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EFFECTS OF MANAGEMENT PRACTICES ON GRASSLAND BIRDS: GOLDEN EAGLE

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GOLDEN EAGLE

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This report is one in a series of literature syntheses on North American grassland birds. The need for these reports was identified by the Prairie Pothole Joint Venture (PPJV), a part of the North American Waterfowl Management Plan. The PPJV recently adopted a new goal, to stabilize or increase populations of declining grassland- and wetland-associated wildlife species in the Prairie Pothole Region. To further that objective, it is essential to understand the habitat needs of birds other than waterfowl, and how management practices affect their habitats. The focus of these reports is on management of breeding habitat, particularly in the northern Great Plains.

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Species for which syntheses are available:

American Bittern
Mountain Plover
Marbled Godwit
Long-billed Curlew
Willet
Wilson's Phalarope
Upland Sandpiper
Greater Prairie-Chicken
Lesser Prairie-Chicken
Greater Sage-Grouse
Northern Harrier
Swainson's Hawk
Ferruginous Hawk
Golden Eagle
Prairie Falcon
Merlin
Short-eared Owl
Burrowing Owl
Horned Lark
Sedge Wren
Loggerhead Shrike
Sprague's Pipit
Grasshopper Sparrow
Baird's Sparrow
Henslow's Sparrow
Le Conte's Sparrow
Nelson's Sharp-tailed Sparrow
Vesper Sparrow
Savannah Sparrow
Lark Sparrow
Field Sparrow
Brewer's Sparrow
Clay-colored Sparrow
Chestnut-collared Longspur
McCown's Longspur
Dickcissel
Lark Bunting
Bobolink
Eastern Meadowlark
Western Meadowlark
Brown-headed Cowbird

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GOLDEN EAGLE

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ORGANIZATION AND FEATURES OF THIS SPECIES ACCOUNT

Information on the habitat requirements and effects of habitat management on grassland birds were summarized from information in more than 4,000 published and unpublished papers. A ***range map*** is provided to the breeding, year-round, and nonbreeding ranges in the United States and southern Canada. Although birds frequently are observed outside the breeding range indicated, the maps are intended to show areas where managers might concentrate their attention. It may be ineffectual to manage habitat at a site for a species that rarely occurs in an area. The species account begins with a brief ***capsule statement***, which provides the fundamental components or keys to management for the species. A section on ***breeding range*** outlines the current breeding distribution of the species in North America. The ***suitable habitat*** section describes the breeding habitat and occasionally microhabitat characteristics of the species, especially those habitats that occur in the Great Plains. Details on habitat and microhabitat requirements often provide clues to how a species will respond to a particular management practice. A ***table*** near the end of the account complements the section on suitable habitat, and lists the specific habitat characteristics for the species by individual studies. A special section on ***prey habitat*** is included for those predatory species that have more specific prey requirements. The ***area requirements*** section provides details on territory and home range sizes, minimum area requirements, and the effects of patch size, edges, and other landscape and habitat features on abundance and productivity. It may be futile to manage a small block of suitable habitat for a species that has minimum area requirements that are larger than the area being managed. The Brown-headed Cowbird (*Molothrus ater*) is an obligate brood parasite of many grassland birds. The section on ***cowbird brood parasitism*** summarizes rates of cowbird parasitism, host responses to parasitism, and factors that influence parasitism, such as nest concealment and host density. The impact of management depends, in part, upon a species' nesting phenology and biology. The section on ***breeding-season phenology and site fidelity*** includes details on spring arrival and fall departure for migratory populations in the Great Plains, peak breeding periods, the tendency to renest after nest failure or success, and the propensity to return to a previous breeding site. The duration and timing of breeding varies among regions and years. ***Species' response to management*** summarizes the current knowledge and major findings in the literature on the effects of different management practices on the species. The section on ***management recommendations*** complements the previous section and summarizes specific recommendations for habitat management provided in the literature. If management recommendations differ in different portions of the species' breeding range, recommendations are given separately by region. The ***literature cited*** contains references to published and unpublished literature on the management effects and habitat requirements of the species. This section is not meant to be a complete bibliography; a searchable, annotated bibliography of published and unpublished papers dealing with habitat needs of grassland birds and their responses to habitat management is posted at the Web site mentioned below.

This report has been downloaded from the Northern Prairie Wildlife Research Center World-Wide Web site, www.npwrc.usgs.gov/resource/literatr/grasbird/grasbird.htm. Please direct comments and suggestions to Douglas H. Johnson, Northern Prairie Wildlife Research Center, U.S. Geological Survey, 8711 37th Street SE, Jamestown, North Dakota 58401; telephone: 701-253-5539; fax: 701-253-5553; e-mail: Douglas_H_Johnson@usgs.gov.

GOLDEN EAGLE
(*Aquila chrysaetos*)

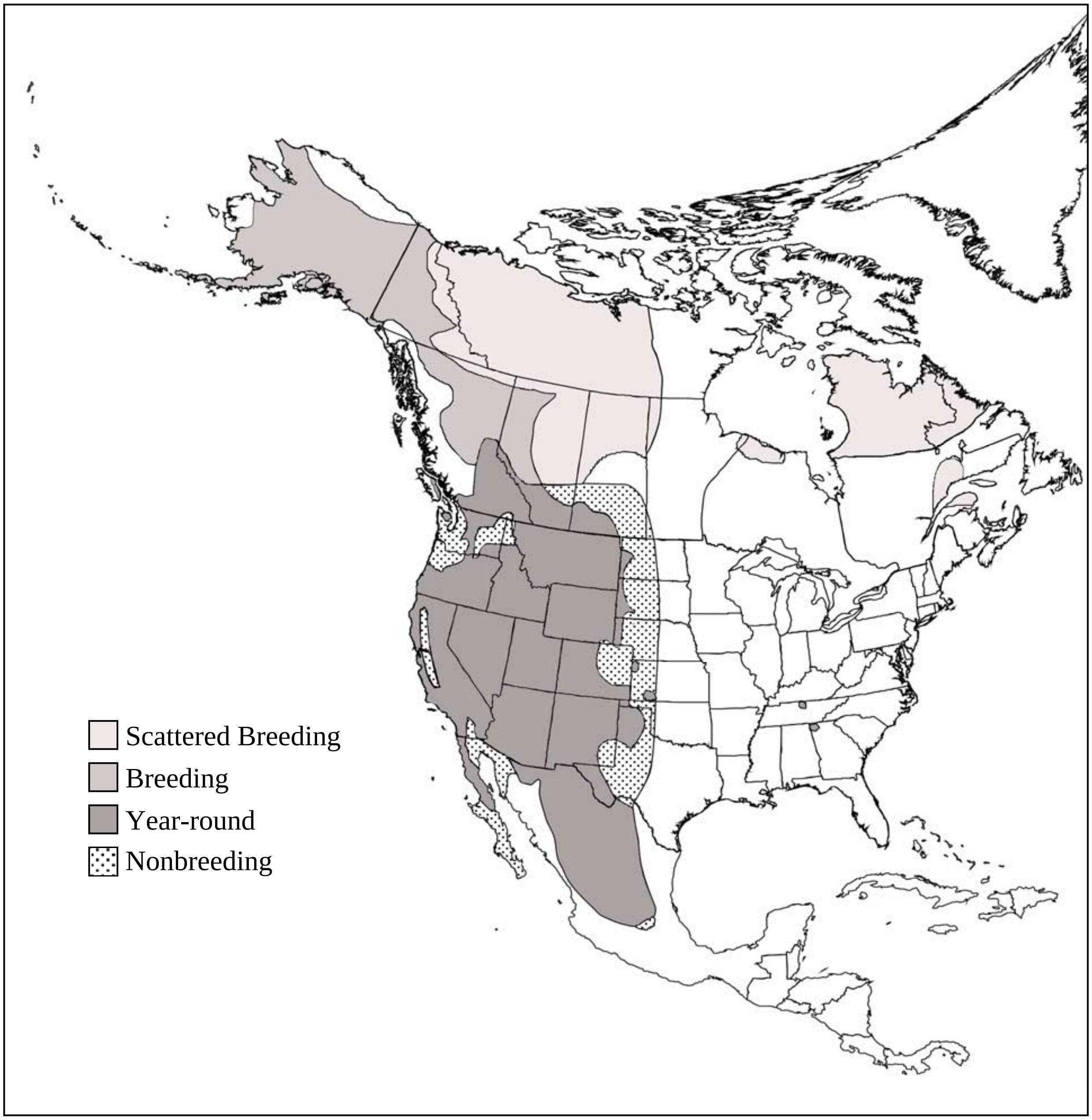

Figure. Distribution of Golden Eagle in North America. Map adapted from Kochert et al. (2002), used with permission of the authors.

Keys to management include providing open landscapes, habitats supporting populations of rabbits and squirrels, and suitable nesting sites such as cliffs and large trees. Nest sites should be protected from disturbance by designating buffer zones around them.

Breeding range:

In North America, Golden Eagles breed from Alaska, the Yukon Territories, and the southwestern Northwestern Territories, south into Mexico and east to central South Dakota. They also breed in extreme northeastern Manitoba and in northern Ontario, central Quebec, and northern Newfoundland (National Geographic Society 1999). Although adults are year-round residents in many areas, subadults may be found outside breeding areas during summer and winter (Beecham and Kochert 1975, Steenhof et al. 1984). (See figure for the breeding, year-round, and nonbreeding ranges of Golden Eagle in the United States and southern Canada.)

In northern Canada and Alaska, Golden Eagles are migratory and occur on breeding areas from mid-March through mid-October (Bent 1961, Hobbie and Cade 1962, Salt and Salt 1976, Young et al. 1995, Brodeur et al. 1996, Kochert et al. 2002). Golden Eagles appear mostly non-migratory in Idaho, Wyoming, Colorado, New Mexico, and California (Boeker and Ray 1971, Steenhof et al. 1984, Phillips and Beske 1990, Hunt et al. 1995). Wintering eagles can be found throughout the breeding range in the conterminous United States and southwestern Canada as well as in the Great Plains, coastal California, and isolated locations in the eastern United States (National Geographic Society 1999, Kochert et al. 2002).

Suitable habitat:

Golden Eagles inhabit open shrubsteppe and grassland habitats in landscapes ranging from arid deserts to tundra (Kochert et al. 2002). In the northern Great Plains, Golden Eagles inhabit shortgrass prairie, mixed-grass prairie, and xeric scrub/grassland habitats in western North Dakota (Stewart 1975, Allen 1987); prairies, riparian areas, and bottomland forests in the Black Hills of South Dakota (Johnsgard 1980, SDOU 1991); shrubsteppe and grassland habitats interspersed with scattered hayfields and woodland in Wyoming (Phillips and Beske 1990, Phillips et al. 1990); and grazed and ungrazed montane grasslands, shrubsteppe, and mixed-conifer woodlands in Montana (Baglien 1975). In the central and southern Great Plains, Golden Eagles inhabit prairie habitats in western Nebraska (Faanes and Lingle 1995), shortgrass prairie and shrubsteppe in northeastern Colorado (Ryder 1972), and shortgrass prairie and pinyon pine (*Pinus edulis*)/one-seeded juniper (*Juniperis monosperma*) habitats in western Oklahoma and southeastern Colorado (Lish 1975, Andersen et al. 1990). In the Great Basin, Golden Eagles inhabit shrubsteppe, native grassland, tame grassland, cropland, and riparian habitats in southwestern Idaho (Collopy and Edwards 1989, Marzluff et al. 1997), and open fields and clearcuts in primarily forested areas in western Washington (Bruce et al. 1982).

Golden Eagles use a variety of nesting substrates. Substrates must be large enough to support the eagles' bulky nests. Golden Eagles also use roosting locations near their nests (Collopy and Edwards 1989); hence, additional ledges and perch sites are beneficial to breeding eagles. Golden Eagles usually nest on cliffs but also use large trees, artificial structures, or the ground, depending in part upon availability (Dixon 1937, Bent 1961, McGahan 1968, Whitfield et al. 1969, Boeker and Ray 1971, Baglien 1975, Lish 1975, Seibert et al. 1976, Olendorff et al. 1980, Bruce et al. 1982, Smith and Murphy 1982, Houston 1985, Menkens and Anderson 1987, MacLaren et al. 1988, Phillips and Beske 1990, Phillips et al. 1990, Bates and Moretti 1994, Morneau et al. 1994). In the western Great Plains, nests are placed on cliffs or in trees (cottonwoods [*Populus* spp.] or green ashes [*Fraxinus pennsylvanica*]) (Lish 1975, Stewart 1975, Johnsgard 1980, SDOU 1991, Faanes and Lingle 1995, Knowles 2001). In Saskatchewan, eagles nest on cliffs (Houston 1985). In the Snake River Birds of Prey (SRBP) area in southwestern Idaho, Golden Eagles nested mainly on cliffs, but they also nested on nesting platforms that were installed on transmission line towers (Steenhof et al. 1993). The transmission line was built through shrubsteppe habitats that were similar to those in existing eagle territories, but nest sites had not existed there previously, presumably because of the lack of nesting substrates.

Generally, Golden Eagles place nests at any height and any aspect on available cliffs (Seibert et al. 1976, Kochert et al. 2002). However, in Montana, eagles avoided nesting on cliffs at elevations exposed to >500 cm of snowfall during the winter (Baglien 1975), presumably because snow still would have covered the ground at the beginning of the nesting season. Nest-site aspects may be chosen to minimize exposure to inclement weather (Kochert et al. 2002). Mosher and White (1976) found that Golden Eagle nests may face any direction, but the directional exposure of nests varied geographically. In northern latitudes, nests tend to have a southerly orientation, whereas in southern latitude, nests tend to have a northerly orientation. In Alaska, 62 nests were oriented more frequently to the south-southeast, and in Montana, 47 nests were oriented significantly more frequently to the south. In Utah, 37 nests were oriented more frequently to the north-northwest, and in Texas, there was a tendency towards a northerly aspect among 20 nests. Selection of nest-site aspects may be related to microclimate factors, with eagles choosing sites to increase solar exposure in the north and decrease it in the south. Within sites, nest orientation was not associated with elevation (Mosher and White 1976). The critical period of thermoregulation for eaglets (3-6 weeks of age) occurred at a time that corresponded with approximately thermoneutral temperatures at each location. In Montana, Baglien (1975) also found that eagles placed nests in southern and eastern aspects more often than expected and in northern and western aspects less often than expected. In northern Quebec, 87% of 31 cliff nests were oriented away from the north, possibly because of potential inclement weather coming from this direction (Morneau et al. 1994), although this pattern was not tested statistically. Of four north-facing nests in Quebec, the only two occupied during the study had overhangs protecting them from inclement weather, and 53% of 31 nest sites in the area had overhangs.

Tree nests typically are built in the top one-third of trees that are isolated, near the edge of stands, or relatively large (Baglien 1975, Bruce et al. 1982, Menkens and Anderson 1987, Phillips et al. 1990). In Washington, eagles nested in Douglas fir (*Pseudotsuga menziesii*) (Bruce et al. 1982). In Montana, eagles nested on cliffs, Douglas fir, and ponderosa pine (*Pinus ponderosa*), and the average height of nests above the ground was 17 m (Baglien 1975). In Wyoming, eagles nested on cliffs and in cottonwood and ponderosa pine trees (Menkens and Anderson 1987, Phillips and Beske 1990, Phillips et al. 1990), and the average diameter-at-breast-height of nest trees was 75 cm (MacLaren et al. 1988). In northeastern Wyoming, no differences in micro-scale habitat characteristics were found among nests placed in ponderosa pines, cottonwoods, or ground locations (Menkens and Anderson 1987), and specific habitat characteristics near nests may be a function of the availability of nesting substrates rather than actual habitat selection by eagles (Menkens and Anderson 1983). In central Utah, eagle territories occurred in valleys, in pinyon/juniper areas, on talus slopes, and in quaking aspen (*Populus tremuloides*)/conifer woodlands (Bates and Moretti 1994).

In general, the amount of non-forested habitat and the availability of nest sites appear to limit the abundance of this species (Whitfield et al. 1969, Boeker and Ray 1971, Seibert et al. 1976, Phillips and Beske 1990, Carrete et al. 2000). However, Golden Eagles appear flexible in use of habitats and will in some cases travel far from their nests to find good foraging habitats or take alternate prey if habitats closer to their nests are of poorer quality (Marzluff et al. 1997). In

Wyoming, eagle density varied among habitats (Phillips et al. 1984). The area with the highest density was characterized by diverse prey and abundant suitable nesting locations, whereas the area with the lowest density was characterized by few nesting locations and fragmentation by cropland. The only habitats in which eagles were absent or rare were flat desert terrain, cropland, and forested areas with no large tracts of open land, although these habitats were not surveyed as intensively as other habitats.

Habitats within territories of resident eagles in the SRBP varied among individual pairs (Marzluff et al. 1997). Most home ranges of breeding eagles included more big sagebrush (*Artemisia tridentata*)/green rabbit brush (*Chrysothamnus viscidiflorus*), less grassland, and less cropland than expected by availability (the amount of land available for use was not given), although this difference was not statistically significant. Also, most home ranges of non-breeding eagles tended to include more big sagebrush/green rabbit brush, less grassland, and less cropland than expected by availability. Eight of nine pairs avoided cropland in their territory, although cropland accounted for up to 24% of available land. In the SRBP, most breeding-season core areas (defined as the area comprising 95% of radio-telemetry locations) included more sagebrush/rabbit brush and salt-desert shrub and less winter fat, cropland, and grassland than expected, although these differences generally were not statistically significant. Eagles with little jackrabbit habitat (typically sagebrush and rabbit brush) in their core areas selected foraging locations with abundant jackrabbit habitat. Productivity and home range size were not related to the amount of jackrabbit habitat in the territory. The total area of sagebrush/grassland within 0.4 km of Golden Eagle nests in Montana was greater than expected (Baglien 1975). There were fewer cliffs visually obstructing the view of sagebrush/grassland from nests than expected, and there was more sagebrush/grassland below the 500-cm snowfall line within 0.8, 1.6, and 3.2 km of the nest than expected (Baglien 1975).

In the SRBP, territories used by subadult Golden Eagles had higher rates of human activity (quantified by percentage of area in agriculture, proximity of nests to nearest roads, proximity of nests to nearest human habitation, and length of powerlines within territories) than areas used exclusively by adults (Steenhof et al. 1983). Human impacts may have caused high rates of nest failure, eagle mortality, or eagle emigration, creating more vacancies than in territories with little human activity. Such areas are then occupied more frequently by subadults, who typically nest only when vacancies are present. A table near the end of the account lists the specific habitat characteristics for Golden Eagles by study.

<u>Prey habitat</u>:

Golden Eagles prey primarily on mammals, although birds, reptiles, fish, and carrion also are eaten (Bent 1961, Olendorff 1976, Brown 1992, Watson et al. 1992, Kochert et al. 2002). A wider variety of prey types are taken when primary prey become less abundant (Steenhof and Kochert 1988). Primary prey in the Great Plains are cottontail rabbits (*Sylvilagus* spp.), jackrabbits (*Lepus* spp.), ground squirrels (*Spermophilus* spp.), and prairie dogs (*Cynomys* spp.) (Gloyd 1925, Lish 1975, Salt and Salt 1976). In Saskatchewan, primary prey are snowshoe hare (*Lepus americanus*), American mink (*Mustela vison*), and birds (Whitfield et al. 1969, Houston 1985). Primary prey in western shrubsteppe are black-tailed jackrabbit (*L. californicus*), cottontail rabbits, Townsend's ground squirrel (*S. townsendii*), and yellow-bellied marmot (*Marmota flaviventris*) (Benson 1981, Steenhof and Kochert 1988, Kochert et al. 2002). Primary prey in the northern Rocky Mountains (Montana, Wyoming, Alberta, British Columbia) are white-tailed jackrabbit (*L. townsendii*), Columbian ground squirrel (*S. columbianus*), Richardson's ground squirrel (*S. richardsonii*), prairie dogs, snowshoe hare, marmots (*Marmota* spp.), and cottontail rabbits (Bent 1961, McGahan 1968, Baglien 1975, Salt and Salt 1976, Boag 1977, MacLaren 1988, Phillips et al. 1990, Harmata and Restani 1995). Primary prey in the central and southern Rocky Mountains (Colorado and New Mexico) are jackrabbits and cottontail rabbits (Boeker and Ray 1971).

Prey abundance influences reproduction in Golden Eagles. In the SRPB, abundance of prey during the winter was positively correlated with several reproductive parameters during the following breeding season including the percentage of pairs laying eggs, the percentage of laying pairs that were successful, brood size at fledging, and number fledged per occupied territory (Steenhof et al. 1997). In Scotland, the abundance of prey during the winter was positively correlated with Golden Eagle density during the following breeding season, and the abundance of prey during the spring and summer was positively correlated with reproductive success (Watson et al. 1992).

Foraging habitat selection by resident eagles in the SRBP differed between the breeding season and non-breeding season (Marzluff et al. 1997). Primary prey during the non-breeding season were black-tailed jackrabbits, and eagles selected jackrabbit habitats (sagebrush and rabbit brush) for hunting during this time and used other habitats (water, agriculture, grassland, winter fat, and salt-desert shrub) less than expected. Primary prey during the breeding season were more variable, and eagles used jackrabbit habitats in proportion to availability. In the SRBP, fires created conditions whereby native shrubsteppe was converted to invasive cheatgrass (*Bromus tectorum*) in some eagle territories (Kochert et al. 1999). Eagles in those territories may have been able to compensate for the reduced amount of shrubsteppe after the fires by foraging in more grassland habitats and taking alternate prey such as Rock Doves (*Columba livia*), waterfowl, yellow-bellied marmots, and mountain cottontails (*Sylvilagus nuttalli*) (Kochert et al. 1999).

Area requirements:

Golden Eagles have large home ranges that are defended, particularly during the breeding season. Home range size may increase or decrease during the non-breeding season. Eagles defend their home ranges or territories during the breeding season and are more tolerant of other eagles during the non-breeding season (Kochert et al. 2002). In the SRBP, adjacent breeding territories overlapped <4%, based on eight territories determined by radio-telemetry (Marzluff et al. 1997). (Territories averaged 22.8 km^2 and ranged from 1.9 to 83.3 km^2.) Nearest-neighbor distances between pairs were rarely <1 km (Kochert et al. 2002). Within territories, activities are concentrated within core areas. In the SRBP, Marzluff et al. (1997) defined core area as the area containing 95% of radio-telemetry locations, which amounted to 14.4% of the breeding territory size.

Researchers who examined breeding-season territories reported that average sizes ranged from 20 to 54 km^2, whereas average sizes of year-round territories ranged from 20 to 92 km^2 (Kochert et al. 2002). In the SRBP, Dunstan et al. (1978) reported that average home range size for three pairs of eagles decreased from 32 km^2 during the breeding season to 8.9 km^2 during the non-breeding season. In southeastern Wyoming, one pair of eagles used a 24-km^2 area during the breeding season and a 13.6-km^2 area during the non-breeding season (Platt 1984). Unlike the eagles observed by Dunstan et al. (1978) and Platt (1984), eight pairs of eagles in the SRBP used non-breeding territories that were larger than the breeding-season territories (Marzluff et al. 1997). Non-breeding territory size of the eight pairs averaged 305 km^2, ten times larger than their mean breeding-season territory size.

Brown-headed Cowbird brood parasitism:

No known records of brood parasitism by Brown-headed Cowbirds (*Molothrus ater*) exist.

Breeding-season phenology and site fidelity:

The start of the breeding season varies geographically (Kochert et al. 2002). In the SRBP, nest initiation was later after severe winters (Steenhof et al. 1997). Eagles commence breeding later in years with heavy snow accumulation, severe winters, or prey shortages (Phillips and Beske 1990, Young et al. 1995, Steenhof et al. 1997). Egg-laying occurs from late March to early May in western North Dakota (Stewart 1975), from mid-February to mid-March in Idaho and New Mexico (Boeker and Ray 1971, Steenhof et al. 1997), from late February to mid-March in California (Hanna 1930, Carnie 1954), from late February to late-March in Wyoming (Phillips and Beske 1990), from mid-March to mid-April in Montana (Baglien 1975), from late March to late April in northern Alaska (Young et al. 1995), and from early April to early May in Quebec (Morneau et al. 1994).

Golden Eagles generally show fidelity to territories and often reuse nests (Kochert et al. 2002). Eagles may maintain one or more nests within a given year; in successive years, a pair of eagles may either switch to an alternate nest or reuse a previous year's nest (Hanna 1930; Carnie 1954; McGahan 1968; Camenzind 1969; Boeker and Ray 1971; Baglien 1975; Phillips et al. 1990, 1991; Steenhof et al. 1993; Morneau et al. 1994). In Utah, 21% of 52 pairs that nested in consecutive years used the same nest (Bates and Moretti 1994). One nest in California was occupied for about 50 yr, although not by the same pair (Hanna 1930). In Wyoming, 86% of 14 eagles returned to their nests 11-316 days after being experimentally displaced more than 400 km away (Phillips et al. 1991). Nine (75%) of the returning eagles reclaimed territories from eagles that had occupied their territories while they were absent. Eagles using artificial nesting platforms on transmission line towers in Idaho always reused nests in subsequent years unless they returned to a formerly-used cliff nesting site (Steenhof et al. 1993).

Renesting has been observed in Golden Eagles. Two of 13 (15%) pairs that failed in their initial nesting attempts in Utah renested on alternate structures, but neither was successful (Camenzind 1969). A pair in southern California laid a replacement clutch after the first clutch was collected by an egg collector (Hanna 1930). In SRPB, eagles renested in only 0.1% of 674 failed nesting attempts, including both successful and unsuccessful attempts, over a 22-year period (M. Kochert, unpublished data).

Species' response to management:

Few studies have examined the effects of burning, mowing, grazing, or other landscape changes on Golden Eagles. However, in California, Hunt et al. (1995) suggested that ground squirrels were attracted to areas grazed by cattle because of the reduced grass height, and that, because ground squirrels were a primary prey of Golden Eagles in the area, eagles used the grazed grasslands for foraging. Bruce et al. (1982) suggested that in heavily forested areas, forest clearing may be beneficial to Golden Eagles by creating open foraging habitats.

In the SRBP, 27 of 36 (75%) territories were burned (from 11 to 100% of the area within 3 km of the nest) by wildfires during a 6-yr period (Kochert et al. 1999). Overall, territory occupancy did not change after the fires. However, occupancy at nine territories where pairs could expand into neighboring vacant territories was higher than territories where pairs could not expand into neighboring vacant territories. Similarly, the nine pairs adjacent to vacant territories did not experience a decrease in reproductive success after the burns, but the pairs not adjacent to vacant territories showed a significant drop in reproductive success. Success at 15 extensively burned territories (>30% of the area within 3 km of the nest), relative to unburned territories, dropped by 2 yr post-burn, was lowest from 4 to 6 yr post-burn, and returned to the 1-yr post-burn level in 10-11 yr. The time lag in effect of the burns was attributed to a temporary concentration of prey in remaining unburned habitats, and the recovery was attributed in part to regrowth of shrubby vegetation. The probability of post-burn territory occupancy was not related to how much of a territory had burned but was positively related to the presence of a vacant neighboring territory, the percentage of cropland within 3 km of the nest, and the percentage of shrubs within 3 km of the nest. The only significant variable in a model to discriminate post-burn pairs that were successful >50% or <50% of the time was nesting success of pairs in the territory in pre-burn years, suggesting that territory or pair quality was an important contributor to long-term nesting success. Previous studies in the SRBP (e.g., Marzluff et al. 1997) provided evidence that eagles may have been able to partly compensate for the effect of burns by concentrating foraging efforts in remnant shrub habitats, ranging over wider areas, foraging in other habitats (e.g., agricultural and riparian areas), and selecting alternate prey. However, it was suggested that the carrying capacity for eagles in the study area might be reduced when eagles expand into vacant neighboring territories.

Golden Eagles appear to be negatively impacted by residential and urban development. From fall through spring in southern New Mexico, eagles were not found in residential, irrigated agricultural, or desert/agricultural edge segments of roadside survey routes (Kimsey and Conley 1988). Urban expansion in the Rocky Mountain front caused the abandonment of some historically-used Golden Eagle nests (Phillips 1986).

Of 39 Golden Eagle territories in eastcentral Utah monitored during a 10-yr period, coal mining activities impacted productivity at two territories (Bates and Moretti 1994). In one territory, escarpment collapses destroyed four nests, and eagles were not able to nest in the area for 4 yr thereafter. Other nests in the vicinity of the escarpment collapses experienced no change in productivity. At another territory, escarpment collapse was imminent, and eyries were covered with chain-link fences to induce nesting in safer locations. The eagles relocated and nested successfully.

Of 21 Golden Eagles found sick or dead over a 2-yr period in 18 states and two Canadian provinces, all had residues of dichlorodiphenyldichloroethylene (DDE), and most had residues of dichlorodiphenyltrichloroethane (DDT), dieldrin, and heptachlor epoxide (Reichel et al. 1969). Of 86 eagles captured in Montana during spring migration over an 8-yr period, 48% had residues of DDE (Harmata and Restani 1995). About 11% of tested birds may have been exposed to cholinesterase-inhibiting pesticides. Of 144 known pesticide-related Golden Eagle deaths in the United States during a 10-yr period, 87% resulted from pesticide abuses (defined as cases in which a pesticide intentionally was used in violation of the legal specifications on the label) and 13% were caused by unknown pesticide uses (Mineau et al. 1999). Thus, 17% of 734 total known raptor deaths were Golden Eagles killed from pesticide abuses (usually by carbofuran), suggesting high susceptibility to this type of intentional killing. Eagle mortalities were not associated with labeled use of pesticides, possibly because of the minimal overlap of the Golden Eagle's distribution with intensive agricultural areas. However, Golden Eagles died after eating waterfowl that were accidentally poisoned in winter wheat fields (Mineau et al. 1999).

Injured or sick Bald (*Haliaeetus leucocephalus*) and Golden eagles brought to a Minnesota wildlife rehabilitation center from Minnesota and neighboring states had a 17.5% incidence of lead poisoning before the federal ban on lead shot for hunting waterfowl and a 26.8% incidence of lead poisoning after the ban (Kramer and Redig 1997). The rate of acute lead poisoning (>1.0 parts per million [ppm] in blood) before the ban was higher than after the ban (35 versus 24%, respectively), and the rate of subclinical lead exposure (between 0.2 and 0.6 ppm in blood) before the ban was higher than after the ban (64 versus 50%, respectively). Most eagles were submitted in November and December. Before the ban, most eagles were submitted for lead poisoning, and after the ban most eagles were submitted for miscellaneous trauma. Seven of 31 (23%) Golden Eagles found dead in Alberta, Saskatchewan, and Manitoba had high lead exposure (>6 ppm in liver and kidney) (Wayland and Bollinger 1999). There was no association between waterfowl hunting intensity and the rate of eagle poisoning across the area, suggesting that eagles ingested lead shot by consuming non-waterfowl prey. Twelve of 16 (75%) eagles found in Idaho during a 9-yr period had elevated (>8 ppm in liver) lead exposure, and five of these eagles died from lead poisoning (Craig et al. 1990). Lead projectiles in stomach contents of two additional eagles were not the type used for waterfowl hunting, suggesting eagles consumed lead from non-waterfowl carcasses. Fifty-six percent of 86 eagles captured in Montana during spring migration over an 8-yr period had elevated (>0.2 ppm) blood lead levels, and 26% of these had blood levels indicating significant recent exposure (>0.4 ppm) (Harmata and Restani 1995). Rates of lead poisoning did not vary by age, sex, or year. Based on observations of shot ground squirrels and of eagle behavior, it was suggested that this lead was acquired from scavenged hunter-killed ground squirrels. Thirty-six percent of 162 eagles captured in California had lead levels greater than background levels (>0.20 ppm), and 6% had clinical or acute lead poisoning (>0.60 ppm) (Pattee et al. 1990). Lead levels were highest in November, December, and March and lowest in June, July, and August. Eagles may have ingested metallic lead projectile fragments from hunter-killed carcasses of coyotes (*Canis latrans*) and California ground squirrels. Of 26 known mortalities in a radio-tracked population of Golden Eagles during the mid-1990's in California, 8% were killed by lead poisoning (Hunt et al. 1997).

Electrocution appears to be a widespread source of mortality for Golden Eagles in North America (Benson 1981, Harness and Wilson 2001). Over 300 electrocutions of Golden and Bald eagles were documented in the United States during a 3-yr period (Boeker and Nickerson 1975). During another 2-yr period, an additional 250 Golden Eagles were found electrocuted in 14 states, mostly in Utah (32%), Nevada (24%), Idaho (12%), and Montana (10%) (Boeker and Nickerson 1975). Many electrocutions occurred along a few stretches of power line; for example, 37 electrocuted Golden Eagles were found along 24 km of power line in Colorado, and 47 electrocuted Golden Eagles were found along 19 km in Utah. Sixteen (94%) eagles killed by electrocution in the Pawnee National Grassland in Colorado were immature. Nearly all documented electrocutions occurred on distribution lines about 8-9 m high with lines spaced 1.0-1.5 m apart. Twenty immature birds banded in the SRBP from 1968 to 1971 were found dead, and 60% of these had been electrocuted (Beecham and Kochert 1975). Eighty-two percent of 416 carcasses found along power lines during surveys in Idaho, Wyoming, Utah, Nevada, New Mexico, and Oregon during a 3-yr period were Golden Eagles (Benson 1981). Of 52 eagle carcasses that could be aged, 54% were immatures, 40% were subadults, and 6% were adults, compared with 183 live eagles aged during transect surveys in which 68% were subadults or immatures and 32% were adults. Of 35 Golden Eagles with known season of electrocution, 28

(80%) died during the winter. During the winter and migration periods, the number of eagles observed per length of power line during transect surveys was positively correlated with both the overall number of rabbits per length of power line and the number of cottontail rabbits per length of power line but not with the number of jackrabbits per length of power line. Immature eagles were thought to be more nomadic in winter than adults and would therefore be more likely to respond to spatially and temporally variable prey abundances. Immature eagles may have used power poles more often than adults because of hunting inexperience and behavior, causing greater rates of electrocution than in adults. Golden Eagles accounted for 54% of 61 raptor electrocutions in Montana during a 6-yr period (O'Neill 1988). The number of electrocuted birds was twice as high on poles situated on hilly grasslands than on poles in flat agricultural land. No significant differences among pole types were found for the frequency of electrocutions, but poles with transformers and double crossarms accounted for 61% of the electrocutions. Of 1428 electrocution records reported by electric utility companies throughout the United States during an 11-yr period, 19% were Golden Eagles (Harness and Wilson 2001). Of 90 eagle mortalities categorized by age, 66% were juvenile. Late winter and spring peaks (January-April) in electrocutions of eagles may have resulted from a spike in discoveries associated with snowmelt or from an increase in risk when feathers become wet from winter storms. Deaths of Bald and Golden eagles by electrocution were associated with groups of three-phase transformers (27%), three-phase tangent structures (21%), three-phase deadends (power line end structures) (20%), and one-phase transformers (14%). Of 26 known mortalities in a radio-tracked population of Golden Eagles during the mid-1990's in California, 19% died from electrocution (Hunt et al. 1997).

Golden Eagles are potentially at risk of collisions with wind-turbine blades at wind-resource areas. Of 26 known mortalities in a radio-tracked population of eagles during the mid-1990s in California, 35% died from collisions with wind-turbine blades (Hunt et al. 1997). At this site, a high density of nesting eagles and an important foraging area in the vicinity of the wind-generation site likely contributed to the rate of collisions (Hunt et al. 1997).

Of 38 Golden Eagle museum specimens collected from throughout Canada, Alaska, and the contiguous United States west of the Mississippi River during an 80-yr period, 29% died of poisoning (64% of these by strychnine) incidental to the poisoning of canids, 11% were caught in traps set for predators, muskrats (*Ondatra zibethicus*), or beaver (*Castor canadensis*), and 6% were shot (Bortolotti 1984). All trapping and poisoning deaths occurred between November and May, with 26% occurring during December. No change in the frequency of trapped or poisoned birds occurred through time. Intense trapping and poisoning for gray wolves (*Canis lupus*) killed many eagles in Montana during the late 1890's (Cameron 1905). Shooting has been a notable source of mortality for eagles in many areas (Roberts 1932, Dixon 1937, Woodgerd 1952, McGahan 1968, Camenzind 1969, Baglien 1975, Beecham and Kochert 1975, Clapp et al. 1982, Houston 1985, Phillips 1986). The extent of shooting Golden Eagles in recent years is unclear. However, no shooting deaths were found in a study in California in the mid-1990's, when 26 mortality events of free-ranging eagles were recorded (Hunt et al. 1997).

Management Recommendations:

These recommendations are suggestions for protecting Golden Eagles.

Conversion of brushland to grassland may reduce rabbit abundance (Knick and Dyer 1997). The abundance of rabbits is a factor in determining the laying rate of Golden Eagles and thus the annual productivity of populations (Steenhof et al. 1997). In southwestern Idaho, managers should strive to maintain shrub stands within 3 km of a nesting site (Kochert et al. 1999). This goal can be achieved through fire suppression and revegetation efforts.

Call (1979) suggested that mining operations should not be conducted within 0.8-1.6 km of eagle nests, but little data are available with which to establish an appropriate buffer zone (M. N. Kochert, U.S. Geological Survey, Forest and Rangeland Ecosystem Science Center, Boise, Idaho, pers. comm.). If disturbance is unavoidable, nests in occupied territories may be physically relocated. Golden Eagle nests in Wyoming have been successfully relocated with careful placement of nest platforms in areas frequently used by the adult eagles (Postovit et al. 1982). Eagles also have been discouraged from nesting at locations where escarpment collapse is imminent by covering eyries with chain-link fencing (Bates and Moretti 1994).

The number of Golden Eagle electrocutions in winter in a given area appear to reflect the local density of eagles, and eagles seem to show a numerical response to winter jackrabbit densities (Kochert 1980). Jackrabbit densities may vary in time and space (Kochert 1980), and as a result there may be annual variation in the location of electrocution problem (Marshall 1940). Improvements in data collection and monitoring procedures regarding avian electrocutions are needed to comprehensively evaluate the factors influencing mortalities by electrocution (Harness and Wilson 2001). Eagles may be discouraged from perching on power-line poles by installing triangular “Eagle Guards” on crossarms (Marshall 1940), and other modifications to current lines may prevent further losses (APLIC 1996). Ensure that new lines are constructed to specifications that prevent raptor electrocutions (APLIC 1996).

Table. Golden Eagles habitat characteristics.

Author(s)	**Location(s)**	**Habitat(s) Studied***	**Species-specific Habitat Characteristics**
Allen 1987	North Dakota	Mixed prairie, shortgrass, shrubsteppe, woodland	Nesting substrates for eagles were on the sides of buttes and in cottonwoods (*Populus deltoides*)
Baglien 1975	Montana	Grassland, shrubsteppe, woodland	Nested primarily on cliffs and occasionally in Douglas fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*) trees; tree nests were in tall and usually isolated trees located at the edge of small stands; tree nests averaged 17 m above the ground; cliff nests were placed in southern and eastern aspects more often and in northern and western aspects less often than expected from aspect availability; nests were placed more often than expected below the 500-cm snowfall line; habitat near nests had more sagebrush/grassland and less snowfall than expected by availability
Bates and Moretti 1994	Utah	Shrubsteppe, woodland	Nested on cliffs and in Douglas fir and cottonwood trees
Beecham and Kochert 1975	Idaho	Cropland, shrubsteppe	Nest densities were higher in areas with more abundant cliffs and lower in areas with more cultivation
Boeker and Ray 1971	Colorado, New Mexico, Wyoming	Not given	Nested primarily on cliffs and occasionally in trees or on earthen mounds; density was related to the availability of nesting substrates
Bruce et al. 1982	Washington	Idle woodland, logged woodland	Nested in Douglas fir and on cliffs; 17 of 18 (94%) tree nests were near edges of forest stands or in small stands of trees near clearcuts or open fields; nests were <500 m from

			open areas or from clearcuts in which primary prey were found
Camenzind 1969	Utah	Shrubsteppe	Nested on cliffs, on the ground, and on artificial structures; of 27 nests, six (22%) faced north, one (4%) faced east, 15 (56%) faced west, and five (18%) faced south
Carnie 1954	California	Not given	Nested primarily in trees and occasionally on cliffs
Collopy and Edwards 1989	Idaho	Shrubsteppe	Territory size was negatively related to the amount of shrub vegetation supporting black-tailed jackrabbits (*Lepus californicus*)
Dixon 1937	California	Cropland, woodland	Nested in oak (*Quercus* spp.) and eucalyptus (*Eucalyptus* spp.) trees and on cliffs; territories were largest where agricultural land was prevalent; used additional roost sites near nests
Houston 1985	Saskatchewan	Not given	Nested on cliffs up to about 46 m high and placed nests anywhere from 3 m above the ground to 1 m from the top; also nested in trees
Hunt et al. 1995, 1997	California	Chaparral, cropland, grazed tame pasture, woodland	Nested in oaks, pines (*Pinus* spp.), sycamores (*Platanus* spp.), cypress (*Cupressus* spp.), and on transmission towers
Knowles 2001	North Dakota	Grassland, woodland	Nested on cliffs and in cottonwoods; one nest was 12 m high in a cottonwood with a diameter at breast height of 60 cm; some historic nests destroyed by fire, lightning, and cliff collapse
Kochert et al. 1999	Idaho	Burned shrubsteppe, shrubsteppe, tame grassland	Shrub cover was reduced in territories that were burned; nesting success declined after wildfires but recovered about 10 yr later

Leslie 1992	Colorado	Cropland, idle mixed-grass pasture, shortgrass pasture, woodland	Nested on chalk bluffs
Lish 1975	Oklahoma	Shortgrass, woodland	Nested on sandstone cliffs; 12 nests averaged 26 m above ground
MacLaren et al. 1988	Wyoming	Shrubsteppe, woodland	Nested on cliffs and in trees (mainly ponderosa pine); 12 nest trees had an average diameter at breast height of 75 cm; average slope at 30 nest sites was 23 degrees; mean distances to nearest water source and road for 30 nests were 0.32 and 0.45 km, respectively
Marzluff et al. 1997	Idaho	Burned shrubsteppe, cropland, shrubsteppe, tame grassland	Nested on cliffs; territories were highly variable in habitat composition; most home ranges included more sagebrush (*Artemisia* spp.)/rabbit brush (*Chrysothamnus* spp.) habitats and less grassland, winter fat (*Ceratoides lanata*), water, and agricultural land than available; most core areas had more sagebrush/rabbit brush and salt-desert shrub and less winter fat, agriculture, and grassland than available; selection for sagebrush/rabbit brush was higher in territories where that habitat was rarer; avoided grassland habitats at all scales studied; selected foraging points in jackrabbit habitat during the non-breeding season but did not during the breeding season
McGahan 1968	Montana	Mixed-grass pasture, montane shrubland, shrubsteppe, woodland	Nested primarily on cliffs, secondarily in Douglas fir trees, and occasionally in cottonwood or ponderosa pine trees; northern exposures of cliffs were avoided as nest sites
Menkens and Anderson 1987	Wyoming	Shrubsteppe, woodland	Nested primarily in deciduous trees, secondarily in ponderosa pine trees, and occasionally on riverbanks or the

			sides of buttes; tree nests were in the upper one-third of trees that typically were larger than nearby trees; shrub cover near nests did not differ between pine and deciduous tree nests
Morneau et al. 1994	Quebec	Forested tundra, tundra, woodland	Nested on cliffs; most cliffs oriented south or southwest, and those oriented north or northwest had overhangs protecting the nest from inclement weather; 31 nests were placed an average of 37 m from the bottom of cliffs averaging 72 m in height
Phillips and Beske 1990	Wyoming	Cropland, grassland, shrubsteppe, woodland	Nested primarily in deciduous trees, secondarily in ponderosa pines, and occasionally on rock outcrops, peaks, human-made structures (windmills, towers, and artificial nest platforms), and creek banks; nests in trees were more successful than nests on human-made structures, creek banks, or rock outcrops
Phillips et al. 1990	Montana, Wyoming	Hayland, riparian grassland, shrubsteppe, woodland	Nested primarily in ponderosa pines, secondarily in cottonwoods, and occasionally on cliffs; nests were typically in upper one-third of tree in lateral branches
Seibert et al. 1976	Nevada	Burned shrubsteppe, montane shrubland, shrubsteppe, tame grassland, woodland	Nested primarily on cliffs and occasionally in trees; cliffs with northerly aspects may have been avoided; the full range of available cliff heights were used for nesting; 80% of nests were in elevations where sagebrush and rabbit brush were dominant vegetation types; 20% of nests were at elevations with pinyon pine (*Pinus edulis*)/juniper (*Juniperus* spp.), montane shrubland, quaking aspen (*Populus tremuloides*), and conifer forests habitats
Smith and Murphy 1982	Utah	Not given	Nested on cliffs or rock outcrops; nests were uniformly distributed across the study area in one year and randomly

			distributed across the study area in another year
Steenhof et al. 1993	Idaho, Oregon	Cropland, shrubsteppe, tame grassland	Nested on platforms placed on electric transmission line towers; in the Idaho segment, raptors overall nested on towers that had more rangeland, fewer roads, and shorter lengths of power line than unused towers, but topographic variation did not differ between used and unused towers; towers used for nesting by all raptors did not differ from unused towers in habitat characteristics (amounts of shrub, grass, or agriculture), topographic variation, or the amount of human structures within 1 km of the tower
Whitfield et al. 1969	Saskatchewan	Woodland	Nested on cliffs with all aspects except northern, southern, and northwestern; nests were near open areas within boreal forest
Young et al. 1995	Alaska	Tundra	Nested on cliffs in the north slope and foothills of the Brooks Range but not in the coastal plain to the north

*In an effort to standardize terminology among studies, various descriptors were used to denote the management or type of habitat. “Idle” used as a modifier (e.g., idle tallgrass) denotes undisturbed or unmanaged (e.g., not burned, mowed, or grazed) areas. “Idle” by itself denotes unmanaged areas in which the plant species were not mentioned. Examples of “idle” habitats include weedy or fallow areas (e.g., oldfields), fencerows, grassed waterways, terraces, ditches, and road rights-of-way. “Tame” denotes introduced plant species (e.g., smooth brome [*Bromus inermis*]) that are not native to North American prairies. “Hayland” refers to any habitat that was mowed, regardless of whether the resulting cut vegetation was removed. “Burned” includes habitats that were burned intentionally or accidentally or those burned by natural forces (e.g., lightning). In situations where there are two or more descriptors (e.g., idle tame hayland), the first descriptor modifies the following descriptors. For example, idle tame hayland is habitat that is usually mowed annually but happened to be undisturbed during the year of the study.

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