	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**	G4 S3	*85.100.00	
**Calocedrus decurrens - Abies concolor / Senecio triangularis*		*85.100.05	
**Calocedrus decurrens - Alnus rhombifolia*		*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. Iyonii*		*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	

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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.

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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.

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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

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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.

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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-

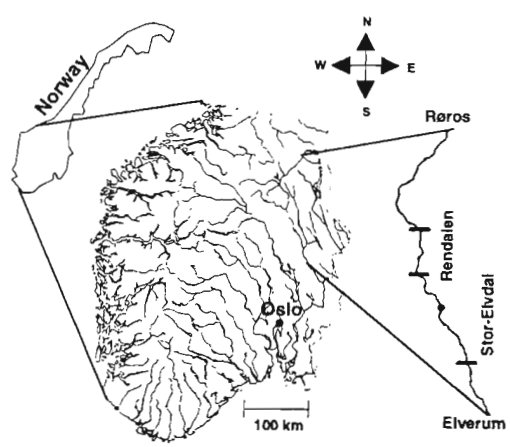

Fig. 1. The study area in Hedmark County, Norway, showing location of the Rørosbanen railway, and the 100 km section of the line including Rendalen and Stor-Elvdal municipalities analyzed in the present study. The dot along the line shows the location of the meteorological station (Evenstad).

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 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).

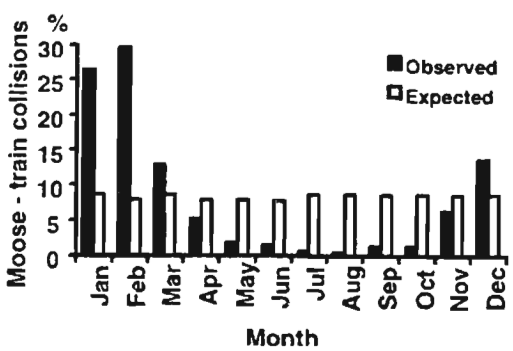

Fig. 2. Proportion of moose - train collisions per month. Goodness of fit between observed number of moose - train collisions and expected number of moose - train collisions (frequency distribution of days per month): $\chi^2 = 965.5$, 11 df, $P < 0.001$.

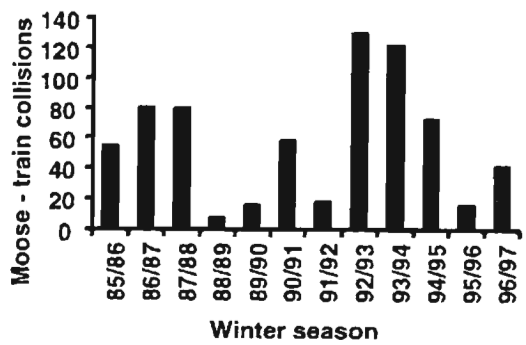

Fig. 3. The number of moose - train collisions recorded per winter season (July 1 - June 30).

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

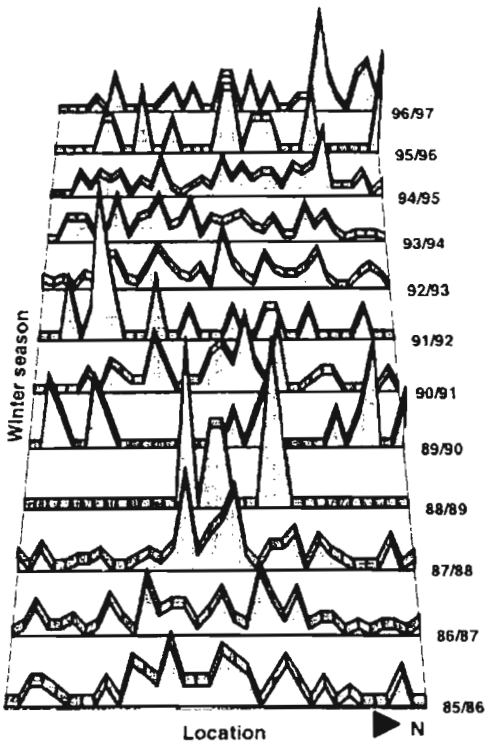

Fig. 4. The spatiotemporal variation in the number of moose-train collisions, depicted as the proportion of accidents recorded per year per 3-km along Stor-Elvdal and Rendalen municipalities. The lines were smoothed by using a running mean procedure.

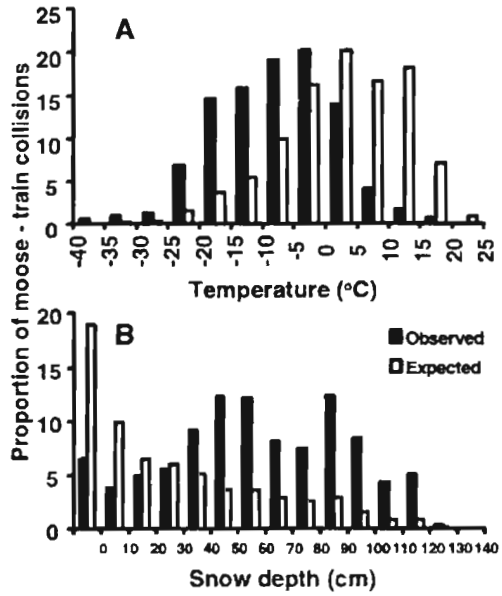

Fig. 5. (A) Proportion of days with different temperatures (expected) and proportion of train-killed moose (observed) ($\chi^2 = 851.0$, 12 df, $P < 0.001$). (B) Proportion of days with different amounts of snow (expected) and proportion of train-killed moose (observed) ($\chi^2 = 1458.0$, 14 df, $P < 0.001$).

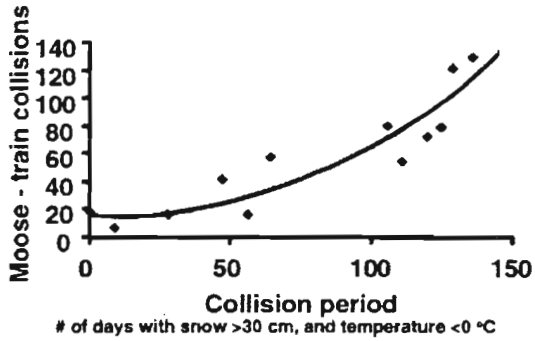

Fig. 6. The relation between the number of collisions and collision period (number of days per year starting when snow depth exceeds 30 cm and ending when the ambient temperature stabilizes above 0° C) ($F_{1,10} = 50.04$, $P < 0.001$). The number of collisions were log-transformed in the statistical analysis.

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

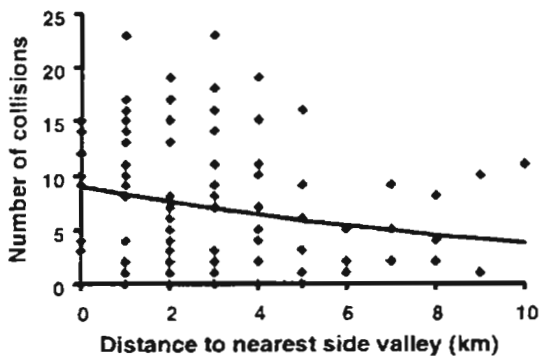

Fig. 7. The relationship between the number of collisions recorded and distance to the nearest crossing side valley. The number of collisions were log-transformed in the statistical analysis.

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

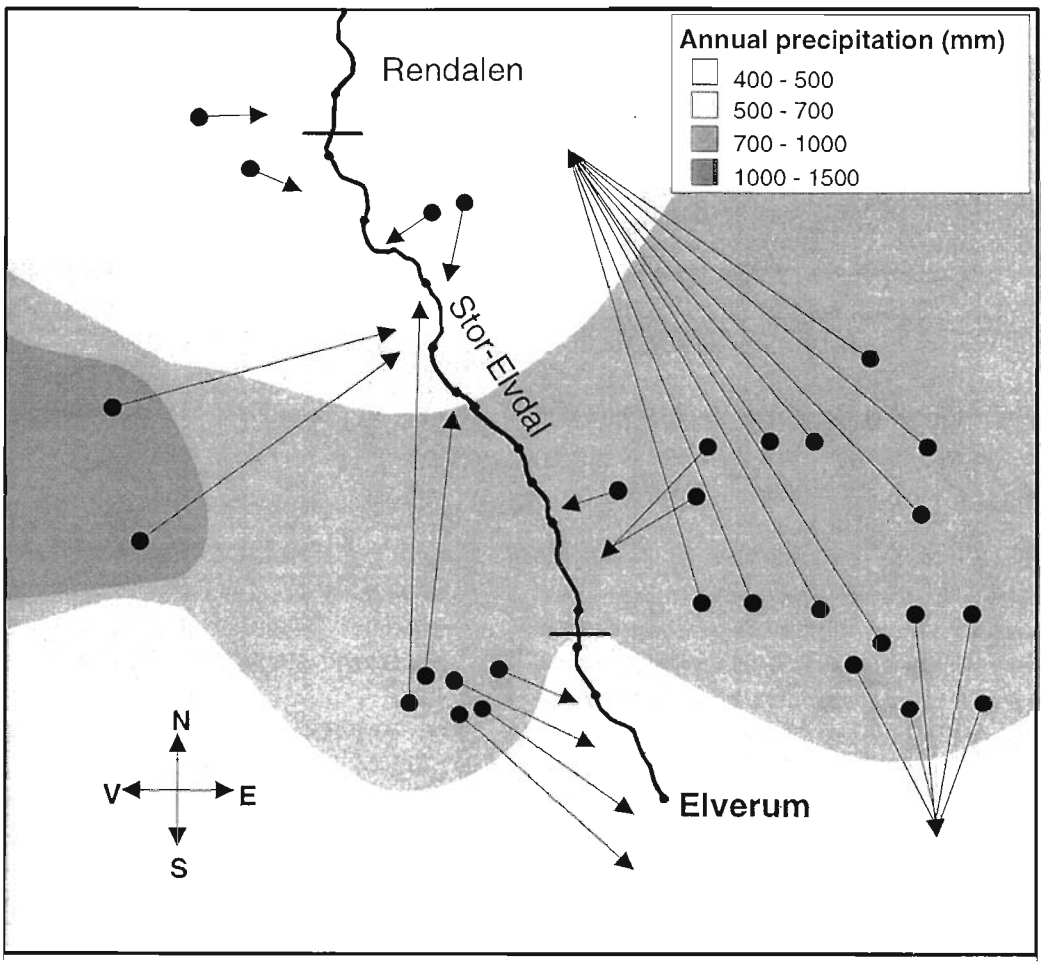

Fig. 8. Some general migratory directions for moose in Østerdalen from summer (black circles) to winter (arrows) habitats (source: Sæther and Heim 1991 and Odden *et al.* 1996) combined with a map of precipitation (source: Anonymous 1996).

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.

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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.

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Railroad-associated mortality hot spots for a population of Romanian Hermann's tortoise (*Testudo hermanni boettgeri*): a gravity model for railroad-segment analysis

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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.

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Keywords: Testudo hermanni boettgeri; road-kill; gravity model; railroad related obstacles; mitigation efforts; Romania.

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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).

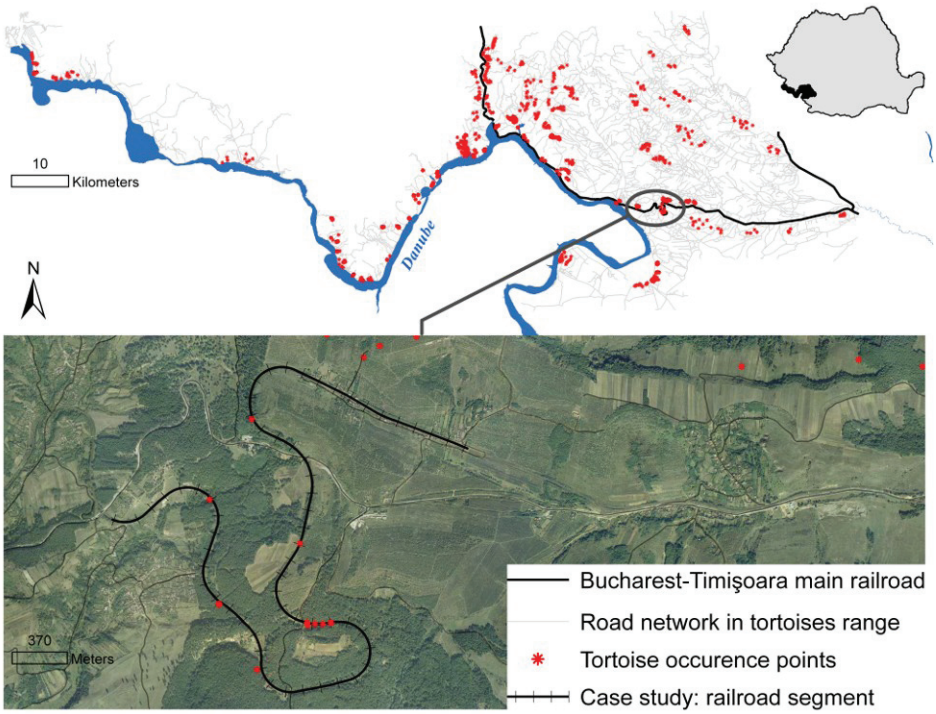

Fig. 1. Study site: a railroad segment of Bucharest-Timisoara main railroad situated on Getic Tableland, SW Romania

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.

$$W_i = u_i / \sum_{j=1}^{n} \pi_{ij} \times u_j \quad (1)$$

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].

$$T_{ij} = k \times W_i \times W_j / d^2 \quad (2)$$

$$T'_{ij} = k \times W_i \times W_j \times C / d^2 \quad (3)$$

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 > $\alpha_{critical}$.

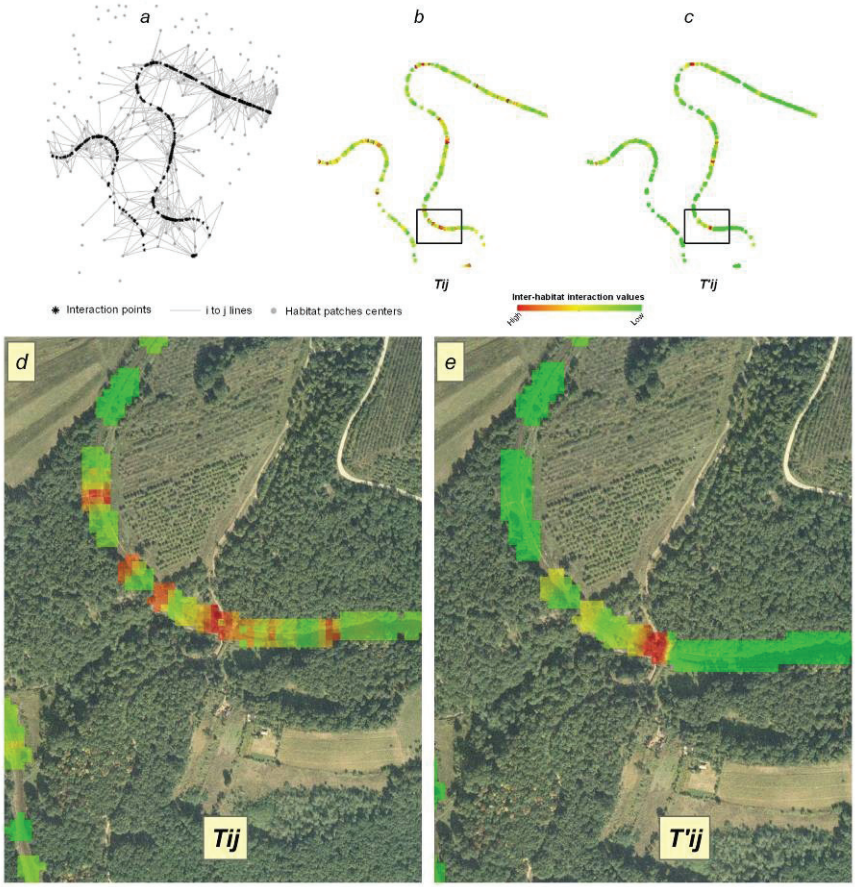

Fig. 2. Spatial interaction pattern at the railroad segment spatial scale (a) and spatial expression of gravity equation without (b) and with (c) weighting coefficient for overtaking obstacles. In the close-up, spatial extent of the hot spots is modified from a wide extending of the simple gravity equation (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].

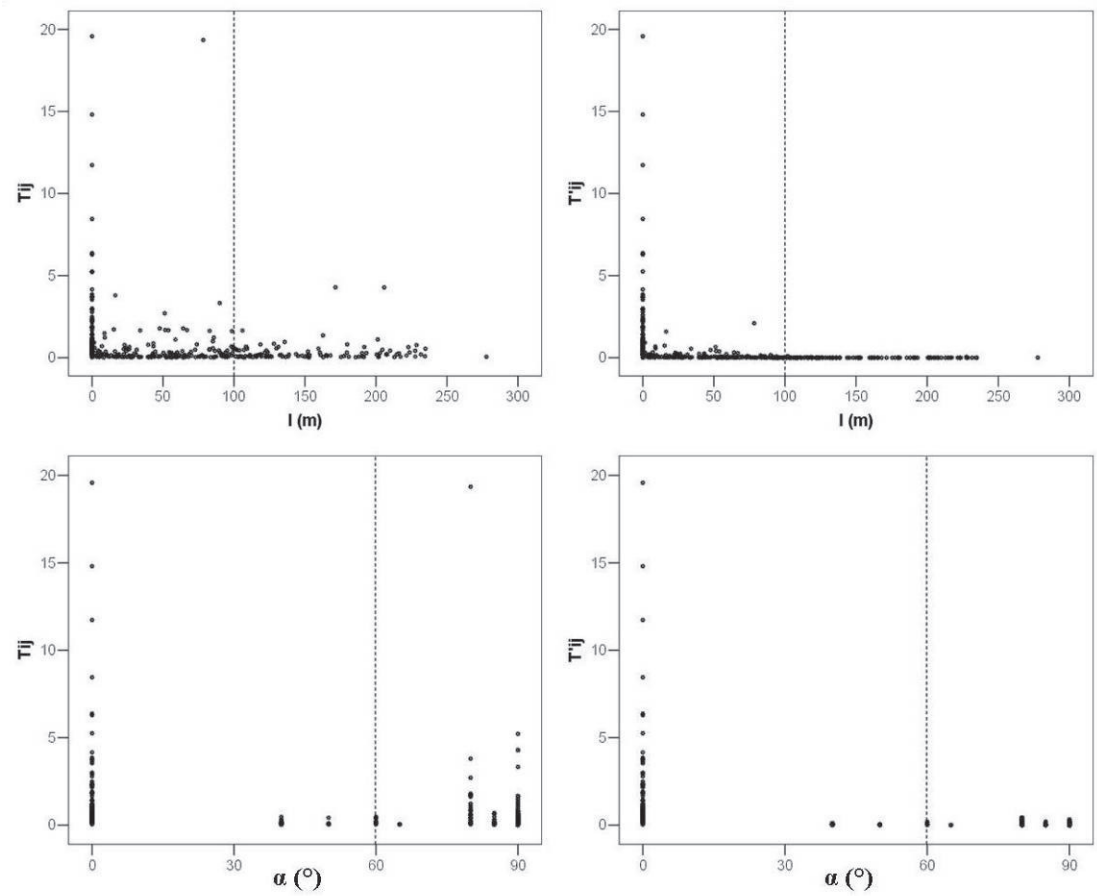

Fig. 3. Relationship between inter-habitat interaction values and the distance from interaction points to obstacles extremities (upper row) and between inter-habitat interaction values and the obstacle slope (lower row). In the left column the gravity equation does not take into account the coefficient 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.

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OVERVIEW OF TRANSPORTATION RELATED WILDLIFE PROBLEMS

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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.

Information Sharing. 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.

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Demography and Genetic Structure of a Recovering Grizzly Bear Population

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Management and Conservation Article

Demography and Genetic Structure of a Recovering Grizzly Bear Population

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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)

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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

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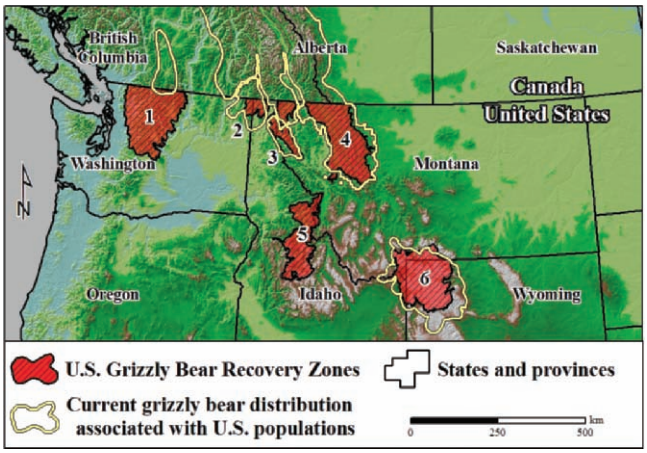

Figure 1. Location of remaining grizzly bear populations and Recovery Zones (established in the U.S. Fish and Wildlife Service [1993] Grizzly Bear Recovery Plan) south of Canada. Recovery zones: North Cascade (1), Selkirk (2), Cabinet–Yaak (3), Northern Continental Divide (4), Bitterroot (5), and Yellowstone (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.

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

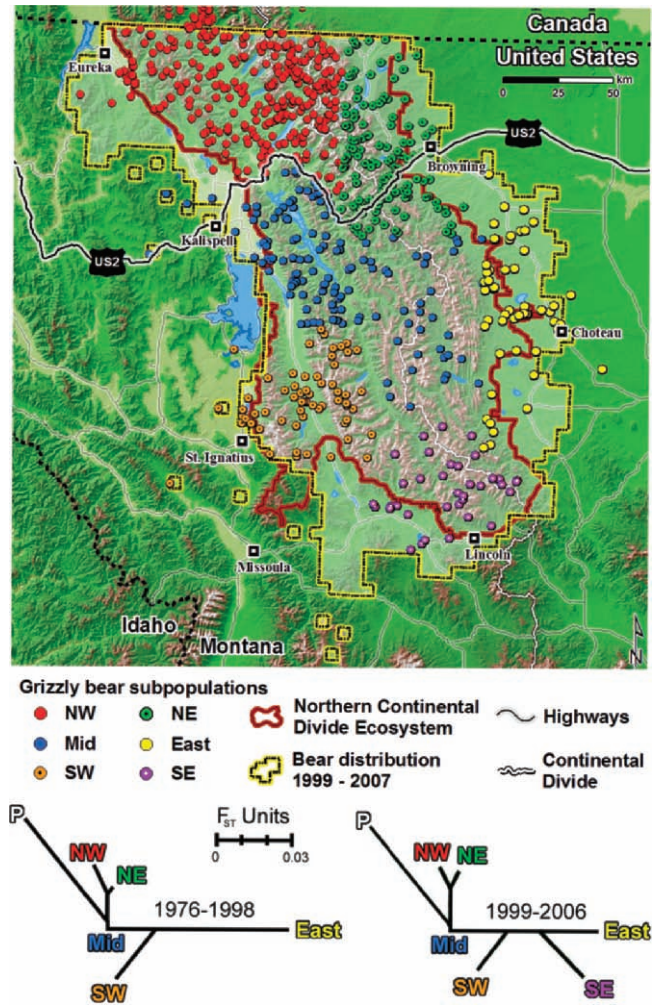

Figure 2. Change in genetic differentiation between regions within the Northern Continental Divide Ecosystem (NCDE) grizzly bear population, 1976–2006. (A) Map of region membership of grizzly bears with ≥13-locus genotypes within the NCDE as grouped by factorial correspondence analysis. Distribution 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.

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-

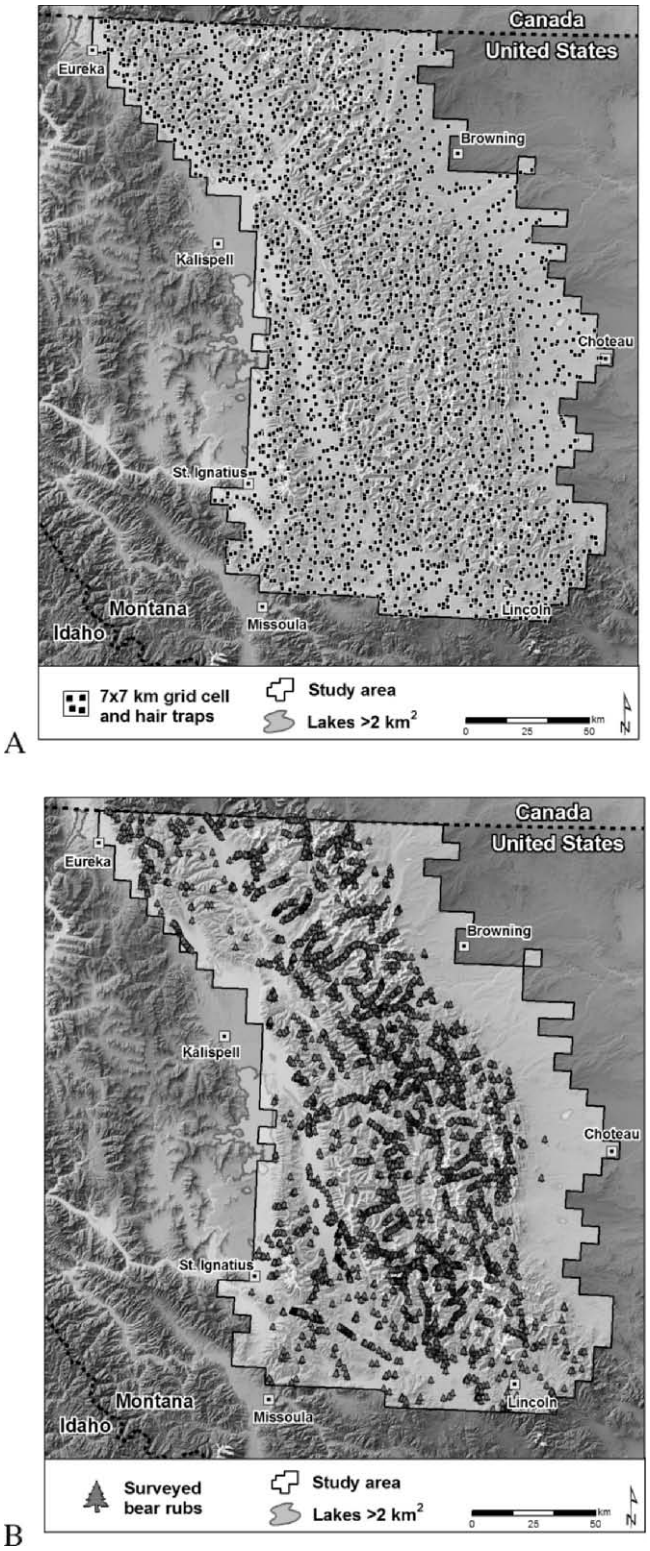

Figure 3. Location of grizzly bear hair snaring sites in the Northern Continental Divide Ecosystem, Montana, USA. (A) Location of bear hair traps (n = 2,558). We conducted hair trap sampling 15 June–18 August 2004. (B) Location of bear rubs (n = 4,795). We surveyed bear rubs on trails, forest roads, 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.

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).

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	95% log-based CI 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

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

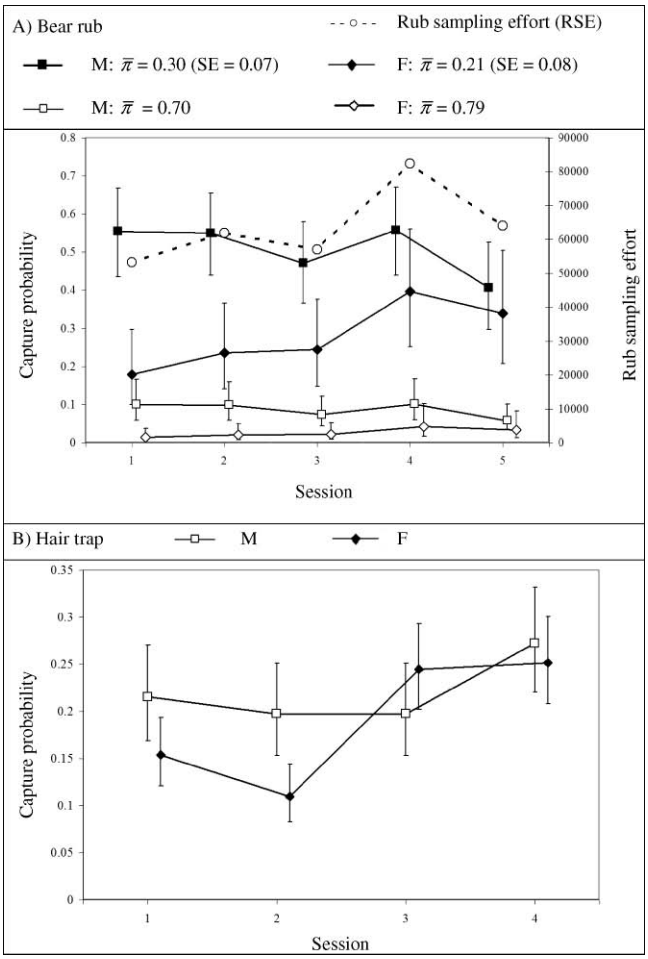

Figure 4. Gender-specific per session grizzly bear capture probability estimates from (A) bear rub surveys and (B) hair traps in the Northern Continental Divide Ecosystem, Montana, USA. Sampling sessions were 2 weeks long, beginning 15 June 2004. Pi (π) values represent the probability that an individual 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

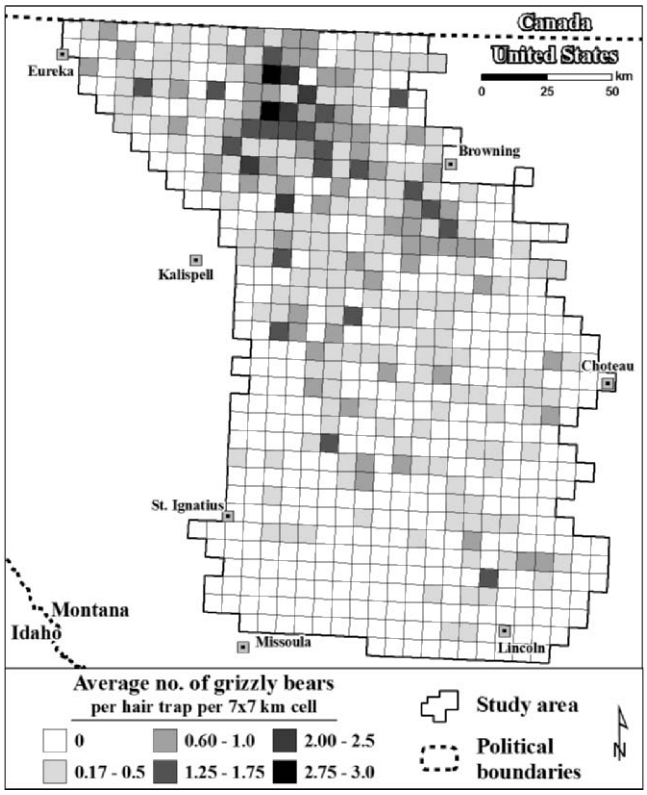

Figure 5. Relative density of grizzly bears in the 31,410-km^2 Northern Divide Grizzly Bear Project study area in northwestern Montana, USA. We conducted sampling 15 June–18 August 2004 at 2,558 hair traps systematically distributed on a 7 × 7-km grid. Because equal sampling effort was required for this 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							

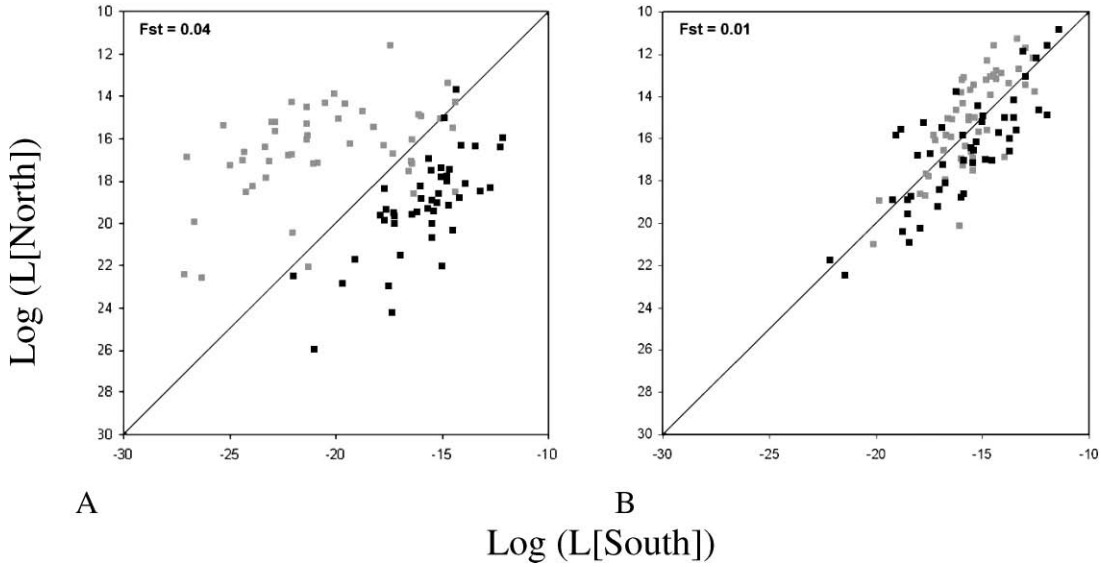

Figure 6. Genetic differentiation determined by assignment test between bears located on either side of the highway corridor for 2 segments of United States Highway 2, northwestern Montana, USA, 2004. Gray squares = bears north of highway; black squares = bears south of highway. (A) Western segment with 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.

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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.

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SYNTHESIS OF SURVIVAL RATES AND CAUSES OF MORTALITY IN NORTH AMERICAN WOLVERINES

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SYNTHESIS OF SURVIVAL RATES AND CAUSES OF MORTALITY IN NORTH AMERICAN WOLVERINES

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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.

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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

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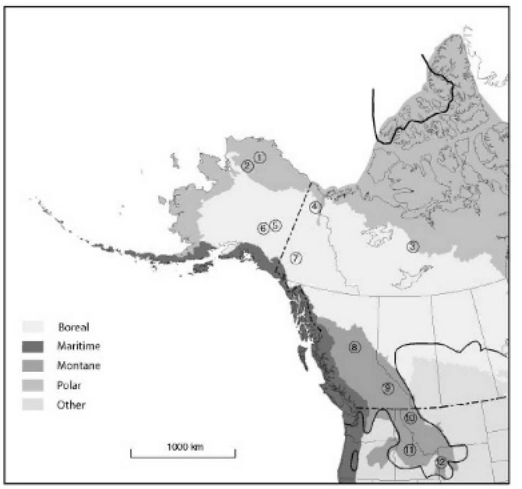

Fig. 1. Ecological zones and locations of wolverine radiotelemetry studies in western North America between 1972 and 2001. 1 = Magoun 1985; 2 = B. Shults, U.S. National Park Service, unpublished data; 3 = Mulders 2001; 4 = D. Cooley, Renewable Resources–Fish and Wildlife Branch, unpublished data; 5 = 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.

Management regime	Age–sex class	Mortality source: Natural: Predation	Natural: Starvation	Natural: Unknown	Human caused: Trapped/Hunted	Human caused: 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.

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MORTALITY OF LARGE MAMMALS ON RAILWAY TRACKS*

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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

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Tighem, 1981; Child, Stuart, 1987; Belant, 1995; Wells, 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, Iuell et al. (2003) and Trocmé (2003) state that transportation kills some 5% of the population of common species (red fox, roe deer, wild boar). Swiss research (Righetti 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 (Pfister, 1999; Iuell et al., 2003).

According to Huijser and McGowen (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 (Trocmé, 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. Further-

more, 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,

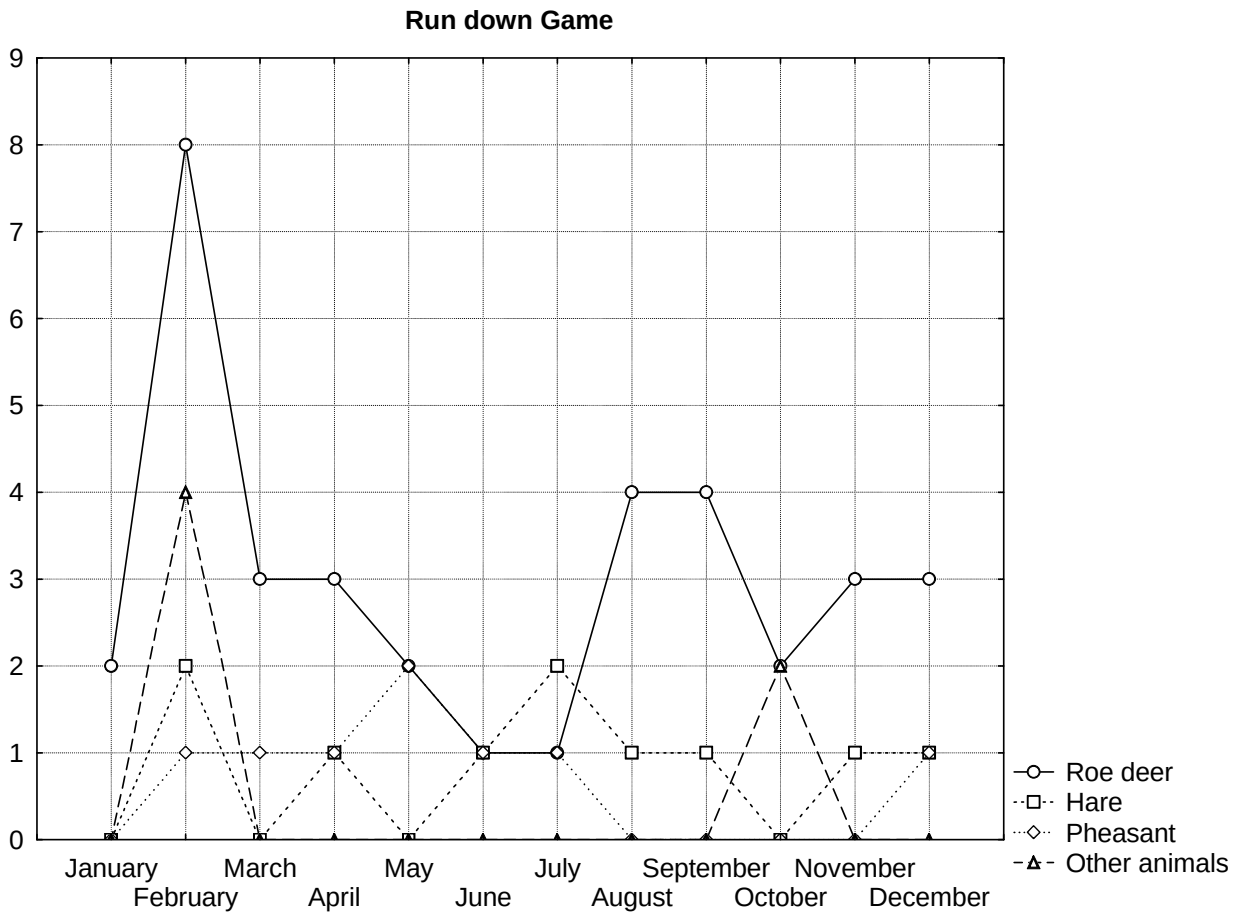
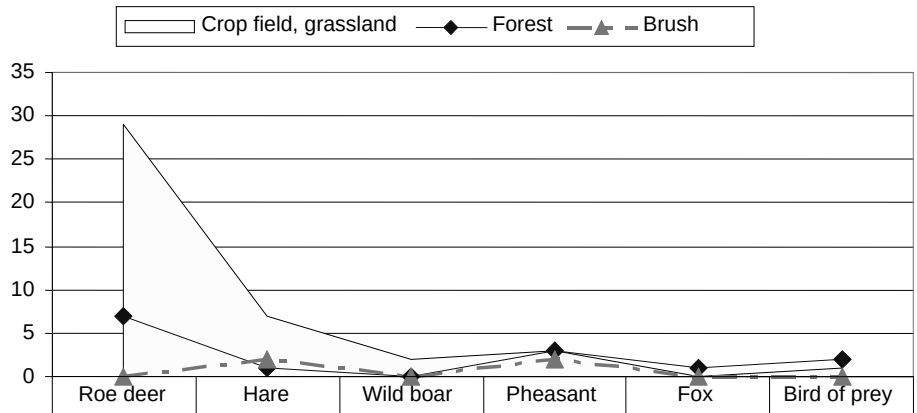


Fig. 1. Mortality of roe deer (*Capreolus capreolus*), European hare *(Lepus europaeus)* and common pheasant (*Phasianus colchicus*) and other animals in the monitored part of the railway



	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

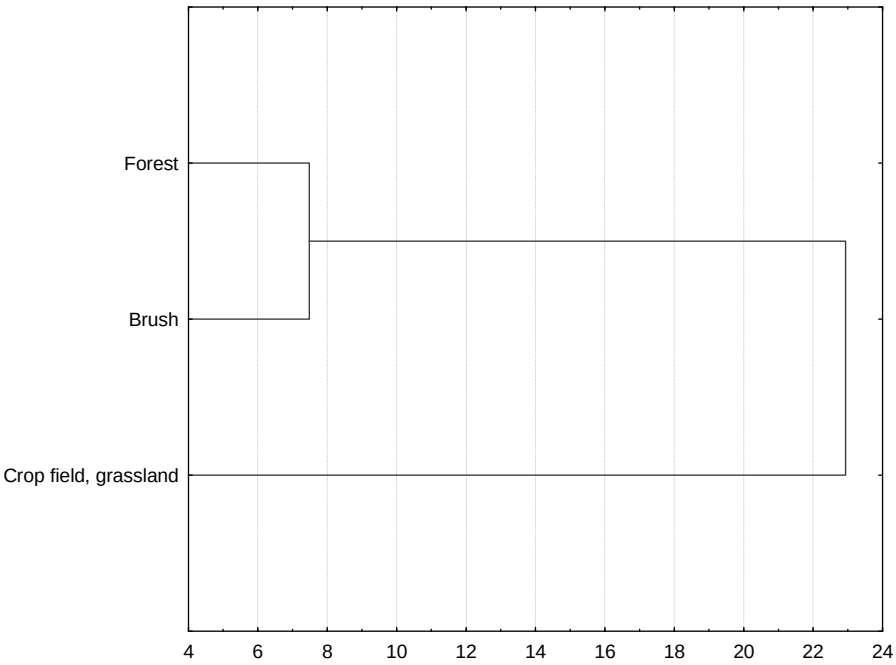


Fig. 3. Results of cluster analysis comparing animal mortality, depending on the type of environment

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 (J a n k o v s k ý , Č e c h , 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-

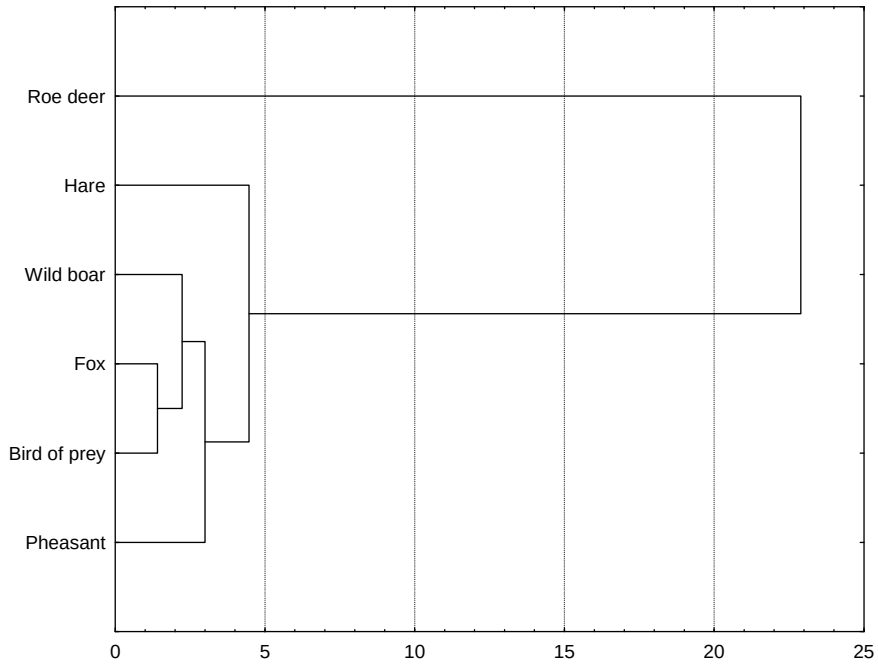


Fig. 4. Results of cluster analysis of comparing animal mortality in the monitored section of track

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 (J a n k o v s k ý , Č e c h , 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 (K u š t a , J e ž e k , 2009).

A n d r e a s s e n 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)* (M a c h , 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 (A n d ě l 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.

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Mortalita velkých savců způsobená železniční dopravou.

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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

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Deer on the railway line: spatiotemporal trends in mortality patterns of roe deer

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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

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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

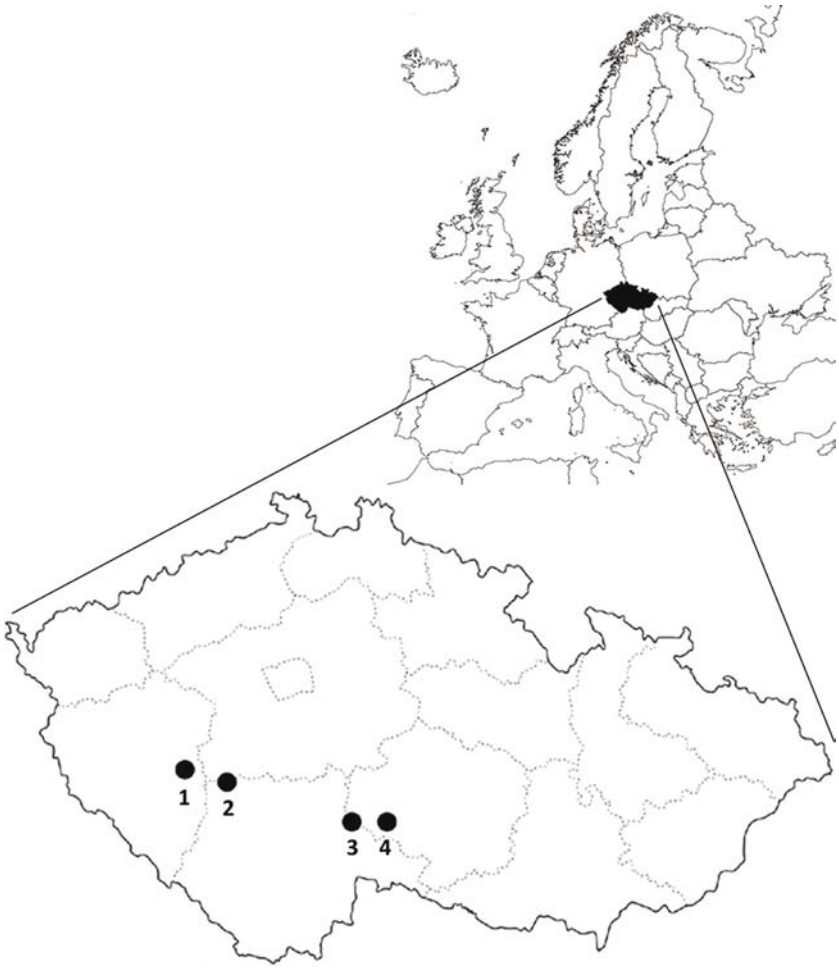

Figure 1. Location of 4 selected railway sections in the Czech Republic.

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

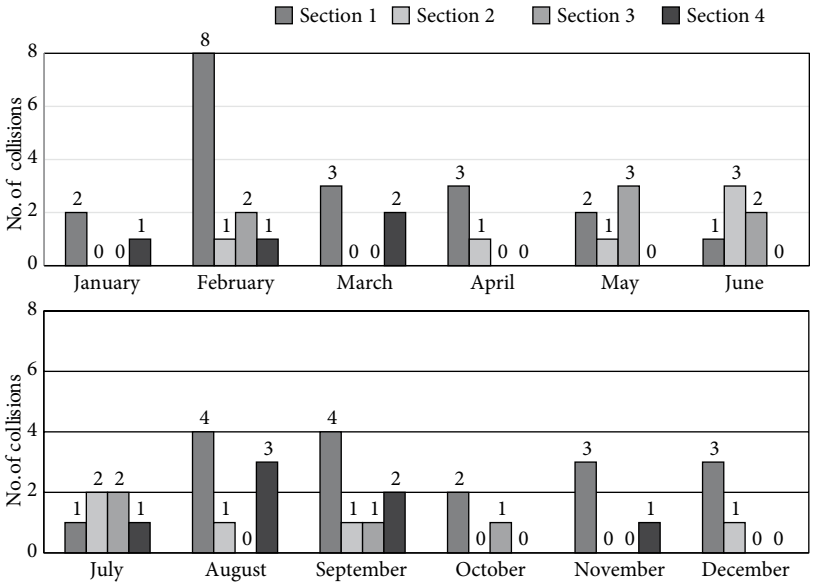

Figure 2. Bar plots showing spatial and temporal patterns of roe deer–train collisions between selected railway sections in the Czech Republic during 2009. The numbers above the bars represent the counts of collisions for each railway section during the particular month. Zero indicates that no collisions 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.

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