitat components and other wildlife habitat values while managing timber and providing for other uses. A broad range of timber management activities will be allowed but will be designed to maintain or improve elk summer and fall habitat components and will include special measures to protect riparian values. These lands will remain in public ownership.

Big Game Summer and Fall Range (43,374 acres) - where the emphasis will be on balancing forage and cover requirements for big game on summer and fall ranges while managing timber and providing for other uses. Timber management will be designed to maintain or improve big game summer and fall habitat, particularly cover and forage relationships, and include special measures to protect riparian values.

Big Game Winter Range (14,494 acres) – where the emphasis will be on enhancing forage production and cover for big game on winter ranges while managing timber and providing for other uses. Timber management will be designed to maintain or improve big game winter range, particularly cover and forage relationships, and include special measures to protect riparian values.

Management activities in riparian zones generally will be designed to maintain or, where possible, improve riparian habitat condition. Roads and utility corridors will avoid riparian zones to the extent practicable. Prescribed fire will not be used within **75** feet of stream channels.

Corrective measures will be applied where unsatisfactory watershed conditions are identified. Such measures may be implemented through project-level plans (watershed, habitat, allotment, or compartment management plans); such measures may also be implemented through stipulations attached to permits, leases, and other authorizations.

All oil and gas leases will be issued with standard stipulations attached. Special stipulations will be attached where needed to protect seasonal wildlife habitat and/or other sensitive resource values. In highly sensitive areas, where special stipulations are not sufficient to protect important surface values, stipulations prohibiting surface occupancy will be attached.

Habitat improvement and maintenance projects will be implemented where needed to stabilize or improve habitat conditions. These projects will be identified through coordinated resource activity plans.

Road and area closures will be pursued for wildlife security and other resource values. Wildlife habitat goals and objectives will be included in all resource activity plans and projects that could affect wildlife habitat.

The Montana Department of Fish, Wildlife, and Parks (MFWP) will be consulted prior to vegetative manipulation projects in accordance with Supplement #1of the Master Memorandum of Understanding, 1977. In addition, MFWP will be consulted on timber harvest and timber stand improvement projects

Management actions within floodplains and wetlands will include measures to preserve, protect, and if necessary, restore their natural functions,

Food Storage stipulations under Special Recreation Permits – Food/attractant storage stipulations for conservation of the grizzly bear and other wildlife – Human, pet and livestock food (except baled or cubed hay without additives), and garbage will be attended or stored in an approved bear-resistant manner (a) during daytime hours, at least one adult person must be physically present within 100' of attractants. During nighttime hours, all attractants shall be stored in a bear-resistant manner and (b) Food, garbage and other attractants will be stored using an approved storage technique when camp is unattended. Attractants will not be buried, discarded or burned in an open campfire. Leftover food, food waste or other attractants may be placed in an appropriate, sealed container and packed out with garbage or could be burned in a contained stove. Wildlife carcasses, birds, fish or other animal parts that are within ½ mile of any camp or sleep area will be stored in a bear-resistant manner during nighttime hours.

DRAFT

Appendix 12

Summary of Protective Measures in the DNRC Habitat Conservation Plan Outside of the PCA

The full document is available online at: http://dnrc.mt.gov/HCP/FinalEIS.asp

On all HCP lands (referred to as PR lands in the HCP) (574,370 acres; 2,324 sq km), the DNRC commits to:

- minimizing construction of new open roads in riparian areas, wetlands, and avalanche chutes. (p. 2-6);
- providing I&E brochures about living and working in bear habitat to all contractors and employees;
- providing bear encounter avoidance training to DNRC personnel every 5 years;
- prohibiting DNRC employees and contractors from carrying firearms while on duty
- requiring all DNRC employees and contractors store food, garbage, and other attractants properly;
- suspending any motorized forest management activity within 0.6 miles of an active den site until May 31 or earlier if DNRC confirms the bear has left the den site vicinity;
- retaining visual cover for grizzly bears in riparian and wetland areas by maintaining a 50 foot no-harvest buffer for Class 1 streams and lakes;
- managing and preventing noxious weeds at gravel pit sites;
- minimizing helicopter operations requiring flights lower than 500m in seasonally important grizzly habitat by designing flight paths at least 1 mile from such areas, where practicable.

On non-recovery occupied habitat and lands in the PCA (NR lands and RZ lands) (220,718 acres; 893 sq km), the DNRC commits to:
The DNRC will manage their forested lands within Zone 1 and the Recovery Zone by their final Habitat Conservation Plan (HCP). This HCP applies to approximately 126,285 acres (511 sq km) outside the PCA in occupied habitat (called "Non Recovery Zone Occupied Habitat" in the HCP). On these lands **and** lands within the PCA, DNRC has agreed to implement the following protective measures for the 50-year term of the HCP:

The DNRC will manage their forested lands within Zone 1 by their final Habitat Conservation Plan (HCP). This HCP applies to approximately 126,285 acres (511 sq km) outside the PCA in occupied habitat (called "Non Recovery Zone Occupied Habitat" in the HCP). On these lands, DNRC has agreed to implement the following protective measures for the 50-year term of the HCP:

- minimizing the construction of new open roads;
- prohibiting commercial forest management activities during the spring period (Apr. 1-June 15) in spring habitat, as defined in the HCP;
- prohibiting pre-commercial thinning and heavy equipment slash treatments during the spring period in spring habitat;
- minimizing motorized activities on restricted roads during the spring period associated with low-intensity forest management;
- discouraging new domestic sheep grazing allotments;
- submitting a mitigation plan to the USFWS 30 days prior to a decision about the use of small livestock to manage weeds;
- minimizing helicopter operations requiring flights lower than 500m in seasonally important grizzly habitat by designing flight paths at least 1 mile from such areas, where practicable;
- discouraging the granting of future easements that relinquish DNRC control of roads, except for reciprocal access agreements, cost share agreements, and other federal road agreements;
- ensuring that vegetation or topographic breaks be no greater than 600 feet in at least 1 direction from any point in the unit for new clear cut and seed tree cutting units (except for when this is impractical due to steep open faces, broadcast burning as a post-harvest treatment, or where insects, disease, prescribed fire, or wildfire have hampered retention of live vegetation);
- submitting a mitigation plan to the FWS 30 days prior to a decision about the use of small livestock to manage weeds;
- limiting the number of active gravel pits in occupied habitat outside the recovery zone to 3 per administrative unit, with no more than 2 of these being large pits
- Retention of visual cover for grizzly bears in riparian and wetland areas by maintaining a 50 foot no-harvest buffer and restrictions on cover removal within defined riparian management zones.

<u>On DNRC lands in the PCA (RZ lands)</u> (147,843 acres; 598 sq km), the DNRC commits to applying these additional protective measures within the PCA for the 50-year term of the HCP:

Development of site-specific mitigation measures to minimize the impacts to important grizzly bear habitat elements (berry fields, avalanche chutes, riparian areas, wetlands, WBP stands, and feeding/congregation areas);

- Retention of up to 100 feet of vegetation between open roads and clearcut or seed tree harvest units;
- Examine and repair all primary road closure devices annually;

- Prohibit authorization of any new grazing licenses for sheep and other small livestock (smaller than a cow);
- Will not initiate any new grazing licenses in this zone. Public generated proposals could be considered;
- Carefully review and incorporate mitigations to the extent possible to minimize adverse impacts associated with granting access easements to private entities across DNRC lands;
- Prohibit motorized activities above 6,300 feet elevation from April 1 through May 31;
- Require access restrictions that are a part of the Stillwater Block and Swan River State Forest that cap open and restricted road amounts;
- Require 4-year commercial activity with 8 year rest restrictions on blocked and scattered lands;
- No net increase in open roads on scattered lands at the administrative unit level;

DRAFT

Appendix 13

Detailed Summary of DNRC Habitat Management Developed for Grizzly Bears in the PCA, Zone 1, and Zone 2

Introduction

The Trust Land Management Division (TLMD) of DNRC manages state trust lands to generate revenue for the maintenance and support of public state schools and institutions. Management actions on state trust lands are carried out under the direction of the Montana Board of Land Commissioners, which consists of Montana's top five elected officials: the Governor, Attorney General, Superintendent of Public Instruction, Commissioner of Securities and Insurance, and the Secretary of State. In cooperation with the Montana Board of Land Commissioners, DNRC's obligation for management of trust lands is to obtain the greatest benefit for the beneficiaries. Within the TLMD, there are four bureaus: 1) the Agriculture and Grazing Management Bureau; 2) the Forest Management Bureau; 3) the Minerals Management Bureau (includes mining and oil and gas development); and 4) the Real Estate Management Bureau. Within the entirety of the NCDE grizzly bear Delisting Area, DNRC manages approximately 574,370 acres of state trust lands. Of these acres, approximately 204,060 occur within the PCA. The following draft measures would be intended to apply to one or more of the four management areas identified in this Conservation Strategy: the Primary Conservation Area (PCA) (existing recovery zone), Management Zone 1, Management Zone 2, and Management Zone 3.

DNRC NCDE GRIZZLY BEAR CONSERVATION MEASURES

PROGRAMS -- ALL [Real Estate, Ag and Grazing, Minerals Management, Forest Management]

1) DNRC shall consider grizzly bears as a sensitive species in Montana during planning and environmental review on all TLMD projects for the term of this Conservation Strategy. **[applicable to all lands covered by this Conservation Strategy]**

2) For the term of this agreement, DNRC trust lands staff, while also considering Trust obligations, shall cooperate with Montana FWP bear management specialists to eliminate or minimize to the extent possible, any associated risks to bears associated with trust lands projects, leases, or agreements that may adversely affect grizzly bears. **[applicable to all lands included in this Conservation Strategy]**

3) For the term of this Conservation Strategy, for all TLMD projects and developments having potential to influence grizzly bears or their habitat, DNRC shall incorporate mitigations to minimize impacts to the extent possible, while also considering Trust obligations. **[applicable to all lands included in this Conservation Strategy]**

4) For the term of this Conservation Strategy, for all TLMD projects and developments on State Trust Lands within **the PCA, Zone 1, and Zone 2**, DNRC will incorporate mitigations into lease, license, and operating plan agreements (as applicable), to minimize adverse impacts to grizzly bears at a level commensurate with the level of intensity, risk, scope, and duration of effects likely to occur as a result of implementing the project or activity. When risk of bear impacts is deemed present, mitigations shall at a minimum consider proper storage of bear attractants (food, garbage, pet foods, livestock

carcasses, game carcasses etc. Attachment 1 below), vegetation/cover alteration, seasonal use of important habitats (particularly riparian), firearms restrictions, information/education and avoidance of bear-human encounters, minimization of new motorized access routes, and minimization of disturbance during spring and fall periods. DNRC employees and contractors and their employees are prohibited from carrying firearms while on duty, unless the person is specifically authorized to carry a firearm under DNRC policy 3-0621 (grazing licensees and lessees excluded).

5) **Inside the PCA, Zone 1, and Zone 2**, all TLMD lease and license agreements that permit uses and/or activities that may involve the use or presence of bear attractants (eg. leases/licenses for cabin and home sites, grazing, outfitting, group use licenses for camping, picnicking etc.) shall contain applicable clauses requiring unnatural bear foods and attractants to be contained and/or managed in a bear-resistant manner.

PROGRAM -- FOREST MANAGEMENT

HCP and Non-HCP Lands **[Portions of the PCA, Zone 1, and Zone 2]**

6) As the primary component of a conservation strategy for grizzly bears on state trust lands associated with the NCDE and elsewhere in western Montana, DNRC would rely primarily on successful implementation of its Habitat Conservation Plan (HCP) for forest management activities, in cooperation with the USFWS. The HCP provides protective measures regarding forest management for grizzly bears across approximately 548,500 acres in western Montana. Within **the PCA, Zone 1, and Zone 2**, the HCP would require the implementation of agreed-to conservation measures on approximately 257,800 acres, of which 147,200 occur within the PCA. The plan contains measures that include: requiring restriction of open road density, requiring food storage protections that apply to employees and contractors, providing security during important seasons, restricting use of firearms, providing cover, protecting important areas for feeding and denning, and monitoring. The term of the HCP and associated Incidental Take Permit is 50 years.

7) Within **the PCA, Zone 1, and Zone 2**, on all non-HCP Trust lands where forest management activities would occur, grizzly bears would be considered a sensitive species and administrative rules for forest management activities would be in place that would provide protective measures addressing: storage of unnatural foods and attractants, firearms possession, cover retention (particularly along riparian areas), duration of activities, seasonal restrictions, protection of important feeding areas, and minimization of roads.

PROGRAM -- AG AND GRAZING

8) Within **the PCA, Zone 1, and Zone 2**, all grazing leases and licenses issued within these geographic areas would require the following language:

a. Re-locate livestock carcasses in areas with high risk of bringing grizzlies into conflict with humans within 24 hours of discovery to minimize risk of human/bear conflicts. Lessee shall cooperate with DNRC managers and FWP bear management specialists as necessary to address prompt removal of problem livestock carcasses.

b. Established bone yards that would promote habituation and frequent use by grizzly bears are prohibited.

9) Within **the PCA** (Recovery Zone) for the term of this Conservation Strategy, DNRC will prohibit authorization of any new small livestock (smaller than a cow) grazing leases, including those for the purposes of weed control, and will also not convert existing licenses to allow the grazing of small livestock.

10) For the term of this Conservation Strategy, within **Zone 1**, grazing of domestic sheep would be discouraged on DNRC lands to minimize risk to grizzly bears. DNRC may authorize grazing of small livestock (including use for weed control) following development and implementation of a management plan incorporating measures effective for minimizing risks to grizzly bears. Mitigation measures in the plan may include, but are not limited to, requirement of a full-time shepherd, guard dogs, nighttime electric pens, prohibition of grazing in spring habitat during spring periods etc. When grazing small livestock in this zone, the lessee shall assume any cost of losses associated with grizzly bears and the bear will typically not be removed unless management authorities judge that the particular circumstances warrant removal and document those circumstances (e.g., the behavior resulted in a human fatality, the bear had a prior conflict history, etc).

11) To limit attractants associated with dispersed recreation on state trust lands within **the PCA, Zone 1, and Zone 2**, DNRC shall maintain its existing pack-it-in/pack-it-out policy for litter control, limit camping to 2 days on leased or licensed lands in areas not designated as campgrounds, and prohibit campfires on leased and licensed lands ARM 36.25.149. Camping shall be restricted in designated campgrounds to 14 consecutive days, and it shall be restricted on unleased or unlicensed lands outside a campground to 14 days per calendar year, unless permission for a longer period is obtained from the department ARM 36.25.149. DNRC lands managed as a part of block management areas and wildlife management areas in cooperation with MFWP, will adhere to regulations agreed to by both agencies specific to each block management area (ARM 36.25.149(i), ARM 36.25.163).

12) For the term of this Conservation Strategy, DNRC will make information/education materials available at all applicable field offices, emphasizing effective storage of foods and other grizzly bear attractants.

13) For the term of this Conservation Strategy, where DNRC lands exist within Wildlife Management Areas (WMA) and Block Management Areas managed by Montana Fish, Wildlife and Parks, food storage policies applicable to the WMA and BMAs as appropriate shall apply and be enforced.

14) For the term of this Conservation Strategy, DNRC will cooperate with other entities and agencies as opportunities arise to enact and enforce food storage measures in high use recreation areas, trailheads etc. to minimize risks to grizzly bears.

PROGRAM -- REAL ESTATE MANAGEMENT [Includes cabin/home sites, other developments, wind generation facilities, outfitting, camping, and other special use licenses etc.]

[Measures 1 through 4 above would also apply.]

15) Within the **PCA, Zone 1, and Zone 2**, for the term of this Conservation Strategy on cabin sites leased by DNRC, containment of garbage, proper sewage disposal, prohibition of livestock and prohibition of the use of firearms would be enforced through DNRC's existing "Rules and Regulations –

[for] DNRC Cabin sites," and "Terms and Conditions –DNRC Residential Lease Lots" and renewal inspections.

16) Within the **PCA, Zone 1, and Zone 2**, in areas where land uses are non-compatible with grizzly bear conservation goals DNRC will, to the extent practicable in its sole discretion, cooperate with other entities to enact land transactions (eg. land sales, conservation easements, land exchanges etc.) that facilitate conservation of grizzly bears.

PROGRAM -- MINERALS MANAGEMENT [Includes oil and gas, coal, gravel, metalliferous and non-metalliferous leases]

Seismic Exploration

17) For the term of this Conservation Strategy, within **the PCA and Zone 1** (**Rocky Mountain Front Portion**), the following measures would be incorporated as applicable into stipulations developed to mitigate impacts to grizzly bears.

a. Limit the window of operation to the extent possible to avoid the spring period from April 1 to June 30, and fall period September 15 to November 30.

b. To minimize disturbance to grizzly bears, limit the duration of activities to the extent possible.

c. Prohibit activities within 0.25 miles of riparian areas and prohibit ground crews from entering such areas.

d. To minimize the spatial extent of displacement, to the extent practicable, conduct activities in a sequential (localized) versus a concurrent, dispersed manner where activities would be occurring at different locations at the same time.

e. To minimize disturbance and displacement of bears, prohibit aerial flight routes within 0.25 miles of dense shrublands, wooded areas and riparian areas.

f. For human safety, train staff conducting ground activities on working safely in bear habitat and the effective use of bear spray and require crews to carry bear spray.

g. Bear attractants (including food and garbage) must be stored in a bear-resistant manner at all times when unattended. On-site camping is prohibited. No vehicle oil changes or petroleum disposal shall occur on the state land.

h. To avoid risk of human/bear encounters in known high use bear areas, nighttime foot travel away from vehicles is prohibited.

i. To minimize potential for disturbance and adverse impacts to important bear foods and feeding areas, all use of vehicles, ATVs and ground crews are not authorized within 100 feet of wetlands and other riparian areas on or adjacent to state lands.

Oil and Gas Exploration and Development

18) Oil and Gas exploration, development and reclamation activities on state lands are under the regulatory authority of the Montana Board of Oil and Gas Conservation. Measures, mitigations, and

reviews will recognize this regulatory permitting process and authority, and may not conflict with regulatory requirements. Where appropriate, the department may participate in or rely on MEPA analysis prepared by applicable regulatory agencies. Any action by the DNRC is contingent upon a determination by the regulatory oil & gas permitting agency that the proposed action creates a significant impact on grizzly bears or habitat within the NCDE area. The DNRC will implement mitigation measures consistent with the requirements of the permitting agency.

State trust lands within **the PCA and Zone 1**, shall be considered as Sensitive Areas and the DNRC Montana Oil and Gas Stipulations (December 2009) shall apply. The density of appreciable surface operations shall be limited to the extent practicable, while allowing for prudent development of the resource and protection from drainage by adjacent operations. Density of surface operations shall be addressed through implementation of these stipulations following appropriate MEPA environmental review and development of approved operating plans that minimize impacts on grizzly bears. Measures as described in the *"Interagency Rocky Mountain Front, Wildlife Monitoring/Evaluation Program, Management Guidelines for Selected Species"* (September 1987) shall be incorporated into operating plans prior to their approval, as specified by the DNRC Montana Oil and Gas Stipulations (December 2009) [Attachment 2].

Mineral Mining

Within the **PCA and Zone 1**, mortality risk to grizzly bears from mineral development on DNRC lands will be largely mitigated through project specific mitigation measures. The purpose of these guidelines is to avoid, minimize and mitigate environmental impacts to grizzly bears and their habitat from mining activities occurring on State lands. The guidelines would be applied during review and approval of a site-specific plan of operations. Operating procedures, reclamation plans, or other mitigating measures would be incorporated into the Operating Plan, or could become agency-imposed operating conditions, provided such measures were consistent with applicable mining laws. All exploration, development production, mitigation measures, reclamation, and closure activities for locatable minerals on Federal, State and private lands are under the regulatory permitting authority of the Montana Department of Environmental Quality (DEQ). DNRC works cooperatively with the DEQ in the administration and management of mining operations. Mitigation measures may not conflict with the regulatory permitting authority of the DEQ. Any action by the DNRC is contingent upon a determination by DEQ [the permitting agency] that the proposed action creates a significant impact on grizzly bears or habitat within the PCA and/or Zone 1. The DNRC will implement mitigation measures consistent with the requirements of the permitting agency. The following measures would apply to all new hardrock mining Plans of Operation on lands managed by the DNRC in both the PCA and Zone 1.

Project Evaluation

The potential effects to grizzly bears and bear habitat, and the necessary mitigation measures will be determined at the project level by the authorizing or permitting agency through project review, an Environmental Assessment or Environmental Impact Statement. For projects with the potential to significantly, negatively affect grizzly bears or their habitat, operating plans, notices and permits will include a mitigation plan with measures to protect grizzly bears and minimize detrimental impacts to them during and after operations. Operators are required to comply with the mitigation plan through the agency's approval of the Operating Plan.

Operating plans and notices will include specific measures to reasonably mitigate potential impacts to grizzly bears or their habitat from the following activities:

- Land surface and vegetation disturbance,
- Water table alterations,
- Construction, operation, and reclamation of mine-related facilities such as impoundments, rights of way, roads, pipelines, canals, transmission lines or other structures,
- Food storage and sanitation.

Performance of operating and reclamation measures, and site-specific mitigation measures used to protect grizzly bears or bear habitat will be enforced through the respective DEQ and Federal surface management regulations. Operators who fail to comply with mitigation measures for grizzly bear protection in the DEQ approved operating plan will be subject to a noncompliance order or notice issued by the DEQ. Non-compliance orders specify the noncompliance and what is needed for the operator to come into compliance. The financial assurance (bond) for reclamation performance will be calculated and managed by the agencies. Bonding may include the cost of implementing the reclamation measures required to mitigate impacts to grizzly bears and bear habitat. The financial assurance instrument for reclamation performance will be held by the Montana DEQ for mining operations on private lands.

For operations where it is determined there is potential for significant impacts ("significance" as determined through environmental review and permitting) to the grizzly bear population or its habitat, a monitoring plan will be developed by the operator with approval by the DEQ, and in close coordination with MFWP for the life of the project. The monitoring plan will outline how changes in habitat and disturbance to bears will be measured (and include monitoring of reclamation measures). The plan will identify trigger levels or criteria for habitat parameters to determine if direct research of local grizzly bears (i.e., capturing and radio-collaring bears) is warranted and to what extent monitoring should be conducted.

Food and Attractants

For projects with the potential to significantly affect grizzly bears or their habitat, mitigations plans will include food storage/handling and garbage disposal measures and will incorporate any existing food storage measures for human occupancy. Mitigation plans for grizzly bears will include the following measures regarding food and attractants:

- Bear proof containers will be used and garbage will be removed in a timely manner at mine facilities.
- Road kills will be removed daily to a designated location determined in close coordination with MFWP.

- The use of clover will be discouraged as part of any reclamation seed mixes used during mine construction, operation, or when reclamation activities are concurrent with operations. Native seed mixes will be promoted and used whenever practicable.
- No feeding of any wildlife will be allowed.

Implementation of the Food and Attractants measures is the sole responsibility of the operator. Compliance with these requirements will be evaluated during site inspections conducted by the authorizing agencies. The number and type of inspections as well as the mechanism for inspections will be identified through the planning process (MEPA or NEPA). Failure to comply with the measures will subject the operator to a noncompliance process as noted above.

Motorized Access

For projects with the potential to significantly affect grizzly bears or their habitat, mitigation plans will include the following measures regarding motorized access:

- New roads constructed for mineral exploration and/or development will be single-purpose roads only and will be closed to public use not associated with mineral activities.
- A traffic management plan will be developed as part of any proposed activity to identify when and how mine roads will be used, maintained, and monitored, if required, and how roads will be closed after mineral activities have ended.
- On State lands only, roads constructed for mineral operations may be retained by the land management agency for use associated with other concurrent or future activities (such as timber sales or rights-of-ways). However, impacts associated with all uses of the road(s) must be analyzed in a MEPA environmental review, and impacts to grizzly bears minimized to the extent practicable.

Habitat

For projects with the potential to significantly affect grizzly bears or their habitat, mitigation plans will include the following measures regarding habitat:

- Mineral exploration and/or development activities will occur at a time or season when the area is of little or no biological importance to grizzlies. If timing restrictions are not practicable, reasonable and appropriate measures will be taken to mitigate negative impacts of mineral activity to the bear.
- Reasonable and appropriate measures regarding the maintenance, rehabilitation, restoration or mitigation of functioning aquatic systems and riparian zones will be implemented. State regulatory permits may include reasonable and appropriate measures as part of a riparian reclamation plan identifying how reclamation will occur, vegetation species used in reclamation, a timeframe of when reclamation will be completed, and monitoring criteria.

- Reclamation and revegetation of roads, drilling pads, and other areas disturbed from mineral exploration and development activities will be completed as soon as practicable by the operator.
- For new projects in the **PCA** with the potential to significantly affect grizzly bears or their habitat, DNRC will work cooperatively with DEQ, lessees and operators to minimize adverse impacts. The level of mitigation required for individual projects would be commensurate with the degree and duration of impacts to affected lands. DNRC would be responsible only for ensuring mitigation of impacts associated with their lands. To minimize potentially significant impacts to grizzly bears the following measures would be considered and implemented to the extent reasonable and practicable as determined by DNRC.
- In the first order of preference, operators shall be required to reclaim the affected area back to suitable bear habitat that has similar or improved characteristics and qualities as the original habitat (such as the same native vegetation).
- If reclamation efforts alone are deemed inadequate or inappropriate by DNRC for mitigating impacts to grizzly bears, the following measures may be considered and applied.
- Operators and/or lessees as applicable may either acquire a perpetual conservation easements or purchase fee title comparable or better replacement grizzly bear habitat in the PCA to mitigate adverse impacts. A purchase rate of >1:1 on an acreage basis would be considered for acquiring habitat, depending on the quality of habitat degraded and the habitat available for acquisition. Acquisition of habitat in distant areas of the PCA associated with identified linkage corridors could also be considered for mitigation, and maybe desirable. Prior to any purchase, MFWP will be given at least 30 days to provide input to DNRC on the quality and suitability of the lands proposed as mitigation. DNRC will have final approval as to the adequacy and suitability of proposed mitigations. Easements/deeds would be transferred to a Federal or State agency, or private conservation organization to ensure the long-term integrity of the habitat as deemed appropriate by DNRC.
- Other feasible measures to offset adverse impacts to grizzly bears could include (but would not be limited to) radio telemetry monitoring of grizzly bear movements in an affected area in coordination with MFWP, or other more intensive grizzly bear research efforts conducted with MFWP involvement. Other feasible measures could include providing regional funding to help support the acquisition and distribution of bear-resistant waste containers, electric fencing materials, information/education outreach efforts regarding living safely in bear habitat, and/or funding a bear management specialist or enforcement officer.

Human Conflict

For projects with the potential to significantly affect grizzly bears or their habitat, the Operating Plan will include the following mitigation measures regarding human conflict:

- Firearms will be prohibited on site during operations except for security personnel and other designated persons. Carrying of bear spray will be recommended to the operator.

- The operator should require employees to attend training related to living near and working in grizzly bear habitat prior to starting work and on an annual basis thereafter.

[ATTACHMENT 1]

Example Recommended Language to Address Food Storage Requirements in the PCA, Zone 1, and Zone 2.

List of measures that would be included in new or existing licenses/leases on renewal to address food storage risks to grizzly bears (adapted from the Draft FWP measures for WMAs dated Feb. 2011).

1. Human, pet and livestock food (except baled or cubed hay without additives), garbage, and all other attractants shall be stored in an approved bear resistant manner or container when camp is unattended. (see definition of attended below) or during nighttime hours.
2. Wildlife carcasses, birds, fish or other animal parts that are within 1/2-mile of any camp or sleeping area shall be stored in an approved bear-resistant manner or container during when unattended. If a wildlife carcass is within an attended camp during daytime hours it may be on the ground. In areas where upright supports such as poles or trees are not present, carcasses shall be removed as soon as prudently possible to minimize the potential for attracting grizzly bears into camp areas.
3. Attractants (such as food leftovers or bacon grease) shall not be buried, discarded, or burned in an open campfire.
    a. Leftover food or food waste products shall be placed in an appropriate, sealed container and packed out with garbage.
    b. Leftover food or other attractants may be burned in a contained stove fire.
    c. Attractants may be placed into a suitable container (i.e. tin can) to prevent leaching into the ground and burned over an open campfire. Any remaining attractants unconsumed by burning shall be packed out.
4. The responsible party shall report the death and location of any livestock to a DNRC employee within 24 hours of discovery.
5. Approved bear-resistant containers for use in grizzly country meet the following criteria: A securable container constructed of solid material capable of withstanding 200 foot-pounds of energy applied by direct impact. The container, when secured and under stress, will not have any openings greater than one-quarter (1/4) inch, that would allow a bear to gain entry by biting or pulling with its claws.
6. Bear-resistant manner means any attractants, including food and garbage, must be stored in one of the following ways if unattended:
    a. Secured in a hard-sided camper or vehicle trunk or cab or trailer cab.
    b. Secured in a hard-sided dwelling or storage building.
    c. Suspended at least 10 feet up (from the bottom of the suspended item) and 4 feet out from any upright support, i.e. tree, pole.
    d. Stored in an agency approved bear-resistant container.

e. Stored within an approved and operating electric fence.

f. Stored in any combination of these methods.

[ATTACHMENT 2]

DNRC MONTANA OIL AND GAS STIPULATIONS (December 2009)

These stipulations may be used on MT oil and gas leases, in the Special Provisions Section (36), “Exhibit A” depending on the specific circumstances for the tract being leased.

Sensitive Areas

F-1. This lease includes areas that may be environmentally sensitive. Therefore, if the lessee intends to conduct any activities on the lease premises, the lessee shall submit to TLMD one copy of an Operating Plan or Amendment to an existing Operating Plan, describing in detail the proposed activities. No activities shall occur on the tract until the Operating Plan or Amendments have been approved in writing by the Director of the Department. TLMD shall review the Operating Plan or Amendment and notify the lessee if the Plan or Amendment is approved or disapproved.

After an opportunity for an informal hearing with the lessee, surface activity may be denied or restricted on all or portions of any tract if the Director determines in writing that the proposed surface activity will be detrimental to trust resources and therefore not in the best interests of the trust.

F-2. This lease is located near the Rocky Mountain Front and includes areas that are environmentally sensitive. Therefore, except as otherwise provided below, the lessee shall not conduct any surface operations on the lease premises. If the lessee determines that surface operation on the lease premises may be required, the lessee shall submit a proposed Operating Plan or Amendment to an existing Operating Plan to the State Board of Land Commissioners describing in detail the proposed operations. No surface activities shall occur on the lease premises unless and until the Operating Plan or Amendment is approved by the Board. In determining whether to approve the proposed Operating Plan or Amendment, the following provisions shall apply:

1) If the lessee proposes an activity that does not entail any significant surface disturbance, the Board may approve the same after completion of the appropriate environmental review in accordance with the Montana Environmental Policy Act (MEPA) and an opportunity for public comment on the proposed activity has been provided.

2) Before the Board approves any proposed activity on the lease premises that entails a significant surface disturbance, an environmental impact statement (EIS) shall be completed in accordance with MEPA. The EIS shall analyze the potential impacts of alternative and future potential levels of oil and gas development and extraction on an ecosystem scale as the ecosystem is defined by

the "Limits of Acceptable Change--Bob Marshall Wilderness Complex" adopted by the Montana Department of Fish, Wildlife & Parks in December 1991. The analysis shall consider all relevant information, which may include, but is not limited to, existing environmental reviews and management plans. Public involvement in the environmental review process shall be actively solicited by the preparer of the environmental review document and shall include, at minimum, adequately noticed public meetings in at least three communities including Great Falls and Helena.

3) The proposed surface activity shall adhere to the "Interagency Rocky Mountain Front, Wildlife Monitoring/Evaluation Program, Management Guidelines for Selected Species" adopted by the Montana Department of Fish, Wildlife & Parks in September 1987, or any successor guidelines thereto.

4) The Board may refuse to approve any proposed surface operations if it determines that they do not constitute the best use of trust resources or are not in the best interest of the State of Montana.

F-3. This lease is located within or adjacent to the Sleeping Giant and Sheep Creek Wilderness Study Area, the Beartooth State Wildlife Management Area, and/or the Gates of the Mountains Wilderness and includes areas that are environmentally sensitive. Therefore, except as otherwise provided below, the lessee shall not conduct any surface operations on the lease premises. If the lessee determines that surface operation on the lease premises may be required, the lessee shall submit a proposed Operating Plan or Amendment to an existing Operating Plan to the State Board of Land Commissioners describing in detail the proposed operations. No surface activities shall occur on the lease premises unless and until the Operating Plan or Amendment is approved by the Board. In determining whether to approve the proposed Operating Plan or Amendment, the following provisions shall apply:

1) If the lessee proposes an activity that does not entail any significant surface disturbance, the Board may approve the same after completion of the appropriate environmental review in accordance with the Montana Environmental Policy Act (MEPA) and an opportunity for public comment on the proposed activity has been provided.

2) Before the Board approves any proposed activity on the lease premises that entails a significant surface disturbance, an environmental impact statement (EIS) shall be completed in accordance with MEPA. The EIS shall analyze the potential impacts of alternative and future potential levels of oil and gas development and extraction on an ecosystem scale. The analysis shall consider all relevant information, which may include, but is not limited to, existing environmental reviews and management plans. Public involvement in the environmental review process shall be actively solicited by the preparer of the environmental review document and shall include, at minimum, adequately noticed public meetings in at least two communities including Great Falls and Helena.

3) The Board may refuse to approve any proposed surface operations if it determines that they do not constitute the best use of trust resources or are not in the best interest of the State of Montana.

F-4. This lease is located within the Rocky Mountain Front area established under federal legislation removing mineral leasing and development on federal fee title lands, and federal minerals and has been identified as environmentally sensitive. The Rocky Mountain Front area is a crucial fish or wildlife area or corridor; has FWP owned surface rights; has an existing or is in the process of having conservation easements established and has important recreational value to the citizens of Montana. Therefore, except as otherwise provided below, the lessee shall not conduct any surface operations on the lease premises. If the lessee determines that surface operation on the lease premises may be required, the lessee shall submit a proposed Operating Plan or Amendment to an existing Operating Plan to the State Board of Land Commissioners and notify the Director of Fish, Wildlife and Parks describing in detail the proposed operations. No surface activities shall occur on the lease premises unless and until the Operating Plan or Amendment is approved by the Board. In determining whether to approve the proposed Operating Plan or Amendment, the following provisions shall apply:

1) If the lessee proposes an activity that does not entail any significant surface disturbance (not in excess of 1 well pad/640 acres), the Board may approve the same after completion of the appropriate environmental review in accordance with the Montana Environmental Policy Act (MEPA). As part of the MEPA process, DNRC will provide for an on the ground consultation with FWP, and an opportunity for public comment on the proposed activity. Public involvement in the environmental review process shall be actively solicited by the preparer of the environmental review document and shall include, at minimum, adequately noticed public meetings in three major daily publications including Missoula, Great Falls and Helena; legal notices to those non-daily papers in the affected counties, and detailed notification of landowners who own the surface rights, or directly adjacent rights, who would be impacted by development.

2) Before the Board approves any proposed activity on the lease premises that entails a significant surface disturbance (in excess of 1 well pad/640 acres), an environmental impact statement (EIS) shall be completed in accordance with MEPA. The EIS shall analyze the potential impacts of alternative and future potential levels of oil and gas development and extraction on an ecosystem scale as the ecosystem is defined by the "Limits of Acceptable Change - Bob Marshall Wilderness Complex" adopted by the Montana Department of Fish, Wildlife and Parks in December 1991, and any successor thereto. The analysis shall consider all relevant information, which may include, but is not limited to, existing environmental reviews and management plans, and new data concerning climate change, private lands conservation efforts, and fish and wildlife distribution and migration patterns. Public involvement in the environmental review process shall be actively solicited by the preparer of the environmental review document and shall include, at minimum, adequately noticed public meetings in at least three communities including Great Falls and Helena.

3) The proposed surface activity shall adhere to the "Interagency Rocky Mountain Front, Wildlife Monitoring/Evaluation Program, Management Guidelines for Selected Species" adopted by the Montana Department of Fish, Wildlife and Parks in September 1987, or any successor guidelines thereto.

4) The Board may refuse to approve any proposed surface operations if it determines that they do not constitute the best use of trust resources or are not in the best interest of the State of Montana.

DRAFT

Appendix 14

Bureau of Land Management Draft Habitat Standards for Management Zone 1

Because the definition of Secure Core habitat requires areas at least 2,500 acres in size and most BLM lands inside the PCA and Zone 1 are scattered parcels or smaller acreages, there are limited amounts of Secure Core habitat managed by the BLM in these areas. BLM lands in Zone 1 were evaluated to determine if they currently provide secure grizzly bear habitat or if they have the potential to provide secure habitat. Secure Core Habitat is defined as areas greater than 500 m from an open motorized route (road or trail) or recurring helicopter flight and at least 2,500 acres in size. Open roads are defined as any roads open to public use during the period of April 1 through November 30. Closed roads or roads open only to administrative uses would not be considered "open" roads. In Zone 1, three blocks of BLM managed lands were identified as currently providing occupied secure habitat (Chamberlain/Murray Douglas, Hoodoos and the Lower Blackfoot Corridor). Occupied bear habitat is also found in Marcum Mountain but conditions could be improved through additional road closures.

All areas currently providing secure habitat are located in the Missoula Field Office. No blocks of BLM land were found to be large enough in the Butte or Lewistown Field Offices to provide secure grizzly bear habitat.

Road density standards and vegetation management standards/guidelines would only be applicable in the Chamberlain/Murray Douglas, Hoodoos, Lower Blackfoot Corridor and Marcum Mountain Areas.

Chamberlain/Murray Douglas - 42,500 acres
Hoodoos - 26,000 acres
Lower Blackfoot Corridor – 11,000 acres
Marcum Mountain – 13,000 acres

Road Density and Secure Habitat Standards

If the BLM is able to provide large blocks of land (greater than 2,500 acres) through acquisitions, analysis would be completed to determine if road density standards should apply in these areas (this would apply to all Field Offices).

Draft Standards for Chamberlain/Murray Douglas, Hoodoos, Lower Blackfoot Corridor and Marcum Mountain Areas (Missoula Field Office)

To minimize disturbance to grizzly bear Secure Core habitat (Chamberlain/Murray Douglas, Hoodoos and the Lower Blackfoot Corridor), open road densities will be maintained below 1 mi/sq. mi unless this is not possible due to rights-of-way, leases, or permits. All practicable measures will be taken to assure that important habitats with low road densities remain in that condition. Currently, open road densities in Chamberlain/Murray Douglas, Hoodoos and the Lower Blackfoot Corridor are under 1 mi/sq. mi.

In the Marcum Mountain Area (potential secure habitat), the BLM will move towards meeting an open road density of less than 2.5 mi/sq. mi. to allow for management activities while improving secure habitat for bears. Road densities in the Marcum Mountain area are currently high at 3-5 mi/sq. mi. Implementation of the habitat standard (<2.5 mi/sq. mi) in Marcum Mountain will begin after on-going restoration activities and would be expected to be met within 10 years. A comprehensive travel plan analysis will be completed during the Resource Management Plan revision and the road density standard for Marcum Mountain could be modified at this time.

Secure Core habitat in the Chamberlain/Murray Douglas, Hoodoos and Lower Blackfoot Corridor areas will be maintained or increased. In the Marcum Mountain Area, Secure Core Habitat will be created through the reduction of open roads.

Adequate vehicle access will be maintained for management activities and treatments. Temporary road locations will be minimized in important bear habitats such as foraging areas, riparian habitats, and elk calving areas.

Temporary roads will be closed or decommissioned within one year of project completion (roads could stay open for one year after project completion to allow for firewood cutting, weed control or other short-term uses of the road). Project completion refers to all work associated with a project including, but not limited to timber harvest, thinning, seeding, broadcast burning, pile burning and weed spraying.

The Missoula Field Office will monitor administrative use of closed roads for 3 years to determine the baseline using surveys and road counters. After baseline levels are determined, the Field Office will identify the appropriate level of administrative use. After the appropriate level of administrative use is identified, this type of use will be monitored. How long-term administrative use is monitored will be identified by the Field Office.

Exceptions to administrative use could be granted for longer term projects (such as habitat restoration activities, salvage logging, etc.) after analysis of the effects to grizzly bear have been completed and disturbance to the bear has been considered and minimized to the extent possible. Another exception to administrative use is for monitoring/documenting trespass livestock.

Vegetation Standards and Guidelines for Zone 1

Apply to Chamberlain/Murray Douglas, Hoodoos, Lower Blackfoot Corridor and Marcum Mountain Areas (Missoula Field Office)

Standards

All proposed management activities will be evaluated for their effects on grizzlies and/or their habitats. Vegetation manipulation projects will be designed to minimize impacts to or improve grizzly bear habitat unless the project is designed primarily to benefit a Federally Listed species.

Timber sale contracts will include a clause providing for cancellation or temporary cessation of activities if needed to resolve a grizzly-human conflict situation (i.e. such as kill sites). Prior to beginning work all contractors, operators and their employees will be informed of safe procedures for working and recreating in grizzly country.

Contracts will include a clause prohibiting firearms on site during operations related to the contracts. Carrying of bear pepper spray will be recommended to contractors.

Contractors, operators and contractor employees must follow food/attractant storage orders.

Contractors must get approval before camping on BLM lands.

Fire camps must follow food/attractant storage orders.

Activities that will permanently reduce habitat quality or quantity, reduce the population of grizzly bear or cause bears to be conditioned to human food or presence will not be permitted.

Vegetation structure, density, species composition, patch size, pattern, and distribution will be managed in a manner to maintain or improve grizzly bear habitat across the landscape.

Whitebark pine restoration will be promoted at suitable sites. Whitebark pine is a minor component of the forests on BLM lands in Zone 1.

Guidelines

Silvicultural treatments, restoration activities, and prescribed burning may be used to improve grizzly bear habitat.

Silvicultural treatments in forested cover should provide a balance of all successional stages at the landscape scale.

Vegetation and fuels management activities should occur at a time or season when the area is of little or no biological importance to grizzlies.

Livestock Grazing Habitat Standards – for Zone 1 Unless Otherwise Identified

No sheep allotments will be allowed in Zone 1.

DRAFT

The use of sheep and goats for the purpose of weed control will be allowed and follow existing federal/state permitting processes.

In areas currently unleased, no new livestock grazing allotments will be created for any class of livestock in Zone 1.

If BLM acquires lands that were grazed before the acquisition occurred, grazing will be allowed for livestock but not for sheep. If monitoring data indicates over utilization or other land health issues, the number of AUMs could be reduced and the season of use modified.

If BLM acquires lands that were not grazed before the acquisition occurred, grazing allotments will not be allowed in Chamberlain/Murray Douglas, Hoodoos, the Lower Blackfoot Corridor and Marcum Mountain Areas. In all other areas of Zone 1, livestock grazing (with the exception of sheep) could be considered on these newly acquired lands.

Within Zone 1, the BLM will include a clause in all new and revised grazing permits/leases requiring the permittee/lessees to properly treat or dispose of livestock carcasses to eliminate any potential attractant for bears. The BLM will work with the permittee/lessee and Montana Fish, Wildlife and Parks (MFWP) on the appropriate manner and location of carcass disposal.

Within Zone 1, the BLM will include a clause in all new and revised grazing permits/leases requiring the permittee/lessee to notify the BLM as soon as practical of any grizzly bear depredation on livestock or conflicts between grizzly bears and livestock, even if the conflict does not result in the loss of livestock.

No apiaries would be permitted in Chamberlain/Murray Douglas, Hoodoos, the Lower Blackfoot Corridor and the Marcum Mountain Areas. Outside these areas, apiaries permitted on public lands must be enclosed within an approved and operating electric fence as described in the NCDE Food Storage Order. Currently, there are no permitted apiaries on BLM lands in Zone 1.

Livestock salting/minerals will be allowed in all Zones.

Oil and Gas Leasing Standard – for the PCA and Zone 1

No Surface Occupancy for all BLM and split estate lands in Zone 1.

Stipulation: No Surface Occupancy. Surface occupancy and use is prohibited within the boundary of the Grizzly Bear Recovery Zone and Management Zone 1.

Objective: To avoid surface disturbing and disruptive activities in the Grizzly Bear Recovery Zone (called the PCA in this Conservation Strategy) and Management Zone 1.

Exception: An exception may be granted by the authorized officer if the operator submits a plan which demonstrates that the proposed action will not affect grizzly bears or grizzly bear habitat. If the authorized officer determines that the action may have an adverse effect, the operator may submit a plan demonstrating that the impacts can be adequately mitigated. This plan must be approved by BLM in close coordination with MFWP.

Modification: This stipulation may be modified if the authorized officer, in coordination with MFWP determines a portion of the area is no longer important to grizzly bear conservation or the boundaries of the stipulated area may be modified if the area can be occupied without adversely affecting grizzly bears or grizzly bear habitat.

Waiver: This stipulation may be waived if the authorized officer, in coordination with MFWP, determines that the entire leasehold can be occupied without adversely affecting grizzly bears or grizzly bear habitat.

Mining Standards for Zone 1

Mining standards would be the same for Zone 1 as described for the PCA in the Conservation Strategy.

Developed Sites Standards and Guidelines in Zone 1

Guidelines

The BLM will try to prevent changes in the capacity of sites or creating new developed sites but this will not always be possible. Any potential detrimental effects to bears will be mitigated to the best of BLM's ability.
Where conflicts occur between grizzly bear and humans in the Chamberlain/Murray Douglas, Hoodoos, Lower Blackfoot Corridor and Marcum Mountain Areas, the BLM will consider elimination of dispersed camping.

New communication site users will be grouped into existing facilities at established communication sites, to the extent practicable, to reduce impacts and expedite application processing.

New right-of-way facilities will be located within or adjacent to existing rights-of-way, to the extent practicable, in order to minimize adverse environmental impacts and the proliferation of separate rights-of-way.

Standards

DRAFT

Any proposed increase, expansion, or change of use of developed sites will be analyzed, and potential detrimental and positive impacts documented through project evaluation by the BLM. Areas with high risk of grizzly bear/human interaction (such as riparian areas) will be avoided.

All new developed sites will have mandatory food storage regulations in place as well as education kiosks.

Communication site plans will be completed prior to authorizing communication site uses in new areas.

Right-of-way applications across roads that have been closed or have seasonal restrictions will be analyzed on a case-by-case basis.

Food/Attractant Storage Strategy for Zones 1 and 2

Introduction

Grizzly bear occurrence is increasing on BLM lands along with an increase in human population and recreational use within the region. In order to reduce the potential for negative human/wildlife conflicts related to accessibility to food, refuse, and other attractants, the Bureau of Land Management (BLM) has developed food storage orders for all BLM managed lands in Zones 1 and 2 identified in the Grizzly Bear Conservation Strategy.

The purpose of these restrictions are to minimize grizzly bear-human conflicts and, thereby, provide for visitor safety and recovery of the grizzly bear within the Northern Continental Divide Ecosystem (NCDE).

Communication Plan:

To educate and inform the public before food storage orders take effect, one or more of the following will be implemented starting upon adoption of the Conservation Strategy:

- Development of press releases for local newspapers, television and radio stations.
- Development of flyers, brochures, and educational materials.
- Development of kiosk notices and signage to be installed at various BLM campgrounds, boat launches, parking areas, and other locations with concentrated recreational use.
- Internal and external dissemination of information to agencies, local governments, clubs, schools, permittees, contractors, outfitters/guides, non-governmental organizations, and the general public.

Management Practices:

- Special Food Order requirements will be applied to BLM lands in Zones 1 and 2 and will be in effect from April 1 to December 1, annually.

- Bear-resistant containers may be placed and maintained at priority BLM locations having the potential for concentrated human activity, such as: campgrounds, trailheads, parking areas, and boat launches.

- The BLM lands in Zone 2 would be placed under mandatory food storage orders except where superseded by site specific regulations such as those for designated campgrounds or developed recreation sites. This exception would mostly be in the high use, high traffic recreation sites (e.g. along the Missouri River) where congestion and urban interface make food storage orders difficult to implement and of marginal effectiveness when considering other activities in the area.

- For campgrounds and recreation areas without specifice regulations, the BLM would review the specific needs of each facility and determine the appropriate food storage restrictions. Mandortory or voluntary food storage orders could be implemented depending on the location of the site and the types of habitat. In additions, there could be a phased-in schedule in conjunction with infrastructure upgrades and public education efforts.

- Should the frequency bear-human interactions (including black bear) increase in the vicinity of recreation facilities, the BLM would modify those areas where mandatory food storage orders would apply.

UNDER THIS FOOD STORAGE ORDER IT IS REQUIRED THAT:

The following restrictions will be implemented in the Missoula, Butte and Lewistown Field Offices within the PCA, Zone 1 and Zone 2. These restrictions shall remain in effect until rescinded or revoked.

1. Human, pet and livestock food (except baled or cubed hay without additives or salt for livestock), and garbage should be attended or stored in an approved bear-resistant manner: Food, garbage, and other attractants, including all livestock grain and pellets, should be stored using an approved storage technique when camp is unattended.

2. Wildlife carcasses, birds, fish or other animal parts that are within 1/2-mile of any camp or sleeping area should be stored in a bear-resistant manner during nighttime hours: If a wildlife carcass is within an attended camp during daytime hours it may be on the ground.

3. Attractants (such as food leftovers or cooking grease) should not be buried, discarded, or burned in an open campfire:

a. Leftover food or food waste products may be placed in an appropriate, sealed container and packed out with garbage.

b. Leftover food or other attractants may be burned in a contained stove fire.

c. Attractants may be placed into a suitable container (i.e. tin can) to prevent leaching into the ground and burned over an open campfire. Any remaining attractants unconsumed by burning should be placed with other garbage and packed out.

4. Approved bear-resistant containers will meet the following criteria: A securable container constructed of solid material capable of withstanding 200 foot-pounds of energy applied by direct impact. Only commercial and personal-use bear-resistant containers, approved for use by the USDA, Forest Service, Missoula Technology and Development Center (MTDC), should be used.

5. The responsible party shall report the death and location of any livestock to a BLM or Forest Service Official within 24 hours of discovery. In some very remote areas, it may not be possible to meet the 24-hour requirement. In these special cases, the responsible party shall report to a BLM or Forest Official the discovery of any dead livestock within 48 hours.

The following persons may be exempt from this order (The BLM State Director is delegated the authority to grant the exemption in writing):

1. Persons with a permit specifically authorizing the prohibited act or omission.

2. Any Federal, State, or local officer, or member of an organized rescue or firefighting force in the performance of an official duty.

Violations for these prohibitions are punishable by a fine of not more than $1,000 or imprisonment for not more than 12 months, or both (FLPMA Section 303 43 U.S.C. 1733).

DEFINITIONS:

1. **Attended:** At least one adult person (attendee) is physically present within 100 feet of attractants during **daytime hours**. During the **nighttime hours**, all attractants must be within 50 feet of the attendee, or attractants must be stored in a bear-resistant manner.

2. **Attractant:** Food as defined below and garbage from human, livestock or pet foods.

3. **Food:** Any nourishing substance, which includes human food or drink (canned, solid or liquid), livestock feed (except baled or cubed hay without additives) and pet food.

4. **Attendee:** An adult (18 years of age or older) in control of attractants.

5. **Bear-resistant container:** A securable container constructed of solid material capable of

withstanding 200 foot-pounds of energy applied by direct impact. The container, when secured and under stress, will not have any openings greater than one-quarter (1/4) inch, that would allow a bear to gain entry by biting or pulling with its claws.

6. **Bear-resistant manner:** Any attractants, including food and garbage, stored in one of the following ways if unattended:

a. Secured in a hard-sided camper or vehicle trunk or cab or trailer cab.

b. Secured in a hard-sided dwelling or storage building.

c. Suspended at least 10 feet up (from the bottom of the suspended item) and 4 feet out from any upright support, i.e. tree, pole.

d. Stored in an approved bear-resistant container.

e. Stored within an approved and operating electric fence.

f. Stored in any combination of these methods, or

g. Stored by methods other than those described in Section #6, a-f, that are approved in writing by the BLM.

7. **Contained fire stove:** a metal stove that completely encloses the fire.

8. **Daytime:** 1/2-hour before sunrise until 1/2-hour after sunset.

9. **Nighttime:** 1/2-hour after sunset until 1/2-hour before sunrise.

10. **Livestock:** A domesticated animal, such as mule, horse, llama, or goat.

11. **Wildlife carcass:** The body, or any parts thereof, of any deceased wild animal, bird, or fish.

12. **An approved electric fence will meet at a minimum the following specifications:**

a. The fence will be set up as a “tight wire” fence. The wire will be tight and under tension, not loose or sagging.

b. Minimum fence height = 4 feet.

c. Minimum post height = 5 feet.

d. Maximum spacing between posts = 8 feet.

e. Conductors (wire): Minimum of 7 wires, with 6-10 inch spacing between wires. Bottom wire must be within 2 inches of the ground. All wire must be smooth metal fence wire of at least 16 gauge or poly wire, except the top wire which may be poly tape of at least six strand stainless steel.

f. The system will be set up to operate both as a ground wire return and a grounded system. The 2 top wires will be hot, with all other wires alternating hot and ground. The minimum length ground rod is 2 feet.

g. Fence charger (minimum): (1) stored energy of 0.7 joules; (2) tested peak output of 5000 volts; (3) 40 shocks per minute. User must be able to test electrical output in the field.

h. The charger must be made inaccessible to disturbance from a bear. The charger may be stored within the interior of the fence or located a minimum of 10 feet above ground.

i. Minimum distance between fence and items enclosed by electric fence = 3 feet.

DRAFT

Appendix 15

Lead Agencies and Tribes Responsible for Monitoring Population and Habitat Parameters under this Conservation Strategy Agencies

TASK	LEAD AGENCY	SUPPORTING AGENCIES
Secure habitat/OMRD/TMRD	USFS	GNP, BLM, FIR, BIR
Developed Sites	USFS	GNP, BLM
Livestock allotments	USFS	GNP, BLM, FIR, BIR, DNRC, MFWP
Prepare annual habitat monitoring reports	USFS	GNP, BLM, FIR, BIR, DNRC, MFWP
Prepare annual population monitoring reports	MFWP	
Private land status	MFWP	
Limiting mortality to sustainable levels	MFWP	GNP, FIR, BIR
Distribution of females w/ offspring	MFWP	USFS, GNP, BLM, FIR, BIR, DNRC
Radio collar sample of 25 females	MFWP	USFS, GNP, FIR, BIR
Annual conflict reporting	MFWP	GNP, FIR, BIR
Public outreach and education	MFWP	
Conflict management and response	MFWP, GNP, FIR, BIR	
Calculate 6-year running average annual population growth rate (i.e., λ) annually	MFWP	USFS, GNP, FIR, BIR
Calculate 6-year running average of independent female survival annually	MFWP	USFS, GNP, FIR, BIR

DRAFT

Appendix 16

Annual Cost Estimates by Agency for Implementing this Conservation Strategy

DRAFT

Appendix 17

Grizzly Bear Management Plan for Western Montana

AVAILABLE ONLINE:
http://fwp.mt.gov/fishAndWildlife/management/grizzlyBear/managementPlan.html

DRAFT

Year of death	Sex of bear	Cause Specific	Inside/outside recovery zone
2013	F	train	inside
2013	F	train	outside
2011	M	train	outside
2011	M	train	outside
2011	M	train	outside
2009	M	train	inside
2009	M	train	outside
2008	F	train	inside
2007	M	train	outside
2007	F	train	outside
2007	M	train	outside
2007	M	train	inside
2007	M	train	outside
2006	F	train	inside
2006	M	train	inside
2006	M	train	inside
2004	F	train	inside
2004	M	train	inside
2003	M	train	inside
2003	F	train	inside
2003	F	train	inside
2002	M	train	inside
2001	F	train	inside
2001	M	train	inside
2001	F	train	inside
2001	F	train	inside
1999	F	train	inside
1999	M	train	inside
1999	M	train	inside
1999	M	train	outside
1999	M	train	outside
1998	F	train	inside
1997	M	train	inside
1997	F	train	inside
1997	F	train	inside
1996	M	train	inside
1996	M	train	inside
1995	F	train	inside
1995	M	train	inside
1992	M	train	outside
1990	F	train	inside
1990	M	train	inside
1990	M	train	inside
1990	F	train	inside
1990	F	train	inside
1989	M	train	inside
1989	F	train	inside
1986	M	train	inside
1985	F	train	inside

	bears killed
1984	1
1985	1
1986	1
1987	0
1988	0
1989	2
1990	5
1991	0
1992	1
1993	0
1994	0
1995	2
1996	2
1997	3
1998	1
1999	5
2000	0
2001	4
2002	1
2003	3
2004	2
2005	0
2006	3
2007	5
2008	1
2009	2
2010	0
2011	3
2012	0
2013	2
total	50

1984	M	train	inside

data received on Sept 17, 2014
sent by Grizzly Bear Recovery Coordinator, USFWS, at request of Chris Servheen
University Hall, Room 309, University of Montana, Missoula, MT 59812
Office: 406-243-4903
grizz@umontana.edu

for NCDE population

Van Why, K.R., and M.J. Chamberlain. 2003. Mortality of black bears, *Ursus americanus*, associated with elevated train trestles. Canadian Field-Naturalist 2003:113-115.

Abstract:

The Louisiana Black Bear (Ursus americanus luteolus), a threatened species in the United States, inhabits the Tensas and Atchafalaya River Basins of Louisiana. These basins contain three breeding populations, but dispersal among the populations is limited due to habitat fragmentation and a lack of corridors. Highways and railroads bisect the few available corridors. and mortalities occur as a result of collisions with vehicles. Waterways and flood control structures used as travel corridors by bears are crossed by road and rail bridges creating the potential for additional mortalities. We documented two mortalities associated with elevated railroad spans. Both occurred along the same span of track located within the Morganza Spillway in Pointe Coupee Parish, Louisiana, and both mortalities were a result of the bear falling from the span or being struck by a train while crossing the trestle.

BioOne RESEARCH EVOLVED

EFFECTS OF TRANSPORTATION INFRASTRUCTURE ON GRIZZLY BEARS IN NORTHWESTERN MONTANA

Author(s): JOHN S. WALLER and CHRISTOPHER SERVHEEN
Source: Journal of Wildlife Management, 69(3):985-1000. 2005.
Published By: The Wildlife Society
DOI: http://dx.doi.org/10.2193/0022-541X(2005)069[0985:EOTIOG]2.0.CO;2
URL: http://www.bioone.org/doi/full/10.2193/0022-541X%282005%29069%5B0985%3AEOTIOG%5D2.0.CO%3B2

BioOne (www.bioone.org) is a nonprofit, online aggregation of core research in the biological, ecological, and environmental sciences. BioOne provides a sustainable online platform for over 170 journals and books published by nonprofit societies, associations, museums, institutions, and presses.

Your use of this PDF, the BioOne Web site, and all posted and associated content indicates your acceptance of BioOne’s Terms of Use, available at www.bioone.org/page/terms_of_use.

Usage of BioOne content is strictly limited to personal, educational, and non-commercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

BioOne sees sustainable scholarly publishing as an inherently collaborative enterprise connecting authors, nonprofit publishers, academic institutions, research libraries, and research funders in the common goal of maximizing access to critical research.

EFFECTS OF TRANSPORTATION INFRASTRUCTURE ON GRIZZLY BEARS IN NORTHWESTERN MONTANA

JOHN S. WALLER,[1] Glacier National Park, West Glacier, MT 59936, USA
CHRISTOPHER SERVHEEN, Grizzly Bear Recovery Coordinators Office, U.S. Fish and Wildlife Service, University Hall Room 309, University of Montana, Missoula, MT 59801, USA

Abstract: Highways and railroads have come under increasing scrutiny as potential agents of population and habitat fragmentation for many mammalian species, including grizzly bears (*Ursus arctos*). Using Global Positioning System (GPS) technology and aerial Very High Frequency (VHF) telemetry, we evaluated the nature and extent of trans-highway movements of 42 grizzly bears along the U.S. Highway 2 (US-2) corridor in northwest Montana, USA, 1998–2001, and we related them to highway and railroad traffic volumes and other corridor attributes. We employed highway and railroad traffic counters to continuously monitor traffic volumes. We found that 52% of the sampled population crossed highways at least once during the study but that crossing frequency was negatively exponentially related to highway traffic volume. We found that grizzly bears strongly avoided areas within 500 m of the highway and that highway crossing locations were clustered at a spatial scale of 1.5 km. Most highway crossings occurred at night when highway traffic volume was lowest but when railroad traffic was highest. Highway crossing locations were flatter, closer to cover in open habitat types, and within grassland or deciduous forest vegetation types. Nighttime traffic volumes were low, averaging about 10 vehicles/hr, allowing bears to cross. However, we project that US-2 may become a significant barrier to bear movement in ~30 years if the observed trend of increasing traffic volume continues.

JOURNAL OF WILDLIFE MANAGEMENT 69(3):985–1000; 2005

Key words: connectivity, Global Positioning System, GPS, grizzly bear, highways, Montana, railroads, roads, transportation, *Ursus arctos*.

The grizzly bear was once common throughout much of the western United States from the Canadian–American border south to the present-day Mexican–American border (Rausch 1963). However, expanding human populations have severely reduced many grizzly bear populations, particularly in the southern portions of their range (Servheen 1999, Mattson and Merrill 2002). Grizzly bears in the United States now occur in only 5 ecosystems within the states of Idaho, Montana, Wyoming, and Washington (Servheen 1990). The extent of grizzly bear movement between these ecosystems is probably minimal, and no natural movement between ecosystems has been documented (Kasworm et al. 1998).

The Grizzly Bear Recovery Plan recommends establishment and maintenance of linkage zones between these 5 ecosystems (U.S. Fish and Wildlife Service 1993) to maintain genetic diversity within each population and to lessen the impacts of demographic and environmental stochasticity (Wilcox 1980). Consequences of reduced population size, isolation, and subsequent inbreeding and demographic vulnerability have been widely discussed (Wright 1931, Soulé 1980, Gilpin and Soulé 1986, Lande 1988, Mills and Smouse 1994, Lande 1995, Paetkau et al. 1998).

Highways and/or railroads currently bisect all 5 grizzly bear ecosystems. Negative effects of transportation corridors have been documented for numerous wildlife species including woodchucks (*Marmota monax*; Woodward 1990), sandhill cranes (*Grus canadensis*; Dwyer and Tanner 1992), ravens (*Corvus corax*; Knight and Kawashima 1993), passerines (Reijnen and Foppen 1994), deer (*Odocoileus* spp.; Romin and Bissonette 1996), and bumblebees (*Bombus* spp.; Bhattacharya et al. 2003); indeed, the negative effects of highways on wildlife have been noted for over 75 years (Stoner 1925, Forman et al. 2002). However, data for grizzly bears are limited.

Previous research on the effects of roads on grizzly bears has been largely confined to tertiary and/or unimproved road systems occurring within forests managed for timber harvest (Archibald et al. 1987, McLellan and Shackleton 1988, Kasworm and Manley 1990, Mace et al. 1996) or within national parks (Mattson et al. 1987). All have shown displacement due to roads. Previously published works from 2 areas specifically addressed the impacts of high-volume highways on brown bears. Chruszcz et al. (2003) found that traffic volume affected crossings on high-volume highways in Banff National Park, Alberta, Canada, and Kaczensky et al. (2003) found a similar situation in Slovenia.

[1] E-mail: john_waller@nps.gov

Our objective was to describe the effects of a high-speed highway and its associated transportation corridor on the movement and habitat-use patterns of resident grizzly bears. Specifically, we studied whether grizzly bears avoided areas near the highway, if resident grizzly bears used specific crossing areas to traverse highways, and whether or not these locations differed from non-crossing areas. We also studied whether or not any existing temporal patterns of highway crossings were related to highway and railroad traffic levels.

STUDY AREA

Our 2730 km^2 study area consisted of 4 fifth-order watersheds located along Montana Highway 49 (MT-49) and US-2, approximately between Essex and East Glacier, Montana. The most northern east-west highway in the contiguous United States, US-2 was a 2-lane highway separating Glacier National Park to the north from the Bob Marshall Wilderness complex to the south. The western portion of the highway lay within the valley bottom of the Middle Fork of the Flathead River and Bear Creek valley until it crossed the Continental Divide at Marias Pass (elevation 1610 m). East of Marias Pass, US-2 dropped into the prairie biome, paralleling the South Fork of the Two Medicine River and crossing the western boundary of the Blackfeet Indian Reservation (BIR).

Another paved 2-lane highway, MT-49, joined US-2 from the north at East Glacier. Carrying primarily local and tourist traffic, it wound through the Rocky Mountain foothills near the eastern edge of Glacier National Park to its terminus with U.S. Highway 89 at Kiowa Junction, Montana. Only small portions of MT-49 lay within the study area.

A major railroad line paralleled US-2 for its entire length within the study area. This railroad line was a primary freight corridor between Chicago, Illinois, and Seattle, Washington, and it was also the primary means of transporting grains from eastern Montana and North Dakota to markets on the West Coast.

Small concentrations of homes, businesses, ranches, and small communities existed within the US-2 corridor, but the majority of the area was undeveloped federal land, (36% of the area lay within the boundaries of Glacier National Park). U.S. Forest Service lands were managed primarily for recreation, timber harvest, and grazing. Tribal lands were managed primarily for cattle grazing.

Topography associated with US-2 varied from flat valley bottoms to steep mountainsides. Dominant vegetation was primarily coniferous forest in the western portions of the study area, where a Pacific maritime climate predominated. Open grass/forb/deciduous tree communities were more common in the east where the climate was continental. The collision of these 2 climatic regimes often resulted in unsettled weather conditions. Riparian areas paralleled the highway for much of its length within the study area. Avalanche chutes were preferred grizzly bear foraging areas (Waller and Mace 1997, McLellan and Hovey 2001) and occurred in numerous locations, often close to the highway.

We chose this particular study area for several important attributes. First, grizzly bears occupied areas on both sides of US-2, and anecdotal observations and preliminary data showed that they crossed this portion of US-2. Second, the level of development within the corridor was significant but not so great as to preclude observations of grizzly bear crossing patterns; and third, we could access areas in which to capture grizzly bears.

METHODS

Capture and Telemetry

To obtain a representative sample of grizzly bears residing within the highway corridor, we placed trap sites as equidistantly as possible along both sides of US-2 within the study area. We captured grizzly bears with Aldridge snares or culvert traps using standard techniques (Johnson and Pelton 1980, Jonkel 1993), or, on the BIR, we fired tranquilizer darts at grizzly bears from tree stands placed over livestock carcasses (Jonkel 1993). All trapping occurred during the months of June and July 1998–2001. We equipped all grizzly bears captured in 1998 with a Telonics model 500RM VHF telemetry transmitter (Telonics Inc., Mesa, Arizona, USA) to assess the extent of highway crossing by resident grizzly bears before beginning full field efforts.

In past research efforts, conclusions concerning specific road segments and their influence zones were limited by existing radiotelemetry technology. Rugged topography often limited ground tracking, and close aerial tracking was limited by frequent periods of inclement weather, restriction to daylight hours, and the high cost of flight time. Further, intensive aerial telemetry in mountainous terrain was dangerous to researchers. Recent incorporation of GPS technology into wildlife telemetry collar systems helped overcome aerial VHF telemetry obstacles. Therefore, during 1999 and 2000, we fitted captured female grizzly bears weighing ≥91 kg with a Telonics Generation IIRM store-on-board GPS collar. During 2001, the final year of fieldwork, we collared male and female grizzly bears. We fitted grizzly bears weighing <91 kg with an ear-tag transmitter (Advanced Telemetry Systems, Isanti, Minnesota, USA).

Our GPS collars obtained a position once every hr, 24 hr per day, and location information was stored within the collar. The GPS collars could obtain either 2-dimensional (2D) or 3-dimensional (3D) positions. The 2D positions are obtained using 3 GPS satellites and 3D positions require ≥4 satellites and generally give a more accurate position. We chose the hourly location rate as a reasonable compromise between battery life and spatial specificity. We estimated battery life would be about 120 days, which was sufficient to provide GPS positions between time of trapping and denning. Because the collar needed to be retrieved and downloaded to obtain the accumulated information, we equipped all collars with a VHF beacon and a programmable breakaway device. The VHF beacon operated concurrently with the GPS unit, and through variable pulse rates, provided information about GPS system status and/or animal mortality. We located all transmitters 2 times per week from fixed-wing aircraft, as weather conditions allowed, to keep track of animals and provide timely cause-specific mortality information. After we retrieved GPS collars and downloaded their information to a computer, we differentially corrected positions using Trimble Pathfinder Office^RM^ (Trimble Navigation Ltd., Sunnyvale, California, USA), and proprietary software developed by Telonics Incorporated.

Traffic Monitoring

We installed Peek Trafficomp II^RM^ pneumatic vehicle counters (Peek Traffic Corporation, Palmetto, Florida, USA) on US-2 at each end of the study area (approximately 35 km apart). The counters operated June through mid-October during 1999–2001. We configured the counters to tally the number of vehicles passing over the counter sensors each hr of a 24-hr day in each lane (east and west-bound lanes). Having counters at each end of the study area provided system redundancy in case 1 of the counters became inoperative and allowed calculation of local vs. through traffic. Because the counters counted axles, we developed a correction factor for multi-axle vehicles by tallying axles and classifying vehicle types during 11 30- to 60-min observation periods. We then compared these actual counts to those collected by the counter to derive a ratio estimate of the true number of vehicles. We then compared this estimate to the statewide correction factor used by the Montana Department of Transportation (MDOT).

We collected railroad traffic data by downloading automatic train counters through modem access provided by the Burlington-Northern Santa Fe railroad. The counters recorded date, time, direction, length, and speed of all trains crossing the counters. We used counters located just west and east of the study area boundaries. We measured differences in railroad traffic between months and between day and night.

Environmental Variables

We collected hourly weather data during 1999–2001 from remote weather stations operated by MDOT located just west of the study area at Essex and 50 km southeast of the study area at Pendroy, Montana. The Essex weather data were most representative of weather conditions west of the Continental Divide while the Pendroy weather data were more representative of conditions east of the Continental Divide. Weather data included temperature, wind speed, wind direction, and presence, type, and rate of precipitation.

We grouped all GPS positions into dawn, day, evening, and night categories based upon day length. Dawn and evening were the periods between civil twilight and sunrise or sunset. Civil twilight was the period between sunrise or sunset and when the sun was 6 degrees below the horizon. Day was the period between sunrise and sunset, and night was the period between the end of evening twilight and the beginning of morning twilight. We calculated sunrise, sunset, and twilight periods for East Glacier, Montana using Sun.exe (http://www.sunrisesunset.com).

We obtained digital cover-type maps from the U.S. Forest Service and imported them into our computerized Geographic Information System (GIS). The Wildlife Spatial Analysis Lab at the University of Montana produced these maps by classifying Thematic Mapper satellite imagery (Redmond et al. 1998). The Flathead National Forest made further refinements based on potential vegetation types and recent wildfires. The minimum mapping unit for these maps was 2.5 ha. We simplified the map by combining similar vegetation types, thus reducing the number of cover types from 25 to 8. The 8 cover types were rock (barren/nonvegetated), grassland, shrubland, riparian, deciduous forest, mixed forest, conifer forest, and water.

We obtained grizzly bear habitat quality maps from the U.S. Forest Service, constructed during cumulative effects modeling efforts for the Northern Continental Divide Ecosystem (NCDE; Mace et al. 1999). Mapped habitat quality values were most strongly influenced by elevation and greenness. Greenness was a measure of herbaceous phytomass and was strongly related to grizzly bear habitat selection (Mace et al. 1999, Stevens 2002).

We constructed digital maps of US-2 and the railroad within the study area by digitizing these features on U.S. Geological Survey (USGS) orthophoto quadrangles with 1-m resolution. We obtained hydrological and 10-m digital elevation data from the USGS. We represented terrain ruggedness along US-2 by calculating the standard deviation of elevation within a 1-km moving circle. The U.S. Forest Service, as part of its cumulative effects modeling efforts, classified campgrounds, housing, and other types of human developments into low, moderate, or high-impact categories based upon a Delphi consideration of their perceived impacts on grizzly bears. We obtained these digital maps of human impact points from the U.S. Forest Service, and we then created maps displaying the distance from each of these development categories. We created a distance-to-cover map by digitizing the border of roadside vegetation from USGS orthophoto quadrangles.

We constructed a road density layer by running a moving circle procedure on digital road maps that we obtained from the U.S. Forest Service and from U.S. Census Bureau TIGER files. The moving circle (or focal-sum) process assigned the number of 30-m road cells within a 1-km circle to the center cell. The circle thus moved across the map assigning a value to every cell (Mace et al. 1996). We used ArcView GIS version 3.2 (Environmental Systems Research Institute, Redlands, California, USA) for all GIS analyses.

Data Analysis

We tabulated observed highway crossing events and examined differences in crossing frequency between sex and age classes, season, and time of day. We regressed crossing frequency on traffic volume and evaluated fit using Kolmogorov-Smirnov and chi-square tests. We compared observed highway crossing frequencies to that expected for each grizzly bear with a GPS collar and that crossed US-2 or MT-49. We calculated expected crossing frequencies by generating 100 random walks within each individual bear's 100% minimum convex polygon (MCP) home range (Serrouya 2000). The random walks used the observed distances applied in random directions, thus preserving realistic rates of movement. We arbitrarily selected the 100% MCP (Burt 1943) as a reasonable means to limit the random walks to the areas in which the grizzly bears actually lived. We then calculated the mean number of times the random walks crossed US-2 along with the ±95% confidence intervals. We considered observed crossing frequencies outside ±95% confidence intervals statistically significant. We generated the home range polygons and random walks using the Animal Movement extension for ArcView GIS (Hooge and Eichenlaub 1997).

We recognized that highway crossing patterns may be proportional to temporal patterns of activity. We compared mean movement distances and rates between highway crossings and non-crossings by individual and tested for significance ($P \leq 0.05$) using the Kruskal-Wallis test (Sokal and Rohlf 1995). We performed this test using mean 24-hr movement rates and mean movement rates calculated for only those hours in which crossings occurred.

To establish a putative distance over which grizzly bears modified their behavior patterns in response to road traffic, we created distance isopleths around US-2 and MT-49 from zero to 1,000 m in 100-m increments. We did not explicitly include the railroad because it generally ran closely parallel with US-2. The mean distance between the railroad and US-2 within the study area was 239 m and ranged from <30 m to 1.7 km (±95% 151–328 m). We assumed that any disturbance associated with the railroad would be additive to that of US-2 and be reflected in isopleth selectivity. We quantified the use and availability of each isopleth by each of the 11 GPS-collared grizzly bears that came within 1 km of US-2 or MT-49 by creating selection ratios (Manly et al. 1993:65). We combined selection ratios over all animals for an estimate of the population selection ratio using equation 4.40 from Manly et al. (1993). We estimated the variance of the population selection ratio as recommended by Manly et al. (1993:38, 67). We tested the selectivity of individual animals by calculating a chi-square statistic with I-1 degrees of freedom, where I was the number of categories. We tested overall selection by summing these statistics over all j animals and testing with n(I-1) degrees of freedom (Manly et al. 1993:66). We then identified the putative disturbance zone using a Friedman non-parametric ANOVA on ranks (White and Garrott 1990) followed by post hoc, multiple comparisons (Conover 1980).

To assess the spatial clustering of highway crossing locations or the lack thereof, we modified the method derived by O'Driscoll (1998) and Clevenger et al. (2003). First, we assumed that the crossing location occurred at the intersection of the highway and a line connecting the subsequent locations on either side of the highway. Given that locations were 1-hr apart, we felt confident that bears crossed the highway reasonably close to that point.

Using all the n intersections as crossing locations, we then calculated the distance between each crossing point i and its nearest neighbor j, along that portion of the highway where crossings occurred (i.e., the highway segment between the most distant crossing points). We then binned the accumulated distances into arbitrary 1-km distance classes, or scales, ranging from 500 m to 38 km. We then summed the number of nearest-neighbor distances in each bin to yield a form of Ripley's K-statistic (Ripley 1981). Because we pooled observations of highway crossings among individual bears, these statistics reflect the spatial distribution of crossing points of those individuals that crossed highways most often.

In order to assess significance of the K-statistics, we drew a random sample of points along the highway of size n, (simulated crossing locations), and then computed K-statistics for each of 100 iterations. We displayed results as plots of $L(t)$, the observed number of crossings minus the simulated mean, against distance. Values of $L(t) > 0$ indicated clustering and values <0 indicated dispersion. We deemed values of $L(t)$ outside the upper or lower 95th percentile significant (O'Driscoll 1998). We then used the scale distance with the first significant level of clustering as the basis for modeling potential crossing areas. We referred to this scale distance as the patch length or maximal cluster scale, and it was independent of clustering intensity, and was represented by the height of the distribution.

Modeling

We used logistic regression to estimate the probability of bears crossing US-2 as a function of landscape factors that we believed might explain the observed clustering of crossing locations. These factors were: distance to water, distance to cover, cover type, change in elevation adjacent to the roadway, road density, distance to low, moderate, or high human impact points, and habitat quality. We tested each factor at both the base map scale (30-m raster map) and at the generalized maximal cluster scale identified above. We calculated factor values at the maximal cluster scale by computing the average (for continuous data) or modal (for categorical data) values within a moving circle with a diameter equal to the maximal cluster scale. We tested each factor for univariate significance with unbalanced, 1-way ANOVA (continuous data) or χ^2-tests computed from the marginal frequencies of $2 \times k$ contingency tables (categorical data). We tested all factors for multicollinearity prior to logistic regression analysis (Menard 1995). We then included all these factors into a full log-linear model. We estimated model parameters using maximum likelihood techniques where the dichotomous response variables were used (1) or available (zero; Manly et al. 1993). During the moving circle procedure on cover type, the values for the rarest types (i.e., rock, riparian, and water) dropped out. We created 0/1 indicator variables for each of the 5 remaining cover types. For the categorical variable cover type, we held out mixed forest as the standard indicator variable against which others varied. We iteratively removed non-significant model parameters based on χ^2-tests of Wald statistics (Hosmer and Lemeshow 1989). We used Akaike's Information Criterion (AIC) to select the most parsimonious model describing grizzly bear crossing areas. We then derived 95% confidence intervals for each parameter estimate by creating a separate model for each $n - 1$ sample of individuals (jackknifing). In this manner, we were able to assess the influence of individual animals on model stability and variability.

RESULTS

Capture and Telemetry

We captured 43 different grizzly bears in 51 capture events (13 adult males, 11 subadult males, 10 adult females, 9 subadult females). We deployed 22 VHF radios on 19 individuals (3 individuals had VHF radios replaced) and 23 GPS collars on 23 individuals. Eight individuals fitted with GPS collars were also given VHF ear-tag transmitters to allow relocation after the GPS collar released (Table 1).

We collected 912 aerial telemetry locations in 242 hrs of flight time during 1998–2001 and 20,944 GPS positions during 1999–2001. Four of the 9 GPS collars deployed in 1999 and 2000 functioned properly. One collar failed due to a fault in the antenna power supply, and 4 failed to initialize properly. We recovered 10 of 14 GPS collars deployed in 2001, and 2 of the 10 failed prematurely. We did not recover 4 GPS collars due to failure of the automatic release mechanism. Success rate over all hourly GPS position attempts was 72% for 2D and 3D locations combined and 39% for 3D only. Accuracy of differentially corrected locations was expressed as 95% circular-error probable (CEP),

Table 1. Identification of grizzly bears captured and collared along US Highway 2 in northwest Montana, USA, 1998–2001, dates of capture, and type of collar used.

Sex-age code/ID[a]	Date of first capture	Collar type[b]	Radio days[c] VHF/GPS[d]	Highway crossings[e] VHF/GPS	Days per crossing[f] VHF/GPS
m2	6 Jun 1998	VHF/GPS	504/0	30/0	17/0
F5	10 Jun 1998	VHF	526	2	263
M6	11 Jun 1998	VHF/GPS	87/18	0/0	
M7	12 Jun 1998	VHF	67	0	
F8	14 Jun 1998	VHF	563	27	21
f9	14 Jun 1998	VHF	666	23	29
F11	14 Jun 1998	VHF	191	7	27
M12	14 Jun 1998	VHF/GPSe	54/26	2/2	27/13
M13	16 Jun 1998	VHF	42	0	
F921	11 Jun 1999	GPSe	239/140	0/0	
F14	12 Jun 1999	GPSe	321/115	0/0	
f922	18 Jun 1999	GPSe	479/140	0/0	
f20	1 Jul 1999	VHF	127	6	21
F24	15 Jun 2000	GPS	121/0	10/0	12/
F26	16 Jun 2000	GPS	59/0	0/0	
m286	22 Jun 2000	GPSe	0/0	0/0	
f293	13 Jul 2000	GPSe	176/100	0/0	
F218	28 Apr 2001	GPSe	180/0	7/0	26/
m34	4 Jun 2001	GPS	104/134	2/8	52/17
M365	6 Jun 2001	GPS	0/17	0/0	
M36	7 Jun 2001	GPS	110/138	0/0	
f37	7 Jun 2001	GPS	105/132	0/10	/13
M925	7 Jun 2001	GPS			
f367	8 Jun 2001	GPS	127/0	0/0	
M181	8 Jun 2001	GPS			
M274	1 Jun 2001	GPSe			
m926	11 Jun 2001	VHF			
M38	15 Jun 2001	GPS	104/124	1/5	104/25
m40	17 Jun 2001	VHF	127	10	13
F224	18 Jun 2001	GPS	0/15	0/7	/2
F42	20 Jun 2001	GPS	27/41	0/0	
m289	5 Jul 2001	GPS	94/86	4/18	23/5

[a] Sex-Age/ID codes: m = subadult male, M = adult male, f = subadult female, F = adult female.

[b] Some individuals wore both GPS and VHF collars at different times, and GPS collars contained a VHF beacon. Bears fitted with a GPS collar and an eartag transmitter are designated GPSe.

[c] Radio days are the number of days between first and last relocations.

[d] Abbreviations: GPS (Global Positioning System), VHF (Very High Frequency) telemetry.

[e] Highway crossings are the number of times successive relocations were on opposite sides of US-2 and/or MT-49, documented with VHF and GPS telemetry.

[f] Days per crossing are crossings/radio days for VHF and GPS telemetry.

which was the distance from the true location encompassing 95% of the positions. Our CEP was 22.4 m for 3D locations and 67.7 m for 2D locations (Graves 2002).

Traffic Monitoring

Our traffic counters recorded over 6,000 hr of traffic from 1999–2001. During 8.5 hr of counter testing, the counters accurately recorded the number of axle crossings (±1%) for 1,063 vehicles, but they overestimated the number of vehicles because every 2 axles counted as 1 vehicle. We estimated the actual number of vehicles to be 84% of the recorded vehicle counts. The standard statewide correction used by MDOT was 82% for principal rural highways.

Traffic patterns on US-2 showed strong daily and seasonal patterns (Fig. 1). Traffic counts peaked during late afternoon then dropped to near zero during pre-dawn hours. Average bi-directional hourly traffic at the west counter was 77 cars/hr (range 0–318), and mean daily traffic was 1,806 vehicles (range 220–3,338). Counts at the east counter were higher: 87 vehicles/hr (range 0–398) and 2,066 vehicles/day (range 17–4,289). Mean hourly counts by year in a given lane never differed by more than 9 vehicles at either location. Traffic counts peaked during the month of July then decreased monotonically through October. We estimated that approximately 30% of the east-bound and 24% of the west-bound traffic was local.

We collected 4,135 hrs of train counts at the west train counter during 1999–2001 and 1,141 hrs at the east counter during 1999–2000. Work and maintenance trains were generally shorter than 21 cars, while freight trains averaged 75 cars. We found that train length (both types included) was consistently higher during early morning and late evening hours than during midday and that rail traffic did not vary substantially between years. Mean bidirectional rail traffic was 1.2 trains/hr and ranged from 0–3.75 trains/hr (Fig. 2). Average rail traffic was slightly higher in October (1.53 trains/hr) than in July–September (1.19–1.34 trains/hr). We also found that rail traffic was higher ($\bar{x}$ = 1.5 trains/hr vs. 1.2 trains/hr) during hours of darkness, particularly the pre-dawn hours, than during the daylight or evening hours. Train speed averaged

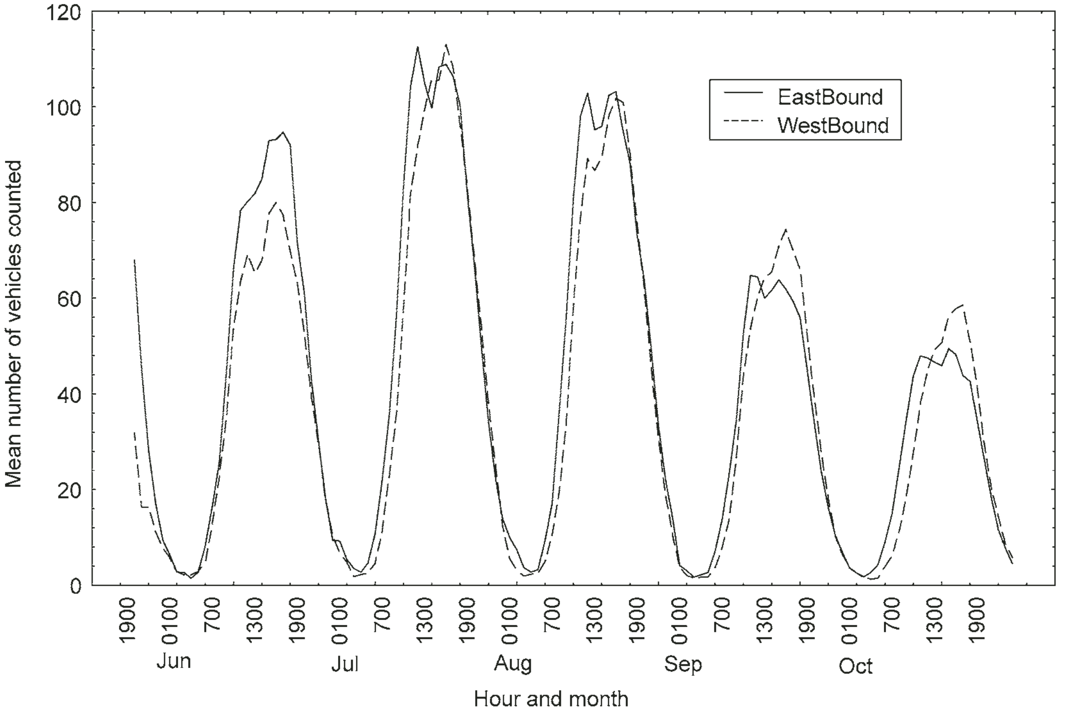


Fig. 1. Corrected bi-directional mean vehicles by hour and month at the west traffic counter on U.S. Highway 2, northwest Montana, USA, 1999–2001.

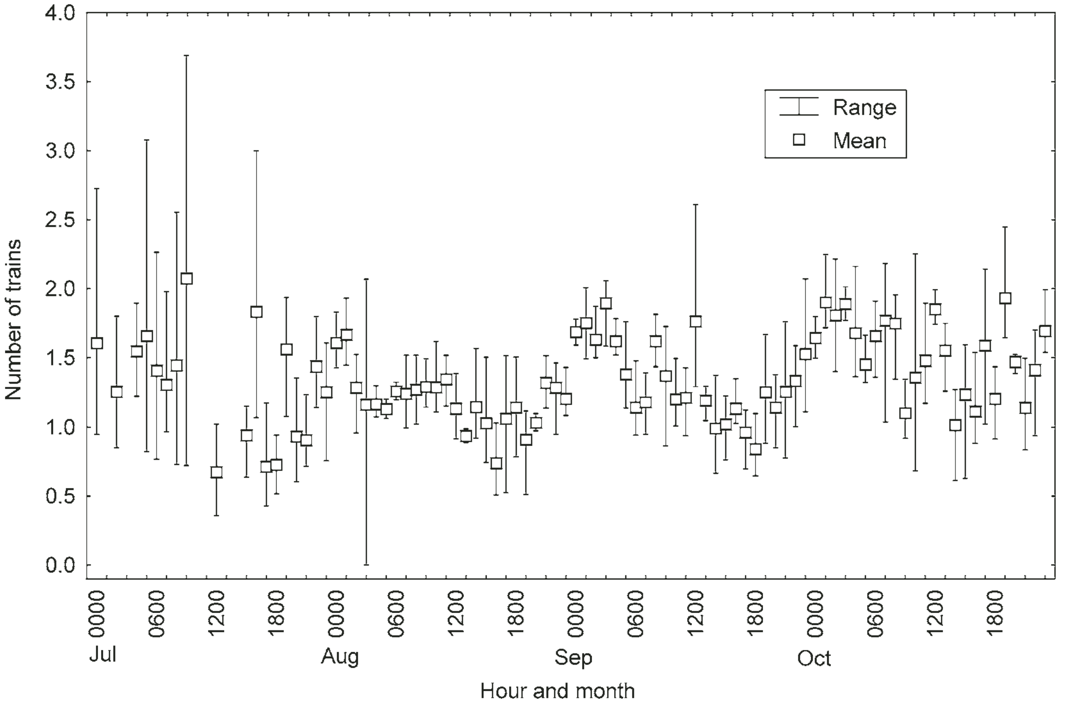


Fig. 2. Range and mean number of trains by hour and month tallied at the west train counter in the U.S. Highway 2 study area, northwest Montana, USA, 1999–2001.

Table 2. Observed total number of highway crossings, crossings of U.S. Highway 2 and the Burlington Northern–Santa Fe railroad (R.R.), and number of observed crossings of both US Highway 2 and the R.R. by Global Positioning System (GPS)-marked grizzly bears compared to that expected in 100 random walks, northwest Montana, USA, 1999–2001.

Bear ID	No. of GPS locations	Observed no. of highway crossings	No. crossings over US-2	Observed no. of R.R. crossings	No. of US-2 crossings also crossing R.R.	No. of highway crossings in 100 random walks					
						$\bar{x}$	–95%	+95%	Minimum	Maximum	SD
F224	236	7	3	5	3	8.5	7.4	9.5	0	26	5.3
m289	1176	18	15	11	6	33.9	31.2	36.5	8	64	13.4
f37	3161	10	10	9	8	53.5	48.5	58.5	6	155	25.4
m34	3216	8	4	6	4	26.6	22.1	31.1	0	87	22.8
M38	2972	5	5	6	5	34.1	29.8	38.5	1	77	21.8
M12	124	2	2	2	2	6.4	5.2	7.6	0	26	6.2

Table 3. Selection ratios, χ^2 values, and their significance for 11 grizzly bears along U.S. Highway 2, northwest Montana, USA, 1999–2001. Selection ratios are the proportions of used/proportion of available road distance categories. Road Distance Categories are 100-m increments beginning with 0–100 m (category zero) through 900–1,000 m (category 9).

	Road distance category											
Bear ID	0	1	2	3	4	5	6	7	8	9	χ^2	*P*
F14	0	3.898	0.375	0.910	0.688	0.492	0.913	1.202	1.647	1.089	25.420	0.002
F42	0.377	0.729	1.298	1.701	1.059	1.453	1.161	1.001	0.640	0.347	23.870	0.004
F224	1.040	1.240	1.268	1.592	0.836	1.846	0.338	0.769	0.759	0.335	10.370	0.321
F921	0.616	0.158	0.538	2.449	0.257	1.386	0.636	0.809	1.555	1.452	16.22	0.062
F922	0	0	0	0.092	0.227	2.088	2.106	2.012	1.464	0.724	168.630	0.001
F37	0.234	0.524	0.573	1.619	1.154	1.048	1.154	0.637	1.086	2.153	123.890	0.001
M6	0	0	0.965	0	0	2.720	1.999	0.657	1.544	0.304	9.570	0.386
M12	0.394	0	0	0	1.260	2.159	0.454	2.205	0.436	3.203	14.090	0.119
M38	0.203	0.150	0.419	0.414	0.283	1.465	3.202	0.732	1.693	1.566	51.480	0.001
m34	0.080	0.546	0.780	1.929	0.999	1.009	1.094	0.977	1.571	1.285	79.610	0.001
m289	3.912	1.003	0.656	0.407	0.202	0.043	0.225	0.990	0.900	1.143	114.410	0.001
Pooled	0.633	0.541	0.620	1.268	0.794	1.128	1.205	1.041	1.273	1.284	637.580	0.001
SE	0.441	0.096	0.100	0.256	0.152	0.035	0.031	0.031	0.016	0.074		
–95%	0.231	0.353	0.422	0.767	0.497	0.761	0.861	0.697	1.025	0.749		
+95%	1.527	0.729	0.818	1.769	1.091	1.495	1.549	1.385	1.521	1.819		

about 56 kph at the west counter, while westbound speeds at the east counter were slower (40 kph) because of the increasing grade towards Marias pass. Average train speed was greater during pre-dawn hours and peaked noticeably (~60 kph) at 0800 and 2000 hr.

Grizzly Bear Movements

We tracked 25 grizzly bears with aerial telemetry, and 13 of these crossed US-2 at least once (52%), for a total of 131 crossings (Table 1). We documented 39 crossings of US-2 by 6 of the 14 bears with GPS collars from which we obtained data. Of these 6 individuals, 3 also made an additional 11 crossings of adjacent MT-49. For those bears for which we had concurrent GPS and VHF crossing data, aerial VHF telemetry captured only 7 of 33 crossings (21%). Based on GPS data, subadult males and subadult females crossed highways the most (8 and 23 days between crossings, respectively), while adult females and adult males crossed the least (61 and 46 days between crossings, respectively). Adult females that crossed highways during monitoring did not do so when accompanied by cubs of the year ($n = 2$) but did so when accompanied by yearlings or 2-year-olds ($n = 2$).

All bears with GPS crossing data crossed highways less than expected when compared to random moves of equal length (Table 2). Because US-2 closely paralleled the railroad tracks for most of its length within the study area, in most cases, bears that crossed US-2 also crossed the railroad tracks during the same move (Table 2). One exception, bear m289, frequented a large riparian area between the railroad tracks and the highway.

Most (85%) crossings of US-2 were made at night and when highway traffic volumes could be expected to be low (Fig. 3). Actual mean traffic volume during crossings was 30 vehicles/hr and ranged from 2–98 vehicles/hr (±95%; 20–40 vehicles/hr). Crossing frequency declined exponentially with increasing traffic volume (Fig. 4), and model fit was quite good (Kolmogorov-Smirnov d = 0.112, $P < 0.001$; $\chi^2 = 0.342$, df = 2, $P = 0.843$). All

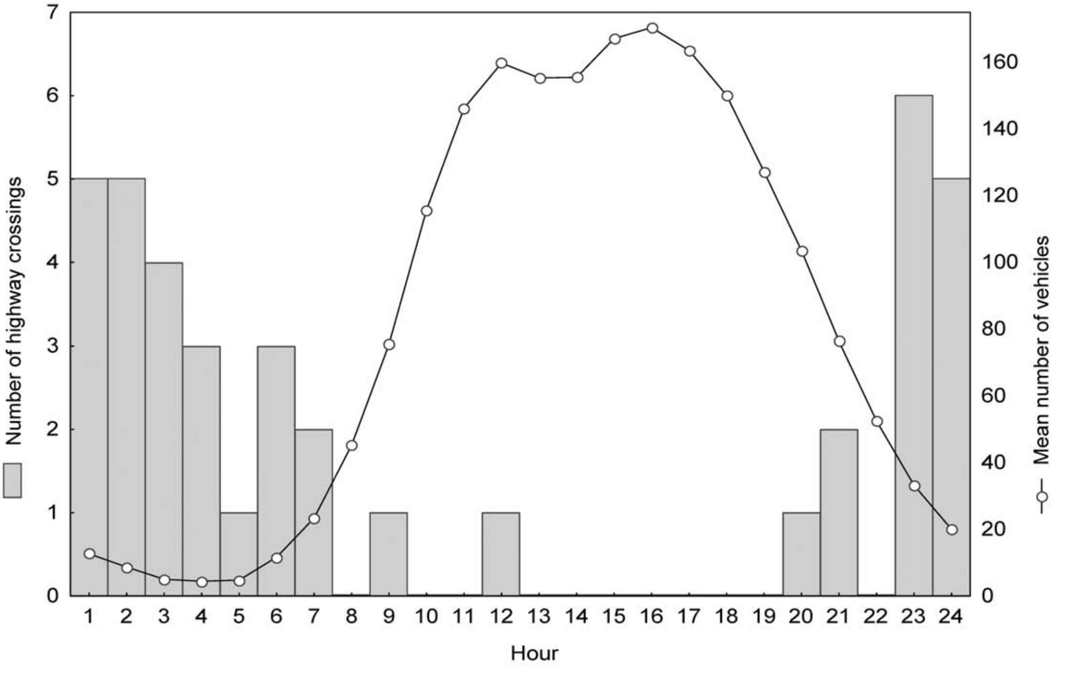


Fig. 3. Frequency of U.S. Highway 2 crossings by grizzly bears during 2001 plotted against mean traffic volume by hour, northwest Montana, USA.

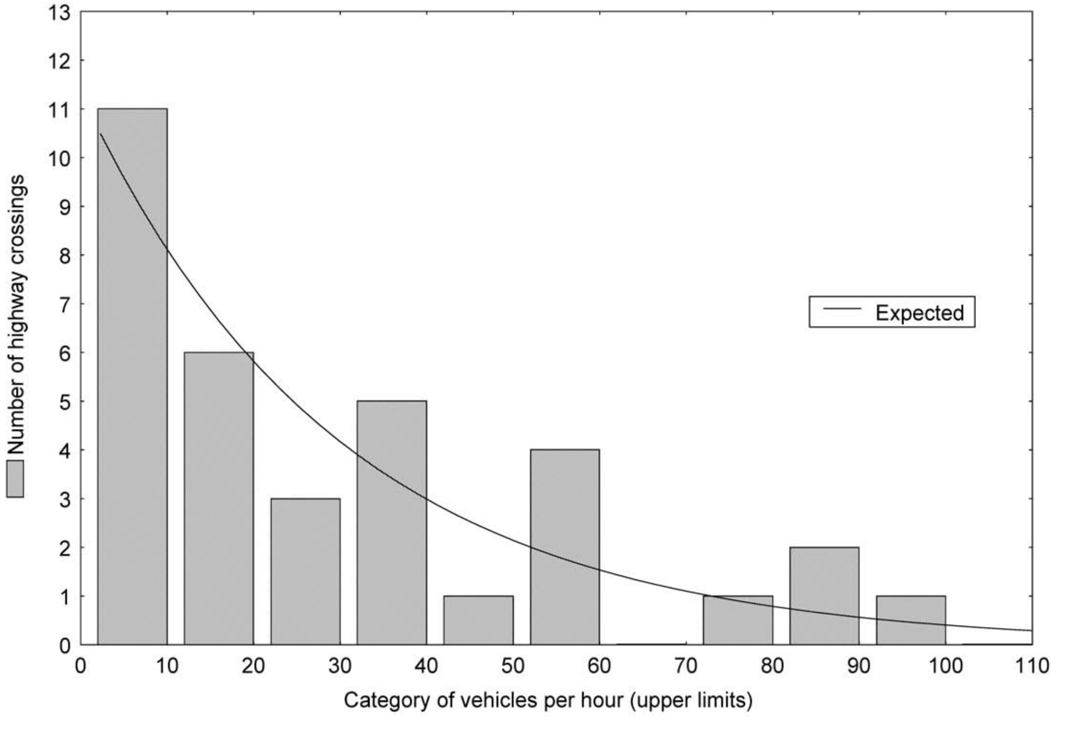


Fig. 4. Observed grizzly bear crossings of U.S. Highway 2 fitted to an exponential distribution with traffic volume categories, northwest Montana, USA, 1999-2001.

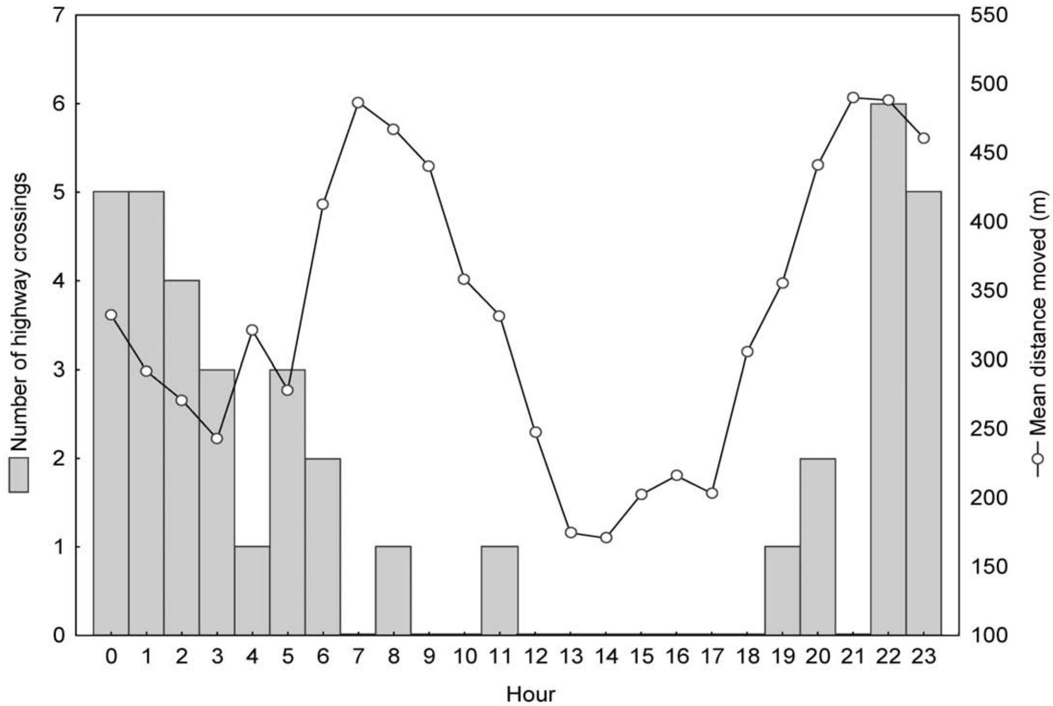


Fig. 5. Frequency of observed grizzly bear crossings of U.S. Highway 2 during 2001 plotted against mean grizzly bear movement distance by hour, northwest Montana, USA.

but 1 of the bears with GPS collars showed strong crepuscular activity patterns regardless of their distance from highways. The exception was an adult female (F14) with a diurnal activity pattern that occupied a tightly constricted home range within Glacier National Park. Morning highway crossings occurred before the morning period of peak bear activity, which was 0600–1100 hr. However, evening highway crossings occurred during the peak of evening bear activity, 1900–2300 hr (Fig. 5). None of the crossings recorded with GPS occurred during periods of precipitation. However, during 2001, precipitation was recorded on only 7 and 16 days at the Pendroy and Essex weather stations, respectively. There did not appear to be any seasonal patterns of crossing frequency.

Only 4 of the 39 recorded crossings of US-2 occurred between fixes >1 hr apart. For 4 of 6 GPS-marked bears that crossed highways, mean sequential movement distances and movement rates were significantly greater when crossing highways than when not crossing highways. Differences were significant considering both mean 24-hr movements (676 m further and 700 m/hr faster) and movements only during those hours when highway crossings occurred (543 m further and 573 m/hr faster).

Eleven of the 14 GPS-marked bears ventured within 1 km of US-2 or MT-49. Based on their selection ratio statistics, most were highly selective of distance isopleths (Table 3). However, 1 individual (m289) was unique in having selectivity for isopleths closer to highways. This subadult male spent large amounts of time within a riparian area close to US-2. The variability introduced by this animal resulted in the Friedman ANOVA failing to detect selectivity ($P = 0.370$). With m289 excluded, ANOVA results were significant ($P = 0.034$). We observed increasing selectivity for distance isopleths to an apparent asymptote within the 500–600-m category (Fig. 6). Based on post hoc multiple comparisons, inspection of the matrix of rank differences between isopleths, and groupings of similar categories based on significant differences, we chose distance isopleths 1–5 (0–500 m) as the disturbance area surrounding the highway and railroad.

Most (64%) of the observed crossings of US-2 were made by 2 subadult bears, f37 and m289. These crossings of US-2, when pooled with those of 4 other GPS-marked bears, were significantly clustered out to a scale distance of nearly 9 km, with an exception at the 3–4 km bin. Crossings were significantly dispersed at scales from 15 km

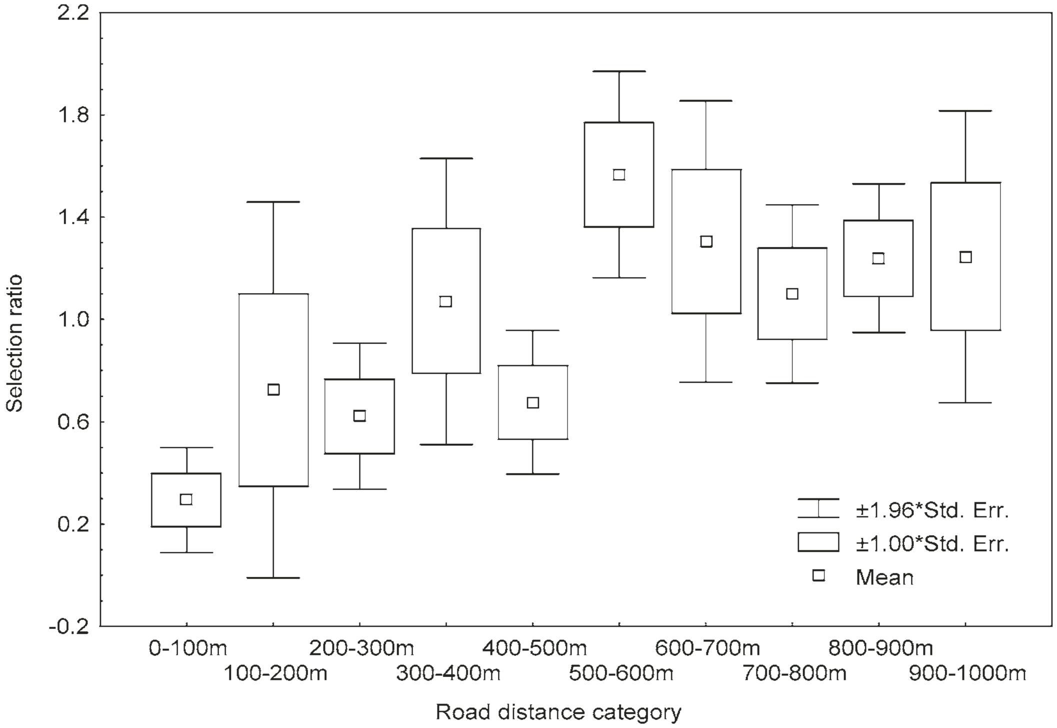


Fig. 6. Selection ratios for 10 grizzly bears (m289 excluded) along U.S. Highway 2, northwest Montana, USA, 1999–2001. Mean and standard errors of selection ratios calculated for each 100-m distance isopleth away from the highway. Values >1.0 indicate selection, and values <1.0 indicate avoidance.

to 26 km (Fig. 7). The strongest clustering we observed was at the 1–2 and 5–6-km scales. Although the clustering intensity was somewhat higher at the 5–6-km scale, we selected the 1–2-km scale for modeling in order to maximize spatial specificity and because the first significant cluster represented the patch length (O'Driscoll 1998). As a result, we used a moving circle radius of 750 m (1/2 patch length) to calculate maximal cluster values in the habitat models.

Modeling

In univariate tests, only distance to cover lacked significance. The other factors attained significance ($P \leq 0.05$) at either the base scale or maximal cluster scale. Significance levels were at least as great at the maximal cluster scale. The only categorical factor, cover type, was also significant at both scales. All but the conifer forest cover type contributed significantly to the total chi-square. We found no significant multicollinearity among the factors ($r \leq 0.51$). The full model was significant, but it contained many nonsignificant terms and unstable standard errors ($-2LL = 279.40$, $\chi^2 = 53.15$, df = 12, $P \leq 0.001$, AIC = 305.40). The low, moderate, and high point distance terms dropped out of the full model, as did distance to water, road density and habitat quality. Our final, most parsimonious model ($-2LL = 287.92$, $\chi^2 = 44.58$, df = 6, P 0.001, AIC = 301.92) consisted of only 3 parameters: elevation SD, distance-to-cover, and cover type (Table 4). Distance-to-cover assumed significance in multivariate models because of its interaction with cover type. Crossing areas in grassland or shrub cover types were significantly closer to cover than crossing areas in forested cover types. Based on the sign and strength of parameter estimates, crossing areas used by grizzly bears appeared to be flatter, closer to cover in open cover types, and more likely to be within grassland cover types (Table 4). Thirty-eight percent of the observed crossings of US-2 were made by m289, so as expected, this individual had the largest effect on model parameter estimates. Exclusion of this individual resulted in a much higher attraction for grassland, shrubland, and conifer habitats and strong avoidance of the deciduous forest cover type, relative to the mixed-forest cover type.

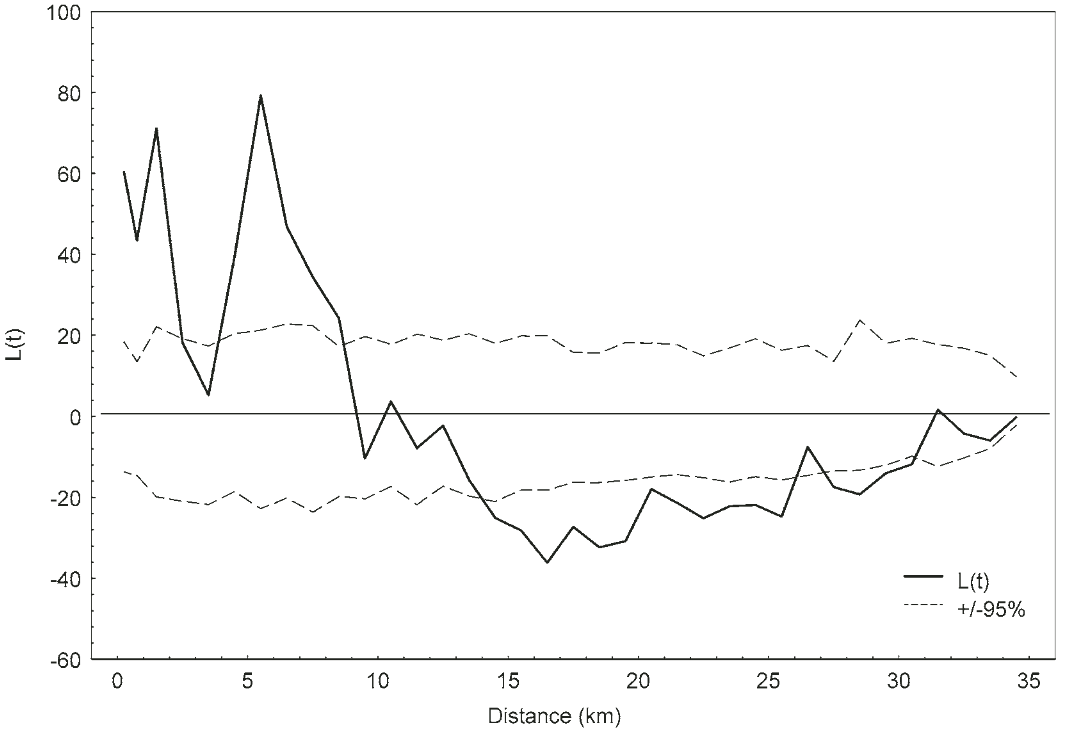


Fig. 7. Plot of L(t) against distance, where L(t) is the difference between the observed number of highway crossings by grizzly bears during 2001 and the simulated mean, northwest Montana, USA. Values of L(t) >0 indicate clustering, values <0 indicate dispersion. We deemed values above or below the 95th percentile significant.

DISCUSSION

We showed that grizzly bears' highway crossings were relatively frequent and successful; nearly half of our sampled population successfully traversed US-2. However, we also presented evidence that US-2 affected grizzly bear movement patterns. All our study animals crossed US-2 significantly less than expected under a random movement hypothesis. Our grizzly bears crossed more often at night, even when outside their normal periods of activity. And when they did cross, they moved farther and faster than normal. Grizzly bears were apparently choosing to cross when they were less likely to encounter highway traffic. Hourly mean traffic during crossings was half that of normal daytime traffic levels. This result suggests that there was a threshold of acceptable traffic level and/or that perceived vulnerability encouraged night crossings. Adult female grizzly bears appeared to be the most sensitive to traffic, especially when accompanied by cubs, whereas subadults and males appeared the least sensitive. This finding somewhat contradicts that of Chruszcz et al. (2003), who found that adult males were less likely to cross low-volume highways than females were.

Chruszcz et al. (2003) found that traffic volume was the single greatest determinate of road crossings and that grizzly bears were reluctant to cross

Table 4. Mean maximum likelihood estimates, their 95% confidence intervals, minimum and maximum values, and *t* statistics for a model describing locations where grizzly bears crossed U.S. Highway 2, northwest Montana, USA, 2001.

	0	– 95%	+ 95%	Minimum	Maximum	SE	*t*	*P*
Constant	–0.962	–2.643	0.720	–4.185	0.0534	0.654	–1.470	0.130
Elevation	–0.144	–0.207	–0.082	–0.195	–0.030	0.024	–5.991	0.001
Distance-to-cover	–0.021	–0.025	–0.016	–0.026	–0.016	0.002	–11.687	0.001
Grassland	1.772	0.441	3.102	0.537	4.175	0.517	3.423	0.008
Shrubland	0.181	–0.961	1.322	–0.888	2.289	0.444	0.407	0.348
Deciduous forest	–2.698	–12.449	7.053	–21.663	1.203	3.793	–0.711	0.288
Conifer forest	–0.277	–1.635	1.081	–2.198	1.879	0.528	–0.525	0.327

roads with high traffic volume. It is difficult to compare our study to that by Chruszcz et al. (2003) because of fundamental differences in methodology. However, Chruszcz et al. (2003) observed that only 11 individuals of 74 crossed the Trans-Canada highway during 12 years of research. Gibeau (2000) observed that traffic volumes on the Trans-Canada highway in Banff National Park can exceed 20,000 vehicles/day, but did not measure temporal changes in traffic volume. In Slovenia, Kaczensky et al. (2003) found similar effects of a 4-lane highway with an estimated traffic volume of 7,500 vehicles/day. In the US-2 corridor, peak traffic volumes are only a tenth that of the Trans-Canada highway and a fourth that observed in Slovenia.

Our study, when considered with the work of Gibeau (2000), Chruszcz et al. (2003), and Kaczensky et al. (2003), indicates the existence of a threshold traffic volume beyond which highways become significant barriers to grizzly bear movement. We hypothesize that this threshold occurs near 100 vehicles/hr (Fig. 4). We believe that connectivity was maintained across US-2 because hourly traffic volumes decreased dramatically at night, sometimes reaching zero vehicles/hr.

In our study area, grizzly bears had to contend with both a highway and a railroad. While grizzly bears appeared to make behavioral adjustments to temporal patterns of highway traffic volume, they were faced with a different situation along the railroad. During hours of low highway traffic, when grizzly bears were choosing to cross US-2, railroad traffic was high. Trains were more frequent, longer, and faster at night than during daylight hours. Furthermore, rail traffic was greater during fall when bears were in hyperphagia. This situation arose for a number of reasons. First, most track maintenance work was accomplished during daylight hours; thus, freight traffic was often curtailed during the day to allow track work to proceed. Second, arrival times for freight trains depended partially on their departure time. Freight trains loaded on the Pacific coast (approx 800 km to the west) during the day left in the evening and arrived in our study area at night the next day, 24–36 hr later. The result was that grizzly bears had to contend with high railroad traffic when highway traffic was lowest. We observed greater grizzly bear mortality caused by trains than that caused by cars on the highway. Between 1980 and 2002, 29 grizzly bears were killed on the 109-km section of railroad track between West Glacier and Browning, Montana, and 23 of these deaths occurred within our study area. During this same period, 2 grizzly bears were killed by vehicles in the study area (C. Servheen, U.S. Fish and Wildlife Service, unpublished data). During our study, 2 radio-marked grizzly bears were struck and killed by trains, and none were killed on the highway within the study area. Historically, grizzly bears have been attracted to the railroad by grain that leaked from cars along the tracks or that accumulated at sites of repeated derailments, and grizzly bears have been struck and killed by trains at these sites. Since the mid 1990s, BNSF has been largely successful in cleaning up and reducing the occurrence of grain spills, however, grizzly bears continue to be killed along this section of railroad. Our GPS data did not show any concentrated relocations on the railroad tracks that suggested the presence of an attractant. This research suggests that the coincidence of high rail traffic volume, low highway traffic volume, and natural grizzly bear movement patterns may be partially responsible for the observed patterns of mortality.

Collar-borne GPS technology greatly improved our ability to assess the extent of highway crossings by grizzly bears. With traditional bi-weekly aerial telemetry, we missed 79% of the highway crossings. Global Positioning System technology also allowed us to examine fine scale avoidance of the highway corridor. Mattson et al. (1987) found avoidance of roads to 500 m for grizzly bears in Yellowstone National Park using aerial relocation data collected between 1974 and 1983. Kasworm and Manley (1990) found road avoidance occurring in a 274–915-m zone in the Cabinet/Yaak ecosystem. Since that time, other authors have used 500 m as an assumed zone of influence (Mace et al. 1996). We also showed avoidance of areas within 500 m of US-2, supporting the contention that 500 m is a representative zone of influence around high-use roads. Conversely, Chruszcz et al. (2003) showed a preference for areas within 1,000 m of low-volume highways. However, our findings were based on more intensive telemetry (hourly vs. weekly) on a smaller number of individuals (11 vs. 24) over a shorter period (3 yrs vs. 12 yrs), and at a finer scale (100 m vs. 200 m). Furthermore, such an analysis does not consider the distribution of habitats within the zones. Changes in topography can drastically alter the distribution of preferred habitats among the zones. Chruszcz et al. (2003) suggest that the extreme topography within Banff National Park constricts bears to zones closer to roads than in other areas.

Spatial patterns of highway mortality suggest that many species utilize specific crossing areas and that the use of crossing areas can be expected to change seasonally as resource needs change (Bellis and Graves 1971). One of our goals was to identify crossing areas and describe their attributes. We were able to show that grizzly bear highway crossing locations were spatially clustered, and we were then able to model the attributes of these locations. However, we are not convinced that terrain, distance to cover, and cover type were the only factors affecting where grizzly bears cross highways. Other factors that we could not model include large-scale topographic position, bear density, and relative position of different age/sex classes. Chruszcz et al. (2003) found similar relationships, but they also found that habitat quality influenced crossings of high-volume highways. Our qualitative assessment is that the large scale attributes of US-2 provided for habitat connectivity. These attributes were low traffic levels, narrow road width, limited human developments, and expansive pristine habitats on either side of the highway.

The highway corridor we studied was the converse of that typically conceptualized in the literature—a narrow strip of habitat in a matrix of human development (Simberloff et al. 1992, Beier 1995, Forman 1995, Beier and Noss 1998). Rather, our corridor was a narrow strip of human development in a matrix of wild land. Such configurations have been termed fracture zones (Servheen et al. 1998). This fracture zone has the potential to act as a population sink or trap because high-quality spring habitats along the highway will tend to bring grizzly bears into close proximity to traffic and human activity. Also, population pressure may cause subdominant grizzly bear sex/age classes, seeking to avoid conspecifics, to place themselves within these fracture zones (Mattson et al. 1987, Allen and Sargeant 1993). We observed that situation here, where a subadult male spent a large amount of time in close proximity to US-2 and other developments. Judging from our capture success within the corridor, the area continues to provide resources for a resident bear population, and even if the area is a population sink, the result may be more grizzly bears and continued connectivity (Pulliam 1988). This suggests that we can continue to maintain large scale habitat connectivity for grizzly bears despite limited development (Boone and Hunter 1996).

MANAGEMENT IMPLICATIONS

Within our study area, mean hourly traffic levels doubled since 1987 from 41.2 vehicles/hr to 77–91 vehicles/hr (Pedvillano and Wright 1987). Continued population growth in Montana's intermontane valleys will undoubtedly perpetuate this trend. Thus, in the future we may expect the US-2 corridor to become an agent of fragmentation requiring mitigative action. Such actions may range from radar-activated warning signs to bridges or tunnels specifically designed for wildlife passage. Currently, mean traffic volume during the time grizzly bears cross US-2 the most (2300–0700 hr) is 10.9 vehicles/hr (range 0–67, SD = 9.5). If highways become impermeable at 100 vehicles/hr, then we expect US-2 to become impassable to grizzly bears in 30 yrs if the current traffic trends continue. Obviously, unforeseen developments could change this estimate. During our study, there was a proposal to widen US-2 into a 4-lane divided highway to encourage local economic development. While the economic benefits of such a project are debatable, the effects on grizzly bears appear predictable. Planning for wildlife passage now may offset some of the financial burden of providing wildlife crossing structures when they become a necessity. These results should help planners anticipate when mitigative action is required and provide insights as to where such actions should occur.

ACKNOWLEDGMENTS

Funding for our project was provided by the Federal Highways Administration (FHWA) and the U.S. Fish and Wildlife Service. We specifically wish to thank P. Garrett of the FHWA for his leadership in funding this project. We also thank Glacier National Park, D. Carney and the Blackfeet Indian Nation; L. Ross and R. Wolff of the Burlington Northern-Santa Fe Railroad; M. Traxler and T. Bengston of the Montana Department of Transportation; T. Manley and E. Wenum of Montana Fish, Wildlife and Parks; D. Hoerner of Red Eagle Aviation; D. Godtel of the Lewis and Clark National Forest; J. de Herrera of the Flathead National Forest; T. Radant and H. Carriles of the U.S. Fish and Wildlife Service; and B. Pilcher, T. McClelland, and T. Graves for field assistance. We thank A. Easter-Pilcher, F. Allendorf, M. S. Boyce, L. Marcum, B. Pilcher, D. Pletscher, J. Potter, and J. W. Thomas for previous reviews of this manuscript.

LITERATURE CITED

ALLEN, S. H., AND A. B. SARGEANT. 1993. Dispersal patterns of red foxes relative to population density. Journal of Wildlife Management 57:526–533.

ARCHIBALD, W. R., R. ELLIS, AND A. N. HAMILTON. 1987. Responses of grizzly bears to logging truck traffic in the Kimsquit River Valley, British Columbia. International Conference on Bear Research and Management 7:251–257.

BEIER, P. 1995. Dispersal of juvenile cougars in fragmented habitat. Journal of Wildlife Management 59:228–237.

———, AND R. F. NOSS. 1998. Do habitat corridors provide connectivity? Conservation Biology 12:1241–1252.

BELLIS, E. D., AND H. B. GRAVES. 1971. Deer mortality on a Pennsylvania interstate highway. Journal of Wildlife Management 35:232–237.

BHATTACHARYA, M., R. B. PRIMACK, AND J. GERWEIN. 2003. Are roads and railroads barriers to bumblebee movement in a temperate suburban conservation area? Biological Conservation 109:37–45.

BOONE, R. B., AND M. L. HUNTER. 1996. Using diffusion models to simulate the effects of land use on grizzly bear dispersal in the Rocky Mountains. Landscape Ecology 11:51–64.

BURT, W. H. 1943. Territoriality and home range concepts as applied to mammals. Journal of Mammalogy 24:346–352.

CHRUSZCZ, B., A. P. CLEVENGER, K. GUNSON, AND M. L. GIBEAU. 2003. Relationship among grizzly bears, highways and habitat in the Banff-Bow Valley, Alberta, Canada. Canadian Journal of Zoology 81:1378–1391.

CLEVENGER, A. P., B. CHRUSZCZ, AND K. E. GUNSON. 2003. Spatial patterns and factors influencing small vertebrate fauna road-kill aggregations. Biological Conservation 109:15–26.

CONOVER, W. J. 1980. Practical nonparametric statistics. Second edition. John Wiley and Sons, New York, USA.

DWYER, N. C., AND G. W. TANNER. 1992. Nesting success in Florida sandhill cranes. Wilson Bulletin 104:22–31.

FORMAN, R. T. T. 1995. Land mosaics: the ecology of landscapes and regions. Cambridge University Press, Cambridge, United Kingdom.

———, D. SPERLING, J. A. BISSONETTE, A. P. CLEVENGER, C. D. CUTSHALL, V. H. DALE, L. FAHRIG, R. FRANCE, C. R. GOLDMAN, K. HEANUE, J. A. JONES, F. J. SWANSON, T. TURRENTINE, AND T. C. WINTER. 2002. Road ecology: science and solutions. Island Press, Washington, D.C., USA.

GIBEAU, M. L. 2000. A conservation biology approach to management of grizzly bears in Banff National Park, Alberta. Dissertation, Resources and the Environment Program, University of Calgary, Alberta, Canada.

GILPIN, M. E., AND M. E. SOULÉ. 1986. Minimum viable populations: Processes of species extinction. Pages 19–34 *in* M. E. Soulé, editor. Conservation biology: the science of scarcity and diversity. Sinauer, Sunderland, Massachusetts, USA.

GRAVES, T. A. 2002. Spatial and temporal response of grizzly bears to recreational use on trails. Thesis, University of Montana, Missoula, USA.

HOOGE, P. N., AND B. EICHENLAUB. 1997. Animal movement extension to ArcView version 1.1. Alaska Science Center—Biological Science Office, U.S. Geological Survey, Anchorage, Alaska, USA.

HOSMER, D. W., AND S. LEMESHOW. 1989. Applied logistic regression. John Wiley and Sons, New York, USA.

JOHNSON, K. G., AND M. R. PELTON. 1980. Prebaiting and snaring techniques for black bears. Wildlife Society Bulletin 8:46–54.

JONKEL, J. J. 1993. A manual for handling bears for managers and researchers. U.S. Fish and Wildlife Service, Grizzly Bear Recovery Coordinators Office. University of Montana, Missoula, USA.

KACZENSKY, P., F. KNAUER, B. KRZE, M. JONOZOVIC, M. ADAMIC, H. GOSSOW. 2003. The impact of high speed, high volume traffic axes on brown bears in Slovenia. Biological Conservation 111:191–204.

KASWORM, W. F., AND T. L. MANLEY. 1990. Road and trail influences on grizzly bears and black bears in northwest Montana. International Conference on Bear Research and Management 8:79–84.

———, T. J. THEIR, AND C. SERVHEEN. 1998. Grizzly bear recovery efforts in the Cabinet/Yaak Ecosystem. Ursus 10:147–153.

KNIGHT, R. L., AND J. Y. KAWASHIMA. 1993. Responses of raven and red-tailed hawk populations to linear right-of-ways. Journal of Wildlife Management 57:266–271.

LANDE, R. 1988. Genetics and demography in biological conservation. Science 241:1455–1460.

———. 1995. Mutation and conservation. Conservation Biology 9:782–791.

MACE, R. D., J. S. WALLER, T. L. MANLEY, L. J. LYON, AND H. ZUURING. 1996. Relationships among grizzly bears, roads and habitat in the Swan Mountains, Montana. Journal of Applied Ecology 33:1395–1404.

———, ———, ———, K. AKE, AND W. T. WITTINGER. 1999. Landscape evaluation of grizzly bear habitat in western Montana. Conservation Biology 13:367–377.

MANLY, B. F. J., L. L. MCDONALD, AND D. L. THOMAS. 1993. Resource selection by animals. Chapman and Hall, London, United Kingdom.

MATTSON, D. J., R. R. KNIGHT, AND B. M. BLANCHARD. 1987. The effects of developments and primary roads on grizzly bear habitat use in Yellowstone National Park, Wyoming. International Conference on Bear Research and Management 7:259–273.

———, AND T. MERRILL. 2002. Extirpations of grizzly bears in the contiguous United States, 1850–2000. Conservation Biology 16:1123–1136.

MCLELLAN, B. N., AND D. M. SHACKLETON. 1988. Grizzly bears and resource-extraction industries: effects of roads on behaviour, habitat use and demography. Journal of Applied Ecology 25:451–460.

———, AND F. W. HOVEY. 2001. Habitats selected by grizzly bears in a multiple use landscape. Journal of Wildlife Management 65:92–99.

MENARD, S. 1995. Applied logistic regression analysis. Sage University Paper Series 106. Sage, Thousand Oaks, California, USA.

MILLS, L. S., AND P. E. SMOUSE. 1994. Demographic consequences of inbreeding in remnant populations. American Naturalist 144:412–431.

O'DRISCOLL, R. L. 1998. Description of spatial pattern in seabird distributions along line transects using neighbor K statistics. Marine Ecology Progress Series 165:81–94.

PEDEVILLANO, C., AND R. G. WRIGHT. 1987. The influence of visitors on mountain goat activities in Glacier National Park, Montana. Biological Conservation 39:1–11.

PAETKAU, D., G. F. SHIELDS, AND C. STROBECK. 1998. Gene flow between insular, coastal and interior populations of brown bears in Alaska. Molecular Ecology 7:1283–1292.

PULLIAM, R. H. 1988. Sources, sinks, and population regulation. American Naturalist 132:652–661.

RAUSCH, R. L. 1963. Geographic variation in size in North American brown bears, *Ursus arctos* L., as indicated by condylobasal length. Canadian Journal of Zoology 41:33–45.

REDMOND, R. L., M. M. HART, J. C. WINNE, W. A. WILLIAMS, P. C. THORNTON, Z. MA, C. M. TOBALSKE, M. M. THORNTON, K. P. MCLAUGHLIN, T. P. TADY, F. B. FISHER, AND S. W. RUNNING. 1998. The Montana Gap analysis project: final report. Montana Cooperative Wildlife Research Unit, University of Montana, Missoula, USA.

REIJNEN, R., AND R. FOPPEN. 1994. The effects of car traffic on breeding bird populations in woodlands. Journal of Applied Ecology 31:85–94.

RIPLEY, B. D. 1981. Spatial statistics. John Wiley and Sons, New York, USA.

ROMIN, L. A., AND J. A. BISSONETTE. 1996. Deer–vehicle collisions: status of state monitoring activities and mitigation efforts. Wildlife Society Bulletin 24:276–283.

SERROUYA, R. 2000. Permeability of the Trans-Canada Highway to black bear movements in the Bow River Valley of Banff National Park. Thesis, University of British Columbia, Vancouver, Canada.

SERVHEEN, C. 1990. The status and conservation of the bears of the world. International Conference on Bear Research and Management, Monograph Series Number 2.

———. 1999. Status and management of the grizzly bear in the lower 48 United States. Pages 50–54 *in* C. Servheen, S. Herrero, and B. Peyton, editors. Bears: status survey and action plan. International Union for Conservation of Nature and Natural Resources, Cambridge, United Kingdom.

———, J. WALLER, AND W. KASWORM. 1998. Fragmentation effects of high-speed highways on grizzly bear populations shared between the United States and Canada. Pages 97–103 *in* G. L. Evink, P. Garrett, D. Zeigler, and J. Berry, editors. Proceedings of the international conference on wildlife ecology and transportation FL-ER-69-98. Florida Department of Transportation, Tallahassee, USA.

SIMBERLOFF, D., J. A. FARR, J. COX, AND D. W. MEHLMAN. 1992. Movement corridors: conservation bargains or poor investments? Conservation Biology 6:493–504.

SOKAL, R. R., AND F. J. ROHLF. 1995. Biometry. Third edition. W. H. Freeman, New York, USA.

SOULÉ, M. E. 1980. Thresholds for survival: maintaining fitness and evolutionary potential. Pages 151–170 *in* M. E. Soulé and B. A. Wilcox, editors. Conservation biology: an evolutionary-ecological perspective. Sinauer, Sunderland, Massachusetts, USA.

STEVENS, S. 2002. Landsat TM-based greenness as a surrogate for grizzly bear habitat quality in the Central Rockies Ecosystem. Thesis, University of Calgary, Alberta, Canada.

STONER, D. 1925. The toll of the automobile. Science 61:56–80.

U.S. FISH AND WILDLIFE SERVICE. 1993. Grizzly bear recovery plan. U.S. Fish and Wildlife Service, Missoula, Montana, USA.

WALLER, J. S., AND R. D. MACE. 1997. Grizzly bear habitat selection in the Swan Mountains, Montana. Journal of Wildlife Management 61:1032–1039.

WHITE, G. C., AND R. A. GARROTT. 1990. Analysis of wildlife radio-tracking data. Academic Press, San Diego, California, USA.

WILCOX, B. A. 1980. Insular ecology and conservation. Pages 95–117 *in* M. E. Soulé and B. A. Wilcox, editors. Conservation biology: an evolutionary-ecological perspective. Sinauer, Sunderland, Massachusetts, USA.

WOODWARD, S. M. 1990. Population density and home range characteristics of woodchucks at expressway interchanges. Canadian Field-Naturalist 104:421–428.

WRIGHT, S. 1931. Evolution in mendelian populations. Genetics 16:97–139.

Associate Editor: Gehrt.