The Effects of Management Practices on Grassland Birds—Northern Harrier (*Circus hudsonius*)

Chapter L of

The Effects of Management Practices on Grassland Birds

Professional Paper 1842–L

U.S. Department of the Interior
U.S. Geological Survey

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By Jill A. Shaffer,[1] Lawrence D. Igl,[1] Douglas H. Johnson,[1] Marriah L. Sondreal,[1] Christopher M. Goldade,[1,2] Melvin P. Nenneman,[1,3] Jason P. Thiele,[1,4] and Betty R. Euliss[1]

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The Effects of Management Practices on Grassland Birds

Edited by Douglas H. Johnson,[1] Lawrence D. Igl,[1] Jill A. Shaffer,[1] and John P. DeLong[1,5]

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U.S. Department of the Interior
U.S. Geological Survey

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DAVID BERNHARDT, Secretary

U.S. Geological Survey
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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)
	Area	
square meter (m^2)	0.0002471	acre
hectare (ha)	2.471	acre
square kilometer (km^2)	247.1	acre
square meter (m^2)	10.76	square foot (ft^2)
hectare (ha)	0.003861	square mile (mi^2)
square kilometer (km^2)	0.3861	square mile (mi^2)

Abbreviations

CRP	Conservation Reserve Program
DDT	dichlorodiphenyltrichloroethane
DNC	dense nesting cover
spp.	species (applies to two or more species within the genus)
WPA	Waterfowl Production Area

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Capsule Statement

The key to Northern Harrier (*Circus hudsonius*) management is providing tall, dense vegetation in extensive mesic or xeric grasslands or in wetlands. Northern Harriers have been reported to use habitats with 15–106 centimeter (cm) average vegetation height, 28–75 cm visual obstruction reading, 24–53 percent grass cover, 18–25 percent forb cover, less than or equal to (≤) 2 percent shrub cover, 3–5 percent bare ground, 23–30 percent litter cover, and 2–6 cm litter depth. The descriptions of key vegetation characteristics are provided in table L1 (after the "References" section). Vernacular and scientific names of plants and animals follow the Integrated Taxonomic Information System (https://www.itis.gov), except for the species name of the Northern Harrier, which follows the 58th Supplement to the American Ornithological Society's Check-list of North American Birds (Chesser and others, 2017).

Breeding Range

Northern Harriers breed from central Alaska and the western Northwest Territories to southern Quebec, Nova Scotia, and Maine; south to southern California, northern Texas, and central Illinois; and east to New Jersey (National Geographic Society, 2011). The relative densities of Northern Harriers in the United States and southern Canada, based on North American Breeding Bird Survey data (Sauer and others, 2014), are shown in figure L1 (not all geographic places mentioned in report are shown on figure).

Northern Harrier. Illustration by Patsy Renz, used with permission.

Suitable Habitat

Northern Harriers prefer moderately open habitats characterized by tall, dense vegetation, and abundant residual vegetation (Duebbert and Lokemoen, 1977; Hamerstrom and Kopeny, 1981; Apfelbaum and Seelbach, 1983; Kantrud and Higgins, 1992). The species uses native or tame vegetation in mesic or xeric grasslands, planted cover (such as Conservation

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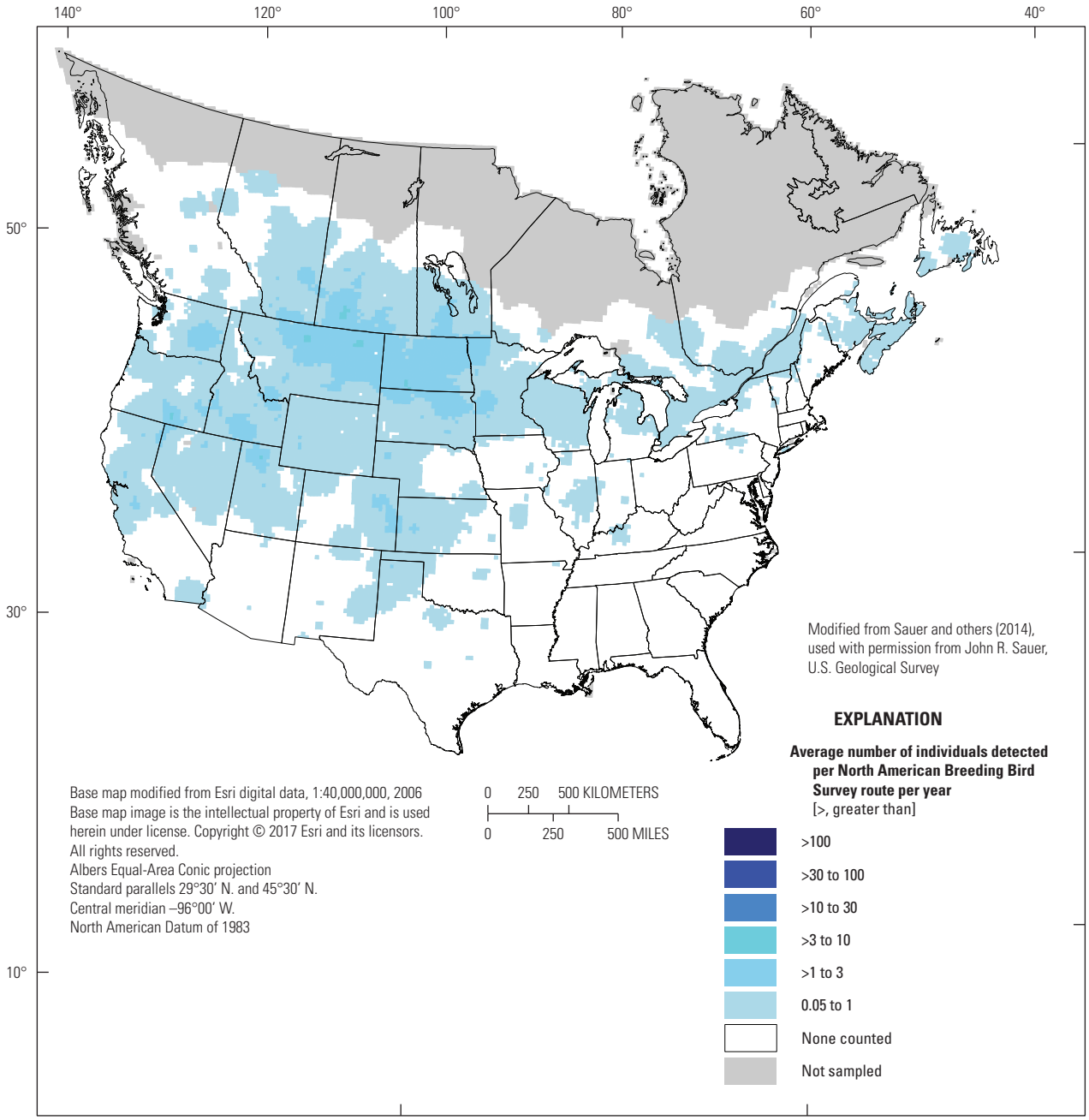

Figure L1. Breeding distribution of the Northern Harrier (*Circus hudsonius*) in the United States and southern Canada, based on North American Breeding Bird Survey (BBS) data, 2008–12. The BBS abundance map provides only an approximation of breeding range edges.

Reserve Program [CRP] fields, dense nesting cover [DNC], Waterfowl Production Areas [WPAs], and Wetland Management Areas), fresh to alkali wetlands, lightly grazed pastures, croplands, fallow fields, oldfields (idle or neglected arable lands that have naturally reverted back to perennial cover), parkland, forest openings, and brushy areas (Stewart and Kantrud, 1965; Clark, 1972; Stewart, 1975; Linner, 1980; Evans, 1982; Apfelbaum and Seelbach, 1983; Faanes, 1983; Kantrud and Higgins, 1992; Svedarsky, 1992; Dhol and others, 1994; Prescott and others, 1995; Prescott, 1997; Evrard and Bacon, 1998; Herkert and others, 1999; Johnson and Igl, 2001; Igl and others, 2008; Smith and others, 2011).

Northern Harriers nest on the ground in open habitats, including grasslands, wet meadows, and vegetated wetlands (Saunders, 1913; Bent, 1961; Sealy, 1967; Clark, 1972; Stewart, 1975; Smith and others, 2011). Ground nests are moderately to well concealed by tall, dense herbaceous vegetation, including low shrubs and living and residual grasses and forbs (Hecht, 1951; Duebbert and Lokemoen, 1977; Hamerstrom and Kopeny, 1981; Kantrud and Higgins, 1992; Herkert and

others, 1999). Wetland nests are located on platforms of vegetation over water in stands of cattails or other emergent vegetation (Saunders, 1913; Sealy, 1967; Clark, 1972).

Although Northern Harriers may nest in cropland and fallow fields, most nests are found in undisturbed wetlands or grasslands dominated by thick vegetation (Duebbert and Lokemoen, 1977; Apfelbaum and Seelbach, 1983; Kantrud and Higgins, 1992). Nest success may be lower in cropland and fallow fields than in undisturbed areas (Kibbe, 1975). In the northern Great Plains, few nests were found in cropland or in areas where litter cover was less than (<) 12 percent of total cover, whereas areas with greater than (>) 40 percent residual cover were commonly used (Kantrud and Higgins, 1992). In fields seeded to grasses and legumes in North Dakota and South Dakota, 52 percent of 27 nests were in cover >60 cm tall and were surrounded by smooth brome (*Bromus inermis*), intermediate wheatgrass (*Thinopyrum intermedium*), and forbs (Duebbert and Lokemoen, 1977). In Wisconsin, the dominant species of grass surrounding 17 Northern Harrier nests in CRP and WPA fields was switchgrass (*Panicum virgatum*), and nests with a greater percentage cover of dead grass and of switchgrass had higher nest success than nests surrounded by live grass or by species other than switchgrass. In a study of various classes of wetlands in North Dakota, the highest densities of Northern Harriers were found in nonsaline semipermanent wetlands with closed stands of emergent cover or with clumps of emergent cover interspersed with open water (Stewart and Kantrud, 1965).

Northern Harriers use native and tame grasslands but, among studies, show no clear preference for either grassland type. In DNC grasslands in Alberta, Northern Harriers preferred native-species plantings to tame-species plantings (Prescott and others, 1995). In Manitoba, Northern Harriers were absent from idle mixed-grass prairies and were as abundant in native as in tame DNC fields (Dhol and others, 1994). Native DNC fields were characterized by western wheatgrass (*Pascopyrum smithii*), thickspike wheatgrass (*Elymus macrourus*), bearded wheatgrass (*Elymus caninus*), streambank wheatgrass (*Elymus lanceolatus*), green needlegrass (*Nassella viridula*), big bluestem (*Andropogon gerardii*), switchgrass, and purple prairie clover (*Dalea purpurea*). Tame DNC fields were characterized by tall wheatgrass (*Thinopyrum ponticum*), intermediate wheatgrass, slender wheatgrass, and alfalfa (*Medicago sativa*). In Illinois, nest placement by Northern Harriers was influenced less by whether the dominant grass cover in fields was native or tame than by whether the field was idled or had been disturbed by burning, mowing, seed-harvesting, or grazing (Herkert and others, 1999). In Missouri, Northern Harriers were present in CRP fields that were planted to either cool-season or warm-season grasses (McCoy and others, 2001).

Northern Harriers tolerate a moderate amount of shrub cover in nesting habitat. In the northern Great Plains, Northern Harrier nests often were associated with western snowberry (*Symphoricarpos occidentalis*) (Sealy, 1967; Messmer, 1990; Kantrud and Higgins, 1992; Murphy, 1993; Sedivec, 1994). In Saskatchewan, success of nests in shrub patches was highly variable, with fledging success ranging from 0 to 100 percent (Sealy, 1967). In northwestern North Dakota, nests were placed in 0.05- to 0.5-hectare (ha) stands of western snowberry or in stands of western snowberry with forbs, grasses, and other shrubs (Murphy, 1993). On an 11-square-kilometer (km^2) island in North Dakota, Northern Harriers nested in areas with western snowberry and tame grasses and legumes more commonly than predicted based on availability of that habitat type (Sutherland, 1987). Furthermore, the height of live vegetation and visual obstruction readings were greater at nest sites than at random sites. Northern Harrier nests in southwestern Missouri were found almost exclusively in blackberry (*Rubus* species [spp.]) patches with a mean size of 98 square meters (m^2) (Toland, 1986). Northern Harriers may have chosen these sites for their protective value; within 90 cm of nests, mean ground cover was 100 percent (Toland, 1986).

Nests placed in wet sites may have an advantage over upland nests in that fewer predators may have access to them (Sealy, 1967; Simmons and Smith, 1985). In New Brunswick, Simmons and Smith (1985) examined the effects of ground moisture and vegetation on reproductive success. Nests placed in wet areas, defined as areas in which standing or running water was present within 1 meter (m) of a nest, were significantly more successful than nests placed in dry areas, defined as areas in which water was not present within 1 m of a nest. Nests were placed in wet sites where depredation was lower but near upland areas where vole (*Microtus* spp.) populations were higher. Female Northern Harriers preferred nest sites in wet areas relative to availability, and nests in cattails (*Typha* spp.) and wetland grasses (bluejoint [*Calamagrostis canadensis*] and prairie cordgrass [*Spartina pectinata*]) were more successful than those in shrubs (speckled alder [*Alnus incana* subspecies *rugosa*] and *Spirea* spp.) or in upland areas. Contrary to results from upland ground nests, the most successful wet-site nests were less concealed. Similar studies are lacking in the Great Plains. In Alberta, 83 percent of young from nine nests in a cattail wetland survived to fledging, whereas the young disappeared from the two nests in wheatgrasses (Sealy, 1967). Northern Harriers may nest semicolonially, even when large tracts of apparently suitable habitat are available, and they also have been found to nest in close association with ducks (Anatidae) and Greater Prairie-Chickens (*Tympanuchus cupido*) (Bildstein and Gollop, 1988).

Prey Habitat

Annual breeding numbers and productivity of Northern Harriers are strongly influenced by the availability of their principle prey, microtine voles, in spring; as such, Northern Harrier populations show considerable local variation from one year to the next (Smith and others, 2011). Voles and other small rodents are the primary prey of Northern Harriers in the northern Great Plains; other mammals, birds, and occasionally

reptiles and frogs also are taken (Sutherland, 1987; Smith and others, 2011). Insects constitute only a small part of the diet and are most frequently taken by recently fledged young (Smith and others, 2011). In Wisconsin, changes in vole abundance were closely paralleled by corresponding changes in numbers and productivity of nesting Northern Harriers (Hamerstrom, 1979; Hamerstrom and others, 1985).

Northern Harriers forage over open habitats of moderate-to-heavy cover, such as ungrazed prairies and wetlands (Smith and others, 2011). On an 11-km^2 island in North Dakota, Northern Harriers foraged in fields of tame grasses and legumes, wetlands, and native prairies (Sutherland, 1987). In shrubsteppe habitats in Idaho, Northern Harriers foraged over alfalfa fields until the alfalfa reached 46 cm and then shifted to foraging in open shrubsteppe (Martin, 1987). In Utah, the species preferred foraging over moist oldfields to foraging over cropland (Linner, 1980).

Area Requirements and Landscape Associations

Northern Harriers may be area sensitive (Ribic and others, 2009). In Alberta, Northern Harriers were more abundant in large (>8 ha) than in small (<1 ha) freshwater wetlands (Prescott and others, 1995). In North Dakota CRP fields, all patches occupied by Northern Harriers were >100 ha in size (Johnson and Igl, 2001). Northern Harrier density was positively correlated with patch size, and the species occupied large patches more than expected based on patch availability. However, in tallgrass prairies in North Dakota and Minnesota, density was not related to patch size (Winter and others, 2006). Density decreased with an increasing percentage of woody vegetation within 200 m of grassland patches, and Northern Harriers were not detected in grassland patches where woody cover exceeded 30 percent. In Illinois, grassland size did not affect nest placement (Herkert and others, 1999). Northern Harriers nested in grassland fragments ranging from 8 to 120 ha; 17 percent of 29 nests were in grassland tracts <45 ha. However, Herkert and others (1999) indicated that Northern Harriers may have been responding to the total amount of grassland available in the surrounding landscape more than to the sizes of individual grassland fragments; small fragments may have been used where larger blocks of contiguous grassland were adjacent to the small fragments. In another Illinois study, Northern Harriers were primarily found at the largest study sites, which included native warm-season grasses and non-native cool-season grasses; grassland patches ranged in size from 3 to 400 ha (mean=160 ha) (Buxton and Benson, 2016). In cool-season grasslands on the southeastern end of the Missouri Coteau of North Dakota, nest density ranged from 1.8 to 9.1 nests per 100 ha (Duebbert and Lokemoen, 1977). In the tallgrass prairies of southwestern Missouri, nesting density was 0.82 pairs per 100 ha, and male home ranges averaged 256 ha (Toland, 1985). A pair in central Wisconsin used approximately 890 ha (Hamerstrom and De La Ronde Wilde, 1973). In Manitoba, males defended 27.7 ha, centered on the nest (Hecht, 1951). In Idaho, home ranges for four pairs averaged 1,570 ha for males and 113 ha for females (Martin, 1987). Using North American BBS data, Forcey and others (2014) evaluated the influence of land-cover and climatic variables at three spatial extents (1,000 ha; 10,000 ha; and 100,000 ha) in the upper Midwest of the United States. The most important model predictors of Northern Harrier abundance were wetland area at the intermediate and coarsest scales and herbaceous upland largest patch index at the intermediate scale. Inclusion of climatic variables in the models made only a small improvement in the model fit.

Brood Parasitism by Cowbirds and Other Species

The Northern Harrier is an unsuitable host of the Brown-headed Cowbird (*Molothrus ater*), and no known records of brood parasitism exist (Shaffer and others, 2019). There is one record of a facultative brood parasite, the Redhead (*Aythya americana*), laying eggs in a Northern Harrier nest; Fleskes (1992) reported a Northern Harrier nest in Alberta that contained 2 Redhead eggs and 5 harrier eggs. There are at least three records of Northern Harriers commandeering nests of other ground-nesting species. Laine (1928) observed a Northern Harrier incubating a prairie-chicken (*Tympanuchus*; species not given) nest with 12 prairie-chicken eggs and hatching at least 1 prairie-chicken egg. In North Dakota, Horn and Maul (1997) reported an observation of a Northern Harrier building its nest on top of a depredated Mallard (*Anas platyrhynchos*) nest. Also in North Dakota, Stackhouse and Geaumont (2011) found a Mallard nest with eight Mallard eggs; the nest was later taken over by a Northern Harrier that laid two eggs of its own in the Mallard nest. At least two of the Mallard eggs and both of the harrier eggs hatched.

Breeding-Season Phenology and Site Fidelity

Northern Harriers arrive on the breeding grounds between late February and early May and nest from April through July (Hammond and Henry, 1949; Stewart, 1975; Duebbert and Lokemoen, 1977; Linner, 1980; Bildstein and Gollop, 1988; Murphy and Ensign, 1996; Smith and others, 2011). Northern Harriers produce only one brood per breeding season; however, renesting may occur if the nest is destroyed or deserted during egg laying (Bildstein and Gollop, 1988; Smith and others, 2011). In Michigan, 1 of 8 pairs renested after nest failure (Bildstein and Gollop, 1988). Northern Harriers leave for the wintering grounds between August and November (Saunders, 1913; Bent, 1961; Bildstein and Gollop, 1988).

Northern Harriers may return to breed in the same general area as in the previous year (Hamerstrom, 1969; Burke, 1979). However, return rates of offspring to natal areas are very low. (Hamerstrom, 1969; Burke, 1979; Smith and others, 2011). Polygyny has been reported in this species (Hecht, 1951; Hamerstrom and others, 1985). During the breeding season, Northern Harriers are not strongly territorial, and the species may nest in loose assemblages, although internest distances may be highly variable (Smith and others, 2011).

Species' Response to Management

Northern Harriers generally prefer dense cover in grasslands and associated wetlands. During extensive nest searching in North Dakota, Duebbert and Lokemoen (1977) found few Northern Harrier nests in annually grazed, hayed, burned, or tilled areas. Similarly, in Delta Marsh, Manitoba, no nests were found in burned or mowed areas (Hecht, 1951). Although Northern Harriers typically avoid nesting in disturbed areas, periodic disturbance may be necessary to maintain suitable habitat. Berkey and others (1993) indicated that DNC in uplands could be hayed periodically to stimulate plant growth. Burning or mowing every 3–5 years is recommended to maintain habitat for Northern Harriers and small rodents, their principal prey (Leman and Clausen, 1984; Hands and others, 1989; Kaufman and others, 1990). In a Wisconsin wetland subjected to chemical shrub control, willows (*Salix* spp.), bulrushes (*Scirpus* spp.) and sedges (*Carex* spp.) were reduced as goldenrod (*Solidago* spp.) and white meadowsweet (*Spiraea alba*) increased; Northern Harriers subsequently switched from nesting in the willows, bulrushes, and sedges to nesting in the goldenrod and meadowsweet (Hamerstrom and Kopeny, 1981).

Use of prescribed burning in drier, more northern areas may have immediate detrimental effects because it reduces litter accumulation and may destroy nests (Kruse and Piehl, 1986; Berkey and others, 1993). In North Dakota, 3 of 4 active nests were destroyed by prescribed burns conducted in June; 1 nest hatched (Kruse and Piehl, 1986). In Kansas, Northern Harriers foraged in annually burned and unburned areas but nested only in unburned areas (Zimmerman, 1993). In Missouri, Northern Harriers preferred large areas of idle prairie with patches of invading woody plants and avoided areas that were annually burned (Toland, 1986). The reduction of cattails by burning or by applying herbicides could eliminate nesting cover in wetlands (Berkey and others, 1993).

In South Dakota and Illinois, Northern Harriers preferred idle areas more than managed areas (grasslands managed through rotary mowing, hay mowing, seed harvesting, grazing, or burning) (Luttschwager and Higgins, 1992; Herkert and others, 1999). In Illinois, Northern Harriers preferred fields that had been idle less than 2 years; only one occupied field had been idle more than 3 years (Herkert and others, 1999). Early mowing can destroy Northern Harrier nests (Hamerstrom, 1986). In North Dakota, mowing displaced Northern Harriers (Messmer, 1990). In South Dakota, Northern Harriers nested in idle strips and blocks within mowed CRP fields (Luttschwager and Higgins, 1992). In Iowa CRP fields planted to switchgrass, Northern Harriers were found in totally harvested plots, strip-harvested plots, and unharvested plots, but no nests were found in totally harvested plots (Murray and Best, 2003). Igl and Johnson (2016) assessed the effects of haying on grassland birds in 483 CRP grasslands in 9 counties in 4 States in the northern Great Plains between 1993 and 2008. Northern Harriers occurred in all nine counties but at relatively low densities in each; Northern Harrier densities were lower in the first year after haying in 8 of the 9 counties but responses were inconsistent in the second, third, and fourth years after haying. Igl and Johnson (2016) concluded that the species' irruptive tendencies during the breeding season might prevent detection of a consistent management response to haying.

Northern Harriers do not use heavily grazed habitats (Stewart, 1975; Berkey and others, 1993; Bock and others, 1993) but may use lightly to moderately grazed grasslands (Kantrud and Kologiski, 1982). Also in North Dakota, the species used lightly grazed native prairies near wooded draws (Faanes, 1983). In North Dakota, Northern Harriers preferred idle areas and had significantly higher nesting densities on ungrazed areas than areas grazed season long (leaving cattle on the same pasture for the entire growing season) or grazed under a twice-over, deferred grazing system (grazing a number of pastures twice per season, with about a 2-month rest between grazing) (Messmer, 1990; Sedivec, 1994). In Montana, Northern Harriers nested only in ungrazed plots, and nest density was positively correlated with visual obstruction readings (Fondell and Ball, 2004). In aspen parkland of Alberta, Northern Harriers were most abundant in deferred grazed (grazed after July 15) mixed-grass prairies but were absent from continuously grazed mixed-grass prairies and deferred or continuously grazed tame pastures (Prescott and others, 1995).

Before regulations and restrictions on the use of dichlorodiphenyltrichloroethane (DDT) in the United States came into effect in the late 1960s and early 1970s, reproductive success of Northern Harriers was reduced owing to eggshell thinning caused by the pesticide (Hamerstrom, 1969, 1986; Smith and others, 2011). Hamerstrom (1986) noted a dramatic decrease in the number of Northern Harrier nests in her study area in Wisconsin during a period of heavy applications of DDT. Northern Harriers also have been killed by various other pesticides, often after consuming prey that had ingested pesticide (Mineau and others, 1999).

Northern Harriers may exhibit behavioral responses to energy development. Smallwood and others (2009) observed Northern Harriers changing flight behavior within 50 m of wind turbines and traveling through turbine rows rather than foraging. In Wisconsin, Northern Harriers appeared to avoid wind-energy infrastructure, as their abundance declined 2-years post-construction (Garvin and others, 2011). Eight years later, Northern Harriers still had not returned to the

wind facility, indicating long-term displacement (Dohm and others, 2019). In the United Kingdom, Pearce-Higgins and others (2009) determined that the zone of significant avoidance around wind turbines for the closely related Hen Harrier (*Circus cyaneus*) was 250 m; the predicted reduction in raptor flight activity within 500 m of turbines was 52.5 percent. The risk of collision with wind turbines is believed to be low (Madders and Whitfield, 2006; Smallwood and others, 2009; Garvin and others, 2011). In Saskatchewan, Northern Harrier occurrence decreased in areas with increasing oil well density (Unruh, 2015).

Management Recommendations from the Literature

Northern Harriers use native prairie and planted grasslands during the breeding season. Collaborations with ranching and farming interests on issues of mutual benefit may help to maintain native rangeland and pastures (Johnson, 1996). Hands and others (1989) and Johnson (1996) emphasized the importance of protecting native grasslands through conservation easements, land purchases, and development of farm programs that hold conservation of wildlife habitat in high priority. Planted grasslands, such as WPA grasslands or those enrolled in the CRP, also provide suitable habitat for Northern Harriers and other grassland birds (Johnson, 1996; Evrard and Bacon, 1998). Several authors have recommended the continuation of the CRP as a means to provide nesting and foraging habitat (Kantrud and Higgins, 1992; Bock and others, 1993). Northern Harriers prefer large blocks of grasslands (100 ha or larger) over smaller blocks (Kantrud and Higgins, 1992; Johnson and Igl, 2001), especially large grasslands that are idle with patches of woody plants, such as western snowberry or blackberry (Toland, 1986; Messmer, 1990; Kantrud and Higgins, 1992; Sedivec, 1994).

Northern Harriers also nest and forage in wetlands during the breeding season. Wetlands may be protected from drainage or tilling through conservation easements, land purchases, tax incentives, management agreements, restoration, continuation of the Wetland Reserve Program, and enforcement of wetland-protection regulations (Hands and others, 1989; Johnson and others, 1994; Johnson, 1996). To avoid the submergence of Northern Harrier nests in wetlands where water levels can be artificially manipulated, Hands and others (1989) indicated that water depth should be maintained below 15 cm from April to August. On large islands, Sutherland (1987) recommended maintaining tame grasses, legumes, and brush for nesting cover and reducing mammalian predators.

Providing a mosaic of grasslands and wetlands will ensure that some units are available for nesting or foraging while other units are being treated to halt succession (Hands and others, 1989; Ryan, 1990; Murphy, 1993). Hands and others (1989) recommended that treated units should be small (100–200 ha) to minimize the number of displaced nesting Northern Harriers, and untreated units should be large enough to meet the requirements of multiple female Northern Harriers during the nesting season.

In the north-central United States, periodic disturbances by mowing, burning, or grazing will help to maintain the 2–5 year old accumulations of residual vegetation preferred by Northern Harriers (Duebbert and Lokemoen, 1977; Hands and others, 1989; Berkey and others, 1993; Murphy, 1993). Where native vegetation composition or structure have been altered by drainage, tillage, overgrazing, or conversion to cropland, Duebbert and Lokemoen (1977) recommended that restoration or reconstruction efforts should emphasize planting native warm-season grasses and legumes. Mowing, burning, or grazing is recommended every 3–5 years to maintain habitat for small mammal prey (Leman and Clausen, 1984; Kaufman and others, 1990). Delaying haying until July 15 may allow Northern Harriers to nest successfully (Berkey and others, 1993). In tallgrass areas, recently idled native or tame grasslands (undisturbed for ≤3 years) may be important for nesting Northern Harriers. Northern Harriers preferred nesting in idle areas over nesting in mowed areas in Illinois (Herkert and others, 1999) and preferred idle areas over annually burned areas in Missouri (Toland, 1986). Increasing the amount of western rangeland from which livestock are excluded, especially in U.S. Forest Service National Grasslands, may benefit Northern Harriers and other species that require relatively dense vegetation (Bock and others, 1993). Northern Harriers preferred idle areas to grazed areas in North Dakota (Sedivec, 1994).

Disturbance of nesting areas during the breeding season, which extends from April through July, may negatively impact Northern Harrier productivity (Hamerstrom, 1986; Toland, 1986; Berkey and others, 1993). Several authors have recommended minimizing disturbances near nests (Hamerstrom, 1969; Toland, 1985; Hands and others, 1989). Pesticides should not be used in habitats that are utilized by Northern Harriers (Hamerstrom, 1969; Hands and others, 1989).

Dohm and others (2019) recommended that developers of wind facilities consider the local raptor community when estimating the impacts of wind developments, as some species, such as the Red-tailed Hawk (*Buteo jamicensis*), may acclimate to wind-energy infrastructure, whereas others, such as the Northern Harrier, may not. Long-term monitoring may be required to determine species-specific duration and magnitude of displacement, such that appropriate mitigation strategies can be developed. Knowledge of habituation behavior can inform the potential for cumulative disturbance impacts on raptors from the development of additional wind facilities in an area (Dohm and others, 2019).

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Table L1. Measured values of vegetation structure and composition in Northern Harrier (*Circus hudsonius*) breeding habitat by study. The parenthetical descriptors following authorship and year in the "Study" column indicate that the vegetation measurements were taken in locations or under conditions specified in the descriptor; no descriptor implies that measurements were taken within the general study area.

[cm, centimeter; %, percent; --, no data; >, greater than; CRP, Conservation Reserve Program; WPA, Waterfowl Production Area; WMA, Wildlife Management Area]

Study	State or province	Habitat	Management practice or treatment	Vegetation height (cm)	Vegetation height-density (cm)	Grass cover (%)	Forb cover (%)	Shrub cover (%)	Bare ground cover (%)	Litter cover (%)	Litter depth (cm)
Duebbert and Lokemoen, 1977 (nests)	North Dakota, South Dakota	Mixed-grass prairie, tame grassland	--	>15	--	--	--	--	--	--	--
Evrard and Bacon 1998 (nests)	Wisconsin	Tame grassland (CRP, WPA)	Idle	106.4	41.6[a]	23.5	18.6	--	--	57[b]	2.6
Fondell and Ball, 2004 (nests)	Montana	Mixed-grass prairie	Idle, grazed	--	28[a]	--	--	--	--	--	--
Kantrud and Higgins, 1992 (nests)	Manitoba, Montana, North Dakota, South Dakota	Mixed-grass prairie	Idle	--	38[a], 57[c]	--	--	--	--	42[b]	--
Murphy, 1993 (nests)	North Dakota	Mixed-grass prairie, tame grassland	Burned, grazed	--	35[a]	--	--	--	--	--	--
Murray and Best, 2003	Iowa	Tame grassland (CRP)	Total-harvested switchgrass	80.9	71[a]	51.6	19.6	0.4	5	23.2	1.9
Murray and Best, 2003	Iowa	Tame grassland (CRP)	Strip-harvested switchgrass	81.7	75[a]	53.3	17.5	0.1	2.8	29.6	3.5
Murray and Best, 2003	Iowa	Tame grassland (CRP)	Unharvested switchgrass	78.1	71[a]	32.9	25.4	2.1	2.9	22.9	5.5
Sedivec, 1994 (nests)	North Dakota	Mixed-grass prairie	Multiple	--	49[a]	--	--	--	--	--	--
Sutherland, 1987 (nests)	North Dakota	Multiple	Multiple	80	48.8[a]	--	--	--	--	--	--
Svedarsky, 1992 (nests)	Minnesota	Tame grassland (WMA)	--	--	54[a]	--	--	--	--	--	--
Toland, 1986 (nests)	Missouri	Tallgrass prairie	Multiple	79.2	--	--	--	--	--	--	--

[a]Visual obstruction reading (Robel and others, 1970).

[b]Standing dead vegetation.

[c]Effective vegetation height.

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