The Effects of Management Practices on Grassland Birds— Merlin (*Falco columbarius*)

Chapter R of

The Effects of Management Practices on Grassland Birds

Professional Paper 1842–R

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The Effects of Management Practices on Grassland Birds—Merlin (*Falco columbarius*)

By Paul M. Konrad,^{1,2} Jill A. Shaffer,¹ and Lawrence D. Igl¹

Chapter R of

The Effects of Management Practices on Grassland Birds

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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
Length		
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
Area		
square kilometer (km ²)	247.1	acre
square kilometer (km ²)	0.3861	square mile (mi ²)

Abbreviations

- DDE dichlorodiphenyldichloroethylene
n.d. no date
PCB polychlorinated biphenyl
spp. species (applies to two or more species within the genus)

Acknowledgments

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The Effects of Management Practices on Grassland Birds—Merlin (*Falco columbarius*)

By Paul M. Konrad,^{1,2} Jill A. Shaffer,¹ and Lawrence D. Igl,¹

Capsule Statement

The key to Merlin (*Falco columbarius*) management is maintaining an interspersed grove of deciduous or coniferous trees for nesting and open grasslands for hunting. Merlins do not build their own nests but rather use former nests of other bird species, including those of corvids (crows, ravens, and magpies) and accipitrids (hawks). In recent decades, Merlins have established breeding populations in urban and residential areas in the northern Great Plains. Vernacular and scientific names of plants and animals follow the Integrated Taxonomic Information System (<https://www.itis.gov>) and the 59th Supplement to the American Ornithological Society's Check-list of North American Birds (Chesser and others, 2018).

Breeding Range

Merlins breed from the northern limits of the tree line in northern Alaska to northern Newfoundland and Labrador; south throughout most of Canada (except the northeastern Northwest Territories and northern Quebec); and into western Washington, Idaho, Montana, Wyoming, North Dakota, South Dakota, Minnesota, Wisconsin, and Maine (National Geographic Society, 2011). The breeding, migration, nonbreeding, and year-round distributions of Merlins in North America are shown in figure R1 (not all geographic places mentioned in report are shown on figure).

Three Merlin subspecies are found in North America (Temple, 1972). This account primarily focuses on the Richardson's Merlin (*F. c. richardsonii*) which breeds in the northern Great Plains and prairie parkland. The Black subspecies, *F. c. suckleyi*, breeds in the dense forested areas of the Pacific Northwest, from western Oregon north to southern Alaska. The Taiga subspecies, *F. c. columbarius*, breeds in the taiga forests from Maine to northern Canada and Alaska, including the northern Rocky Mountain forest region of Idaho, western Montana, western Wyoming, and western Alberta.

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²Wildlife Adventures (current).

Merlin. Illustration by Patsy D. Renz, used with permission.

The breeding ranges of the Taiga and Richardson's subspecies have expanded southward in recent years (Cava and others, 2014; Pfannmuller and others, 2017).

Suitable Habitat

In the Great Plains, Merlins prefer open grasslands for hunting and native or planted tree groves for nesting (in former nests of other species). Merlins inhabit shortgrass and mixed-grass prairies, tame grasslands, pastures, hayland,

Figure R1. The breeding, migration, nonbreeding, and year-round distributions of the Merlin (*Falco columbarius*) in North America. Map modified from Warkentin and others (2005, used with permission).

shrubsteppe, woodland, wetland, cropland, and urban habitats, especially where these habitats have adjacent riparian woodland (Bent, 1961; Fox, 1964; Ellis, 1976; Hodson, 1976, 1978; Oliphant and Thompson, 1976; Oliphant and McTaggart, 1977; Smith, 1978; Houston and Schmidt, 1981; Young, 1981; Becker, 1984; Oliphant and Haug, 1985; Dekker, 1988; Warkentin and James, 1988; Sieg and Becker, 1990; Sodhi, 1991a; Sodhi and others, 1992; Houston and Hodson, 1997; Minnesota Ornithologists' Union, 2002; Bildstein and Thérien, 2018; Boal, 2018). Historically, Merlins inhabited rolling plains that contained small groves of cottonwoods (*Populus* species [spp.]), aspens (*Populus* spp.), and other deciduous trees that were used for nesting (Bent, 1961). Throughout southern Saskatchewan, Merlin nest sites were along major river systems (Oliphant and McTaggart, 1977). Shelterbelts and groves of deciduous trees within tame grasslands also were used by nesting Merlins in Saskatchewan (Fox, 1964). In southeastern Montana, ponderosa pine (*Pinus ponderosa*)

woodlands provided nesting habitat and some hunting habitat, as well as perches and night roosts (Becker, 1984).

In southeastern Montana, nest sites usually were on south-facing slopes in areas with reduced tree density and within short distances of open grasslands where Merlins hunted (Becker, 1984). Merlins preferred nesting on south-facing slopes above adjacent grazed prairies that were dominated by western wheatgrass (*Pascopyrum smithii*), blue grama (*Bouteloua gracilis*), prairie junegrass (*Koeleria macrantha*), and needle and thread (*Hesperostipa comata*) (Sieg and Becker, 1990).

As with other falcon species, Merlins do not build their own nests. Throughout their range in the northern Great Plains, nearly all nesting pairs use former nests built by American Crows (*Corvus brachyrhynchos*) or Black-billed Magpies (*Pica hudsonia*) (Ellis, 1976; Hodson, 1976; Houston and Schmidt, 1981; Becker, 1984; Oliphant and Haug, 1985; Warkentin and James, 1988; Sieg and Becker, 1990; Houston

and Hodson, 1997). Urban-nesting Merlins commonly use former crow nests built in spruce (*Picea* spp.) (Oliphant and Thompson, 1976; Smith, 1978; Warkentin and James, 1988; Sodhi and others, 1992; Minnesota Ornithologists' Union, 2002). In Grand Forks, North Dakota, two breeding pairs of Merlins nested in former American Crow nests in spruce trees (D.O. Lambeth, Grand Forks, North Dakota, written commun. [n.d.]). One nest was in the yard of a university fraternity house, near a busy intersection. In Minot, North Dakota, Merlins nested in a former American Crow nest about 11 meters (m) above the ground in a spruce tree in a residential area (R. Martin, Minot, North Dakota, written commun. [n.d.]).

In rural Alberta and Saskatchewan, former magpie nests were used more than former crow or hawk nests (Fox, 1964; Hodson, 1976; Young, 1981; Houston and Hodson, 1997). Of 125 Merlin nests in Saskatchewan, 102 originally were built by magpies and 21 were built by crows (Houston and Hodson, 1997). In Montana, Ellis (1976) found seven of eight Merlin nests in former Black-billed Magpie nests; one pair used a former American Crow nest in a conifer. Also in Montana, all of 42 Merlin pairs used former magpie nests in conifer trees; all nests had a stick canopy and 60 percent had a mud cup in the base (Becker, 1984; Sieg and Becker, 1990). Merlins elsewhere have nested in former magpie nests built in groves of coniferous trees adjacent to grasslands; those locations include western North Dakota (Stewart, 1975; Postovit, 1979; Sieg and Becker, 1990), western South Dakota (Pulkrabek and O'Brian, 1974; Sieg and Becker, 1990; South Dakota Ornithologists' Union, 1991), eastern Wyoming (Sieg and Becker, 1990), and northwestern Nebraska (Sieg and Becker, 1990; Sharpe and others, 2001).

Besides corvid nests, Merlins also have been reported to nest in former nests of raptors, in cavities, and on the ground. Three Merlin pairs in Saskatchewan used former Swainson's Hawk (*Buteo swainsoni*) nests (Houston and Schmidt, 1981; Houston and Hodson, 1997). In Alberta, one Merlin pair nested in a former Ferruginous Hawk (*Buteo regalis*) nest (Hodson, 1976). Near Calgary, Alberta, three Merlin pairs nested in cavities at the top of a broken balsam poplar (*Populus trichocarpa*) (Bent, 1961). In Saskatchewan, two Merlin pairs nested in natural tree cavities (Fox, 1964). Although no specific information was provided, Richardson's Merlins were reported to have nested occasionally in former magpie nests built in holes in cliffs, and a few Merlins were reported to have nested on the ground (Call, 1978).

Merlins nest in coniferous and deciduous trees and shrubs. Coniferous trees that have supported Merlin nests include ponderosa pine (Bent, 1961; Ellis, 1976; Becker, 1984; Sieg and Becker, 1990), spruce (Bent, 1961; Fox, 1964; Oliphant and Thompson, 1976; Smith, 1978; Oliphant and Haug, 1985; Warkentin and James, 1988; Sodhi and others, 1992; Houston and Hodson, 1997; Minnesota Ornithologists' Union, 2002), jack pine (*Pinus banksiana*) (Fox, 1964), Douglas-fir (*Pseudotsuga menziesii*) (Ellis, 1976), and limber pine (*Pinus flexilis*) (Ellis, 1976). Conifers provide easy access and maximum concealment (Becker, 1984). In southeastern

Montana, Merlins also use conifers (pines) near nest sites as night roosts (Becker, 1984). Deciduous trees and shrubs that have supported Merlin nests include maple (*Acer* spp.) (Hodson, 1976; Houston and Hodson, 1997), boxelder (*Acer negundo*) (Fox, 1964; Hodson, 1978), aspen (Bent, 1961; Fox, 1964; Young, 1981; Houston and Hodson, 1997), balsam poplar (Bent, 1961; Hodson, 1976, 1978; Oliphant and Thompson, 1976, 1978; Smith, 1978), black poplar (*Populus nigra*) (Bent, 1961), cottonwood (Houston and Hodson, 1997), birch (*Betula* spp.) (Fox, 1964), green ash (*Fraxinus pennsylvanica*) (Houston and Hodson, 1997), elm (*Ulmus* spp.) (Houston and Hodson, 1997), willow (*Salix* spp.) (Bent, 1961; Fox, 1964; Hodson, 1976, 1978; Oliphant and Thompson 1976, 1978; Young, 1981), and chokecherry (*Prunus virginiana*) (Houston and Hodson, 1997). Of 125 Merlin nests in Saskatchewan, 66 were in maple, 22 in aspen, 13 in green ash, 11 in willow, 5 in elm, 2 in cottonwood, 2 in spruce, 1 in chokecherry, and 3 in unidentified species (Houston and Hodson, 1997). Nest heights among all studies varied from 2 m in willows (Oliphant and Thompson, 1978) to 19 m in spruce (Warkentin and James, 1988).

Each member of a Merlin pair uses a favorite perch, typically a branch in a tall dead tree that overlooks the pair's territory (Fox, 1964). A plucking perch commonly is used by males to prepare prey before transferring it to the female (Sodhi, 1991a). Perches also are important for hunting; of 286 hunting attempts in Saskatchewan, 95 percent were initiated from perches (Sodhi and others, 1991b).

In the 20th century, the Richardson's Merlin expanded the northern limits of its winter and breeding distributions (James and others, 1987a; Bildstein and Therrien, 2018). By the 1970s, Richardson's Merlins began colonizing urban, residential, and industrial areas in some Canadian cities (Bildstein and Therrien, 2018), most notably in Edmonton, Alberta (Smith, 1978) and Saskatoon, Saskatchewan (Oliphant, 1974; Sodhi and others, 1992; Warkentin and others, 2005). The colonization of urban areas by the species followed the influx of nesting American Crows and Black-billed Magpies (Houston and Schmidt, 1981), whose former nests are used by Merlins. In Edmonton, Merlins used the river valley and upland nesting habitats, and the species nested in white spruce (*Picea glauca*) planted in the river flood plain after the trees grew to a height of at least 15 m (greater than [$>$] 35 years old) and supported former American Crow nests in their branches (Smith, 1978). However, only six locations outside the river valley contained this nesting habitat, mainly in parks and cemeteries. The release in 1979 of six captive-raised Merlins in Regina, Saskatchewan, may have contributed to the establishment of a breeding population in Regina that included about 20 breeding pairs in 2005 (Warkentin and others, 2005). Urban habitats used by Merlins in Saskatoon include residential yards, city parks, cemeteries, semi-industrial areas, and university cropland and livestock areas (Oliphant and McTaggart, 1977; Sodhi, 1991a). Also in Saskatoon, the average nest site characteristics at 58 active Merlin nests were 12.5 m nest tree height, 40.6 centimeters (cm) nest tree diameter at

breast height, 8.9 m nest height, 1.9 percent shrub coverage within 10 m of the nest tree, 57.2 m distance from nest tree to nearest building, 22.4 m distance to nearest road, and 35.6 m distance to nearest light pole (Warkentin and James, 1988). Recent nesting records of Merlins have been reported throughout northern and central North Dakota (Martin, 1999, 2000), northern Minnesota (Pfannmuller and others, 2017), and Minneapolis, Minnesota (Minnesota Ornithologists' Union, 2002). In 2 years in Minneapolis, seven Merlin nests were discovered in backyards of the city's metropolitan area (Minnesota Ornithologists' Union, 2002).

Few studies have examined the effects of weather on Merlin reproduction or survival. In Saskatoon, Sodhi and others (1992) reported that weather (mean monthly temperature, number of days with measurable precipitation, and total precipitation in a month) did not seem to affect the breeding phenology of urban-nesting Merlins. Lieske and others (2000) determined that survival rates of juvenile Merlins in Saskatoon fluctuated stochastically and independent of Merlin densities, and food availability or weather conditions may have played an important role in influencing their survival. In Alberta, cold, rainy weather during hatching resulted in severe nest losses by Merlins (Hodson, 1976).

Prey Habitat

Grasslands are a primary component of Merlin foraging habitat. Merlins require an interspersed of grasslands and tree groves to meet the food requirements of pairs and their young (Hodson, 1976; Evans, 1982). Foraging areas typically include at least 50 percent grassland. In Alberta and Saskatchewan, grasslands in Merlin hunting ranges were primarily mixed-grass prairies dominated by needlegrass (*Achnatherum* spp., *Stipa* spp.) and wheatgrass (*Pascopyrum* spp., formerly *Agropyron* spp.), or shortgrass prairies dominated by grama (*Bouteloua* spp.) and needlegrass (Hodson, 1976). The composition of grasslands was dependent on grazing pressure; in heavily grazed grasslands, fringed sagewort (*Artemisia frigida*) and needleleaf sedge (*Carex duriuscula*) were common. Merlins may prefer native grasslands, probably because native vegetation supports the passerine species upon which Merlins prey (Hodson, 1976). The conversion of native grassland to cropland has destroyed much of the traditional Merlin foraging habitat in southwestern Saskatchewan (Hodson, 1976).

In Alberta, hunting ranges adjacent to 40 nest sites that were occupied during a 6-year period contained an average of 78 percent grassland and 22 percent cropland and woodland (Hodson, 1976). In southeastern Montana, the hunting ranges of three radiotagged male Merlins were studied in an area that included five physiognomic habitat types: grassland, prairie riparian, sagebrush (*Artemisia* spp.), agriculture (grain, fallow, and hay fields), and ponderosa pine (Becker, 1984; Becker and Sieg, 1987b). The three Merlins showed greater use of sagebrush (43.4 percent) and grassland (34 percent) habitats in June and July compared to the use

of agriculture (18.5 percent), riparian (3.3 percent), and pine (0.8 percent) habitats during that same period (Becker and Sieg, 1987b).

Merlins prey primarily on small birds, usually in open grasslands or sites associated with human habitation (urban and rural). In shortgrass prairies in southern Alberta, Merlins hunted for prey primarily over grasslands, which typically were grazed (>75 percent of the fields), although some grasslands were hayed and others remained idle; 50 percent of 2,070 prey remains at 46 Merlin nests were Horned Lark (*Eremophila alpestris*), 37 percent were Chestnut-collared Longspur (*Calcarius ornatus*), 3 percent were Western Meadowlark (*Sturnella neglecta*), 2 percent were Vesper Sparrow (*Poocetes gramineus*), and 8 percent were other species (Hodson, 1978). In southwestern Saskatchewan, 53.5 percent of Merlin prey items found at nests were Horned Larks, 13.6 percent were Chestnut-collared Longspurs, 13.3 percent were Brown-headed Cowbirds (*Molothrus ater*), 6.7 percent were Vesper Sparrows, 6.7 percent were Song Sparrows (*Melospiza melodia*), and 6.7 percent were Baird's Sparrows (*Centronyx bairdii*); the total number of nests and total prey remains examined were not provided (Fox, 1964). In Saskatoon, male and some female Merlins generally avoided hunting over cropland, preferring instead to hunt in residential areas, city parks, and grasslands, both inside and outside of the city, during the incubation, nestling, or postfledging periods (Sodhi, 1991a). Merlins probably avoided cropland because this habitat had the smallest prey abundance among available habitats. Near Edmonton in central Alberta, Merlins that hunted in pastures and cropland preyed on eight species of sandpipers (Charadriiformes) and five species of passerines during spring and fall (Dekker, 1988). Merlins also captured numerous dragonflies (Odonata) and one bat (Chiroptera).

In southeastern Montana, Becker (1984) examined evidence of prey remains at 20 active Richardson's Merlin nests and studied habitat utilization of three hunting male Merlins using radio telemetry. Evidence of remains at the 20 Merlin nests included at least 427 individual prey, representing 28 bird species, 3 mammal species, 1 reptile species, and 2 insect families (Acrididae and Noctuidae). Of the 28 bird species included among the prey remains, seven were bird species typically associated with woodland habits and 17 were species typically associated with grassland habits. Grassland birds represented 83 percent of the 427 individual prey recorded. Horned Larks, Lark Buntings (*Calamospiza melanocorys*), and Vesper Sparrows accounted for 57 percent of the total prey across the 2 years. The three radiotagged males used riparian, sagebrush, and ponderosa pine habitats more than expected and grassland and agricultural habitats less than expected, based on availability (Becker, 1984; Becker and Sieg, 1987b). The prey composition, however, emphasized the importance of open grassland habitats for Merlins in this study area, and suggested that the use of grasslands by Merlins was underrepresented by radio-locations, probably because hunting perches were lacking in grasslands.

In urban areas, an abundant prey base (for example, nonmigratory House Sparrows [*Passer domesticus*]) provides an easily accessible food source throughout the year (Warkentin and Oliphant, 1990; Sodhi, 1991a; Bildstein and Therrien, 2018). In residential or commercial urban areas, House Sparrows are the most common prey throughout the year, and waxwings (*Bombycilla* spp.) are important prey during the winter (Oliphant and McTaggart, 1977; Smith, 1978; Servheen, 1985; Warkentin and Oliphant, 1990; Sodhi, 1991a; Bildstein and Therrien, 2018; Boal, 2018). In Saskatchewan, maturation of ornamental mountain-ash (*Sorbus* spp.) and crabapple (*Malus* spp.) trees and the resulting fruit crops attracted more consistent populations of some winter birds, particularly Bohemian Waxwings (*Bombycilla garrulus*), making residential areas more attractive for Merlins during winter (Houston and Schmidt, 1981).

In Saskatoon, the average number of birds (potential prey) increased with the distance from Merlin nests (Sodhi and others, 1990). During 2 years in which House Sparrow nests were monitored, more House Sparrow fledglings were available during the Merlin nestling and fledgling periods, when more food (prey) was required by Merlin families (Sodhi and others, 1992). Potential prey species at five point counts in each of four Saskatoon habitats included averages of 4.5 prey species in urban habitats (that is, human habitation in and outside of the city except parks and cemeteries), 3.7 species in city parks and cemeteries, 2.7 species in grasslands, and 1.5 species in cropland (Sodhi, 1991a). The total numbers of individual birds used as prey increased from the Merlin's incubation period to its nestling period but decreased markedly during the fledgling period.

Area Requirements and Landscape Associations

Breeding Merlins require a large area that provides a nest site and adequate populations of small birds. Three radiotagged male Merlins in southeastern Montana had home ranges that were between 13 and 28 square kilometers (km²) in size and elongated in shape (Becker and Sieg, 1987b). Each male's home range overlapped with the home range of at least one other male. The male Merlins traveled as many as 8–9 kilometers (km) from their nests.

In Saskatoon, the sizes and locations of hunting ranges of 16 radiotagged male Merlins and 11 radiotagged females were studied by Sodhi (1991a). Of the 16 male Merlins, 12 were defined as residents that hatched in Saskatoon, and four males were defined as immigrants that hatched at an unknown location outside of Saskatoon. The average size of hunting ranges of the 12 resident males averaged 6.3 km², whereas the average size of hunting ranges of the four immigrant males averaged 33.7 km². The size of hunting ranges of three resident

and eight immigrant females averaged 6.6 km² and 8.6 km², respectively. Eight of the 12 resident males and all four immigrant males spent some time hunting outside of the city. Seven of eight immigrant females hunted outside of the city compared to only one of three resident females. Merlin home ranges were smaller where prey was more abundant, suggesting that prey abundance is an important variable affecting the size of Merlin home ranges (Sodhi, 1991a). Most of the male Merlins in Saskatoon adjusted the size of their range from one breeding period to another (for example, incubation period to nestling period to fledgling period) in accordance with changes in prey abundance. Hunting-range size of female Merlins in urban Saskatoon was inversely correlated with their body mass and with House Sparrow abundance. Merlins did not defend hunting ranges for exclusive use; therefore, neighboring Merlins exerted minimum pressure on hunting-range sizes. Some overlap of hunting ranges also was documented during Sodhi's (1991a) study.

In Edmonton, two Merlin pairs nested within 1.5 km of one another in the Saskatchewan River Valley (Smith, 1978). In rural Saskatchewan, the minimum distance between nests (number of breeding pairs not given) along the North Saskatchewan River was 2.5 km (Oliphant and Thompson, 1978). In the Kerrobert area of Saskatchewan, three Merlin nests were in a line, each separated by 1.6 km (Houston and Schmidt, 1981). In Saskatoon, the distance from a nest site to the nearest adjacent nest site averaged 1.2 km for 16 nests and ranged from 0.7 to 2.3 km (Oliphant and Haug, 1985).

In rural areas, nesting densities were 17.5 pairs per 100 km² in southern Alberta (Smith, 1978) and 3.8 pairs per 100 km² in southeastern Montana (Becker and Sieg, 1985). However, in Edmonton, eight pairs nested in a 40-km² area, indicating that urban habitats were as attractive, or more attractive, than available rural habitats (Smith, 1978). Breeding densities were greater in urban residential areas, city parks, and cemeteries than in prairie and cropland habitats. During one breeding season in Saskatoon, 16 Merlin pairs nested within a 29-km² area (Oliphant and Haug, 1985). Average Merlin nesting densities were 20 pairs per 100 km² in Edmonton (Smith, 1978) and 25.4 pairs per 100 km² in Saskatoon (Sodhi and others, 1992).

Brood Parasitism by Cowbirds and other Species

The Merlin is an unsuitable host of the Brown-headed Cowbird, an obligate brood parasite, and no known records of cowbird brood parasitism exist for this species (Shaffer and others, 2019). Interspecific and intraspecific brood parasitism may be rare in this species, in part, because adults strongly defend their nests from intruders during the breeding season (Wiklund, 1990; Sodhi, 1991a, 1991b).

Breeding-Season Phenology and Site Fidelity

Male Merlins typically arrive on breeding areas about 1 month before females. On the northern edge of the Great Plains, male and female Merlins may be present on breeding territories as early as February, and some may begin courtship activities immediately (Feldsine and Oliphant, 1985). In Alberta, males are common by early April (Bent, 1961). In western Saskatchewan, male Merlins arrive in late February or early March (Fox, 1964). In southeastern Montana, Merlins arrive about mid-March (Becker, 1984; Becker and Sieg, 1985). Merlins are one of the last migrants to leave southern Alberta in the fall; the latest fall sighting was in early December (Bent, 1961). In western Saskatchewan, juvenile Merlins begin migrating southward during mid-August, and the fall flight of migrant Merlins across the Saskatchewan prairies has ceased by mid-October (Fox, 1964). Some individuals may overwinter in the Great Plains (Warkentin and others, 2005).

Renesting rarely has been reported for Merlins in the wild; however, apparent renesting has been reported in southern Alberta (Bent, 1961; Hodson, 1976). Double-brooding has not been reported for Merlins (Sodhi, 1989), but one case of polygyny has been reported in Saskatoon (Sodhi, 1989). One male occupied two different nest sites that were about 450 m apart and was paired with a different female at each site. At one nest, four nestlings successfully fledged; the second nest was deserted about 5 weeks after nesting began.

Both sexes of Merlins exhibit fidelity to previous nesting areas, but site fidelity (that is the propensity to return to a former breeding area) typically is higher in adult males than in adult females. In Alberta, 9 of 12 banded adult males were recaptured at their original nest sites, 2 males were less than 4 km from their original nest sites, and 1 male was 12.9 km from his original site (Hodson, 1976). Of 10 banded adult females recaptured, 2 females were captured at their original nest sites, 6 females were captured 16.1–32.2 km away, and 2 females were captured more than 120.7 km from their original nest sites. Male Merlins in Saskatoon also were more likely than females to return to a particular site between breeding seasons (Warkentin and others, 1991). Of 29 territories on which breeding male Merlins were captured in Saskatoon, 41 percent contained the same males from 1 year to the next (James and others, 1989). Of 49 territories on which breeding female Merlins were captured in Saskatoon, 20 percent contained the same birds from 1 year to the next. Breeding dispersal (movements between two or more breeding places) averaged 1.1 km for 15 males and 2.3 km for 29 females. In Alberta, Hodson (1976) suggested that former breeding pairs mate again only by chance in ensuing years. Mate fidelity between breeding seasons in Saskatoon was low (20 percent of 60 nesting attempts involved the same male and female in 2 or more consecutive years) and was apparently related to site fidelity (Warkentin and others, 1991). No differences in productivity were associated with site or mate fidelity. One ground nest in Newfoundland was used

by nesting Taiga Merlins for 23 consecutive years, although it is unknown whether the same pair occupied this site during this period (Trimble, 1975).

James and others (1989) reported that natal dispersal of male Merlins in Saskatoon was greater than natal dispersal of female Merlins. Average natal dispersal (movements between hatch place and breeding place) was 4.1 km for 25 males and 3 km for 15 females. These distances reflected movements within the study area and did not reflect longer movements that may have been made outside of the study area. James and others (1989) also determined natal dispersal by comparing the proportions of adults that were captured that had been banded locally as chicks. Sixty percent of 68 males and 39 percent of 89 females were banded locally as chicks, indicating that females dispersed farther from their natal areas than males. Female Merlins in Saskatoon showed greater average natal dispersal (24.2 km) than male Merlins (4.0 km) (James and others, 1987b). Shorter-than-normal natal dispersal distances may result in close inbreeding events in Merlins (Warkentin and others, 2013). In Saskatoon, Warkentin and others (2013) reported 2.8 percent of 35 Merlin pairs were father-daughter pairings, and 2.3 percent of 88 Merlin pairs were mother-son pairings.

Species' Response to Management

Murphy (1991) considered the Merlin to be one of the prairie raptors that benefits from disturbance of uplands by burning, mowing, or grazing techniques that yield light-to-moderate grass and forb cover, which forms a habitat mosaic for prey. For example, grazing practices provide open hunting areas for Merlins and habitat for the prey species on which Merlins depend. In shortgrass prairies in southern Alberta, Merlins hunted for prey primarily over grazed grasslands, where little escape cover existed for potential prey (Hodson, 1978). Hodson (1978) concluded that Merlins seldom used idle grasslands because idle grasslands likely provided better escape cover for potential prey. In a 2-year study in southeastern Montana, low-to-moderate grazing of grassland and sagebrush habitats may have created a diverse mosaic of favorable habitats for prey species preferred by Merlins (Becker, 1984, 1985). Intensive grazing or overstocking of livestock may reduce vegetative diversity of grassland and sagebrush habitats and subsequently reduce prey diversity. Grazing also may negatively affect trees that are used by Merlins for nesting. In southwestern Saskatchewan, Merlins nested in shelterbelts or in groves of deciduous trees in which the trees had been rubbed bare of the lower branches by cattle and the undergrowth was trampled and destroyed (Fox, 1971). These disturbances to trees and tree plantings seem to be the first stage in the destruction of the trees by cattle.

Conversion of native grasslands into cultivated farmland has reduced suitable breeding habitat for Merlins (Trimble, 1975; Hodson, 1976). The breeding range of Richardson's

Merlins contracted rapidly during a 20-year period beginning in the mid-1950s (Hodson, 1976). This contraction has been attributed, in part, to the conversion of native grasslands to cultivated farmland. Richardson's Merlins that nested in rural Alberta and Saskatchewan shifted their distribution in response to cultivation of prairie by inhabiting cities where nest sites and prey were common. Smith (1978) reported that Merlin nesting habitat was created after conifers were planted in the river flood plain in Edmonton, where conifers historically had been absent or scarce. The youngest tree in which an active Merlin nest was found was 35 years old. Although urban areas can provide Merlins with high quality nesting habitat, stable nesting territories, reduced predation, and sometimes high reproductive output compared to natural habitats, Merlin survival in urban areas can be reduced by a suite of anthropogenic causes of mortality (for example, collisions with vehicles and stationary objects, electrocution, diseases, and destruction of nests during tree trimming) (Dwyer and others, 2018).

Merlin populations may be adversely affected by pesticide contamination, especially those that result in eggshell thinning and reduced nesting success. Chemicals causing contamination include dichlorodiphenyldichloroethylene (DDE), dieldrin, heptachlor epoxide, polychlorinated biphenyl (PCB), and mercury (Ellis, 1976; Fyfe and others, 1976; Hodson, 1976; Fox and Donald, 1980; Evans, 1982; Becker, 1984; Becker and Sieg, 1987a; Noble and Elliot, 1990). The most severe cases of pesticide contamination may go undetected because heavily contaminated Merlins may not attempt to nest or may die without detection (Fyfe and others, 1976; Fox and Donald, 1980; Noble and Elliot, 1990). Because Richardson's Merlins winter in the Great Plains of southern Canada, the United States, and northern Mexico, the subspecies may not be exposed to the same levels of persistent pesticides as those encountered by the Taiga Merlin subspecies, which winters in Central America and northern South America (Cade, 1982; Evans, 1982), where continued use of organochlorine pesticides and other persistent pesticides may adversely affect Merlin populations and their productivity (Evans, 1982). Because of legislation that prohibits use of some persistent pesticides in the United States and Canada, most Merlin populations seem to have recovered from pesticide contamination and are reproducing successfully; however, Merlin eggs collected as recently as 1988 from the prairie Provinces in Canada contained pesticide levels high enough to affect reproductive success (Noble and Elliot, 1990). In southeastern Montana, the average weight and thickness of Merlin egg shells collected in 1978–81 were 13 and 20 percent lower, respectively, than pre-1946 values (Becker and Sieg, 1987a). Becker and Sieg (1987a) suggested that the presence of organochlorine pesticides in Merlin eggs may have contributed to a smaller egg shell weight and thickness; residues or trace amounts of DDE, dieldrin, heptachlor epoxide, oxychlordane, cis-chlordane, trans-chlordane, and PCB were detected in the egg samples from 1978 to 1981 from southeastern Montana. In a continentwide survey between 1985 and 1995, no Merlins were

reported among 734 raptors killed by pesticides (Mineau and others, 1999).

Merlins and other raptors may be particularly vulnerable to energy development because of their large home ranges, slow life histories, and sensitivity to human disturbances and habitat alterations (Carlisle and others, 2018). Merlins may be a good indicator species from which to assess the impact of environmental disturbances, such as coal mining (Becker and Ball, 1983). Merlin populations seem to fluctuate less from year to year than populations of raptors that depend on cyclical populations of rodents for food. Merlins obviously can tolerate some human disturbance, because Merlins successfully nest in urban residential areas (Oliphant and McTaggart, 1977; Smith, 1978; Servheen, 1985; Warkentin and Oliphant, 1990; Sodhi, 1991a, 1991b; Bildstein and Therrien, 2018; Boal, 2018). Where breeding Merlins already are established and persistent disturbance is subsequently imposed, populations may decline from increased stress and reduced productivity (Becker and Ball, 1983). If suitable nesting habitat can be maintained in coal-mining recovery areas, Merlins could serve as an indicator of the success of maintenance or recovery efforts of prairie ecosystems. Because Merlin nests typically are relatively easy to find compared to some other forest raptor nests, breeding and productivity can be monitored to provide information that is more biologically sensitive than a presence-or-absence measurement (Becker and Ball, 1983).

Merlin collision risk with wind turbines may be relatively low. Beston and others (2016) developed a prioritization system to identify avian species (among 428 species evaluated) most likely to experience population declines in the United States from wind facilities based on their current conservation status and their expected risk from wind turbines. In the overall prioritization, the Merlin ranked low with an average priority score of 1.81 out of nine; 1.63 percent of the Merlin breeding population in the United States is estimated to be exposed to wind facilities. Loss and others (2013) reviewed published and unpublished reports on collision mortality at monopole wind turbines (that is, with a solid tower rather than a lattice tower) in the contiguous United States; three Merlin mortalities were reported at three wind farm facilities. Wulff and others (2016) examined diurnal flight heights of Merlins and determined that the species' mean flight height was 7.5 m, which is not within the rotor-swept zone (32–124 m) of wind-turbine blades.

Other human activities also may impact breeding Merlins. Illegal shooting does not seem to be a major mortality factor for Merlins (Fyfe, 1977), although shooting probably had a detrimental impact on the species in earlier decades (Evans, 1982). Bildstein and Therrien (2018) indicated that declining human persecution in the latter one-half of the 20th century may have played a role in the species' shift from migratory to nonmigratory behavior in urban areas in southern Canada and the northern United States. James and others (1989) reported that, of 88 Merlin fatalities in Saskatchewan, 43 percent were from collisions, 7 percent from shootings, 2 percent from poisoning, 2 percent from predation

by domestic cats (*Felis catus*), 1 percent from weather, and 44 percent from unknown causes. Harvesting Merlins for falconry (that is, capturing and removing live raptors from the wild for use in falconry) likely has not had a significant impact on populations of wild Merlins and other raptors in the United States because of the low participation rate in falconry and because most raptors used in falconry are produced through captive breeding rather than through harvesting birds from the wild (Millsap and Allen, 2006). In southeastern Montana, permanent recreation facilities, such as camping or picnic areas, were likely to displace local nesting pairs of Merlins (Becker, 1984). In Utah, Parrish and Maurer (1991) reported an injury to a Merlin that was caught on a fishhook attached to a discarded fishing line.

Management Recommendations from the Literature

Protection of nesting and hunting habitats is considered the most critical management need for Merlins (Becker and Ball, 1983). Becker (1984) and his colleagues (Becker and Ball, 1983; Becker and Sieg, 1987b) emphasized the importance of limiting human activities in habitats where Merlins are known to nest, and preserving large expanses of grassland, sagebrush-dominated grasslands, and stands of trees adjacent to grassland and sagebrush for nesting and foraging Merlins.

Grazing and other management activities may affect Merlins during the breeding season. Becker (1984) recommended rest-rotation grazing or similar grazing alternatives that maintain or create a mosaic of livestock grazing areas with a variety of grazing intensities to provide a diversity of microhabitats for Merlin prey species. Becker (1984) encouraged minor alterations of grazing schedules and other activities (for example, fence building, impoundment construction) to minimize disturbances to Merlins during the breeding season. Intensive grazing or overstocking of livestock may reduce vegetative diversity of grassland and sagebrush habitats, and in turn may reduce Merlin prey abundance (Becker and Ball, 1983; Becker, 1984). Exclusion of cattle from mature trees may protect suitable nest trees for Merlins. Evans (1982) suggested that agricultural practices on the Great Plains, such as mowing and burning around prairie pothole wetlands, may have historically reduced Richardson's Merlin habitats, including nesting sites and habitat for prey.

Merlins and other raptors may be adversely affected by pesticide contamination (Evans, 1982), which emphasizes the importance of following the guidelines and restrictions on the use of pesticides in the United States and Canada, as well on the species' wintering areas in Central and South America. Additional monitoring of Merlin egg shell quality and organochlorine residues levels is recommended to enable managers to identify trends in Merlin reproductive performance (Becker and Sieg, 1987a).

The expansion of Merlin populations into urban areas reflects the adaptability of this species and the health of these urban environments (Warkentin and others, 2005). Urban areas provide components, often unintentionally, of the Merlin's preferred habitat, including abundant prey (for example, House Sparrows) and the availability of former nests from crows, magpies, and other species (Bildstein and Therrien, 2018; Boal, 2018). Urban areas also provide increased mortality risks related to living in landscapes affected by humans; these risks include destruction of active nests or nesting substrate, collision with buildings and other objects, exposure to and poisoning by chemical contaminants, persecution, disturbance, increased exposure to disease vectors, and electrocution (Dwyer and others, 2018). Mitigation of these risk factors (for example, trimming trees during the nonbreeding season to avoid destruction of active nests) will require knowledge of and interest in the welfare of urban-nesting raptors and involvement of local biologists (Dwyer and others, 2018).

Carlisle and others (2018) reported that raptors vary in their behavioral responses to energy development across different environmental contexts; the authors recommended that future studies on the effects of coalbed-methane development on Merlins and other raptors should consider habitat preferences and fitness outcomes while controlling for key factors such as local prey availability, raptor densities, and weather. Kennedy (1980) stressed the importance of collecting baseline information about Merlin populations in areas proposed for mining, including data on nesting pairs, productivity, prey utilization, and habitat utilization. Becker (1984) suggested providing work crews at mines with information (such as, locations of Merlin habitats and nests, critical periods in the nesting cycle, and guidelines to minimize disturbances) that can be used to minimize impacts of mine development on nesting Merlins. Limiting human activities within 400 m of active nests during the Merlin's breeding season (March 15 to July 30) will be beneficial to the species, especially where concentrations of nesting Merlins occur. Important considerations during planning and development include the location, timing, and activities of the mining facility before roads or industrial facilities are developed, and how these factors affect breeding Merlins. Becker and Ball (1983) recommended protecting natural nest sites, habitats, and populations during the development phase of mining or during mining activities when Merlin nesting and hunting habitats are likely to be disturbed or destroyed. Protecting mature trees whenever possible will benefit Merlins, because it may take several decades to reestablish trees that are suitable for nesting, perching, or roosting by Merlins (Becker and Ball, 1983); however, destruction, loss, or lack of nest sites can be compensated for by relocating magpie nests into an area or by constructing artificial nest sites.

During the reclamation phase after mining activities have ceased, Becker (1984) recommended rapid reestablishment of diverse native vegetation and transplanting large trees as replacement nest sites. In reclamation areas that are being grazed, existing or transplanted trees can be protected

from livestock damage by fencing. In reclamation areas where human activities may impact Merlin nesting territories, a 400-m radius zone of no disturbance can be established around known or suspected nest sites from March 15 to July 30; any exceptions can be examined on a case-by-case basis (Becker and Ball, 1983).

To prevent collisions of Merlins with wind turbines, Wulff and others (2016) recommended avoiding wind-turbine placement in locations with high concentrations of trees or shrubs that provide nesting and perching habitat and avoiding placement in locations with high prey densities in which raptors concentrate their foraging activities. Loss and others (2013) stressed the importance of considering species-specific and location-specific risks and making multiscale decisions about where to site wind facilities and individual wind turbines in the context of risks to individual bird species.

Becker (1984) suggested locating permanent recreational facilities (for example, camping and picnic areas) away from known or potential Merlin nest sites. The location of recreational facilities, the timing of disturbances, and human uses of the facilities may potentially impact breeding Merlins and their habitats and are important factors to consider before developing recreational areas and associated roads (Trimble, 1975; Becker, 1984).

Falconers in North America harvest a small number of juvenile, subadult, or adult Merlins each year (Millsap and Allen, 2006). Falconers in North America are required to obtain the necessary licenses and permits, and falconry is carefully regulated to ensure that Merlin and other raptor populations are not impacted locally, regionally, or rangewide (Trimble, 1975). Millsap and Allen (2006) recommended that falconry harvest rates for juvenile raptors in the United States should not exceed one-half of the estimated maximum sustainable yield up to a maximum of 5 percent; however, Millsap and Allen (2006) suggested that lower harvest rates are recommended for some raptor species, such as the Merlin, until better estimates of vital rates confirm greater harvest potential.

Merlins are more susceptible to nest abandonment when disturbed early in their nesting cycle (Becker and Ball, 1983). The species may desert their nests if the nest site is disturbed during early incubation; researchers and others who climb nest trees are encouraged to avoid or minimize disturbances at Merlin nests during this period (Oliphant, 1974). Merlins may be more tolerant of disturbances at their nests later in the nesting cycle; for example, in southeastern Montana, Merlins tolerated repeated nest visits during the brood-rearing period (Becker and Ball, 1983). Radio-transmitters that weighed about 2 percent of the body mass of an adult Merlin seemed to have no significant effect on reproductive success or survival (Sodhi and others, 1991a).

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