Northwestern Plains Golden Eagle Conservation Strategy

Prepared for U.S. Fish and Wildlife Service Western Golden Eagle Team by Teton Raptor Center.

Northwestern Plains Golden Eagle Conservation Strategy

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Disclaimer

The findings and conclusions in this article are those of the author(s) and do not necessarily represent the views of the U.S. Fish and Wildlife Service.

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List of Acronyms

AAF – Area-adjusted frequencies
ANS – Apparent nest success
APLIC – Avian power line interaction committee
AR – Anticoagulant rodenticide
BCR – Bird Conservation Region
BLM – Bureau of Land Management
BMP – Best management practice
CEC – Commission for Environmental Cooperation
CRP – Conservation Reserve Program
EPA – United States Environmental Protection Agency
FAA – Federal Aviation Administration
FGAR – First generation anticoagulant rodenticide
GPS – Global Positioning System
PRECorp – Powder River Energy Corporation
MET – Meteorological Evaluation Tower
MCP – Minimum convex polygon
NDVI – Normalized difference vegetation index
NLCD – National Land Cover Database
NND – Nearest neighbor distance
NSO – No-surface-occupancy
NPS – National Park Service
NWPL – Northwestern Plains conservation assessment region
RND – Relative nest site density
RSF – Resource selection function
RWD – Relative winter density
SGAR – Second generation anticoagulant rodenticide
SOS – Strength of selection
USDA – United States Department of Agriculture
USFS – United States Forest Service
USFWS – United States Fish and Wildlife Service
USGS – United State Geological Survey
WGET – Western Golden Eagle Team
WNv – West Nile Virus

Ecoregional Conservational Strategies for Golden Eagles

Diversification of U.S. energy supplies will require increasing reliance on landscape-scale assessments of development risk to vulnerable wildlife species. Vulnerability of golden eagles to collision with wind turbine blades, combined with legal protection under the Bald and Golden Eagle Protection Act, has stimulated considerable research into mortality risk and mitigation strategies for this species. Comprehensive conservation planning for this species, however, is lacking. In 2013, the U.S. Fish and Wildlife Service established the Western Golden Eagle Team (WGET) to develop landscape-scale conservation strategies to support management of golden eagles in the western U.S.

To account for geographic variation in golden eagle distribution, habitat associations, prey communities, and population limiting factors, WGET developed conservation strategies at the scale of Level III Ecoregions (Commission for Environmental Cooperation 1998). This enables the strategies to serve as landscape-specific assessments that can be scaled up to Bird Conservation Regions (Level II Ecoregions) and Flyways.

Each **Ecoregional Conservation Strategy** consists of two parts: a technical assessment of current information pertaining to golden eagles, and a regional conservation strategy for the species.

The Conservation Assessment provides information resources, data, and predictive models to support eagle management, including:

- Review and synthesis of published information, local research results, and current research on golden eagle populations, habitat associations, diet, prey communities, and population limiting factors;
- Results of ecoregion-specific predictive modeling of habitats used for breeding, wintering, and movement; and
- Results of ecoregion-specific analyses and modeling of threats such as electrocution, collisions with vehicles, and exposure to contaminants.

The Conservation Strategy is based on information and modeling results compiled in the assessment, and provides tools and management approaches for direct application in eagle conservation, including:

- Ecoregion-specific risk assessments and decision support tools for energy development, mitigation, and eagle conservation planning;
- Spatial prioritization modeling to identify areas of high resource value and high risk; and

- Integration with State, Flyway, Tribal, and other regional conservation planning efforts for golden eagles, as well as plans for other species of concern, such as greater sage-grouse.

Development and implementation of conservation strategies required collaboration of numerous stakeholders, including State and Federal agencies, research institutions, industry, Tribes, and NGOs. As work on each ecoregional strategy was initiated, WGET and partners strove to identify and coordinate with regional entities involved in eagle research and management. Our conservation strategies are intended to be complementary to State and Flyway management plans for golden eagles by providing new conservation planning tools and best-available information.

I. Conservation Assessment

The Conservation Assessment is a technical review of current information pertaining to golden eagles within the Northwestern Great Plains and portions of the Northwestern Glaciated Plains regions. The assessment provides information resources, data, and predictive models to support eagle management and identify key gaps in knowledge. These include review and synthesis of published information, local research results, and current research on golden eagle populations, including seasonal information on density, space-use, habitat associations, fecundity, diet, prey communities, and population ecology, including regional status and population limiting factors.

1. Introduction to Conservation Strategy Area

The area addressed by this assessment (Figure 1.1) includes the Northwestern Great Plains ecoregion and a large portion of the Northwestern Glaciated Plains ecoregion between the Missouri River and the Canada border, as defined by the Commission for Environmental Cooperation (Level III CEC; Wiken et al. 2011). We modified the eastern border of the Northwestern Glaciated Plains ecoregion using the US Forest Service (USFS) Ecological subsections (i.e., Kuchler Sections, Ecomap) division between the Glaciated Northern Grasslands and the Northeastern Glaciated Plains (McNab et al. 2007). The USFS subsections included in this assessment are the Northwestern Glaciated Plains and Glaciated Northern Grasslands because golden eagle breeding ecology is similar between the two ecoregions and the Northwestern Great Plains. The remainder of the Northwestern Glaciated Plains was not included because nesting records of golden eagles were not known to occur within the largely agricultural dominated habitats to the east. We renamed this combined conservation strategy area to the Northwestern Plains (hereafter NWPL) to avoid confusion with the CEC and USFS nomenclature.

The models developed by the US Fish and Wildlife Service (USFWS) Western Golden Eagle Team (WGET) include a 6.4-km (4-mi) spatial buffer surrounding the NWPL boundary to incorporate golden eagles that may be nesting just outside the boundary polygon but using the NWPL for foraging. The northern border of the modeling extent along the United States/Canada border does not include this buffer. The Black Hills section of the Middle Rockies ecoregion was included in describing the NWPL, habitat modeling, and conservation assessment of this document because it was not in proximity to the main portion of the Middle Rockies ecoregion (which was also not modeled at the time of this report).

1.1. Geographic boundaries

The NWPL encompasses the majority of eastern Montana, northeast Wyoming, the western Dakotas, and a small portion of northern Nebraska (Figure 1.1). Within the NWPL, there are several isolated small mountain ranges (Sweetgrass Hills, Bears Paw, Highwood, and Little Rocky) that are considered part of the Middle Rockies Level III CEC ecoregion but are included in this assessment due to their small and isolated nature compared to other ranges within the NWPL (Big Snowy and Black Hills). Excluding those two larger ranges, the total area within the NWPL is 42.53 million ha (425,363.98 km^2). The majority of the NWPL is within Montana (51.6%; 219,484.20-km^2) followed by South Dakota (22.4%; 95,332.74 km^2), North Dakota (12.9%, 54,775.20 km^2), Wyoming (11.8%; 50,102.86 km^2), and Nebraska (1.3%; 5,660.61 km^2).

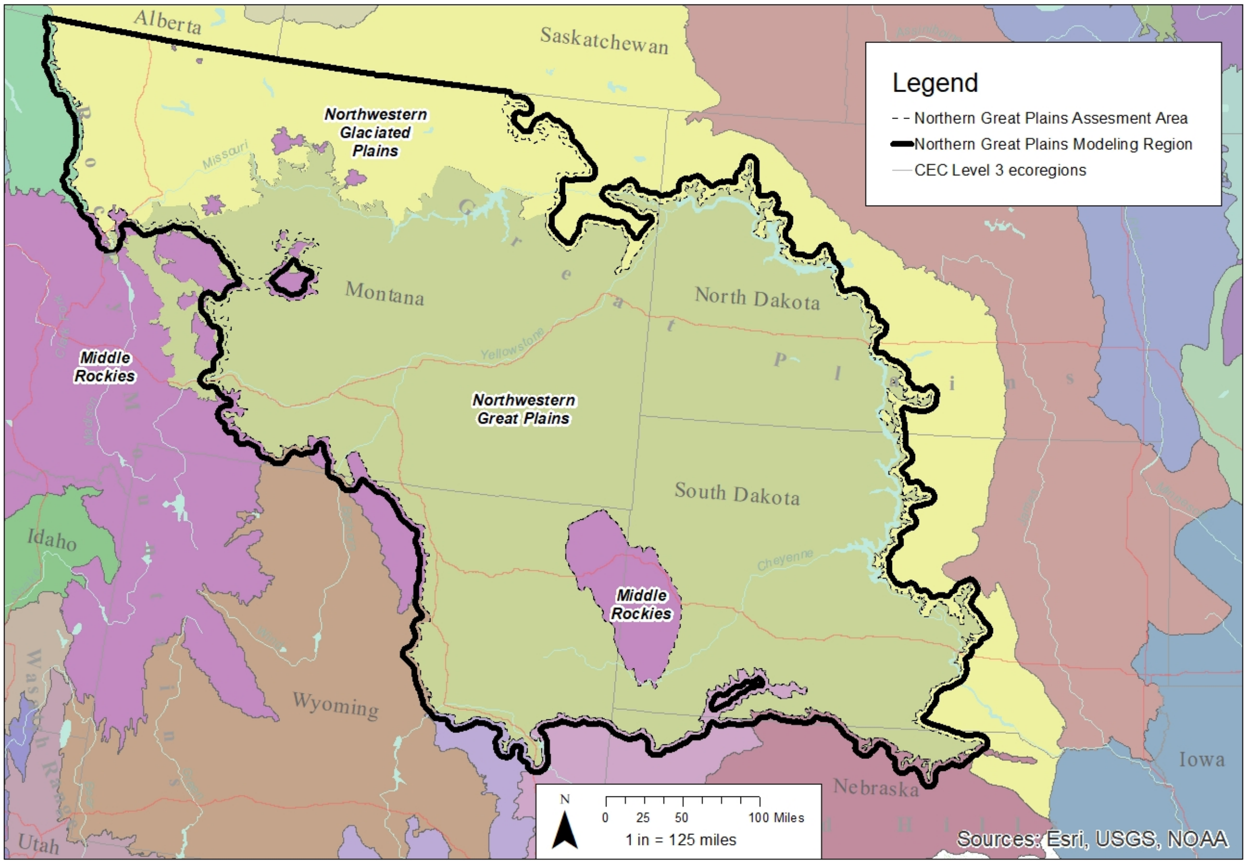


Figure 1.1 The Northwestern Plains (NWPL) Golden Eagle Conservation Assessment area and modeling region. The NWPL encompasses 425,355.60-km^2 in portions of Montana, South Dakota, North Dakota, Wyoming, and Nebraska.

1.2. Geographic and Geologic Features

1.2.1. Topography

The NWPL is mainly an unglaciated, semi-arid grassland/shrubland of the Great Plains that encompasses the Missouri Plateau. The Rocky and Bighorn Mountains comprise much of the western border, while agricultural habitat dominates the eastern border. The Glaciated Plains extend beyond the Canada border to the north and are likely similar, but this plan does not address regions north of the conterminous United States. The NWPL is mainly rolling plains of shale, siltstone, and sandstone-derived soils punctuated by occasional buttes and badlands. Badlands and flat-topped buttes typically have eroded escarpments with soft soils. The plains have shallow soils with high clay content that is generally not conducive for crop agriculture.

Elevation ranges from 413–2800 m, with elevation generally decreasing from west to east. The Missouri River comprises the majority of the eastern NWPL boundary, while several large prairie rivers [>5th order and >322-km (200-mi) long; Strahler 1957] transect the region (Figure 1.2). The entire NWPL falls within the Missouri River watershed [Hydrologic Unit Code (HUC) 2] that can be classified into 14 subregions (HUC 4, Figure 1.2) or 22 basins (HUC 6). The rivers are generally fed by intermittent prairie or mountain streams. Waterways flow northward towards the Yellowstone or Missouri in Montana and Wyoming, while streamflow is easterly in the Dakotas and Nebraska.

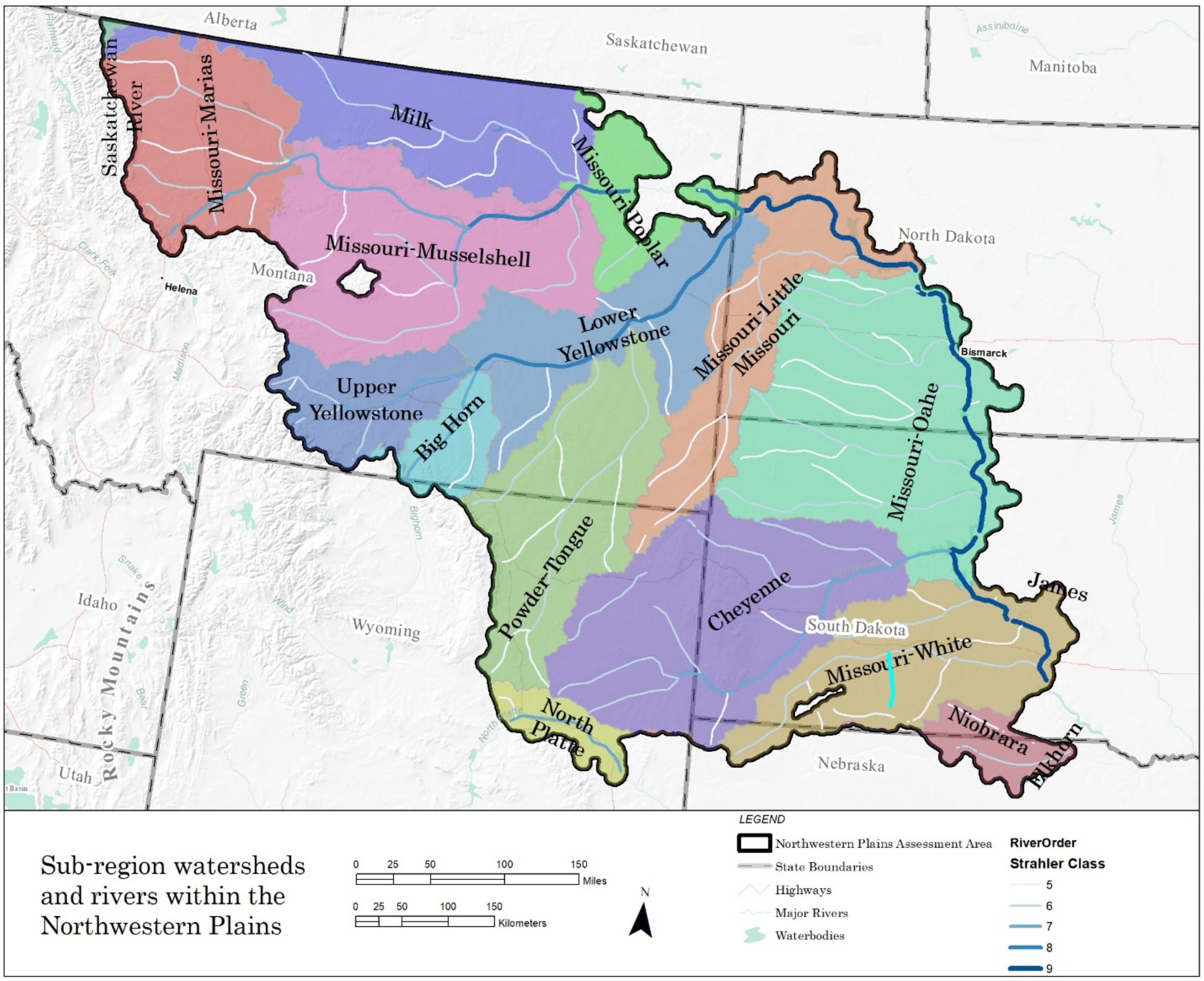
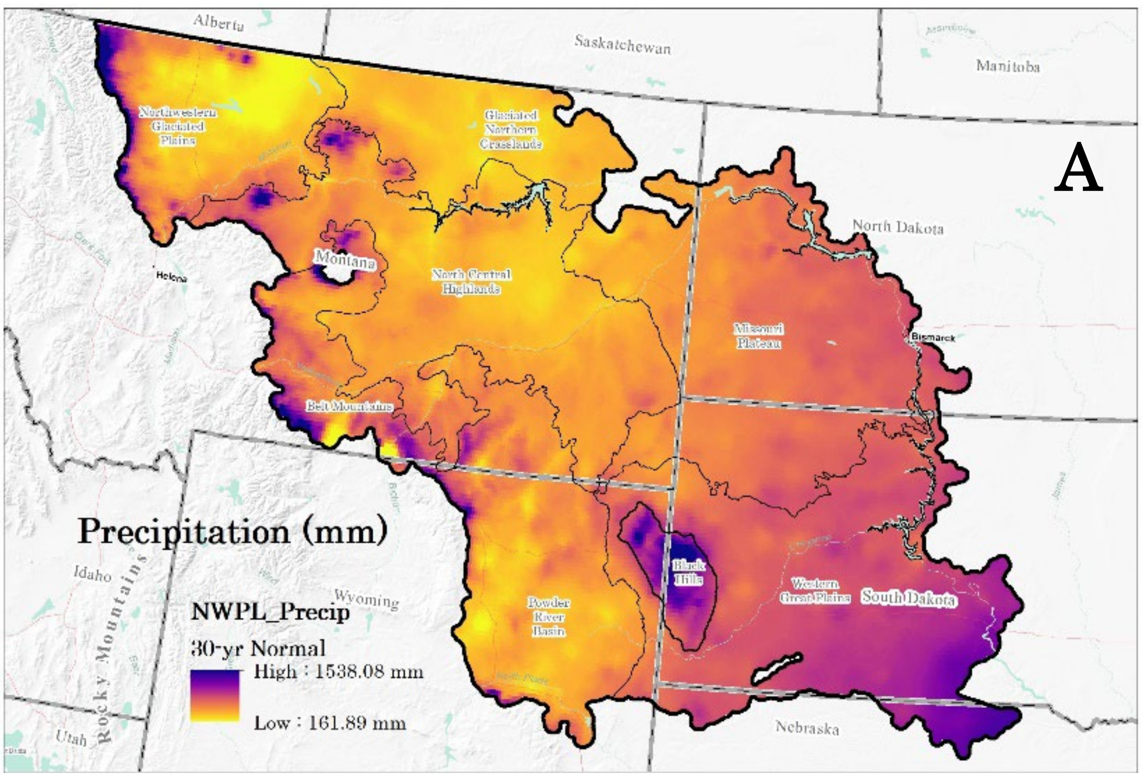


Figure 1.2. Level 4 Hydrologic Unit Code watersheds and >5th order streams (Straher classification) within the Northwestern Plains conservation assessment area.

1.2.2. Climate

Because of the large area within the NWPL, regional variation in temperature and precipitation can vary widely across the region. Precipitation varies annually with a 30-yr (1981-2010) average ranging from 185–937 mm (PRISM Climate Group 2014, Figure 1.3). The amount of precipitation increases from west to east and the highest amounts occurring in South Dakota and Nebraska. Pockets of high precipitation occur in the isolated mountain ranges and in the foothills along the western edges of the NWPL, which typically falls as snow. The Northwestern Great Plains is the driest region within the NWPL but the Powder River Basin and Glaciated Northern Plains also experience relatively little precipitation.

More importantly than average precipitation is the annual variability and seasonality of precipitation. Winters can be extremely cold with strong and consistent desiccating winds. Minimum annual average temperature ranges from -5.0–3.1 ºC. Northern latitudes are generally colder but the Powder River Basin also remains relatively cool throughout the year. Southern South Dakota and the area near Billings remain relatively warm. The growing season is generally 100–160 days (McNab and Avers 1994).



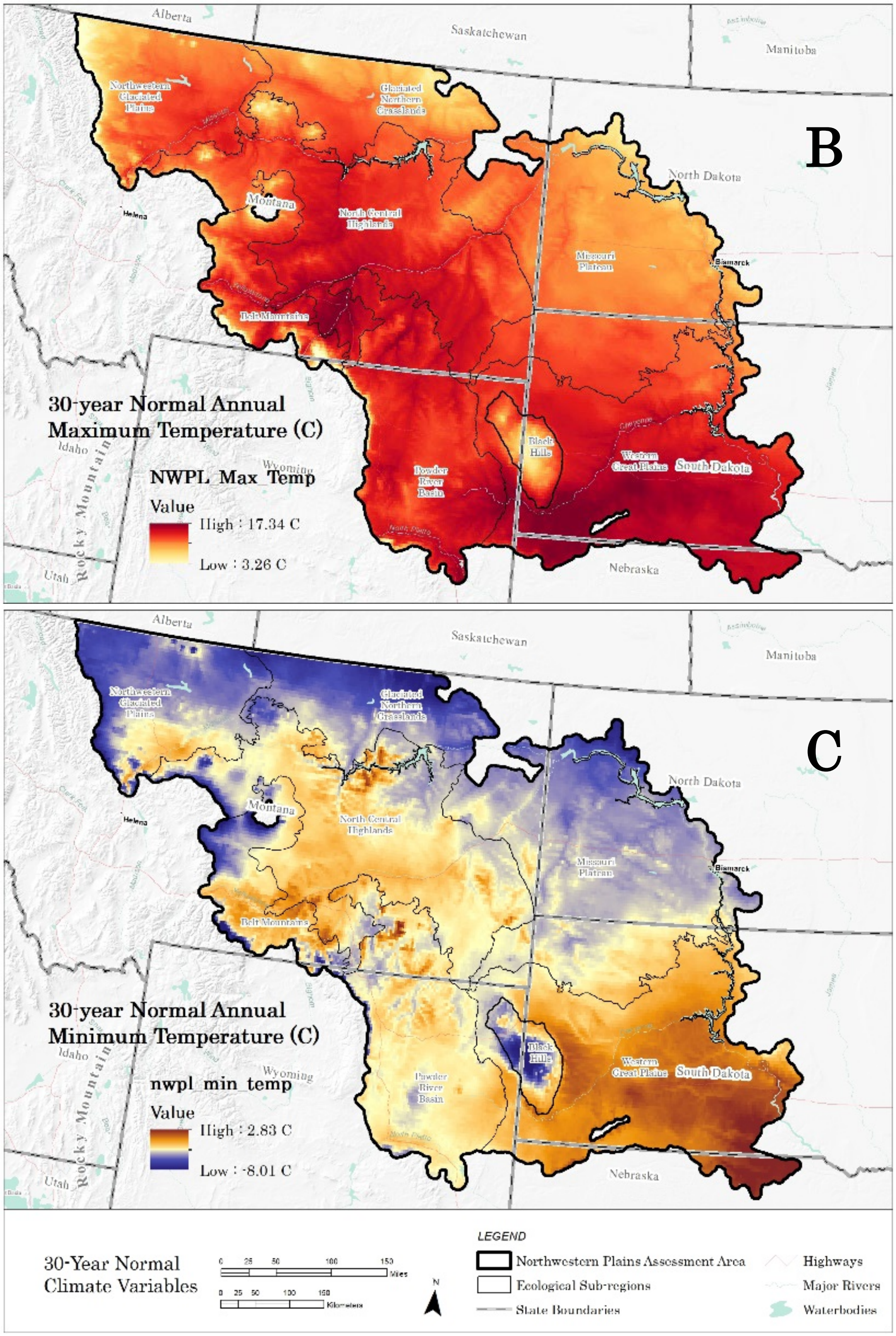


Figure 1.3. Climate of the Northwestern Plains conservation assessment area. **A.** Mean annual precipitation (mm), **B.** maximum temperature (°C) and **C.** minimum temperature (°C), 1981-2010. (PRISM Climate Group 2014)

1.2.3. Vegetation

Native prairies cover the majority of the region and include western wheatgrass (*Pascopyrum smithii),* needlegrasses (*Achnatherum* spp., *Nassella* spp., *Stipa* spp.), blue grama (*Bouteloua gracilis*), needle-and-thread (*Hesperostipa comata*), and buffalograss (*Bouteloua dactyloides*). Bluebunch wheatgrass (*Pseudoroegneria spicata*), little bluestem (*Schizachyrium scoparium*) and sideoats gama (*Bouteloua curtipendula*) occur in shallow soils (Barker and Whitman 1988). Mixed grass prairies dominate the landscape but shortgrass and long grass prairies all exist within the NWPL. Dominant shrubs include serviceberry (*Amelanchier* spp.), skunkbush sumac (*Rhus trilobata*)*,* snowberry (*Symphoricarpos* spp.), silver buffaloberry (*Sheperdia argentea*), shrubby cinquefoil (*Potentilla fruticosa*), silverberry (*Elaeagnus commutata*) and creeping juniper (*Juniperus horizontalis*). Silver sagebrush (*Artemisia cana*) shrublands occur on flat alluvial deposits of floodplains, terraces or benches, and alluvial fans. Several large expanses of big sagebrush (Artemesia tridentada) steppe and understory grasses include Idaho fescue (*Festuca idahoensis),* spike fescue (*Leucopoa kingii*), or poverty oatgrass (*Danthonia spicata).* Mat saltbrush shrubland occurs in limited patches across the NWPL, comprised mainly of Gardner's saltbush (*Atriplex gardneri*) and/or birdfoot sagebrush (*Artemisia pedatifida).* Shallow soils with high clay content allow for the sparse and short grassland habitats across the NWPL. These habitats are poor for cultivated cropland but provide cover for golden eagle prey species such as leporids and sciurids. In the eastern portions of the NWPL, soils and climate generally become more conducive for agriculture.

Trees provide important nest sites for breeding Golden eagles across the NWPL. Ponderosa pine (*Pinus ponderosa*) is the dominant conifer on buttes and breaks, while juniper (*Juniperus* spp.) are common in draws. Cottonwoods (*Populus* spp.) are the dominant tree species along most riparian corridors, streams, irrigation ditches, and other major drainageways (mainly *Populus deltiodes*). Cottonwoods also occur at homesteads, abandoned irrigation ditches, water impoundments or ephemeral streams, often occurring as a single tree and not classified using remote sensing techniques. Other deciduous trees in the NWPL include quaking aspen (*Populus tremuloides*), boxelder (*Acer negundo*), green ash (*Fraxinus pennsylvanica*), American elm (*Ulmus americana*), American plum (*Prunus americana*), and Rocky Mountain maple (*Acer glabrum*).

From 1986 to 2000, the largest shift in land use was from agriculture to grassland/shrubland, likely a result of the Conservation Reserve Program (CRP) implemented in 1985 (Drummond 2007). Using the 2015 edition of the 2001 to 2011 National Land Cover Database (NLCD) land cover change index (Homer et al. 2015), only 1.57% of the NWPL experienced change in that decade. Contrary to the previous decade, the largest land cover conversion was from one native cover class to another native cover class (0.86%); only 0.39% of the NWPL was converted from native to non-native vegetation, as classified by the NLCD change index. However, the NLCD change index does not take into account introduction and expansion of invasive species such as cheatgrass (*Bromus tectorum*), smooth brome (*Bromus inermis*), and Kentucky bluegrass (*Poa pratensis*). These invasive species continue to increase and threaten native grasslands throughout the region (DeKeyser et al. 2013, Ellis-Felege et al. 2013).

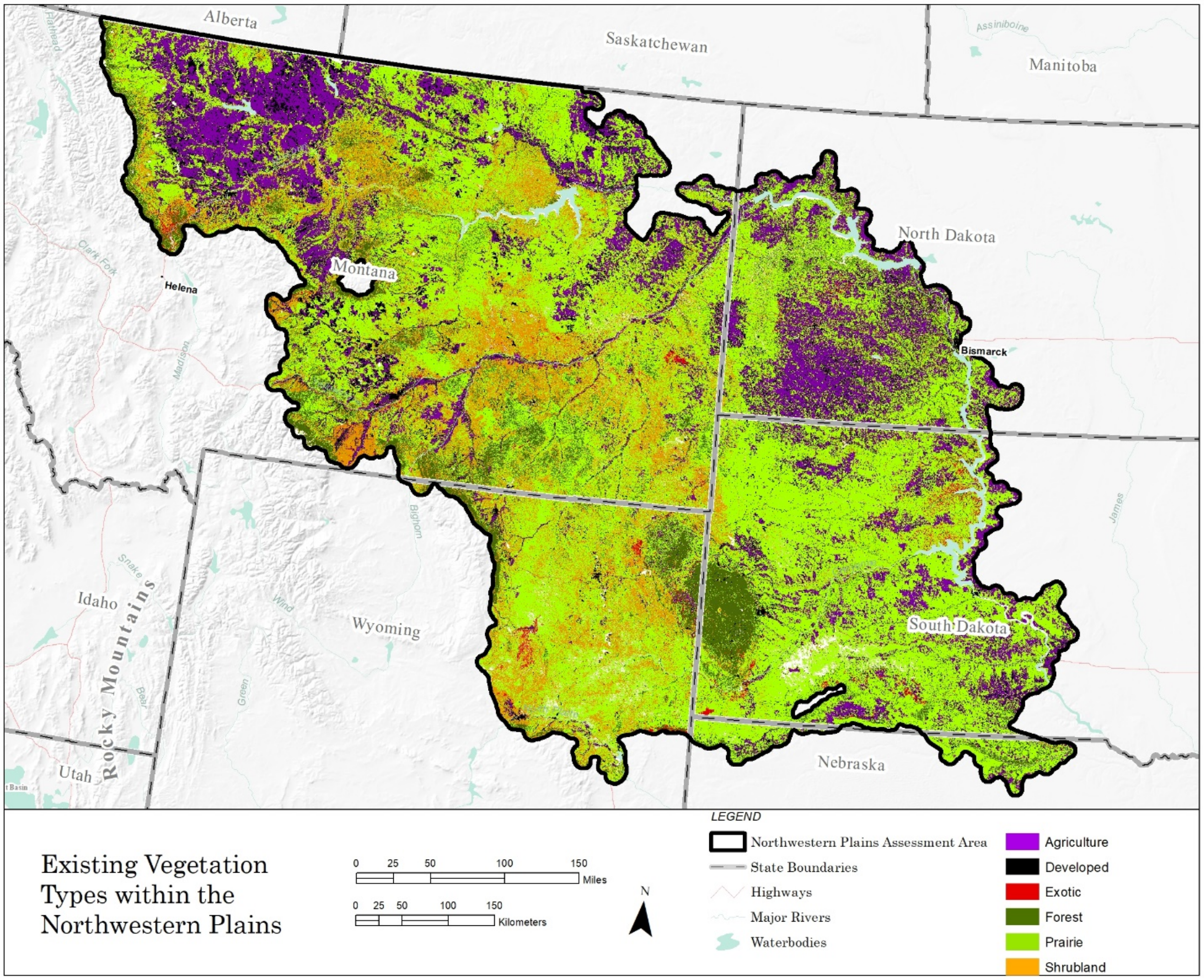


Figure 1.4. Classified vegetation types within the Northwestern Plains (LANDFIRE 2016). See Table 1.1 for descriptions of vegetation types.

Table 1.1. Land cover in the Northwestern Plains conservation assessment area. Categories are groupings of existing vegetation types from LANDFIRE 1.4.0 (LANDFIRE 2016)

Category	Type	Area km^2	% of NWPL	Description
Grasslands	Prairie	240,670	51%	All prairie types combined
	Other Grassland	6,896	1%	Grassland, mountain meadow, and transitional herbaceous vegetation
Anthropogenic	Agricultural	73,825	15%	Mainly wheat fields and fallow/idle cropland with some row crop and pasture
	Developed	34,079	7%	Mostly developed grasslands. Includes roads, cities and other developed habitat
	Exotic	5,537	1%	Introduced grassland/forbs
Shrublands	Sagebrush Steppe	56192	12%	Mostly big sagebrush steppe with some greasewood and other shrubland/scrub
	Shrubland/Scrub	4,006	1%	Mainly greasewood with mountain mahogany shrubland
Forests	Riparian	17,501	4%	Cottonwood dominated riparian and floodplains
Woodlands	Conifer Forest	24483	5%	Mostly ponderosa pine forests with a small amount Douglas-fir and other pine forests
	Hardwood Forest	1,416	0%	Bur oak savannah and aspen forests
Other	Sparse Vegetation/Barren	6,487	1%	No dominant lifeform
	Open Water/Snow/Ice	5,910	1%	

1.2.4. Sub-regions of the Northwestern Plains

The patterns of topography, hydrology, climate, vegetation, and land use described above are the basis for the classification of the NWPL into level-IV ecoregions, which illustrate clearly the key habitat types in the area (Chapman et al. 2004; Figure 1.5). There are 38 Level IV ecoregions within the NWPL and portions of an additional 40 Level IV ecoregions encompassed within the 6.4 km buffer zone of the modeling area. Within the NWPL, most Level IV ecoregions are less than 5% of the total area. The predominant Level IV ecoregions are the Missouri Plateau (13.3%), Montana Central Grasslands (12.9%), River Breaks (8.2%), Powder River Basin (7.5%), Glaciated Northern Grasslands (6.4%), and North Central Brown Glaciated Plains (6.3%).

To aid in model validation and conservation assessments, the NWPL modeling area was also described using the USFS ecological Kuchler subsections (McNab et al. 2007, Figure 1.6) Within the modeling extent, we slightly modified the boundaries into eight sections and extended the outer boundaries of sub-sections to our modeling extent. Glaciated plains and grasslands make up most of the area north of the Missouri River in Montana. The Belt Mountains, North Central Highlands, and Missouri Plateau bisect the central portion of the NWPL while the Powder River Basin and Western Great Plains sections lie to the south. The Black Hills comprise the mainly coniferous, rugged habitat along the Wyoming, South Dakota border.

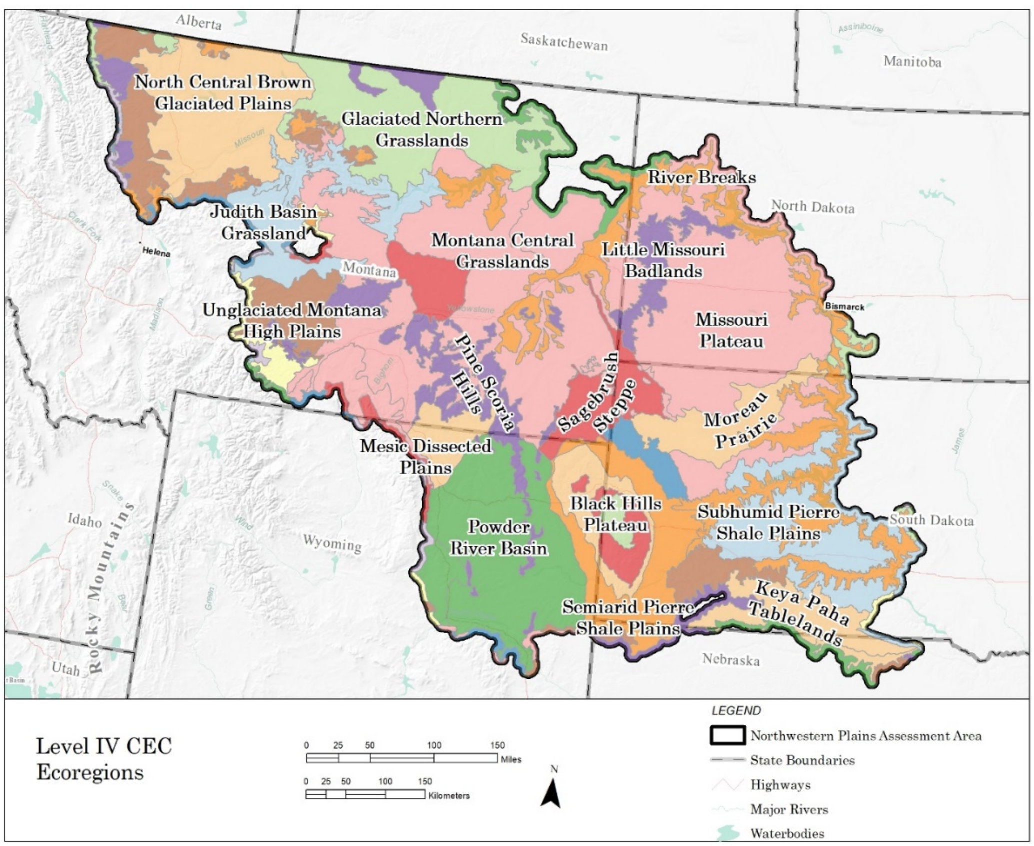


Figure 1.5 Level IV Commission for Environmental Cooperation ecoregions within the Northwestern Plains conservation assessment area. Smaller ecoregions not labeled.

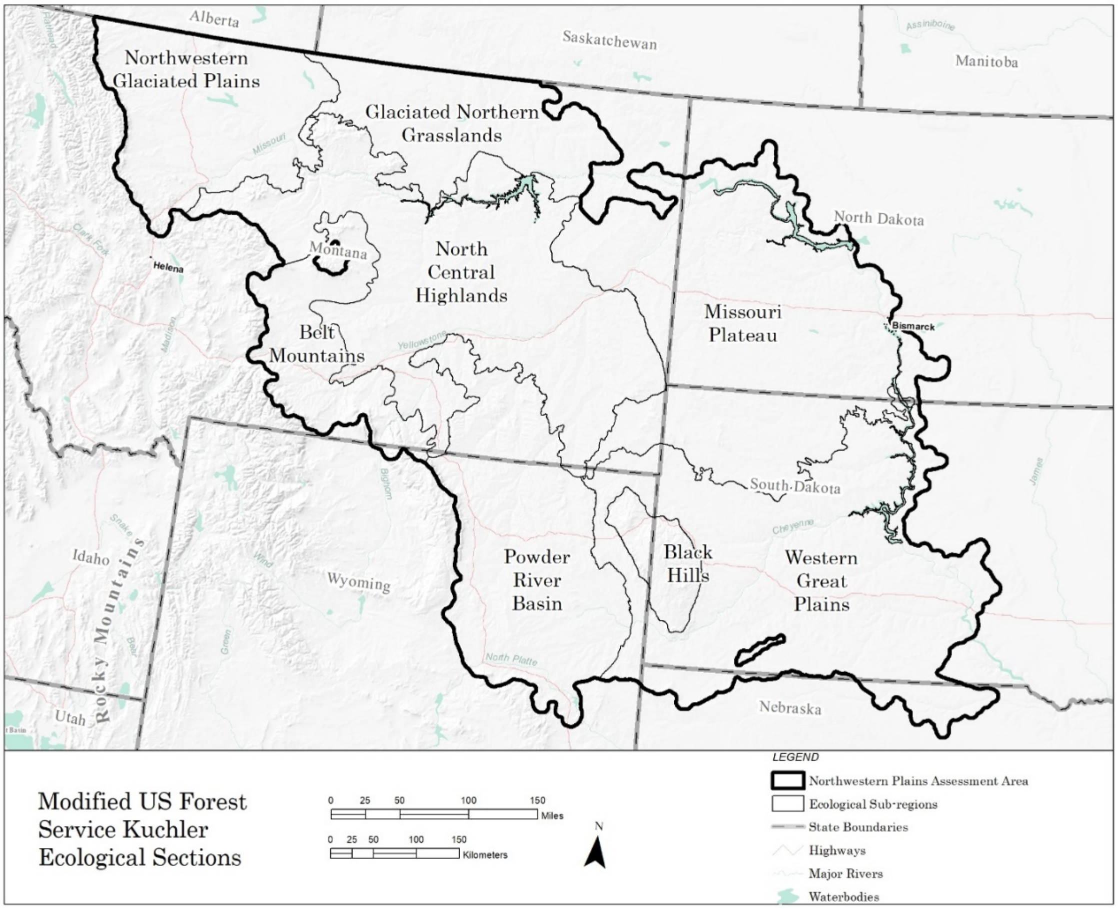


Figure 1.6 Slightly modified US Forest Service potential natural vegetation ecological sub-sections within the Northwestern Plains conservation assessment area. Sub-sections based on Kuchler (1964).

1.3. Surface Management and Consumptive Uses

1.3.1. Surface Management

The majority of surface management within the NWPL is controlled by private landowners (Figure 1.7; Table 1.2). Tribal management comprises the majority of non-privately held lands within the NWPL, followed by the Bureau of Land Management (BLM), the USFS, and state lands (Table 1.2). All other surface management agencies are responsible for less than 5% of the NWPL. Of privately held lands, 1.6% occurs with conservation easements. Most privately owned land is rural ranchland, with little agriculture due to poor soils for crops. Livestock grazing is the dominant land use practice throughout the NWPL (Figure 1.8). Tribal land management comprises the second largest type of surface occupancy of the NWPL and is comprised of 17 tribal nations on 12 federally recognized reservations. Each nation can independently manage land and resources, within the confines of US federal regulations (e.g., the Bald and Golden Eagle Protection Act). The majority of BLM lands occur across four administrative districts in Montana, two districts in Wyoming, and one district in South Dakota. The dominant vegetation type of BLM lands is prairie grasslands (61%) followed by shrublands (28%). The USFS manages several large tracts of land within the NWPL, including Dakota Prairie Grasslands, Thunder Basin National Grasslands, Nebraska National Forest and Custer National Forest. The USFWS manages the Charles M. Russell National Wildlife Refuge along the Missouri River in north-central Montana that has permanent land protections.

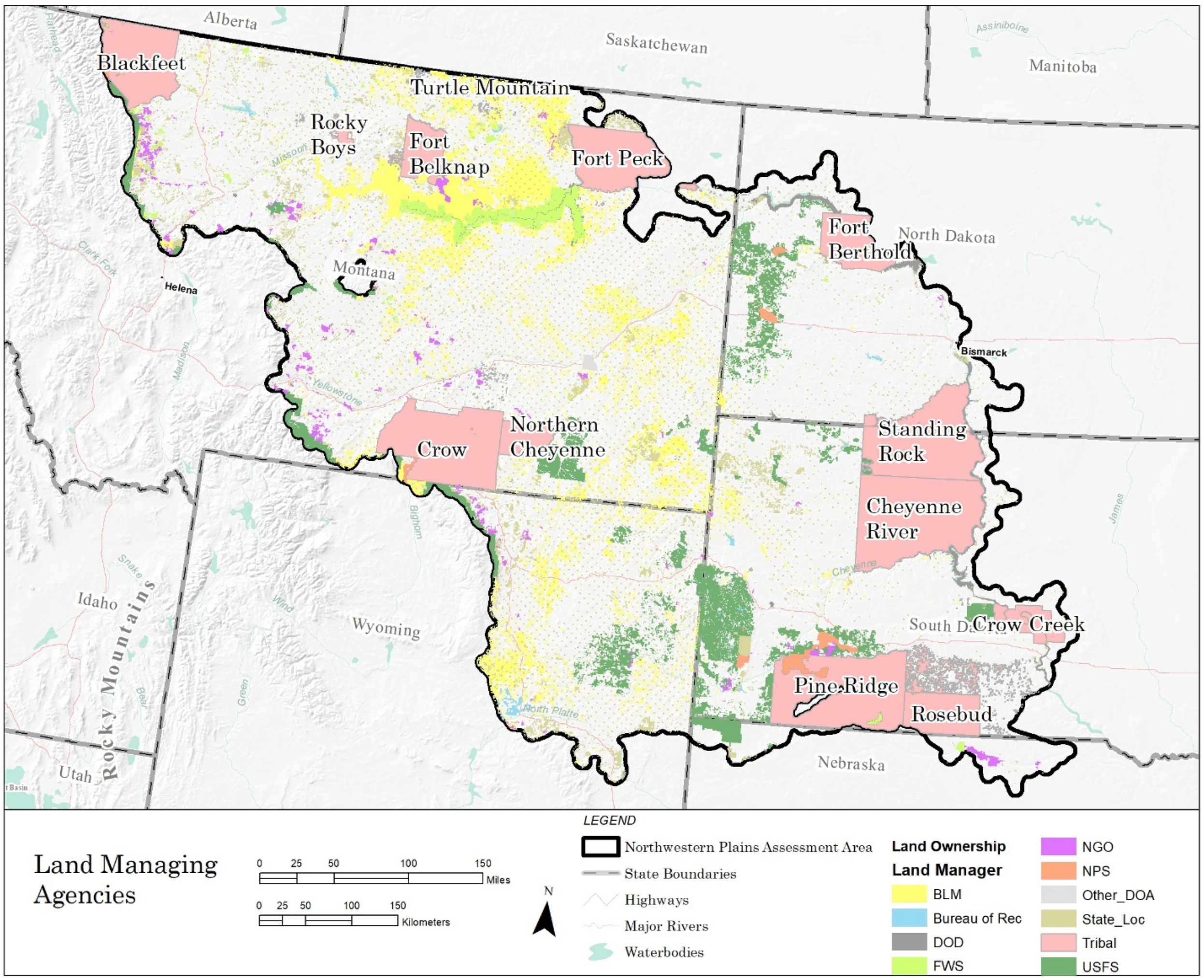


Figure 1.7. Agencies and entities responsible for surface management within the Northwestern Plains. No color represents private lands. Data obtained through the Protected Areas Database of the US. (Version 1.4; USGS-GAP 2018)

Table 1.2. Agencies and entities responsible for surface management of the Northwestern Plains conservation assessment area. Information was obtained through the Protected Areas Database of the US. (version 1.4; USGS-GAP 2018)

Administrative Agency or Entity	Area (km^2)	% of NWPL
Private	250,013.87	58.8
Tribal	61,810.50	14.5
Bureau of Land Management	38,526.73	9.1
Forest Service	26,429.69	6.2
State	23,050.24	5.4
Bureau of Reclamation/Army Corps of Engineers	10,685.73	2.5
US Fish and Wildlife Service	5,756.08	1.4
Private with Easement	4,094.66	1.0
Non-governmental Organization	2,814.54	0.7
National Park Service	1,699.76	0.4
Other, Unknown	401.93	0.1
Local Government	80.25	<0.1

1.3.2. Anthropogenic Development

There were 862,748 residents counted within the NWPL during the 2010 US population census (US Census Bureau 2010). The NWPL is largely rural and agricultural development, with few city hubs, including Billings, Miles City, and Glendive, MT; Sheridan and Gillette, WY; Rapid City, Sturgis, and Belle Fouche, SD; and Williston and Dickinson, ND. Billings, MT is the largest urban center within the NWPL, home to ca. 112,000 residents.

The primary economic land use in the NWPL is agricultural. For much of the NWPL, cattle grazing on untilled rangeland is the primary agricultural use, but cultivation increases towards the eastern edge of the NWPL in the Dakotas. As of 2012, there were an estimated 254,723 head of cattle in counties of the NWPL [United States Department of Agriculture (USDA) 2014, Figure 1.8]. Some county boundaries extend beyond the NWPL boundary, so this estimate may slightly overestimate cattle numbers, but minimally on the total scale of the NWPL. Wheat production is the primary crop production (48%) of the cultivated lands within the NWPL (15%), followed by row crops (25%) and fallow/idle cropland (19%) (LANDFIRE 2016).

Overall, less than 2% of the NWPL is permanently protected from extractive uses. The NWPL is host to two extensive oil and gas deposits; the Powder River Basin in Wyoming and the Williston Basin in North Dakota, Montana, and South Dakota (Figure 1.9). As of 2016, there were ca. 28,000 active extraction wells within the NWPL portion of the Powder River Basin and an additional 6,100 active wells within the NWPL portion of the Williston Basin (data compiled from Montana Board of Oil and Gas Production, North Dakota Dept. of Mineral Resources, South Dakota Geological Survey, Wyoming Oil and Gas Conservation Commission). The Powder River Basin is primarily used for coalbed methane extraction while the Williston Basin is a shale (tight) oil production field. The highest well density is in the Powder River Basin.

All but one existing mine in the NWPL are surface coal mines and the largest complexes occur within in the Powder River Basin. We gathered coal mine permit boundary areas from state Department of Environmental Quality offices (Figure 1.9). Total production of surface coal in 2017 was 334,626,000 short tons with 91% of total production from the Powder River Basin mine complexes (U.S. Energy Information Administration 2018).

Wind energy facilities occur across the NWPL, but mainly in four main installation areas. Diffendorfer et al. (2015) digitized a total of 957 two- or three-megawatt wind turbines within the NWPL. The largest installation complex occurs east of Casper, WY (36% of turbines), followed by the Kevin Rim in the northwest (28%), the Oliver and Bison Projects near Bismarck, ND (16%), and Judith Gap, MT (12%). Additional turbines have been installed since Diffendorfer et al. (2015) but likely total less than 100.

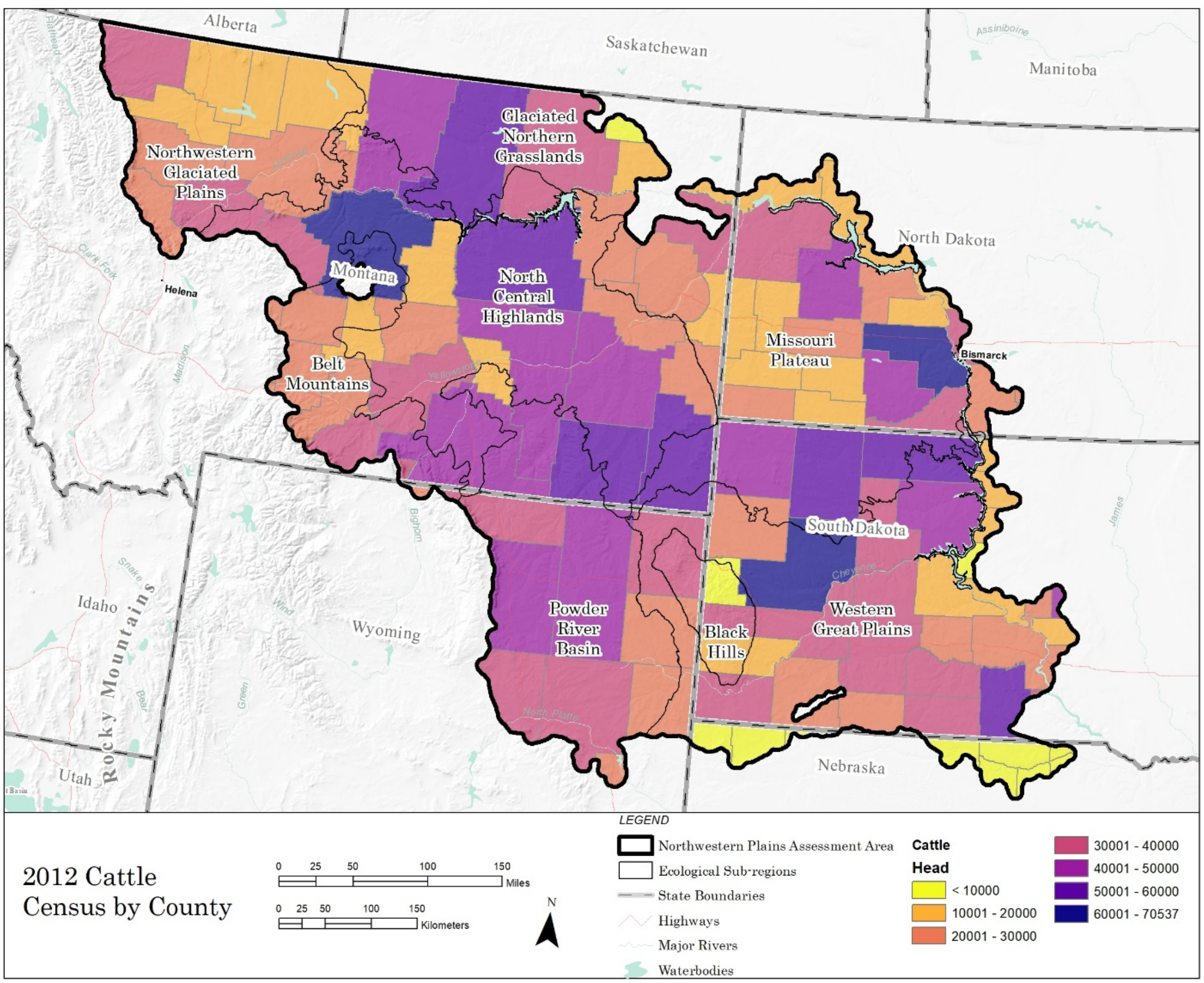


Figure 1.8. 2012 cattle inventory by county within the Northwestern Plains conservation assessment area. Data obtained from USDA National Statistics Service.

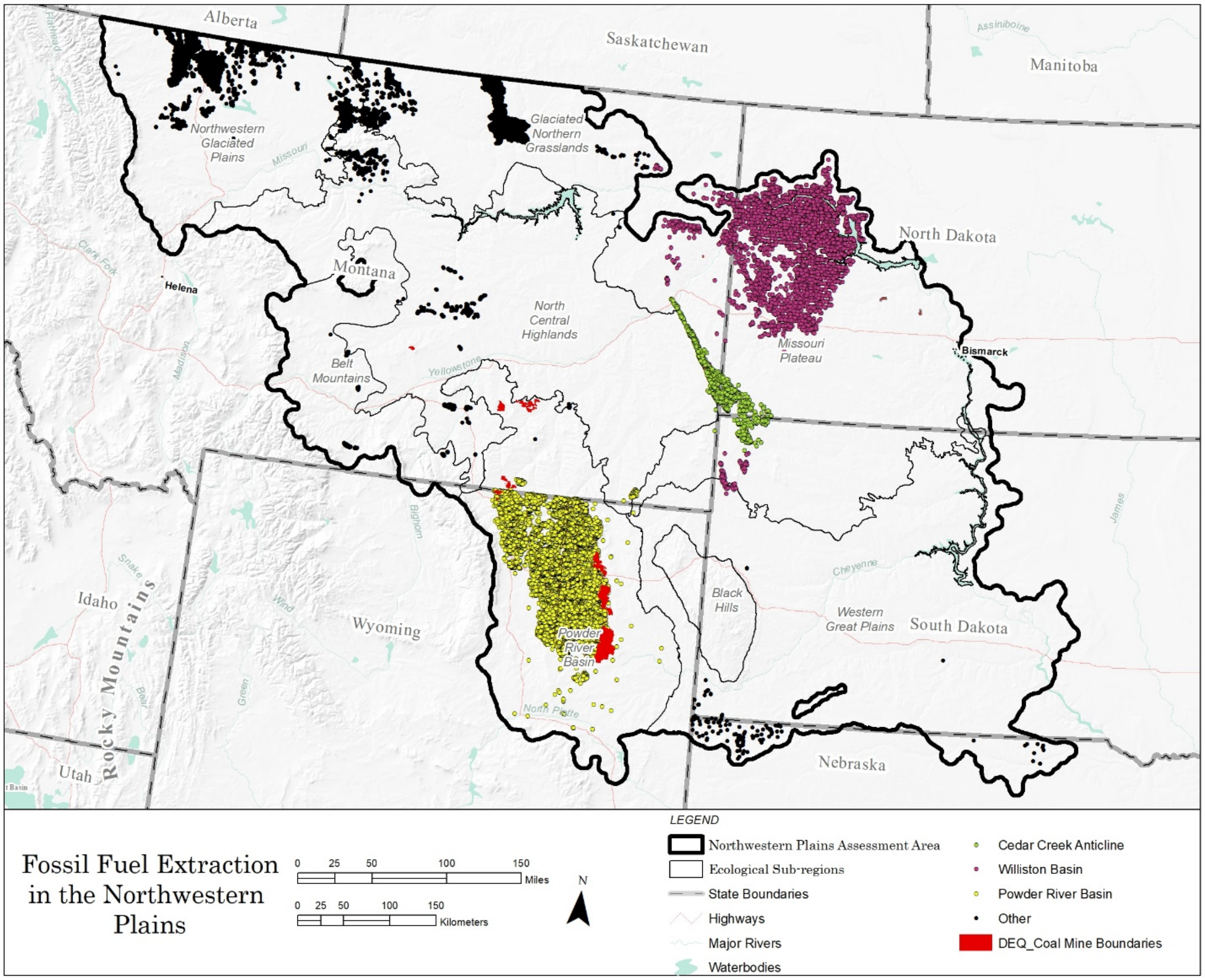


Figure 1.9. 2016 fossil fuel extraction within the Northwestern Plains conservation assessment area. Active oil and gas wells (yellow = Powder River Basin, magenta = Williston Basin, green = Cedar Creek Anticline, Black = other). Surface coalmine leasing boundaries in red. Data compiled from Montana Board of Oil and Gas Production, North Dakota Dept. of Mineral Resources, South Dakota Geological Survey, Wyoming Oil and Gas Conservation Commission and state Department of Environmental Quality offices.

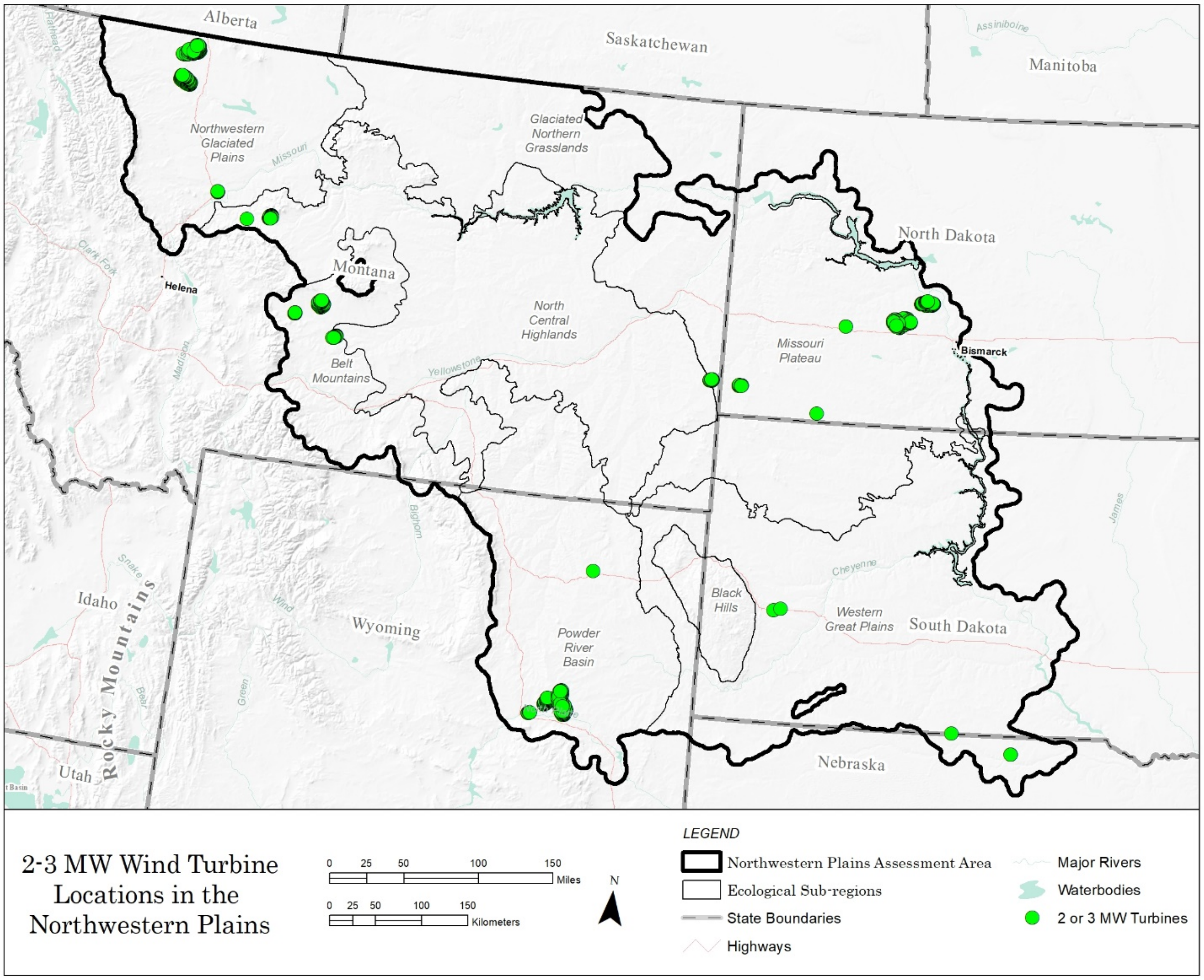


Figure 1.10. Locations of operating large-capacity (2-3 MW) wind power generating turbines within the Northwestern Plains conservation assessment area. Source Diffendorfer et al. 2015.

2. Golden Eagle Populations

The NWPL is host to some of the densest breeding populations of golden eagles in the conterminous United States. The NWPL also provides key habitat for pre-breeding, local, and migrant golden eagles from Canada and Alaska that likely compete with breeding populations for spatial and food resources. Historically, golden eagles across eastern Montana (and presumably all of NWPL) were close to extirpation in the late 1800s resulting from wolf and coyote bounties (Cameron 1905). During the late 1800s, trappers frequently used strychnine in ungulate carcasses and leg-hold traps to kill mammals which resulted in large numbers of eagle mortalities as by-catch (Cameron 1905). This likely was true across most western states, with high federal bounties between 1885–1920.

Unlike many other areas within the United States, breeding eagles within the NWPL use less rugged terrain for foraging areas and a greater proportion of trees for nesting substrate. The NWPL provides plentiful, but fluctuating, food resources during the breeding season as well as regionally abundant ungulates for carrion food resources, year-round. Many data on golden eagle ecology exist for particular regions, such as the Powder River Basin in Wyoming, while there are very limited data for golden eagles in the rest of the NWPL. There are limited, but increasing movement data during various eagle life-stages, including breeding, pre-breeding and overwintering habitat use. Most golden eagle monitoring efforts were typically short-term in nature, limited geographically, and often sporadic monitoring of nests that are not systematically surveyed during development operations. However, some of the best historical data on resident populations occur from several long-term studies within the NWPL and offer a unique opportunity to understand the current population status of golden eagles.

In this section, we summarize the state of knowledge on golden eagle populations in the NWPL by reviewing research on their density, space-use, habitat selection, fecundity, movements, diet, and winter-season ecology. We present spatial models developed by WGET to characterize habitat use of golden eagles during the breeding and winter seasons. This summary forms the foundation for identifying limiting factors to survival and fecundity in the following section on Population Ecology, as well as the spatial Conservation Prioritization, Regional Risk Assessment, and recommended Regional Conservation Measures in the Conservation Strategy section. By summarizing the available data, we aim to identify critical gaps in knowledge, facilitate comparisons with other regions, and establish benchmarks of demographic rates in the NWPL to support monitoring and management.

****NOTE** Terminology varies across time and studies in regards to golden eagle breeding ecology. Terminology in this assessment follows that of Steenhof et al. (2017) and historical terminology in each paper was considered and changed to Steenhof et al. (2017) for consistency in this document******

2.1. Resident Populations

Golden eagles regularly occur and breed across much of the NWPL but density generally decreases towards the eastern boundary in the Dakotas. Breeding eagles within the NWPL are generally year-round residents (B. Bedrosian, unpubl. data, Crandall et al. 2019, Harmata 2015) though a limited number of breeders may migrate south into the Wyoming Basin and High Plains ecoregions (Crandall et al. 2019).

2.1.1. Abundance and Density

Monitoring golden eagle population size and trend requires robust estimates of abundance. Although estimates of golden eagle abundance specific to the NWPL are not available, studies have been conducted to estimate density of breeding pairs in smaller study areas within Wyoming and Montana (Table 2.1). Several studies have also been conducted estimating abundance of breeding pairs and individuals across larger areas that include portions of the NWPL.

2.1.1.1. Nest Sites

Wyoming, North Dakota, and Montana have collected and collated large numbers of nest observations through the Montana Natural Heritage Program and the Wyoming Wildlife Observation System and Natural Diversity Database. Collectively, a very large number of nests have been identified in the NWPL, but the overwhelming percentage of identified nests has been within the Powder River Basin of Wyoming and the Williston Basin in North Dakota as a result of surveys associated with oil and gas development (Figure 2.1). Montana has increased aerial surveys in recent years to help fill in gaps of nesting density across some areas of the NPG.

2.1.1.2. Breeding Pairs

Density of breeding pairs is a common index of population size and habitat quality for raptors (Bildstein and Bird 2007). Many areas have been surveyed for eagle nests within the NWPL, but robust estimates of nesting density and abundance using systematic approaches do not exist for most of Montana, North Dakota, South Dakota and Nebraska. There have been several historical and on-going monitoring efforts in smaller study areas that help provide insights into breeding populations across the NWPL (Figure 2.2). Nesting density and abundance varies across the region but can be among the highest nest densities for the species (e.g., Phillips et al. 1990, Millsap et al. 2013, Crandall et al. 2015).

Nesting density estimates are available for several areas within the NWPL (Figure 2.2). In the Livingston/Big Timber, MT region, there are both historical and current estimates of nesting densities within an intensively monitored 2,700 km^2 study area (McGahan 1966, 1968, Reynolds 1969, Crandall 2014, Crandall et al. 2015). Nesting densities were estimated several times across the Wyoming portion of the NWPL (Phillips and Beske 1990, Phillips et al. 1990, Olson et al. 2015). Additionally, many golden eagle nests have been monitored in the Powder River Basin as a result of surveys for of oil and gas development (e.g., Carlisle et al. 2018, Thunder Basin National Grasslands unpubl. data), but generally not systematically or consistently across years. Because of mining or other extraction activities (e.g., South Coal Mines in Wyoming), small numbers of consistent nesting territories have been intensively monitored for many years.

On the southwestern edge of the ecoregion in the Livingston study area (Figure 2.2), Crandall et al. (2015) found golden eagle nesting density has significantly increased since 1964 (Table 2.1). In the Tongue River drainage spanning the Montana and Wyoming border, nesting density was estimated to between 36–29 km^2/territorial pair from 1981–1985 (Phillips et al. 1990). Phillips and Beske (1990) found nesting density as high as 51 km^2/territorial pair in areas that the authors attempted to find all eagle nests. Within and adjacent to the southeast corner of the Phillips and Beske (1990) study area, Orabona (2008) found a nesting density of 58 km^2/territorial pair while surveying the area by fixed-wing. Most recently, Olson et al. (2015) estimated nesting density within the non-forested regions of the WY portion of the NWPL at 100.6 km^2/territorial pair by extrapolating results from randomly surveyed townships within the region. However, the Olson et al. (2015) surveyed only areas with ferruginous hawks (*Buteo regalis*) occurrence records and likely underestimate eagle nesting density upland habitats were not included in the study. In North Dakota, Allen (1987) estimated a state-wide nesting territory density of 95 (± 75) pairs using a stratified random sampling design with aerial surveys.

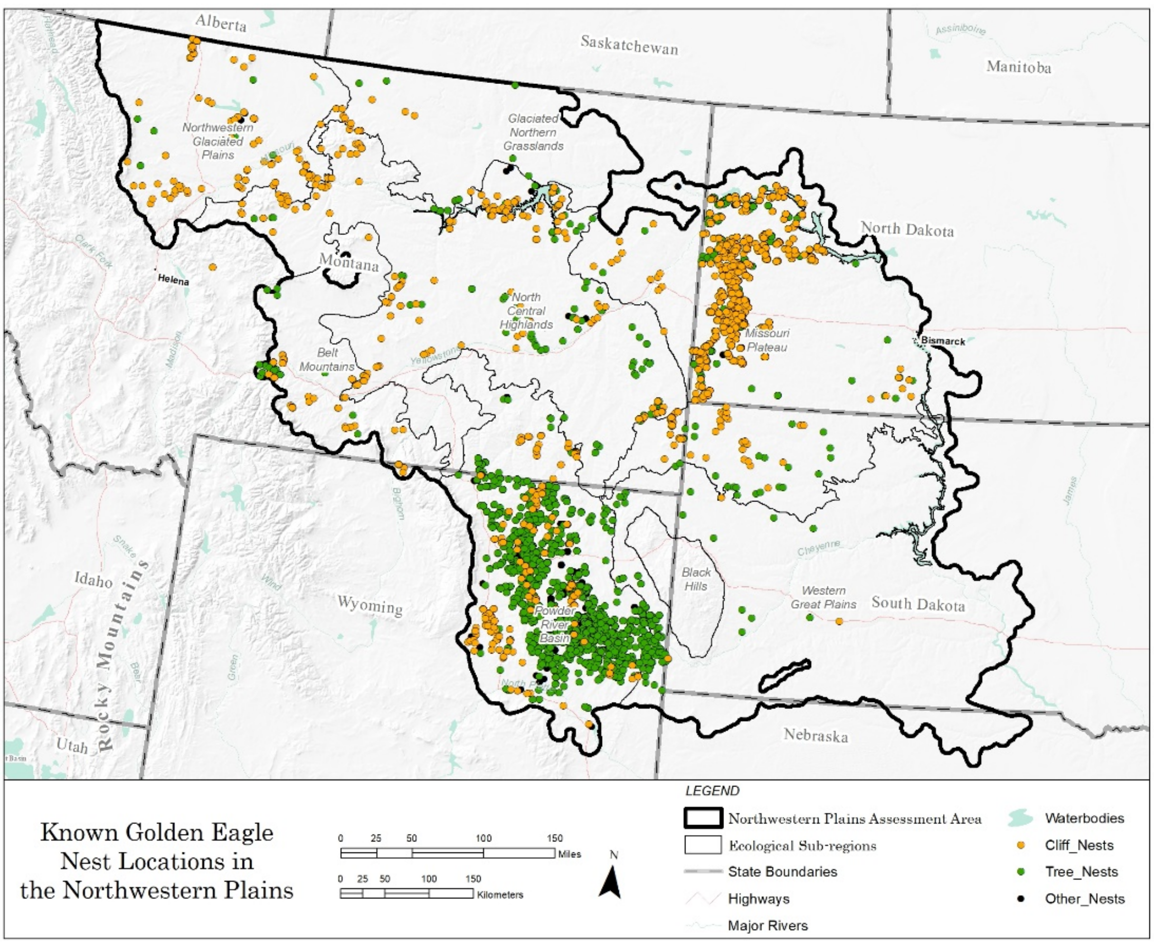


Figure 2.1. Known golden eagle nest records by nesting substrate within the Northwestern Plains conservation assessment area.

Comparing estimates of nesting territory density can be problematic, both within a study area and between study areas. Length of study, type of survey, and habitat can all lead to unknown biases. The majority of eagle nests within the NWPL occur in trees (2.1.3). Aerial surveys for nests may significantly underestimate tree nests, particularly in conifers (Crandall et al. 2015). Detection probabilities across Wyoming for golden eagle cliff nests indicated a 0.60 and 0.67 detection probability of finding nests from a fixed-wing airplane or helicopter, respectively, but no coniferous nests were found as part of that study (a function of survey design, Olson et al. 2015). Similarly, detection estimates of cliff nests in Alaska from aerial surveys were 0.68 (Booms et al. 2010) but did not include tree nests. Detection probability is typically lower for tree nests than cliff nests. Further, among tree nests, detection in conifers is likely lower than nests in deciduous trees, particularly if aerial survey flights are conducted before leaf-out. All study areas outlined above had identified tree nests within their samples, though to varying degrees.

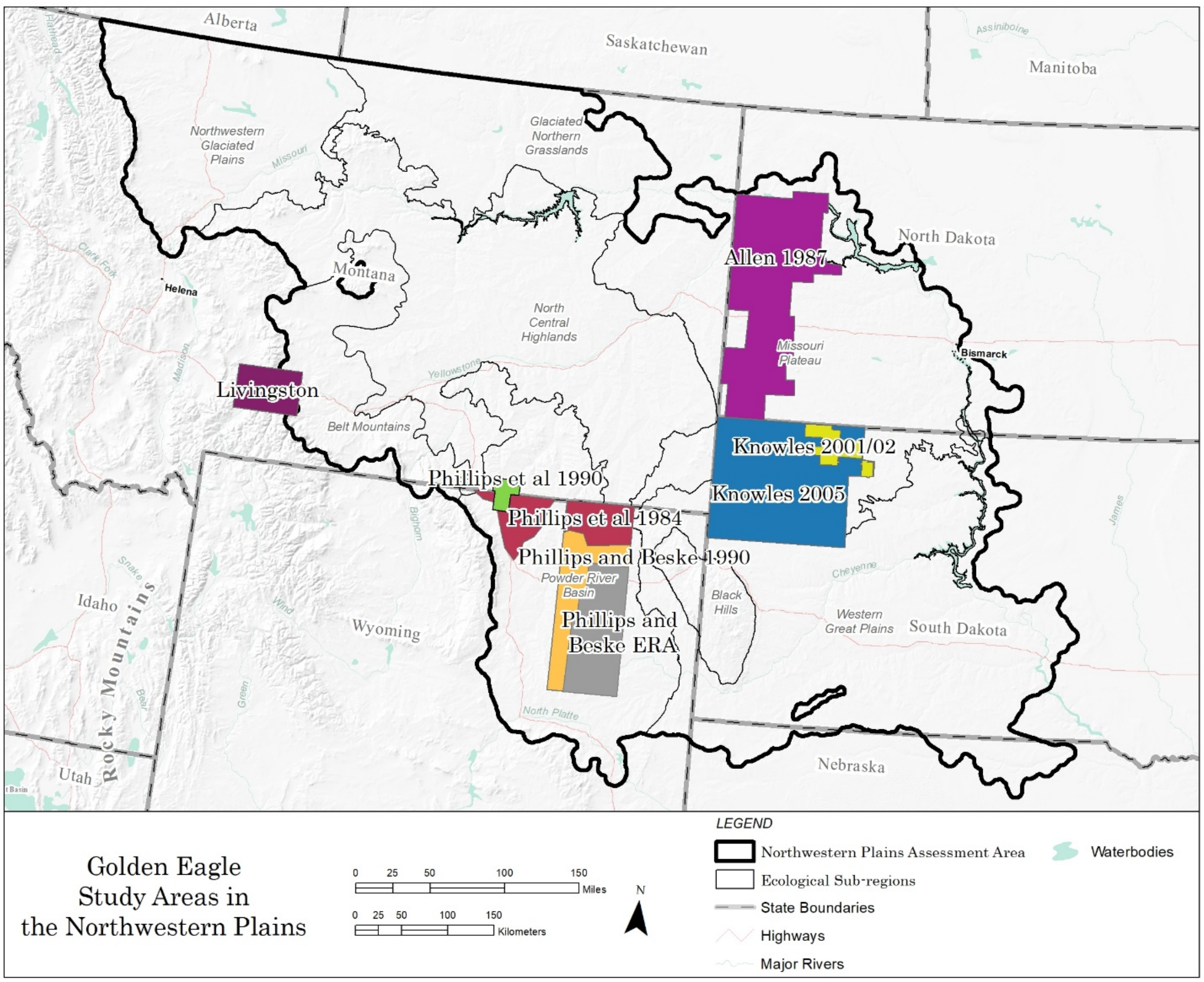


Figure 2.2. Golden eagle study areas that have estimated nesting density of breeding golden eagles within the Northwestern Plains Conservation Assessment area.

Table 2.1. Nesting density estimates of golden eagles from studies overlapping the Northwestern Plains conservation assessment area. Shown are the study area name, years and source of data, density, and survey methods used. Overlapping study areas are grouped.

Study Area Name	State	Years of Study	Study Area size (km^2)	Number of Territories	Nesting Density (km^2/pair)	Mean NND (km)	Survey Method(s)	Source
Sheridan[a]	WY	1976-1982[b]	2074	37	56.1	4.9	Aerial	Phillips et al. 1984
Sheridan	WY	1975-1985	863	30	28.8	4.4	Aerial, Ground	Phillips et al. 1990
Recluse	WY	1976-1982[b]	1753	29	60.4	5.4	Aerial	Phillips et al. 1984
Gillette (ESA)	WY	1980-1981	7115	120	59.3	5.8	Aerial	Phillips et al. 1984
Gillette (ESA)	WY	1981-1989	7115	140	50.8	4.3	Aerial, Ground	Phillips and Beske 1990
Gillette (Outside ESA)	WY	1981-1985	7439	62	120.0		Aerial	Phillips and Beske 1990
Gillette	WY	2008	2720	47	57.9	4.0	Aerial	Orabona 2008
Kaycee	WY	1976-1982[a]	749	13	57.6	5.2	Aerial	Phillips et al. 1984
Random Townships in WY	WY	2010-2011	2797[c]	16	100.6[d]		Aerial	Olson et al. 2015
Livingston	MT	1962-1964	3263	19	171.7		Ground	McGahan 1986
Livingston	MT	1965-1967	3263	23	141.9		Ground	Reynolds 1969
Livingston	MT	2010-2014	2700	45	60.0		Ground	Crandall et al. 2015
Little Missouri	ND	1983-1994	11,072-15,944[c]	95[e]	111.1[e]		Aerial, Ground	Allen 1987
Grand River Grasslands	ND	2001	433	5	86.6	14.6	Aerial, Ground	Knowles 2001A, 201B
NW South Dakota	SD	2005	20798	73	284.9	6.9	Aerial	Knowles 2005

[a] Listed as 16 pairs in 648 km^2 (40.5 km^2/pair) in Phillips and Beske 1990

[b] Surveyed only one year during study period, but specific year not reported

[c] Not continuous study areas

[d] Calcuated from DISTANCE analysis

[e] Mean composite Bayesian population estimate based on combining "independant samples" from 1983 and 1984

2.1.1.3. Individuals

Many management actions focus on breeding populations of raptors and surveys of breeding pairs. However, golden eagles have delayed maturation for up to six years and it is important to understand all life-stages for comprehensive species management. Estimates of overall population size and abundance need to encompass more than breeding pairs to include juveniles, sub-adults, floaters, and overwintering eagles. There is surprising consistency in several estimates of individual abundance within the NWPL.

Neilson et al. (2014) and Neilson et al. (2016a) provided estimates of late-summer golden eagle abundance with the Badlands and Prairies Bird Conservation Region (BCR 17), which encompasses most of the NWPL, excluding the western edge in Montana and the area north of the Missouri River to the Canada border. From those aerial surveys, they estimated total abundance (all age classes) of 6,877 golden eagles in the most recent survey year (2015; 90% CI = 4,384–9,964). The highest estimate from 2003–2015 was 9,223 in 2006 and as low as 4,792 in 2012 (Neilson et al. 2016a). Excluding juveniles, the abundance of golden eagles in BCR 17 in 2015 was estimated at 5,480 individuals. Millsap et al. (2013) estimated >10,000 individuals within BCR 17 during the summer using Breeding Bird Survey data, but did not find the estimates significantly different than Neilson et al. (2014). No trends in eagle density were observed for all eagles (or just juveniles) in BRC 17 from 2006–2010 (Millsap et al. 2013, Neilson et al. 2016a), nor were any significant density trends observed from extrapolated data from 1968–2010 (Millsap et al. 2013). While studies have not shown trends in eagle abundance, there are observed nest occupancy rate declines from 1970s–2010s in some areas (B. Oakleaf, personal communication, see 2.1.5)

Across years in BCR 17, Neilson et al. (2016) found an average of 10.5% juveniles during the annual surveys and USFWS (2016) estimated floater to breeder ratio of 1.13:1. The area of BRC 17 is 82% of the total area of the NWPL, so that density would equate to an abundance of 9,013 eagles within BCR 17. However, it is not valid to assume equal abundance across the entire NWPL, and the Wyoming portion of the NWPL (Powder River Basin) hosts larger than average nesting densities compared to the remainder of the assessment area (see 2.1.4).

Partners in Flight also estimated abundance of 10,000 individuals using Breeding Bird Survey data from 1998-2007 within BCR 17 (Blancher et al. 2013, Partners in Flight Science Committee 2013). The data quality of the Partners in Flight estimate was good to fair and is consistent with the other estimates.

2.1.2. Spacing, home range, and core areas

Restriction of disturbance around nest sites and core use areas is a common management action for golden eagles. Information on nesting territory spacing, home-range size and shape, and movement within core areas is, thus, important to inform management. In this section, we summarize spacing data from within the NWPL to assess key use areas around nesting territories. While the core areas and home ranges of breeding adults is a key metric for management, non-breeding and overwintering golden eagles may exhibit different patterns of space use. We also attempt to summarize the limited data for these individuals within the NWPL.

2.1.2.1. Breeding Spacing and Home Range

Nearest neighbor distance (NND) may provide a good proxy for home range size, as golden eagles are highly territorial and vigorously defend nesting territories. The average NND in the Tongue River drainage was 4.4 km and 4.3 km in the Powder River Basin (Table 2.1). Not surprisingly, in linear features such as river bottoms or in habitats where nest sites are limited such as isolated buttes, NND decreases. Phillips and Beske (1990) reported the mean NND in riparian areas, ponderosa pine, and sagebrush/grassland habitats as 3.1, 3.4, and 5.2 km, respectively. Coyle (2008) found similar results within the Little Missouri study area (NND = 6.3 km), with increased densities of nest sites in riparian corridors, mid-range densities in the breaks surrounding waterways, and lowest in the plains habitats of North Dakota.

From an observational study of one egg-laying golden eagle pair in the western NWPL (Livingston study area, Figure 2.2) in 1965, Reynolds (1969) documented that home range of the pair was 83 km^2 (core area 34 km^2). Few studies of radio-marked adults have occurred across the NWPL. Tyus and Lockhart (1979) estimated home ranges sizes of 26.4–54.5 km^2 from two male and three female eagles outfitted with VHF transmitters. One of the most intensive studies of breeding golden eagles using Global Positioning System (GPS), satellite transmitters occurred in the same Livingston study area (Crandall et al. 2015). From 12 individuals tracked with hourly GPS locations during the breeding season, the mean 95% kernel density estimate home range estimate was 27.3 km^2, with a core area estimate (50% kernel density estimate) of 2.1 km^2. Mean minimum convex polygon (MCP) estimates of home ranges of these individuals was 16.7 km^2 at the home range scale and 2.3 km^2 for core areas. Assuming a circular home range surrounding a nest, the MCP home range estimate of 16.7 km^2 equates to roughly a 2.3 km radius surrounding the nest, which is roughly equivalent to ½ NND within that study area. The differences in home range size within the same study area from the 1960s to current estimates also reflect the increase in nesting territory density within that study area (Table 2.1).

2.1.3. Breeding Habitat

The NWPL represents the eastern edge of the species' breeding range in the western conterminous United States (Kockert et al. 2002). Across much of the NWPL, eagles regularly nest in most habitats but tend to avoid urban areas, agricultural areas, and dense forests. As agricultural land use increases in the eastern portions of North Dakota, South Dakota and Nebraska, nesting habitat for golden eagles decreases until it eventually becomes too sparse to support nesting territories (see 3.3.2.2).

2.1.3.1. Regional characteristics

Nest sites across the NWPL regularly occur on both cliffs and trees. Most breeding habitat within the NWPL occurs in riparian corridors, isolated buttes, and "breaks" habitats. Eagles will regularly build cliff nests on large igneous and sandstone cliffs when available and, to a lesser extent, smaller mud banks, scoria outcrops, and hilltops. Tree nests regularly occur in riparian habitats, irrigation channels, on isolated buttes, and ecotone boundaries. In the NWPL, golden eagles typically build tree nests in plains cottonwoods (*Populus deltoids*), green ash (*Fraxinus pennsylvanica*), Douglas fir (*Pseudotsuga* *menziesii*) and ponderosa pine (*Pinus ponderosa*) but also in other species such as narrowleaf cottonwoods (*P. angustifolia*), limber pine (*Pinus flexilis*) and juniper (*Juniperus* spp.). Eagles also use man-made structures such as power lines, communication towers, nesting platforms, old windmills, and gas wells for nesting sites, and in rare occasions build ground nests (Coyle 2008).

2.1.3.2. Nest Site Characteristics

Monitoring and management of golden eagles is typically focused on nest sites. Nests offer a sample unit that is practical because the large stick structures are relatively conspicuous and ecologically meaningful because they are essential to reproduction, serve as activity centers in home ranges, and are likely to be reused for many years (Kochert et al. 2012). Understanding the characteristics of nest sites used by golden eagles is, thus, essential to support effective monitoring and management.

Nesting substrate within the NWPL varies across the region and local availability of habitat types likely influences nest site selection. Several studies have quantified breeding habitats and nest site selection within the NWPL. In central Montana, Bedrosian et al. (2013) found 32% of nests were in trees (both cottonwood and pine) and 68% on cliffs. Knowles (2014) found that roughly 50% of Golden eagle nests were located in trees towards the eastern half of Montana, likely reflecting fewer available "cliff" nesting habitats (cliffs, rimrock, mud banks, etc.). However, coniferous forests were not thoroughly searched, likely inflating cliff nesting rates. Surveys in North Dakota found 85% and 86% of nests on cliffs (Ward et al. 1983 and Knowles 2001b, respectively), but both surveys focused on the Missouri and Little Missouri badlands and breaks, which may inflate estimates of cliff nests due to availability of that habitat type. Coyle (2008) found that cliffs were used much more than expected in North Dakota. In South Dakota, Knowles (2005) found that 42% of nests were in cottonwood trees. Typically, aerial surveys found a greater percentage of cliff nests than tree nests (e.g., Coyle 2008, Knowles 2014, MTFWP unpubl data).

Several studies using ground-based surveys, at least in part, have occurred in the NWPL. In the western portion of the NWPL, 47% of nests observed from 2010–2014 within the Livingston study area (Figure 2.2) were located in trees and 53% on cliffs (Crandall et al. 2016). Of tree nests from that study, 75% were located in Douglas fir and 25% in cottonwoods. There was no difference in apparent nest success or daily survival rates between nesting substrates (Crandall et al. 2016). In the Sheridan study area (Figure 2.2) spanning the Wyoming/Montana border, 88% of nests were located within trees (80% ponderosa pine and 18% cottonwood) (Phillips at al. 1990). In the Powder River Basin Eagle Research Area (Figure 2.2), Phillips and Beske (1990) found 82% of eagle nests within trees but with opposite species composition than the study areas to the west [70% deciduous trees (presumably mostly cottonwoods) and 30% ponderosa pine]. Within this study area, some pairs consistently produced more young than others but 56% of tree nests were successful while 43.5% of cliff and creek bank nests were successful (Phillips and Beske 1990).

Man-made structures can also provide important nest sites in some areas of the NWPL. Between 1960–1990, nesting platforms were erected in the Powder River Basin as a means of mitigation for nesting habitat loss due to mines and for specific studies (Phillips and Beske 1990, McKee 2018; Figure 2.4). Golden eagles will use these, communication towers, distribution poles, and large power line towers for nest sites within the NWPL. In the Powder River Basin, Powder River Energy Corporation (PRECorp) regularly and successfully moves active Golden eagle nests from transmission poles to nesting platforms in less than 10 minutes (T. Jones, PRECorp, personal communication). Nests have also been successfully moved annually within occupied territories adjacent to and within mining areas by moving exiting nests to platforms up to 2.1 km (McKee 2018).

Within the WGET nest database, there are 24,204 nest records compiled within the NWPL from 1900–2015. Of the 21,637 records with recorded nesting substrates, 53.1% were recorded in trees (76.7% deciduous, 15.0% coniferous, and 7.7% unrecorded). Cliff nests accounted for 40.3% of the records, with the remainder (6.6%) recorded on utility poles, outcrops, and "other" (Figure 2.1).

2.1.3.3. Photo Gallery

The following photos are intended to represent the range substrates used by golden eagles nesting the NWPL.

Figure 2.3. Typical nest in a Plains Cottonwood within the Northwestern Glaciated Plains. Adjacent sandstone banks also provide nesting habitat. Photo by Moosejaw Bravo.

Figure 2.4. Nesting platform (without a nest) in an active black-tailed prairie dog colony in the Gillette Study Area likely erected as part of the Phillips and Beske (1990) study in the early 1980's. Photo by Bryan Bedrosian.

Figure 2.5. Golden eagle nests in plains cottonwoods in the Powder River Basin, WY. Photos by Bryan Bedrosian.

Figure 2.6. Golden eagle nests in small ponderosa pines in the Powder River Basin, WY. Photos by Nathan Hough and Bryan Bedrosian.

Figure 2.7. Golden eagle nest in a ponderosa pine snag in the Northern Glaciated Plains. Photo by Deniz Bertuna.

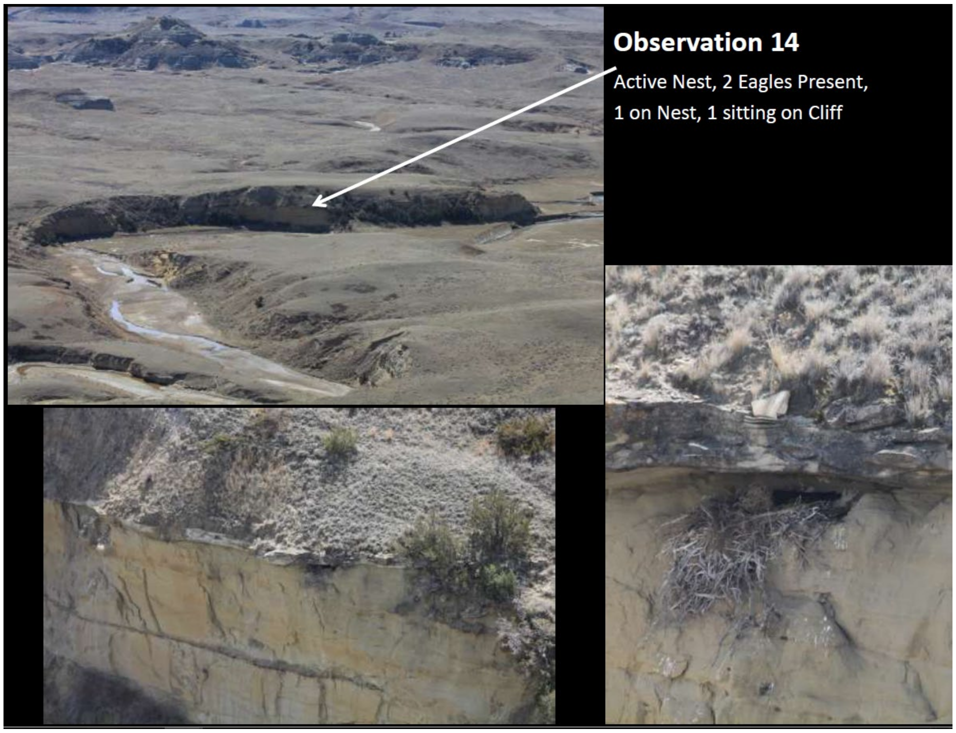


Figure 2.8. Typical Golden eagle cliff nest along an erosion embankment in the Charles M. Russell National Wildlife Refuge. Photos by: Randy Matchett.

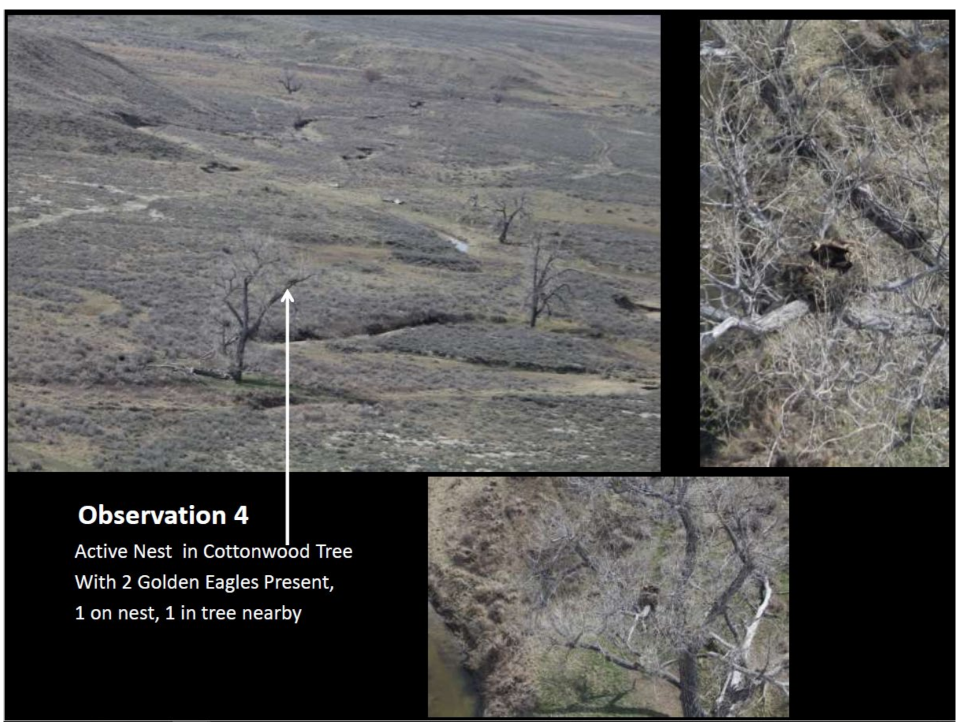


Figure 2.9. Typical Golden eagle nest in lone plains cottonwood prior to leaf-out in Charles M. Russell National Wildlife Refuge. Photos by: Randy Matchett.

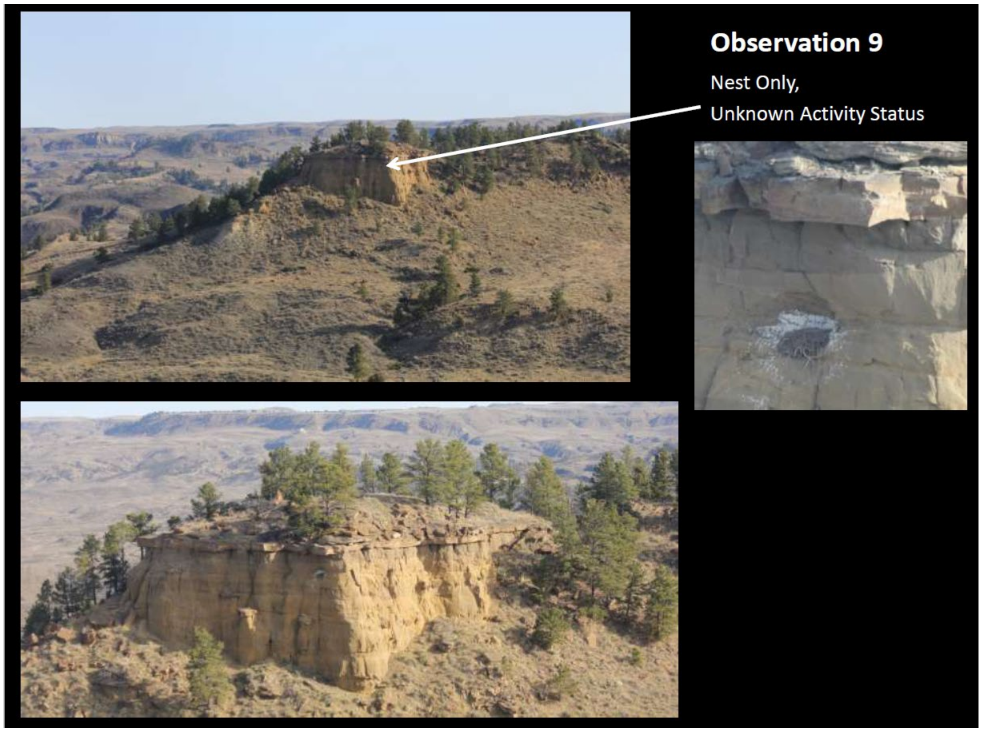


Figure 2.10. Typical Golden eagle cliff nest on an isolated, treed butte in Charles M. Russell National Wildlife Refuge. Photos by Randy Matchett.

Figure 2.11. Golden eagle cliff nest in breaks habitat in the Charles M. Russell National Wildlife Refuge. Photos by Randy Matchett.

Figure 2.12. Golden eagle cliff nest in breaks habitat in the Charles M. Russell National Wildlife Refuge. MT. Photos by Randy Matchett.

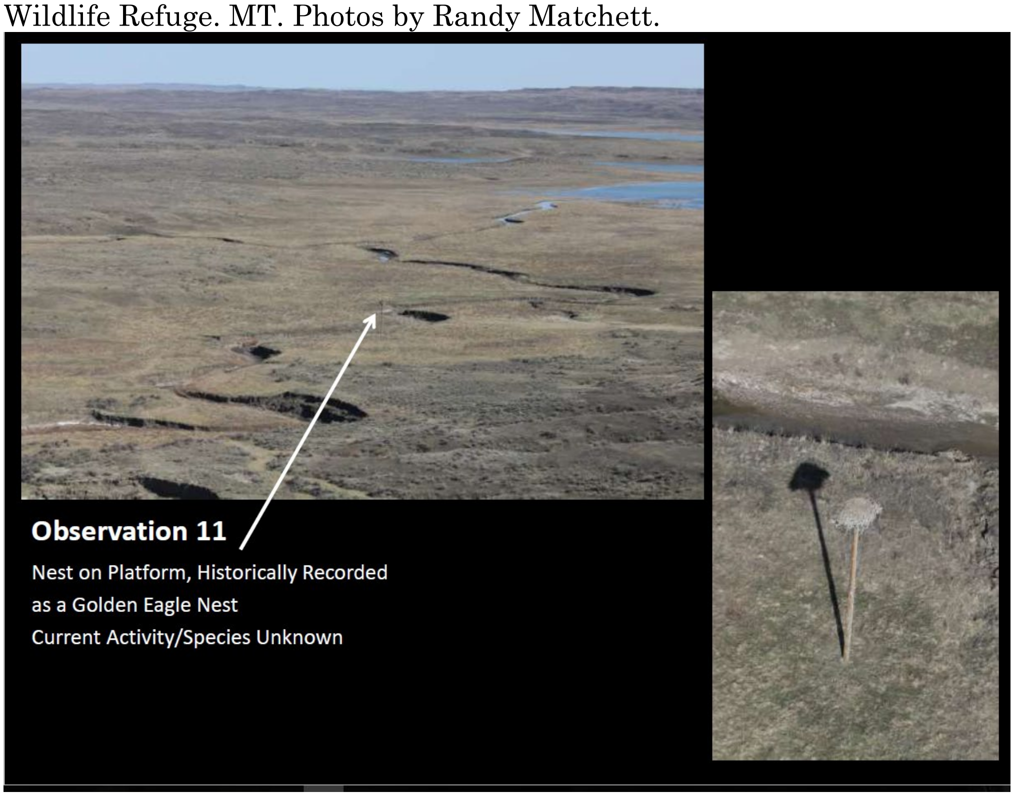


Figure 2.13. Nesting platform used by Golden eagles in habitat otherwise devoid of nesting structures in the Charles M. Russell National Wildlife Refuge. Photos by Randy Matchett.

Figure 2.14. Occupied golden eagle nest in-use on a GSM communication tower in the Powder River Basin. Photo by Bryan Bedrosian.

2.1.3.4. Nest Site Selection

Breeding habitat selection using GPS telemetry relocation data has only been investigated within the NWPL in the Livingston study area (Figure 2.2). Using resource selection models derived from GPS tracked breeding adult eagles, Crandall et al. (2015) found that eagles selected home-ranges at core-area scale (not home-range scale) that had a higher proportion of mixed shrub and grassland with higher terrain ruggedness. This study found that within the home range, eagles selected for high terrain ruggedness in close proximity to prey habitats (mixed shrub or grassland), close to their nests, with a western aspect. Prey habitat was an important factor for selection at both the landscape and within home-range scales, highlighting the importance of hunting habitat for breeding eagles. Further, while eagles selected for terrain ruggedness within home-ranges, the probability of use of rugged terrain decreased as the distance to prey habitat increased. The selection of western aspects also reflects the primary wind direction. Selecting western facing rugged terrain close to prey habitat may help facilitate hunting by providing better lift and flight conditions. These data highlight that prey habitat quality should not be overlooked when attempting to manage or map breeding habitats.

Phillips and Beske (1990) surmised that golden eagles likely prefer conifers over deciduous trees and prefer isolated or scattered trees over dense stands of conifers or cottonwoods for nesting. However, even in territories with available cliff nesting habitat, eagles often nested in trees (Crandall et al. 2016, B. Bedrosian, pers. obs.). Cottonwoods often provide the only available nesting substrate within a territory across the NWPL, and can occur within existing riparian areas or singly. In the event isolated cottonwoods are lost, displacement of a territorial pair can occur (Phillips and Beske 1990). Coyle (2008) found that nests were located on cliffs with a southerly aspect in North Dakota.

2.1.4. WGET Relative Nest Density (RND) Model

Nesting habitat is an essential resource for reproduction and persistence of golden eagle populations. To understand the distribution and characteristics of golden eagle nesting habitat in the NWPL, WGET developed a model of Relative Nest Site Density (RND). The model predicted the relative density of golden eagle nesting territories across the region by relating locations of known nests to habitat variables using MaxEnt software (Phillips et al. 2006). The RND model is one of three key data products supporting the conservation strategy, together with models of winter habitat use (2.2.3.2.b. Winter Habitat Use) and movement (2.3. Movements and Migration). Here we provide a brief summary of modeling methods and focus on results describing the attributes of golden eagle nesting habitat in the NWPL. We describe the distribution of priority breeding areas in the NWPL based on these model results in section 4.2.1. Details of modeling methods and a complete report on development and evaluation of models for this ecoregion is in Dunk et al. (2019). A description of the area used for modeling can be found in Section 1.

2.1.4.1. RND Model Development

Training data for the model included 977 nests that were selected from 23,991 based on evidence of occupancy/use, occurring on natural (not man-made) structures, and thinned to reduce spatial redundancy of multiple records within the same breeding territory (Dunk et al. 2019). An initial screening process to identify model covariates began with 457 variables derived from 42 environmental variables that occurred at six different spatial scales within a 20-km radius around each sample nest. After reducing variables using a multi-stage variable screening process and minimizing multicollinearity, 20 covariates were included in the MaxEnt modeling process. The final model predictions were created using the nine covariates that contributed ≥ 1.0% to the best MaxEnt model.

The MaxEnt model was optimized by independently evaluating eight regularization values using cross-validation, with a regularization value of 4.0 having the lowest mean squared error (Dunk et al. 2019). The performance of the model within 10 equal-interval bins was validated using 10 k-folds of 25% withheld training data and through geographic cross-validation in subregions based on USFS Ecological Sections within the NWPL (Figure 1.6). Model fit was confirmed by high correlation and overlapping error bars (mean ±2 standard errors) between numbers of predicted and actual nests in each bin. There were some relative nest density bins (10% bins) that had moderate model performance (e.g., North Central Highlands). However, 73.8% of the differences between predicted and actual number of nests was < 5 and all error bars between observed and expected were overlapping, indicating that the model performed good-to-excellent in most sub-regions (Dunk et al. 2019). Model predictions derived from 20-km radii surrounding the training data were projected to the remaining area of the NWPL.

2.1.4.2. RND Model Results

The final RND model included 12 predictor covariates representing topography, vegetation, and lift (Table 2.2). Terrain variables contributed most to the model (51.3%), followed by landcover variables (42.8%) and lift (5.8%). Evaluation metrics indicated that model performance was good-to-excellent. The tested performance of the projected model to the entire NWPL was similar to the training data and the differences between predicted and actual nests in each of the sub-regions assessed were small. Differences were <3 nests in 58.8% and <5 nests in 73.8% of the sub-regions. See Dunk et al. 2019 for details.

The standard deviation of grade at a 120-m scale was the largest contributor to the final relative nest density model within the NWPL (Table 2.2). Grade is topographic index of slope (in degrees) calculated from elevation within the US Geological Survey (USGS) national hydrology dataset and had a positive influence on relative nesting density. The mean percentage of sparsely vegetated area within 6.4 km also had a positive effect on the model while the standard deviation of the percentage of cropland within a 6.4 radius had a negative effect on relative nest density. The average percentage of cottonwood cover within 1 km, thermal uplift within 2 km, ponderosa pine cover within 6.4 km, and normalized difference vegetation index (NDVI) within 6.4 km, percent of grassland cover within 2 km, and the proportion of flat areas within 6.4 km each contributed between 1.2–6.7% of the model. Measures of orographic uplift, steepness and topographic wetness index each contributed <1.0% to the model and may have helped influence other covariates, likely have little function biological contribution to the relative nesting density of golden eagles in the NWPL. Overall, the three most influential covariates contributed 75.5% to the model's predictions.

Dunk et al. (2019) estimated area-adjusted frequencies (AAF) (Boyce et al. 2002) for the RND model. These AAF surfaces represent the extent to which nesting densities throughout the NWPL varied from a random distribution (i.e., proportional to the areal extent of each RND bin). To emphasize pixels closer to the center focal pixel of the moving window, the AAF surfaced was smoothed using a weighted Gaussian kernel (also known as a radial basis function kernel; Bedrosian et al. in press; Figure 2.15) generated using the 80% upper confidence interval of the grand mean core area size based on telemetry data for breeding territorial adult golden eagles (8.69 km^2; R. Crandall, personal communication).

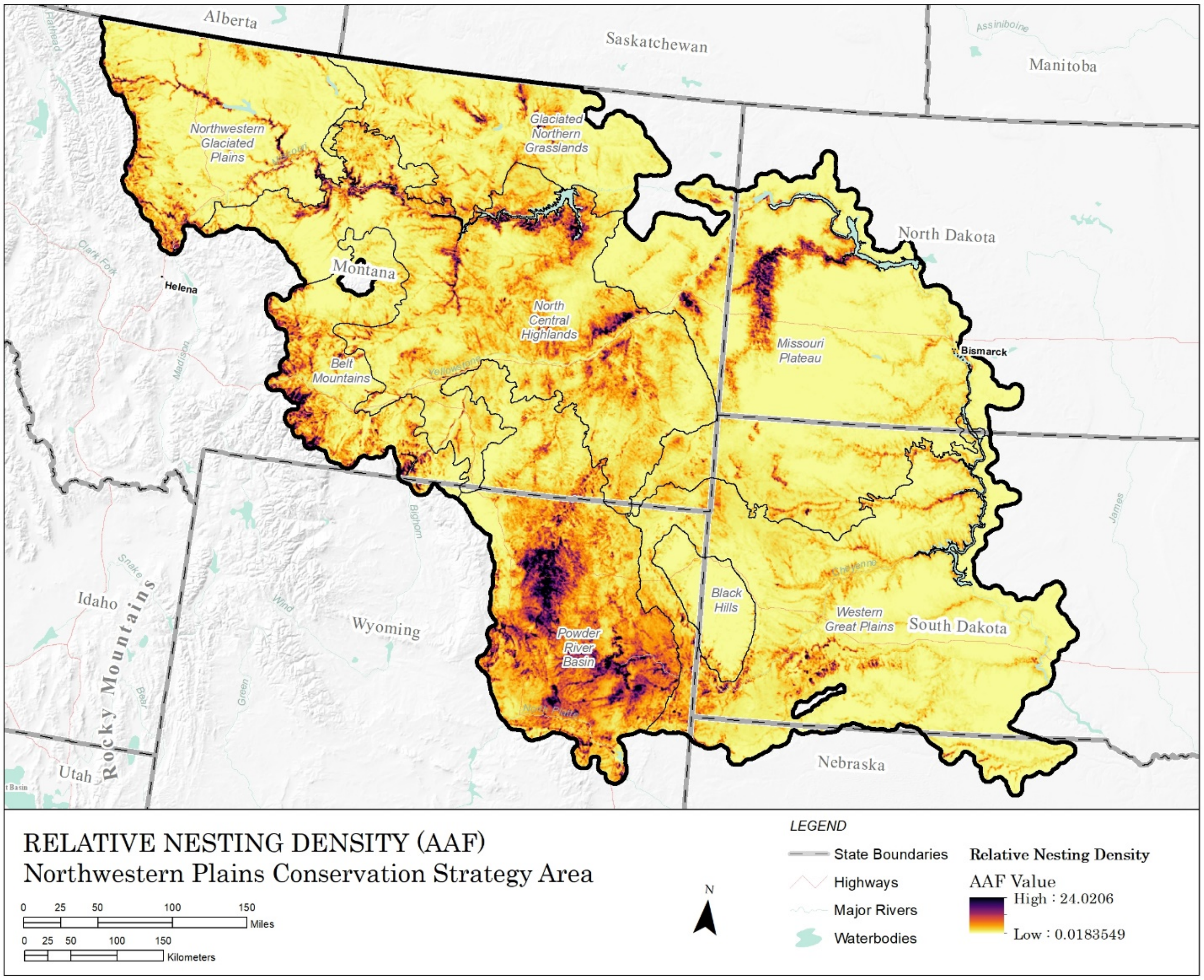


Figure 2.15. Relative Nest Site Density model (area-adjusted frequency) for the Northwestern Plains. USFS Ecomap sections shown as the sub-regions used for model validation.

Dunk et al. (2019) calculated a strength-of-selection (SOS) metric using the model results to further investigate the relative importance of areas across the NWPL for nesting densities (Figure 2.16). SOS is an index of the expected nest density within various bins if nests are distributed proportional to the area within each respective bin (Dunk et al. 2019). Using the training area within the NWPL and dividing it into 10 equal-interval bins, Dunk et al. (2019) found that SOS varied from -9.44 to 27.10 for the lowest and highest bins. This means that in the lowest RND bin, there were 9.44 times fewer nests within the area than would be expected, given the land area. Conversely, in the highest bin, there were 27.10 times as many nests than would be expected. Within the training area, 36.5% of all the nests were contained within bins >0.6 but the area represented ca. 4% of the training area, while 19% of the nests were within bins <0.3 which contained 71.4% of the surface area (Dunk et al. 2019). After projecting the model to the remaining modeling area, only about 3% of the entire region was estimated to be within bins >0.6.

Table 2.2. Variables contributing to the model of relative nest site density for golden eagle territories within the Northwestern Plains. Shown are variable name, basic description, size of the neighborhood in which the variable was evaluated, focal statistic used for evaluation, and percent contribution to the final model. Detailed descriptions of variables, sources, and model development available in (Dunk et al. 2019).

Covariate	Description	Neighborhood Size	Neighborhood Focal Statistic	% Contribution
Grade1_120m_sd	Slope index	120 m	Standard Deviation	49.9
Sparse1_6.4km_mn	Proportion sparsely vegetated area	6.4 km	Mean	14.6
Crop3_6.4km_sd	Proportion cultivated cropland	6.4 km	Standard Deviation	11
Cttnwood1_1km_mn	Proportion of cottonwood cover	1 km	Mean	6.7
Uplifttherm1_2km_mn	Thermal uplift	2 km	Mean	5.1
Ponderosa1c_6.4km_mn	Proportion of ponderosa pine cover	6.4 km	Mean	4.8
NDVIb_6.4km_mn	Normalized Difference Vegetation Index	6.4 km	Mean	3.8
Grass1_2km_mn	Proportion of grassland cover	2 km	Mean	1.9
Flat1b_6.4km_mn	Proportion flat areas	6.4 km	Mean	1.2
Upliftoro1_2km_sd	Orographic uplift	2 km	Standard Deviation	0.7
Steep1b_2km_sd	Terrain steepness index	1 km	Standard Deviation	0.2
TWI1_120m_sd	Topographic wetness index	120 m	Standard Deviation	0.2

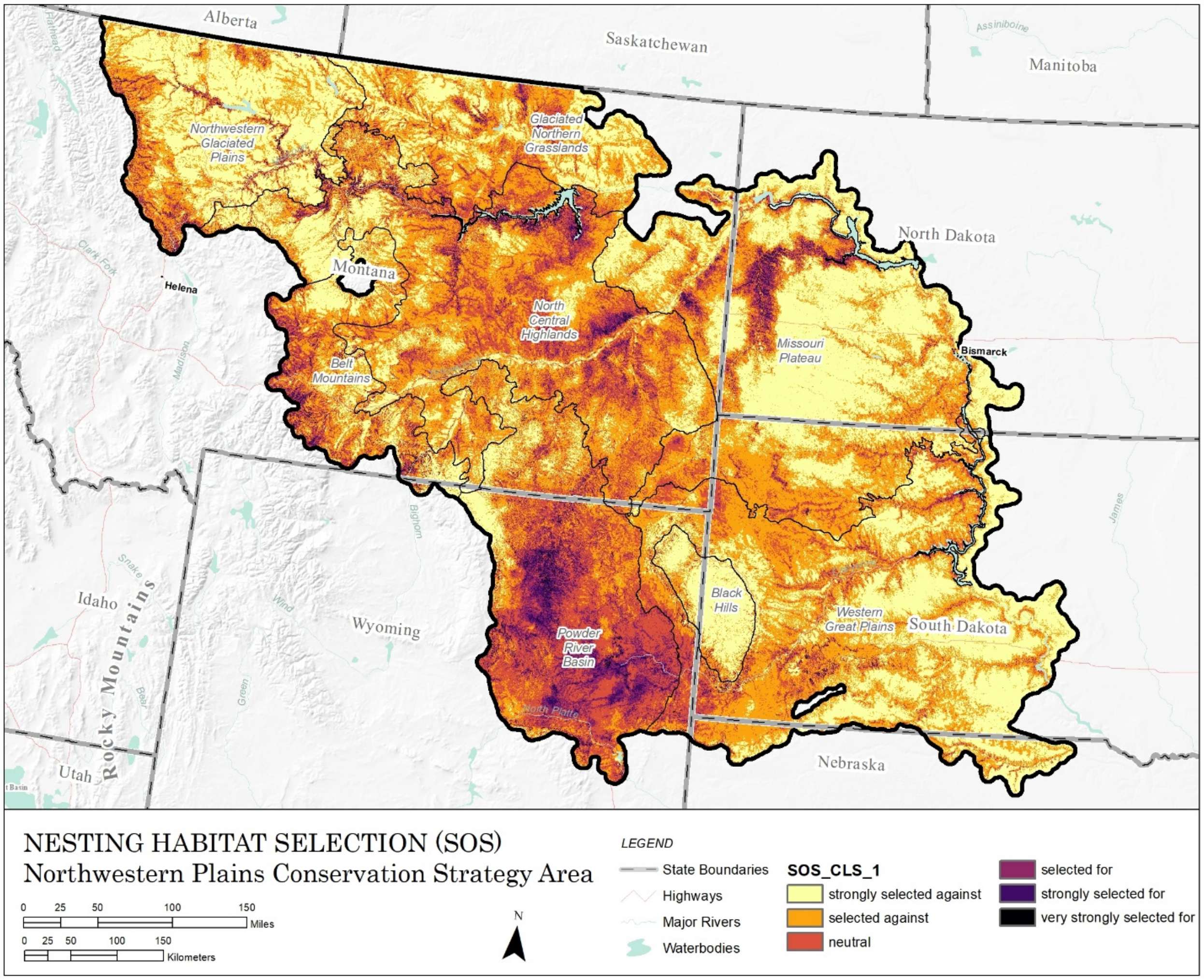


Figure 2.16. Predicted relative density of golden eagle nesting territories in the Northwestern Plains conservation assessment area. Displayed as relative strength of selection (SOS).

2.1.4.3. RND Model Discussion

The variables included in the RND model were selected to make the best possible spatial predictions of relative nesting territory density, not necessarily to serve as a mechanistic model of golden eagle ecology. To further describe golden eagle habitat associations, we used model deconstruction (Dunk and Hawley 2009, Zielinski et al. 2012) to explore correlations of the RND model predictions with additional environmental variables. These variables were not included in the final model, but represented environmental factors known to be important to the species, as well as variables that are of interest to resource managers because they can be manipulated as part of restoration and mitigation efforts.

The largest positive influence on the relative density of golden eagle nesting territories in the NWPL was the variation in slope at the fine-scale (120 m), representing half of the predictive contribution to the model. In many areas, golden eagle nesting habitat is generally linked to high terrain ruggedness (e.g., Crandall et al. 2015), typically due to cliff habitat used for nest placement (Kocher et al. 2002). However, cliff habitats are very limited within the NWPL but eagles still appear to be selecting for locally variable terrain that likely offers opportunities for thermal uplift and/or nesting sites such as erosional cliff banks.

The amount of sparse vegetation at the large-scale (6.4 km) provided the second largest positive contribution (14.6%) to the RND model within the NWPL. The LANDFIRE classification of sparsely vegetated systems within the Western Great Plains represent badlands, sandstone bands, and areas where geologic uplifts have permitted down-cutting by ancient streams with < 10% vegetation cover (LANDFIRE 2015). These areas are also consistent with variable slope and often occur as breaks, badlands, and rock outcrops. These features within the NWPL typically provide any available cliff-type nesting habitat along with small pockets of ponderosa pines for nesting while the larger-scale habitat may have less vegetation.

The proportion of cultivated cropland at the large-scale (6.4 km) provided the next largest contribution to the model output (11%). As the variation in cropland increased, the habitat suitability for golden eagles in the NWPL decreased. Golden eagles have been shown to avoid cultivated cropland across the West, presumably due to decreased prey resources in cultivated fields (Marzluff et al. 1997, Domenech et al. 2015, Crandall et al. 2015). Given golden eagle avoidance of croplands, the avoidance of high variability in cropland at the home-range scale suggests eagles in the NWPL are selecting for habitats more uniformly lacking cultivated croplands.

Together, the three most influential covariates represented 75.5% of the contributions of all the RND model covariates, indicating the strong selection for variable terrain not associated with cultivated cropland. The vast majority of the NWPL is devoid of trees and other nesting substrate except for riparian systems and isolated, remnant cottonwood trees. The mean proportion of cottonwoods within a 1-km window provided a 6.7% positive contribution to the model. Across the NWPL, golden eagles regularly nest in cottonwood trees (see sections 2.1.3.2, 2.1.3.3). In areas with little relief, cottonwoods provide the main nesting substrate when suitable prey exist in the area. Golden eagles also appear to avoid large conifer tracts within the NWPL (e.g., the Black Hills), with the proportion of ponderosa pine within a 6.4-km window having a 4.8% negative contribution to the model. Nesting in ponderosa pine is a regular occurrence across the NWPL but generally occurs near the edge of pine forests or in isolated patches in draws and small outcroppings. The inclusion of this covariate suggests that eagles are selecting against larger tracts of continuous pine forests.

Mean thermal uplift at the moderate scale (2 km) also positively contributed to the model (5.1%). This variable represents thermal uplift index (for March-May), developed using methods similar to those presented in Bohrer et al. (2012) and Dennhardt et al. (2015). In the NWPL, updrafts from rugged terrain for directed movement and hunting are limited by the generally flat topography. Thermal uplift can help facilitate movements and hunting in areas of limited topography and likely has similar biological implications for eagle ecology as slope variability. The mean NDVI from 2003–2013 at the home-range scale had mixed effects on nesting density. As NDVI increased, nesting density increased to a point, then rapidly declined with increasing NDVI. Crandall et al. (2015) suggested that the amount of prey cover at the home-range scale positively influenced breeding golden eagle habitat selection. NDVI, or the greenness, at the home-range scale is a good indicator of moisture content within the vegetation and higher NDVI is likely indicative of relatively greater prey abundance and diversity. However, because there are large amounts of cultivated cropland in the eastern portion of the NWPL, NDVI would be much higher in agricultural fields than moisture rich native habitats and pasturelands. As seen in the contribution of cultivated cropland (above), nesting density decreased with increased proportions of cropland (which has high NDVI values). The proportion of grassland and herbaceous cover at the moderate-scale also positively contributed to the model, presumably due greater prey in those habitats (see 2.1.7).

2.1.4.4. RND Model Deconstruction

We estimated the mean, standard deviation, and coefficient of variation for 44 variables within seven SOS bins. Values of SOS closer to 1.0 suggest similar density of observed and expected nests (e.g., 10% of nests occurring in an RND bin that contains 10% of the landscape), whereas large positive or negative values suggest selection for or against areas in an RND bin (e.g., an SOS of 7.5 for an RND bin that contains 10% of the landscape is interpreted as strong positive selection because 75% of nests occur in only 10% of the landscape). We interpreted variables that had strong patterns in strength of selection and decreasing coefficient of variation in higher SOS bins as suggestive of golden eagle habitat associations.

Some interesting patterns emerge in the variables apparently associated with SOS in the NWPL. At the fine-scale (120 m), only terrain variables were associated with a greater density of nests, with all indicating selection for rougher, steeper terrain. No habitat, climate or wind variables were associated with SOS at the fine-scale. Conversely, the only topographic covariate associated with SOS was the variation in the steepness index at the 2-km scale, with strongly selected habitat having ca. ≥ 4 times the variability in steep terrain (16%) as habitat classified as neutral or selected against.

The variability in mean degree days >5 C^{o}, annual moisture index, and terrain wetness index all positively influenced SOS at the fine-scale. The mean orographic uplift index was much higher in the very high density category than any other for SOS (0.21 index value compared to a range of .016-.018 for all other categories).

No habitat covariates were associated with SOS at the fine-scale, but many had positive associations with SOS at the moderate-scale (1–3.2 km). The proportion of both cottonwoods and shrubs at the 1-km scale were positively associated with SOS, but the apparent association was largest in the avoidance categories, rather than large differences in selected-for categories. The variability of cottonwoods, shrubs, barren ground, sparsely vegetated habitats, tall sagebrush, greasewood and forest all positively influenced SOS at the moderate-scales. Gross primary production and the proportion of alfalfa were negatively associated with SOS at this scale. Flat, cultivated areas at the home-range scale (6.4 km) with larger variation in road landcover seem to negatively affect the SOS model results.

The amount of tall sagebrush and sparse vegetation at the home-range scale were the only other covariates influencing SOS, with greater proportions of these habitat types in selected-for categories.

These results are consistent with the habitats within the NWPL and known golden eagle ecological preferences. Areas that offer terrain suitable for nests sites such as breaks, buttes, and cliffs provide valuable nesting substrate in an otherwise relatively flat ecoregion. Across much of the western US, golden eagles are known to prefer these habitat features for nesting (Kochert et al. 2002). Similarly, in areas without these habitat types, golden eagles in the NWPL will find suitable trees for nesting, which include cottonwoods and conifers on buttes and ecotones (Phillips and Beske 1990, Crandall et al. 2016), which may explain the positive associations of these habitat types with SOS and inclusion in the RND model. The variability in native habitats at moderate-scales with avoidance of agriculture at larger-scales were generally associated with a higher density of nests. Crandall et al. (2015) also found eagles selected for rugged terrain in proximity to prey habitat along the western edge of the NWPL, which help corroborate these results. Negative selection of agriculture is also consistent with Domenech at al. (2015).

2.1.4.5. RND Applications and Limitations

Maps of predictions from this model are powerful tools with potential applications for prioritization of landscapes for conservation and mitigation, as well as informing design of future surveys and monitoring efforts in the NWPL. However, the data and methods used to generate this model place some limitations on its interpretation and application. RND values represent *relative* density of nest sites within the ecoregion and do not predict actual locations of golden eagle nest sites or actual nesting density. Although the model predicted habitat suitability within 120-m^2 cells, caution should be used in applying model predictions for management at fine spatial scales. Golden eagle core use and home-range extents are much larger than the 120 m x 120 m spatial resolution, thus mapped predictions underestimate the extent of habitat that is actually required to support breeding by golden eagles. Covariates in the model should not be interpreted to represent the ecological niche of nesting golden eagles; results of model deconstruction are more useful for management applications, but still represent correlations with relative density of nesting territories, rather than a mechanistic model of golden eagle breeding habitat selection.

Training data did not include nests on human-made substrates; therefore, caution should be used when applying the model in areas where golden eagles are known to nest on power poles, artificial platforms, oil and gas tanks, and other infrastructure. The Powder River Basin is one such area, so RND results may underestimate use in that area due to anthropogenic nest sites. All covariates included for model selection were remote sensing data, with the finest scale of 120 m x 120 m cells. At this scale, lone trees, such as cottonwoods, are not captured in the classification and are likely under-represented.

The RND model provides an estimate of relative nesting density *within* the ecoregion; direct comparisons between the NWPL and other ecoregions (e.g., the Wyoming and Unita Basin Ecoregion) should not be made. Standardization of ecoregional RND models may be possible by transforming relative density to predicted density based on observed densities in the training data and calibrating to on-the-ground intensive study areas with high confidence in known density of nesting golden eagles (Bedrosian and Lickfett 2019).

2.1.5. Fecundity

Golden eagle monitoring commonly involves tracking rates of nesting territory occupancy, nesting success, and productivity within nesting territories (Bildstein and Bird 2007). Such data provide baselines of fecundity necessary to assess population status and impacts of disturbance, while regionally-specific information on breeding phenology can inform timing of seasonal restrictions on activity near nest sites. Long-term declines in fecundity can occur in response to habitat conversion (Steenhof et al. 1997) or chronic disturbance (Steenhof et al. 2014), while inter-annual changes track climatic variation (Wiens et al. 2018), fluctuations in prey abundance (Preston et al. 2017), and short-term disturbance (Spaul and Heath 2016). Fecundity of golden eagles in the NWPL has been documented by five studies spanning 1962–2018 (Table 2.1).

2.1.5.1. Nesting Territory Occupancy

Territory occupancy within the NWPL is high relative to other ecoregions. Phillips and Beske (1990) found 100% occupancy rates among 36 nesting territories consistently monitored from 1981–1989 in the Gillette ESA. Similarly, Phillips et al. (1990) documented 100% occupancy rates for nests within the Sheridan study area from 1975–1985, including several years of documented low prey abundance. Crandall et al. (2016) documented an average 92% occupancy rate among 45 territories in 2010–2014 in the western portion of the NWPL. Territory occupancy should be determined from the ground in the years following territory discovery. A minimum of four visits on separate days totaling at least four hours should be used to document occupancy since many alternate nest sites could be present within a territory (Driscoll 2010). Occupancy rates made from aerial observations are generally not accurate because aerial surveyors are unlikely to observe territorial behaviors and/or nest maintenance on all nests within a territory during flights.

Territory occupancy may be lower in the Dakotas, as compared to other areas. Knowles (2001a and 2001b) suggested there was a significant decline in occupancy of historic territories from the 1980's to 2001 in the Little Missouri and Grand River National Grasslands. Using the assumption that all good to fair condition nests represented a territory, Knowles (2001a and 2001b) estimated occupancy rates from 43–60%. However, it should be noted that these estimates of occupancy were determined from one aerial visit to each territory and likely underestimate true occupancy.

2.1.5.2. Breeding Success

Breeding success is most often measured as apparent nest success (ANS), which may overestimate true nesting success but is a useful metric to compare between studies or investigate long-term trends (Brown 2014. Steenhof et al. 2017). Nest success fluctuates greatly across time, likely a result of prey abundance (Reynolds 1969, Phillips and Beske 1990, Kochert et al. 2002) and studies <5 years in length may not capture these fluctuations. For example, from 1963–1968 in the Livingston study area, McGahan (1968) and Reynolds (1969) found an average 76% ANS (range = 55–95%). McGahan (1968) estimated ANS as a 2-yr average of 91.7%, while productivity significantly declined over the next four years to an average of 69.4% (Reynolds 1969). However, it is not clear if McGahan determined ANS using occupied territories or in-use nests. Given the methodology reported, it appears that his measure was likely the percentage of successful nests/in-use nests since they report alternate nest sites within given territories.

From 1976–1985 in the Sheridan study area, Phillips et al. (1990) found an average 55% ANS (successful/in-use nest) and Phillips and Beske (1990) documented a 54.8% ANS from 1981–1985 in Campbell Co. More recently, Crandall et al. (2016) found 62% ANS (CI =0.49) in the Livingston study area. Using that same dataset and a Bayesian hierarchical modeling approach (Brown and Collopy 2012), the daily nest survival rate was 0.995 and annual survival rate was 0.62 (Crandall et al. 2015, Crandall et al. 2016). Increased terrain ruggedness at the core-area level decreased survival. Nesting substrate does not appear to affect nest success or productivity in the NWPL (Phillips and Beske 1990, Crandall et al. 2016). Weather has a significant impact on nesting success in the NWPL, with high winds blowing nests down and wet snow or rain causing failures (Phillips et al. 1990, B. Bedrosian pers. obs.).

2.1.5.3. Reproductive Rates

Reproductive rates are generally consistent across the NWPL (Table 2.3) and comparable to estimates in other regions. Kochert et al. (2002) reported 0.83 young/occupied nest from five long-term studies, while the USFWS (2016) estimated 0.55 young/occupied nest. The number of fledglings produced from successful nests ranged from 1.38–1.56 across five studies (Kochert et al. 2002) and NWPL studies have documented similar success (1.3–1.5; Table 2.3).

Typical clutch size for golden eagles in the NWPL is two eggs (90%) and only 8% of nests have three eggs (McGahan 1968, Reynolds 1969). Hatching success is 86% and 38% of nestlings do not survive to fledging (Reynolds 1969).

Productivity of golden eagles within the Livingston study area appear to be limited by density dependent selection since overall productivity declined as nesting territory density increased. In that region, density has more than doubled while productivity declined by 28%. Additionally, the most productive territories may have been occupied in the 1960s and the increase in nesting territory density may have been of lower-production territories, thereby lowering the population-level productivity estimate. Particular nest sites can consistently have higher production than others within a particular area (up to 10 times greater), whether a result of experience or territory quality (Reynolds 1969, Phillips et al. 1990, Phillips and Beske 1990).

2.1.5.4. Nest Chronology

Nesting chronology within the NWPL can vary with prey abundance (Phillips and Beske 1990) or weather, particularly annual snowpack, spring temperatures and/or precipitation (G. McKee pers. comm.). Low prey abundance may delay incubation up to two weeks (Phillips and Beske 1990). Further, nest initiation can vary by up to one month in the same region and up to two months if eagles re-nest after an early failure (Phillips and Beske 1990, B. Bedrosian, pers. obs.). Typically, there can be a three-week disparity for the start of incubation among nests (Phillips and Beske 1990), or even between siblings within a nest (Figure 2.17). In the Sheridan study area, the median lay date was 20 March, but began as early as 24 February (Phillips and Beske 1990). Fledging typically begins in early July but can be as late as early August for some nestlings. Dates are generally consistent across the NWPL and over the past 30 years (Phillips and Beske 1990, B. Bedrosian, unpub. data).

Figure 2.17. Example of a ca. 3-week disparity of nestling age within one golden eagle nest in Powder River Basin, 2016. Photo credit: Moosejaw Bravo.

Table 2.3. Golden eagle fecundity rates in the Northwestern Plains conservation assessment area.

Study Area	Years of Study	Mean Nesting Territory Occupancy	Mean % Successful/ Breeding Attempt	Mean % Successful/ Occupied Territory	Fledglings/ Occupied Territory	Fledglings/ Breeding Attempt	Fledglings/ Successful Nest	Source
Sheridan	1975-1985	100		54 (30-90)	0.78		1.5	Phillips et al. 1990
Gillette (ESA)	1981-1989	100	68	55 (37-71)	0.81	1.01	1.48	Phillips and Beske 1990
Livingston	1962-1967		69.4 (55-77.8)			1.11	1.43	McGahan 1968, Reynolds 1969
Livingston	2010-2014	92	62.1 (31.6-76.9)	46.9 (36.6-64.5)	0.60	0.81	1.3	Crandall et al. 2015
North Dakota	2002-2006		67.1 (52.1-81.6)			0.92	1.4	Coyle 2008

2.1.6. Breeding Season Diet

Golden eagle nesting density and fecundity are influenced by local abundance and availability of prey (Bedrosian et al. 2017). Some areas within the NWPL offer wide prey diversity (e.g., Livingston), while eagles in areas such as the Powder River Basin may rely almost exclusively on one species (e.g., blacktailed-prairie dogs (*Cynomys ludicianus*). Overall, the NWPL has a wider dietary breadth relative to other ecoregions, with the exception of limited information on diets in Western Cordillera based on a single long-term study (Bedrosian et al. 2017).

The diet of breeding eagles can be quite diverse in the NWPL (McGahan 1968, Bedrosian et al. 2017) and likely reflects prey abundance and diversity within a territory (Reynolds 1969). Few studies have investigated the breeding season diet of golden eagles with in the NWPL but all suggest that family Leporidae [cottontail rabbits (*Sylvilagus* spp.), jackrabbits (*Lepus* spp.)], (hereafter leporids) and Sciuridea [prairie dogs (*Cynomys* spp.) and Richardson's ground squirrel (*Urocitellus richardsonii*)] (hereafter Sciurids) are the primary prey for golden eagles in the NWPL. Leporid abundance is correlated to nest initiation and productivity in the NWPL (Reylonds 1969, Phillips et al. 1990). In south-central Montana, leporids were the major prey item for breeding eagles in the 1960s, but diets shifted in low leporid years towards birds and yellow-bellied marmots (*Marmota flaviventris*) (Reynolds 1969). While marmots typically do not occur within most eagle territories due to elevation differences, recent telemetry data suggest that eagles forage in higher elevations later in the breeding season (B. Bedrosian, pers. obs.).

Contemporary data from the Livingston study area suggests a diet shift towards pronghorn (Crandall and Preston, unpubl. data), likely resulting from jackrabbit population declines in in this region. Pronghorn remains found in nests within this study area were primarily young pronghorn (B Bedrosian, pers. obs.) and fawns may be an important prey resource during the breeding season. Historical accounts of high predation rates of pronghorn by eagles resulted in bounties on golden eagles in central Montana in the mid-20th century but subsequent analysis of stomach contents of 51 killed eagles revealed that the primary prey was jackrabbits (51% of stomachs contained jackrabbits) while only 15% contained pronghorn remains (Woodgerd 1952). This study documented a relatively large number of small mammals as prey items, which is likely an artifact of methodology or because breeding eagles consume these small items rather than bring them back to the nest. In areas devoid of pronghorn, it is likely that young deer (*Odocoileus virginianus* and *O. hemionus*) are also used as prey.

In areas where prairie dogs (primarily black-tailed prairie dogs) are abundant, there is evidence to suggest that they are the main prey for territories that overlap prairie dog colonies, comprising up to 65% of the diet (Phillips et al. 1990). In North Dakota, a wide array of prey remains were documented in and below active eagle nests but totals or estimates of number of items found were not reported (Coyle 2008). Domestic sheep (primarily lambs) are reported as a prey item in many historical diet studies (Cameron 1905, Woodgerd 1952, Arnold 1954, McGahan 1968, Reynolds 1969) which led to the removal or relocation of eagles from areas within and adjacent to the NWPL as recently as 2019 (Watte and Phillips 1994, T. Byer, personal communication). Most often, dietary shifts towards domestic livestock and alternative prey occur in years of low leporid abundance where scurids do not occur with regularity. See McGahan (1968) and Reynolds (1969) for detailed lists of other prey species recorded in the NWPL.

2.1.7. Prey Community

Leporids occur throughout the NWPL and their populations can annually fluctuate. The combined ranges of three species of cottontails cover the majority of the NWPL. Mountain cottontail (*Sylvilagus nuttallii*) and desert cottontail (*S. audubonii*) ranges overlap in most of the Montana and Wyoming portions of the NWPL, while the Dakotas host primarily eastern cottontails (*S. floridanus*) and desert cottontails. Cottontails typically occur in shrubland and grassland habitats but need hiding cover such as downed wood, shrubs, rocks, or anthropogenic sources of cover (Hansen et al. 2017). Using shrubland and grassland habitat types as a proxy for prey habitat, Crandall et al. (2015) found that distance to prey habitat had a significant positive relationship in predicting golden eagle habitat use and the proportion of 30-70% shrub and herbaceous cover the nesting territory positively influenced productivity.

Cottontail populations fluctuated in an approximately 8-year cycle in Wyoming (Fedy and Doherty 2011) and low cottontail abundance years negatively affected golden eagle productivity within the NWPL (Reynolds 1969, Phillips et al. 1990, Oakleaf et al. 2014). Since 1978, cottontail populations in Wyoming reached high levels in 1983 and 1991 but since the peak in the early 1990s, cottontail populations have remained at low levels (Oakleaf et al. 2014). The population increased in the mid-2000s, but only to half of the level of previous population peaks.

White-tailed jackrabbits (*L. townsendii*) occur across the majority of the NWPL and have dramatic population fluctuations, both annually and seasonally. There have been recent concerns about declining jackrabbit populations in the NWPL (Schaible and Dieter 2011, Dieter and Schaible 2014), and general concensus is that white-tailed jackrabbits are declining across their range (Simes et al. 2015). Anecdotal accounts or short durations of surveys periodically appear in the literature about jackrabbit densities in the NWPL. Ensign (1983) estimated an average of 0.45 and 0.30 jackrabbits/km in southeastern Montana in 1981 and 1982, respectively, using vehicle headlight surveys. On the Kevin Rim, results of vehicle headlight surveys declined from 0.56/km (Harmata 1991), to 0.19/km, 0.09/km, and 0.06 in 1991, 1992, and 1994, respectively (Van Horn 1993, Zelenack 1996). More recently, Dieter and Schaible (2014) used distance sampling from surveys in 2004–05 to create population estimates ranging from 0.43–27.12 jackrabbits/km^2 in western South Dakota. Jackrabbit home ranges were 1.34 km^2 and 1.09 km^2 for males and females in South Dakota, with smaller home ranges in agricultural habitats relative to native rangelands (Schaible 2007).

Avian prey communities vary widely across the NWPL. Greater sage-grouse (*Centrocercus urophasianus*) populations occur across much of the central portion of the NWPL but are relatively low. Even in areas with relatively higher populations of sage-grouse, golden eagle predation on the species is low (Preston et al. 2017). Ring-necked pheasant (*Phasianus colchicus*) occur in high numbers across much of Montana and the Dakotas and overlap much of the nesting habitats of golden eagles in the NWPL. Many breeders and farms annually supplement pheasant populations and release captive bred birds that may be easier prey for eagles than wild-hatched pheasants. Black-billed magpies (*Pica pica*), common ravens (*Corvus corax*), and great horned owls (*Bubo virginianus*) are regularly taken as prey in the region and are nearly ubiquitous across the landscape. Black-billed magpies are often associated with cattle operations and other anthropogenic subsidies.

Pronghorn occur across the NWPL. Population estimates for states within the NWPL are roughly 6,000 pronghorn in North Dakota (Christie et al. 2015), 35,000 in South Dakota (South Dakota Department of Game, Fish and Parks 2014), 158,000 in Montana (Montana Fish Wildlife and Parks 2017), and 147,000 in the Wyoming portion of the NWPL [estimated from Job Completion Reports (https://wgfd.wyo.gov/Hunting/Job-Completion-Reports/2017-Big-Game-Job-Completion-Reports). Christie et al. (2016) found that pronghorn in the NWPL selected sagebrush steppe habitats and avoided agriculture, wetlands and rough terrain. Populations are also negatively affected by heavy snowfall, cold winter temperatures and oil and gas well density (Christie et al. 2015).

2.2. Non-Breeding Populations

Golden eagles have delayed maturation and generally do not become territory holders until they are at least 4.5 years old (Kochert et al. 2002). However, some eagles become part of a breeding pair as a sub-adult (Steenhof et al. 1983, B. Bedrosian personal observation), which may be indicative of populations with high adult mortality (Whitfield et al. 2004). Conversely, other adult eagles (i.e., *floaters*) may not gain access to a territory until much older in saturated nesting habitat with low adult mortality. Movements and habitat use of sub-adults and non-territorial adults is likely influenced by having to navigate the landscape through defended territories and their movements may not be similar to movements of adults, particularly breeding pairs. Maintaining this segment of the eagle population is important for recruitment and maintaining population size.

In addition to non-migratory sub-adults and floaters, a large portion of the golden eagle population in western North America is migratory. During the winter months, thousands of eagles of all age classes migrate into and overwinter across the conterminous United States. See Section 2.4 for more details on winter ecology.

2.2.1. Abundance and Density

Little data exist on the abundance and density of sub-adults and floaters in the NWPL. Neilson et al. (2016a) estimated 1,397 juvenile golden eagles in BCR 17 (90% CI: 770–2,185), or 20% of the total individuals estimated. During the winter months of 2014, Neilson et al. (2015) estimated only 2% golden eagles as juveniles.

2.2.2. Space Use

Sub-adults and floaters do not have to defend nest sites or specific resources, and therefore can more freely roam than their breeding conspecifics. Harmata (2015) described the MCP home range estimates of three adult floaters in the NWPL: 6,564 km^2 from a female during

February – July, 2013; 13,014 km² from of a male during August – January 2012; and 14,780 km² from a male during March – August 2013.

Using an unpublished dataset provided by B. Bedrosian (Teton Raptor Center), we determined the MCP estimates of 23 sub-adult golden eagles captured in the NWPL from 2012 – 2014 and tracked through 2017 via GPS and Argos satellite transmitters. Restricting the analysis to non-migratory eagles within the dataset ($n = 9$), we found that the mean annual MCP estimate was 6,513 km² (range = 1,248 – 54,672 km²). There did not appear to be a pattern for seasonal home range sizes among the sample. Home range estimates ranged from 99 – 25591 km² (mean = 6182 km²) in the summer (May–August) and 489 – 34989 (mean = 6513 km²) in the winter (Nov – Feb). Some eagles expanded their home range in winter while others had larger home ranges in summer (Figure 2.18).

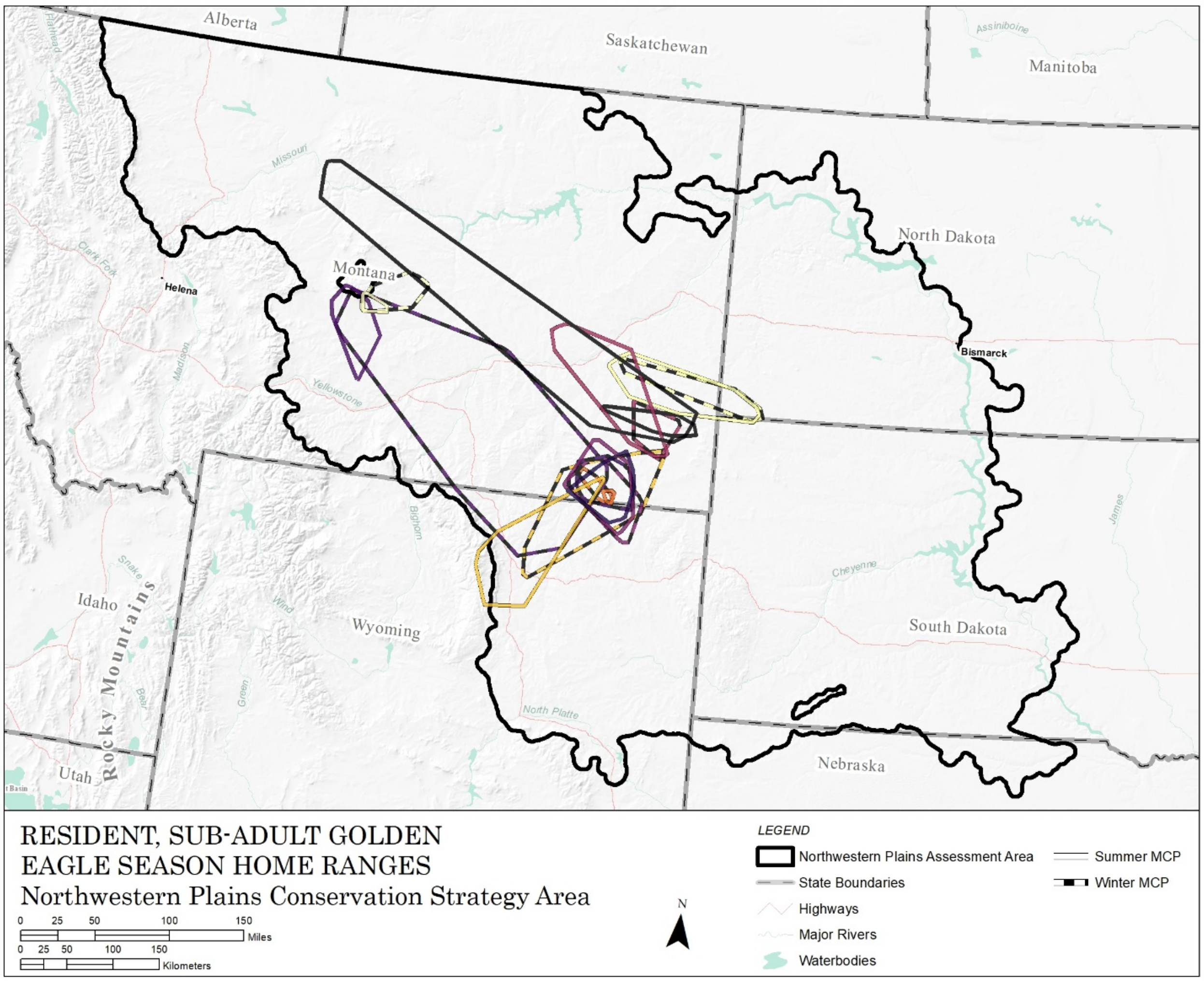


Figure 2.18. Minimum convex polygon (MCP) home range estimates for nine resident, sub-adult golden eagles within the Northwestern Plains conservation assessment area. Eagles were tagged and tracked between 2012-2017. Summer (May-August) MCPs are denoted by solid outlines, and winter (November – February) are dotted outlines. Data provided by B. Bedrosian, Teton Raptor Center.

2.2.3. Habitat use of non-breeding eagles

No published data are available on non-breeding habitat use within the NWPL but there is on-going work being conducted that can offer initial insights into this segment of the population. B. Smith (USFWS – Region 6), B. Bedrosian (Teton Raptor Center), and M. Hayes (University of Wyoming) have been working to model habitat selection of non-breeding eagles in the Wyoming Basin and NWPL.

Using the same covariate dataset and model selection methods used for the WGET RND models, we created a Resource Selection Function Model (RSF) in a use-available model design within the boundaries of the NWPL and Wyoming. The covariate scales used for our analysis were 30, 120, 1000, and 2000-m pixels to account for point specific and landscape level selection, similar to the RND model. We added the 30-m scale to match the accuracy of GPS location data (only GPS location were used in the modeling). We considered selection of covariates at the 30-m or 120-m scale to be fine-scale selection, 1000-m as moderate-scale selection and 2000-m as large-scale selection.

Data used for these analyses were from 43 golden eagles tagged as nestlings with GPS transmitters within the Wyoming Basin and NWPL, or sub-adults tagged during winter in the NWPL. Datasets were filtered for accuracy and to remove any movements outside of the modeling area or when eagles were migrating. After testing for differences between age, gender, and season we found no difference between gender, but hatch-year eagles were using the landscape differently than sub-adults, and winter (Nov-Mar) differed from summer (Apr – Oct). Because young eagles often remain near and may not be excluded from their natal territory (See 2.3.2), the following describes habitat selection of sub-adults (1.5–5 years-old).

2.2.3.1. a. Summer habitat use

Sub-adults showed greater selection for both wetter habitats and higher variability in the amount of sagebrush at the large-scale. There was a negative relationship to the variability of roads and crops at the large scale (Table 2.4). These trends are relatively consistent with the RND models, but seemingly focus more on productive habitats for prey items instead of ruggedness for nesting substrate (Figure 2.19, Figure 2.20).

To investigate if sub-adults were actively avoiding breeding habitat, we compared the sub-adult summer RSF model to the breeding RND model. We reclassified each continuous raster to a 10-quantile bin raster and calculated the difference between the two (Figure 2.21). Functionally, that compared each quantile to find large differences. For example, if a cell was within the top 10% of the adult (RND) values (value = 10) and top 20% of the sub-adult (RSF) values (value = 9), the difference would be 1, indicating similar selection. If the cell was within the bottom 10% of the one age class (value = 1) and the top 20% of the other age class values, then the output would be 8 or -8, indicating a large disparity in selection.

Much of the NWPL had similar values of RND and RSF by sub-adults. However, there were a few areas with large disparity. Much of the Powder River Basin fell within the high RND bins but was used less by sub-adults, relative to the rest of the NWPL. Conversely, sub-adults selected for the Black Hills, the base of the Bighorns and forested hillsides in the northern portion of the Powder River Basin sub-region in southern Montana, while RND was negatively impacted by the presence of large forest tracts. This is suggestive of differential habitat selection by age in the southern half of the NWPL. Conversely, there was similar habitat selection along the Missouri River in Montana and North Dakota where high breeding habitat value was predicted.

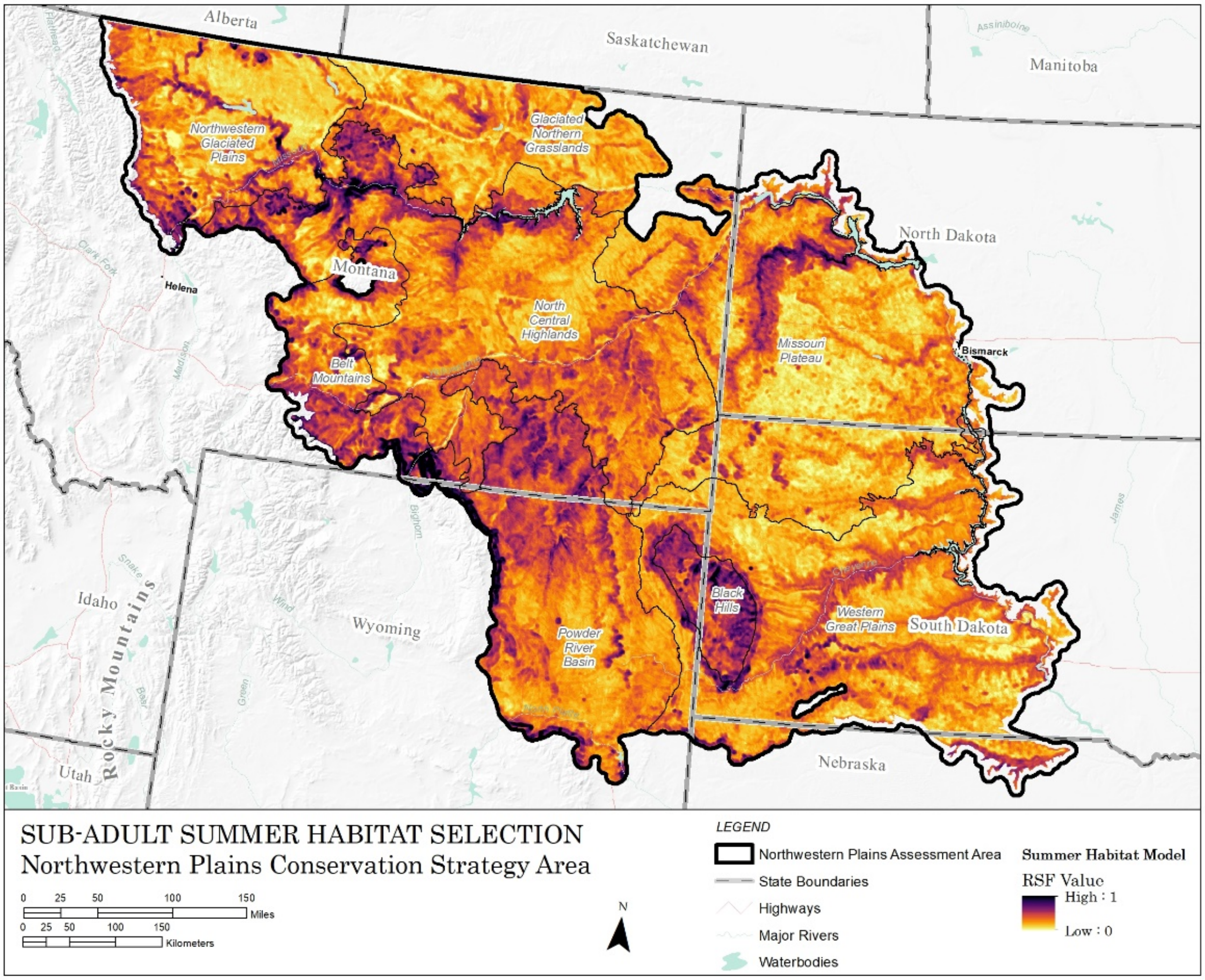


Figure 2.19. Resource Selection Function model of summer sub-adult golden eagle habitat selection within the Northwestern Plains conservation assessment area. The model was built from data across the NWPL and Wyoming Basin and clipped to the NWPL. Data provided by B. Bedrosian, B. Smith and M. Hayes.

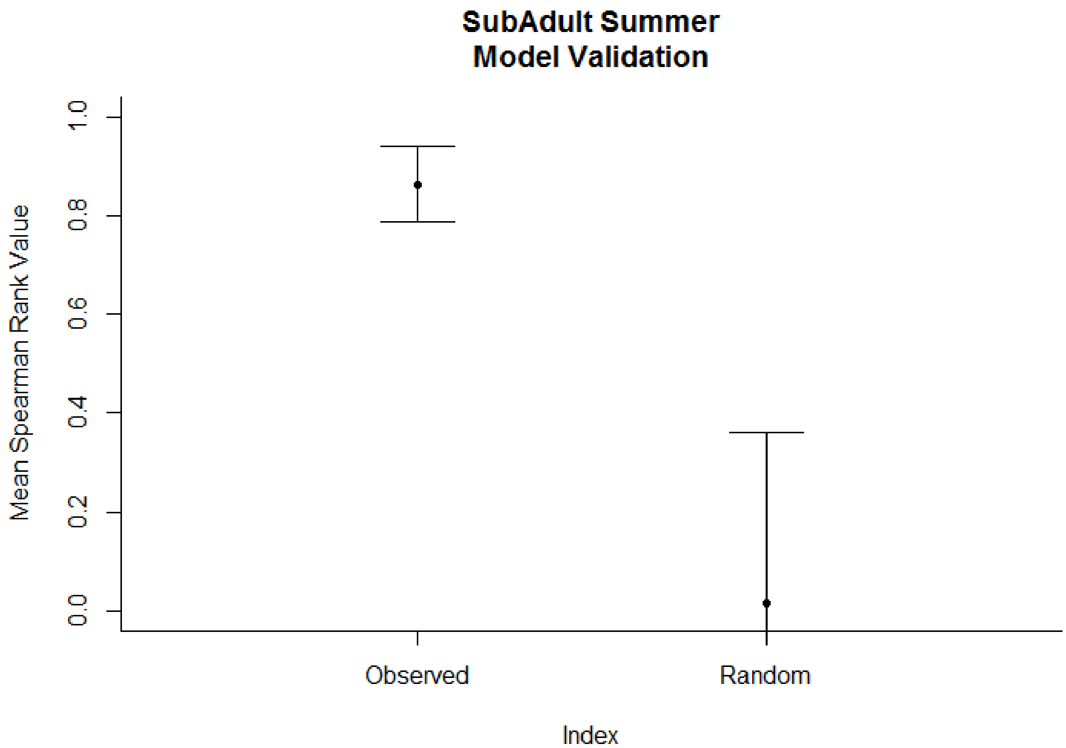


Figure 2.20 Mean 95% confidence interval Spearman-rank-order correlation values from 100x cross fold validation of used versus available locations of modeled sub-adult summer habitat in the Wyoming Basin and NWPL.

Table 2.4. Resource selection model output results (organized from most to least influential covariates) and covariate descriptions for summer habitat selection models of sub-adult golden eagles in the Wyoming Basin and Northwestern Plains conservation areas. Significance codes; P < * 0.05, ** 0.01, ***.001.

Covariate	Description	Scale	Scale Focal Statistic	Estimate	Standard Error	t value	Probability (>|t|)	Significance
Intercept		n/a	n/a	0.2154	0.0171	12.565	< 2e-16	***
sagelow1_2km_SD	Low sagebrush	1 km	SD	0.6834	0.0858	7.963	1.88E-15	***
wetland3_2km_MN	Emergent wetland	2 km	Mean	0.5451	0.1480	3.684	0.0002	***
devroad1_2km_SD	Road cover	1 km	SD	-0.3799	0.1253	-3.033	0.0024	**
crop2_2km_SD	Pasture and hay	1 km	SD	-0.1798	0.0526	-3.416	0.0006	***
crop3_2km_SD	Cultivate crops	1 km	SD	-0.0919	0.0402	-2.283	0.0224	*
sagetall1_2km_SD	Tall sagebrush	1 km	SD	0.0848	0.0394	2.154	0.0313	*
aspect1_1km	Terrain aspect	1 km	Mean	-0.0063	0.0018	-3.575	0.0004	***
TWI1_30m	Wetness Index	30 m	Actual Value	-0.0060	0.0020	-3.062	0.0022	**
grade1_2km_SD	Terrain slope	1 km	SD	-0.0051	0.0023	-2.273	0.0230	*

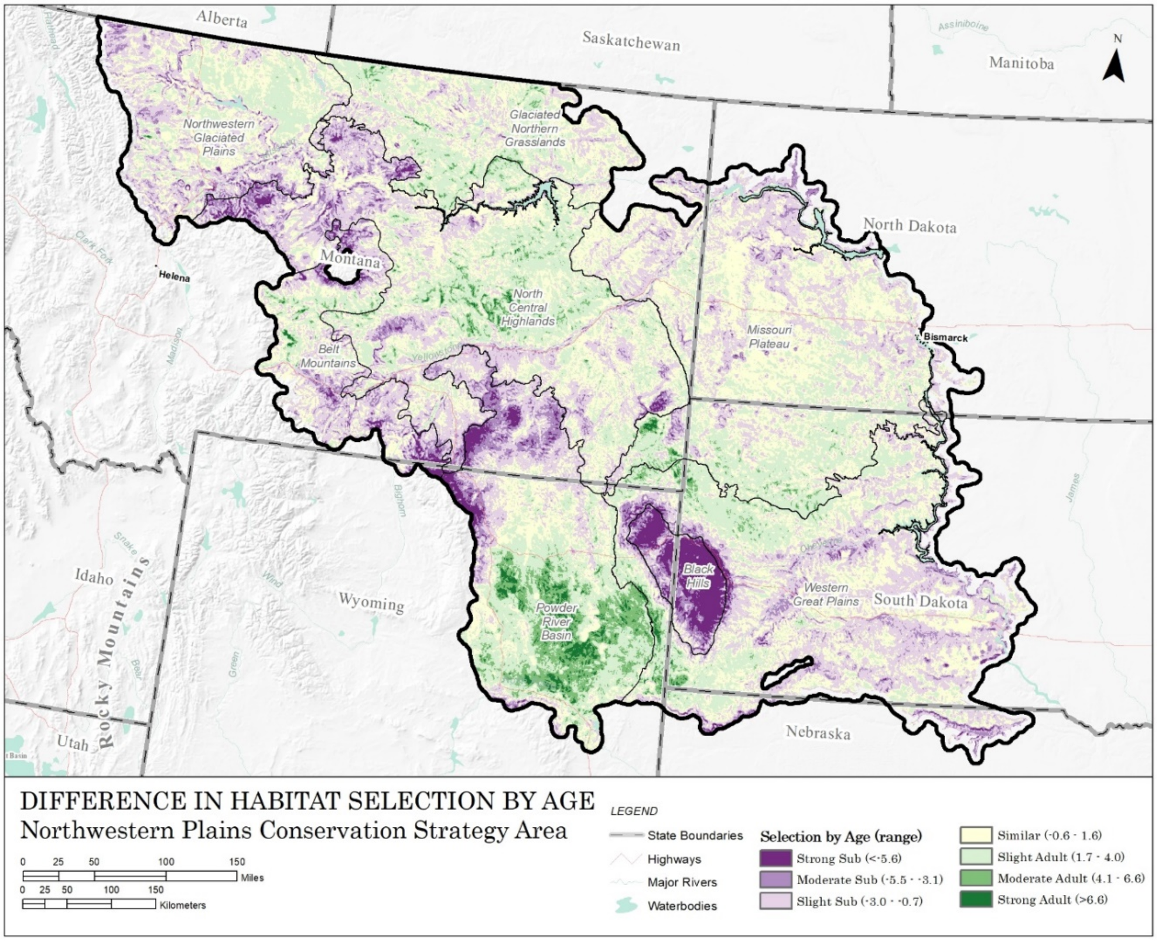


Figure 2.21. A visual representation of similar relative use of the landscape by breeding adults (green) and sub-adult (purple) golden eagles in the Northwestern Plains Conservation Assessment area. Values were generated by subtracting the Relative Nest Density and summer sub-adult Resource Selection Function model outputs, each classified as 10 quantile bins. Purple values represent strong selection by sub-adults and low selection by adults while green represent strong selection by adults and low selection by sub-adults. Yellow areas suggest similar selection by age, but does not represent selection for or against.

2.2.3.2. b. Winter habitat use

Similar to the summer RSF models for sub-adults, we analyzed the previous dataset for winter use. The winter models included individuals that were year-round resident sub-adults (known and presumed hatched within the NWPL and Wyoming Basin) and sub-adults that also over-wintered in the NWPL but summered in Alaska and northwestern Canada. The Overall, there was more uniform use of the NWPL during the winter months by sub-adults (

Figure 2.22) and the final model had good validation (Figure 2.23). Similar to the summer model, the top winter RSF model was positively influenced by the proportion of wetlands and sagebrush and negatively influenced by the variability in proportion of roads at the large-scale. Sub-adults tended to avoid highly variable terrain ruggedness but selected more variability in aspect. Other non-significant variables included in the final model were the proportion of croplands, proportion of roads, and grasslands (Table 2.5).

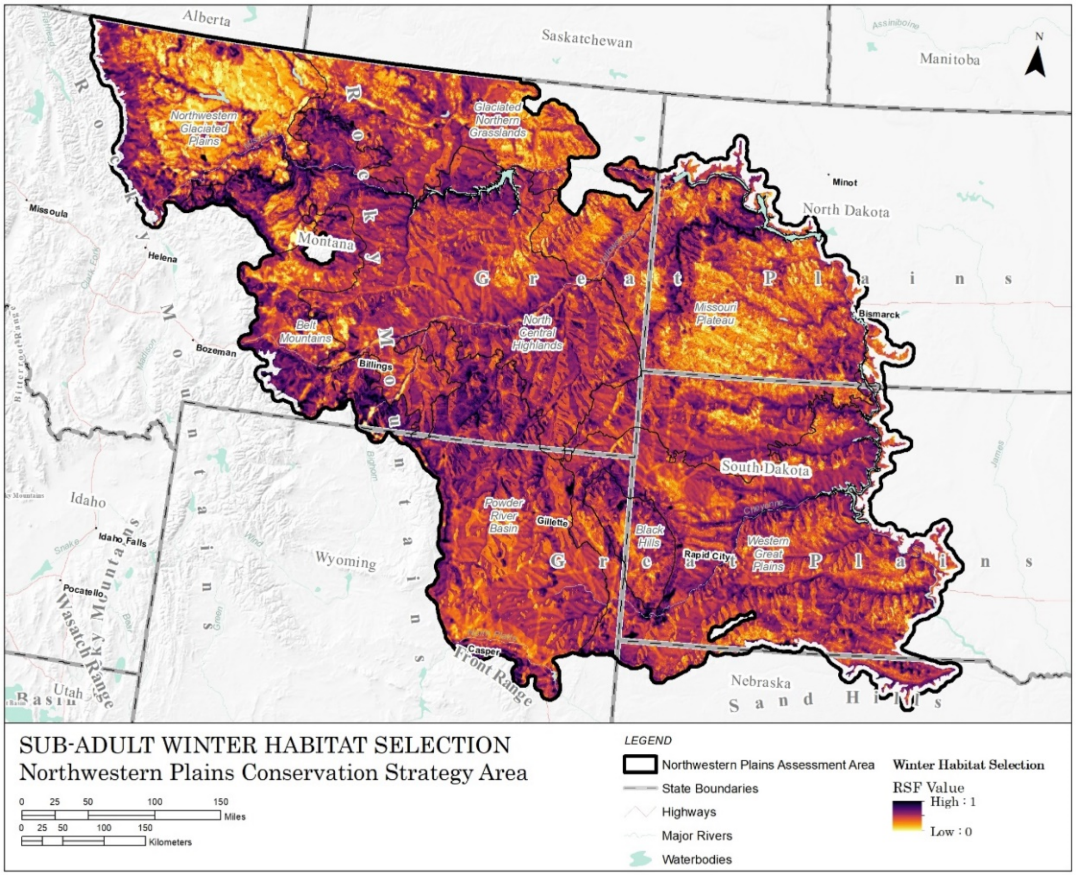


Figure 2.22. Resource Selection Function model of winter sub-adult golden eagle habitat selection within the Northwestern Plains conservation assessment area. The model was built from data across the NWPL and Wyoming Basin and clipped to the NWPL. Data provided by B. Bedrosian, B. Smith and M. Hayes.

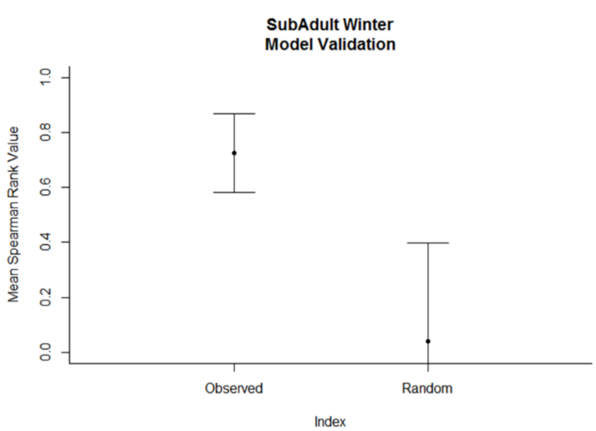


Figure 2.23 Mean with 95% confidence interval Spearman-rank-order correlation values from 100x cross fold validation of used versus available locations of modeled sub-adult winter habitat in the Wyoming Basin and NWPL.

Table 2.5. Resource selection model output (organized from most to least influential covariates and significance) and covariate descriptions for winter habitat selection models of sub-adult golden eagles in the Wyoming Basin and Northwestern Plains conservation areas. Significance codes; P < . 0.1, * 0.05, ** 0.01, ***.001.

Covariate	Description	Scale	Scale Focal Statistic	Estimate	Standard Error	t value	Probability (>|t|)	Significance
(Intercept)		n/a	n/a	0.206	0.019	11.035	< 2E-16	***
sagelow1_2km_MN	Low Sagebrush	2 km	Mean	0.654	0.148	4.424	9.84E-06	***
devroad1_2km_SD	Road Cover	2 km	SD	-0.553	0.218	-2.536	0.011	*
wetland3_2km_MN	Emergent wetland	2 km	Mean	0.381	0.154	2.475	0.013	*
TRI1_2km_SD	Terrain Ruggedness	2 km	SD	-0.140	0.037	-3.773	0.000	***
grade1_2km_SD	Terrain Slope	2 km	SD	0.080	0.018	4.385	0.000	***
forest1_30m	Forest Cover	30 m	Actual Value	-0.039	0.017	-2.318	0.020	*
aspect1_2km_MN	Aspect	2 km	Mean	-0.009	0.002	-4.317	0.000	***
elevation1_2km_MN	Elevation	2 km	Mean	0.000	0.000	-3.027	0.002	**
devroad1_2km_MN	Road Cover	2 km	Mean	0.621	0.360	1.728	0.084	.
crop3_30m	Cultivated Crops	30 m	Actual Value	-0.041	0.021	-1.958	0.050	.
crop2_2km_MN	Pasture and Hay	2 km	Mean	-0.115	0.078	-1.478	0.139	
intanngrass1_2km_MN	Introduced Annual Grass	2 km	Mean	0.210	0.130	1.612	0.107	

2.3. Movements and Migration

Golden eagles are a highly mobile species with a complex life-history and population structure (Watson 2010). Movement behavior of eagles varies among age-classes, seasons, and natal origin with some individuals remaining in a relatively localized area year-round and others ranging widely across the western U.S. (Kochert et al. 2002). In this section, we summarize the information available on directed, long-distance movements of golden eagles in the NWPL, as distinct from the localized space-use patterns of territorial adults. Golden eagles engage in long-distance, directed movements during various life-stages and seasons, beginning with dispersal of fledglings from natal territories (McIntyre et al. 2008, Murphy et al. 2017). After initial dispersal, pre-breeding eagles may range widely across the continent until they reach sexual maturity at 4 or 5 years of age (Soutullo et al. 2008, B. Smith, unpubl. data). After establishing a breeding territory, adult eagles continue to make directed movements within territories, which increase in size during the non-breeding season (Domenech et al. 2015). Adult eagles from other regions migrate into the NWPL during the non-breeding season, including long-distance migrants from Alaska and Northern Canada and short-distance migrants from other parts of the western U.S. (R. Murphy, Personal communication, Bedrosian et al. 2018a). Some migrants settle in the NWPL during the non-breeding season, while others simply pass through during spring and fall (McIntyre et al. 2008, Bedrosian et al. 2018a). Pre-breeding eagles from the NWPL and other regions move within and through the region while prospecting for territories and settling (Steenhof et al. 1984). Additionally, non-territorial adults, or "floaters", comprise a poorly understood segment of the population with the potential to move within and between regions (Hunt 1998, Caro et al. 2011).

Several significant efforts to track various life-stages of golden eagles within the NWPL are currently on-going. Early banding efforts began to provide insights into natal dispersal (McGahan 1968) from the Livingston area and Crandall et al. (2019) recently described movements of several nestling eagles from this region with satellite telemetry. Harmata (2015) described the movement of a limited number of floaters. A large dataset from satellite and GPS tracked sub-adults is currently being compiled by the USFWS, Craighead Beringia South and Teton Raptor Center (B. Smith and B. Bedrosian). Preliminary RSF models have been created for the NWPL using these datasets but final analyses were not completed at the time of this publication. Crandall et al. (2015) describe the movements of local, breeding adults.

Along and near the western border of the NWPL, many data exist on fall migration trends from raptor migration stations at Rodger's Pass and Nora Ridge east of Lincoln, MT (Raptor View Research Institute), Bridger Bowl (Montana Audubon), and most recently from Duck Creek Pass in the Big Belts (Montana Audubon). Bedrosian et al. (2018a) describe this migration corridor in both spring and fall using GPS data from adult golden eagles.

WGET has compiled most satellite tracking from golden eagles (n = 571) in North America from 1992–2017 to conduct a pooled analysis of eagle movements. Brown et al. (2017) initially investigated these data to determine if they could distinguish any spatial clustering patterns, but found that eagle movements did not conform well to any existing ecological mapping systems investigated.

2.3.1. WGET movement models

Add Model Results When Available

2.3.2. Movements of locally produced young

The earliest nestling banding studies in the NWPL began in the Livingston study area by McGahan (1968). The four eagles recovered from the 55 tagged were found as far away as 2,076 km to the south in Kerrville, TX. Crandall et al. (2019) tracked 12 fledglings for 57–1,368 days. Several individuals dispersed into the Wyoming Basin (as far as Laramie, WY), while others remained in the vicinity of their natal territories. Of 10 nestlings tagged across the Montana portion of the NWPL in 2012–2014, fledglings generally dispersed within the NWPL (B. Bedrosian, Unpublished data). Several dispersed south into the Wyoming Basin and the northern Rocky Mountain region of Colorado (Figure 2.24). Coyle (2007) tracked nine fledglings from western North Dakota and found most dispersed to winter ranges in central South Dakota. Data from young eagles with multiple years of tracking data showed most returned to summer in western North Dakota following their first and/or second winters, but ranged over large areas (i.e., most of the Little Missouri Drainage; Coyle 2007).

The mean MCP home range area estimate of eight fledglings tagged within the NWPL and tracked for ≥ 6 months post-fledging was 73,811 km^2 (range = 12,388 – 152,206 km^2; SD = 46,310 km^2; B. Bedrosian, Unpubl. data, Figure 2.24). Dispersal timing was extremely variable, with some fledglings dispersing in September of their hatching-year, while other remained on their natal territory >1 year. It appeared that fledglings remained on their natal territory longer when the adults did not breed in the subsequent year (B. Bedrosian, Personal observation).

Young eagles typically dispersed less than 100 km from their natal nest (Figure 2.25), while most did not start dispersing until roughly 200 d post-fledging. Long-distance dispersers generally left sooner (between ca. 50–125 d) and dispersed up to 300 km from their natal nest (Figure 2.25). There was no significant directionality to dispersal in the NWPL (Figure 2.26). Murphy et al. (2017) found similar results in the Four Corners region of the southwestern US, with long-distance dispersers leaving earlier and most eagles dispersing within 120 km. However, Murphy et al. (2017) found directionality to dispersal, while none was observed in the NWPL.

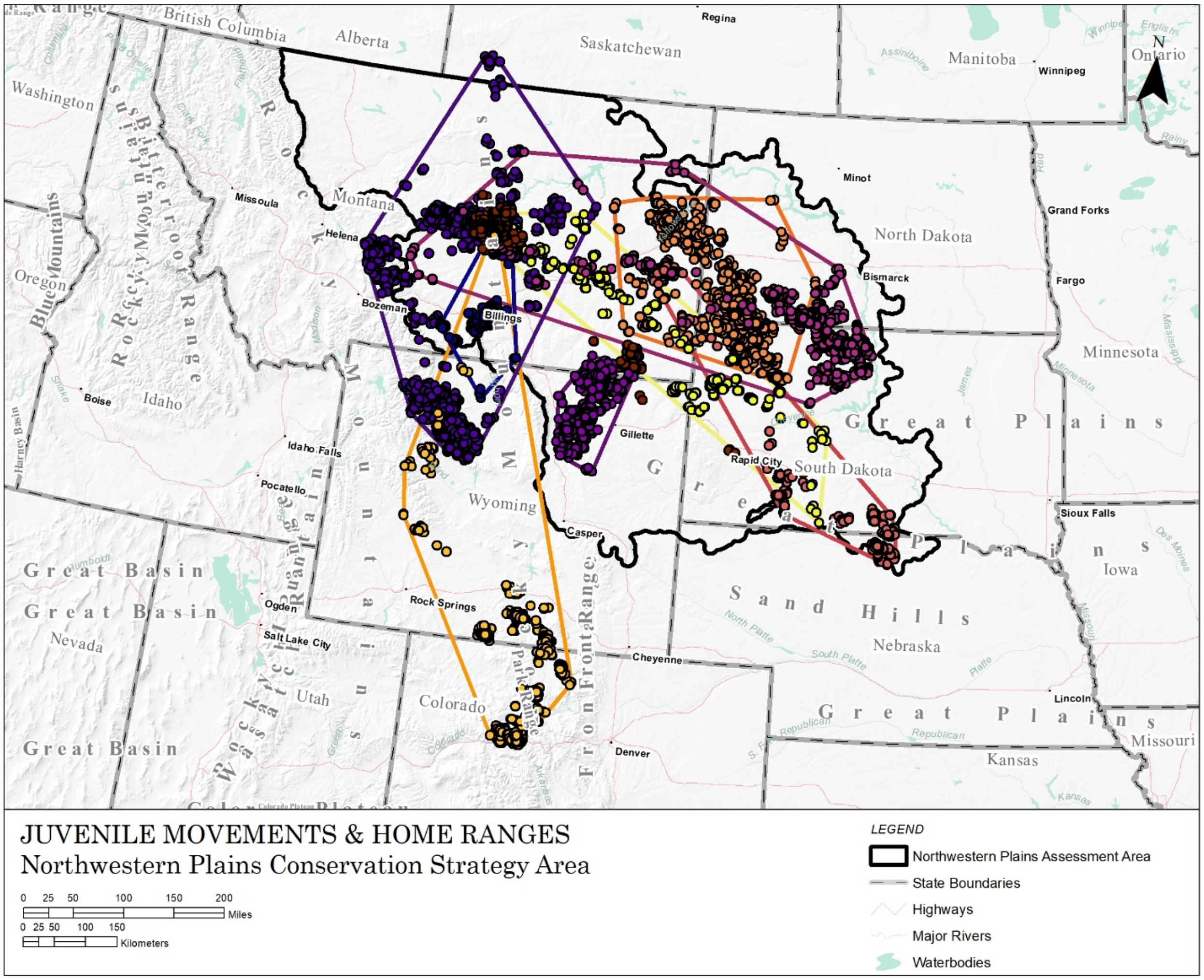


Figure 2.24. Movements (dots) and minimum convex polygon home ranges (polygons) of eight young golden eagles produced in in Montana from 2012–2014. Unpublished data provided by B. Bedrosian.

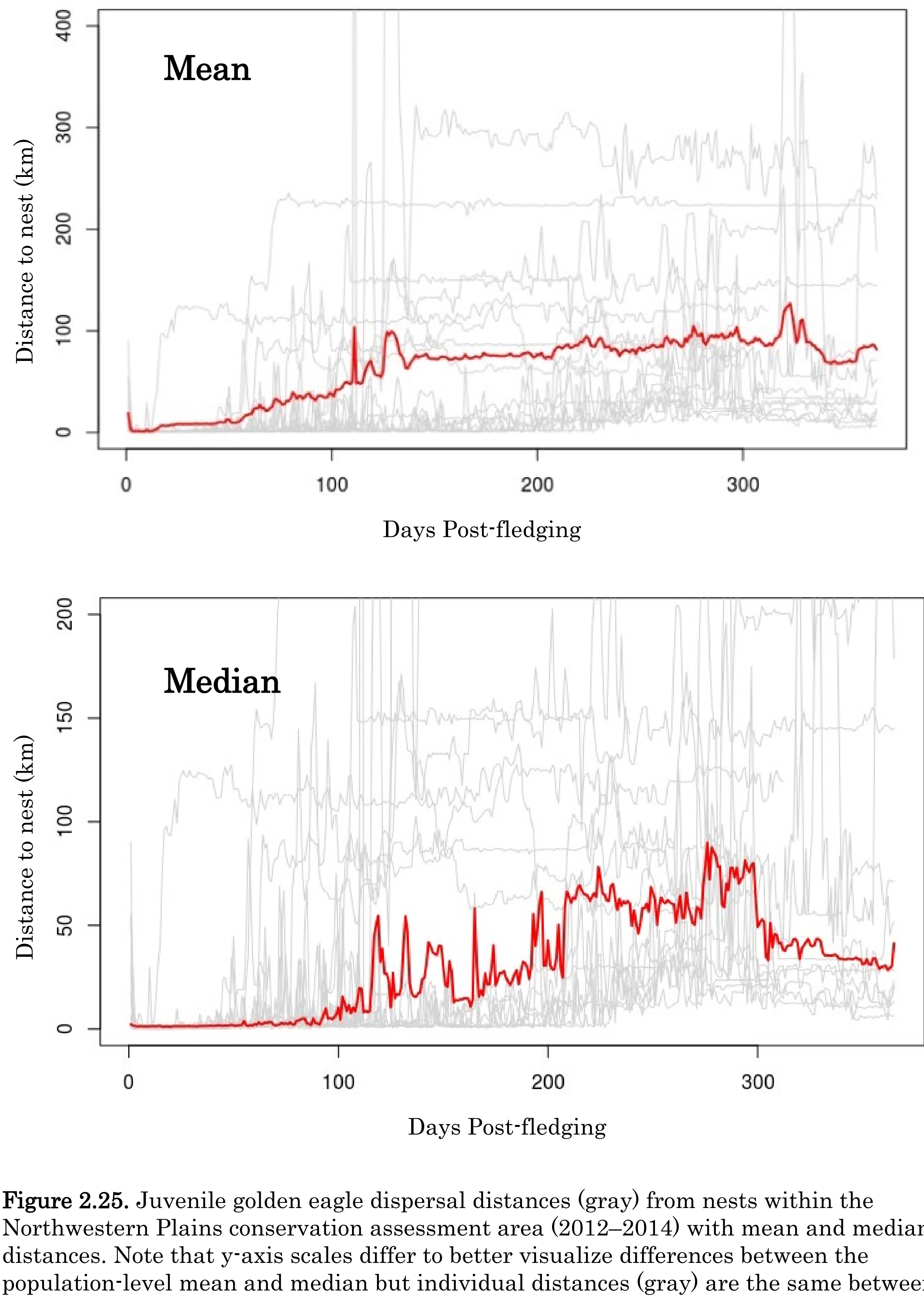


Figure 2.25. Juvenile golden eagle dispersal distances (gray) from nests within the Northwestern Plains conservation assessment area (2012–2014) with mean and median distances. Note that y-axis scales differ to better visualize differences between the population-level mean and median but individual distances (gray) are the same between figures. Unpublished data provided by B. Bedrosian.

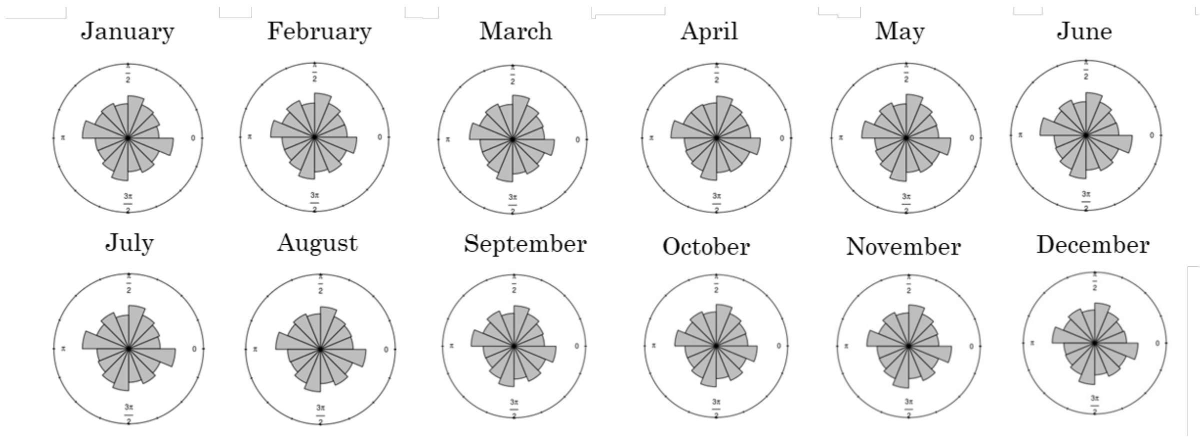


Figure 2.26. Magnitude of movements by direction from 11 year-round, resident sub-adult golden eagles by month in the Northwestern Plains conservation assessment area (2012–2017). Unpublished data provided by B. Bedrosian.

2.3.3. Movements of territorial adults

Territorial adults within the NWPL are generally year-round residents and do not leave their territories (Crandall et al. 2019). Harmata (2015) tracked one unsuccessful territorial male from Nov–Apr 2013 that had a 15-km^2 MCP estimate centered around its nest site. The mean MCP home range estimate from 12 breeding eagles in the Livingston study area was 16.73 km^2, while the core area (50% MCP) was 2.28 km^2 (Crandall et al. 2015). All territorial adults but one stayed within their territories, year-round, for the several years each was tracked. One breeding male migrated south near Denver, where it was recovered as a mortality (Crandall et al. 2019). Based on these MCP estimates, Crandall et al. (2015) suggested a 1000-m radius around the nest site as the core area and 2,500-m radius to define the home range of golden eagles in this area.

2.3.4. Movement into and through region from elsewhere

The largest golden eagle migration corridor in North America lies on the northwestern edge of the NWPL along the Rocky Mountain Front (Bedrosian et al. 2018a). Annual fall and spring counts have been conducted along the Front Range near Mount Lorrette in the Kananaskis Valley (70 km west of Calgary) since 1993. Roughly 3,000 eagles are counted each fall there, just north of the Canada/US border US (Sherrington 2017a). Each spring, roughly 2,500 eagles return through that same location (Sherrington 2017b). Both seasons have been experiencing significant and continuous negative count trends since the mid-1990s (Sherrington 2017a, 2017b).

Many eagles migrating south pass through the adjacent ecoregions to the west, as they travel along mountainous ridges like the continental divide (Bedrosian et al. 2018a). On east-wind days during the peak migration season, many individuals move out to the Front and migrate using thermals on the western edge of the NWPL (R. Domenech, Raptor View Research Institute, Personal communication). Golden eagle counts on the Continental

Divide (Rogers Pass) east of Lincoln, Montana, annually count roughly 1,200 eagles. In the Bridger Range, Montana Audubon regularly count an average of 1,330 eagles every fall from 1992–2016, and have also documented a significant negative trend (Davis et al. 2017). Most recently, in the Big Belts, fall golden eagle counts were as high as 2,740 in 2016 (Grayum et al. 2017), indicating that the Rogers Pass and Bridger sites are counting only a portion of eagles using this migration corridor. Peak migration for golden eagles through the NWPL occurs from mid-September through early November, with the peak typically during the first half of October. Eagles begin migrating around 10:00 and generally stop around 17:00 to take advantage of the best weather conditions for updrafts and thermals. Eagles may move and feed locally during the morning and evening hours or on days with inclement weather, low cloud ceiling, or east winds.

Bedrosian et al. (2018a) recently mapped this migration corridor using the summation of individual dynamic Brownian bridge movement models from 64 adult eagles, similar to how Mojica et al. (2016) mapped Bald Eagle migration routes in the eastern US. We found that spring migration was more dispersed and corridors tended to be further east into the NWPL than fall routes that centered on ridgelines in the Rocky Mountains (Figure 2.27). The key migration corridors outlined in Bedrosian et al. (2018a) were representative of the sampled population from northern North America. Data from individuals that winter across the NWPL indicate widespread and dispersed migration routes to and from their respective wintering areas (McIntyre et al. 2008, B. Bedrosian Unpubl. Data, T. Booms, AK Dept. Fish and Game, Unpubl. Data). The total number of eagles wintering and migrating into the NWPL remains unknown but may be a substantial portion of the North American migratory population.

Many eagles overwinter in the NWPL, but not uniformly. Bedrosian et al. (2014) captured and tagged wintering eagles across the NWPL section of Montana and conducted winter aerial surveys for golden eagles annually from 2012–2015. As evidenced by eagles feeding on carrion bait provided, counting eagles seen while watching bait, and wintering surveys, distribution of eagles was not uniform across the landscape (Bedrosian et al. 2014). The forested hills along the Musselshell River, the Powder River Basin, and around Ekalaka, MT hosted the highest of concentrations of eagles observed from 14 trapping regions (2–10 bait stations in each region) across the southeast third of Montana (Bedrosian et al. 2014, Bedrosian, Personal observation). Generally, all of the forested hills and breaks in the southern half of Montana had much higher concentrations of overwintering eagles than the open plains (See 2.2.3.2.b.).

Eagles overwintering in the NWPL summer across northern North America; in Alaska, Yukon, Northwest Territories, and Nunavut (Bedrosian et al. 2014, Bedrosian, Unpubl. data). McIntyre et al. (2008) documented eaglelets from Alaska appeared to have higher apparent survival than cohorts overwintering north of the NWPL in Canada. There is also migration and dispersal into the NWPL during the summer months. Long-distance dispersal movements from the southwestern US into the NWPL has occurred (R. Murphy, Personal Communication). Juvenile dispersal into the NWPL also occurs eastward from the Rocky Mountains (Crandall et al. 2019) and northward from the Wyoming Basin (B. Smith, USFWS, Unpublished data).

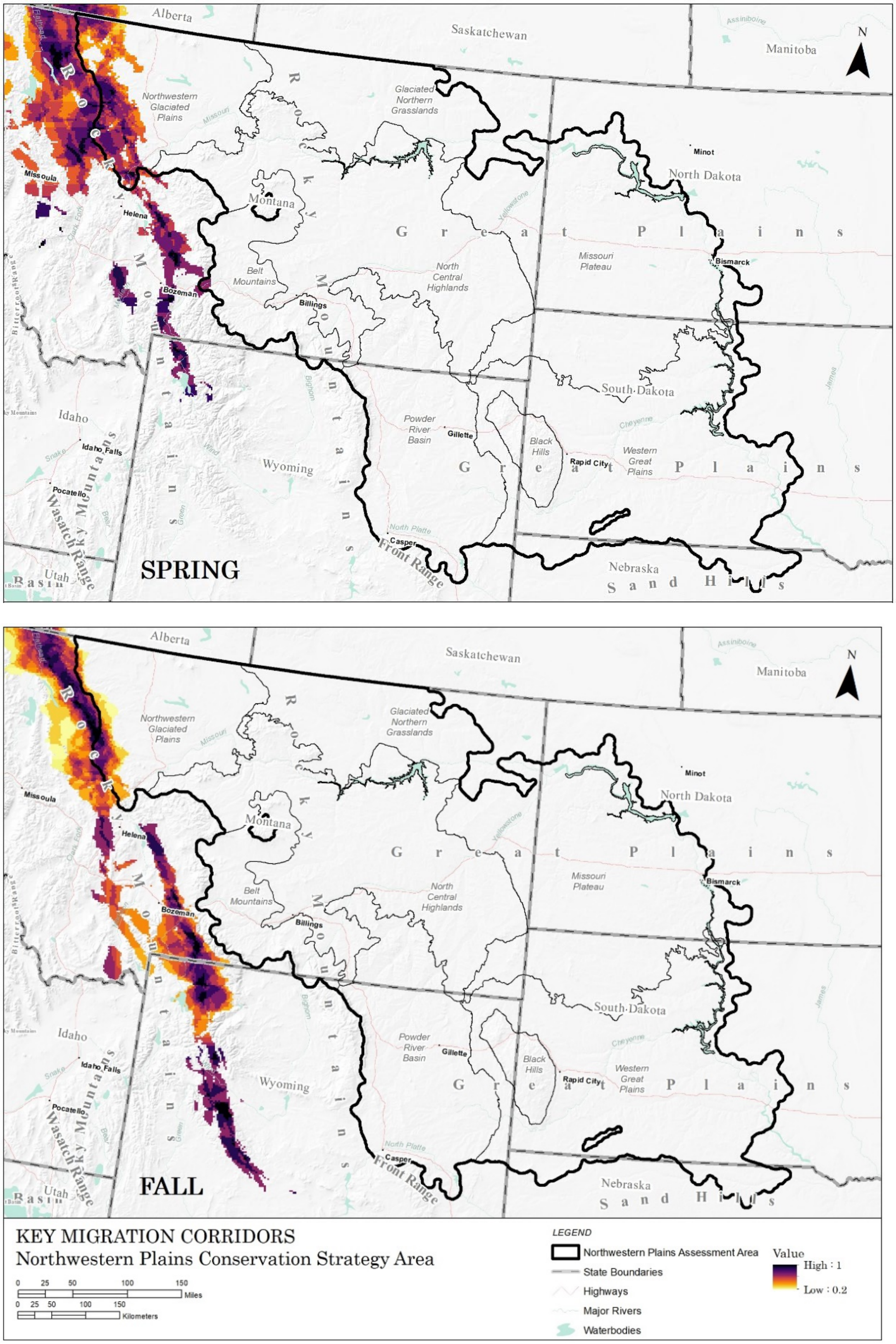


Figure 2.27. Key fall (left) and spring (right) golden eagle migration corridors in relation to the Northwestern Plains conservation assessment area. Data from Bedrosian et al. (2018a)

2.4. Winter Ecology and Distribution

On-going efforts are underway in the NWPL to better define winter-season abundance and space use. The most data come from studies of non-breeding sub-adult eagles (See Section 2.2.3.2.b.). Two additional efforts are currently underway to capture and track golden eagles from Alaska by the Alaska Department of Fish and Game (T. Booms) and Denali National Park/USFWS (C. McIntyre and S. Lewis). Undoubtedly, some eagles tagged in Alaska for those studies will overwinter in the NWPL and provide additional information on habitat use by adults.

There appears to be an increase in abundance of golden eagles during the winter across the NWPL. Resident, adult breeding eagles do not normally leave their territory (Crandall et al. 2019) and locally-produced young may disperse from their natal territories but generally stay within the NWPL (Coyle 2007, Crandall et al. 2019). Adding to those individuals are a host of migrants during the late-fall to early-winter (McIntyre et al. 2008, Bedrosian et al. 2014, Bedrosian et al. 2018a). There is little evidence to suggest that breeding or overwintering eagles in the higher elevations of the northern Rockies move into the NWPL during the winter (R. Domenech, Raptor View Research Institute, Unpublished Data). Adult eagles exhibit fidelity to wintering areas and have much larger home ranges than territory holders (Domenech et al. 2015). There is also evidence to suggest that dispersing young eagles show fidelity to overwintering sites (Coyle 2007).

2.4.1. Abundance and density

Higby (1975) conducted the first estimate of wintering abundance of golden eagles in a 78,000 km^2 area of Wyoming that excluded major mountain ranges and covered (but did not separate) the Powder River Basin during January of 1972–1973. Results from this survey were used to estimate abundance of 11,069 golden eagles of all age-classes in 1972 and 9,046 (95% CI: ±1,448) in 1973 (Wrakestraw 1973), which translate to densities of 1.42 eagles/100 km^2 in 1972 and 1.16 eagles/100 km^2 in 1973.

In 2014 and 2015, WEST Inc. flew mid-winter golden eagle surveys for the USFWS in the western US, including BCR 17, which covers much of the NWPL (Details described above; Neilson et al. 2015). They found the density of golden eagles during the winter months highest in BCR 17, compared to the Great Basin, Northern Rockies, and Southern Rockies BCRs. The mean density from the 2014 and 2015 surveys in BRC 17 was 3.35 eagles/100 km^2, or a mean total estimate of 34,364 eagles. This estimate is 33.13% higher than the mean estimated total for eagles during the late-summer in this BCR (22,949), equating to an additional ca. 11,400 migrant and dispersing eagles overwintering in the NWPL.

2.4.2. Winter habitat use

In an effort to characterize golden eagle habitat selection and movement corridors, WGET has worked with many eagle biologists across North America to collate all tracking data from individual research studies for large-scale pooled analyses. Data types, sources, and spatial location of study areas are provided in Brown et al. (2017). Major products from this effort have been the creation of seasonal habitat selection and movement models for the western US.

To model relative winter density (RWD), the WGET team used movement and remote-sensed landcover data from across western North America to create a use-availability model. The MaxEnt model was created with presence-only data at a continental scale with all age-classes and both genders. Because the model was not specifically created for the NWPL and at a large-scale (3-km x 3-km cells), nuances of winter habitat within the NWPL are likely underrepresented and need to be interpreted with caution. Nevertheless, the model can provide some valuable insights into the relative importance of winter habitat across the NWPL.

Movement data from December 1 – February 28/29 were used to define the winter season for this analysis. Movement data from 556 eagles, including 109,145 unique observations (telemetry fixes), were used to develop the models. Data were screened to remove outliers and duplicates. Modeling sites were determined as the centroid of the cell from which any eagle location was within, but filtered by no more than one per seven days. For example, if a 3-km x 3-km cell had 30 locations from one individual within a week, that cell was used as an eagle location once (1 deployment). Alternatively, if there were 30 locations from one eagle over two weeks or if two eagles visited the grid multiple times in one week, then it was included twice (2 deployments). This process led to 42,265 unique locations (cells), expanded by the number of deployments per cell, for a total of 106,744 modeling sites used across the conterminous western United States (J. Brown and D. LaPlant, personal communication).

It is important to note that the RWD model was created for the entire western US, not specifically for the NWPL. The resulting maps are clipped to the NWPL for visualization purposes, but the results are broad-scale and may differ when considering only the NWPL and influences on winter habitat use and selection there.

Covariates explored for inclusion in the model represented landcover, climate indices, wind and uplift indices, topographic indices and landforms, and vegetation indices using various focal statistics (mean, standard deviation, and distance-to) and scales for each (3km, 5km, 10km, 15km, 20km). A total of 626 covariates were initially screened for model inclusion, subjected to collinearity reduction, and reduced to a set of 87 potential covariates.

There were 10 covariates that contributed > 5% to the final RWD model predicting wintering golden eagle habitat (Table 2.5). The largest contributing covariate to the model (20.6%) was the variability in Weiss plains landform index (Weiss 2001; broad, flat areas) at a 20 km scale. The Weiss plains landform is a topographic position index that is calculated for each raster cell within a digital elevation model relative to the mean elevation from a specified neighborhood around that cell. Values of 10-km and 50-km for small and large neighborhoods, respectively, were used to calculate topographic position index for this analysis. Positive topographic position index values represent locations that are higher than the average of the large neighborhood (e.g. ridges), negative values represent lower than normal (i.e. valleys), and values near zero represent flat areas.

Climate indices contributed 18.4% to the model (and two of the top four covariates included in the final model). The daily mean amount of downward shortwave radiation flux at ground level during the winter at the 3km-scale contributed 10.1% to the model. Shortwave radiation flux is a measure of the amount of incoming solar energy hitting the surface during the daylight hours. Solar radiation absorbed by the surface can lead to warmer ground surface and less snowpack. Additionally, reflected solar radiation can increase thermal convection, often used by eagles for reducing energy output for long-distance movements. The mean number of degree days > 5 ºC at the small-scale also provided 8.3% contribution to the final model.

The only vegetation index included in the model was the mean gross primary productivity calculated from Aqua MODIS satellite data at the small-scale (8.8% contribution), while the variability in shrub cover at the 5 km-scale and the mean proportion of crop landcover contributed 7.5% and 5.4% to the model, respectively. While details on the direction of selection were not provided by Brown and LaPlante, unpubl. data), it is likely that the direction of selection was positive for shrub cover and negative for crop cover based on the relationship of these covariates to prey habitat (see Section 2.1.4 for details).

The remaining three of the top ten covariates included in the RWD model were wind and uplift indices. The mean magnitude of north-south winds, variability in the daily thermal energy gradient (Duerr et al. 2015), and the mean maximum value for turbulent kinetic energy (i.e. variable winds) contributed a sum contribution of 18% to the final model. Although the biological mechanisms for how these covariates influence eagle habitat use needs additional clarification, it is likely that eagles were selecting areas with higher thermal potential and avoiding areas with strong, variable winds.

Within the NWPL, higher predicted concentrations of winter use occurred along the western edge of the NWPL (Figure 2.28), generally at the ecotone of mountain and plains. Winter use decreases east of Montana and Wyoming, but also in north-central Montana, which may be due to the presence of croplands in those regions (Figure 1.4). Most of the mountain ranges and areas of higher topographic relief across the NWPL exhibit high winter habitat values, such as the Bear Paw, Judith, Little Rocky, Sawtooth, Pryor, Big Horn, Big Snowy, and Laramie ranges. The Custer National Forest, Ekalaka Hills, Chalk Buttes, Big Sheep Mountains, and Sweet Grass Hills all provide moderate winter habitat.

Also see section 2.2.3.2.b on details on winter habitat selection of sub-adult eagles in the NWPL. While the sub-adult winter RSF model did not include climate or wind potential covariates, they were fairly consistent in predicting similar areas of winter habitat. Both predicted high winter using in mostly the same regions. Even in areas predicted with lower overall intensity of use in the WGET model, such as North and South Dakota, both models predicted the relative importance of the same areas for those states.

Table 2.6. Top ten covariates included in the golden eagle Relative Winter Density model created for the entire conterminous western United States. If applicable, covariates were re-classified using data from the winter season (December 1 - February 28/29).

Covariate	% Contribution	Variable Category	Definition	Spatial Index	Scale	Source Date Range
wlf_05_plains1b_3km_sd_20km	20.60	Topographic Landform	Proportion of Weiss plains landform 5. Open, Flat Areas (Weiss 2001)	SD	20km	n/a
dswrf1_sfc_semnlt_dailymn_wi_3km_xx_00km	10.13	Climate	Amount of solar radiation that hits the ground	Mean	3km	1992–2016
gpp1_ansdlt_8day_xx_3km_xx_00km	8.72	Vegetation Index	Mean gross primary productivity	Mean	3km	2003–2016
dd51_3km_mn_03km	8.34	Climate	Mean number of degree days >5 ºC	Mean	3km	1961–1990
shrub2b_3km_sd_05km	7.55	Landcover	Proportion of shurbland and savanah areas from CEC North America 2010	SD	5km	2010
vwnd1a_30m_semnlt_dailymn_wi_3km_xx_00km	6.22	Wind and Uplift	Mean magnitude (not direction) of n-s winds at 30m above the surface	Mean	3km	1992–2016
dte1_lb2_semnlt_dailysd_wi_3km_xx_00km	6.15	Wind and Uplift	Daily thermal energy gradient index (Duerr et al. 2015)	SD	3km	1992–2016
tke1_hyb_semnlt_dailymx_wi_3km_xx_00km	5.75	Wind and Uplift	turbulent kinetic energy (i.e.Variable winds)	Mean Max	3km	1992–2016
crop2_3km_mn_20km	5.45	Landcover	Proportion of crop landcover from CEC North America 2010	Mean	20km	2010
wlf_04_valleys1_3km_mn_15km	5.03	Topographic Landform	Proportion of Weiss Landform 3 (U-shaped valleys) (Weiss 2001)	Mean	15km	n/a

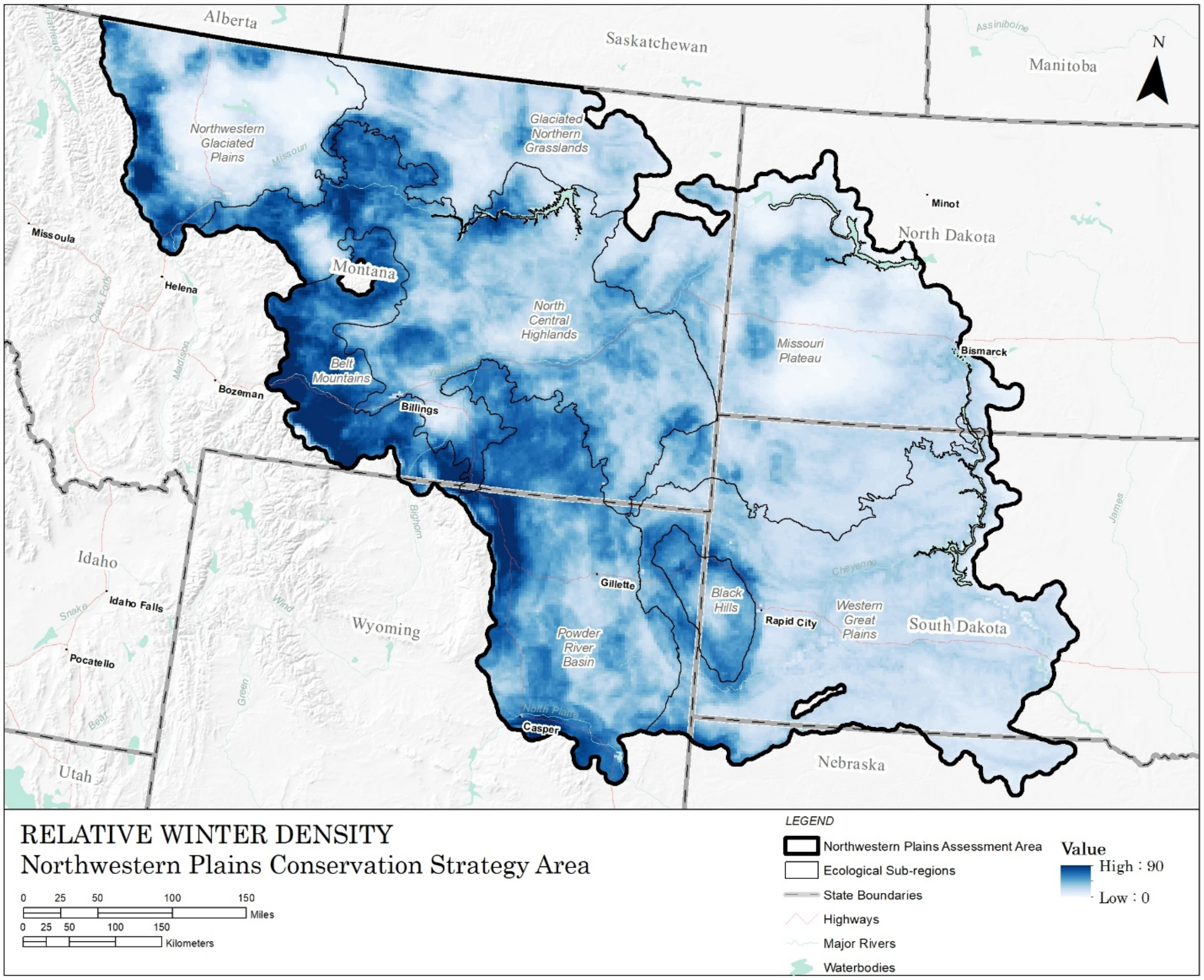


Figure 2.28. Western Golden Eagle Team predictive model of winter habitat built for the western conterminous United States and clipped to the Northwestern Plains golden eagle conservation assessment area.

2.4.3. Winter diet and prey communities

Little information is available on the winter-season diet of golden eagles, due in part to the difficulty of observing foraging or feeding outside the breeding season (Bedrosian et al. 2017). Developing a better understanding of golden eagle winter-season diet may be important to maintaining populations, because reproductive success in the subsequent season is influenced by winter body condition (Newton 2010). Furthermore, an improved understanding of winter diet and foraging ecology could inform efforts to reduce mortality from collisions with motor vehicles while feeding on road-killed carrion, which is a substantial source of mortality for golden eagles during winter (Riginos et al. 2017).

It is generally assumed that the diet of golden eagles shifts in winter from capturing live prey to a greater reliance on scavenging carrion, including road- and winter-killed ungulates (Kochert et al. 2002). Increased exploitation of ungulate prey during winter in the NWPL is supported by examples of up to seven (presumably) different golden eagles feeding a single roadkill per day during winter trapping operations (e.g., Bedrosian et al. 2014). In areas such as the Powder River Basin, golden eagles likely prey on black-tailed prairie dogs because they remain active above ground during the winter. Similarly, eagles continue to take avian species like pheasants, grouse, corvids, and owls. Likely, some occasionally kill live pronghorn as they do in the neighboring Wyoming Basin (Deblinger and Alldredge 1996, Beckmann and Berger 2005). Feeding on carrion by golden eagles may increase during severe winters (Woodgerd 1952, Hayden 1984) and may also be influenced by the composition of the local prey community.

3. Population Ecology

Golden eagle populations in North America cannot sustain current levels of human-caused mortality without experiencing declines (USFWS 2016). In this section, we review evidence for trends in the golden eagle population in the NWPL and identify factors with the potential to limit survival and fecundity in the region. Our review is focused on hazards that are caused by humans and have the potential to be addressed through management actions. We describe the mechanisms behind each hazard, provide available evidence of the magnitude of risk in the NWPL, and describe spatial and temporal patterns in risk to support the risk assessments and regional conservation measures presented in the Conservation Strategy Section.

3.1. Status and Trend

Golden eagle populations in the western U.S. are stable or possibly declining (USFWS 2016). Composite models using data from the North American Breeding Bird Survey and the west-wide USWFS golden eagle surveys (described above) suggested populations were stable during 1968–2014 (Millsap et al. 2013, USFWS 2016), while demographic models project a gradual decline due to human caused mortality USFWS 2016). In BCR 17, which encompasses the majority of the NWPL, the population was estimated at almost twice the size than any other BCR in the contiguous US. Neilson et al. (2016a) reported no trend in juvenile abundance in BCR 17 from an analysis of the west-wide golden eagle survey data.

Migration counts along the western edge of the NWPL from 1993–2017 show significant declines in passage rates of eagles moving along the Rocky Mountain Front. During the fall, Sherrington (2017) and Davis et al. (2017) both reported significant declines (up to 50%) in passage rates of eagles from the early 1990s to 2009, with populations appearing to stabilize post 2009 at a lower rate than the previous decade. This suggests a change in the behavior of migrating eagles or a decline in migrant population size prior to 2009. There did not appear to be a change in adult:immature ratios during that time (Sherrington 2017). Immature counts are always lower in the spring, but mirror ratios counted in the previous fall (Sherrington 2017). However, lower numbers of young eagles moving in the spring should not be directly interpreted as over-winter mortality since younger eagles have more dispersed and later migration than adults (B. Bedrosian, Unpublished Data).

Even if golden eagle populations appear stable over broad areas, there may be different trends at regional and local scales. For example, regional declines were reported in the number occupied nesting territories in southwestern Idaho, northeastern Colorado, and Southern California, and productivity in north-central Utah (Kochert et al. 2002). Conversely, there was a marked increase in nesting territories within the Livingston study area from the 1940s to contemporary estimates (see Section 2.1.1). An excellent opportunity exists to revisit several historic study areas within the NWPL to assess long-term trends.

3.2 Population Limiting Factors – Direct effects on survival

Golden eagles are a long-lived species with low fecundity and delayed sexual maturity (Watson 2010). For golden eagles, like other species with "slow" life histories, adult survival is the most critical factor influencing population performance (Tack et al. 2017). Although recent historical trends in the western U.S. and the NWPL appear to have been stable (Millsap et al. 2013), demographic models show that current levels of human-caused mortality experienced by golden eagles in North America will most likely cause a population decline (USFWS 2016). In this section, we review factors known to have direct effects on survival of golden eagles, focusing as much as possible on direct evidence from the NPG. The factors included in our review are based on sources of mortality identified by USFWS (2016), an expert elicitation (Brown 2014), and our review of literature on potential hazards to golden eagles in the NWPL (Table 3.1).

3.2.1 Energy Infrastructure

Resource extraction occurs across the NWPL and differences in state and federal management of energy resources are largely influential on the relative density of energy infrastructure. For example, density of oil and gas extraction is much lower in Montana than neighboring states of Wyoming and North Dakota. Renewable and conventional energy development present unique sources of mortality for golden eagles (e.g., collision with wind turbines or drowning in oil pits), while other hazardous infrastructure and activities are common to all forms of energy development (e.g., roads, vehicle traffic, and power lines). This section is focused on forms of energy infrastructure with direct effects on survival of golden eagles, including electrocution, collision with wind turbines and transmission structures, oil and gas development, mining, and power generation. Indirect effects on survival of golden eagles from disturbance associated with energy development are addressed in Section 3.3.2. Road and human density resulting from energy infrastructure may affect survival both indirectly (3.3.2.1) and directly (e.g., as a result of collision with vehicles, see 3.2.2).

Table 3.1. Factors affecting survival and fecundity of golden eagles in the NWPL evaluated in this report, with links to spatial risk assessments and recommended regional conservation measures.

Demographic Rate Affected	Category	Hazard	Spatial Risk Assessment	Regional Conservation Measures
Survival	Energy Infrastructure	Electrocution	Yes	Yes
		Wind Resource Development	Yes	Yes
		Oil and Gas Development	Yes	Yes
		Mining and Power Generation		Yes
	Collisions	Motor vehicles	Yes	Yes
		Transmission structures		Yes
	Contaminants	Lead	Yes	Yes
		Anticoagulant Rodenticides		Yes
		Others		Yes
	Disease and Parasites	West Nile virus	Yes	Yes
		Others		Yes
	Persecution	Direct persecution		
		Poaching		
Fecundity	Disturbance	Recreation (OHVs, hikers)		Yes
	Prey & Nesting Habitat	Habitat loss from wildfire	Yes	Yes
		Habitat conversion to agriculture	Yes	Yes
		Loss of remnant cottonwood trees		Yes
		Climate Change		Yes

3.2.1.1. Electrocution

Electrocution on power infrastructure is among the leading causes of mortality for golden eagles in North America (USFWS 2016) and around the world (Lehman et al. 2007, Mojica et al. 2018). Electrocution accounted for 8% of deaths for satellite-tagged golden eagles in North America from 1997–2013, and an estimated 504 deaths annually (95% CI = 124–1,494; USFWS 2016), but the actual number of electrocution mortalities is likely higher than this estimate given lack of monitoring and the wide credible interval (Mojica et al. 2018). Golden eagles are more vulnerable to electrocution than smaller species because their greater wingspan and body length increase the likelihood of making connections between an exposed energized component with another component on power poles (Dwyer et al. 2015). Most electrocutions occur on distribution lines, rather than transmission lines, due to the closer spacing of equipment and greater abundance of distribution poles across the landscape (APLIC 2006). Mojica et al. (2018) identified eight electrocution risk factors for golden eagles, with the highest risk factors being pole configuration and eagle age. Juveniles are more likely to be electrocuted at roughly twice the rate of any other age category. Other risk factors include habitat quality, prey abundance, winter habitat, inclement weather, and intraspecific interactions (Mojica et al. 2018). Other, difficult to measure, factors such as health may also have a significant effect on electrocution but are not addressed in the literature. For example, increased sub-lethal lead levels have been shown to affect balance in birds (Burger and Gochfeld 2000) and increase risk with power line collisions in swans (O'Halloran et al. 1989). Mostly, toxicities and other health measures are not measured in most eagle electrocution cases since carcasses are typically desiccated when found.

Avoidance and mitigation of avian electrocutions has been the focus of collaboration among government and industry, including the formation of the Avian Power Line Interaction Committee (APLIC; http://www.aplic.org). Compared to other hazards, relatively more research has been dedicated to understanding the magnitude and prevention of avian electrocution. Retrofitting power poles is, thus, the only currently approved from of compensatory mitigation to offset programmatic take of golden eagles (USFWS 2013).

During a prospective study of electrocutions in a 1,600 km^2 area near Roundup, MT between 1996–2001, Shomburg (2003) found 4% of 4,090 power poles electrocuted ≥1 golden eagle. Of the 219 eagles found dead resulting from power lines, 90% were electrocuted and 10% were a result of mid-span collisions. There was no influence of gender, but adults only constituted 12% and 18% of the electrocutions and collisions recorded, respectively. Power pole configuration was the highest risk factor, followed by habitat type.

Spatial information on power poles and distribution lines are not available for most utility companies and remain proprietary information of the utility providers if they are. Although mapped locations of distribution poles with configurations dangerous to golden eagles are generally not available, density of poles can be used as a surrogate for electrocution risk (Figure 3.1; Dwyer et al. 2016). To inform spatial prioritization of retrofitting efforts, WGET and EDM International developed a model of power pole density for the states of Wyoming and Colorado and demonstrated that it could be overlaid with data on golden eagle habitat to identify areas of elevated risk (Dwyer et al. 2016). The model was developed, in part, using a large dataset of known pole locations from within the NWPL and performed very well at predicting 1-km x 1-kmcells of low (<5), medium (5–10 poles), medium-high (11–15) and high density (>15 poles)(Figure 3.1; Dwyer et al. 2016). The model was later updated with additional data and projected across Montana (Dwyer et al. 2017a).

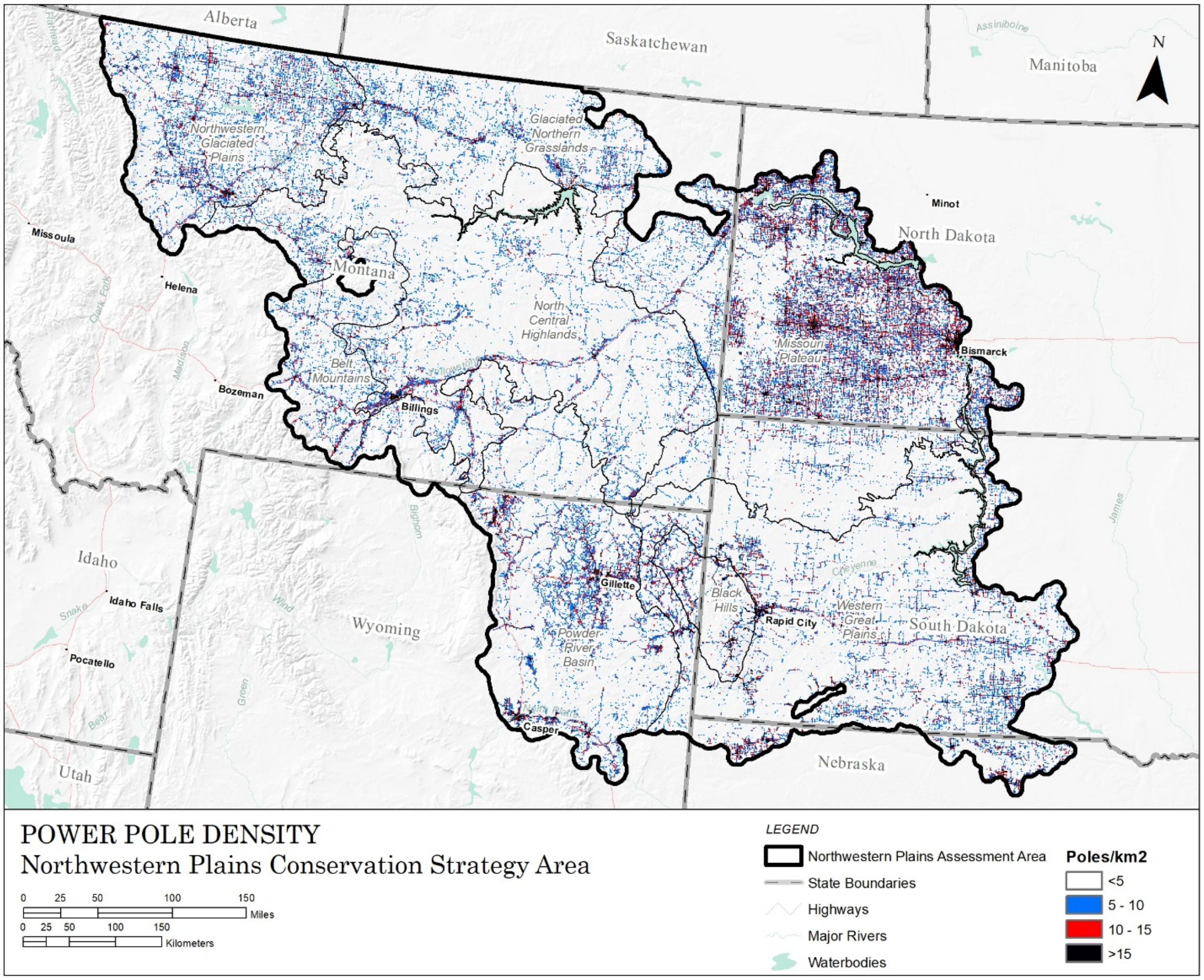


Figure 3.1. Predicted power pole density in the Northwestern Plains conservation assessment area, binned into low density (<5 poles/km^2), medium density (5–10 poles/km^2), medium-high density (11–15 poles/km^2) and high density (>15 poles/km^2). See Dwyer et al. (2016) and Dwyer et al. (2017a) for modeling methodology.

Despite widespread retrofitting efforts, dangerous poles persist in the landscape due in part to the vast number of distribution lines, but also because retrofitting typically proceeds at the scale of individual electrical utilities leaving some high-risk areas unaddressed. The NWPL is serviced by 30 electric utility providers with service areas ranging from county-level service for small municipal utilities and cooperatives to >435,000 km^2 for large multistate power companies (estimated from reported service areas for providers within the NWPL). Regional coordination across utilities is needed to identify and prioritize retrofitting in areas with the greatest risk (Dwyer et al. 2016). The pole density model suggested densities of distribution poles were greatest in areas with more roads, more oil and gas wells, and relatively flat terrain (Dwyer et al. 2016). In the NWPL, this included areas around towns and cities, oil and gas fields, and pivot irrigation (Dwyer et al. 2016). Much of the NWPL has low power pole density, but areas associated with oil and gas in the Powder River and Williston Basins, and agriculture in North Dakota can have high densities of poles.

To investigate the accuracy of the model on a more site-specific scale, we investigated the relationship of the model to power pole data from Schomburg (2003) in a study area near Roundup, MT. The model predicted a total of 5,702 power poles, while Schomburg reported a total of 4,090 poles. Errors in digitizing the study area boundary, missed power poles on private property, poles added from 2001–2014, or model error may all contribute to this difference. Likely, Schomburg did not do a complete survey of the study area because his reported study area size was 1,600 km^2, while our measured area of the digitized study are was 2,573 km^2. If we assume that Schomburg surveyed 62% of the total area and reduce the model results by 22%, then the predicted density would be 4,448 poles, indicating close parity. To illustrate how average pole density may relate to mortality, the area depicted in Figure 3.2 has a mean pole density of 1.98 poles/km^2 (calculated from model output) and an average of 33 electrocuted eagles per year (Schomburg 2003).

In this report, we build on the work of EDM International by overlaying the pole density model with seasonal models of golden eagle habitat to identify areas where power pole retrofitting could provide maximum conservation benefit (see 4.3.1).

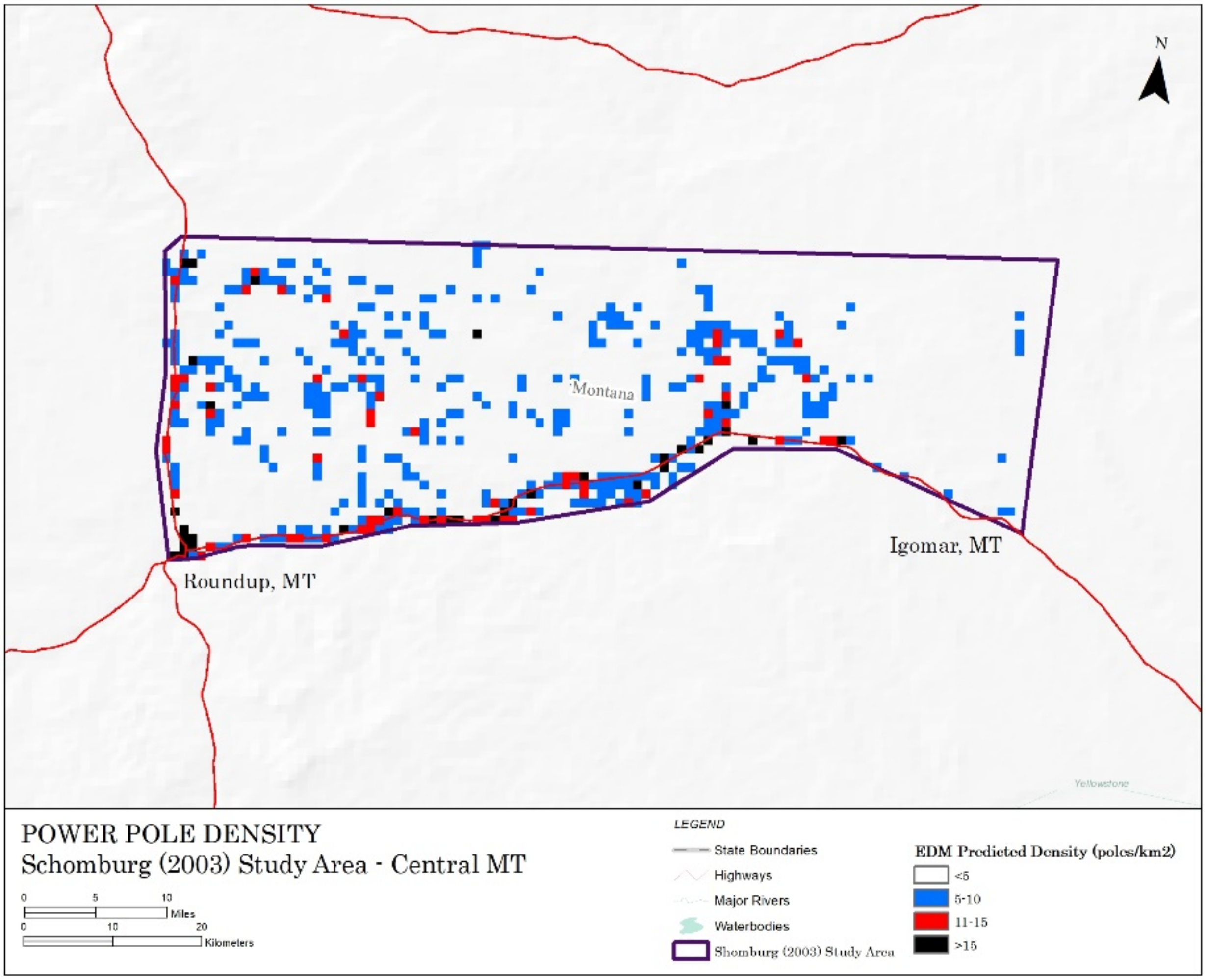


Figure 3.2. Power pole density model output (Dywer et al. 2016) within a digitized polygon of the Schomburg (2003) study area, which had an average of 33 eagle electrocutions/year from 1996-2001.

3.2.1.2. Wind resource development

Collision with turbine blades at wind energy facilities is recognized as a substantial and increasing source of mortality for golden eagles (Smallwood and Thelander 2008, Pagel et al. 2013). Turbine-strike mortality can affect individuals from a broad area around wind energy facilities (Katzner et al. 2017b) and has the potential for population-level impacts to golden eagles (Beston et al. 2016, but see Hunt et al. 2017). As wind resource development increases in North America (Wiser and Bolinger 2016), research to inform effective mitigation (USFWS 2016, Allison et al. 2017) has focused on understanding the behavioral and environmental factors that influence exposure of golden eagles to turbine-strikes (May 2015, Hunt and Watson 2016), and developing methods to estimate rates of collision (New et al. 2015), and mortality (Huso et al. 2016). Results suggest risk of turbine-strike is influenced by a complex interplay of factors that include the location and design of wind energy facilities (Katzner et al. 2012b), height and blade length of turbines (Loss et al.

2015), season (Pagel et al. 2013), and degree of overlap with other resources important to golden eagles, such as prey, nest sites, perches, and updrafts (Hunt and Watson 2016).

The state of Wyoming is among the areas of North America with the greatest potential for on-shore wind energy development: Wyoming contains >50% of areas with the highest ranked wind capacity in the continental U.S. (wind power classes 6 and 7) but ranks 16th for installed capacity (American Wind Association 2018). There is currently 3,000 MW in construction across Wyoming, but this is outside the NWPL in the Wyoming Basin. Montana ranks third highest in the country for wind potential but lack of transmission capacity significantly limits wind energy growth, particularly in eastern Montana (Oteri et al. 2018). There was 695 MW of installed capacity across the state, as of December 2017, which is among the lowest for states across the country (American Wind Association 2018). There is 105 MW currently under construction from two project areas in south-central Montana, with two additional projects in advanced development in this area (American Wind Association 2018). North Dakota also has high wind resource potential and had 2,996 MW of wind capacity installed by the end of December 2017 (American Wind Association 2018). Several large installations occur within the NWPL and two new projects are in advanced deployment in the NWPL (American Wind Association 2018). Most wind projects in South Dakota and Nebraska are outside the NWPL and no projects are currently underway or in advanced development in those states (American Wind Association 2018).

Within the RND modeling extent of the NWPL, there were 1,509 turbines as of July 2018 (Hoen et al. 2018). Six large-scale installations occur across the NWPL (Figure 3.4). The largest complex of turbines occurs within the "Glenrock/Top of the World" project with 352 1.5-2.3 MW turbines in Converse County, WY (Glenrock, Glenrock III, Top of the World, Campbell Hill, Rolling Hills, Casper Wind Farm, and Pioneer Wind Park projects). The Oliver/Bison complex is host to 269 1.5-3.0 MW turbines across Oliver and Morton Counties from the Oliver I, II, III, Oliver Wind Energy, and Bison 1A, 1B, 2, 3, 4 projects. The Brady Wind I and II project in Stark and Hettinger Counties host 171 1.7-2.1 MW turbines. In Montana, the Kevin Rim area has 266 1.5 MW turbines in Glacier and Toole Counties from the Glacier I, II, and Rimrock projects. There are 90 1.5 MW turbines in the Judith Gap project in Wheatland County. Other smaller-scale projects occur in the western edge of Montana ranging from 6-38 turbines. Other projects in North Dakota and eastern Montana range from 1-54 turbines. The seven projects across South Dakota and Nebraska host between 1-55 turbines and are generally along the eastern edge of the NWPL.

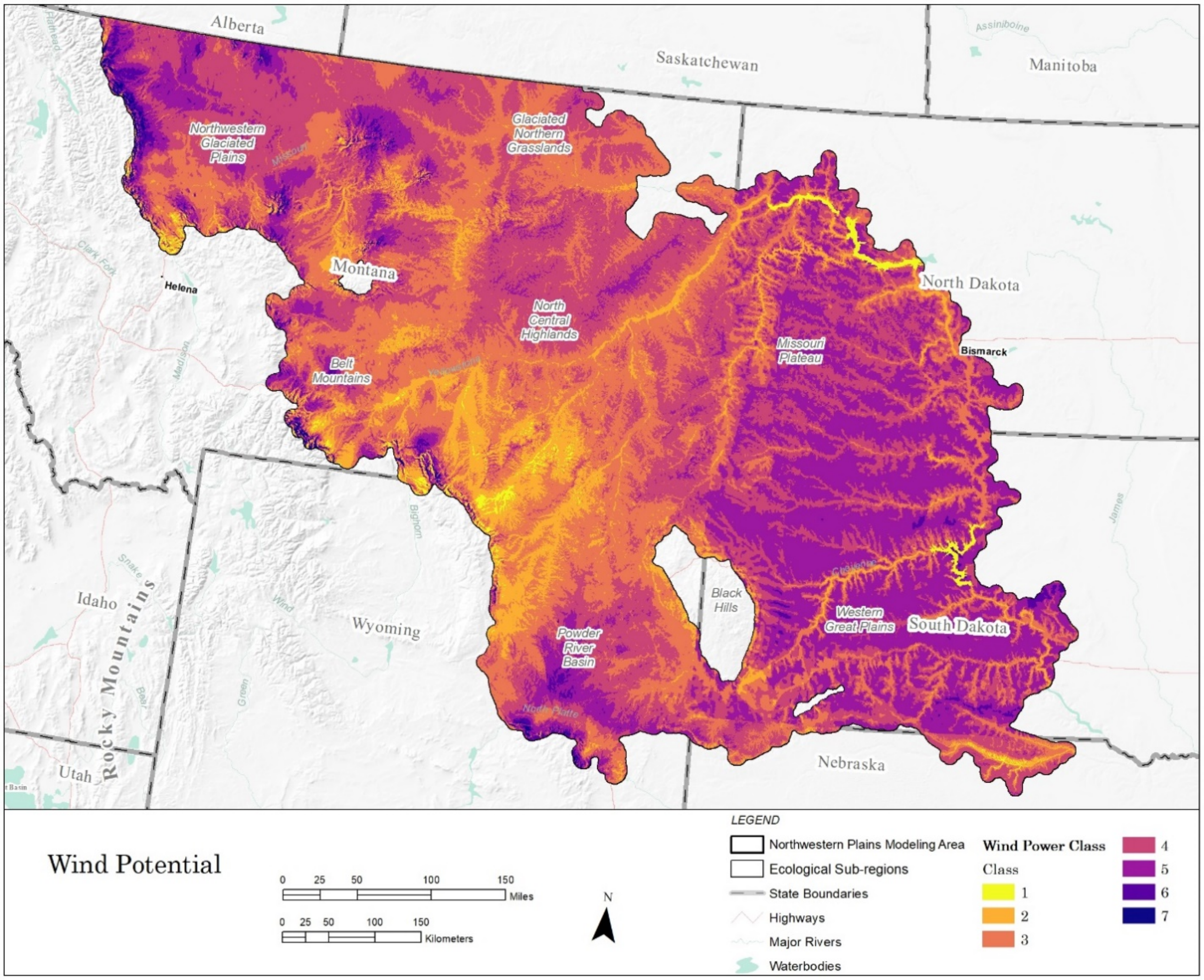


Figure 3.3 Wind potential in the Northwestern Plains golden eagle conservation assessment area. Wind power classes at 100 m accessed from the U.S. Department of Energy, Natural Resources Energy Lab, January 2019.

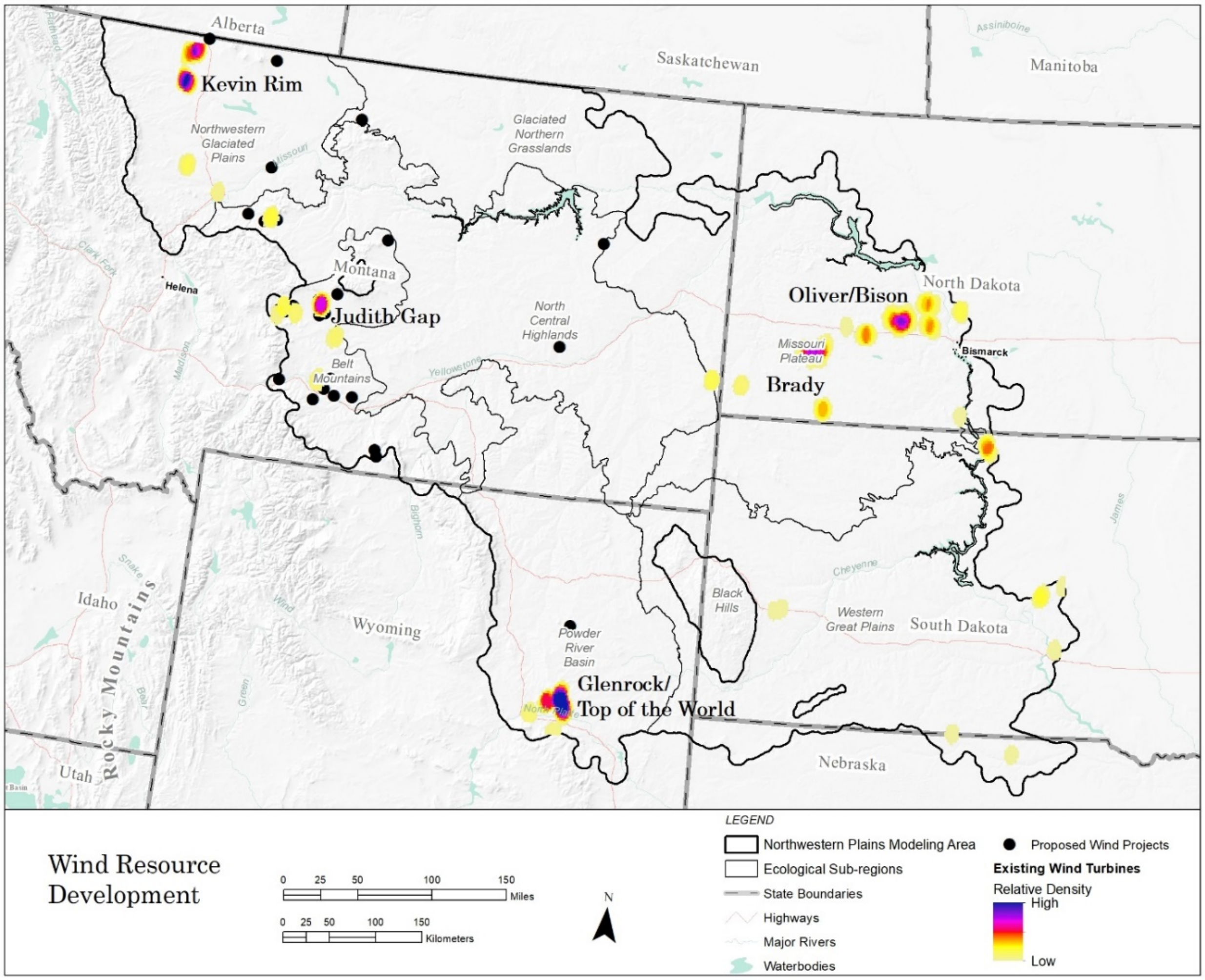


Figure 3.4. Density of industrial wind energy turbines and proposed wind projects in the Northwestern Plains golden eagle conservation assessment area. Common names of wind facilities are presented for reference but may not reflect all operators or facilities within each area.

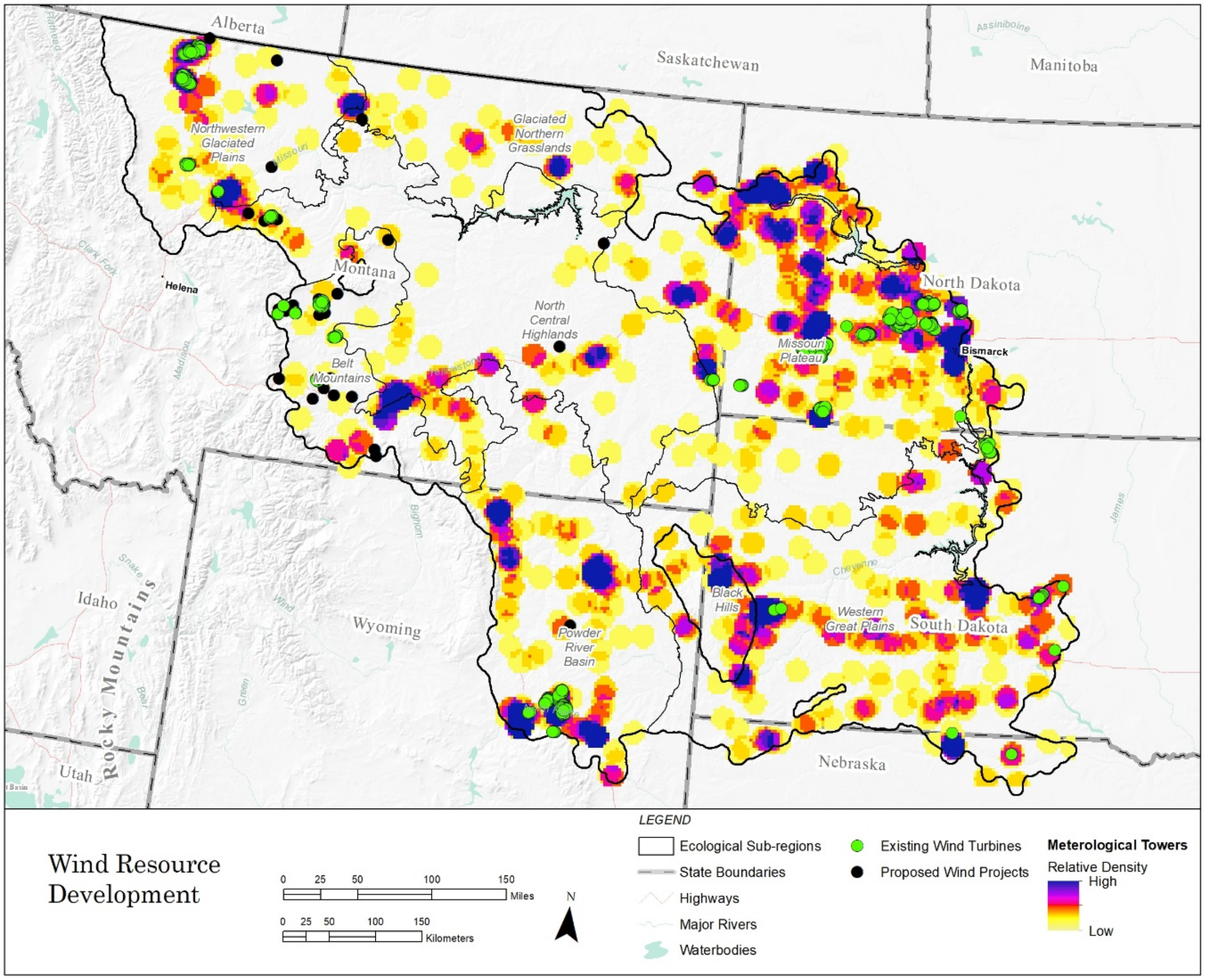


Figure 3.5 Wind energy extraction projects operating (green) and in development (black) in the NWPL. Also depicted is a density of Meteorological towers recorded in the Federal Aviation Administration database, which may provide insights into areas of future wind development. Overlapping turbines or projects in development may not be visible.

Information on proposed wind farms is not publicly available until an Environmental Impact Statement is submitted and may never be released if project areas do not include any public lands. While it is nearly impossible to locate all prospective future wind facilities, utilization of Meteorological Evaluation Tower (MET) locations may provide insights into future development. Wind developers typically erect MET towers to measure wind speeds and other data for ca. 1–2 years in potential development areas to determine economic viability of erecting wind turbines and the towers required to be registered with the Federal Aviation Administration (FAA) as aviation obstacles. We used the FAA digital obstacle file (https://www.faa.gov/air_traffic/flight_info/aeronav/digital_products/dof/) and reduced the dataset to only items classified as "Towers," which may include other towers, such as telecommunication towers. We created a density map of towers within the RND modeling area. We also digitized a project list of development in construction or in development for Wyoming and Montana from the Northwest Wind Resource and Action Center (https://renewablenw.org). Using these datasets, it appears that an expansion of wind power generation near existing facilities is occurring and likely to continue. Other significant areas of growth may occur along much of the western edge of the NWPL. Potential new areas of development include the Havre, MT area, where three developments are currently underway and many MET towers are operating (Figure 3.5). Areas along Interstate 94 in Montana may experience increased growth, particularly near Columbus and Glendive. Hotspots identified in Figure 3.5 along Interstate 90 may be more indicative of communication towers in larger cities such as Sheridan, Gillette, and Rapid City. It is likely that hotspots near Top of the World identify areas of wind development potential in Wyoming. North Dakota will likely experience the greatest growth of wind energy development, particularly from Williston, along the Highway 85 and Interstate 94 corridors. The Valentine, NE area may also be an area of future development.

Data on rates of turbine-strike mortality are not publicly available for most wind energy facilities in the NWPL. Bay et al. (2016) estimated mortality rates at the Campbell Hills wind farm (66 turbines in the Glenrock/Top of the World area) as the highest from 40 wind facilities across the county, at 2.87 eagles/yr. In 2014, PacificCorp Energy pled guilty to a violation of the Migratory Bird Treaty Act for killing 38 golden eagles from 2009–2013 at their Seven Mile Hill and Glenrock/Rolling Hills wind facilities (237 total turbines; US Dept. of Justice Press Release 14–1435). Similarly, Duke Energy Renewables, Inc. pled guilty to killing 14 golden eagles at the Campbell Hill/Top of the World projects between 2009–2013 (US Dept. of Justice Press Release 13-1253). As a result, the sites have undertaken significant measures to reduce collisions, such as having year-round observers with the ability to stop individual turbines as eagle approach (B. Bedrosian, Personal Observations).

Despite the abundance of both wind and golden eagles in the NWPL, spatial hazard analyses have identified some areas where wind speeds suitable for commercial development have minimal overlap with golden eagle nesting habitat in Wyoming (Tack and Fedy 2015; Bedrosian et al. 2018b) and undisturbed wildlife habitat across the great plains (Fargione et al. 2012). As of 2012, however, only 0.002% of current turbines and 3% of proposed turbines in Wyoming were located in areas classified as having low impacts to wildlife habitat (Fargione et al. 2012) (results from this study are available as an online decision support mapping tool: http://www.lowimpactwind.tnc.org/). Montana, North Dakota, South Dakota and Nebraska had greater proportions of existing (35–48%) and proposed (21–50%) turbines on "low impact" areas. However, golden eagle habitat, specifically, was not used to help define areas of low impact.

Siting of wind energy developments in areas with high potential for conflict with golden eagles is due in part to a lack of understanding of the overlap of golden eagle habitat and wind resources. However, wind energy siting decisions are also influenced by numerous other factors, including: access to transmission capacity and energy markets; local, State, and Federal incentives; land ownership and management; approval by industrial siting commissions; conflicts with other wildlife species (e.g., greater sage-grouse) and resource values (e.g., view sheds); and public opinion. Owing to the difficulty of predicting many of these factors, most studies have used wind speed as a proxy for development potential. In this report, we take an approach to risk assessment similar to that of Tack and Fedy (2015), and extend the assessment to include habitats used for wintering (see 4.3.2).

3.2.1.3. Collisions with transmission structures

Collision with transmission lines is a source of mortality for golden eagles, but little is known about its magnitude, proximate causes, or avoidance measures. Raptors in the NWPL are attracted to transmission structures because they offer elevated substrates for perching and nesting in otherwise open landscapes (See Figure 2.14 for example). Shomburg (2003) reported that 10% of mortalities in central Montana associated with power lines were a result of mid-span collisions. Mojica et al. (2009) documented 34% of bald eagle mortalities associate with power lines in Maryland were attributable to collision. While Mojica et al. (2009) was not studying golden eagles, these two studies highlight that this source of eagle mortality may be substantial.

Eagles may be more susceptible to collisions when electrical lines are placed within movement corridors (Mojica et al. 2009), such as key migration corridors within the NWPL (see 2.3.4.) or in breeding areas where undulating display flights may occur in low light (Eccleston and Harness 2018). Collision risk generally increases in species with high wing-loading (Perrins and Sears 1991) and golden eagles have relative high wing loading for a raptor (Lish et al. 2016). Ingestion of toxins, such as lead, may also increase risk of collision with power lines (Kelly and Kelly 2005).

3.2.1.4. Oil and gas development

There were 54,358 active oil and gas wells in the NWPL in 2016 (NDIGC 2016, MTBOG 2016, SDDENR 2016, WOGCC 2016, NOGCC 2016). Oil and gas wells occur in all regions of the NWPL, with major fields in the Williston Basin (Bakken Field), Powder River Basin and the North Central Coal Region. While the extraction of oil and gas is not a direct threat to survival of golden eagles, development involves infrastructure and activities with the potential to increase hazards with known negative effects. State and Federal guidelines and mitigation strategies can help reduce these risks, but likely do not eliminate them. Distribution lines that power oil and gas wells increase risk of electrocution (Lehman et al. 2010) and golden eagles are at risk of drowning in waste pits in oil fields (Trail 2006). Roads built in previously undeveloped areas and increased traffic on existing roads increases risk of eagle-vehicle collisions and facilitates access for persecution of eagles and their prey (e.g., black-tailed prairie dogs; USDI Bureau of Land Management 2007). An estimated 840,000 birds of all species die annually in the U.S. from drowning in oil pits, approximately 8% of which are birds of prey (Trail 2006). Although drowning of golden eagles in oil pits has not been documented in the NWPL, it has occurred in other areas (Trail 2006) and uncovered oil pits in the region could pose a hazard to the species. Vehicle traffic, human presence, and activities associated with construction and maintenance of oil and gas fields may also cause disturbance to golden eagles that can reduce individual fitness and reproductive success (see 3.3.2.1). Further, this type of development can cause habitat fragmentation at a scale resulting in cumulative effects from these indirect impacts.

In this report, we present a spatial hazard analysis identifying areas where seasonal habitat of golden eagles overlaps areas with high oil and gas development potential (see 4.3.3), and spatial models of electrocution risk that can be applied to prioritize retrofitting efforts in existing oil and gas developments (see 4.3.1).

3.2.1.5. Mining and power generation

Some of the largest surface coal mines in the western United States occur within the NWPL. Over 450 million short tons of coal are produced annually within the NWPL from 23 active mines ranging from 309,144 to 92,863,811 tons per mine (EIA 2018). The largest producing mines occur in the Powder River Basin at Antelope, North Antelope Rochelle, and Black Thunder Coal Mines, with 190 million tons produced from these three mines. Fifteen hydroelectric power plants, with the largest capacities along the Missouri River, 10 natural gas and three petroleum power plants operate within the NWPL.

Railway and vehicle traffic and distribution and transmission lines associated with mining and power generation are possible sources of mortality for golden eagles, while habitat loss from surface mining and disturbance from vehicle traffic, human presence, and activities associated with construction and maintenance of mines and power plants can affect breeding and foraging golden eagles (see 3.3.2). Loss of breeding habitat may also be associated with hydroelectric power plants by altering river and stream flow, which affects cottonwood regeneration (see 3.3.3). One mine operator in the Powder River Basin was granted permission to preclude nesting of one golden eagle pair, thereby causing loss of production in that and future years (McKee 2018). Operation permits for many coal mines in the NWPL require monitoring of raptor nests and prey, and the resulting data represent some of the longest-term studies of golden eagles in the region (McKee 2018). However, monitoring of mortality is not included in these requirements, and the relatively small number of nests within each mine area makes the data impractical for trend analysis.

3.2.2. Collisions with vehicles

Collisions with motor vehicles are a major source of mortality for golden eagles (Russell and Franson 2014, USFWS 2016) that has increased over the past century (Lutmerding et al. 2012). In the NWPL, vehicle collision mortality of golden eagles is mainly associated with feeding on road-killed ungulates and jackrabbits during winter. However, eagle-vehicle collisions likely occur to some extent in all seasons and may be associated with factors other than feeding on road kill (Riginos et al. 2017, Londsdorf et al. 2018). Given the strong association of vehicle collision mortality with winter feeding on road kill, removal of carcasses from highways has been identified as a measure to reduce risk to golden eagles (USFWS 2013) and suggested as a possible form of compensatory mitigation to offset programmatic take at wind energy facilities (Allison et al. 2017, Lonsdorf et al. 2018).

An analysis of deer collision records collected by the Wyoming Department of Transportation revealed “hotspots” of deer-vehicle collision in the state (Teton Science

Schools 2016). Riginos et al. (2017) overlaid the deer-vehicle collision model with models of golden eagle habitat (RND, migration and RSF models described in sections 2.1.4, 2.2.3, and 2.3.4) to identify seasonal concentrations of collision risk. Assuming deer-vehicle collision rates as a surrogate for collision hazard and proportional to risk of eagle-vehicle collision, the results of their analysis can be used for spatial prioritization of roadkill removal to maximize benefit to golden eagles. Eagle-vehicle collision risk was greatest in areas of Wyoming outside the NWPL, but relative risk with the NWPL only highlighted areas surrounding Buffalo during the fall and summer as riskiest (Figure 3.1).

Lonsdorf et al. (2018) also modeled eagle-vehicle collision risk within each county of Wyoming using a different methodology. They estimated the eagle population within each county by uniformly extrapolating the results of Neilson et al. (2014) and Neilson et al. (2016) across each county, and used expert elicitation to estimate the rates of discovering a carcass, persistence of a carcass, age-specific scavenging rates, eagle-vehicle collision rate by age, and response of eagles to traffic volume. They gathered traffic volume data and carcasses removed from roadways from a Wyoming Department of Transportation dataset, and used three scenarios of carcass removal intervals. Using this suite of covariates and the model, they estimated an annual mortality rate of 5.2, 14.6, and 35.0 eagles/year for counties within the NWPL using 3.5, 7, and 14-day carcass removal intervals, respectively.

It is important to note that neither of these modeling efforts included small animals. Smaller road-kill, such as leporids or scuirids, often freezes to the roadways and creates a larger relative risk to eagles as they try to remove the food resource from the road as vehicles approach (S. Slater, HawkWatch Int., Personal Communication). However, no consistent data are collected on road-kill rates of animals smaller than pronghorn.

Lonsdorf et al. (2018) found that the rate of big-game carcass removal significantly affects eagle-vehicle collision risk. In Wyoming, removal of road-killed big-game by the general public is not legal, whereas it is in Montana, North Dakota, and South Dakota. Allowance of the public to remove road-kill for personal consumption likely significantly reduces the amount of road-kill, particularly on secondary highways and county roads where stopping is easier than interstate highways.

Risk of wildlife-train collisions is generally unknown for most wildlife in the United States, but can be greater than vehicle collisions (Dorsey et al. 2015). Ungulates and other wildlife are regularly struck by trains, which can lead to eagle-train collisions when eagles are feeding on train-caused carrion. For example, train collisions are the leading cause of mortality for white-tailed sea eagles in Germany (Krone et al. 2002). Trains that transport agricultural products (such as grains) can attract wildlife and can cause greater risk of collisions (Dorsey et al. 2015), but all train types pose a wildlife collision risk. Across the NWPL, there were 6,704.7 km of active railways in 2018 (Federal Railroad Administration 2018) that mainly parallel major roadways.

Golden eagles occasionally collide with aircraft, although this is likely not a major source of mortality. During 1990–2013, 14 golden eagle strikes with aircraft were reported to the Federal Aviation Administration in the Intermountain West Region (Washburn et al. 2015).

Most collisions in the western U.S. occurred at low flight altitudes, with 81% below 305 m above ground level (AGL) and none above 915 m AGL (Washburn et al. 2015).

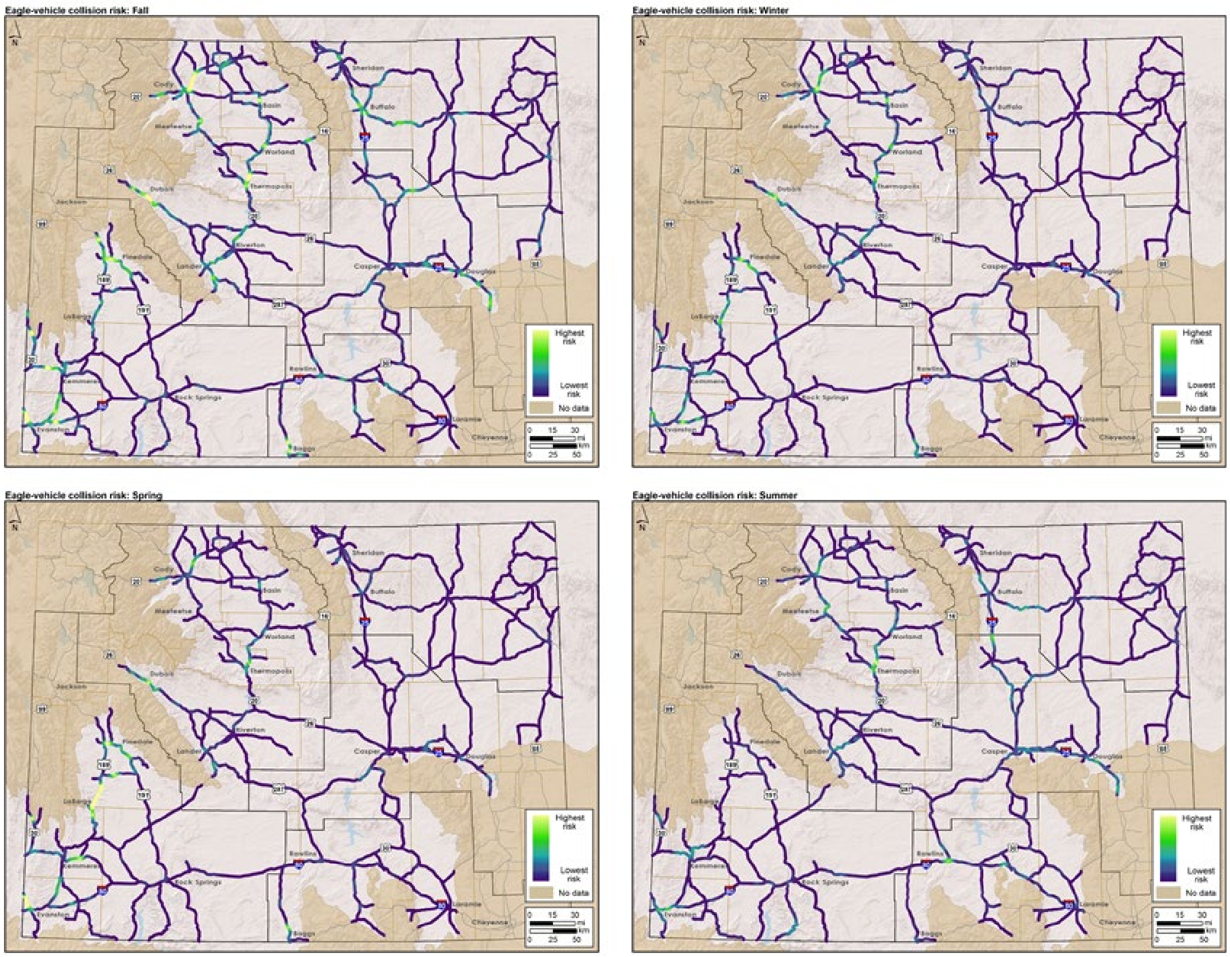


Figure 3.6. Relative risk of eagle-vehicle collisions during fall (October–November), winter (December–February), spring (March–April), and summer (June–August) in Wyoming, from Riginos et al. (2017).

3.2.3. Contaminants

Exposure to environmental contaminants is a significant threat to persistence of golden eagle populations. Poisoning and lead toxicosis account for a combined 1,185 (20%) golden eagle deaths annually in North America (USFWS 2016). Contaminants may be an important source of mortality in golden eagles because it is generally indiscriminate of age, and increases in adult mortality may affect population trends at a greater rate than juvenile or sub-adult mortality (Tack et al. 2017). Poisoning and lead toxicosis is estimated to account for 2.8% of hatch-year mortality and 21.6% of after-third-year mortality (USFWS 2016), highlighting the importance of these sources of mortality for eagle populations.

3.2.3.1. Lead

Lead poisoning is a widespread and persistent hazard to golden eagles in North America (Craig et al. 1990, Stauber et al. 2010, Russell and Franson 2014, Langner et al. 2015). The primary pathway of exposure is through lead bullet fragments and shotgun pellets ingested by golden eagles scavenging on animals killed by hunters (Herring et al. 2017). In the NWPL, sources of lead-laden carrion include hunting of big game animals and upland game birds, shooting of prairie dogs and ground squirrels for recreation and pest control, and shooting of coyotes for predator control. Large numbers of big game animals are harvested annually by hunters on public and private lands across the NWPL, where abundant populations of ungulates occur in diverse habitats. The offal (gut piles) left in the field by hunters, as well as animals wounded and not recovered, are one of the primary sources of lead for golden eagles in the region. Fragments of bullets disperse widely throughout carcasses on impact and even tissues with no noticeable fragments may contain concentrations of lead dangerous to golden eagles (Hunt et al. 2006, Golden et al. 2016). The importance of big game carcasses as a vector of lead exposure was confirmed by numerous studies documenting a seasonal pattern of elevated blood lead levels in golden eagles and other avian scavengers during and after the big game hunting season in fall and early-winter (Kramer and Redig 1997, Stauber et al. 2010, Craighead and Bedrosian 2008, Bedrosian et al. 2012, Legagneux et al. 2014, Langner et al. 2015, Ecke et al. 2017). Estimates based on telemetered golden eagles suggest acute lead toxicosis accounts for 160 (3%) mortalities annually in North America (USFWS 2016), while rates from studies using opportunistically recovered eagle carcasses were higher, ranging from 10–44% (Kochert et al. 2002). However, the cumulative exposure and sub-clinical exposures that increase mortality from other risks, such as electrocutions, collisions with vehicles and wind turbines, remains unknown.

Several factors affect relative risk of lead exposure to golden eagles and any resulting direct or indirect mortality. Exposure is largely influenced by the ability of eagles to access offal or unretrieved carasses, maximum number of available gut piles to each eagle, how much lead is assimilated per scavenging event, and the amount of lead in each gut pile (Cochrane et al. 2015). Further, the relationships between blood levels and cumulative exposure events affect mortality rates. Across the NWPL (excluding North Dakota because we could not access harvest data), the 5-year average harvest rates were 0.07 elk/km^2 (range = 0–0.39, SD = 0.09), 0.37 deer/km^2 (range = 0–2.53, SD = 0.44). For the Wyoming and Montana portions of the NWPL, there was an average of 0.17 pronghorn/km^2 (range = 0–1.55, SD = 0.27). Detailed harvest data were not available for North Dakota or antelope harvest in South Dakota. On average, gut piles of deer and elk contain approximately 170 visible fragments on an x-ray and un-retrieved carcasses contain 235 fragments (Hunt et al. 2006, 2009, Craighead and Bedrosian 2008, Knott et al. 2010). The fragmentation rate has not specifically been investigated for pronghorn, but it is likely similar. Using a 0.44 animals harvested/km^2 combined mean (deer, pronghorn and elk) harvest rate across the Wyoming, Montana, and Nebraska portions of the NWPL (range = 0–3.82, SD = 0.31), an average eagle core area (8.09 km^2, Ross Crandall, personal communication) could contain 0–30 gut piles each fall. An average home range (20–33 km^2, Kochert et al. 2002) could contain as many as 126 gut piles every fall. Lead risk from big game hunting is seasonal in nature and is a larger risk to eagles during the fall and early winter (Table 3.2). Model estimates suggest that gut pile removal may not be as effective as non-lead ammunition use for lead mortality mitigation (Cochrane et al. 2015).

Table 3.2. Big-game season dates in states with significant harvest in the NWPL.

	Montana		Wyoming		North Dakota		South Dakota	
	Open	Close	Open	Close	Open	Close	Open	Close
Deer	15-Sep	27-Nov	15-Sep	30-Nov	4-Nov	20-Nov	11-Nov	26-Nov
Elk	15-Sep	27-Nov	15-Aug	31-Jan	7-Oct	31-Dec	1-Oct	15-Dec
Pronghorn	8-Oct	13-Nov	10-Sep	20-Nov	30-Sep	16-Oct	30-Sep	15-Oct

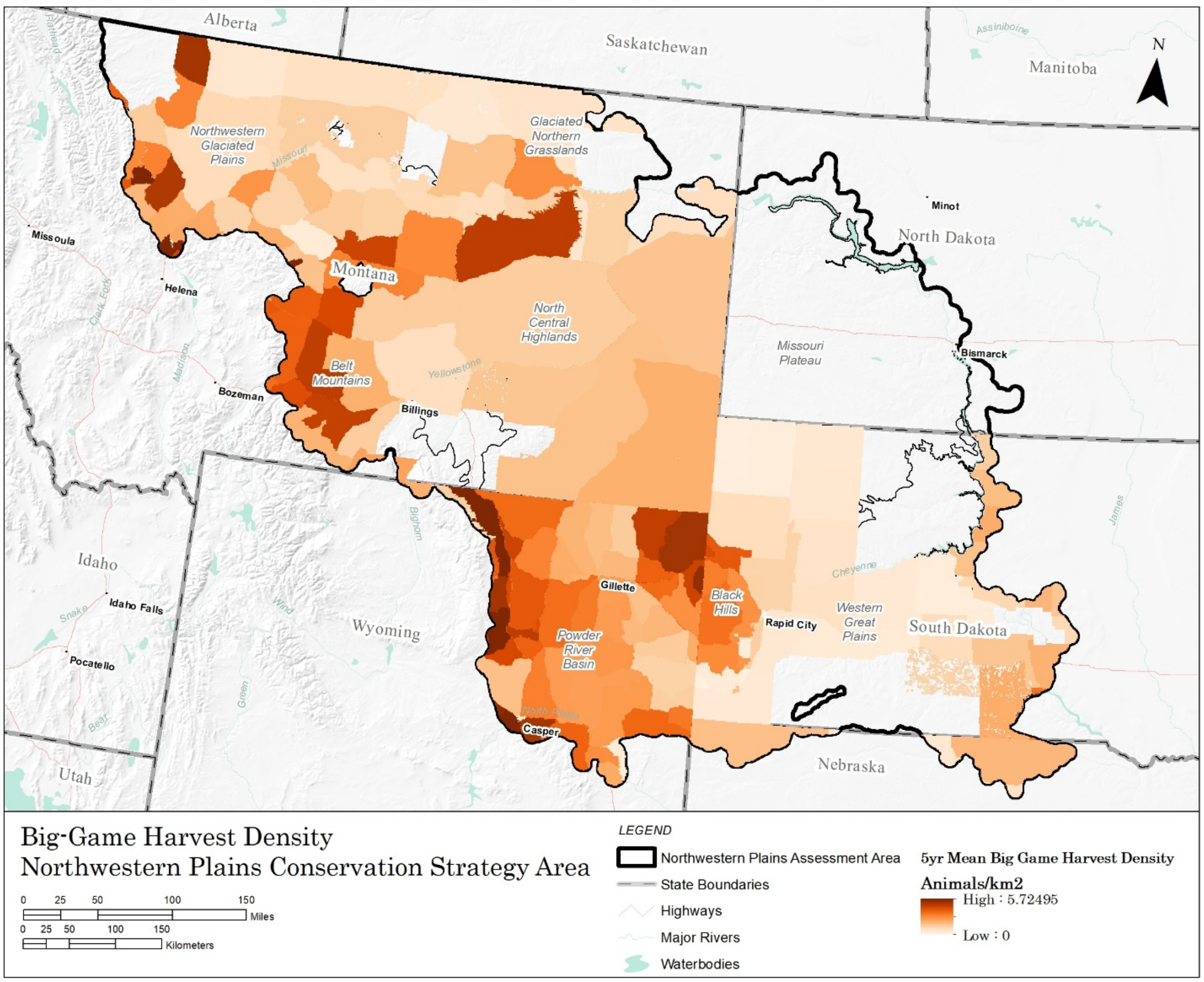


Figure 3.7 Average big-game harvest (animals/km^2) from 2011–2015 in the Northwestern Plains conservation assessment area. Harvest rates for Wyoming, Montana, and Nebraska include deer, antelope and elk. Harvest rates for South Dakota include deer and elk (pronghorn data not available). No data available for North Dakota or other areas without color (mainly tribal lands).

Deer hunting is the most prevalent form of big-game hunting within the NWPL. Pronghorn hunting is also widespread, particularly in the southern portion of the NWPL. Elk hunting occurs in limited areas, particularly forested habitats in the eastern portion of the NWPL. Currently, only two areas require non-lead ammunition for big game hunting (or elk reduction programs) within the NWPL: Theodore Roosevelt National Park and Wind Cave National Park. The American Prairie Reserve will soon be requiring use of non-lead ammunition for big-game hunting on their properties and leased lands. No areas require the use of nontoxic ammunition for varmint hunting or control.

Other potentially significant sources of lead deposition through firearms are depredation and recreational shooting of varmints and predators. Lead has been identified in carcasses of ground squirrels and prairie dogs in concentrations potentially lethal to hawks and eagles (Knopper at al. 2006, Pauli and Buskirk 2007, Stephens et al. 2008, Herring et al. 2016). Recreational shooting and organized hunting of prairie dogs and ground squirrels occurs typically from June–September and outfitters advertise typically shooting 200–500 rounds/day/hunter. Hunting occurs both on public lands and leased/owned private lands. Most prairie dog complexes in North Dakota and Montana have at least one homeowner in the vicinity that provide lodging for prairie dog shooters (Knowles 2012). Some landowners assess hunters a fee for access to colonies on private lands, but most do not (Knowles 2012). In 2011, biologists from the Lower Brule tribe in South Dakota estimated that 39,000 BTPD were killed that year (90% by non-tribal members) from a total of 6,190 acres of BTNP colonies (6.3 BTPD/ac), using an estimated 117,000 bullets fired (19 bullets/ac; S. Grassel, pers comm). Using this estimate of BTPDs killed/acre and the estimated 222,173 acres of BTNP colonies across South Dakota (Kempema et al. 2015), and assuming kill rates across the state and years are equal, ca. 1.4 million BTPD may be shot, annually.

In the Thunder Basin National Grasslands, nestling eagles were tested for lead exposure from prairie dog hunting in 2002, but no evidence of lead poisoning was detected (Stephens et al. 2005). Golden eagles were observed in prairie dog colonies at a rate of 0.34 eagles/hr and shooter activity was low that year due to a sylvatic plague (*Yersinia pestis*) outbreak. This may also explain why Stephens et al. (2008) detected low lead levels in nestling golden eagles. More recently, Bedrosian et al. (2017) found evidence to suggest that nestling eaglets are ingesting lead from prairie dogs within this same area, as evidenced by linking Pb isotopes of lead in eagle to the Pb isotopes from ammunition removed from randomly shot prairie dogs within the study area. Although impacts from this practice are expected to be relatively localized, lead exposure for golden eagles could be considerable because the number of animals shot is not restricted by bag limits (e.g., >100 prairie dogs per shooter per day), carcasses are typically not retrieved, and raptors may preferentially scavenge in shooting areas (Herring et al. 2016).

Some counties within the NWPL also host coyote hunts and offer bounties for control. For example, in Natron County, WY, the Predator Animal Board spent $6,160 in 2013 on $20/coyote bounties, equating to 308 coyotes killed and reported for the bounty program. Organized hunting contests for coyotes also occur in Wyoming and South Dakota. Wildlife control of animals classified as "predators" for depredation using firearms does not require a permit or reporting. Therefore, estimates of lead deposition through these sources are difficult to quantify, but may be a significant source of lead exposure for eagles. Furthermore, depredation hunting and control occurs year-round, creating lead exposure risk outside of the typical big-game hunting seasons.

Upland game hunting occurs throughout the NWPL and the majority of ammunition used is lead-based. Upland game include pheasant, gray partridge (*Perdix perdix*), chuckar partridge (*Alectoris chukar*), sharp-tailed grouse (*Tympoanuchus phasianellus*), greater sage-grouse, ruffed grouse (*Bonasa umbellus*), dusky grouse (*Dendragapus obscurus*), and spruce grouse (*Falcipennis canadensis*). Limited greater sage-grouse hunting occurs in a small section of the NWPL within Wyoming and is likely not a significant risk for lead ingestion in Golden Eagles. Sharp-tailed grouse, partridge, and pheasant hunting is widespread and hunting can occur in high densities in some areas. Ruffed, dusky, and spruce grouse hunting generally occurs within forested habitats and wounded, unrecovered game are less likely to be encountered by golden eagles compared to plains game species. Wounding rates are typically unknown for upland game and can vary by habitat type and if retrieval dogs are used. While wounding loss rates have been estimated for waterfowl and grouse species in Europe, few estimates exist for prairie grouse but may be as high as 29% (Burger 1964). In Montana Fish, Wildlife, and Parks upland game Management Regions 5–7 (which encompass the NWPL), an average of 254,646 upland game were estimated to be harvested annually from 2002–2007 (data from 2008–2018 were not available). In Wyoming, the Wyoming Game and Fish Department upland game Management Zone 3 encompasses the NWPL section in that state. Within that zone, the 5-year (2011–2015) average harvest estimate for pheasant, chuckar, partridge, ruffed grouse, dusky grouse, sharp-tailed grouse, and sage-grouse (Management Zone C) was 11,065 birds/year. In the South Dakota counties within the NWPL, pheasant hunting is the largest proportion of upland game hunting. The five-year average (2011–2015) for pheasant, partridge, and grouse estimated harvest was 319,608 birds/year. Using a conservative 15–25% wounding loss rate, there may between 87,798–146,330 unretrieved, wounded upland game (excluding North Dakota) that may have lead shot remaining in their tissue, annually. While harvest estimates were not available for North Dakota, the number of upland game harvested is likely similar to South Dakota and Montana, and may add another ca. 75,000 birds to this estimate. More information is needed to assess the risk of lead exposure to golden eagles from upland game hunting in the NWPL.

3.2.3.2. Anticoagulant rodenticides

Anticoagulant rodenticides (ARs) have been used to control rodent pests since the 1940s. ARs inhibit blood clotting, causing the death of animals by internal hemorrhaging and external bleeding. As a facultative scavenger, golden eagles can be exposed to ARs by scavenging or preying on rodents that have consumed AR laced baits or other predators that have consumed AR-exposed rodents (Herring et al. 2017). Poisoned rodents are easier to capture and there is evidence that raptors (i.e., ferruginous hawks) preferentially foraged in black-tailed prairie dog colonies that had been poisoned with ARs (Vyas et al. 2017). Two types of ARs are used to control rodent populations in the NWPL, first generation ARs (FGAR) and second generation ARs (SGAR). FGARs including warfarin, chlorophacineone (e.g., Rozol®), and diphacinone (e.g., Kaput®), generally require multiple ingestions in a short timeframe to cause mortality. SGARs, including brodifacoum, bromadiolone, difenacoum, and difethialone, are often fatal with one dose and more persistent in vertebrate livers, creating a higher risk to eagles. Herring et al. (2017) provide a detailed review of AR exposure in Golden Eagles. All ARs are considered hazardous to raptors, including golden eagles, although the scope of exposure, lethal dosage, and effects at sublethal levels are poorly understood (Herring et al. 2017). Similar to lead, the sublethal effects of ARs may be additive with other stressors, including contaminants, parasites, and diseases (Herring et al. 2017). Sublethal doses of ARs have been shown to cause behavioral effects such as lethargy in golden eagles (Savarie et al. 1979), which could increase risk of collisions with infrastructure (Herring et al. 2017).

FGAR prairie dog baits are currently US Environmental Protection Agency (EPA) approved for use with a Restricted Use Pesticide Applicator's or Dealer's License (EPA 2017). Each rodenticide type has particular restrictions and use guidelines outlining application date and geographic restrictions accessed on the product label. BLM offices need an Environmental Assessment prior to use on BLM managed lands, but applications can occur on private and state-leased lands without an Environmental Assessment. Other federal lands, such as Thunder Basin National Grasslands, do not allow use of ARs, with the exception of a ¼ mi buffer of private lands on the Thunder Basin National Grasslands (T. Byer, Personal Communication).

Prior to 2012, FGAR use was only permitted in Wyoming but ranchers frequently purchased FGARs in Wyoming and transported them to Montana (and likely South Dakota) for use (Knowles 2012). FGAR application is allowed from October 1–March 15. Applicators are directed to return to application sites within 4 days and at 1–2 day intervals for two weeks to collect dead or dying prairie dogs using a 200-ft line-transect method. However, there are documented cases of applications of FGARs outside of the restricted season and other label misuses such as dispersed baiting from moving vehicles. (Knowles 2012). Recently, six bald eagles were killed as a direct result of improper application of 39,600 lbs. Rozol® across 5,408 acres for BTPD control on the border of North and South Dakota (EPA 2016). There have also been recent cases of widespread use of SGARs in the field, though recommended uses are for the immediate vicinity of buildings only. For example, Knowles (2012) describes a case in North Dakota in which Ramik Green® was being supplied to local ranchers for deployment in prairie dog colonies.

Other instances of rodent control have been observed or described within the NWPL that also may affect golden eagle survival through secondary poisoning, such as the use of anhydrous ammonia and strychnine for prairie dog control (Knowles 2012). Strychnine is not registered with the EPA for prairie dog control and was likely more prevalent before the FGARs became legal for use in Montana and the Dakotas.

It is common for resident golden eagles to use prairie dogs or ground squirrels for food resources almost exclusively when a colony exists within their territory in the NWPL (B. Bedrosian, personal observation). ARs generally take up to 21 days to cause mortality and eagles can consume many times the lethal dose prior to death. Black-tailed prairie dogs emerge from burrows during good weather year-round and animals that have ingested ARs can become lethargic and easy prey for raptors. There is even evidence to suggest that raptors actively select for colonies that have been treated, presumably due because of easier-to-capture prey (Vyas et al. 2017). Therefore, secondary poisoning from ARs may occur year-round based on the timing of AR application. Based on label restrictions, mortality risk occurs primarily during the fall and winter months, affecting both residents and over-wintering eagles. Off-label use in prairie-dog colonies and AR use in ground squirrel colonies have the potential to affect resident and young eagles. Due to year-round territoriality of residents in the NWPL, the greatest AR poisoning risk is likely at colonies on private and state-owned lands in the vicinity of eagle nesting habitat.

3.2.3.3. Other Contaminants

Golden eagles are exposed to numerous other contaminants, including heavy metals (e.g., mercury), poisons intended for predators (e.g., strychnine), insecticides (e.g., phorate, carbofuran), and organochlorides (e.g., DDT, DDE) (Kochert et al. 2002); however, information on the extent of exposure and effects are lacking for most contaminants. Reynolds (1969) reported on pesticide residues in golden eagles and their prey in the NWPL from 1966–67. During this period, average pesticide residues in prey collected from nests ranged from 0.023–0.038 ppm DDE (dependent on prey species), 0.018–0.022 ppm DDD, and 0.008–0.035 ppm DDT, 0–0.008 ppm dieldrin. All pesticide levels (including heptachlor epoxide) from 10 eagle eggs were <0.57 ppm. Nestling levels were generally low but one individual had DDE levels of 10.7 ppm in pectoral adipose tissue. Pesticide residues were all low (<0.23 ppm) from one adult muscle sample.

Records are not available on the number of golden eagles killed by poison baits intended for mammalian predators (e.g., coyotes) in the NWPL, but research from other regions suggests they are a considerable threat, with greater mortality for females and during winter (Bortolotti 1984). As recently as 2013, a ranch within the NWPL was actively poisoning carcasses to kill predators, with a 55-gallon drum found on-site full of dead golden eagles (Anonymous Source, personal communication). A rancher in eastern Montana recently pled guilty to unintentionally killing a bald eagle and a hawk with a poisoned calf carcass set to kill coyotes (Associated Press 2017). Similar instances have been prosecuted in South Dakota and North Dakota in recent years. Even relatively rare incidents of poisoning can have cumulative effects. For example, one incident of poisoning with the livestock euthanasia agent pentobarbital was the cause of death for 4 of 73 (5%) golden eagles processed by Wyoming State Veterinary Laboratory during 1997–2016 in the adjacent Wyoming Basin ecoregion (Terry Creekmore, Wyoming Game and Fish Department, personal communication).

3.2.4. Disease and parasites

Starvation/disease is the leading cause of golden eagle mortality in North America, accounting for an estimated 1,334 (22%; CI 681–2,626) deaths annually (USFWS 2016). Diseases and parasites of golden eagles are not well documented in the NWPL; records are limited to eagles that were found opportunistically or captured for research purposes. While golden eagle populations in the region appear to be stable (see 3.1), changes in climate and land use may increase exposure to native and introduced pathogens. Insect-borne pathogens (e.g., West Nile virus from mosquitoes and leucocytozoonosis from blackflies) and insect pests (e.g., blow flies, Mexican chicken bugs) will likely increase in response to rising temperatures and changing precipitation regimes (Walker and Naugle 2011), while diseases vectored by prey of golden eagles (e.g., trichomaniasis from pigeons, avian cholera from waterfowl, and avian pox) could increase if native habitat of primary prey species is lost (Heath and Kochert 2015). Increased sampling effort is necessary to determine the current prevalence of diseases and parasites of the golden eagles in the NWPL and establish baselines to detect potential increases in response to changing conditions.

3.2.4.1. West Nile Virus

West Nile virus (*Flavivirus* sp.; WNv) is a mosquito-borne pathogen that infects humans, birds, and other animals, including golden eagles (CDC 2016). Although mosquitos are the primary vector for WNv, golden eagles could also contract the virus from feeding on tissue of infected animals (Straub et al. 2015). Introduced to North America in 1999, WNv spread rapidly across the continent, and was first reported in all states within the NWPL in 2002. Peak outbreaks occurred in 2003 and elevated outbreaks in 2005-07, 2012, and 2013, depending on state (CDC 2017).

In the Powder River Basin, there have been significant WNv outbreaks over the past several decades that may have put eagles at risk of exposure. All reporting of WNv cases is both opportunistic and voluntary and likely influenced by many factors, such as human and animal population densities (e.g., likelihood of finding dead animals). The NWPL is predicted to have high variability in WNv occurrence due to high topographic diversity, large areas with heterogeneous activity, and inter-annual climate variability (Harrigan 2014). Wildlife data on WNv occurrence in the NWPL are generally best represented in sage-grouse studies. For example, Walker and Naugle (2011) provided an overview of WNv ecology in sagebrush habitats within the NWPL. In Montana, researchers found a direct relationship between infection rates in populations of white pelicans (*Pelecanus erythororhynchos)* and human reporting, suggesting that occurrence of human infections may be a valuable indicator of risks to wildlife (Johnson et al. 2010).

There have been several confirmed cases of WNv in golden eagles in the NWPL, all of which were in nestlings. In 2005, one tagged nestling from northwestern North Dakota was confirmed to have died from WNv (Coyle 2008). One nestling within the Powder River Basin had a confirmed mortality as a result of WNv (McKee 2018) and three eaglets from two nests tagged near Douglas, WY were confirmed to have died due to WNv in 2015 (B. Smith, unpublished data). Other deaths of nestlings have been suspected across the NWPL but not confirmed.

Data from eastern Montana suggest that the seasonal abundance of *Culex tarsalis,* the main WNv vector mosquito species in the NWPL (Goddard et al. 2002, Zou et al. 2006), begins to increase the first week of July, with peak occurrence the last two weeks of July and first week of August (Friesen and Johnson 2013). In northern Montana, golden eagles fledge around the first week of July and have limited flight for the first few weeks after fledging, creating a higher risk of infection than adults that have greater mobility. Further, siblings may increase risk of infection due to proximity of multiple birds.

The incidence of WNv outbreaks in the NWPL can be influenced by many factors, including amount of larval habitat, distance to eagle nests, weather, flooding, etc. The larval habitats of *C. tarsalis* are small areas of standing water (<4 ha) with high organic matter (Beehler and Mulla 1995) that may or may not be ephemeral. The majority of breeding areas are created by human activities within the NWPL and include livestock watering ponds, water-storage areas, and discharge watering ponds in coalbed methane extraction regions (Denke and Spackman 1990). Irrigated agricultural sources of larval ponds produce significantly less mosquitos than coalbed methane ponds and outlets, and for a shorter duration (Doherty 2007). Further, Zou et al. (2006) mapped potential mosquito breeding areas through remote sensing in the Powder River Basin and found a 75% increase in area of potential larval habitats from 1999–2004, particularly in coalbed methane extraction areas.

Predictive models of *C. tarsalis* habitat suitability in Montana (Figure 3.8) suggest that fluctuations in summer temperature, land cover, early spring precipitation, and early spring mean temperature are the four most important variables contributing to suitable habitats (Hokit et al., in Review). The model suggests that regions with differences >17ºC between the min-max temperature in July-August provide the most suitable habitat. Land cover types associated with *C. trasalis* are agriculture, developed and wetlands, while forested habitats were least suitable. Areas in which mean temperatures were greater than 2.5ºC and precipitation was <50 mm in March and April were most suitable (Hokit et al, in Review).

WNv risk primarily depends on the habitat suitability for *C. tarsalis*, distribution of virulently-competent bird species and temperature dynamics (Hokit et al. in Review). Drought may also exacerbate outbreaks by concentrating host and associated vector species at restricted water locations. Future increases in heating degree days late in the summer due to future climate change may increase risk of WNv infection in golden eagles.

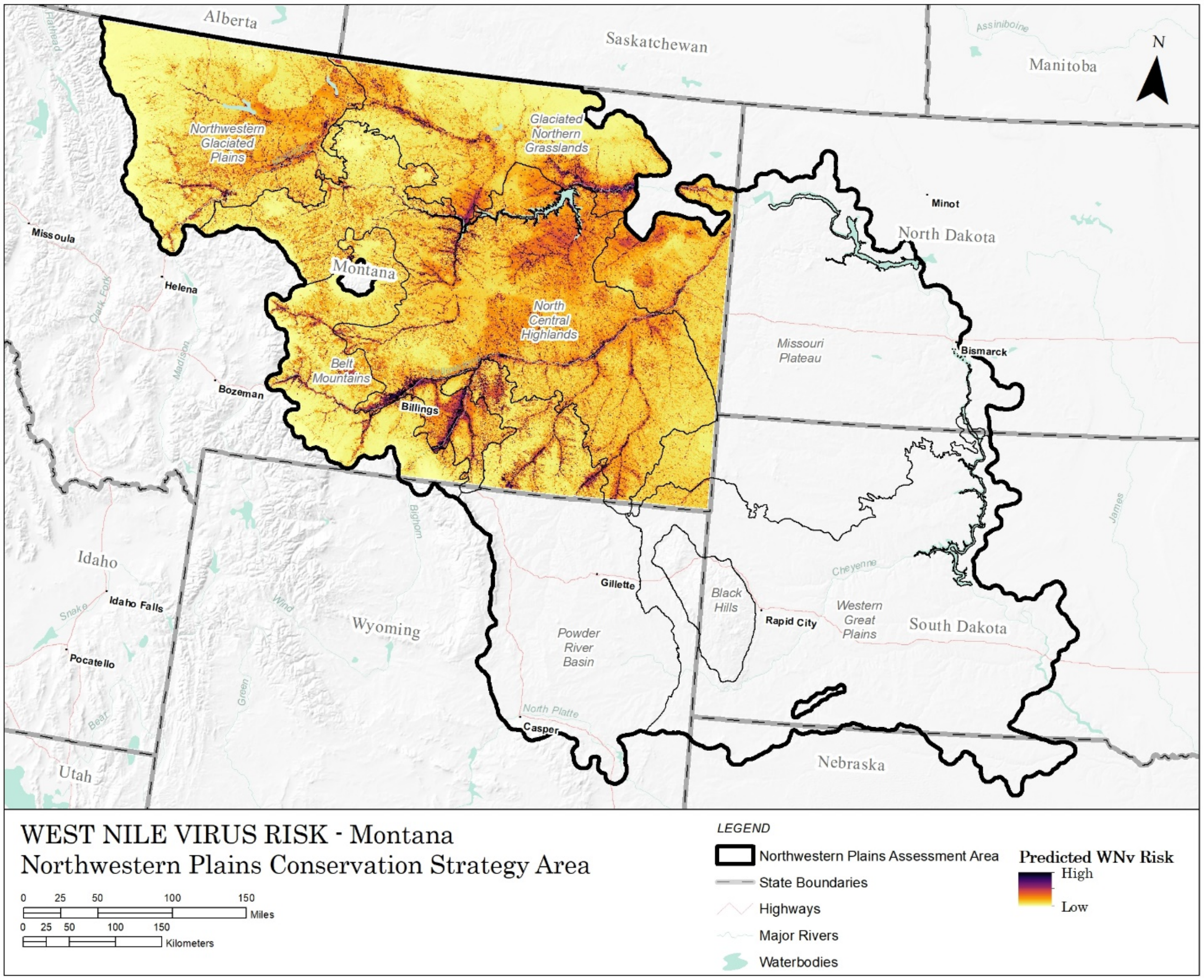


Figure 3.8. MaxEnt modeling results for *Culex tarsalis* habitat suitability in Montana (Hokit et al. in Review).

3.2.4.2. Trichomaniasis

Trichomaniasis is a disease of the upper digestive tract caused by the protozoan parasite *Trichomonas gallinae*. Golden eagles contract trichomaniasis (i.e., "frounce") by consuming rock pigeons (*Columba livia*) and other doves in the family *Columbidae*. Primarily known to affect nestling golden eagles, the disease causes the formation of lesions in the mouth and throat that can lead to death by starvation or suffocation (Kochert 1972, Dudek 2017). In the NWPL, golden eagles occasionally prey on rock pigeons (Reynolds 1969), and could also potentially contract the disease from mourning doves (*Zenaida macroura*) and Eurasian collared doves (*Streptopelia decaocto*). Trichomaniasis was documented in only 1 of 73 golden eagles processed by Wyoming State Veterinary Laboratory during 1997–2016 (Terry Creekmore, personal communication). However, actual prevalence of trichomaniasis may be greater because few nestlings were submitted to the lab and a limited number of research projects in the region included the intensive nest monitoring necessary to document diseases of nestlings. In other areas of the western United States (the Snake River Plain

Ecoregion) 4% of nestlings died from trichomaniasis (Kochert 1972) and 41% of nestlings tested positive for *T. gallinae* infection (Dudek 2017). High incidence of trichomaniasis resulted from increased consumption of rock doves due to declines in leporid populations following loss of native shrub-steppe habitat to wildfire (Heath and Kochert 2015). Although similar habitat changes have yet to occur in the NWPL, climate change is predicted to cause the spread of annual invasive grasses and drought conditions that could result in a similar future scenario.

3.2.4.3. Other diseases and parasites

Leucocytozoonosis is a disease caused by the hemosporidian blood parasite *Leucocytozoon toddi* that is transmitted to golden eagles by blackflies (*Simulian* spp.). While it rarely causes the death of raptors, leucocytozoonosis can weaken immune response to other diseases (Remple 2004). Leucocytozoonosis was documented in only 1 of 73 golden eagles processed by Wyoming State Veterinary Laboratory during 1997–2016, in which it contributed to a death by hepatitis (Terry Creekmore, personal communication). Blackfiles, themselves, occasionally result in mortality for raptors by causing enough physiological trauma that nestlings leave the nest prematurely (Smith et al. 1997).

Dermestid beetles (*Dermestes* spp.) and other arthropods can be quite abundant in occupied raptor nests (Neubig and Smallwood 1999). However, dermestid abundance can increase to the point where they consume the majority of prey brought in for nestlings and therefore reduce eaglet weights, which can potentially lead to death (Ellis 1979). In in the NWPL, Ellis (1979) estimated thousands of dermestids in one nest he observed, which caused a rougly 25% reduction in eaglet weight over 2.5 weeks. It has been surmised that alternate nests and added greenery which add aromatic compounds to reduce ectoparasites help reduce overall insect abundance (Ontiveros et al. 2008).

Little data exist on parasites within the NWPL, such as blackflies, louse flies, myiasis flies, carnid flies, cimicid bugs (bed bugs), fleas, lice, ticks, or mites. Feather mites and feather louse can be regularly found on nestling or over-winter golden eagles across eastern Montana but no other parasites were regularly observed in studies from 2013–2017 (B. Bedrosian, personal observation).

3.2.5. Direct persecution and poaching

Persecution of golden eagles by shooting, trapping, and poisoning was widespread in the 20th century (Beans 1997, Kochert et al. 2002) and has likely declined since the 1980s (Lutmerding et al. 2012). Persecution can result from a range of factors, including real and perceived conflicts with livestock (Beans 1997), opportunistic target shooting, and non-target capture by recreational and management trappers (Bortolotti 1984). Persecution of golden eagles is difficult to study because incidents often occur in rural areas, perpetrators may be intentionally secretive, and legal actions are typically confidential. Despite declines from historical levels, persecution remains a leading cause of golden eagle mortality in North America: shooting accounts for an estimated 926 (15%) deaths per year and trapping for 231 (4%) (USFWS 2016). Retrospective studies of golden eagles submitted to veterinary laboratories suggest similar levels: gunshot was the cause of death for 196 golden eagles (13.7%) and trapping for 30 (2.7%) submitted to the National Wildlife Health Center from

1982–2013 (Russell and Franson 2014). Gunshot was the cause of death for six golden eagles (6%) admitted to the Colorado State University Veterinary Teaching Hospital during 1995–1998 from an area including Wyoming, Colorado, and Nebraska (Wendell et al. 2002). Thorough necropsy methods that include X-rays for bullet fragments and lab tests for poisons are important to accurately document persecution because the cause of death may not be apparent in the field. For example, at least 10 of 108 (9%) golden eagles found below power poles in a study of electrocution rates in the neighboring WYUB in northwestern Colorado had actually been shot (Lehman et al. 2010).

Current levels of persecution in the NWPL are unknown, but several recent incidents across the NWPL suggest that illegal take for feather trafficking regularly occurs at high rates. At least one incident of a golden eagle tagged with a satellite transmitter was recovered in south-central Montana sans tail with bullet fragments within the carcass; federal law enforcement knew of additional similar instances within the area (B. Bedrosian, personal observation). Several closed cases of individuals prosecuted for selling golden eagle feathers have occurred across the NWPL (e.g., DOJ 2013, 2014). In a two-year operation, the USFWS investigated 43 illegal transactions involving a minimum of 80 eagles in South Dakota and Montana (DOJ 2013). A similar USFWS operation resulted in 31 indictments across South Dakota, Montana, Wyoming, Nebraska, and Iowa for illegal sales that included 100–250 bald and golden eagles (United States of America v. Alvin Brown, Jr., Michael Primeaux, and Juan Mesteth, 2017, CR 17-50035).

Another significant, but largely unknown, source of direct persecution in the NWPL is poisoning of golden eagles due to the real, and perceived, risk of golden eagles predating livestock. Golden eagles have been verified to depredate at least 142 lambs and one ewe on seven ranches in South Dakota in a single season, and can occur at higher rates in low leporid years (Watts and Phillips 1994). O'Gara (1978, 1981 *in* Phillips and Blom 1988) estimated 76% of lamb losses to predators was attributed to golden eagles. In a survey of 391 USDA Animal and Plant Health Inspection Service personnel in 1986, Phillips and Blom (1988) estimated that at least 237 ranches incurred loss to golden eagles in the states occurring, at least in part, in the NWPL during that time. Recent estimates of livestock loss from golden eagles are not available within the NWPL, but the perceived risk still leads to localized areas of intentional eagle (and other predator) poisonings. Even as recently as 2013, a ranch within the NWPL was actively poisoning carcasses to kill predators, with a 55-gallon drum found on-site full of dead golden eagles (Anonymous Source, personal communication) and golden eagle relocations and removals for falconry were conducted in the Wyoming portion of the NWPL in 2019. A rancher in eastern Montana recently pled guilty to unintentionally killing a bald eagle and a hawk with a poisoned calf carcass set to kill coyotes (Associated Press 2017). Similar instances have been prosecuted in South Dakota and North Dakota in recent years. The full extent of poisonings related to depredation remains unknown but continues to persist in the NWPL.

By-catch in leg-hold, snare, and conibear traps also regularly occurs across the NWPL but is largely unreported. One adult female eagle tagged with a satellite transmitter was recovered in a snare trap near Round-up, MT (R. Domenech, Raptor View Research Inst., Personal Communication) and another was found by the USFWS near Glascow, MT (DOJ

2015). Another was captured during a study in 2014 near Columbus, MT with a severed leg that was likely a result of a leg-hold trap (B. Bedrosian, personal observation). In many areas across the NWPL, counties employ trappers (in addition to USDA trappers) to reduce predator populations. Conversations with several of these individuals also indicate they unintentionally capture golden eagles on a regular basis during these operations (B. Bedrosian, personal observations).

3.2.6. Drowning

Golden eagles are at risk of drowning in various water bodies, including oil pits (see 3.2.1.4) and stock tanks. Drowning accounts for an estimated 119 (2%) golden eagle deaths annually (USFWS 2016). Although no instances have been documented in the NWPL, proactive measures like installing netting over oil pits (Trail 2006) and wildlife escape ramps in stock tanks (Taylor and Tuttle 2007) could reduce risk to golden eagles.

3.3. Population limiting factors – Fecundity

Factors that limit fecundity of golden eagles can have negative impacts on populations. Fecundity of golden eagles is influenced by numerous factors, including prey abundance and availability, human disturbance, climate and weather, and predation (Kochert et al. 2002). We focus here on prey resource limitation, human disturbance, and loss of nesting substrate because they are the most well studied and potentially responsive to management actions in the NWPL.

3.3.1. Prey resource limitation

Successful reproduction by golden eagles requires adequate abundance and availability of prey to support the full breeding cycle: from sustaining adults during courtship, egg laying, and incubation, to provisioning chicks, and enabling survival of fledglings. While the link between golden eagle fecundity and prey populations is intuitive, relatively few studies have monitored eagles and their prey over sufficiently long periods of time to document a direct connection (e.g., Smith and Murphy 1973, Phillips et al. 1990, Steenhof et al. 1997, Nyström et al. 2006, McIntyre and Schmidt 2012). Moreover, prey abundance alone may be a poor predictor of fecundity because numerous factors interact to influence the likelihood of golden eagles to breed, the number of eggs laid, and the number of young fledged in a given year (Steenhof et al. 1997). Nonetheless, long-term studies from the NWPL and other regions suggest maintaining prey populations is essential to sustaining fecundity of golden eagle populations (Kochert et al. 2002).

In the NWPL, Phillips et al. (1990) found that the number of golden eagle fledglings was strongly correlated to the abundance of cottontail rabbits from 1975–1985. In the neighboring Wyoming Basin, Preston et al. (2017) also found fewer fledglings in years with decreased abundance of cottontails. In areas with wider diet breadths, such as the Livingston study area (Figure 2.2), occupancy and productivity do not appear to annually fluctuate as much as areas where eagles rely more heavily on specific prey types.

A recent example of the relationship between fecundity and prey in the NWPL comes from the Thunder Basin National Grassland. In a non-exhaustive search for active eagle nests surrounding a large black-tailed prairie dog colony, 68% of 19 occupied territories produced young in 2017 (B. Bedrosian, unpubl. data). That fall/winter, sylvatic plague caused the near extirpation of prairie dogs within the colony and the following spring, only one of 23 occupied territories (4%) produced young. Management options to support prey populations include conservation and restoration of habitat, efforts to combat diseases, and incentives for cessation of hunting and poisoning (see II.7).

3.3.2. Disturbance

Human disturbance to golden eagles qualifies as "take" under Bald and Golden Eagle Protection Act if the activity has the potential "...to agitate or bother a … golden eagle to a degree that causes, or is likely to cause, based on the best scientific information available, (1) injury to an eagle, (2) a decrease in its productivity, by substantially interfering with normal breeding, feeding, or sheltering behavior, or (3) nest abandonment, by substantially interfering with normal breeding, feeding, or sheltering behavior" (USFWS 2007). In addition to direct sources of injury and mortality, many human activities in the NWPL have the potential to negatively affect golden eagle populations by reducing their fecundity. These include presence of humans (e.g., hikers, ranching activity, shooters, researchers), vehicle traffic (e.g., cars, trucks, farm equipment, OHVs), and construction (e.g., drilling oil and gas wells, installing wind turbines, building roads and houses) (Hansen et al. 2017). Golden eagles are most sensitive to disturbance during the early stages of nesting (Fyfe and Olendorff 1976, Richardson and Miller 1997, Spaul and Heath 2016), but may be affected throughout the nesting and fledging period (Fyfe and Olendorff 1976), as well as during the non-breeding season (Holmes et al. 1993). Management to protect golden eagles from human disturbance typically involves restricting human activities and surface occupancy within spatial buffers around nest sites on a seasonal or permanent basis. While application of nest buffers is integrated into stipulations for industrial activities, like oil and gas development, dispersed recreational and agricultural activities, like recreational shooting, OHV use, and cattle operations, are more difficult to study and regulate.

Severity of a disturbance can be characterized by its duration and intensity, ranging from events that are short-term and low-intensity to those that are long-term and high-intensity. Ideally, studies of disturbance to wildlife should relate direct measures of the disturbance (e.g., amplitude and duration of noise, number vehicle passes) to multiple measures of response (e.g., physiological, behavioral, demographic) (Tarlow and Blumstein 2007); however, in practice most studies use surrogates for disturbance and response. Research on disturbance of golden eagles in the NWPL is limited to correlative studies that use landscape features (e.g., number of oil and gas well, length of roads) as surrogates for disturbance from energy development. Given the lack of research in the region, studies from other regions provide valuable information on the response of golden eagles to human disturbances that occur in the NWPL.

3.3.2.1. Energy Development

Conventional and renewable energy development involve a suite of human activities with the potential to disturb nesting golden eagles, including noise and visual disturbance during construction, increased road density and traffic, and ongoing human presence associated with maintenance of facilities (Wallace 2014). Carlisle et al. (2018) did not find any difference in occupancy rates of individual golden eagle nests (not territories) within and outside an 800-m radius of existing coalbed methane wells in the Powder River Basin from 2003–2011. Similarly, Wallace (2014) found no relationship between occupancy rates of golden eagle territories and length of roads or number of oil and gas wells in Wyoming. However, both studies were retrospective and did not address potential changes in occupancy resulting from construction of oil and gas fields.

By contrast, use of nesting territories by golden eagles in Utah declined during a 3-year period of expansion of a natural gas field, but stabilized 2 years later, suggesting eagles either responded more strongly to construction than maintenance or habituated to the disturbance (Smith et al. 2010). Relationships of nesting golden eagles to roads in energy fields varied with scale and road-type: proportional use of nest sites in Utah and Wyoming decreased as density of oil and gas development increased within an 800-m radius, but increased with density of non-oil and gas roads within 2.0 km (Smith et al. 2010). These results suggest roads in close proximity to nests cause disturbance, while at a broader scale roads may alter habitat to the benefit of raptors and their prey (Smith et al. 2010).

Mining activities can reduce fecundity of golden eagles through direct loss of nest sites and disturbance (e.g., heavy vehicle traffic, blasting) (Phillips 1984). Long-term monitoring data suggest some golden eagle pairs have habituated to disturbance at coal mines in Wyoming (McKee 2018). Early mitigation actions from mining activities in the Powder River Basin included relocating nests and young chicks to known or new alternate nest locations (Postovit et al. 1982, Postovit and Postovit 1987, McKee 2018). Since 1980, at least 21 nests from 14 territories have been relocated from seven mine properties with a minimum success rate of 46% (McKee 2018). Long-term and targeted observational studies indicate that some nesting golden eagles have become acclimated to disturbance within 800 m of nest sites, even when human activities are within view of the nest (McKee 2018).

3.3.2.2. Agricultural Activities

Conversion of native grassland habitats to cultivated crops can significantly alter and reduce prey habitat within the NWPL. The northwestern corner and eastern portion of the NWPL have already experienced significant loss of native habitats to agriculture and land conversion to agriculture is projected to increase over the next 100 years (Sleeter et al. 2012, Sohl et al. 2012). Based on modeled changes in land use and land cover from 2006–2100 in the NWPL, Sleeter et al. (2012) projected between 3,218.5 to 106,108.7 km^2 of the NWPL being converted to cultivated croplands (excluding pasturelands and hayfields), depending on free market pressure, environmental protections, population growth and GDP growth scenarios. The most likely "business-as-usual" scenario (B1 scenario; T. Sohl, USGS, Personal Communication), modeled an additional 47,794.75 km^2 converted to cultivated crops by 2100 across the NWPL (Figure 3.9). Increases in biofuel production may significantly increase agriculture in the Great Plains (Sohl et al. 2019) and climate change may additionally reduce the range for many avian species in the NWPL (Sohl 2014). The areas of most significant land cover change in the NWPL occur across the grasslands of the Dakotas, northern Montana, and central Montana. Given the avoidance of agriculture for breeding and non-breeding habitat (2.1.4, 2.2.3), this is likely to reduce golden eagle habitat across the NWPL in the coming decades.

Conversion from native habitats to hay/pasturelands also has the potential to impact golden eagle populations by reducing shrubs and increasing the extent monoculture of an area. Hay production generally results in the total loss of shrubs while pasturelands can maintain the shrub component of the habitat. However, livestock grazing in pasturelands can reduce leporid populations in prairie ecosystems (Flinders and Hansen 1975), thereby causing secondary impacts to eagles by reducing prey. Similarly, there may be additional secondary impacts to eagles from increased human presence and conflict in pasturelands. In the NWPL, habitat converted to hay production and pasturelands is projected to increase by 270% and 550% by 2050 and 2100, respectively, under the business-as-usual scenario (Sleeter et al. 2012). A total of 30,755 km^2 and 62,610 km^2 is projected to be converted to hay/pasturelands in the NWPL by 2050 and 2100, respectively.

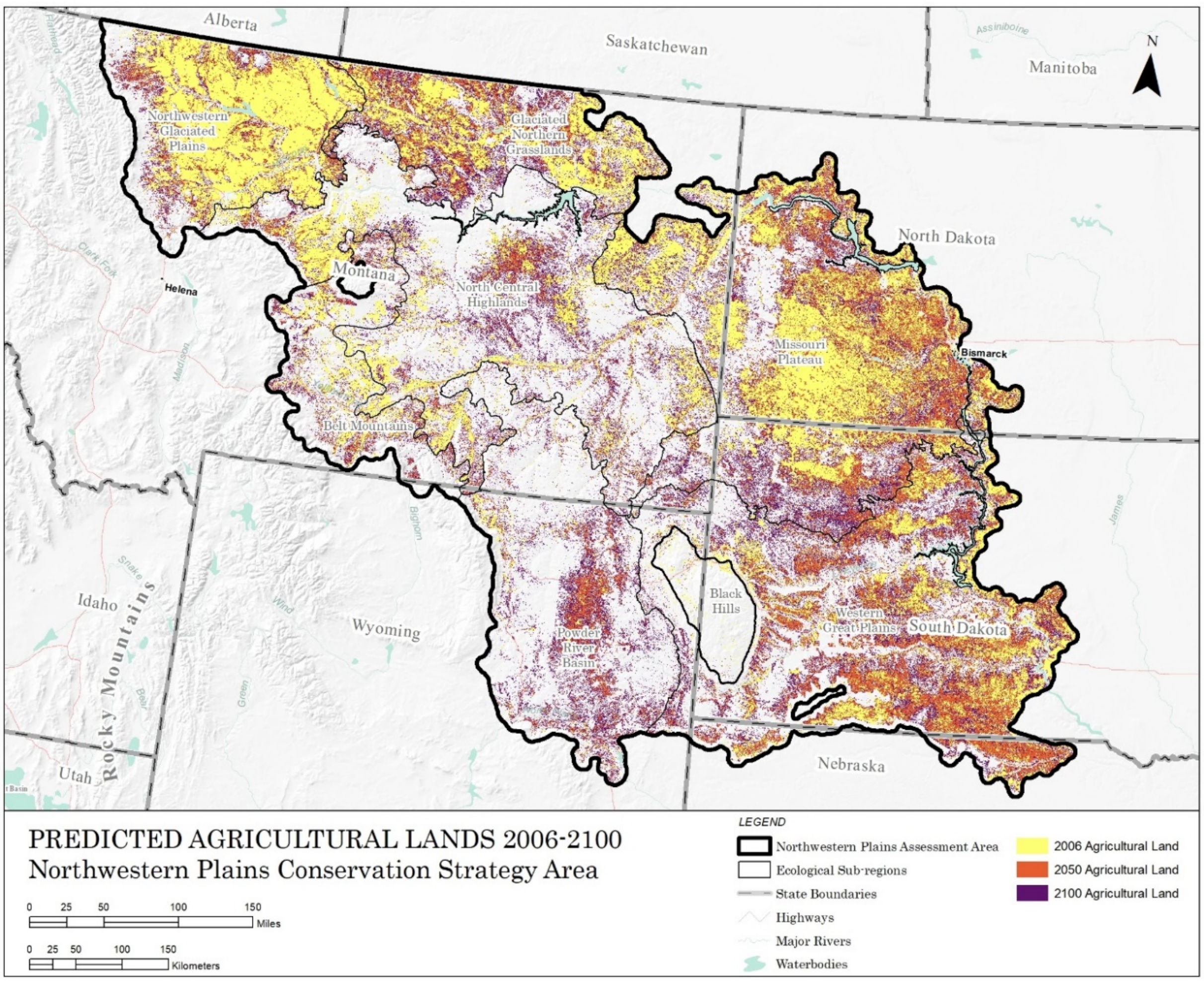


Figure 3.9. Agricultural lands (cultivated croplands and hay/pasture) in the Northwestern Plains conservation assessment area in 2006 and additional conversion of habitats to agriculture projected in 2050 and 2100. Model projections based on the "business-as-usual" economic, growth, and environmental scenario (see Skeeter et al 2012 and Sohl et al. 2012 for details).

No studies are available on direct impacts of agricultural or ranching activities on golden eagles in the NWPL. Agricultural and ranching activities likely have different effects on golden eagles. The main issues to golden eagles from agriculture is habitat conversion while human presence and secondary habitat effects from grazing and persecution are more likely a result of ranching. Livestock ranching is one of the main economic activities in the NWPL and likely to affect a limited number of eagles. In areas where eagle nesting and calving or lambing overlap, increased human presence near nest sites may affect fecundity if eagles are repeatedly disturbed during nesting season (see 3.2.5). Off-highway vehicle use to move livestock and check stock tanks areas can result in nest disturbance, particularly if the rider transitions to walking, but likely does not occur at rates associated with reduced nest attendance (Spaul and Heath 2016). Livestock depredation by golden eagles, particularly for lambs, can be a significant loss to local ranchers in the NWPL (Watte and Phillips 1994). This risk to economic loss for ranches can also lead to direct persecution of eagles (see 3.2.5). Conversely, if persecution is not prevalent or can be avoided, the increased food resource from livestock afterbirth or provided carcasses during the nesting season may help increase fitness of nesting eagles, Increased cattle herbivory may also led to lower rates of cottonwood regeneration and girdling of mature nest trees (see 3.3.3).

3.3.2.3. Recreational Activities

Most of the NWPL is rural with low human population density, so disturbance to golden eagles from recreational activities is generally lower than other portions of the West (e.g., Spaul and Heath 2016). While no studies of recreational disturbance occurred within the NWPL, recreational shooting is likely the most common disturbance, particularly at prairie dog colonies on public lands. This type of disturbance is generally both short and seasonal in nature. Even at nests where shooters have fired hundreds of rounds for up to 2 hours within 300 m of an active nest, the eagles successfully fledged young (B. Bedrosian, Personal Observations). However, this type of recreation may also lead to increased risk of direct mortality (See 3.2.3.1). Other recreational activities included localized increase of human presence due to activities like rock climbing and hiking.

3.3.2.4. Research and monitoring activities

No studies are available on impacts of scientific research activities on golden eagles in the NWPL. Although research activities are likely to affect only a small number of golden eagles in the NWPL each year, fecundity can be impacted by researchers entering nests for banding and observing nests from close distances (Steenhof and Kochert 1982), while individual behavior and fitness may be affected by stress from trapping and carrying telemetry instruments (Stahlecker et al. 2015). Harmata (2015) and Millsap and Zimmerman (2015) expressed concerns for survival of golden eagles wearing telemetry devices attached via back-pack style. However, Crandall et al. (2019) recently did not find any evidence to suggest impacts to the survival of breeding golden eagles wearing backpack transmitters in the NWPL.

The proprietary nature of energy harvest exploration and increased financial risk to siting development in areas of high eagle use has led to an increase in efforts by both energy companies and state agencies to aerially locate and monitor golden eagle nests across the

NWPL (L. Hanuska-Brown, MT FWP, personal communication). Strategies to minimize research and monitoring impacts to golden eagles include coordination among agencies and consultants to reduce redundant nest visits, use of non-invasive techniques when possible, and compliance of all entities involved in raptor monitoring with Institutional Animal Care and Use standards for animal welfare.

3.3.2.5. Disturbance distances

Agencies and entities in the NWPL recommend buffers of various sizes and durations, which can be difficult to interpret and plan for by development companies. Only one empirical study is available on flushing distances of golden eagles (Spaul 2015), and other estimates of the distances at which golden eagles are impacted by various types of disturbance come from expert elicitations (Suter and Joness 1981, Whitfield et al. 2008, USFWS 2017a). Accordingly, data are not available on flushing distances specific to the NWPL. Results from expert elicitations suggest buffer sizes of 0.5 mi (800 m) currently recommended by most agencies in the NWPL may be sufficient to protect many golden eagles from disturbance (USFWS 2017a), while results from Spaul (2015) suggest 1000-m (0.62 mi) buffers would be necessary to achieve a 95% reduction in flushing. Although flight initiation distance is a common metric for response to disturbance, effects on behavior and reproduction may occur at greater distances. Flight initiation distance decreases when vehicles stop near nest sites, and when persons transition from vehicles to walking (Spaul and Heath 2017). Experts estimated golden eagles could fail to breed in response to various forms of human disturbance within 914–1,408 m (USFWS 2017a). Additionally, buffering only recently occupied nest sites may fail to protect the full territory of a breeding pair of golden eagles. For example, golden eagles in Idaho reused 34% of alternative nest sites at greater than 10-year intervals (Kochert and Steenhof 2012), and eagles perching and foraging away from nest sites can also be affected by disturbance, and sometimes at greater rates (Spaul 2015, Spaul and Heath 2017). Experts consulted by USFWS agreed that buffers including all known nests or sized to the core areas of breeding territories would be the most effective way to protect golden eagles from human disturbance (USFWS 2017a).

3.3.3. Cottonwood loss

Plains cottonwoods are an important nesting substrate for Golden Eagles within the NWPL. Nests occur typically in older-aged cottonwoods, often within riparian corridors and irrigation channels with shallow groundwater. Loss of cottonwood regeneration can significantly affect the ability of local eagle pairs to nest and for other ecosystem services. Often in the NWPL, few cottonwood trees occur in otherwise suitable nesting habitat and provide the only potential nesting substrate. As those remnant cottonwoods are lost and not replaced, this functionally decreases golden eagle nesting habitat within the NWPL.

Cottonwoods also regularly occur near homesteads, stock tanks, and other areas where planting occurred for shade and/or windbreaks. Cottonwood seed establishment is generally restricted to bare, moist sites protected from intense physical disturbance (Bradley and Smith 1986, Friedman et al. 1995) and natural cottonwood establishment is associated with large flooding events occurring as infrequently as every 16 years in natural systems (Scott et al. 1997). Flooding maintains cottonwood regeneration by providing moisture during germination periods, depositing sediments and nutrients, stimulating decomposition, dispersing seeds, and forming new sediment bars for colonization (Dixon et al. 2012). Cottonwood seedlings are poor competitors (Johnson 1994) and therefore require recently disturbed soils for regeneration. However, seedlings are also sensitive to flooding, herbivory, and ice drives (i.e., scouring by large pieces of ice floating downstream) or other disturbances once sprouted (Auble and Scott 1998). Conditions must exist in which a very high water flow in one year creates barren soils and moisture for germination but is followed by several years of moderate flow levels to allow for establishment with limited mortality from herbivory, ice drives, and flooding. Water flow regulation significantly influences cottonwood regeneration in alluvial river channels and floodplains (Johnson et al 1976, Johnson et al. 2012). Large dams erected in the 1930s–1950s in the NWPL on large river systems (e.g., Missouri River) have channelized many sections of river (Dixon et al. 2012), drastically reduced seasonal flows (Johnson et al. 2012), and significantly impeded cottonwood regeneration (Dixon et al. 2012). Further, timing of high flows must correspond to seed dispersal and regulated flows may affect this relationship (Benjankar et al. 2014).

Within the NWPL, riparian cottonwood regeneration below dams is significantly lower than above the dams (Bradley and Smith 1986). Scott et al. (1997) and Dixon et al. (2012) estimated very little cottonwood loss on the section of the Missouri River largely uninfluenced by dams downstream from Fort Benton to Fort Peck Lake over the past ca. 110 years but this area is host to a minimal amount of cottonwoods (Dixon et al. 2012). Conversely, downstream from Fort Peck, 55.2% of riparian forest has been lost 1982–2006 (Dixon et al. 2012). That study also measured a 25.9% reduction of riparian forest downstream of the Garrison dam during the same period. Dixon et al. estimated 44% forest loss between 1892–1950s and an additional 9% since the 1950s along the below-dam sections of Missouri River from Fort Benton, MT to Ponca, NE. However, these estimates do not include all habitat loss caused by the reservoir flooding.

Lack of regeneration further compounds cottonwood habitat loss. Scott et al. (1997), Dixon et al. (2012), and Johnson et al. (2012) all found significant reduction of cottonwood recruitment along the Missouri River post-1950s. In the 1970s, cottonwood diameter at breast height measurements in the Garrison Reach resembled a negative exponential form, indicative of a self-maintaining, balanced population (Meyer 1952, Johnson et al. 2012). Recent measurements within the same areas now indicate a normal distribution, highlighting that these forests are not regenerating in recent years.

Many small strands and single cottonwood trees occur across the NWPL because of current and remnant agriculture. Many homesteads planted and irrigated cottonwood trees as shade and windbreaks around buildings. As those buildings are abandoned or destroyed and human activity is minimized, the remaining trees can become golden eagle nesting habitat. Additionally, irrigation ditches from agriculture in the early half of the 1900s provided moisture and soil disturbance that led to cottonwood growth in some areas.

Coupled with water impoundment and decreased flooding, grazing has also contributed to the decline of cottonwood recruitment. First, the loss of apex predators in the Great Plains led to trophic cascades resulting in the increase in wild ungulates, domestic livestock, and the resulting increase in foraging on cottonwood sprouts (Beschta 2005, Ripple and Beschta

2007). Livestock grazing can significantly reduce seedling densities by foraging (Crouch 1979, Auble and Scott 1998), cause soil compaction that limits germination, and girdle larger saplings and pole trees. In areas such as Thunder Basin National Grasslands, cottonwood galleries only exist in washes too steep and deep for cattle to regularly graze (T. Beyer, pers comm).

Exotic species can also impede cottonwood regeneration in the NWPL. Russian-olive (*Elaeagnus angustifolia*) occur across much of the NWPL, generally outcompete cottonwoods, are labor-intensive to remove (Shaforth et al. 1995). The germination conditions for cottonwoods are much narrower in time, water conditions, and shade, whereas Russian olive successful germination conditions are broader in all respects. Russian-olive also spreads to sufficiently moist upland areas, such as near irrigated fields and prairie potholes (Olson and Knopf 1986). Tamarisk (*Tamarix* spp.) is another non-native shrub or small tree that colonizes riverbanks and compete with cottonwoods in the southwestern US. In the NWPL, however, Lesica and Miles (2001) suggest that tamarisk, currently, has little influence on cottonwoods because cottonwoods grow faster than tamarisk, eventually shading and causing the decline of the non-native.

While dam removal and restoration of natural streamflow regimes would certainly enhance cottonwood regeneration, another potential source of cottonwood regeneration in the NWPL is wildfire. Following wildfire, over-mature cottonwood stands can be rejuvenated through clonal sprouting of remnant stumps (Gom and Rood 2000, Rood et al. 2007). Clonal regeneration can also be a viable source of regeneration in areas of crown-fire events that result in the loss of mature trees (Wonkka et al. 2017) and cottonwood regeneration generally outpaces invasive woody plant regeneration (Rood et al. 2007, Wonkka et al. 2017). Conservation actions targeted at increasing cottonwood recruitment or plantings may help maintain and enhance golden eagle populations across the NWPL.

3.3.4. Fire

Fire has largely been absent from the Great Plains of North America for the past century (Donovan et al. 2017), largely due to human suppression efforts, conversion of grasslands to agriculture, fragmentation, and anti-fire education (Higgins et al. 1987, Twidell et al. 2013). However, there has been at least one large (>400 ha) burn in the NWPL every year for the past three decades. In the Northwestern Great Plains ecoregion, the number of fires has increased by 100% across the past three decades, from 99 large fires in 1985–1995 to 218 large fires in 2005–2014 (Donovan et al. 2017). The fire season is bimodal, with some fires occurring in the spring (typically April) but most occurring from June-Sept. The largest number of fires annually occurs in July and August and annual likelihood of occurrence is 100% (Donovan et al. 2017). Within the Northwestern Glaciated ecoregion, fires historically occurred in late-winter, early-spring in the 1985–1995 decade, but then shifted to the late-summer/fall periods in recent decades. The total number of area burned has increased 350% from 229,000 ha between 1985-1994 to 1 million ha in 2005–2014 (Donovan et al. 2017).

Fires in the NWPL will generally rebound quickly, with drought being a large factor in how quickly grass and forb production occurs (Engle and Bultsma 1984). Northern grasslands typically recover the following year, but spring precipitation is the key factor in production

(Vermeire et al. 2011). While fire typically does not affect production the following years, it does change the species composition by reducing nonnative annual grasses with annual C_3 perennial grasses and reducing standing dead plant materials.

Unlike other ecoregions where burning within eagle territories affected productivity (e.g., Kochert et al. 1999), late-summer burns within territories within the NWPL likely has few long-term effects due to the resiliency of the prairie ecosystems to wildfire (Brown 2008). Where fires may affect nesting and demographics are along the grassland/upland ecotones where fires may burn nesting trees and tree stands. Along these ecotones in the NWPL, fires historically occurred regularly every 10–12 years from the 1500s to the late 1800s, when they essentially ceased (Brown and Sieg 1999). Within increasing downed and dead vegetation buildup within the forested buttes and hillsides across the NWPL over the past century, larger stand-replacing fires are now more typically than the surface-scar fires of the historical record. These types of fires have been increasing along the Montana/Wyoming border badlands/breaks habitats in recent years north and east of the Wolf Mountains and along the Missouri River Breaks (Figure 3.10). As the severity and size of these fires increase with time, the risk to golden eagles mainly results from nesting substrate loss, since many eagles within those area use conifers for nesting (see 2.1.1.1).

Wintering eagles have been found to select for forested habitats to a greater extent than breeding populations (Bedrosian et al. 2014, Domenech et al. 2015). WGET modeling of winter habitat across the western United States also indicated that shrub communities were selected for by over-wintering eagles (see 2.4.2). Large-scale, intense fires within forested and shrubland communities within the NWPL will likely decrease winter use by golden eagles in those areas.

Because of the low population densities across much of the NWPL volunteer fire department and local municipalities and usually the first fire incident responders. These responders may not have the capacity or equipment to contain fires, and may need additional education on how to reduce ground damage, when possible. As fire frequency increases across the NWPL, the risk of breeding and wintering habitat loss becomes an increasing issue for golden eagles in the NWPL.

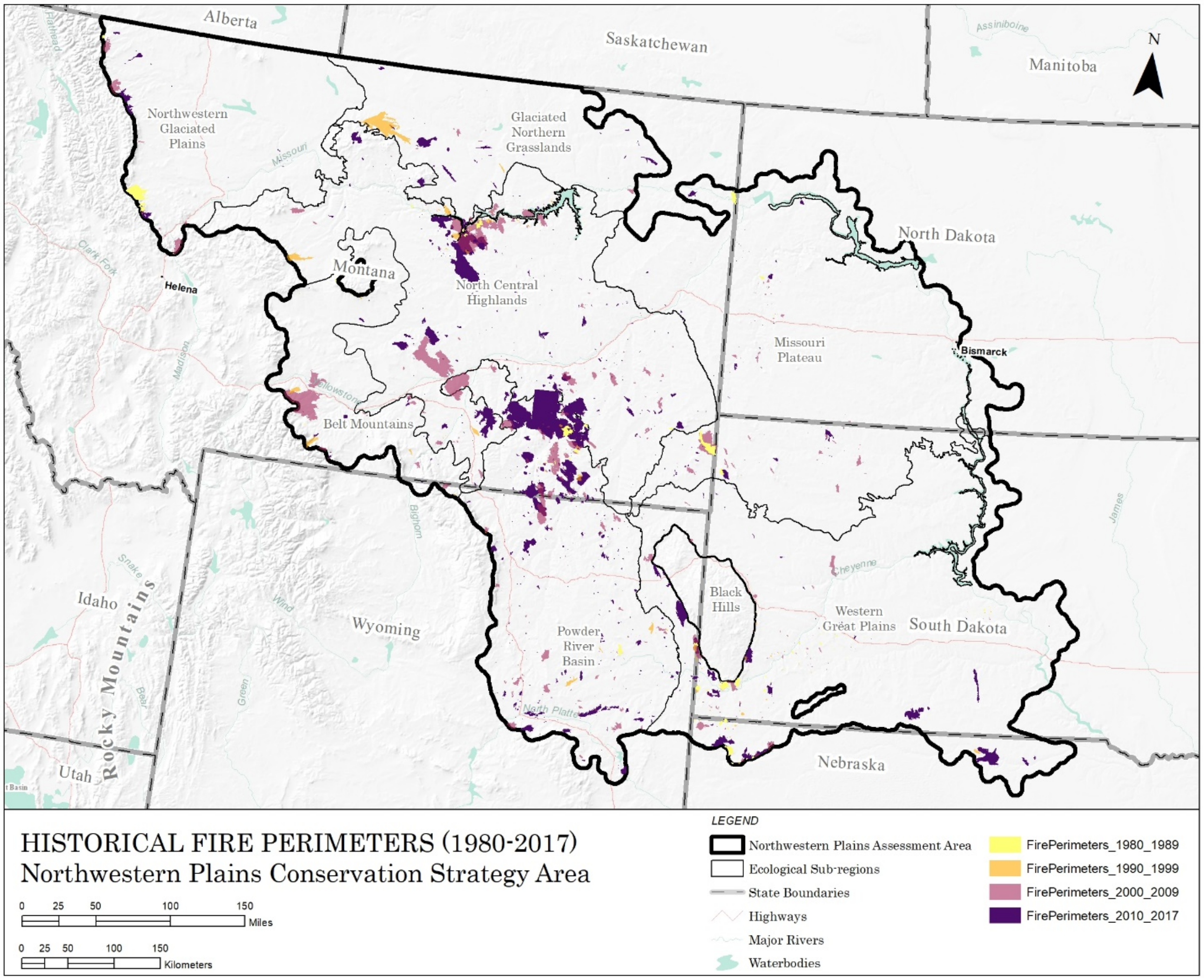


Figure 3.10. Historical fire perimeters (1980-2017) within the Northwestern Plains golden eagle assessment area by decade. Data accessed from GeoMAC.gov.

3.3.5. Climate Change

Changes in air temperatures and precipitation have the potential to cause shifts in forage production across the Great Plains, thereby affecting cover and food resources for the prey of golden eagles. Compared to historic levels within the NWPL, there is evidence to suggest that aridification is increasing across the region. Hoell et al. (2019) found that moderate droughts are 1.2–1.5 times more likely and intense-to-severe droughts are 1.7–5 times more likely in the current climate (1987–2016) as compared to the historical record (1920–1949). This change is not caused by differences in precipitation, but rather significant increases in evapotranspiration in May–June coupled with a significant temperature increase (0.5 – 0.6 ^{o}C), causing lower soil moisture (Hoell et al. 2019). Climate models predict a clear warming trend across the NWPL, with a projected increase of 15–35 days above 90 ^{o}F and a decrease of at least 30 cold days (minimum temperatures < 20 ^{o}F) by the mid-21st century (USGCRP 2018). This is projected to extend the growing season, allowing for expanded agricultural activities. Similar to what Hoell et al. (2019) found from the historic to current climate, predictions suggest that future precipitation will not significantly change from current levels or may be a slight increase that is countered by increase evapotranspiration from increasing temperatures (USGRP 2018).

In the NWPL, climate change may alter golden eagle fecundity in a variety of positive or negative ways. First, increasing temperatures during the breeding season may lead to heat-stress for chicks. While this has not been observed in the NWPL, reduced nesting success due to heat stress has been documented in other areas (Kochert et al. 2019). Longer growing seasons and reduced cold days may enhance eagle reproduction (Steenhof et al. 1997) and reduce native habitat by agriculture conversion (see 4.3.4). Lower soil moisture will likely cause an increase in the abundance and competitive ability of weeds and invasive species (USGRP 2018), which may lead to greater fire risk/severity. Fewer cold days, increased hot days, decreased snowfall, and longer summer seasons all increase the risk of fire intensity and frequency across the NWPL, which may not only affect prey habitat, but also eagle nesting habitat (see 3.3.4). Increasing summer temperatures may also concentrate water sources, thereby increasing risk of West Nile Virus (3.2.4.1).

4. Conservation and Risk Assessments

The Conservation Strategy provides tools and management approaches for direct application in eagle conservation based on information and modeling results compiled in the assessment. These include a regional habitat conservation prioritization, spatial risk assessments for major hazards, and recommended conservation measures.

4.1. Conservation Status

Golden eagles in the U.S. receive federal protection under the Bald and Golden Eagle Protection Act (16 U.S.C. 668-668c) and the Migratory Bird Treaty Act (MBTA; 16 U.S.C. 703-712). The Bald and Golden Eagle Protection Act prohibits unauthorized "take" of golden eagles, which includes to "pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, destroy, molest or disturb" (16 U.S.C. 668c; 50 CFR 22.3). In addition to Federal protection, golden eagles receive various conservation designations from Federal and State management agencies in the NWPL. Golden eagles are a Tier 2 Species of Greatest Conservation Need in North Dakota, Wyoming, and Nebraska (Dyke et al. 2015, Wyoming Game and Fish Department 2017, Schnieder et al. 2018). Collaborative groups have been formed to advance conservation of golden eagles in the NWPL, including state golden eagle working groups in Montana and Wyoming.

4.2. Conservation prioritization

The conservation prioritization identifies where concentrations of high-quality golden eagle habitat occur in the NWPL. To describe the distribution of habitat value within the NWPL, we calculated the proportion of total habitat value and ratio of habitat value to area within sub-regions (i.e., ecological sections) using the WGET RND and RWD models. To assign habitat value, we interpreted the output of these models as an *index of relative habitat quality.* We then identified where opportunities exist for management and conservation by summarizing the amount and proportion of habitat within administrative areas (i.e., surface management entities, BLM Field Offices), and the current protected status of golden eagle habitat based on Gap Analysis Project protection categories (USGS-GAP 2018) and habitat protections for greater sage-grouse.

The proportion of total habitat value is a measure of the amount of habitat value in a given area as a percentage of the total amount of habitat value across the assessment area. We calculated it as the sum of the cell values from the habitat model within the focal area divided by the sum of all cells in the study area. The ratio of habitat value to area is a measure of the density or concentration of risk in a given area relative to what would be expected based on the size of that area. We calculated this as the percentage of habitat value within the focal area divided by the percentage of the study area composed by the focal area minus one, with negative numbers indicating less habitat value than expected based on area and positive numbers indicating higher density of habitat value. Taken together, these metrics may be useful to prioritize areas within the NWPL for conservation or development based on the amount and concentration of golden eagle habitat value they contain.

This assessment identifies concentrations of high-quality habitat; however, we recognize that golden eagles inhabit most areas of the NWPL. Some management actions may be most effective when implemented in the concentrations of high-quality habitat identified here (e.g., establishment of protected areas), while others may provide disproportionate benefit in areas of marginal habitat (e.g., prey habitat restoration). Additionally, it is important to recognize that conservation measures can benefit eagle populations at a range of scales, from a single nest site, to an administrative unit, to the entire NWPL, and beyond. The conservation prioritization presented here is best applied at broader scales of landscapes to ecoregions (Bedrosian et al. 2019).

4.2.1. Breeding priority areas

The NWPL hosts important breeding areas for golden eagles, both at the ecoregion level and at the national level. High-quality breeding areas also represent important year-round habitat because breeding eagles in the NWPL are mainly non-migratory and young can reside within their natal territories for up to a year (B. Bedrosian, unpublished data). Within the NWPL, there are sub-sections that host a larger concentration of high-quality breeding habitat and some of the highest nesting densities in the contiguous United States (e.g., the Powder River Basin, Figure 4.1). Identification and conservation of these areas can help land managers safeguard golden eagle populations at both the ecoregional and national levels.

Golden eagles are highly selective of the best quality nesting habitat, which only occurs within a very small portion of the NWPL. Based on the WGET RND model, only 0.1% of the land area of the NWPL modeling area consisted of the highest quality habitat (RND >0.9) and only 3.0% was of moderate-to-high quality (RND >0.6). Most of the modeling area (79.2%) was composed of lower quality habitat (RND <0.3). The largest proportion of land mass within the NWPL modeling area consisted of the lowest quality habitat (34.6%; RND <0.1). Most other ecoregions (except the Wyoming and Uinta Basins) for which WGET created habitat models were predominately composed of lands with very low nesting densities (e.g., RND < 0.1 in >65% of the Northern Basin and Range Conservation Strategy Area and >60% of the Central Great Basin Conservation Strategy Area; Dunk et al. 2019). Relative to most other ecoregions, the NWPL hosts more golden eagles during the breeding season (Neilson et al. 2016) but priority breeding habitat is generally restricted within the ecoregion.

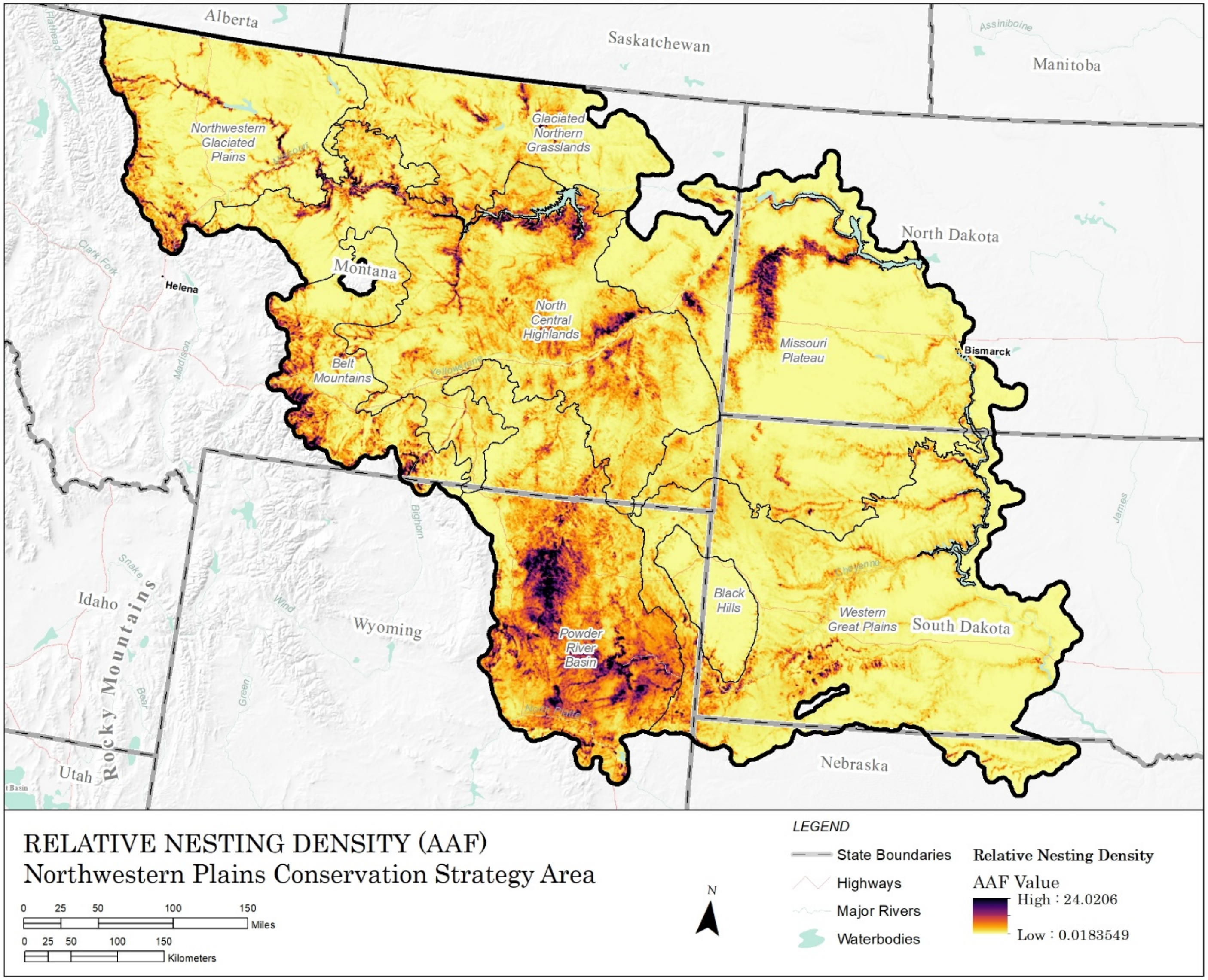


Figure 4.1. Relative Nest Density model (Area Adjusted Frequency) for the Northwestern Plains. USFS Ecomap sections shown as the sub-regions used for model validation.

The North Central Highlands and Powder River Basin each contained 23% of the habitat value (Figure 4.2). The Western Plains and Missouri Plateau also contained large amounts of breeding habitat values, with 17% and 16%, respectively. The three largest ecological sections each comprised 20–22% of the NWPL while the Powder River Basin comprised 13% of the total area and accounted for the higher proportion of habitat values than expected (Figure 4.2). The Northwest Glaciated Plains, Glaciated Northern Grasslands and Belt Mountains all contained 6–7% of the habitat values, while the Black Hills only contained 1% (Figure 4.2). The Belt Mountains contained much more high quality habitat than expected, given the small size of this section. The ecotone of the Middle Rockies ecoregion and the NWPL along the western edge of the Belt Mountains contained the highest quality habitat in that area. Similar ecotones between forested areas and the plains contained high habitat values within the Black Hills section. The breaks habitats along the Powder River and Crazy Woman Creek corridors south of Montana and along the Cheyenne River and Antelope Creek drainages contained much of the high value breeding habitats in the Powder River Basin. In the North Central Highlands, the breaks habitats north of the Yellowstone River between Miles City and Terry, Montana and south of the Missouri River in and near the Charles M. Russell National Wildlife Refuge contained the highest quality habitats. The plains and grasslands sections all contained less habitat than expected, and all have higher proportions of cultivated lands and less topographical relief.

Distribution of golden eagle breeding habitat among surface management entities (Table 1.2) was generally proportional to their areas, with the greatest amount of habitat values on private lands (61.9%), followed by BLM (11.5%), tribal lands (11.2%), state/local government lands (6.2%) and USFS (5.6%). The National Park Service (NPS) administers lands containing 1.5% habitat values and other managing entities contained <1% of habitat values (Figure 4.3). Private and tribal lands contained slightly less habitat value than expected, while BLM, USFWS, and NPS all contained much higher values of breeding habitat than expected (Figure 4.3). Other protected areas contained slightly higher habitat values than expected.

The habitat values within BLM field office management regions generally corresponded to the size of the field office. Using the sum of habitat values just within BLM jurisdiction in the NWPL, the Miles City Field Office contained the largest percentage of habitat values (22.1%), while containing 19% of the BLM land area (Figure 4.4). The Wyoming BLM Field Offices all contained higher habitat values than expected and both the Casper and Buffalo Field Offices contained roughly double the proportion of habitat values to their area. The South Dakota and North Dakota Field Offices both held slightly less habitat value than expected with 17.4% of habitat values and 23.3% of land area and 8.5% habitat values and 12.6% of land area, respectively. The Havre Field Office also contained slightly less habitat value than expected, while the proportion of habitat values to boundary size was relatively constant for the remaining field offices in the NWPL. Habitat values within only tribal lands were all directly proportional to the area each tribe manages (within 2 percentage points), with the Cheyenne River Sioux Tribe, Oglala Sioux Tribe, Standing Rock Sioux Tribe, and Crow Tribe having 17%, 16%, 14%, and 14% of habitat values on tribal lands. All other 10 tribes contained ≤9% of habitat values (range = 9.0–0.3%).

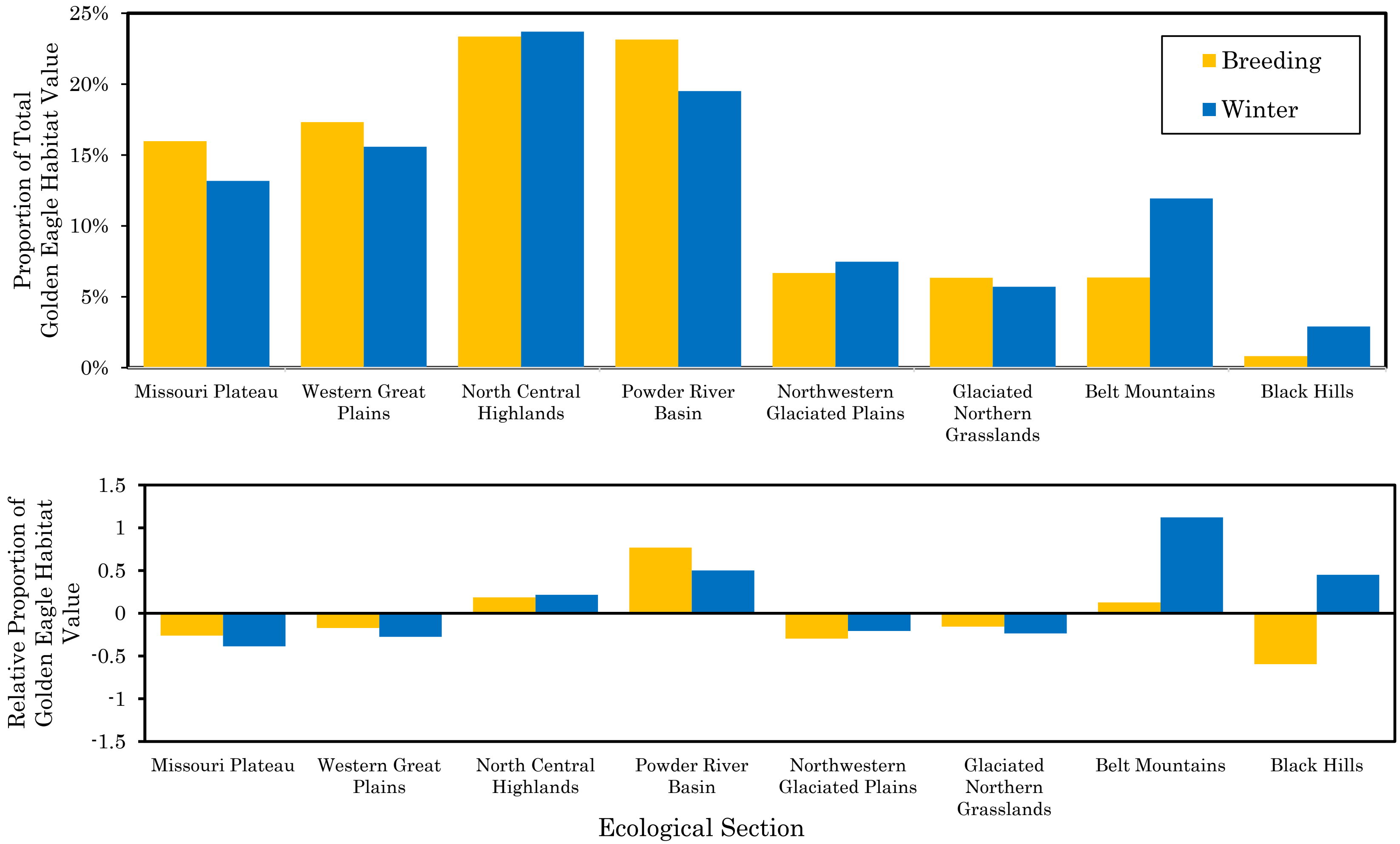


Figure 4.2. Golden eagle breeding and winter habitat value within eight ecological sections of the Northwestern Plains conservation assessment area. Proportion of total habitat value (top) shows the relative amount of habitat in each area, while the proportion of habitat value to area (bottom) shows the relative concentration of habitat. Ecological subsections are shown in descending size order from left to right.

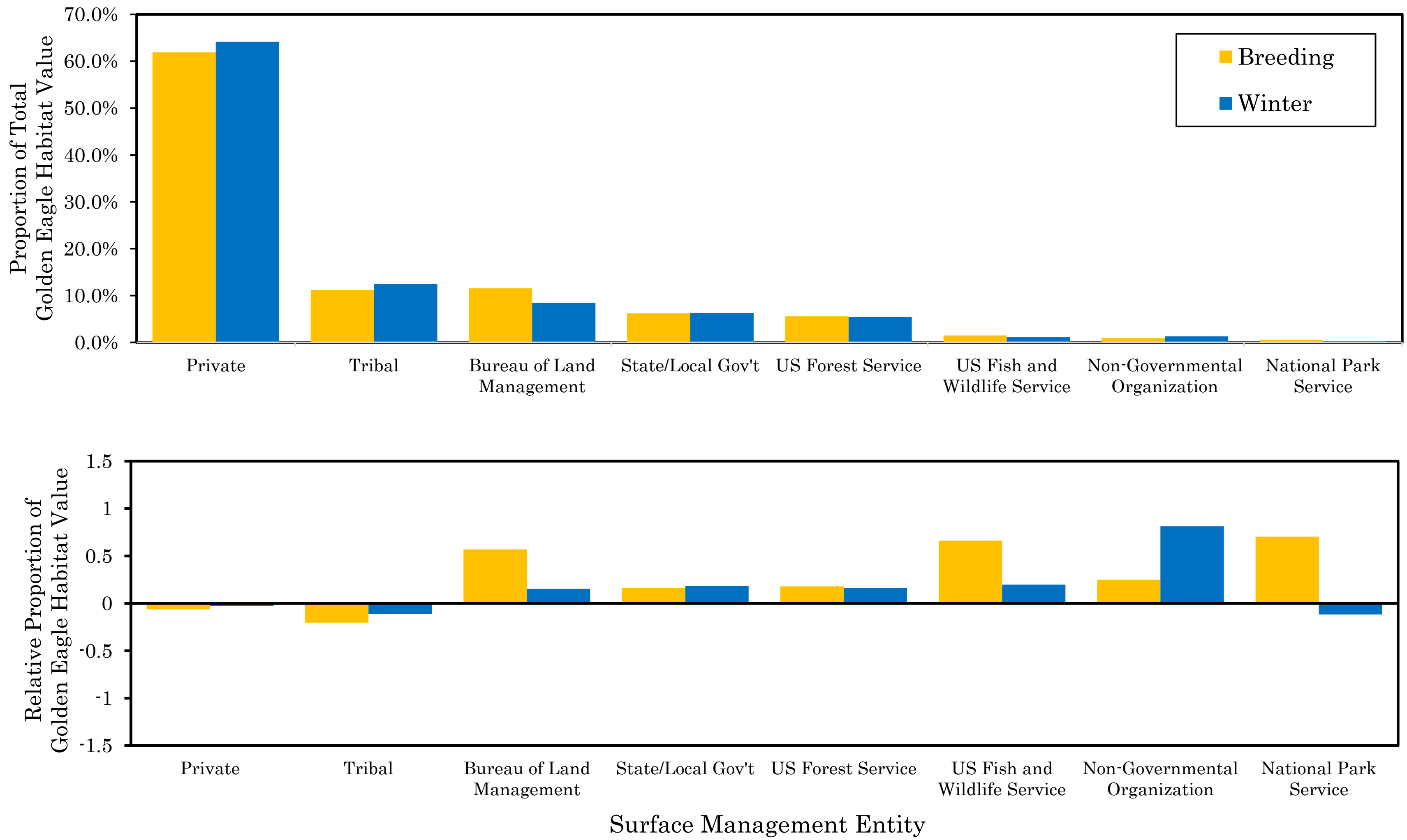


Figure 4.3. Golden eagle breeding and winter habitat value by surface management entity in the Northwestern Plains conservation assessment area. Proportion of total habitat value (top) shows the relative amount of habitat in each area, while the proportion of habitat value to area (bottom) shows the relative concentration of habitat. Management entities with > 0.5% Relative Nest Density or Relative Winter Density values are shown and occur in descending size order from left to right.

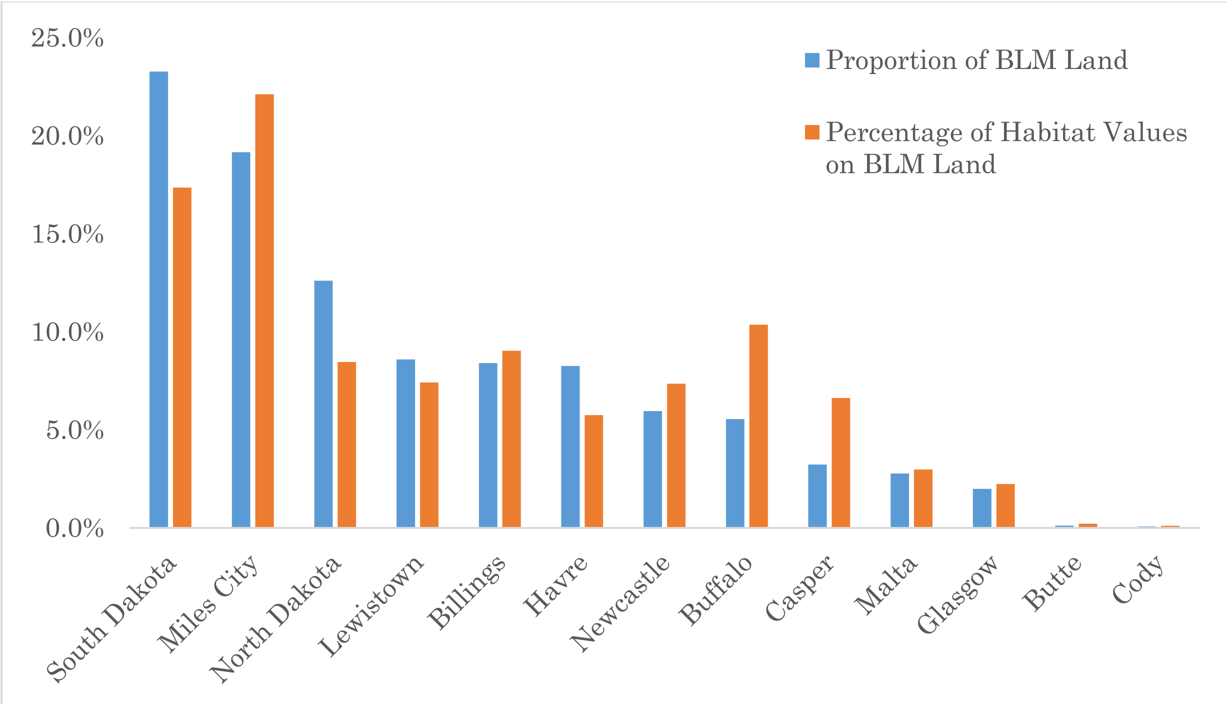


Figure 4.4. Percentage of BLM land managed by BLM Field Offices in the Northwestern Plains conservation assessment area and the percentage of golden eagle Relative Nest Density habitat values within each field office.

4.2.2. Winter priority areas

Winter habitat selection by golden eagles in the NWPL was broader than breeding habitat selection. However, the RWD model incorporated eagle data from all age classes, breeding and migratory status. The RND model was built only using nests and therefore represents only adult, breeding eagles and their young. Undoubtedly, if summer habitat selection models were built using data from all age classes of golden eagles, it is likely that a broader portion of the NWPL would be selected by golden eagles (see Section 2.2.3.1).

Similar to breeding habitat, the highest quality winter habitat within the NWPL (winter use probability >0.9 from the RWD model) occupied a very small portion of the NWPL (0.3%). Moderate-to-high quality winter habitat (>0.6) occurred in only 7.6% of the ecoregion and 63.9% of the NWPL was comprised of low quality habitat (<0.3). Almost all of the higher use winter range occurred along the western edge of the NWPL and most of the Dakotas and Nebraska hosted almost no moderate-to-high quality habitat. Much of the area north of the Missouri River is also modeled as low-quality winter habitat. Most higher-quality winter habitat was associated with topographic relief and avoidance of agriculture.

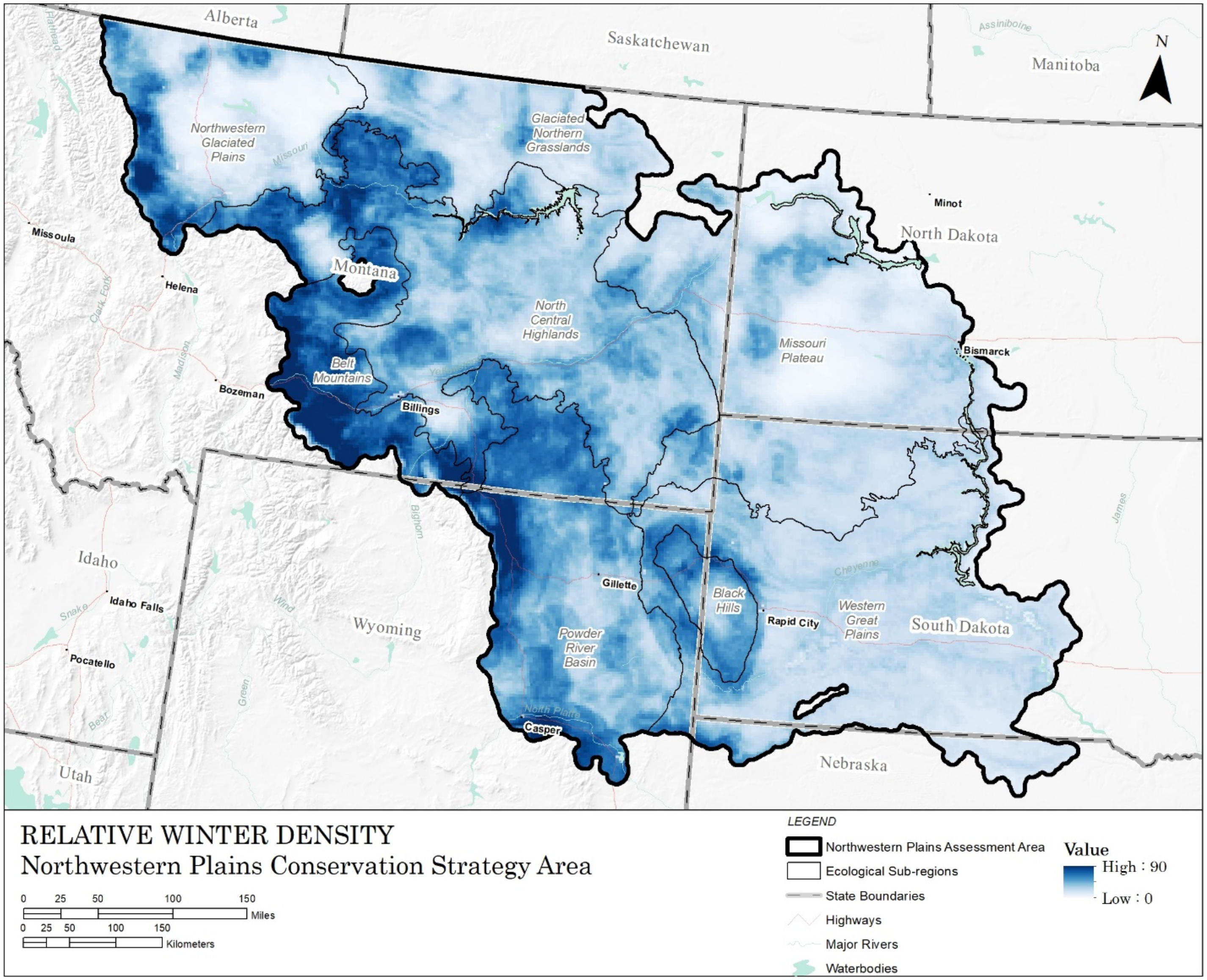


Figure 4.5. Western Golden Eagle Team predictive model of winter habitat built for the western conterminous United States and clipped to the Northwestern Plains golden eagle conservation assessment area.

While the RWD model was created from a national dataset, there was good parity between the RWD model and regional efforts to model winter habitat (see 2.4). The regional RSF model highlighted more relative use of the Dakotas than WGET's RWD model, and typically more focused along riparian areas. Using the RWD model, the Powder River Basin contained much more high quality winter habitat than expected compared to all other ecological sections within the NWPL (Figure 4.5). The North Central Highlands and Belt Mountains also contained slightly more winter habitat than expected, while areas north and east of the Missouri River contained less than expected (Figure 4.2). Higher concentrations of winter habitat generally occurred along the western edge of the NWPL near the ecotone of the Middle Rockies and the plains.

The expected winter habitat values mirrored the expected results in the summer with the notable exception of non-government organization protected lands, which held much higher winter habitat values than expected. The American Prairie Reserve north of the Charles M. Russell National Wildlife Refuge and easements along the Middle Rockies/NWPL interface held by the Montana Land Reliance and The Nature Conservancy (in Wyoming and Montana) account for most of the high winter habitat values held by non-government organizations. The Charles M. Russell National Wildlife Refuge accounts for the majority of higher than expected winter habitat values.

4.2.3. Migration Priority Areas

A portion of both fall and spring high-use migration corridors occur in the northwestern corner of the NWPL (Bedrosian et al. 2018a, see 2.3). These corridors host eagles migrating largely to ecoregions south of the NWPL. The spring migration corridor extends further east into the NWPL, as eagles migrate north use thermals and foothills for updrafts to a greater extent than the fall. Many eagles also migrate to and from wintering areas across the NWPL in a more dispersed pattern (Bedrosian et al. 2018a) but priority migration areas of eagles overwintering in the NWPL have not yet been identified. Within the NWPL modeling area, most of the spring and fall migration priority areas outlined by Bedrosian et al. (2018a) occur on private lands (Figure 4.6). A large section of the spring corridor occurring in the NWPL is on the Blackfeet Reservation.

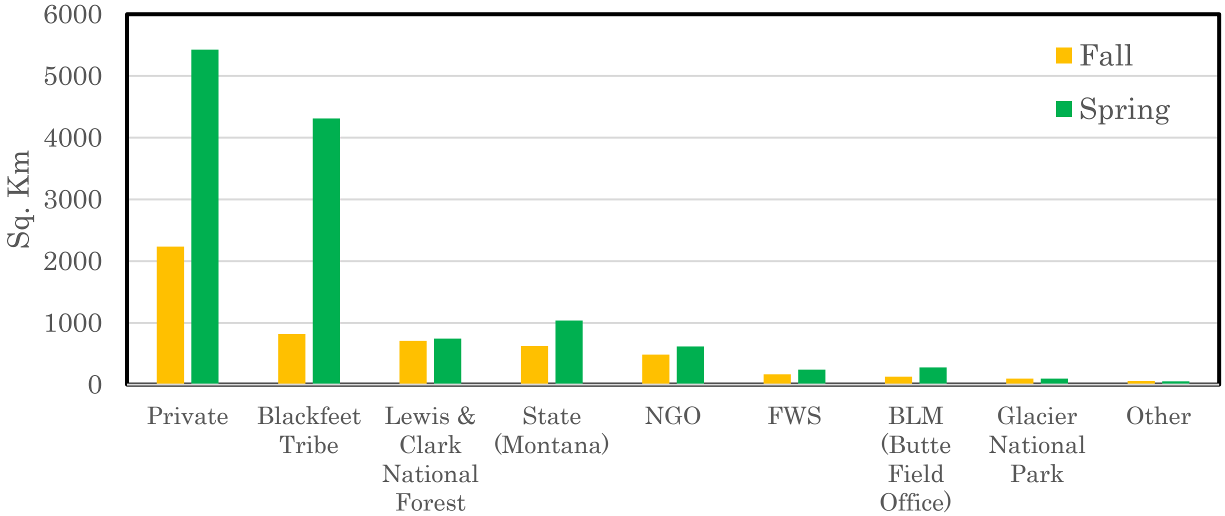


Figure 4.6. Proportion of high-use migration corridors within the Northwestern Plains Conservation Assessment area by land management entity.

4.2.4. Combining Priority Areas

The identification of year-round priority areas for golden eagles is often important in conservation prioritization and project planning. Understanding seasonal habitat selection may be important for understanding and minimizing temporary risks/disturbances, such as insect-borne diseases, or factors that only affect fecundity rates, such as cottonwood loss. However, the majority of risks to golden eagle populations occur on a year-round basis, such as the risk of electrocution, collisions with vehicles and wind turbines, and habitat loss. A singular visual representation of priority areas and spatial risk assessments would often be ideal for planning and conservation prioritization. To visually represent the year-round priority areas within the NWPL, we binned the WGET RND and RWD models into seven use categories and overlapped models to prioritize year-round habitat (Bedrosian et al. 2018b).

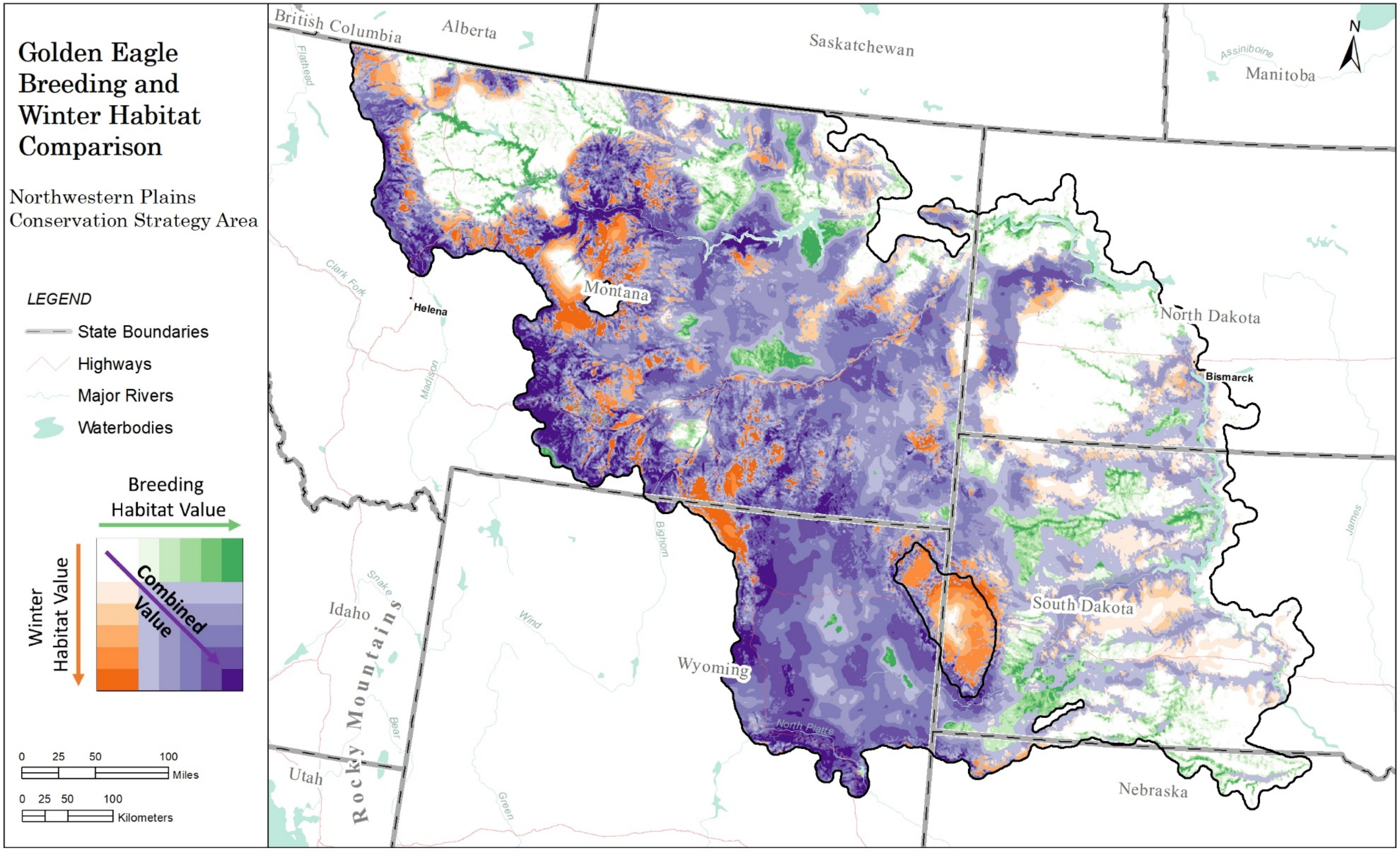


Figure 4.7. Comparison of breeding and winter habitats of golden eagles in the Northwestern Plains conservation assessment area. Breeding habitat value (relative nest site density) is shown in shades of green, winter habitat (probability of use during December–February) in orange, and areas of overlapping high habitat value in purple

Only a very small portion of the NWPL (3.3%; 2,400 km^2) contained areas of highest quality breeding and wintering habitat (Figure 4.7, Table 4.1). Much of the highest quality overlap habitat in Montana occurred along the western edge of the Belt Mountain sub-region between Big Timer and Harlowton, the southern edge of the Powder River drainage, around the Missouri River Breaks National Monument, and the central portion of the Charles M. Russell National Wildlife Refuge surrounding the Devils Creek Recreation Area. In Wyoming, the highest overlap habitat near the base of the Bighorn Mountains between Sheridan and Kaycee, along Pine Ridge, and along the Platte River corridor between Casper and Glendo.

The combined upper two bins in overlapped models accounts for 11.5% of the total area of the NWPL (Figure 4.7, Table 4.1). A larger extent of the Middle Rockies Ecoregion and NWPL and the breaks habitats in Montana surrounding the Missouri, Musselshell, Yellowstone, Tongue and Powder Rivers fall within this high use category. Area within this category extends the areas previously described as important and also adds Thunder Basin National Grasslands and the Black Hills foothills. The largest area of combined habitat occurs within the Powder River Basin sub-section (30.4%), followed by the Belt Mountains (21.6%) and North Central Highlands (10.6%). All other ecological sub-sections had < 7% of this combined class.

Table 4.1 Percentage of the Northwestern Plains golden eagle conservation assessment area by value of combined breeding and winter habitat. Breeding and winter habitat relative importance into seven bins (1 = lowest, 7 = highest) based on the Western Golden Eagle Team Relative Nest Density and Relative Winter Density models (see 2.1.4. and 2.4 for model details).

Golden Eagle Wintering Habitat \ Golden Eagle Breeding Habitat	1	2	3	4	5	6	7
1	5.5	3.9	2.2	1.2	0.8	0.5	0.3
2	3.1	2.6	2.3	1.9	1.7	1.5	1.2
3	1.9	2.0	2.1	2.0	2.1	2.0	2.0
4	1.4	1.8	2.1	2.2	2.2	2.4	2.3
5	1.0	1.5	2.1	2.3	2.4	2.6	2.4
6	0.8	1.3	1.9	2.3	2.6	2.7	2.8
7	0.7	1.2	1.7	2.3	2.6	2.6	3.3

Values are % of total area

4.3. Spatial Risk Assessments

Golden eagles have large home ranges and can move great distances during dispersal and migration (Brown et al. 2017, Murphy et al. 2017, Bedrosian et al. 2018a). As a result, eagles can be exposed to numerous hazards across wide geographic areas (USFWS 2016). Understanding the relative magnitude of a hazard and its distribution in relation to eagle use of the landscape is important to effective conservation and management. To address variation in golden eagle exposure to risk, WGET and collaborators developed regional-scale, predictive models of golden eagle distribution (Dunk et al. 2019) and movements (Brown et al. 2017) throughout the year. To prioritize relative risk across the landscape, we evaluated the overlap between spatial models of golden eagle habitat suitability and spatial data on hazards to eagles (Bedrosian et al. 2018b). Specifically, we overlapped models of relative habitat use by breeding and wintering golden eagles with data on potential of electrocution, development of wind and oil and gas resources, lead exposure from big game hunting, habitat conversion to agricultural uses, and fire. The resulting spatial risk assessments can be used to inform planning for conservation and development at regional scales, including targeted mitigation, land acquisition, and siting of conventional and renewable energy developments. However, because these assessments provide a relative ranking of risk, they are not appropriate for calculating absolute exposure rates or estimating golden eagle fatalities at finer spatial scales (e.g., within a project footprint).

Effective wildlife conservation strategies rely on clear definitions of the factors that influence animal populations, including terminology pertaining to threats, risk, and risk management. Risk assessments are often described as the process of determining the likelihood that a specified event (e.g., mortality) will occur. In practice, however, it is often impossible or impractical to quantify the absolute probability of such events. Thus, we assessed the relative spatial risks within a given region (i.e., risk is higher in some places and lower in others, but the exact probability of an event is unknown) using the following definitions adapted from Smith (2003) and Connelly et al. (2018):

Risk — the relative threat to individual golden eagles or populations of reduced survival or reproductive success caused by a specific hazard. Risk is estimated as the combination of hazard, exposure, and vulnerability. Risk assessments are formal evaluations that take into account two or more of these components.

Hazard — natural or anthropogenic object, condition or event that, over some period of time, could potentially result in the death or significant reduction in fitness of one or more golden eagles.

Exposure — the degree of opportunity to encounter hazards, sometimes approximated by the relative density of golden eagles occurring in a particular area.

Vulnerability — the likelihood and magnitude of effect to an individual, population, or species upon exposure. Vulnerability may vary according to numerous intrinsic factors such as life-history, age class, and behavior, and extrinsic factors such as habitat, weather, and season. For example, large numbers of eagles may migrate through an area with dense electrical infrastructure (high hazard and high exposure), but if they rarely stop to perch on power poles, their vulnerability may be low. Vulnerability may increase, however, if inclement weather causes the eagles to halt migration and roost or forage. Due to the difficulty of quantifying and predicting vulnerability, our risk assessments are limited to measures of exposure and hazard.

We visualized relative risk using color-coded maps and tables. Both show areas with high eagle use and low hazard in green, areas with high hazard and low eagle use in orange, and areas where high eagle use coincides with high hazard (i.e., high risk areas) in purple (Figure 4.8). These maps and tables were designed to identify areas of high risk where mitigation could be targeted and development avoided, as well as areas of opportunity where development of resources (e.g., wind power) is expected to have lower risk to eagles.

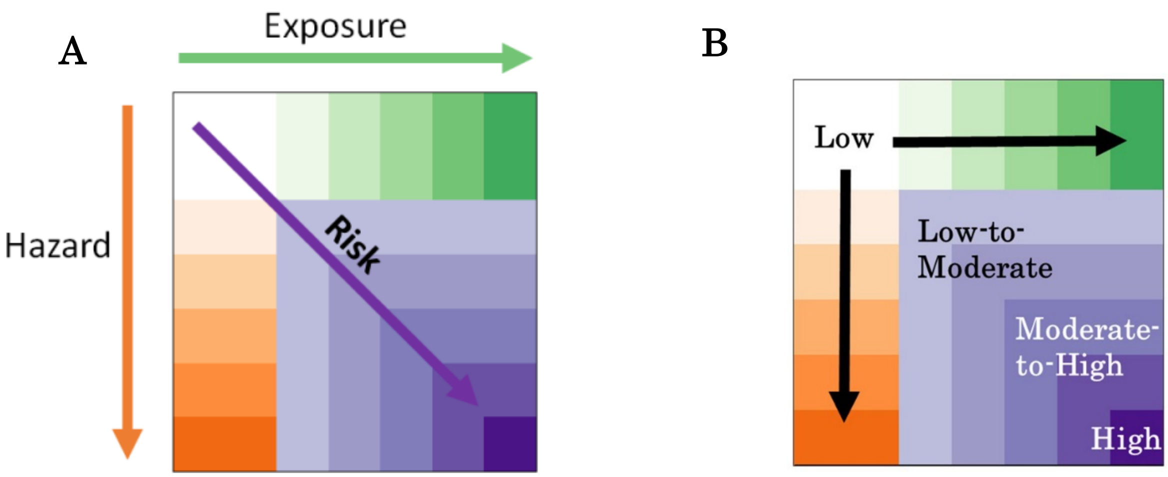


Figure 4.8. (A) Color scheme for visualizing relative golden eagle habitat exposure (greens), hazard (oranges), and resulting risk (purples), and (B) terminology used in sections 4 and 5 of this document to describe risk levels relative to each color.

To further describe the pattern of risk within the NWPL, we calculated the *proportion of total risk and ratio of risk* to area within ecological sub-regions and administrative units. The percentage of total risk is a measure of the amount of risk in a given area as a percentage of the total amount of risk across the study area. It was calculated as the sum of the cell values from the risk model within the focal area divided by the sum of all cells in the study area. The ratio of risk to area is a measure of the density or concentration of risk in a given area relative to what would be expected based on the size of that area. It was calculated as the percentage of risk within the focal area divided by the percentage of the study area composed by the focal area and then subtracting 1 to put it on a -1 to 1 scale. Negative numbers indicate less risk than expected based on area and positive numbers indicate higher density of risk. Taken together, these metrics may be useful to prioritize areas within the NWPL for conservation or development based on amount and concentration of risk.

4.3.1. Electrocution

To assess risk to golden eagles from electrocution (identified in the 3.2 Population Limiting Factors – Direct effects on survival), we overlapped models of eagle breeding and wintering habitats with predicted density of power distribution poles (Dwyer et al. 2016). The resulting maps identify areas of elevated electrocution risk to golden eagles, where high-quality eagle habitat coincides with high densities of power poles (Figure 4.10; Table 4.2). Relative to other mapped ecoregions in the western United States, the NWPL has similar or slightly elevated risk (Figure 4.9). East of the Rocky Mountains, power pole density increases, but areas like North Dakota and the Powder River Basin have higher densities than would be expected, given the human population densities there.

These risk assessments can also be used to identify high-priority areas where power pole retrofitting and other conservation measures (detailed in the Conservation Strategy) are expected to provide the greatest benefit to golden eagles within the NWPL. The resulting risk assessments are relative risk within the NWPL, not at a national level. While some areas may be relatively low density within the NWPL, they may still have risk for eagles and be relatively high in comparison to other ecoregions (Figure 4.9).

We used models of power pole density as a surrogate for electrocution hazard because spatial data of actual power poles were not available. Results of this assessment should be compared with current, local data on power pole locations, configurations, and existing retrofits when assessing the feasibility of mitigation projects.

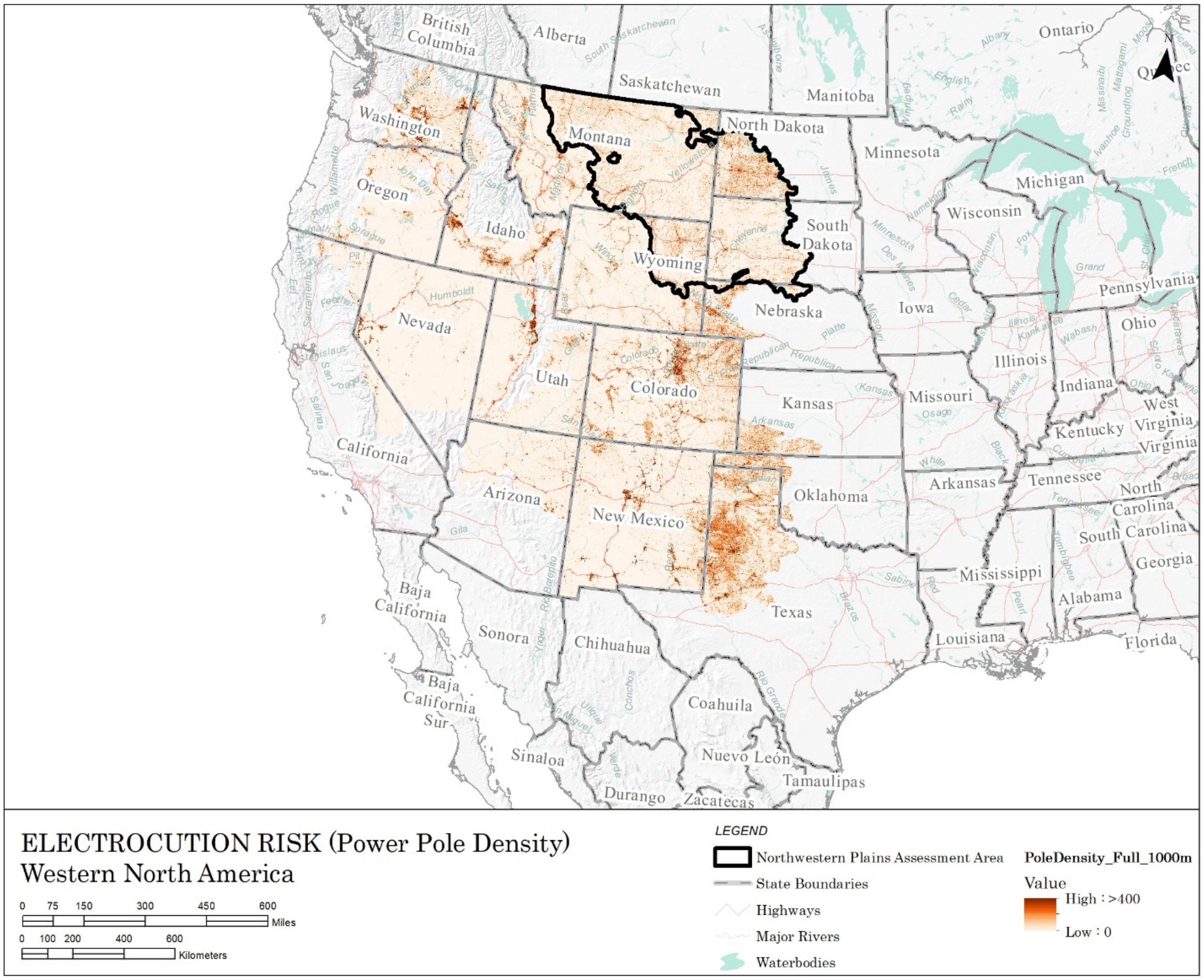


Figure 4.9 Power pole density models for most of western United States (Bedrosian et al. 2018b). Areas with no color are not modeled.

4.3.1.1. Risk of electrocution

A small portion of the NWPL was classified as very high risk (1%) during the breeding season, and an additional 11.5% was classified as moderate-to-high risk. The majority of the NWPL had low risk (53.8%), because of low power pole density or relatively low quality habitat. The winter had greater risk and was more dispersed across the NWPL (Table 4.2, Figure 4.10). A total of 15.4% of the NWPL was classified as moderate-to-very-high risk, while 51.8% was classified as low risk.

A test of this risk assessment method in the PRECorp service area of Wyoming and Montana found that 88% of golden eagle electrocutions in breeding habitat occurred in moderate-to-very-high risk areas and 99% occurred in the purple risk areas of Figure 4.8 (Bedrosian et al. 2019). These results confirmed indicated that the modeling process was successful at discriminating high-risk areas. The observed electrocutions were more than three times higher than expected in the very high risk bin (3.59; Bedrosian et al. 2018b). A high level of conservation efficiency could be achieved by focusing retrofitting efforts in these areas: for example, the high-to-very-high risk area of the NWPL composed only 23% of the landscape, but accounted for 65% of electrocutions; focusing retrofitting effort in that area could more than double the effectiveness of mitigation efforts. The northern Powder River Basin in Wyoming is one such area that provides this type of benefit. Likewise, much of the western edge of the NWPL in Montana provides this conservation opportunity (Figure 4.10).

Table 4.2. Relative risk of electrocution for golden eagles in the Northwestern Plains conservation assessment area within (A) breeding and (B) winter habitats. Colors match the maps in Figure 4.8. Cell values show the percentage of the total assessment area in each risk class.

A Golden Eagle Breeding Habitat

Power Pole Density	1	2	3	4	5	6	7
1	0.5	0.7	1.6	2.4	2.8	3.0	3.3
2	0.8	1.4	1.9	2.4	2.6	2.7	2.6
3	1.0	1.7	2.1	2.3	2.3	2.3	2.3
4	1.5	2.0	2.2	2.2	2.2	2.1	2.1
5	2.4	2.6	2.3	2.0	1.8	1.7	1.6
6	3.4	3.0	2.3	1.7	1.5	1.4	1.3
7	4.9	3.0	2.0	1.3	1.1	1.1	1.0

B Golden Eagle Winter Habitat

Power Pole Density	1	2	3	4	5	6	7
1	0.6	2.1	2.1	2.1	2.1	2.4	2.8
2	0.8	2.0	2.3	2.4	2.5	2.3	2.1
3	1.2	2.0	2.1	2.3	2.4	2.2	2.1
4	1.6	2.0	2.0	2.2	2.2	2.2	2.2
5	2.4	2.1	2.0	2.0	1.9	1.9	2.0
6	3.2	2.2	1.9	1.8	1.8	1.8	1.7
7	4.6	2.0	1.7	1.6	1.5	1.5	1.5

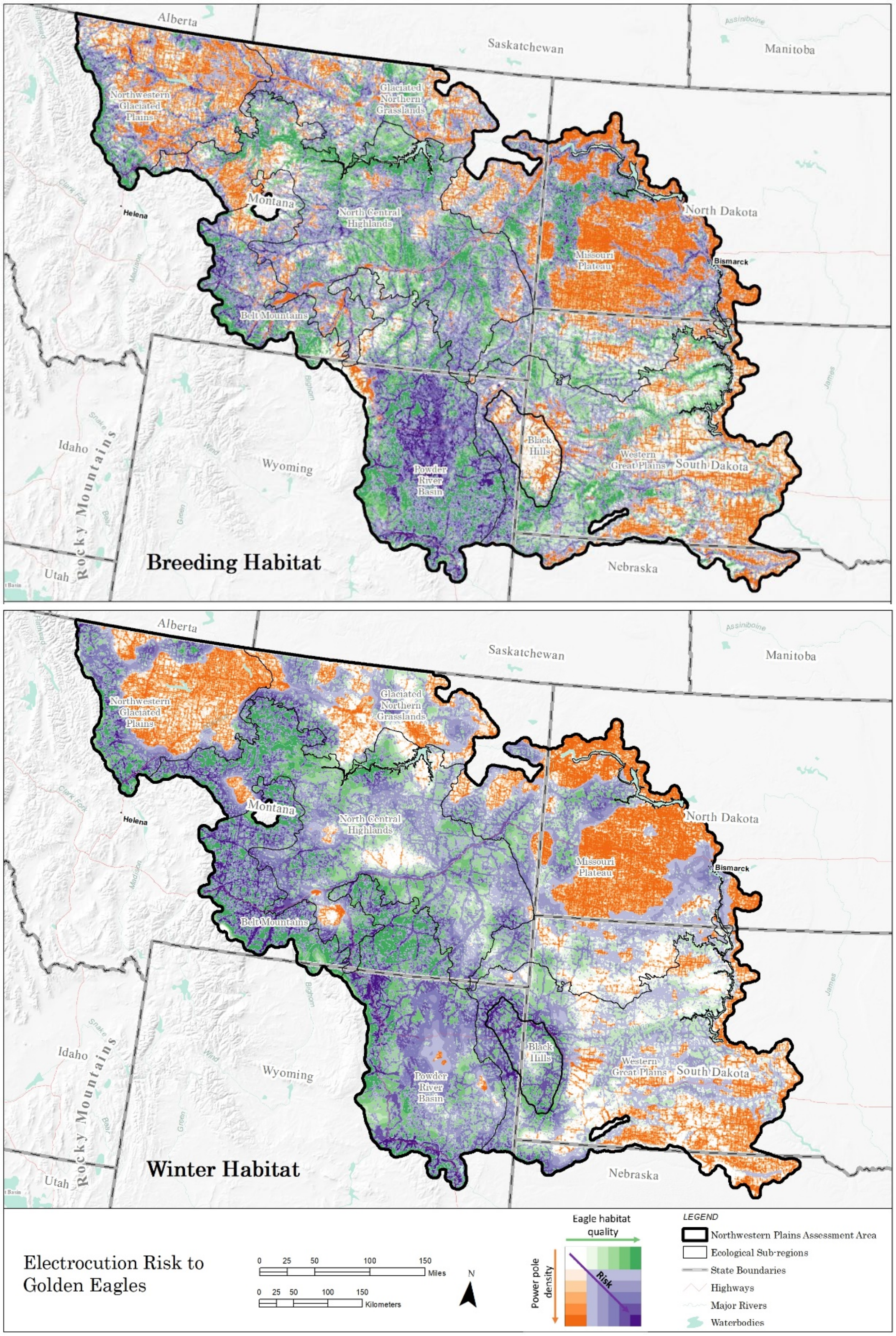


Figure 4.10. Relative risk of electrocution for golden eagles in the Northwestern Plains conservation assessment area within breeding and winter habitats. Colors match the cells in Figure 4.8.

4.3.1.2. Risk by region

Electrocution risk varied widely across the NWPL, and many areas are generally low risk. The highest densities of power poles generally occurs in the Missouri Plains, much of which is low quality breeding habitat. Presumably, the high power pole density coincides with increased agriculture in that area of North Dakota, which generally precludes golden eagle nesting (see 3.3.2.2). Much of high quality breeding habitat in Montana does not have high densities of power poles due to low human populations in most of the North Central Highlands. Across much of Montana and North Dakota, risks are higher within river drainages where roadways and ranches tend to congregate and overlap with higher eagle use due to the presence of cottonwood galleries and cliffs for nesting. The largest area with high relative potential conflict in the NWPL occurred in the northern Powder River Basin of Wyoming, in much of the PRECorp service area. The Belt Mountains also contain relatively high proportion of risk relative to its size.

Risk in winter is more pronounced along the western border of the NWPL, particularly in the Belt Mountains and north of Sheridan, Wyoming. Areas with increased topography and forests, such as the Black Hills, also had higher risk in the winter, likely due to increased associations of wintering eagles and forested habitats (Domenech et al. 2015). Risk in the Powder River Basin lessens in the winter since that area hosts less quality winter habitat.

Within ecological subsections, the Powder River Basin has much higher risk in both breeding and winter habitats relative to its size (Figure 4.12). This is likely due to the high amount of quality habitat and high level of development that occurs there. Prioritization of conservation measures, such as power pole retrofitting, would have relatively high benefit in the Powder River Basin. Both the Belt Mountains and Black Hills have higher risk during the winter.

4.3.1.3. Risk by management entity

The largest risk from electrocution across the NWPL occurs on private lands (ca. 78%, year-round) and at a greater proportion relative to the total private land area (Figure 4.11). All other land management entities held <10% of the electrocution risk in the NWPL and all except non-government agency lands had less risk than expected. Much of the non-government agency lands with high risk (particularly in winter) were easements held by Montana Land Trust between Big Timber and Red Lodge, Montana and easements held mainly by The Nature Conservancy along the eastern foothills of the Bighorns west of Sheridan, Wyoming.

While the Buffalo BLM Field Office only holds 7.9% of the total BLM lands within the NWPL, there is significantly higher electrocution risk to eagles relative to the size of that Field Office. There is almost three times the expected risk to breeding eagles and 1.5 times the expected risk in the winter (Figure 4.13). The Casper Field Office has relatively increased opportunities for reducing electrocution risk on BLM lands since that area has more expected risk relative to the area.

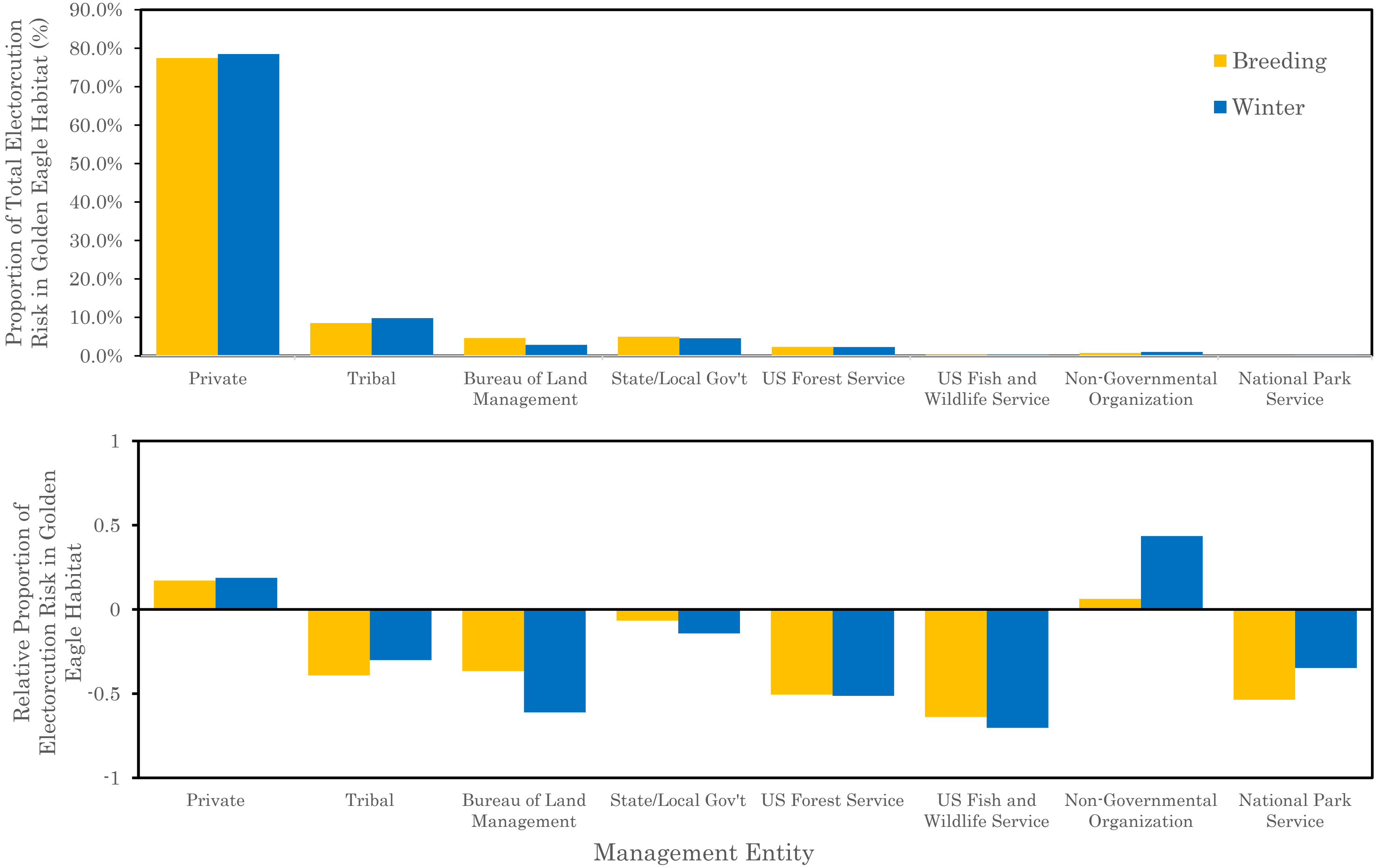


Figure 4.11. Electrocution risk in breeding and winter habitats of golden eagles by surface management entity within the Northwestern Plains conservation assessment area. Proportion of total risk (top) and ratio of the proportions of risk to management area (bottom). Management areas are shown in descending size order from left to right.

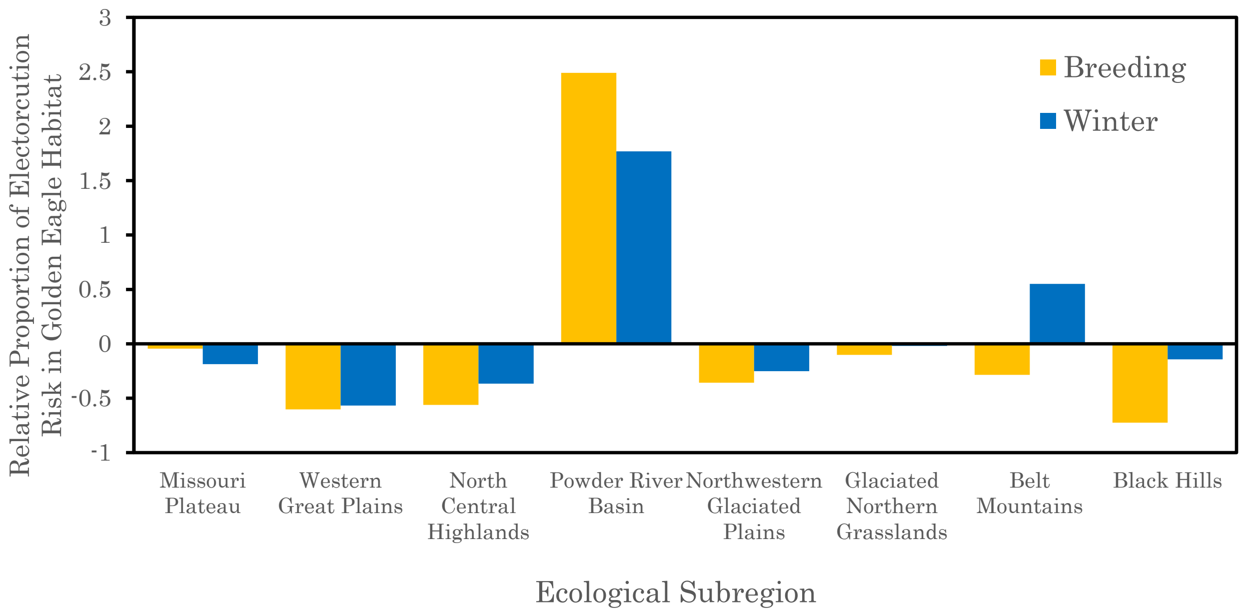


Figure 4.12. Electrocution risk in breeding and winter habitats of golden eagles by ecological subregion within the Northwestern Plains conservation assessment area. Ratio of the proportions of risk to subregion size is shown. Ecological subregions are shown in descending size order from left to right. Note that the y-axis scale is from -1 to 1.5.

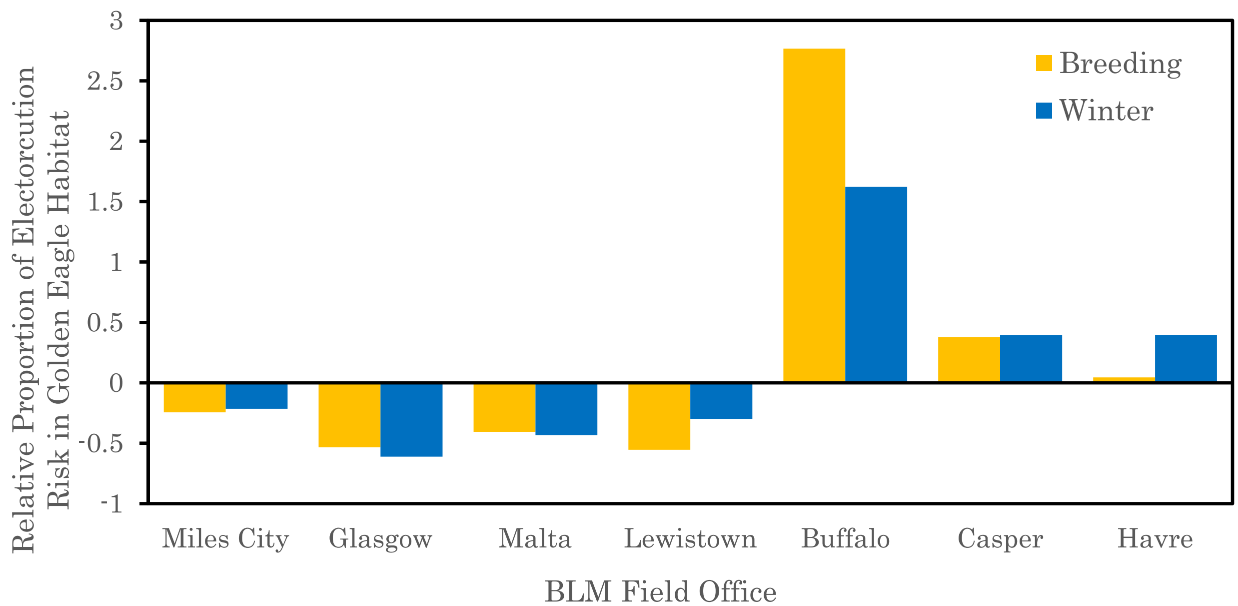


Figure 4.13. Ratio of electrocution risk in breeding and winter habitats of golden eagles relative to the size of Bureau of Land Management (BLM) Field Offices within the Northwestern Plains conservation assessment area. Only BLM Field Offices that hold ≥5% of total BLM area within the NWPL are shown. BLM Field Offices areas are shown in descending size order from left to right. Note the y-axis scale is from -1 to 3.

4.3.2. Wind Resource Development

To assess spatial risk to golden eagles from hazards associated with wind energy development (identified in 3.2.1.2) we overlapped models of eagle breeding and wintering habitats with data on wind speeds at 120 m above-ground-level (National Renewable Energy Laboratory 2015, Figure 4.14). The resulting maps identify areas of elevated risk to golden eagles, where high-quality eagle habitat coincides with high wind speeds and areas of opportunity for wind resource development where high-wind speeds coincide with lower-quality eagle habitat (Figure 4.14 and Table 4.3). These maps can be used to avoid and minimize conflicts with golden eagles during preliminary site evaluation, equivalent to tiers 1 and 2 of the Wind Energy Guidelines (USFWS 2012) and Stage 1 of the Eagle Conservation Plan Guidance (USFWS 2013). They can also be used to guide application of additional conservation measures (detailed in the Conservation Strategy). The binning classes used in the following risk assessment were from National Renewable Energy Laboratory's pre-binned wind power classes (1-7) at a national scale, not the quantile binning used in other risk assessments. Most of the NWLP is at relatively high risk compared to other ecoregions in the western United States (Figure 4.14).

We acknowledge that wind energy siting decisions are influenced by factors in addition to wind speed (e.g., access to transmission, land ownership and management, permitting). However, due to the difficulty of predicting these factors, we have followed other studies (Tack and Fedy 2015, Mojica et al. 2016) that used wind power classes as a surrogate for the likelihood of development. Results of this assessment should be compared with current, local data when assessing the feasibility of development or conservation of a given area.

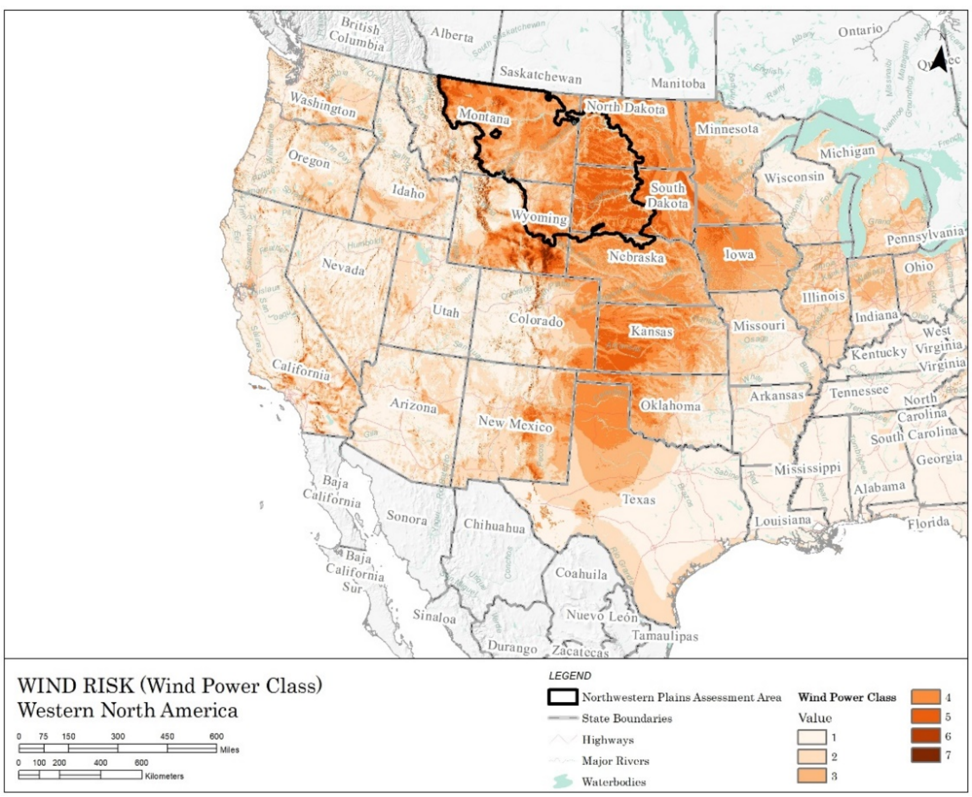


Figure 4.14 National wind power classes (National Renewable Energy Laboratory 2015) used as a surrogate for wind resource development risk to golden eagles.

4.3.2.1. Risk from wind resource development

A very small portion of the NGPL hosted the highest quality eagle habitat (both breeding and winter) and wind potential class 7 (0.1% for each season, Table 4.3). However, of the 1,509 existing wind turbines within the NWPL, most existing turbines occur within class 5 (63.4%), followed by class 4 (23.3%), class 6 (10.2%) and class 3 (2.5%)(Table 4.4). Collectively, 6.5% of the NWPL has the highest risk of conflict for eagle collisions, (eagle breeding habitat bin 7 and wind power classes 4–7), and an additional 14.4% with moderate-high risk (eagle breeding habitat bins 5–6 and wind classes 4-7; Table 4.3). Risk in the winter was similar but slightly less, with 5.7% of the NWPL with highest risk and 13.5% with moderate-high risk.

The majority (91.1%) of the NWPL is suitable for wind development (wind classes 3–7). Because of the widespread wind development potential, the risks to eagles generally coincide with the spatial distribution of eagle habitat quality. Risks to eagles decreases in the northwestern and eastern portions of the NWPL where eagle habitat quality is relatively low. Only a small portion of the NWPL exhibits moderate-to-highest quality habitat where wind speeds are too low for development (green areas in Table 4.3, Figure 4.15), and mainly occur in breaks habitats. Preservation of golden eagle habitat in these areas is unlikely to conflict with wind development. Conversely, 27.4% and 27.7% of the NWPL exhibit areas of opportunity for wind development (wind classes 3–7) that coincide with areas of low breeding or winter habitat (bins 1–2), respectively. Moreover, 10.8% and 22.1% of the NWPL has excellent quality wind resources (wind classes 5–7) and low potential conflict with eagles (bins 1-2 for breeding and winter habitat, respectively) (Figure 4.16).

Table 4.3. Relative risk of wind resource development for golden eagles in the Northwestern Plains conservation assessment area within (A) breeding and (B) winter habitats. Colors match the maps in Figure 4.8. Cell values show the percentage of the total assessment area (474,170-km^2) in each risk class.

A Golden Eagle Breeding Habitat

Wind Potential Class	1	2	3	4	5	6	7
1	0.1	0.1	0.1	0.1	0.1	0.1	0.2
2	0.5	0.6	0.9	1.1	1.4	1.7	2.2
3	2.0	2.8	3.6	4.4	5.3	5.6	5.5
4	5.6	6.2	5.6	5.4	5.2	4.9	4.6
5	6.1	4.5	3.9	3.1	2.1	1.7	1.6
6	0.1	0.1	0.2	0.2	0.2	0.2	0.2
7	0.0	0.0	0.0	0.0	0.0	0.1	0.1

B Golden Eagle Winter Habitat

Wind Potential Class	1	2	3	4	5	6	7
1	0.3	0.1	0.0	0.0	0.0	0.1	0.3
2	0.3	0.3	0.3	0.5	1.0	2.5	3.6
3	2.5	3.1	2.9	4.6	6.0	5.5	4.6
4	7.5	5.7	5.3	6.6	5.4	3.7	3.2
5	3.7	5.0	5.8	2.7	1.8	2.1	1.9
6	0.1	0.1	0.1	0.0	0.1	0.3	0.5
7	0.0	0.0	0.0	0.0	0.1	0.1	0.1

Table 4.4. Number (A) and percentage (B) of existing wind turbines within the Northwestern Plains conservation assessment area by wind potential class and golden eagle relative nesting density bin. All turbines within golden eagle habitat bin 7 were located in Wyoming.

A Golden Eagle Breeding Habitat

Wind Potential Class	1	2	3	4	5	6	7
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	4	2	11	9	4	0	7
4	134	24	29	10	0	23	132
5	543	190	50	14	1	6	153
6	29	14	26	13	11	6	56
7	0	0	0	1	4	2	1

Values are number of existing turbines.

B Golden Eagle Breeding Habitat

Wind Potential Class	1	2	3	4	5	6	7
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.3	0.1	0.7	0.6	0.3	0.0	0.5
4	8.9	1.6	1.9	0.7	0.0	1.5	8.7
5	36.0	12.6	3.3	0.9	0.1	0.4	10.1
6	1.9	0.9	1.7	0.9	0.7	0.4	3.7
7	0.0	0.0	0.0	0.1	0.3	0.1	0.1

Values are percent of existing turbines.

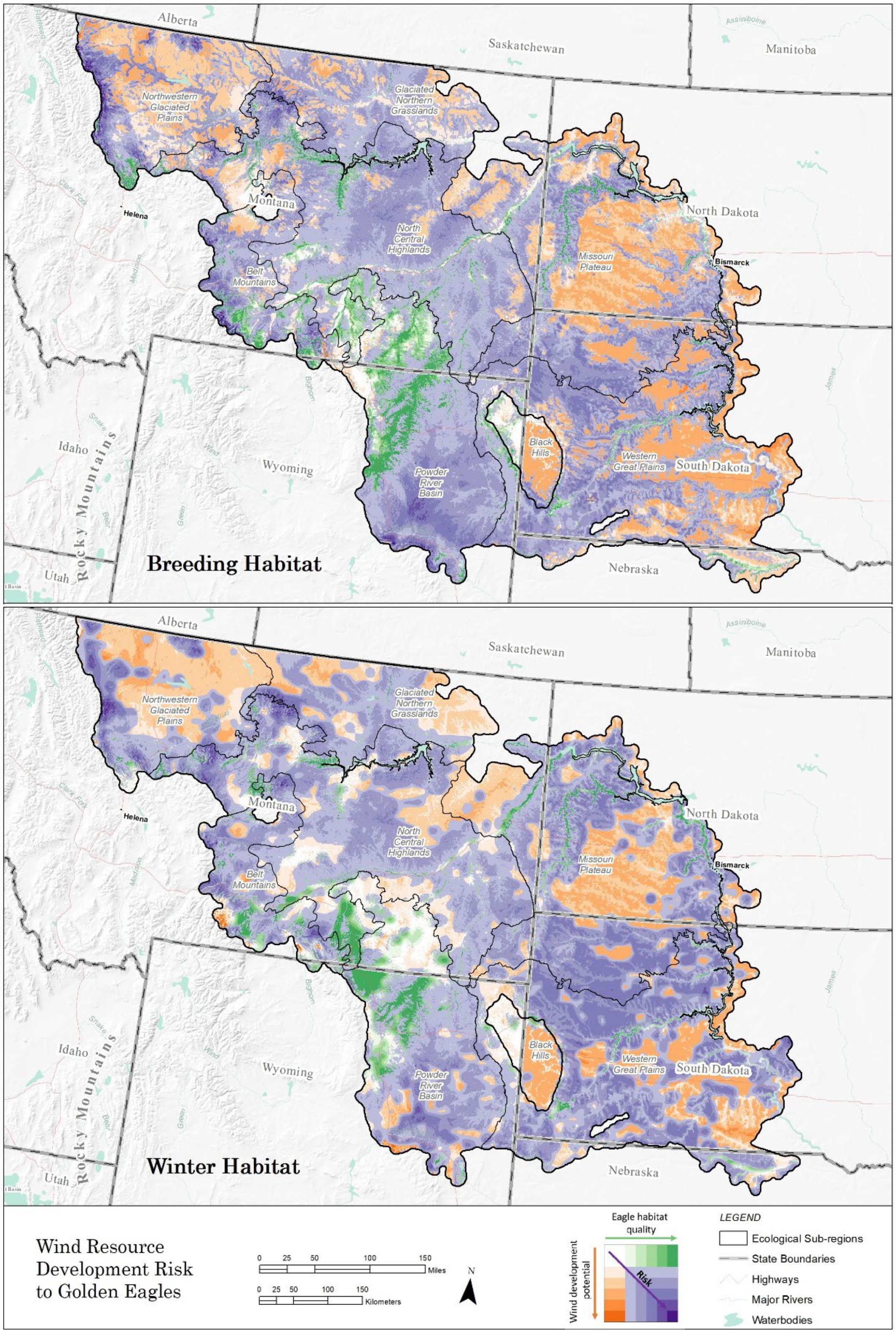


Figure 4.15. Relative risk of wind resource development for golden eagles in the Northwestern Plains conservation assessment area. Colors match the cells in Figure 4.8.

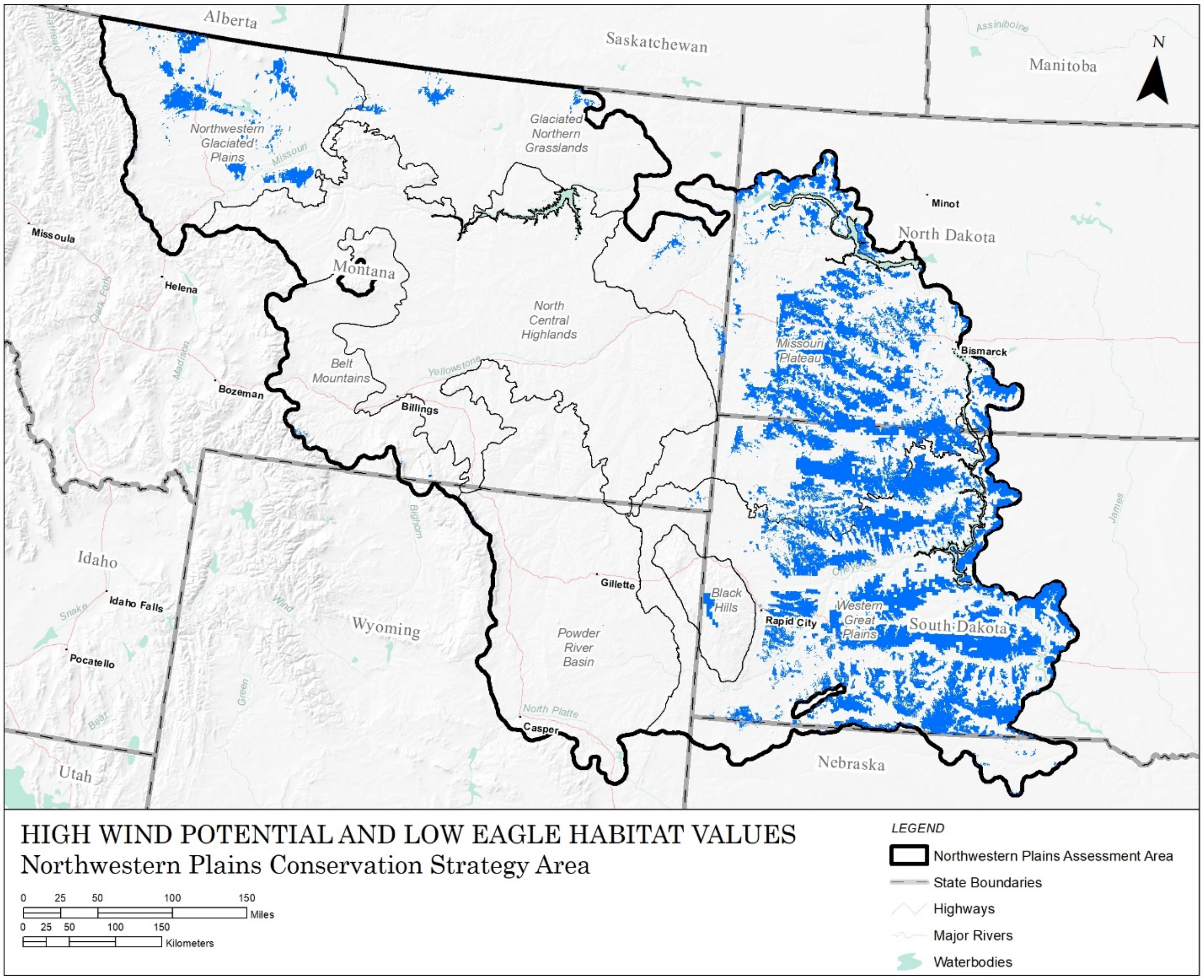


Figure 4.16 Areas within the Northwestern Plains conservation assessment area that exhibit high wind potential (wind power classes 5-7) and also are within the lowest two bins of both the golden eagle relative nest density model (Dunk et al. 2019) and the relative winter density (Brown et al. 2018).

4.3.2.2. Risk by region

The Rocky Mountain Front stretching across all of Montana is one of the riskiest sections of the NWPL from wind development potential, with high wind speeds occurring in some of the highest quality breeding habitat (Figure 4.15). Much of this area is within the 4-km buffer used for the breeding RND model and is steep, montainous terrain that generally precludes wind development. Almost all of the North Central Highlands sub-region has moderate-high risk, but also has few transmission cooridors to facilitate large wind energy facilities. The Bears Paw range south of Havre, Montana has the largest area of wind and breeding habitat overlap east of the Front in Montana. The Powder River Basin in Wyoming has a very large, contiguous area of overlap, with the I-25 corridoor between Casper and Glendo and north of Glenrock exhibiting relativly high risk. This latter area is host to two existing, large fcailities (Glenrock and Top of the World; Figure 3.4). Much of west-central South Dakota, in areas without much contiguous agriculture has relatively high risk for breeding eagles that state. The breaks around the Little Missouri have the highest potential of conflict of wind and breeding eagles in North Dakota. Winter risk areas generally mirrored breeding habitat with some notable exceptions along the western and southern boundary of the NWPL near Big Timber, Montana and Casper, Wyoming. The Black Hills model to be good wind and low eagle risk, but that are is unlikely to be developed due to terrain and habitat type.

Overall, 30% of existing 1,509 wind turbines within the NWPL are located in moderate to highest quality breeding habitat bins 4–7 and 23% are situated within the highest quality breeding habitat (bin 7) (Table 4.4). Of the turbines in North Dakota (n = 573), South Dakota (N = 352) and Nebraska (N = 2), only one turbine exists in eagle breeding habitat bin 6 and none occur in bins 5 or 7. In Montana, 12% of existing turbines occur in high quality eagle breeding habitat bins 5–7 (0.3% in bin 7). Wyoming has the highest proportion of turbines in risky locations for eagles. Almost all (94.9%) of the existing 352 turbines in Wyoming occur in the highest breeding habitat bin (7).

Because there are very few areas not suitable for wind development in the NWPL (Figure 4.15), the relative risk to eagles by ecological sub-regions or surface management entity generally follows the relative amount of habitat within each (Figure 4.15, Figure 4.3).

4.3.3. Oil and gas development

To assess spatial risk to golden eagles from hazards associated with oil and gas development (identified in 3.2.1.4), we overlapped models of eagle breeding and wintering habitats with predicted oil and gas development potential (Copeland et al. 2009, Figure 4.17). The resulting risk assessment maps and tables (Figure 4.18, Table 4.5) identify areas where golden eagles are more likely to be exposed to hazards from infrastructure and activities associated with oil and gas development, including electrocution, collision, disturbance, and drowning within the NWPL. The variation in risk across the NWPL is similar to other regions such as the Wyoming Basin and the Great Basin (Figure 4.17).

These risk maps can also be used to identify high-priority areas where implementation of conservation measures (detailed in the Conservation Strategy) are expected to provide the greatest benefit to golden eagles. We used a predictive model of development potential as a surrogate for the suite of hazards associated with oil and gas developments. Results of this assessment should be compared with local data on current and planned locations of oil and gas developments when assessing the feasibility of management actions. Separate maps of breeding and winter habitat (Figure 4.18) may be useful for managing seasonal disturbances to golden eagles from oil and gas development. Breeding habitat models identify areas where seasonal nest buffers could be used to protect nesting eagles, while winter habitat models provide information on areas where wintering eagles are likely to be affected by seasonal activities, like well drilling.

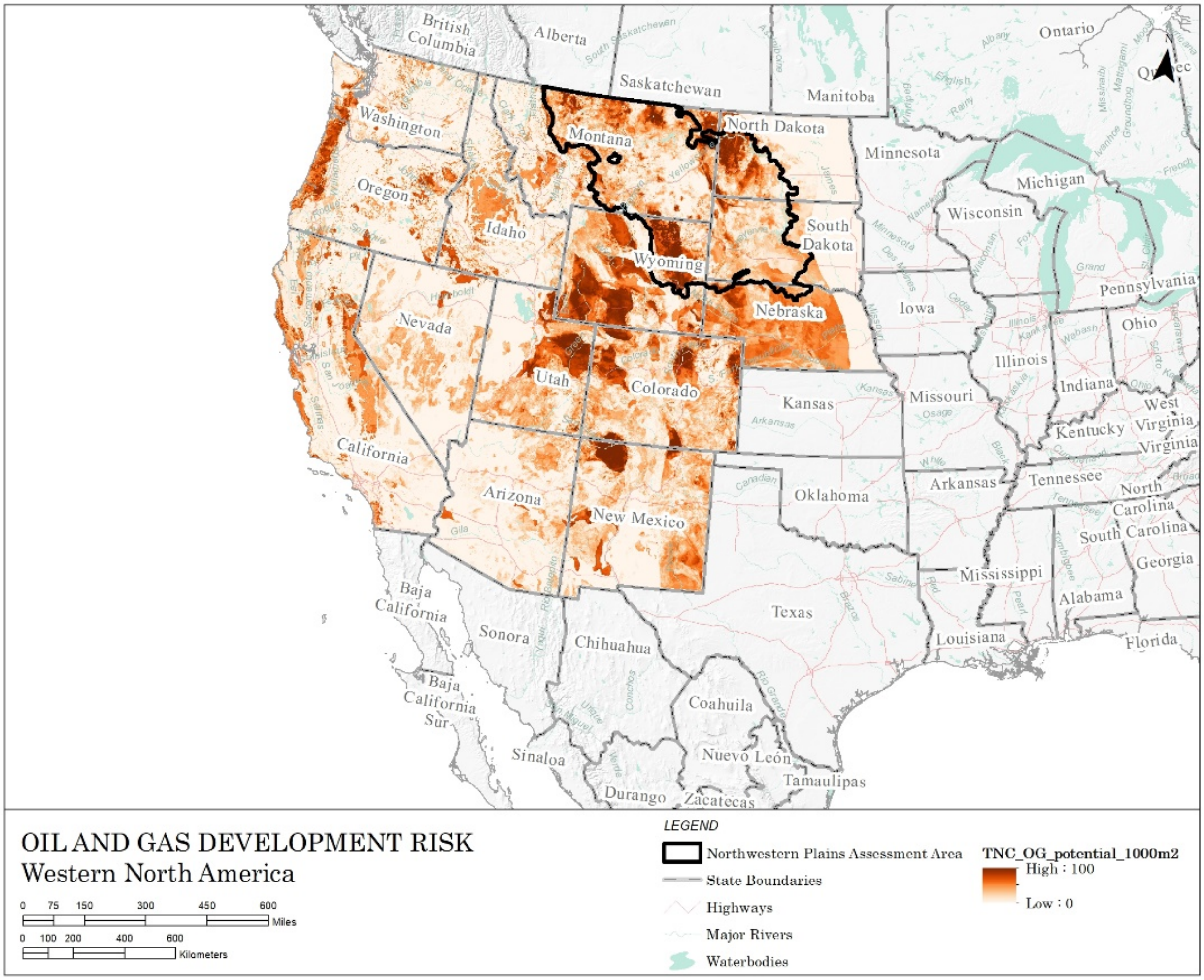


Figure 4.17 Risk of oil and gas development across western United States (Copeland et al. 2009).

4.3.3.1. Risk of oil and gas development

A substantial portion of the NWPL was classified as very high risk (4.8%) or moderate-to-high risk (13.9%) to breeding eagles from oil and gas development (Table 4.5). Most of the NWPL had low risk (51%; Table 4.5) or low-to-moderate risk (30%; Table 4.5). Risk categories in winter were nearly identical to breeding with the exception of the very high-risk category. However, risk among the combined categories of moderate-to-very-high risk were the same between seasons (19%). The NWPL included 54,358 active wells in 2016 (data compiled from Montana Board of Oil and Gas Production, North Dakota Dept. of Mineral Resources, South Dakota Geological Survey, Wyoming Oil and Gas Conservation Commission; Figure 1.9); 40.9% of the wells were located within the very-high risk and 73.8% were within the moderate-to-very high breeding habitat classification. The percentage of wells in the highest risk winter habitat category was considerably lower (27.9%) and slightly lower in the combined winter moderate-to-very high risk categories (65.1%).

Table 4.5. Relative risk of exposure to oil and gas development for golden eagles in the Northwestern Plains conservation assessment area within (A) breeding and (B) winter habitats. Colors match the maps in Figure 4.8. Cell values show the percentage of the total assessment area in each risk class.

A Golden Eagle Breeding Habitat

Oil & Gas Development Potential	1	2	3	4	5	6	7
1	1.0	1.4	1.9	2.4	2.8	2.8	2.0
2	2.1	2.1	2.2	2.4	2.3	2.1	1.4
3	2.3	2.2	2.2	2.2	2.1	1.8	1.3
4	2.3	2.3	2.2	2.2	2.1	1.9	1.3
5	2.8	2.3	2.2	2.0	1.9	1.7	1.3
6	2.4	2.4	2.2	1.9	1.7	1.7	1.9
7	1.5	1.7	1.4	1.2	1.5	2.3	4.8

B Golden Eagle Winter Habitat

Oil & Gas Development Potential	1	2	3	4	5	6	7
1	0.9	1.1	1.5	2.7	3.1	2.7	2.2
2	1.2	2.7	2.9	2.3	1.9	1.9	1.6
3	1.7	2.4	2.7	2.2	1.7	1.7	1.8
4	2.0	2.4	2.3	2.0	1.6	1.8	2.1
5	2.7	2.4	1.9	1.6	1.5	1.9	2.4
6	3.3	2.1	1.5	1.5	1.6	1.8	2.5
7	2.5	1.3	1.4	2.1	2.9	2.4	1.7

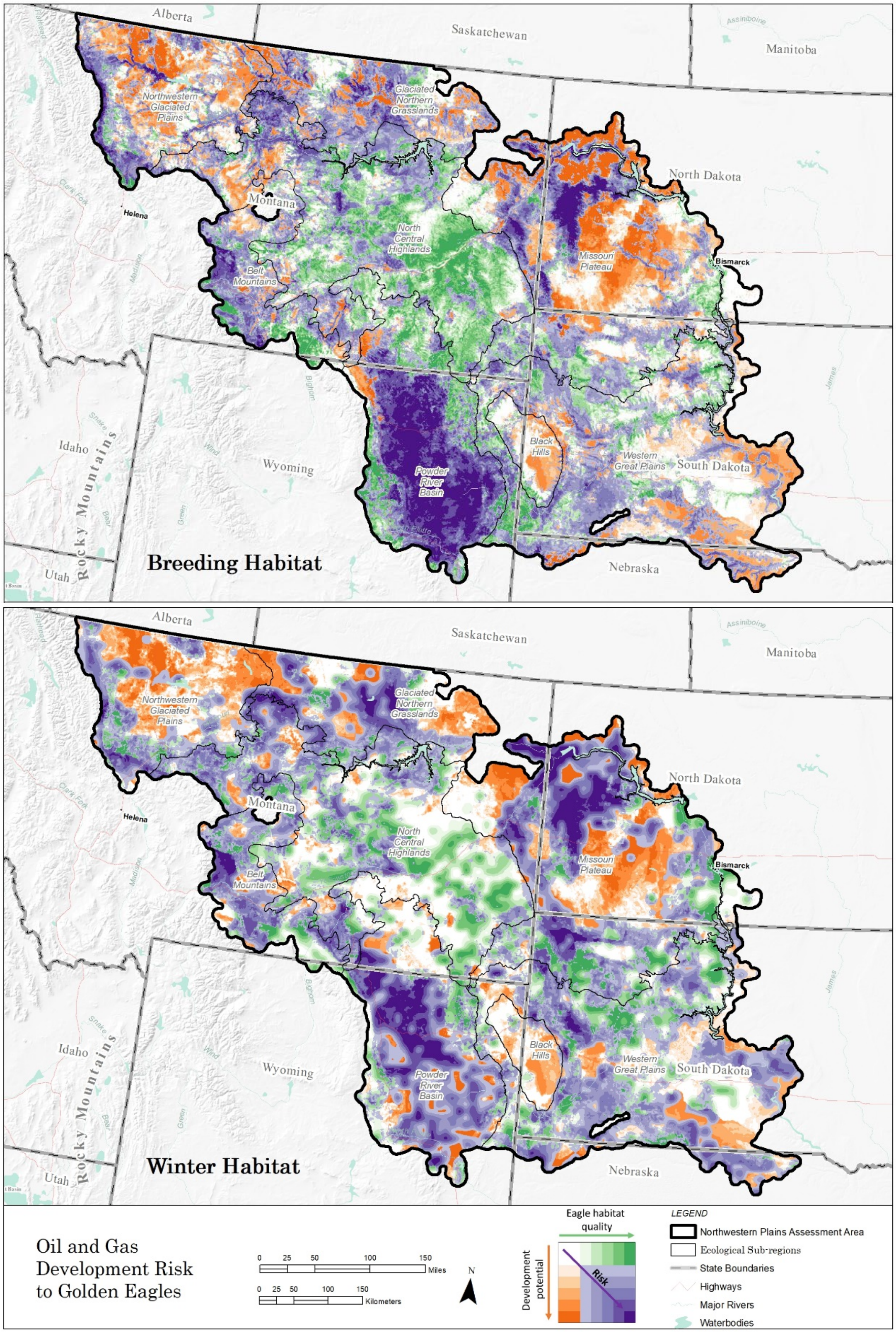


Figure 4.18. Relative risk of oil and gas development for golden eagles in the Northwestern Plains conservation assessment area. Colors match the cells in Figure 4.8.

4.3.3.2. Risk by region

Wyoming hosts the largest number of active wells within the NWPL (69.2%). Montana and North Dakota have a similar number of active wells (15.6% and 14.2%, respectively), followed by South Dakota and Nebraska that both have <1%. The highest risk from oil and gas development to breeding eagles occurs in the majority of Powder River Basin in Wyoming (Figure 4.18). High development potential and high-value eagle habitat also overlaps within the Williston Basin of the Missouri Plateau subregion; the greatest risk occurs along the Little Missouri River corridor, particularly in and near the Dakota National Grasslands and along the Cedar Creek anticline in Montana and North Dakota. Much of the area within the Williston Basin and areas surrounding current development in northern Montana have high development potential that does not overlap high quality breeding habitat. Conversely, few areas of development potential occur outside quality eagle habitat in the Powder River Basin (Figure 4.18). There is relatively lower risk for wintering eagles in the southern and eastern portion of the Powder River Basin sub-region but the highest quality winter habitat generally occurs where there is currently oil and gas development. Much of the Cedar Creek anticline falls within the low or low-to-moderate winter habitat classification. A similar distribution of seasonal habitat quality occurs across the Williston Basin.

Oil and gas development risk varied widely across the NWPL. Risk was highest in the low basins of the region where geological features associated with oil and gas deposits overlapped areas of high-quality golden eagle habitat. Within ecological subsections (Figure 4.19), the greatest amount of risk was in the Powder River Basin (Breeding: 45.1%, Winter: 35.8%), followed by the Missouri Plateau (Breeding: 20.6%, Winter: 17.6%). All other subregions had <10% of the risk to breeding habitat and all subregions except the North Central Highlands (12.4%) had <10% risk to winter habitat. Risk was generally proportional to the area of ecological subsections, except risk was much more concentrated than expected in breeding and winter habitats of the Powder River Basin subsection. Otherwise, only the Belt Mountains were classified as slightly higher risk than expected during the winter, while all other subsections had slightly lower risk than expected (Figure 4.19).

4.3.3.3. Risk by management entity

Private lands had by far the greatest amount of oil and gas development risk (Breeding: 66.1%, Winter: 68.2%), followed by tribal lands (Breeding: 14.0%, Winter 8.7%), BLM (Breeding: 7.3%, Winter: 7.7%), State/Local Government (Breeding: 5.3%, Winter: 6.9%), and USFS (Breeding: 4.7%, Winter 6.0%). All other land management entities had <1% risk. Of the producing wells across the NWPL in 2016, 77.7% were located on private lands, 10.1% were on BLM, 7.5% on state or local government owned lands, 2.2% were on USFS, and 1.4% were on tribal lands. Concentration of predicted risk on private lands was proportional to area. Risk was greater than expected on BLM, USFS and state lands and less than expected on tribal lands. We calculated the greatest relative proportion of risk for NPS lands, but the actual risk is virtually non-existent due to the protected status of national parks.

The BLM field offices within the Powder River Basin of Wyoming all have a greater than expected risk relative to their sizes, with the Buffalo Field Office having the greatest relative risk (Breeding: 31.5%, Winter: 22.8%) while only accounting for only 7.9% of all BLM lands within the NWPL. These field offices also contained a higher proportion of habitat values, relative to their sizes (Figure 4.4). The Havre Field Office had a lower risk than expected in the breeding season, but higher in the winter. The risk across the Malta Field Office was proportional to its size and risk was lower than expected in both the Miles City and Glasgow Field Offices.

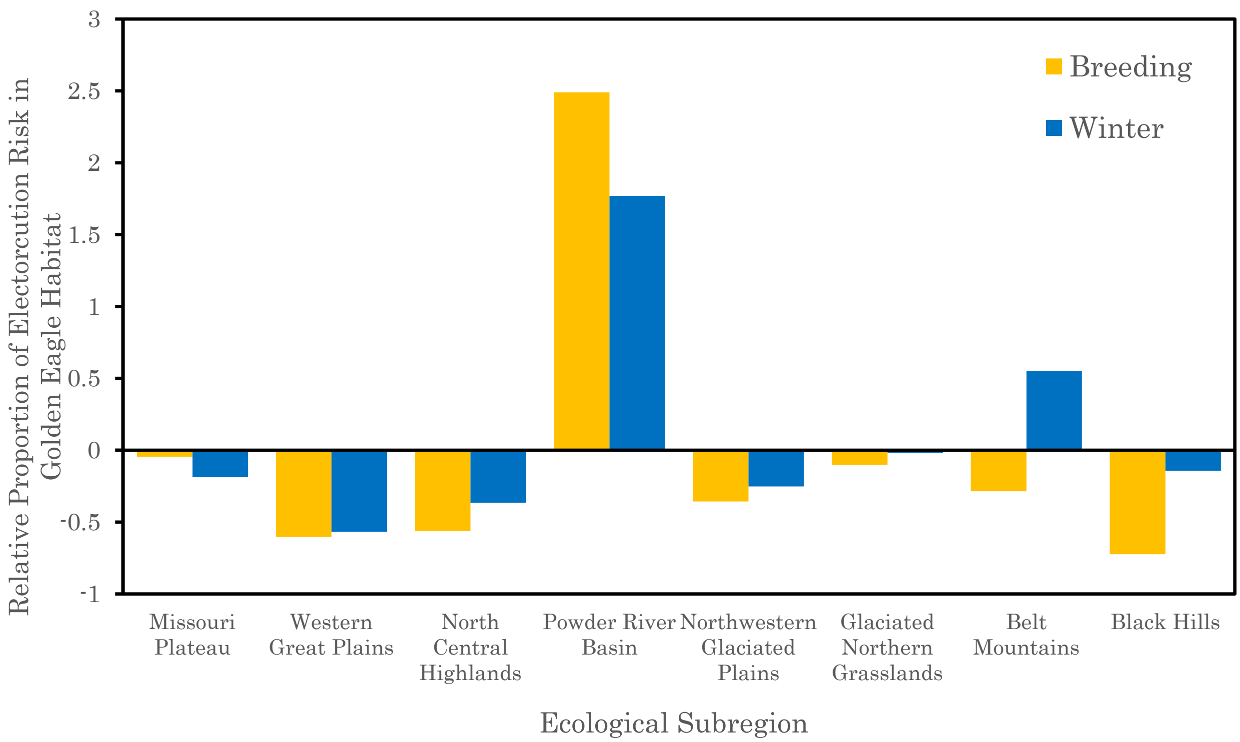


Figure 4.19. Risk of oil and gas development in breeding and winter habitats of golden eagles by ecological subregion within the Northwestern Plains conservation assessment area. Ratio of the proportions of risk to subregion size is shown. Ecological subregions are shown in descending size order from left to right. Note that the y-axis scale is from -1 to 3.

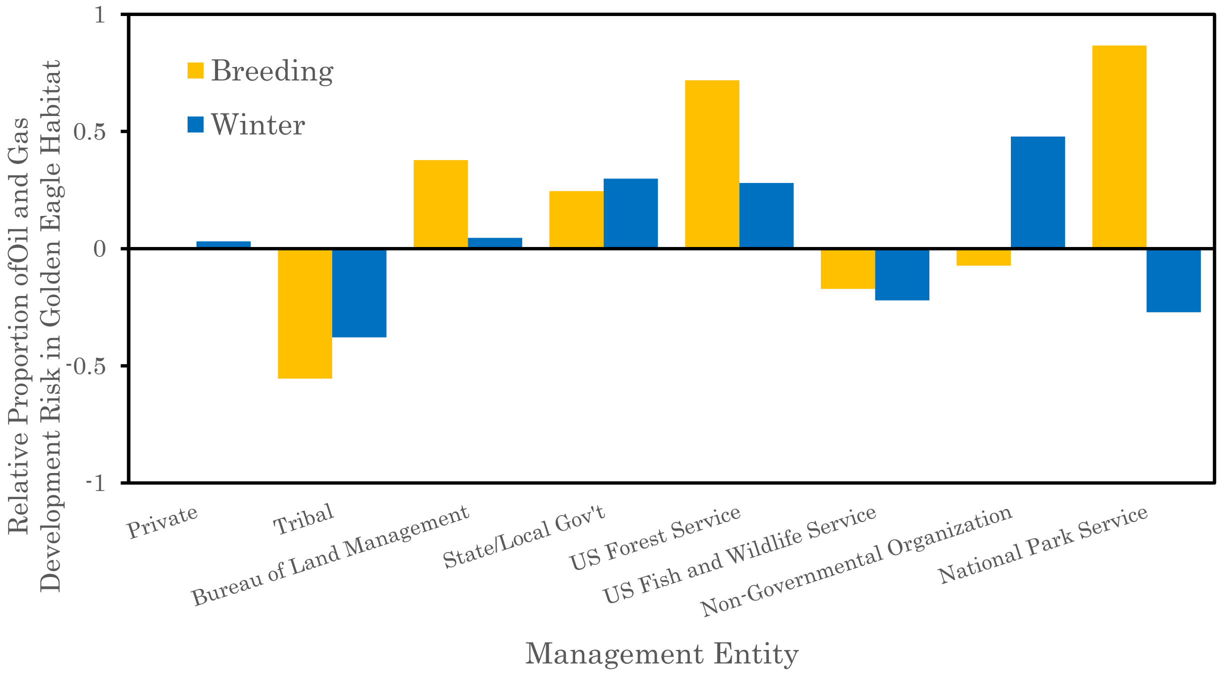


Figure 4.20. Proportions of risk to management area size for oil and gas development risk in breeding and winter habitats of golden eagles by surface management entity within the Northwestern Plains conservation assessment area. Management areas are shown in descending size order from left to right.

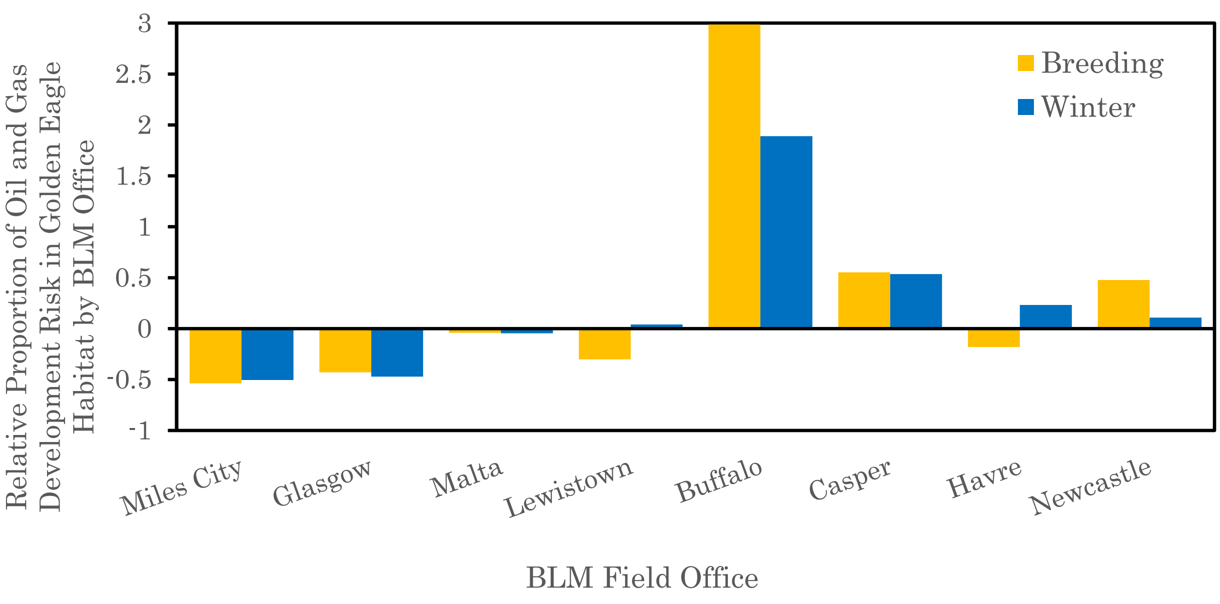


Figure 4.21. Ratio of risk of oil and gas development in breeding and winter habitats of golden eagles relative to the size of Bureau of Land Management (BLM) Field Offices within the Northwestern Plains conservation assessment area. Only BLM Field Offices that hold ≥5% of total risk in either season shown. BLM Field Offices areas are shown in descending size order from left to right. Note the y-axis scale is from -1 to 3.

4.3.4. Lead exposure from gut piles and un-retrieved big game carcasses

To assess spatial risk to golden eagles from exposure to lead from shot big game carcasses and gut piles (identified in the Conservation Assessment), we overlapped models of eagle breeding and wintering habitats with data on harvest rates of big game animals (Lau et al. 2016, South Dakota Game, Fish, and Parks). The resulting maps and tables (Figure 4.23 and Table 4.6) identify areas where golden eagles are more likely to be exposed to big game carcasses and gut piles from firearm hunting that may contain fragments of lead bullets. These risk maps can also be used to identify high-priority areas where implementation of conservation measures for lead exposure (detailed in the Conservation Strategy) are expected to provide the greatest benefit to golden eagles. We used the 5-yr average (2011–2014) number of deer, elk, and antelope harvested per km^2 as a surrogate for lead exposure (Lau et al. 2016). Only deer and elk harvest information were available for South Dakota, so estimates in that state do not include antelope harvest and may underestimate risk.

Big game harvest data were only available at the relatively coarse scale of hunt units and no data were available for tribal lands. Results of this assessment should, therefore, be compared with local data on harvest rates, patterns of harvest within hunt units, and knowledge of areas where other routes of exposure (e.g., varmint shooting) may be more prominent. Regional knowledge of golden eagle fall migration routes and post-breeding habitat should also be considered in planning because they align with the timing of big game hunting seasons in fall and early-winter. It should be noted that breeding eagles generally reside on territory year-round, so risks during the fall hunting season to local, breeding eagles can be spatially mapped using nest sites (RND). The winter (RWD) model was created with movement data from Dec–Feb, so the results of the winter risk exposure should be interpreted with caution since most big-game rifle hunting seasons end prior to those dates and persistence rates of carcasses and offal piles are unknown.

Relative to other regions in western North America, the NWPL has relatively high harvest rates, particularly in the western portion of the NWPL (Figure 4.22). Excluding Texas, Montana has among the highest annual big game harvest rates. Again, harvest rates in South Dakota are underestimated due to missing antelope harvest data. While some areas of the NWPL may appear to have low harvest rates in the subsequent risk assessments, the risk map is relative to the NWPL. Low rates within the NWPL may correspond to high harvest estimates in other ecoregions. The high harvest rates in Montana, Wyoming and northwest Colorado and the corresponding relatively dense populations of nesting and wintering golden eagles may help prioritize national non-lead reduction and mitigation efforts.

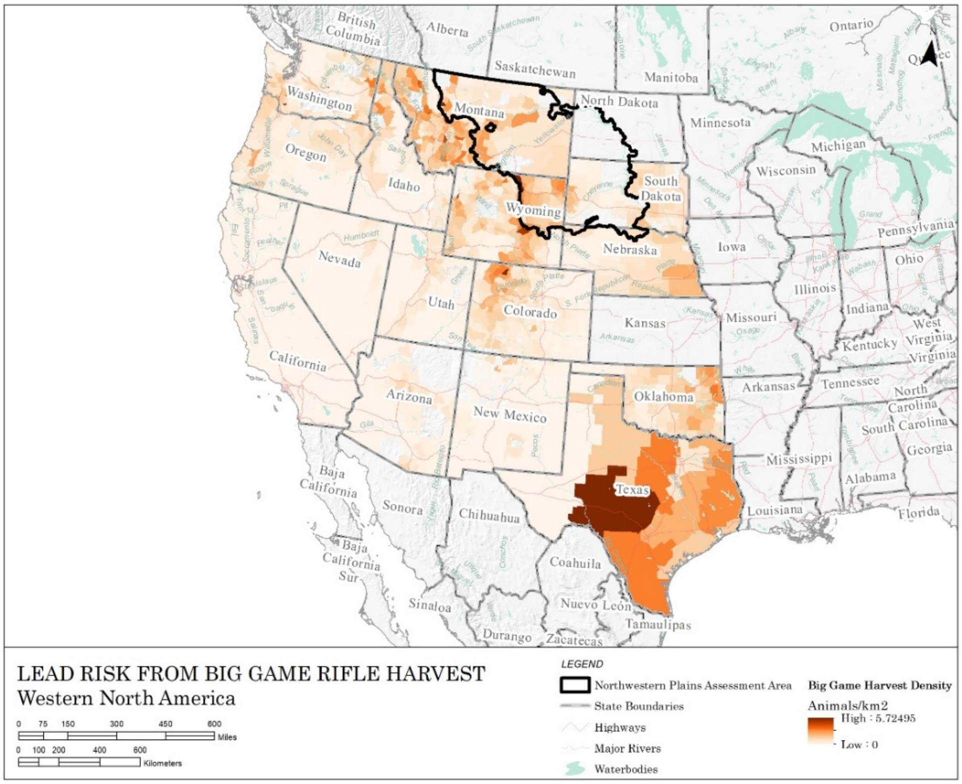


Figure 4.22 Big-game (deer, antelope, and elk combined) 5-year mean harvest rates (animals/km^2, 2011–2014) in western North America. Mean harvest rates were compiled for each species group by state hunting management zone and assigned the same rate for each pixel in the zone. Then, pixels for each species group were added to for the composite harvest rate. Data for North Dakota, Kansas, and tribal lands were not available. South Dakota only includes deer and elk harvest data.

4.3.4.1. Risk from lead exposure

Big game hunting is prevalent across most of the NWPL. We could not assess risk in 25.4% the NWPL due to lack of or no access to accurate harvest data. In the areas we could spatially assess potential lead exposure risk to breeding eagles from rifle hunting, 3.8% of that area was considered very high risk and 23% was high-very high risk (Table 4.6). Across the area we could assess, 45.5% was low risk. Most of the area considered low risk was in South Dakota, and it is important to note that risk is underestimated there since antelope harvest data were not included. In the winter, 5.6% of the area was considered very high risk and 25.4% was high-very high risk.

The spatial scale at which this risk assessment was completed was extremely course. Harvest data are available only by state hunt management zones, which were as large as 20,231 km^2 in the NWPL. Hunting pressure and timing is not continuous across hunting zones due to ungulate habitat selection and hunter land access. We did not assess risk by management agency because of these reasons. While access to public lands for hunting is much greater than private lands, ungulates tend to congregate on private lands during the hunting season. While there may be a higher number of hunters on public lands, harvest density on private lands may exceed that of public lands when ungulate densities are higher there. This is further complicated by state run private-lands access programs like “Hunter/landowner assistance program” in Wyoming, which tries to congregate hunters on private lands with crop depredation problems or “Block Management Program” in Montana, in which the state compensates private landowners for allowing public hunting access to their lands.

Table 4.6 Relative risk of exposure to lead from big game rifle hunting for golden eagles in the Northwestern Plains conservation assessment area within (A) breeding and (B) winter habitats. Colors match the maps in Figure 4.8. Cell values show the percentage of the assessment area in each risk class. Note that big game harvest density estimates was not continuous over the assessment area, so the percentage of the area within the assessment region for which lead risk was estimated. Big-game estimates for South Dakota did not include antelope, so underestimate risk there. In the Relative Winter Density model, there most values in bins 2–3 were identical, so they were lumped into category three for habitat.

A Golden Eagle Breeding Habitat

Big Game Harvest Density	1	2	3	4	5	6	7
1	2.7	2.8	2.8	2.7	1.8	1.3	0.9
2	2.4	2.7	2.3	2.2	2.0	1.5	1.0
3	1.9	2.4	2.0	2.0	2.3	2.5	2.2
4	1.5	1.8	2.4	2.6	2.8	2.6	1.7
5	1.4	1.1	1.3	1.7	2.2	2.5	1.8
6	2.1	1.2	1.1	1.3	1.6	2.4	4.6
7	1.8	1.4	1.5	1.6	1.8	2.4	3.8

B Golden Eagle Winter Habitat

Big Game Harvest Density	1	2	3	4	5	6	7
1	8.6		2.3	2.2	0.8	0.6	0.1
2	7.8		1.5	2.4	1.9	1.1	0.7
3	3.5		1.4	3.9	1.8	1.5	1.6
4	3.1		1.0	3.2	3.6	3.2	1.3
5	3.3		1.2	3.0	2.8	1.9	1.1
6	2.5		0.8	2.6	3.7	2.9	1.6
7	0.6		0.3	1.5	2.6	3.1	5.6

4.3.4.2. Lead exposure risk from big game hunting by region

Areas with high harvest rates for multiple species had the among the greatest harvest densities. The eastern edge of the Bighorns in Wyoming was one such area, with high deer densities and a large number of elk hunters. All along the Rocky Mountain Front had relatively high harvest rates, along with the Black Hills and the breaks south of the Missouri River in the Charles M. Russell National Wildlife Refuge. While it appears that South Dakota has relatively low risk, the harvest estimates do not include antelope and therefore underestimate risk.

We could not assess relative exposure risk in the Missouri Plateau or Western Great Plains, but the Black Hills, Belt Mountains and Powder River basin all had greater risk than expected, while the Glaciated Northern Grasslands had less. The North Central Highlands and Northwestern Glaciated Plains were both relatively close to expected.

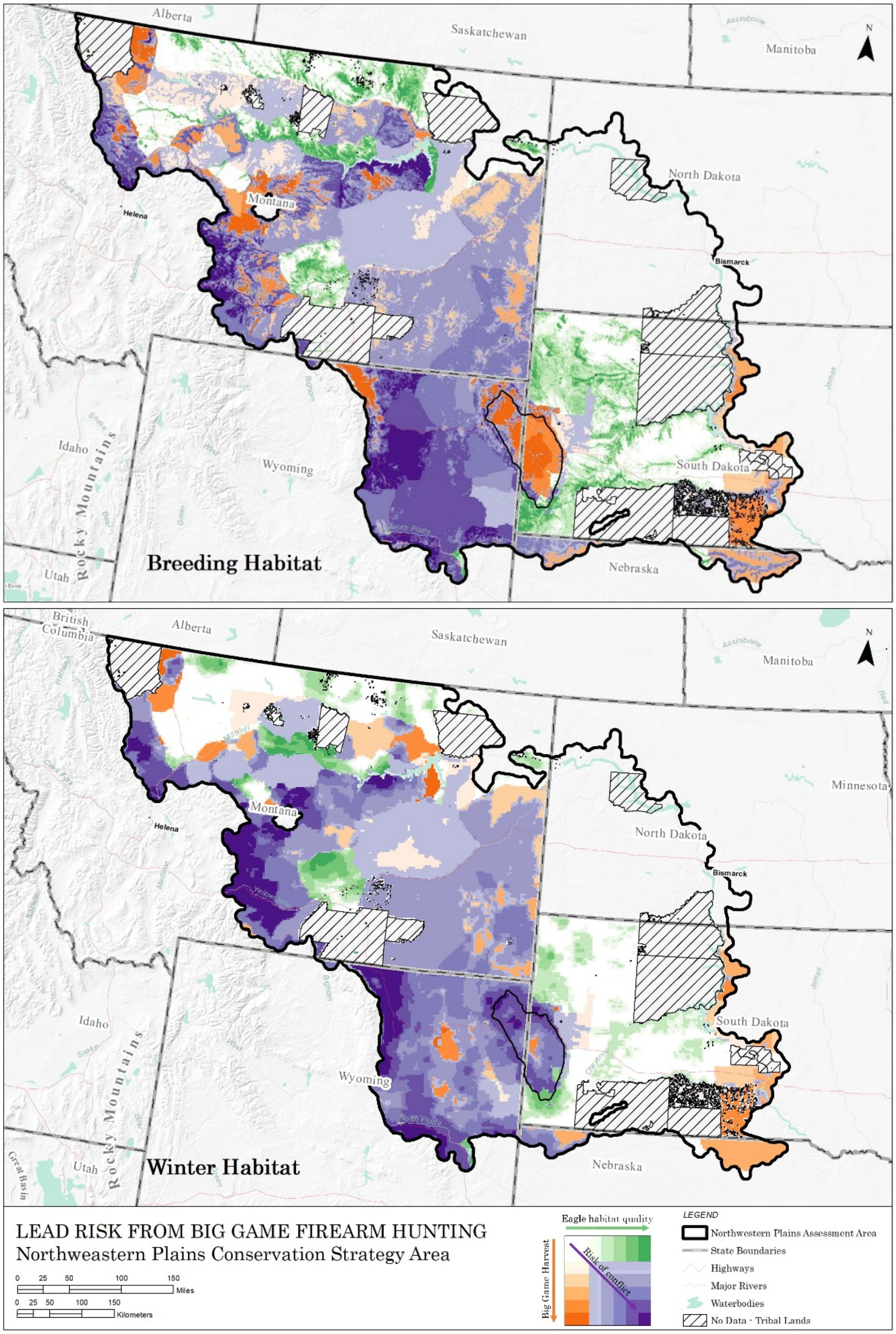


Figure 4.23 Relative risk of exposure of golden eagles to lead from big game carcasses in the Northwestern Plains conservation assessment area within breeding and winter habitats. Colors match the cells in Figure 4.8.

4.3.5. Habitat to agriculture conversion

To assess spatial risk of habitat loss due to agriculture conversion (identified in 3.3), we overlapped models of eagle breeding and wintering habitats with the current land use classification and a predictive model of land use in 2050 under "business-as-usual" scenario (Sohl et al. 2012; B1 scenario; Figure 4.24). The NWPL is predicted to experience one of the most pronounced habitat changes in high value eagle habitat due to agriculture conversion across ecoregions in the West (Figure 4.25). Model scenarios are based on four storylines from the Intergovernmental Panel on Climate Change Special Report on Emmision Scenarios (IPCC 2000). The B1 scenario models potential conditions in land use and land cover based on the assumption of moderate population growth, high economic growth, high environmental and social consciousness, and a globally coherent approach to sustainable development (Figure 4.24). Changes in any of these assumptions can significantly alter the model predictions and differences between scenarios are most pronounced along the Missouri River corridor of the NWPL (Sohl et al. 2012).

This risk assessment can be modified using alternative scenarios to account for changes in economic, social, or environmental pressures. For example, if environmental protections are relaxed (e.g., Farm Bill is not renewed) or if market pressure for agricultural products typically produced in the NWPL (e.g., biofuels) increases, risk may be underrepresented in this risk assessment.

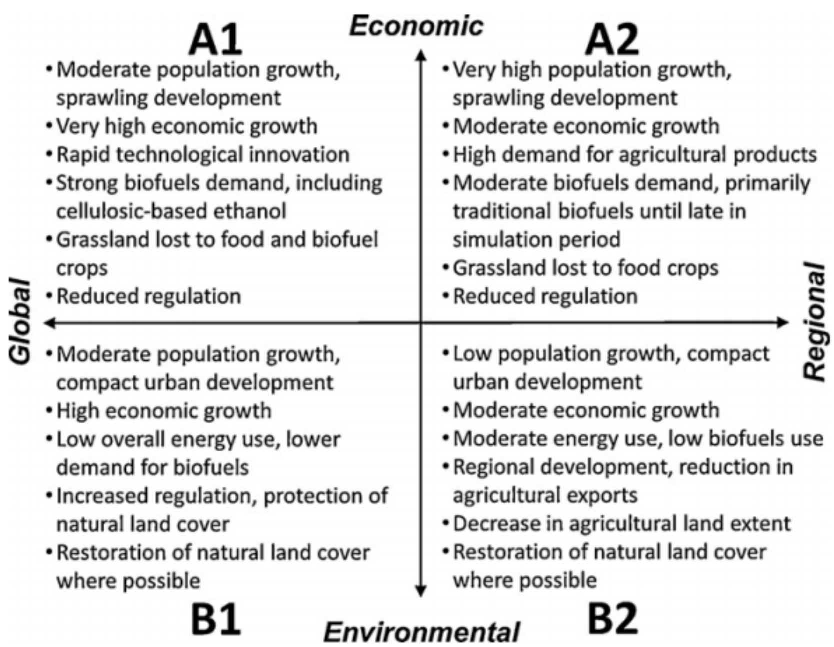


Figure 4.24. Major assumptions in land use/land cover change model scenarios in Sohl et al. (2012) and Sleeter et al. (2012) based on shifts in economic growth vs. environmental protection and global vs. regional development. Figure reproduced from Sohl et al. (2012).

Both models of golden eagle breeding and wintering habitats in the NWPL showed an avoidance of agricultural lands and these resulting risk assessment maps can be used to identify priority areas for implementation of conservation measures (detailed in the Conservation Strategy) to provide the maximum benefit to golden eagles. These maps can also help identify areas for agricultural opportunities with limited impact to eagle populations in the NWPL. While Sohl et al. (2012) provided several scenarios of land use and land cover changes to 2100, we chose to use their "business-as-usual" scenario (T. Sohl, personal communication) modeled to 2050 to asses risk to eagles in this assessment.

This assessment is somewhat different to the previous assessments because here we used a predictive model of *future* risk. The predictions in the various scenarios classify each land cover class predicted to be present in year 2050, not a measure of the likelihood of change. Therefore, the risk assessment identifies areas predicted to be converted to agriculture in the various eagle habitat bins. This assessment can be used to identify areas of high quality eagle habitat that is predicted to be converted to agriculture. Results of this assessment should be used in conjunction with regional and local knowledge of agricultural pressures, land owners, land use regulations, project scale and other relevant factors when considering the efficacy of conservation measures within a given area.

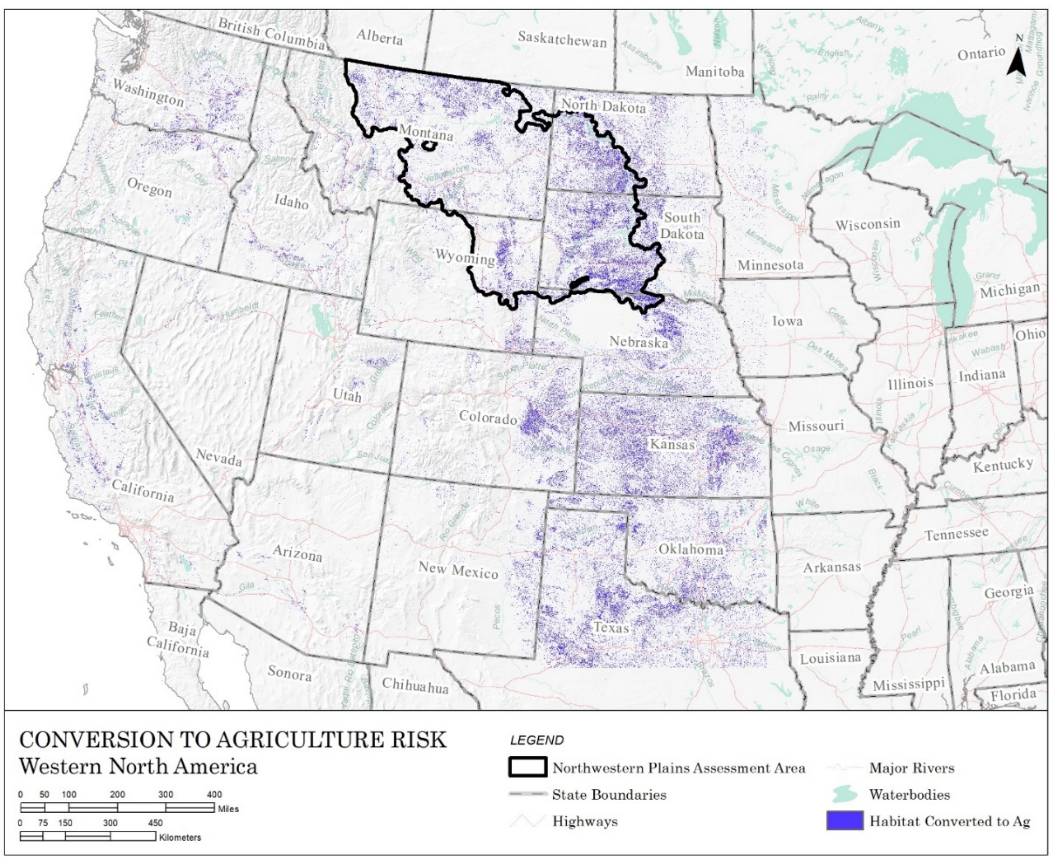


Figure 4.25 Areas predicted across the western United States to be converted to agricultural use (cropland or hay/pasture) by 2050 using the US Geological Survey FORE-SCE modeling in the "business-as-usual" scenario (Sleeter et al. 2012).

4.3.5.1. Risk of habitat conversion to agriculture

In 2006, 108,311.8 km^2 of land was in agricultural use across the NWPL. That projection increased to 168,069.5-km^2 and 230,952.7-km^2 in 2050 and 2100, respectively, under the "business-as-usual" prediction scenario. The two landcover classes used to define agricultural use were cropland and hay/pasture. Of those, cropland was projected to increase by 30% in 2050 and 62% by 2100 (as compared to 2006; Figure 4.26). Hay and pasture was projected to increase 270% by 2050 and 550% by 2100. The total landcover projected to be converted to cropland by 2100 is 60,030.4 km^2 and 62,610.5 km^2 to hay/pasture.

We calculated the percentage of breeding and winter eagle habitat predicted to be converted to agriculture by 2050 compared to the 2006 land us/land cover estimates under the B1 scenario (Sleeter et al. 2012). In 2050, 2.8% of high-to-very-high quality breeding habitat is predicted to be converted to agriculture and 7.4% of moderate-to-very-high quality breeding habitat is predicted to be converted (Figure 4.27). No habitat in low quality eagle habitat is predicted to be converted to agriculture, suggesting that any loss of native habitat to agriculture will affect eagle breeding habitat. A similar proportion of winter habitat is expected to be lost to agriculture conversion (2.7% and 6.8% of high-to-very-high and moderate-to-very-high, respectively). An additional 3.2% of habitat is predicted to be converted in low quality eagle winter habitat.

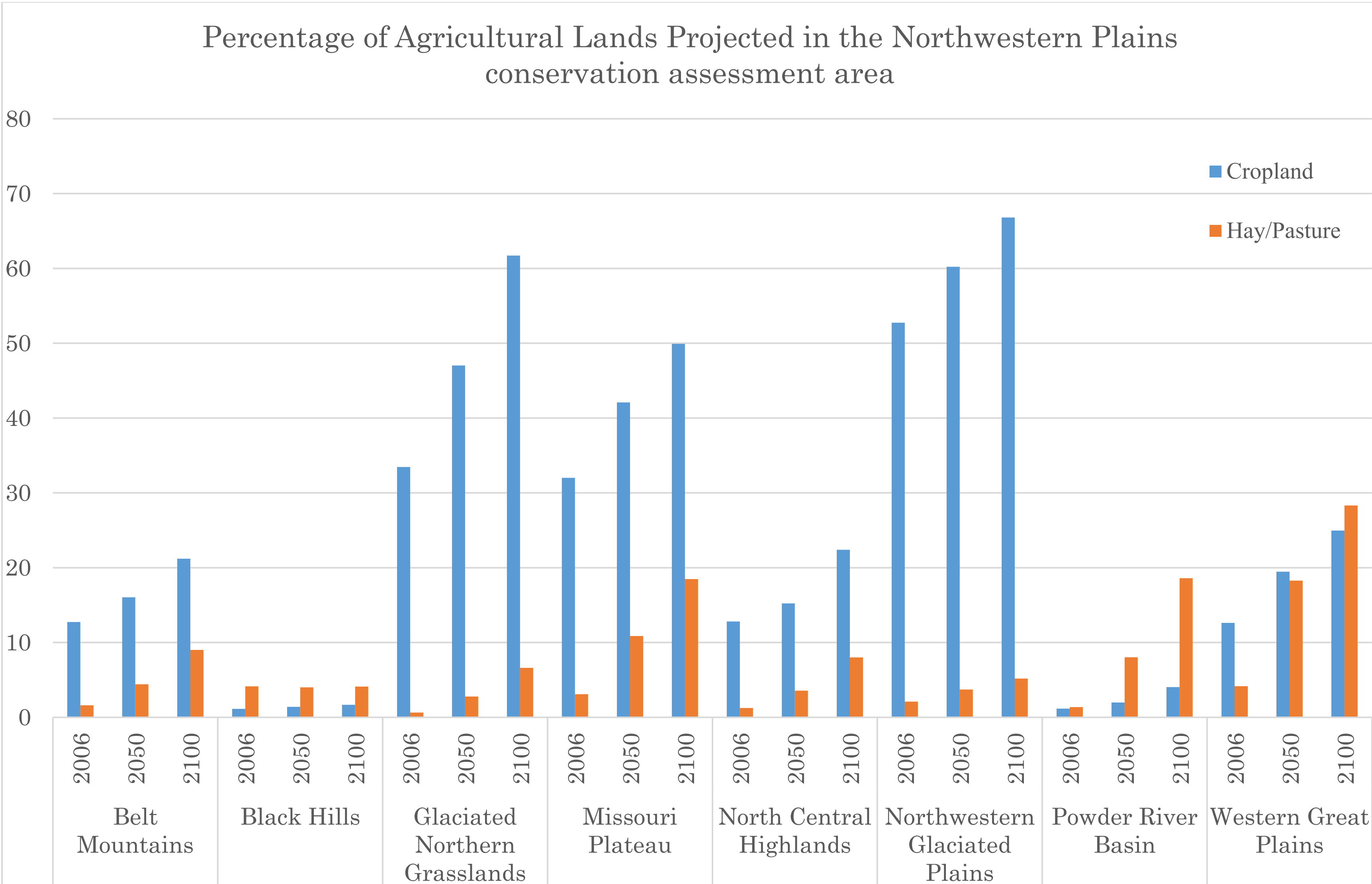


Figure 4.26. Percentage of each ecological sub-region within the Northwestern Plains conservation assessment area projected to be in agricultural land use between 2006–2100.

4.3.5.2. Risk of habitat conversion to agriculture by region

The largest projected conversion to cropland by 2050 occurred in the Missouri Plateau (10,264 km^2), followed by the Western Great Plains (6,966 km^2), the Glaciated Northern Grasslands (4,793 km^2), Northwestern Glaciated Plains (3333 km^2), and North Central Highlands (2,230 km^2). However, the largest increase in percentage of the total sub-region was in the Glaciated Northern Grasslands, increasing from 34% cropland in 2006 to 53% in 2050. The Missouri Plateau is projected to have a similar increase from 35% to 53% (Figure 4.26).

While hay/pasture lands are projected to increase by a much larger percentage of use across years, the total percent of the NWPL in hay production and pasture lands is much smaller than cultivated crops. The Western Great Plains is expected to increase the most, from 4.2% of the total area in 2006 to 18.3% in 2050. The Missouri Plateau was projected to increase hay/pasture lands from 3% to 11% and the Powder River Basin from 1% to 8%. Other sub-regions all were projected to have <5% of the total area as hay/pasture lands.

Much of the northern and eastern portions of the NWPL that is not already used for agricultural purposes is predicated to be converted by 2050 (Figure 3.9). The greatest future risk of habitat conversion within golden eagle breeding habitat is in north-central and central Montana, particularly Garfield, Blaine, Phillips, and Blaine Counties. Continued agriculture in North and South Dakota will have the potential to impact nesting eagles in those areas, but relatively less than other areas within the NWPL due to lower breeding densities in the Dakotas. Conversely, conversion of native habitats to agriculture may have larger impacts in the Dakotas to wintering eagles. In southern North Dakota and South Dakota, habitat conversion may effectively eliminate most of the predicted golden eagle winter habitat (Figure 4.27). Predicted increases in agriculture use in the Powder River Basin were largely driven by increasing hay production and/or pasture lands.

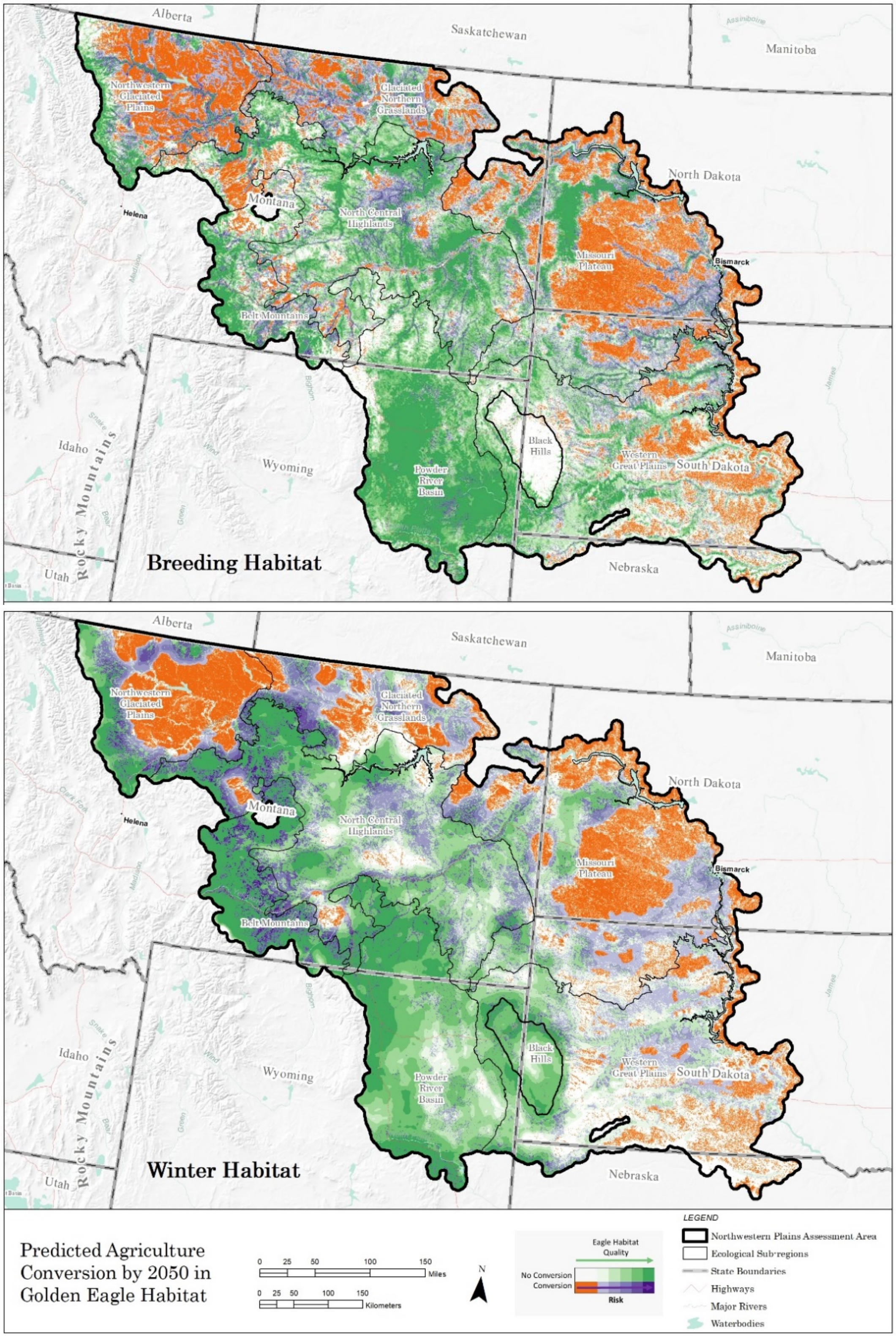


Figure 4.27. Relative risk of habitat predicted to be converted to agricultural use (crops, hay/pasture) by 2050 in golden eagle breeding and winter habitat in the Northwestern Plains conservation assessment area. Colors match the cells in Figure 4.8.

4.3.6. Fire

The risk of fire effects to golden eagles in the NWPL has the potential to decrease densities of breeding and over-wintering golden eagles (see 3.3.4 for details). To spatially assess the fire risk to golden eagles within the NWPL, we overlapped models of eagle breeding and wintering habitats with a probabilistic model of wildfire hazard [USDA Forest Service Large Fire Simulator (Short et al. 2016)]. The Large Fire Simulator predicts the contemporary (not future) burn probability of a wildfire burning in a given 270-m cell as well as fire intensity level (Short et al. 2016, Figure 4.28). Relative to other ecoregions, the NWPL had relatively low fire risk (Figure 4.28). The following maps are relative risk within the NWLP, not relative to a national level.

The resulting risk assessment maps identify areas of elevated fire risk to golden eagles, where high-quality eagle habitat coincides with high burn probabilities and fire intensity. These risk maps can also be used to identify high-priority areas where fire suppression and other conservation measures (detailed in the Conservation Strategy) are expected to provide the greatest benefit to golden eagles in the NWPL. Results of this assessment should be compared with current, local data on burn probabilities, existing fuel loads, and access to fire suppression personnel when assessing the feasibility of mitigation projects. Both breeding and winter risk assessments can be used to refine regional fire response plans, cheatgrass abatement programs, prescribed low-intensity fires to reduce fuel loads, and other fire mitigation techniques.

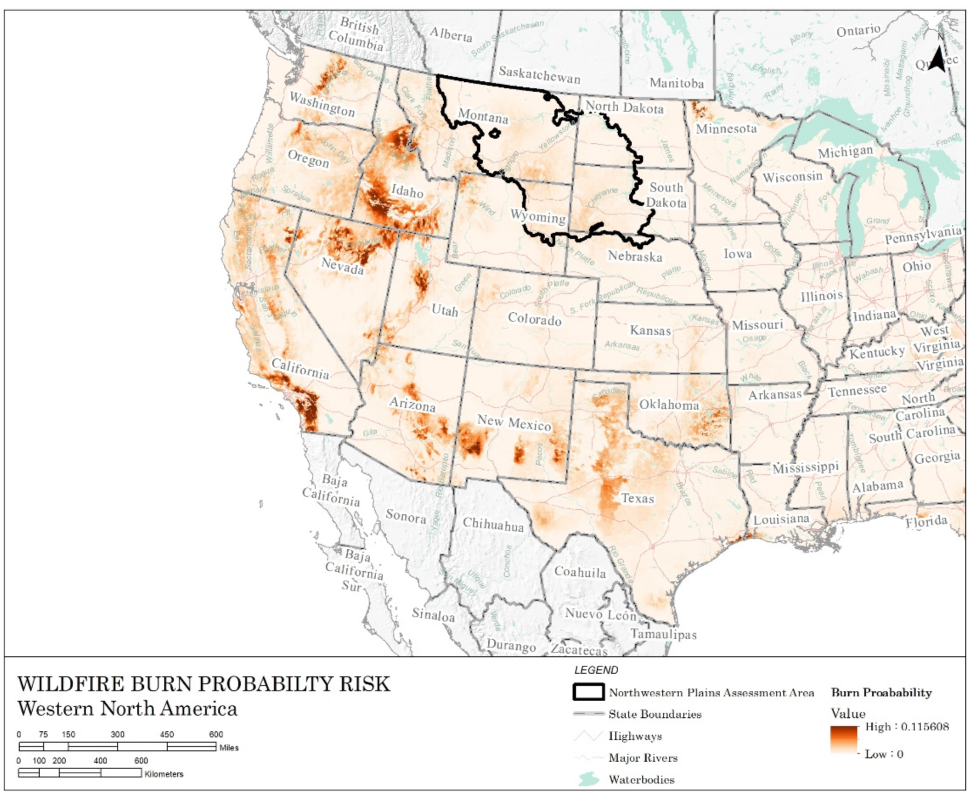


Figure 4.28 Burn probability for the United States from the USDA Forest Service Large Fire Simulator (Short et al. 2016).

4.3.6.1. Risk of Wildfire

The majority of the NWPL has a relatively low burn probability, compared to other western ecoregions, with the exception of the Wyoming Basin. However, there was a fairly high risk of burning within the highest quality breeding habitat (3.0% of the NWPL) and winter habitat (3.1%). An additional 22.5% and 20.6% of the NWPL was within the moderate-to-high risk category for breeding and summer. There were similar amounts of low-risk area across the NWPL during the breeding and winter seasons (39.9% and 41.0%, respectively).

Table 4.7 Relative risk of wildfire burn probability for golden eagles in the Northwestern Plains conservation assessment area within (A) breeding and (B) winter habitats. Colors match the maps in Figure 4.8. Cell values show the percentage of the total assessment area (474,170-km^2) in each risk class.

A Golden Eagle Breeding Habitat

Burn Probability	1	2	3	4	5	6	7
1	6.4	3.8	1.7	0.7	0.5	0.4	0.4
2	3.3	3.2	2.5	1.8	1.5	1.2	1.0
3	2.0	2.3	2.4	2.0	2.0	1.9	1.8
4	1.1	1.8	2.2	2.3	2.4	2.4	2.3
5	0.6	1.5	2.1	2.5	2.6	2.5	2.6
6	0.4	0.9	1.7	2.4	2.7	2.8	3.4
7	0.3	0.8	1.7	2.6	2.7	3.3	3.1

B Golden Eagle Winter Habitat

Burn Probability	1	2	3	4	5	6	7
1	7.2	2.4	1.6	1.1	0.8	0.7	0.5
2	3.9	2.6	1.7	1.6	1.5	1.4	1.6
3	1.7	2.3	2.2	2.2	2.1	1.6	2.4
4	0.7	1.8	2.4	2.7	2.4	1.9	2.4
5	0.5	2.0	2.8	2.7	2.2	2.1	2.1
6	0.2	1.6	2.0	2.4	2.8	2.9	2.3
7	0.1	1.7	1.6	1.7	2.6	3.6	3.0

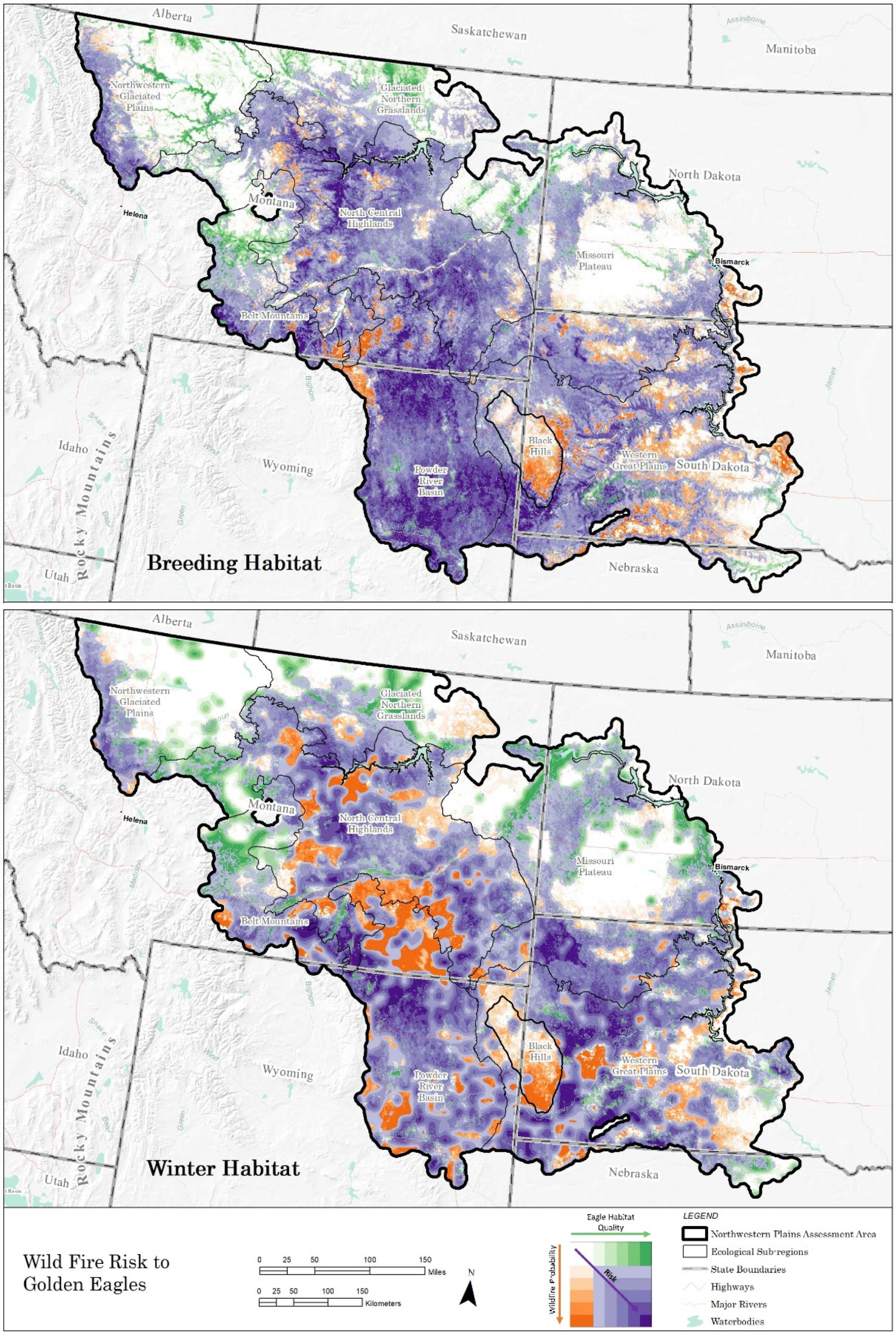


Figure 4.29. Relative risk of wildfire burn probability for golden eagles in the Northwestern Plains conservation assessment area. Colors match the cells in Figure 4.8.

4.3.6.2. Risk by Region

There are key differences in risk from wildfire to eagles by season in the NWPL. Risk to breeding habitat is greatest in the Powder River Basin and along the Missouri River Breaks in the North Central Highlands. Moderate-to-high risk also occurs across much of the southeastern portion of the North Central Highland (in the timbered hills south of the Yellowstone River) and south of the Black Hills along the Wyoming/South Dakota border. Typically, risk is greatest on timbered hills and breaks habitat along river corridors across the Northwest Great Plains. Wildfire risk is less along the northern edge of the NWPL in the Northwest Glaciated Plains.

The Missouri Plateau, Northwest Glaciated Plains, and Glaciated Northern Grasslands all had 4–6 times less than expected risk in golden eagle winter habitat (Figure 4.30). This is likely a result of higher agriculture and northern latitudes of these regions that serve as high quality winter habitat (and not as high quality breeding habitat). Conversely, the Powder River Basin had risk more than four times than expected for winter habitat. The Powder River had slightly more risk than expected to breeding habitat, with 18.8% of the risk and 13.0% of the habitat within the NWPL. The West Great Plains and North Central Highlands both had slightly more risk to breeding habitat than expected. The Belt Mountains and Black Hills had risk proportional to their size, while other sub-regions had less.

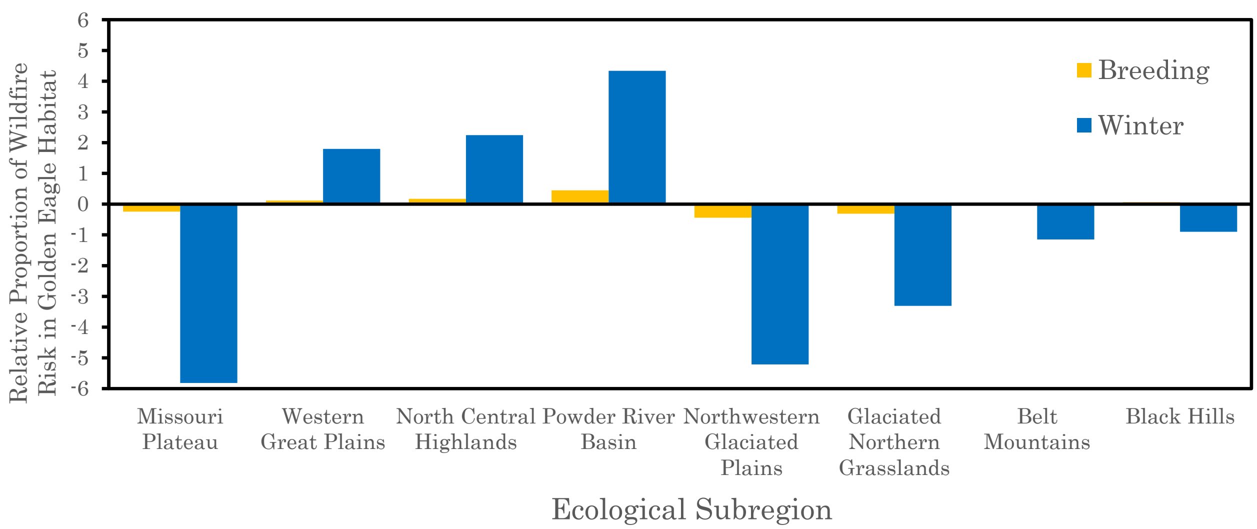


Figure 4.30 Risk of wildfire in breeding and winter habitats of golden eagles by ecological subregion within the Northwestern Plains conservation assessment area. Ratio of the proportions of risk to subregion size is shown. Ecological subregions are shown in descending size order from left to right. Note that the y-axis scale is from -6 to 6.

4.3.6.3. Risk by Managing Entity

The burn probability was relatively proportional to the size of the landowner across the NWPL (Figure 4.31). While >65% of the NWPL is privately owned land, there was a slightly lower risk of wildfire on private lands (62.5%). The greatest proportion of risk was held by the USFS, USFWS, and BLM. The relatively higher risk in USFS lands likely results from the Thunder Basin National Grassland, Buffalo Gap National Grassland and Dakota Prairie Grasslands. Higher risk in USFWS lands was largely due to high risk in much of the Charles M. Russell National Wildlife Refuge. Because risk was proportional to land area (relative to other risks), we did not further classify wildfire risk by BLM office.

Figure 4.31 Proportions of risk relative to area size for wildfire risk in breeding and winter habitats of golden eagles by surface management entity within the Northwestern Plains conservation assessment area. Land managing entities are shown in descending size order from left to right. Note that the y-axis scale is from -0.5 to 0.5.

II. Conservation Strategy

The abundance of golden eagles across the NWPL makes conservation efforts in this region vital to maintaining the golden eagle population in the conterminous United States. The distribution of high quality breeding, wintering, and pre-adult habitats provide both opportunities and challenges for conservation. Further, the scale and geopolitical boundaries in the NWPL provide additional challenges to landscape-scale conservation efforts. Across the region, there are significant differences in habitat quality, with the highest quality priority habitats being generally rare. This offers an opportunity for efficient planning of conservation measures.

Effective conservation and management of golden eagles in the NWPL will require a combination of coordinated, regional- and landscape-scale planning to avoid development and loss of the highest-priority habitat, with implementation of conservation measures to mitigate impacts elsewhere. Proactive, collaborative efforts will be essential to golden eagle conservation, as one federal and four state wildlife agencies manage golden eagles, and two federal land-management agencies (BLM and USFS), 10 Native American tribes, and private landowners manage the majority of habitat in the region, which has little or no permanent protection from development. Partnerships with extractive and agricultural industries will also be essential, as significant hazards to golden eagles result from conventional and renewable energy development and agricultural habitat conversion, which are also the primary economic drivers in the region.

The Conservation Strategy is a collection of conservation measures known to benefit golden eagles and their populations. The focus is on actions with the potential to avoid, minimize, or mitigate regional hazards identified in the Conservation Assessment. Conservation measures include management actions that can be implemented over a range of scales from landscapes, to project areas, to individual nest sites. The maps of priority eagle habitat and spatial risk assessments can be used to target implementation of conservation measures in areas where they will have the greatest benefit. Spatial risk assessments address six key hazards: electrocution, wind resource development, oil and gas development, lead exposure from big game carcasses, habitat conversion to agriculture, and wildfire. Risk assessment maps are useful to inform broad-scale planning and prioritization, especially when less is known about the pattern of a given hazard relative to eagle habitat. For other hazards, maps of priority eagle habitat can be used in combination with regional knowledge of hazards to guide spatial planning. This approach may be more useful when region-wide spatial data on a hazard are lacking, the location of a hazard is already well known, or the area of interest is constrained (e.g., by state, management agency, project area).

The conservation measures described here are not officially endorsed by USFWS and do not represent a complete list of possible management actions to benefit golden eagles. Rather, they are intended as a “toolbox” of techniques and recommendations to be considered in management planning (e.g., Resource Management Plans, Forest Plans, Avian Protection Plans), and implemented proactively by government, tribal, NGO, and industry partners. Because these measures do not constitute a coordinated plan, each agency or entity will be independently responsible for measuring success and adapting management actions to meet management objectives.

1. Electrocution prevention

Electrocution on power infrastructure is a leading cause of mortality for golden eagles in North America (USFWS 2016). Best management practices (BMPs) for avoidance and minimization of raptor electrocutions have been the subject of extensive research (see Electrocution above). The most complete source of information on preventing avian electrocution is the Avian Power Line Interaction Committee (APLIC; http://www.aplic.org/).

To assess the risk of electrocution in the NWPL, we overlapped spatial models of golden eagle habitat and distribution pole density. The resulting risk assessment maps and information can be used for conservation planning and to prioritize retrofitting of power poles in higher-risk areas.

Avoidance: lower-risk construction

All utility providers should have a current and regularly updated avian protection plan (APLIC and USFWS 2005). For new construction projects or poles rebuilt due to car-strikes, weather events, etc. the best approach is to build structures with configurations likely to avoid or greatly reduce the potential for electrocution. Critical dimensions and configurations of electrical equipment necessary to prevent electrocution of golden eagles are detailed in Dwyer et al. (2015). In the NWPL, construction of new distribution lines in golden eagle habitat is often associated with energy development, rural and suburban housing, and agriculture (Dwyer et al. 2016). Agencies and entities with permitting authority for power distribution projects should use APLIC BMPs to build infrastructure to "eagle-friendly" standards. Spacing of equipment sufficient to avoid electrocution of golden eagles will have the added benefit of preventing electrocution of other raptors because eagles are the largest raptor regularly found in the NWPL.

Minimization and mitigation: power pole retrofits

When potentially hazardous equipment has been installed, poles should be retrofitted to minimize risk. The spatial risk assessment in this report can be used to prioritize retrofitting efforts in areas with higher concentrations of power poles and eagle use. WGET risk maps (See I.4.2) can be complemented by local knowledge on patterns of eagle use, nest sites, eagle electrocution locations, industry data on dangerous pole configurations, and information on where retrofits have already been implemented. For mitigation efforts, the highest risk areas within or closest to the project areas should be prioritized to offset local-area mortality (Cole 2011, USFWS 2013). Once priority areas are selected, the riskiest poles can be identified on the ground and prioritized for remediation (APLIC 2006, APLIC 2014). Longevity and type of modification (e.g., pole rebuild, covers, perch discouragers) should be considered based on local area conditions and desired outcome of the mitigation effort. The greatest benefit to eagles in the NWPL is rebuilding poles to conform to APLIC (2006) standards, followed by properly installed retrofit covers, then perch discouragers

(Dwyer et al. 2017a). Retrofitting should follow BMPs for equipment selection, training of installers, and installation of covers and perch discouragers to maximize their effectiveness and avoid common errors that can make retrofits ineffective or even increase risk (Dwyer et al. 2017b). Any remedial actions should be regularly inspected, maintained, and monitored to maximize the success of this mitigation technique.

In the event that golden eagles build a nest on existing power distribution poles, the nest should be moved to reduce electrocution risk to both breeding adults and young. Proper training of linepersons should be conducted prior to moving a nest and the new nesting platforms should conform to known standards for golden eagle nests (McKee 2018). A USFWS permit is required for moving nests, but generally can be quickly acquired with consultation with the regional USFWS personnel. Nests relocated should be on a separate pole taller than nearby power poles, have proper shading and drainage, an attached perch, and be located further from existing roads than the power poles. All power poles within the territory should also be retrofitted to reduce electrocution risk during perching and to dissuade future nest building.

Research and monitoring

Detailed locations and configurations of power distribution poles across the NWPL does not currently exist. Data on raptor electrocution collected in the NWPL vary among utility providers and agencies. While there are guidelines for data collection (APLIC 2006), no central repository for data storage exists among the NWPL or at a national level. Coordinated monitoring and data compilation among providers within the NWPL could improve efforts to prevent electrocutions by providing data necessary to refine risk models and improve understanding of environmental, seasonal, and behavioral risk factors. Monitoring should include areas where poles have already been retrofitted to verify that retrofits are functioning properly (Dwyer et al. 2017b). Reporting of avian electrocutions also varies among utility providers in the NWPL. Education and outreach to encourage utility personnel to document and report electrocutions could improve knowledge of this problem in the region. Similarly, education of industry and agencies on best practices for retrofitting could reduce errors that make retrofits ineffective or even increase risk. Guidance documents on avian protection plans, reducing electrocutions and strikes, suggested BMPs, mitigation techniques, and mitigation agreements are provided by the USFWS online.

2. Wind resource development

The potential for conflict between commercial wind resource development and golden eagles is high in much of the NWPL, due to the region's high wind speeds and high-quality eagle habitat (see Wind Resource Development above). Wind energy development is the only hazard to golden eagles with a Federal permitting and mitigation framework (USFWS 2013). Retrofitting of electrical poles is the only currently approved form of mitigation for permitted take of golden eagles at wind energy facilities. However, other mitigation options are in development (Allison et al. 2017) and many other techniques are available to proactively reduce impacts to eagles. These include siting wind energy facilities away from high-quality golden eagle habitats (all seasons and migration areas), micro-siting turbines in portions of project areas with lower eagle use, curtailing turbines when eagles are nearby, supporting research on interactions between eagles and windfarms, and improving regional population monitoring.

To assess the risk of wind resource development in the NWPL, we overlapped spatial models of golden eagle habitat and wind speeds. The resulting risk assessment maps and information can be used to inform implementation of conservation measures and siting of wind energy developments.

Avoidance: siting and design

Landscape-scale siting of wind energy facilities away from concentrations of nesting, wintering, and migrating eagles is the best way to avoid turbine strikes. The spatial risk assessment in this report can be used to identify areas of opportunity for development with high wind speeds in relatively low-quality golden eagle habitat. Within the NWPL, there are many areas with low risk to eagles with high wind potential. These areas tend to be in agriculturally developed areas in North and South Dakota, and few areas in northern Montana (Figure 4.16). The spatial risk assessments and important habitat maps can be complemented by regional knowledge on other considerations for development, like access to transmission, land ownership and management, and permitting. The spatial risk assessments should also be used with local-knowledge and site-specific surveys for nests, wintering eagles, and migrants following USFWS (2013) survey protocols. Developments within the home ranges of nesting eagles should be avoided to reduce risk to breeding eagles.

A feasible way to reduce wind/wildlife conflict is siting wind energy developments in areas where wildlife habitat has already been disturbed by other activities, like conventional energy development, agriculture, and human settlement (Kiesecker et al. 2011). Technological progress towards more efficient and safer turbines is an important consideration for long-term planning of development. Vertical axis turbines may reduce avian collision rates and bladeless "vibration" turbines can significantly reduce risk from wind energy harvesting. Alternatively, taller towers and longer blades are expected to allow commercially viable development of areas with lower wind speeds, which can allow for greater flexibility of siting in low-risk areas to eagles.

Minimization: micro-siting and curtailment

Once a project has been sited in golden eagle habitat, collisions can be minimized by placing turbines in areas used less frequently by golden eagles, but this does not eliminate risk. Determining patterns of eagle use should be documented using on-the-ground field methods recommended by USFWS (2013). Likewise, individual turbine curtailment can be used to reduce risk to eagles. At facilities within the NWPL, like Top of the World, observers in a tower centrally located within the project can curtail individual turbines when eagles are observed nearby. Technological advances in automated eagle detection hardware and software (e.g., IdentiFlight) have shown promise in the curtailment methods but need further research on effectiveness before widespread use across the NWPL.

Mitigation: power pole retrofits

Power pole retrofitting is the only currently approved method to mitigate programmatic take of golden eagles at wind energy facilities (USFWS 2013). Maps from the spatial risk assessment in this report can be used to prioritize retrofitting efforts in areas with higher concentrations of both eagle use and power poles. Further information on implementation of retrofits is included in the conservation strategy for electrocution prevention.

Research and monitoring

Ongoing research and monitoring are necessary to improve strategies to reduce golden eagle mortality from wind turbine strikes. At the project scale, surveys of nest sites and habitat use are recommended by USFWS (2013) to characterize the level of risk and estimate annual take for permitting. Project-scale monitoring should be complimented with regional-scale surveys to estimate population trends and cumulative impacts. Golden eagle population trend estimates are currently available at the scale of BCRs (Nielson et al. 2014), but data on trends specific to the NWPL or states within the region are lacking. Standardization of monitoring protocols and increased data sharing among industry, agencies, and researchers would increase the value of project-level data by allowing them to be compared more directly. Similarly, collaboration among state agencies and other regional groups could support regional-scale population monitoring, or enable broad-scale monitoring programs, like the USFWS western golden eagle survey (Nielson et al. 2014), to be scaled down to areas smaller than BCRs. In addition to monitoring of trend and distribution, further research is necessary to understand behavior of golden eagles around wind turbines. Studies from other regions on interactions of golden eagles with wind energy developments should be replicated in the NWPL to test their applicability in the region.

Additional research is needed to provide alternative mitigation options (Allison 2017). Spatial assessments of risks, such as lead ammunition for big game hunting, can be used in modeling frameworks (e.g., Cochrane et al. 2015) to create defensible estimates of eagles "saved" within the NWPL. Other potential mitigation options in the NWPL include nest site enhancement (e.g., cottonwood planting, artificial nesting platforms), prey enhancement or supplementation, and road-kill carcass removal, but need more research before they meet the quantitative requirements for mitigating eagle take from wind development (USFWS 2013).

3. Oil and gas development, mining, and power generation

The extraction of oil, gas, and mineral resources is not a direct threat to golden eagles; however, energy development can significantly reduce and/or alter both breeding and foraging habitat and requires infrastructure and activities that increase hazards with known negative effects (see Oil and gas development above). These include electrocution on distribution lines, collisions with vehicles, collisions with transmission structures, increased road access for persecution of eagles and their prey, drowning in oil waste pits, and disturbance by vehicle traffic, human presence, and other activities associated with construction and maintenance of facilities. Disturbance can be at both nest sites and foraging habitat, which may lead to decreased use by eagles. Habitat fragmentation and loss from roads, train tracks, well pads, mining pits, and other infrastructure increases risk of noxious weeds and changes in prey populations. Mining and other power generation activities in the NWPL are generally confined and there is a low probability of new large-scale activities. Conservation measures for mining activities generally include minimizing, mitigation, and reclamation. Conversely, oil and gas development is likely to increase areas in production. Conservation measures for oil and gas development consist of strategies to avoid and minimize associated hazards.

To assess the risk of oil and gas development in the NWPL, we overlapped spatial models of golden eagle habitat and oil and gas development potential. The resulting risk assessment maps and information can be used to inform implementation of conservation measures and siting of oil and gas developments.

Avoidance: siting and design

Mining

Generally, new large-scale mines are not likely to occur in the NWPL due to falling economic incentives for coal production in the United States, the primary mining resource in the region. Siting of new mines and other energy facilities away from high-value eagle habitats is the best method to avoid impacts to eagles in the NWPL. For smaller-scale mining activities and other mineral extraction activities, models of golden eagle breeding and winter habitat can be used to avoid high-value eagle habitats. Models should be used with local knowledge of nesting territories and nest surveys within and around the project area to avoid occupied territories.

Oil and gas

Landscape-scale siting of oil and gas fields and associated facilities away from concentrations of nesting, wintering, and migrating eagles is the best way to avoid impacts. The spatial risk assessment and maps in this report can be used to identify areas of opportunity for development in relatively low-quality golden eagle habitat. In practice, however, consideration of golden eagle habitat is unlikely to influence broad-scale siting of fossil fuel developments. Instead, avoidance and minimization of impacts to golden eagles are more likely to happen in the design and configuration of energy developments. These include siting infrastructure, like wells, power lines, access roads, and oil pits away from high-quality eagle habitat. No-surface-occupancy (NSO) buffers and seasonal timing restrictions are required in agency management plans for some areas. Siting, NSO buffers, and seasonal timing restrictions have typically been used around nest sites, but information on the territory (when known) can greatly enhance the protections for nesting eagles. Using these avoidance techniques at a territory-level, rather than at a singular nest location, can provide more robust protections for nesting eagles. Similarly, eagle-vehicle collisions can be avoided if roads maintained as non-paved with low speed limits or are sited away from nest sites and important foraging areas, like prairie dog colonies (U.S.

Bureau of Land Management 2007). Construction of new infrastructure in energy fields is an opportunity for agencies to require BMPs, like configuration of distribution poles to prevent electrocution and covering oil pits with netting.

<u>Minimization</u>: reduce threats from known hazards

Mining

Most existing mining permits outline eagle disturbance minimization strategies, including annual nesting surveys, weekly nest monitoring of in-use nests, prey surveys, and continual monitoring during blasting activities near nests within the project area, where observers can delay mining activities if eagles appear disturbed. At mines where activities approach existing nests, active nests have been successfully moved to nesting platforms to reduce negative fecundity effects (McKee 2018). Nest removal from high-walls or moving known nest requires and USFWS permit.

Conservation measures can be used to mitigate risks from other associated infrastructure, including retrofitting distribution poles to prevent electrocution and removing road-kill/ train-kill animals to minimize risk of eagle-vehicle and eagle-train collisions. Persecution can be minimized through education of mining personnel and the general public about the value and legal protections of raptors.

Oil and gas

In existing developments where avoidance measures were not implemented, conservation measures can be used to mitigate risks. These include retrofitting distribution poles to prevent electrocution, reducing speed limits and removing road-killed animals to minimize risk of eagle-vehicle collisions, and covering oil pits with netting (flagging only is not sufficient to prevent drowning; USFWS 2017a). Where NSO buffers have not been implemented, disturbance of nesting eagles can be minimized with seasonal buffers for construction and other disturbing activities. Persecution can be minimized through education of oil and gas field personnel and the general public about the value and legal protections of raptors.

<u>Mitigation</u>: Reclamation

Reclamation is required on federal lands (BLM, USFS) for any energy extraction activity that required a federal action, such as Environmental Impact Statement or Environmental Analysis. A reclamation plan and strategy should be designed with 1) an initial phase to stabilize the area and control runoff or erosion, 2) an interim phase to restore vegetation and landcover in any areas not essential for operational function during the project, and 3) final reclamation and restoration to return the land to the approximate condition and function prior to disturbance. Reclamation plans should follow any BLM or USFS BMPs for the region. Specific to golden eagles, reclamation plans should replace any lost nesting habitat (e.g., cottonwood trees) and prey habitat, particularly for lagomorphs and prairie dogs.

Research and monitoring

Standardization of methods and metrics for eagle monitoring in the NWPL are needed to facilitate the integration of project-level datasets to inform management. Large amounts of nest monitoring data are collected in oil and gas fields and other energy developments across the NWPL every year. Unfortunately, the lack of standardized survey protocols, datasheets, data repositories, and not releasing proprietary data limit the ability to combine these data in regional-scale analyses. Additionally, project-level monitoring is rarely implemented as part of broader, design-based studies and/or monitoring is not conducted adequately for survival analysis or delineation of nesting territories. This limits the ability to make inference on urgent management questions, including impacts of disturbance to golden eagles nesting near resource extraction, effectiveness of current measures used to minimize disturbance (i.e., nest buffers), and effects of development on prey.

Greater coordination is needed among producers, consulting biologists, and other parties monitoring and/or researching eagle nests near developments. Often, several producers will conduct surveys for and monitor nests within a gas field and associated buffers that overlap each other. When these surveys are completed aerially or close to nests, disturbance risk increases proportionally to the number of times the nest is surveyed. To reduce this risk (and minimize expenditures), all parties conducting nesting surveys in or near a gas field should coordinate data collection activities prior to each nesting season.

4. Collisions with vehicles

Golden eagles are known to collide with vehicles, including motor vehicles, trains, and occasionally aircraft (see Collisions with Vehicles above). Risk of collisions generally increases with traffic volume, in areas with higher densities of ungulates and lagomorphs, during the fall/winter, and in high-use eagle habitat. However, traffic can reach a volume in which vehicles are almost constantly on the roadway that will generally preclude eagle use and therefore reduce risk (e.g., interstate highways).

Avoidance: siting

To avoid collisions, roads can be routed away from nest sites, known foraging and wintering areas, and other high-use habitats. Maps of golden eagle habitat priority areas in this report can be used to route roads away from important habitats.

Minimization: signage, speed limits, carcass removal

Risk of collision can be minimized by signage, reduced speed limits, not paving rural roads, and removal of road-killed animals from the right-of-way that attract golden eagles to roads. Maps of golden eagle habitat priority areas in this report can be used to target conservation measures like carcass removal in areas where they will provide the greatest benefit to eagles. In Montana, state laws allow residents to salvage vehicle-killed ungulates for personal consumption, and >1,000 salvage permits were estimated to have been issued in 2014 (Field 2016). Adoption of this practice in other states in the NWPL can significantly reduce road-killed wildlife along roadways. In high volume ungulate movement corridors, wildlife-safe crossings can be constructed to significantly reduce ungulate collisions (McCollister and Van Manen 2010). Wildlife warning reflectors are not an effective method to minimize ungulate collisions and should not be used as a technique to reduce vehicle-wildlife collisions (Benten et al. 2018). Removing road-killed animals during the fall and winter will have the greatest impact to eagle populations in the NWPL. Ungulates should be removed from the right-of-way but not completely removed from the system because this is a valuable food resource to eagles in the NWPL. Further, smaller animals, such as lagomorphs, should also be moved because they may put eagles at a higher risk than road-killed ungulates. Smaller animals tend to stay within the roadway and may become frozen to the pavement in winter and eagles may stay on the road-kill longer, trying to remove it from the roadway before vehicles approach.

Train-wildlife collisions are generally not reported in the United States due to a low frequency of passenger trains, but train-wildlife collisions can exceed vehicle-wildlife collisions in Europe, where is has been extensively studied (Seiler and Olsson 2017). To date, the only effective strategy to reduce train-wildlife collisions has been acoustic warnings using natural predator and conspecific alarm ungulate calls (Barbinska-werka et al. 2015). Eagles frequenting airports can be hazed away from runways using trained birds of prey or other techniques; hazing and harassment of golden eagles requires a permit from USFWS.

Research and monitoring

Greater coordination is needed for road-kill reporting among transportation department personnel, between states, and other reporting agencies (e.g., law enforcement, game wardens). There is a need for standardizing data collection methods, smartphone apps, and data storage. There is a lack of reporting of smaller vehicle-killed animals in most state transportation department's databases. Creating an easier data collection and entry methods may aid in gathering more and consistent data on all road-killed animals, including eagles. Further research is necessary to identify hot spots of vehicle collision where and when conservation measures can be applied, as well as to quantify the effectiveness of techniques, like carcass removal, wildlife safe crossings, and speed limit reductions.

5. Contaminants

Exposure to environmental contaminants is a significant threat to golden eagle populations (see Contaminants above). While the extent of exposure and population-level effects to golden eagles from most contaminants remain poorly understood, conservation measures are available to proactively avoid and minimize their impacts.

5.1. Lead poisoning

Lead poisoning is a widespread and persistent hazard to golden eagles in North America, mainly from ammunition sources (see Lead above).

Avoidance and minimization: non-lead ammunition and gut pile removal

Voluntary incentive programs for use of non-lead ammunition and removal of big game gut piles have been proposed as mitigation measures to offset permitted take of golden eagles. Results of simulations by Cochrane et al. (2015) suggested median golden eagle mortality in the area around Casper, Wyoming could be reduced by 50% if half of hunters switched to non-lead ammunition, while removal of 50% of big game gut piles reduced mortality rates by only 30%. Although gut pile removal may be an option for some areas in the NWPL, it is not feasible for elk hunting due to the size and weight of gut piles. Burial of gut piles will have limited effectiveness because many will be exposed by mammals (e.g., black bear, coyotes, fox, etc). The best option for avoiding lead ingestion by eagles from gut piles is voluntary programs to incentivize use of non-lead ammunition for hunting. Such programs have been successful in areas of Wyoming and Utah outside the NWPL (Bedrosian et al. 2012, Utah Division of Wildlife Resources 2017). Once hunters have sighted their rifle(s) in for non-lead ammunition, they usually continue using that type of ammunition (B. Bedrosian, personal observation). This method allows for long-term use of non-lead ammunition and passing down methods between generations of hunters.

While data do not exist for the prevalence of lead ingestion from golden eagles foraging on wounded or unrecovered upland game, this is certainly an avenue of lead ingestion in golden eagles in the NWPL. Similar to big game hunting, use of non-lead shotgun ammunition is the best method for avoiding lead ingestion in golden eagles across the NWPL. Both big game and upland game hunting are additive sources of lead ingestion and reduction of lead use for one or both will have benefits to eagle populations.

Varmint shooting is an additional source of lead ingestion in both adult and nestling golden eagles in the NWPL. Exposure to nestling eagles may result in higher risk because of increased effects during development (Herring et al., in Review). Of 258 nestling golden eagles tested for lead exposure across the West (including the Wyoming Basin, but not the NWPL), >30% of nestlings had lead levels above background from ingesting shot varmints (Herring et al. in Review). Eaglets with high lead levels also had reduced delta-aminolevulinic acid dehydratase activity, suggesting anemia and cellular damage. Using non-lead ammunition for varmint hunting and removal will result in reducing lead exposure in eagles across the NWPL. Alternatively, removal of shot varmints is much more feasible than big game gut pile removal and an option to reduce lead occurrence. Varmints are often small, easy to locate, and relatively accessible once dead. We suggest managers require hunters to remove of any varmints shot with lead ammunition in the NWPL as an alternative to regulating ammunition type.

Maps from this report overlapping hunt-unit level data on big game harvest in the NWPL with seasonal models of golden eagle habitat could be used to identify priority areas for mitigation efforts. Unlike big game harvest, spatial data on locations of upland game hunting and varmint shooting are not available; instead, regional knowledge of hunting and shooting hot spots (e.g., Thunder Basin National Forest, Wyoming) could be used in concert with maps of golden eagle habitat to prioritize areas to incentivize use of non-lead ammunition, removal of carcasses, or cessation of varmint shooting.

Research and monitoring

Further research is necessary to understand sub-lethal effects of lead exposure on golden eagle and nestlings. Additionally, most research has been conducted on migrating eagles and less is known about impacts and pathways for exposure to lead for breeding adult eagles, nestlings and over-winter eagles in the NWPL. There is a notable lack of knowledge on lead ingestion risk to eagles from crippled and un-retrieved upland game birds. Ongoing efforts to test lead concentrations in live eagles and carcasses will contribute to understanding the problem in the NWPL.

5.2. Anti-coagulants and other poisons

Poisoning by anti-coagulant rodenticides (ARs) is increasingly recognized as a hazard to golden eagles and other raptors (see Anticoagulant rodenticides above). The extent of AR use in the NWPL is unknown, but is likely restricted to local efforts to control sciurid populations on private lands and ¼ buffers into some USFS lands (e.g., Thunder Basin National Grasslands) surrounding private ranches (USFWS 2017c). AR use is prohibited on other USFS lands (e.g., Dakota Prairie Grasslands) and BLM lands, except where rodent colonies threaten human health. Use of chlorophacione (e.g., Rozol®) is prohibited by USFWS in black-footed ferret management areas (USFWS 2017c). Thunder Basin National Grasslands is currently proposing to allow landowners to request up to a ¾ mile buffer zone surrounding private lands and the use of rodenticides (not ARs) within the Grasslands (USDA 2019).

Avoidance and minimization:

Poisoning can be avoided through incentives for private landowners and lessees not to use ARs in areas frequented by golden eagles. Efforts for black-footed ferret conservation in the adjacent WYUB provide a model of successful, collaborative management of prairie-dog habitat that could benefit golden eagles. Additionally, alternative control methods to ARs should be used, such as 2% zinc phosphide treated oats or gas incendiary devices, which are not known to produce secondary effects for scavengers. Maps of golden eagle habitat priority areas in this report can be used to target conservation measures like cessation of AR use in areas where they will provide the greatest benefit to eagles. Other poisons responsible for killing eagles in the NWPL include the agricultural euthanasia agent pentobarbital. To minimize poisoning of golden eagles, carcasses of animals euthanized with pentobarbital or other chemicals should be buried, covered, or incinerated.

Research and monitoring

Better data on the magnitude and locations of AR use in the NWPL is necessary to understand effects on golden eagles. Data on amounts and locations of AR application could be required with the Restricted Use Pesticide Applicator's License necessary to use of ARs, and by BLM when use of ARs is permitted on public lands. Further research is also needed on the pathways of AR exposure, and effects of ARs on reproduction and behavior of eagles. Linking data on AR exposure to characteristics of eagle habitat, like human settlement and agriculture, could support spatial risk assessments to inform planning.

6. Diseases and parasites

Diseases and parasites of golden eagles are not currently known to be widespread in the NWPL; however, changes in climate and land use could increase exposure of eagles to both native and introduced pathogens (see Diseases and parasites above). Insect-borne pathogens (e.g., WNv from mosquitoes and leucocytozoonosis from blackflies) and insect pests (e.g., blow flies, Mexican chicken bugs) could increase in response to rising temperatures and changing precipitation regimes (Walker and Naugle 2011). Diseases vectored by prey of golden eagles (e.g., trichomaniasis from pigeons or Eurasian collared doves and avian cholera from waterfowl) could increase if habitats of primary prey species are lost to wildfire or other disturbances (Heath and Kochert 2015) or if non-native species continue to increase their ranges and abundance.

Avoidance and minimization: habitat management and nest treatment

Conservation measures to minimize diseases and parasites involve habitat management or treatment of eagles and nests. None of these techniques have been applied and broad scales and should currently be considered experimental. Research on management strategies to prevent WNv in wildlife, which has focused on greater sage-grouse, suggests risk of WNv could be reduced through mosquito control and limiting the extent of human-made surface water (Walker and Naugle 2011). Conversely, Hokit et al. (in Review) suggest that limited surface water may lead to increasing prevalence of WNv by concentrating mosquito breeding areas. Efforts should taken to conserve and expand bat populations across the NWPL to naturally aid mosquito control. Limiting surface water may also reduce exposure to leucocytozoon, which is spread by blackflies. Preservation and restoration of native prey habitat could prevent dietary shifts to rock pigeons and Eurasian collared doves that vector trichomaniasis and waterfowl that vector avian cholera (Heath and Kochert 2015). If nests with parasites are identified, medical treatments are available for trichomaniasis. Similarly, application of insecticides to control Mexican chicken bugs and other ectoparasites have proven effective. Such intensive nest management is unlikely to be practical at a broad scale, but may be applicable for local study areas, mitigation banks, and other areas where nests are closely monitored. Maps of golden eagle habitat priority areas in this report can be combined with regional knowledge on patterns of risk to target conservation measures in areas where they will provide the greatest benefit to eagles.

Research and monitoring

Data on diseases and parasites are limited to eagles that are found opportunistically and submitted to wildlife laboratories or captured for research purposes. Increased sampling effort is necessary to determine the current prevalence of diseases and parasites of the golden eagles in the NWPL and establish baselines to detect potential increases in response to changing conditions. Additional research on the prevalence of trichomoniasis in pigeons and collared doves and the extent to which eagles prey on these species is needed before removal programs are initiated. Additional research on the efficacy of the WNv vaccine for nestlings to determine its utility at project-level scales or in mitigation banks.

7. Prey resource limitation

Healthy prey populations are vital to the reproduction and survival of golden eagles (see Prey resource limitation above). Despite the necessity of small mammalian prey to eagles and other raptors, relatively little research is available on the habitat requirements of prey species or management strategies to sustain prey populations in perpetuity. Studies in the Bighorn Basin, WY (Preston et al. 2017a) and elsewhere (reviewed in Bedrosian et al. 2017) have established a strong link between prey abundance and golden eagle productivity, but none have quantified the baseline densities of prey required for successful reproduction or the extent and condition of habitat required to support sufficient prey.

Avoidance and minimization: prey habitat conservation and management

Management techniques that conserve or restore native vegetation in golden eagle habitat are expected to support the long-term persistence of eagle populations. Compared to other regions in the West, much of the native habitats in the NWPL are at risk from agriculture conversion. With the increasing demand for biofuels and climate change extending the growing season, much of the native prairies are expected to be tilled in the future. The focus of management should be on maintaining native grasslands and sagebrush steppe. Programs like the CRP should be maintained and expanded in the NWPL. As CRP enrollments expire across the NWPL, landowners should be encouraged to continue and/or create new enrollments. Maps of golden eagle priority habitat can be used to prioritize CRP enrollment programs and increasing CRP rental rates in high value eagle habitats could encourage enrollments that would increase prey habitats in the NWPL.

In addition to habitat loss, prey species may be negatively affected by habitat fragmentation from anthropogenic development (e.g., energy development, exurban expansion) and associated infrastructure (e.g., roads, well pads, pipelines, power lines). Current research on habitat fragmentation is equivocal, with indications that anthropogenic infrastructure could increase densities of some small mammals, while negatively affecting others. Management strategies that preserve native vegetation communities are expected to provide the greatest benefits, until the thresholds at which surface disturbance constitutes habitat loss for golden eagles and their prey are firmly established.

Diets of golden eagles in the NWPL are variable, but tend to be dominated by locally-available prey species (see Prey community above). Minimization of varmint shooting and poisoning in areas where golden eagles rely on prairie dogs is a possible management strategy to support reproductive success of eagles. Limiting varmint shooting and poisoning in eagle habitat may also have the added benefit of reducing exposure to poisons and lead from carcasses. Burrow dusting with deltamethrin or providing oral vaccinations against sylvatic plague to prairie dogs will help reduce the abundance and extent of colony collapses and should be used as a management technique in high quality eagle habitat. Reducing hunting quotas for deer and pronghorn in high quality eagle habitat may also provide benefit to eagles by both reducing lead risk from gut piles but also increasing these prey populations. Actions to increase prey populations are likely to have an added, positive impact to sheep ranchers and sage-grouse populations within the NWPL because predation risk to lambs, calves, and sage-grouse could decrease if eagles are not food stressed due to low native prey densities.

Research and monitoring

More research is necessary to understand distribution and habitat associations of golden eagle prey species in the NWPL. Few contemporary studies exist across the NWPL on golden eagle prey selection. Increasing regional knowledge of prey selection by eagles can help direct prey and prey habitat enhancement efforts. Restoration of prey habitat to increase golden eagle productivity has been proposed as a possible mitigation strategy for take of eagles; however, current knowledge of golden eagle ecology is insufficient to support this approach. Implementation of prey-based mitigation would require regional studies to quantify both the relationship of habitat conditions to prey density and prey density to golden eagle reproduction. Monitoring and maintenance of prairie dogs is needed to prevent large-scale colony collapses that negatively affect eagle fecundity and abundance. Ongoing studies of vegetation treatments for greater sage-grouse offer an opportunity for collaborative research to understand effects of habitat manipulations on key prey species of golden eagles in sagebrush steppe habitats; however, research funding is rarely dedicated to jackrabbits and cottontails because they are not considered species of concern. Potential impacts of climate change on prey abundance are unknown, including direct (i.e., physiological) and indirect (i.e., habitat-mediated) effects. Finally, fluctuations of leporid populations remain poorly understood. Rigorous, long-term monitoring of golden eagles and their prey are needed to clarify the role of prey abundance in eagle reproduction, and to separate cyclic, prey-driven variation in breeding success from potential long-term declines.

8. Disturbance by recreation

Recreational activities, like OHV riding, hiking, boating, and rock climbing can have negative effects on reproductive success of golden eagles (see OHVs and other recreational activities above). Disturbance by recreation is minimal in most areas of the NWPL relative to other ecoregions, but is likely to increase as demand for backcountry access and OHV vehicle use increases in popularity. The best times to consider disturbance effects from increased backcountry and OHV use is prior to the disturbance occurring, instead of mitigating for effects after. Hence, there is an opportunity in the NWPL to create management goals and avoidance guidelines prior to negative effects to golden eagles.

Avoidance: siting and design of road and trail systems

Disturbance to golden eagles from recreation can be avoided by routing roads and trails away from nest sites, foraging areas, and other high-use habitats. Comprehensive maps of roads and OHV trails are not available for the NWPL. Instead, maps of golden eagle habitat priority areas in this report can be used in conjunction with regional knowledge on hot spots of recreational use to inform road and trail design as forest service offices and other land managers revisit travel management plans. Local, ranching, and farming OHV use should be avoided or minimized near any active nest(s) when possible.

Minimization: seasonal closures

Conflicts of motorized and non-motorized recreation with golden eagles can be minimized with seasonal restrictions on heavily used roads, trails, or climbing routes in priority eagle habitats. These include seasonal restriction of rock climbing, hiking, OHV riding, and other activities taking place near nest sites. Research in the Snake River Plain ecoregion showed that motorized and non-motorized recreation had negative effects at different stages of the nesting cycle (Spaul and Heath 2016). Results from this study can inform timing of seasonal restrictions for different types of recreation. For example, areas with higher average seasonal OHV use had lower occupancy rates, while non-motorized recreation affected egg laying and nest attendance. Boating and fishing is likely to increase across the NWPL and many eagle nests are located within the cottonwoods along riverbanks and on cliffs surrounding waterways. While boating and waterways cannot be re-routed (avoidance), defining and enforcing "no-stopping" stretches of waterways in close proximity to nests may help reduce disturbance to nesting golden eagles. Backcountry camping should be precluded near and below any known golden eagle nest site.

Research and monitoring

Monitoring is necessary to document OHV and recreational back county use in the NWPL. It is important to research impacts of different recreation types and intensity on golden eagles in the NWPL since studies from other regions have documented negative effects of motorized and non-motorized recreation on nesting eagles.

9. Agriculture

A variety of agricultural activities have the potential to impact golden eagles. Hazards posed to eagles by agriculture include habitat loss and degradation, electrocution on distribution power poles, exposure to agricultural poisons (including secondary poisonings from pesticides and rodenticides), drowning in stock tanks, disturbance at nest sites, and trapping and harassment resulting from livestock depredation.

Loss of golden eagle habitat from conversion to cropland is a significant hazard in the NWPL (see Agricultural Risk above). As demand for biofuels increases and climate change lengthens the growing season, additional native grasslands and prairies will be converted to croplands in the NWPL. There is also a predicted increase in pasturelands and hayfields. Nesting golden eagles have been shown to avoid agricultural lands and increasing native habitat conversion will reduce habitat quality for nesting eagles and their prey. Potential impacts of livestock grazing on the habitats of golden eagle prey are unknown. However, livestock grazing and other agricultural practices with the potential to degrade shrublands, reduce cottonwood regeneration, and negatively alter grassland habitats for key prey, which all would have negative impacts to eagles.

Avoidance and minimization

Land conversion to cropland and hayfields is the largest risk to eagles from agriculture. Conservation easements, enrolling and renewing lands in the CPR, grazing allotment retirements, and other land conservation programs can be used to reduce land conversion in the NWPL. State and federal assistance programs exist to help off-set costs to farmers and ranchers that engage in land conservation programs, such as the Farm Bill (CRP) and the USFWS Grassland and Wetland Program. Maps of priority golden eagle habitat can be used to help direct easements into areas of high value for nesting golden eagles in the NWPL.

Agricultural areas with center pivots, well pumps, and other infrastructure introduce relatively high densities of power poles into golden eagle habitat. Recommendations to avoid, minimize, and mitigate risk of electrocution in agricultural developments are the same as for other areas. These include using lower-risk configurations for new poles and retrofitting existing poles (see Electrocution prevention above).

Poisons used to control agricultural pests are a known hazard to eagles, including common poisons for prairie dogs and ground squirrels (see Anticoagulant rodenticides above). Impacts from rodenticide poisoning can be avoided by discontinuing use in important habitats of golden eagles. Additionally, chemicals used to euthanize livestock are known to kill eagles (see Other contaminants above). Poisoning by euthanasia agents can be avoided by burying, covering, incinerating, or otherwise disposing of carcasses in such a way that eagles cannot feed on them.

Livestock depredations by golden eagles are greatest in open range lambing operations, are usually localized, and typically involve young lambs and goats (Phillips and Blom 1988, Matchett and O'Gara 1991, Avery and Cummings 2004). Depredations can be avoided or minimized with interventions like installation of netting over lambing pens, using "scarecrows" on ridges where lambs bed for the night, removing dead livestock and other potential eagle attractants, and the use of guard dogs (O'Gara and Rightmire 1987). Depredation rates increase when natural prey resources are low (O'Gara and Rightmire 1987), and may be magnified by increases in habitat conversion. Relocations of eagles from ranches with significant depredation problems exist has not been successful in the NWPL or any other ecoregion (Phillips and Blom 1988, O'Gara and Rightmire 1987, Miner (1975). Most breeding adults (12 of 14) moved >400 km returned within 11 to 316 days (Phillips et al. 1991). Of 432 golden eagles moved from nearby Dillon, MT had little-to-no effect on lamb depredation rates from 1975-1983 (*in* Avery and Cummings 2004). Seasonal shifts in agricultural activities, like lambing, away from known golden eagle nests and habitat can also reduce impacts. Concentrating lambing fields with "scarecrows" and other harassment activities (noises, flashes, etc) may reduce predation rates on the open range. Minimizing opportunities for livestock depredation by golden eagles could help reduce persecution in the long term by helping to shift negative cultural perceptions of eagles as predators. Harassment or trapping of golden eagles requires an Eagle Depredation Permit from USFWS (https://www.fws.gov/pacific/eagle/permit_types/depredation.html).

Simple, wildlife escape ladders installed in stock tanks can prevent drowning of eagles and other wildlife (Rocky Mountain Bird Observatory 2006).

Research and monitoring

More research is necessary to understand effects of grazing practices on habitat and abundance of golden eagle prey. Management of risks from other hazards associated with agriculture, including electrocution, poisoning, and harassment from livestock depredation could benefit from improved data collection and educational outreach. Further research is needed to determine how best to minimize agricultural losses to predation from golden eagles. No published research has been conducted on eagle/lamb depredation in the past three decades and ranches have few options to deal with losses. Some ranchers in the NWPL have been waiting >5 years for depredation permits (K. Glover, Senator Barasso's Natural Resource Advisor, Personal Communication). Delays in the ability to deal with losses may increase risk of illegal persecution or take (Avery and Cummings 2004). In 2019, the first permits were approved for removal of depredating eagles for use in falconry in the WY portion of the NWPL but the results that program were not available at the time of this report completion.

10. Cottonwood loss, nest management, and enhancement

Mature cottonwood trees available as nest sites across the NWPL are decreasing (see Cottonwood Loss above). Large-scale hydrology management in the NWPL is a large factor in cottonwood regeneration rates on larger and medium sized rivers, like the Missouri, Little Missouri, Yellowstone, Powder, and others across the region. Interventions to conserve or enhance individual cottonwood trees and nests are an option for smaller management areas. Possible measures include planting cottonwoods, exclusion fencing for cattle and ungulate grazing, restoration or improvement of nest sites, insecticide treatment of nests, and medical treatment of nestlings.

Avoidance and minimization

Restoring natural hydrology flows in waterways is the ideal method to re-establishing cottonwood regeneration across the NWPL, but is unlikely to happen given water rights and irrigation needs. Management actions such as exclusion fencing for herbivores in newly planted or naturally re-seeded areas can enhance cottonwood propagation. Use maps of breeding season habitat priority areas can be used to help direct management actions to the highest value breeding habitat to maximize efforts and funding. Similarly, restrictions on and rotational grazing programs can be implemented in riparian areas to reduce grazing on cottonwood seedlings. Smaller-scale individual tree plantings would have benefit in areas of high predicted habitat value with no existing nesting structure.

For nest enhancement techniques, installation of shade structures at nest sites is being tested experimentally as a method to increase nestling survival by reducing heat stress (Kochert et al. 2019). This technique could be useful for eagle territories where nestlings experience heat stress and alternative nest sites that offer more shade are not available. For sites where ectoparasites affect nestling survival, nestlings can be treated with medications and nests treated with insecticides (see Diseases and parasites above).

Mitigation

In eagle territories with few suitable nesting substrates, loss of a nest site can constitute the loss of the territory. For example, nests in some territories in NWPL are on isolated, senescent cottonwood trees that decay and fall over. Likewise, nests on lone rock outcrops or cliffs are sometimes lost when substrates fracture, erode, or are removed by development. In these situations, a breeding territory could be conserved with a relatively simple intervention, like reinforcing a rock ledge or replacing a fallen tree with an artificial nesting platform.

Research and monitoring

Further research is necessary to understand the effectiveness of nest management techniques. Artificial nest platforms have been used extensively to relocate and replace nest sites; however, it is difficult to determine the factors that influence their effectiveness because they are typically deployed on a case-by-case basis and may not receive long-term monitoring. Experimental studies could provide valuable information on the effectiveness of nest platforms, including the feasibility of creating new territories by installing platforms in areas that lack suitable substrates. Nest enhancements, like shade structures, treatment of nests with insecticides, and medication of nestlings should also be tested experimentally in the NWPL.

11. Poaching and persecution

Despite declines from historical levels and several protective federal laws, poaching and persecution persist as causes of golden eagle mortality in the NWPL.

Avoidance and minimization

Two of the leading reasons for poaching and persecution in the NWPL is the real and/or perceived predatory threat of golden eagles on livestock or game species and for sale/trade of feathers for religious purposes. An increased effort should be taken to find an effective management technique to reduce livestock depredation (see Agriculture strategy). Increased education and outreach to local ranchers and communities can also help reduce negative attitudes that may lead to persecution. The time needed to obtain a take permit should also be significantly reduced so individuals that have proven eagle depredation problems can effectively deal with target eagles in a timely manner.

Long wait times from native tribal members to receive feathers for religious purposes from the USFWS National Eagle Repository may contribute to the high black-market value of eagle parts. The current wait period of an estimated 7 years 6 months (https://www.fws.gov/eaglerepository/documents/current_wait_times.pdf) to receive a tail of a young golden eagle (one of the most prized parts). This wait period can lead to illegal take, poaching of roadkill, and illegal trade. Further, the advertised prizes for powwow dancing competitions can be >$250,000 and costumes with larger numbers of juvenile golden eagle feathers typically score higher than others. This leads to monetary incentives for poaching in tribal communities. It is likely that reducing both the wait period from the National Eagle Repository and purse winnings at Powwow competitions may help reduce the black-market value and demand for illegal golden eagle parts. Strategies to reduce poaching and persecuting of golden eagles also include law enforcement, prosecution of offenders, and education on legal protections of golden eagles and negative effects of trafficking on wildlife populations. Incidents can be reported to USFWS Office of Law Enforcement (https://www.fws.gov/le/regional-law-enforcement-offices.html) for Region 6 (Wyoming, Colorado, Utah, and Montana) or Region 1 (Idaho). Dead eagles should be reported as soon as possible to USFWS or state wildlife management agencies, so they can be collected before they are taken by poachers.

12. Research and monitoring activities

Research activities affect only a small number of golden eagles each year in the NWPL. Nonetheless, impacts of research on eagles should be minimized by selecting non-invasive methods when possible and following best-practices when using invasive techniques. Monitoring affects a greater number of eagles within the NWPL than hands-on research activities, but the level of disturbance from monitoring is typically less than hands-on research activities.

Avoidance and minimization

Invasive research methods provide essential data on golden eagle ecology. For example, models in this report could not have been developed without the use of GPS telemetry data from eagles that were trapped and instrumented with transmitters. Likewise, essential information on parasites, diseases, and contaminants could not have been obtained without entering nests and capturing free-flying eagles. Many research questions important to the conservation of eagles, however, can be answered using non-invasive methods like structured visual surveys. Researchers should consider choosing the lowest impact method that will address their objectives and have their methods approved by appropriate ethics bodies (e.g., Institutional Animal Care and Use Committees). Common recommendations include measures to minimize handling stress and reducing the number and duration of nest visits. To improve understanding of sources of mortality, including potential impacts of transmitters, all instruments attached to golden eagles should include technology that allows them to be located and recovered in the event of mortality. Golden eagles can potentially live for >30 years and most tracking devices last less than four years. To reduce any potential long-term research impacts on golden eagles, all harnesses for telemetry devices should use methods designed to allow the device to fall off after they study is complete or after the useful lifespan of the device (D. Driscoll and B. Bedrosian, unpublished data).

Monitoring of eagle nests is conducted both on the ground and aerially. Helicopters offer a better ability to detect nests and count young, but can be cost prohibitive. In the NWPL, many nests are in cottonwoods and easily visible from a fixed-wing airplane. All of these methods have the potential to disturb nesting birds and should be conducted at the minimum frequency needed for effective monitoring and research. Further, increase coordination among companies required to conduct raptor nesting surveys, consultants, and research groups needs to occur to reduce nest visits at any given nest site (see Oil and gas development strategy).

Research and monitoring

Data from ad hoc research designs, like opportunistic deployment of transmitters and nest checks, can contribute to meta-analyses. However, inferences are stronger when research is conducted as part of coordinated studies with clear objectives and hypotheses, design-based sampling, and target sample sizes based on power-analysis. Following basic principles for the design of scientific studies increases the value of data that are necessarily collected at the expense of golden eagles. Similarly, monitoring efforts conducted for industrial compliance on public lands should be required to use standardized methods and metrics to facilitate data integration. Where study areas overlap, improved coordination among entities that monitor nests is essential to avoid disturbance of eagles by excessive, repeated surveys.

13. Wildfire

Wildfires can cause significant habitat conversion and risk of wildlife is generally increasing across the West due to the rapid expansion of invasive species, such as cheatgrass. Golden eagles in the NWPL are mainly affected by wildfire by loss of nesting habitat, occupied nests, or through direct mortality of nestlings and/or fledglings.

Avoidance and minimization

Removal and reduction plans for invasive species, such as cheatgrass, will benefit golden eagles by reducing wildfire risk and maintaining native plant communities for prey species. All land management entities should maintain a current wildfire response plan that can be informed by maps of priority eagle breeding habitat. Fires should be actively fought and extinguished in areas with very high breeding habitat values. Fires in grasslands and prairies may benefit from a lower response priority since these areas tend to rebound quickly and positively in the NWPL. Local area knowledge of nest sites can help inform immediate response actions to save existing nest sites and/or nestlings. Education and knowledge of local response plans should be distributed to all municipality and volunteer fire stations.

14. Climate change

Golden eagles are likely to be affected by climate change; however, little is currently known about the timing and severity of potential impacts to eagles, their habitats, or prey. Potential direct effects include heat-stress of nestlings, increases in insect pests and diseases, and loss of nesting attempts to severe storms. Indirect effects could reduce prey abundance from direct and indirect impacts on key prey species, such as conversion of native habitats to agriculture due to longer growing seasons. Loss of prey habitat from wildfire has impacted fecundity of golden eagles in the neighboring Snake River Plain ecosystem, and risk of wildfire will likely increase in the NWPL under climate change. Asynchrony of eagle and prey phenology could also become an issue, if burrowing-rodent prey begin to estivate earlier in summer when eagle fledglings are learning to forage.

Avoidance and minimization

In the short-term, conserving prey by protecting and restoring native vegetation communities in golden eagle habitat is the best strategy to increase resiliency of eagle populations to climate change (see Prey resource limitation above). In the long term, reductions in carbon emissions is necessary to minimize catastrophic negative effects of climate change (IPCC 2018).

Research and monitoring

Intensive studies of golden eagle diet, reproduction, and prey habitat are urgently needed to predict potential changes in prey abundance and golden eagle reproduction under climate change scenarios. Further research is also necessary to understand effects of heat-stress on eagles and identify potential refugia, like higher-elevation nesting and foraging habitats, and shaded micro-habitats in existing territories. Finally, states and management agencies in the NWPL should collaborate to implement monitoring programs sufficient to establish current densities and reproductive rates of golden eagles in the region. Robust baseline data are essential to detect impacts and inform management of golden eagle populations in response to climate change and other stressors.

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