The Effects of Management Practices on Grassland Birds—Horned Lark (*Eremophila alpestris*)

Chapter U of

The Effects of Management Practices on Grassland Birds

Professional Paper 1842–U
Version 1.1, July 2022

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

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Background photograph: Northern mixed-grass prairie in North Dakota, by Rick Bohn, used with permission.

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By Meghan F. Dinkins,[1,2] Lawrence D. Igl,[1] Jill A. Shaffer,[1] Douglas H. Johnson,[1] Amy L. Zimmerman,[1] Barry D. Parkin,[1] Christopher M. Goldade,[1,3] and Betty R. Euliss[1]

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Edited by Douglas H. Johnson,[1] Lawrence D. Igl,[1] Jill A. Shaffer,[1] and John P. DeLong[1,4]

[1]U.S. Geological Survey.

[2]U.S. Forest Service (current).

[3]South Dakota Game, Fish and Parks (current).

[4]University of Nebraska-Lincoln (current).

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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
decimeter (dm)	3.937	inch (in.)
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
	Area	
hectare (ha)	2.471	acre
square kilometer (km^2)	247.1	acre
hectare (ha)	0.003861	square mile (mi^2)
square kilometer (km^2)	0.3861	square mile (mi^2)
	Volume	
liter (L)	33.81402	ounce, fluid (fl. oz)
liter (L)	2.113	pint (pt)
liter (L)	1.057	quart (qt)
liter (L)	0.2642	gallon (gal)
liter (L)	61.02	cubic inch (in^3)
	Mass	
gram (g)	0.03527	ounce (oz)
kilogram (kg)	2.205	pound (lb)

Abbreviations

AUM animal unit month

BBS Breeding Bird Survey

CRP Conservation Reserve Program

CV coefficient of variation

DNC dense nesting cover

PCP Permanent Cover Program

ppm parts per million

SD standard deviation

spp. species (applies to two or more species within the genus)

ssp. subspecies

Acknowledgments

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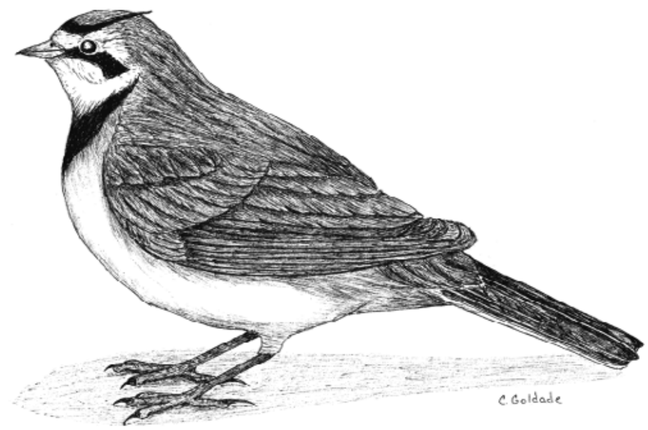
The Effects of Management Practices on Grassland Birds—Horned Lark (*Eremophila alpestris*)

By Meghan F. Dinkins,[1,2] Lawrence D. Igl,[1] Jill A. Shaffer,[1] Douglas H. Johnson,[1] Amy L. Zimmerman,[1] Barry D. Parkin,[1] Christopher M. Goldade,[1,3] and Betty R. Euliss[1]

Capsule Statement

The key to Horned Lark (*Eremophila alpestris*) management is maintaining areas with short, sparse vegetation by burning, mowing, or grazing. Horned Larks have been reported to use habitats with less than or equal to (≤) 70 centimeters (cm) average vegetation height, 3–26 cm visual obstruction reading, 15–67 percent grass cover, 3–70 percent forb cover, ≤21 percent shrub cover, 1–44 percent bare ground, ≤63 percent litter cover, and ≤9 cm litter depth. The descriptions of key vegetation characteristics are provided in table U1 (after the "References" section). Vernacular and scientific names of plants and animals follow the Integrated Taxonomic Information System (https://www.itis.gov).



Horned Lark. Illustration by Christopher M. Goldade, U.S. Geological Survey.

Breeding Range

Horned Larks breed throughout North America except in portions of central Canada and the southeastern United States (National Geographic Society, 2011). The Horned Lark may be a year-round resident in all but the most northern parts of its breeding range (Beason, 1995). Twenty-one subspecies of Horned Lark are recognized in North America (Beason, 1995). Several other subspecies also are present in Europe, Asia, and Colombia in South America. This account deals primarily with those subspecies associated with the North American Great Plains (Dickerman, 1964; Beason, 1995), which include *E. a. enthymia*, *E. a. leucolaema*, and *E. a. praticola*. The relative densities of Horned Larks in the United States and southern Canada, based on North American Breeding Bird Survey (BBS) data (Sauer and others, 2014), are shown in figure U1 (not all geographic places mentioned in report are shown on figure).

[1]U.S. Geological Survey.

[2]U.S. Forest Service (current).

[3]South Dakota Game, Fish and Parks (current).

Suitable Habitat

Horned Larks prefer sparsely vegetated grasslands, deserts, and agricultural lands with little or no woody vegetation (Beason, 1970, 1995; Wiens, 1973; Creighton, 1974; Skinner, 1974, 1975; Rotenberry and Wiens, 1980; Dale, 1983; Renken, 1983; Sample, 1989; Camp and Best, 1993; Prescott and Murphy, 1996; Davis and Duncan, 1999; Martin and Forsyth, 2003). The species breeds in a variety of grassland habitats that have been recently burned, hayed, or grazed, including shortgrass, mixed-grass, tallgrass, bunchgrass, and restored prairies and tame grasslands (Strong, 1971; Porter and Ryder, 1974; Ryder, 1980; Kantrud, 1981; Bock and Webb, 1984; Greer, 1988; Lueders and others, 2006; Kennedy and others, 2009; Olechnowski and others, 2009; White, 2009; Earnst and Holmes, 2012; Johnson and others, 2012; Richardson, 2012; Roberts and others, 2012; Sliwinski and Koper, 2012). Horned Larks also nest in shrubsteppe and sagebrush (*Artemisia* species [spp.]) habitats and alpine meadows (Cassel, 1952; Earnst and others, 2009; Gilbert and Chalfoun, 2011). The species commonly nests in cropland, such as wheat (*Triticum* spp.) and other small grains, soybeans (*Glycine* spp.), corn (*Zea mays*), bare fields, fallow fields, and crop stubble (Bent,

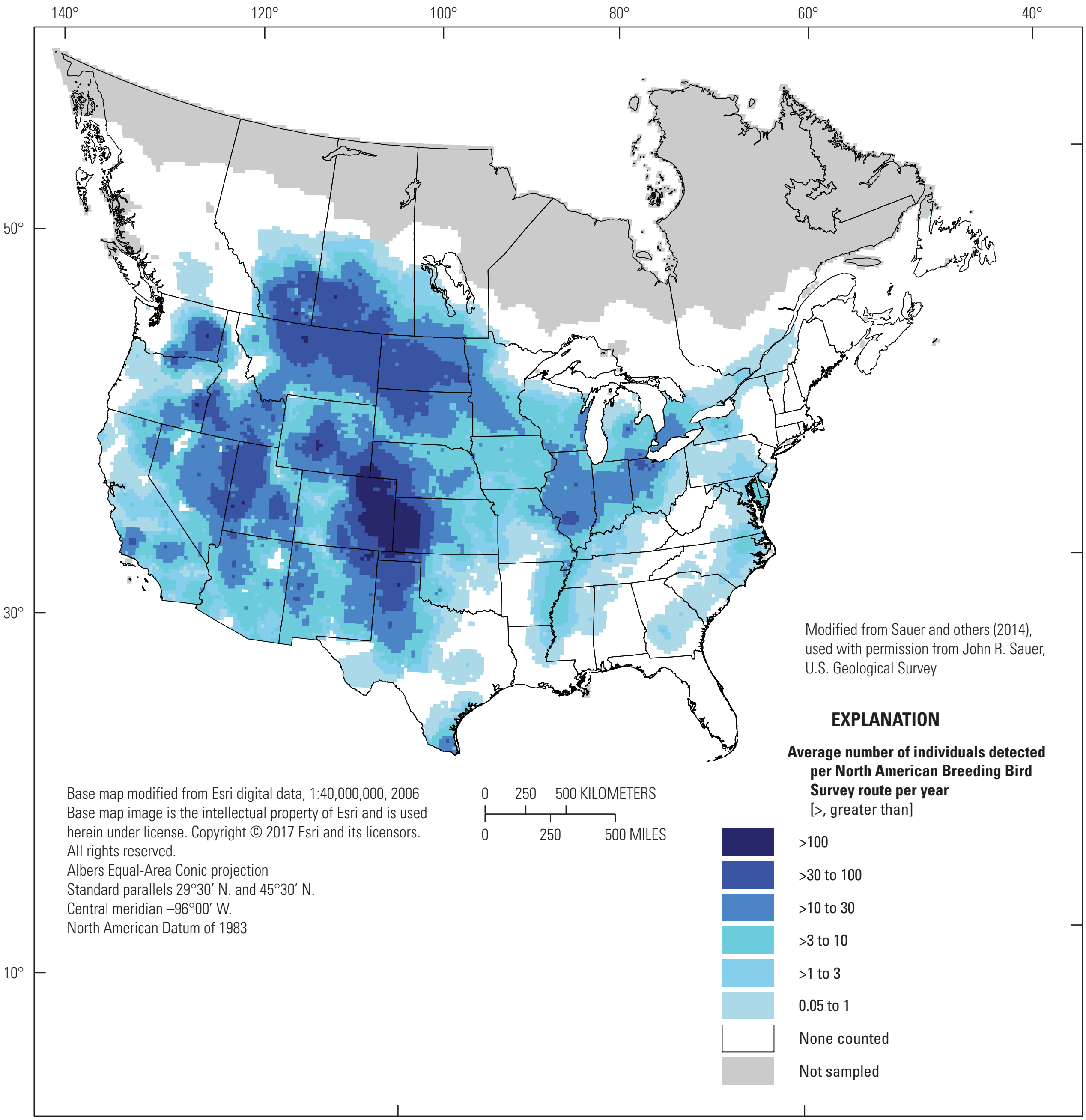


Figure U1. The breeding distribution of the Horned Lark (*Eremophila alpestris*) in the United States and southern Canada, based on North American Breeding Bird Survey (BBS) data, 2008–12. The BBS abundance map provides only an approximation of breeding range edges.

1942; Graber and Graber, 1963; Beason, 1970; Stewart, 1975; Ducey and Miller, 1980; Castrale, 1985; Kahl and others, 1985; Faanes and Lingle, 1995; DeJong and others, 2004). Horned Larks occasionally inhabit planted cover, such as Conservation Reserve Program (CRP) fields, dense nesting cover (DNC), and Permanent Cover Program (PCP) fields, but Horned Larks prefer newly seeded fields to those with well-established vegetation (Best and others, 1990; Johnson and Schwartz, 1993a, 1993b; Hartley, 1994a, 1994b; King and Savidge, 1995; Patterson and Best, 1996; McMaster and Davis, 1998, 2001; Herkert, 2009; Ribic and others, 2009; Riffell and others, 2010). Horned Larks also use herbaceous fencerows, road rights-of-way, and grassed waterways in agricultural areas (Best and Hill, 1983; Bryan and Best, 1991; Camp and Best, 1993; Best, 2001). In Missouri, Skinner (1974) observed Horned Larks in disturbed areas created by livestock and American bison (*Bison bison*).

Horned Larks have been reported in colonies of white-tailed (*Cynomys leucurus*), black-tailed (*Cynomys ludovicianus*), and Gunnison's (*Cynomys gunnisoni*) prairie dogs (Campbell and Clark, 1981; Clark and others, 1982; Agnew and others, 1986; Tyler and Shackford, 2002; Augustine and Baker, 2013). In Oklahoma, Horned Larks were positively associated with black-tailed prairie dog towns, but Horned Larks also used shortgrass prairies in the absence of prairie dogs, fallow crop fields, sand sagebrush (*Artemisia filifolia*) plains, and CRP fields (Smith and Lomolino, 2004). In South Dakota, Horned Larks were more abundant on black-tailed prairie dog towns during the growing season than on adjacent mixed-grass prairie sites in the absence of prairie dogs (Agnew and others, 1986). Kotliar and others (1999) considered the Horned Lark as weakly facultative in their dependence on prairie dogs (that is, a species that would likely decline locally following a decline in prairie dogs if alternative habitat was unavailable or limited).

Horned Larks occupy areas with short, sparse herbaceous vegetation; occupied areas typically are characterized by moderate bare ground cover (Speirs and Orenstein, 1967; Skinner, 1974; Dale, 1983; Greer, 1988; Sample, 1989; Davis and Duncan, 1999; Bleho, 2009; Kalyn Bogard, 2011). Numerous studies have evaluated the effects of vegetation structure and composition on Horned Lark distribution and abundance. Summaries of the results from those studies are presented below, beginning with studies in the northern and western portions of the species' breeding range. In aspen parkland areas of Alberta, the species preferred short grass that was uniform in height (Prescott and Murphy, 1996). In mixed-grass prairies in southeastern Alberta, Horned Lark abundance declined at higher percentages of live grasses and forbs; abundance increased at small percentages (less than [<] 10 percent) of crested wheatgrass (*Agropyron cristatum*) cover but declined at intermediate and larger percentages (Rodgers and Koper, 2017). In southern Alberta mixed-grass prairies, Horned Lark densities were negatively related to vegetation height, vegetation density, and litter depth and positively related to percentage of bare ground (Koper and Schmiegelow, 2006). In Alberta, Manitoba, and Saskatchewan, Horned Lark presence was positively associated with the amount of bare ground and the number of forb contacts in the fifth and sixth decimeter above ground, depending on ecoregion (that is, mixed grassland, moist-mixed grassland, and aspen parkland; McMaster and Davis, 2001). Presence was negatively associated with the number of broad-leaved grass contacts in the first centimeter above ground, contacts of dead vegetation in the third decimeter above ground, forb contacts in the first decimeter above ground, degree of latitude, and vegetation height.

In grazed and ungrazed grasslands in southern Saskatchewan, Horned Larks occupied areas having little or no vegetation or litter (Dale, 1983). In native and seeded pastures in southern Saskatchewan, Horned Lark occurrence was positively associated with bare ground and fringed sagewort (*Artemisia frigida*) and negatively associated with vegetation height, litter depth, thickspike wheatgrass (*Elymus macrourus*), and western snowberry (*Symphoricarpos occidentalis;* Davis and Duncan, 1999). In a 2-year study in mixed-grass prairies in southern Saskatchewan, Horned Lark response to vegetation varied by year (Davis, 2003, 2004). In 1 of the 2 years, Horned Lark occurrence was positively related to the density of live grasses 0–10 cm above the ground and negatively related to the density of live grasses and standing dead vegetation 10–20 cm above the ground. In the second year, lark occurrence was positively related to the density of live grasses 0–10 cm above the ground and negatively related to the density of standing dead vegetation 0–10 cm above the ground and distance to the nearest shrub. In another mixed-grass prairie study in southern Saskatchewan, Bleho (2009) evaluated the relationship between Horned Lark abundance and vegetation structure at the plot and pasture levels, whereby plots were circular areas of 100-meter (m) radii within pastures that were grazed season-long (June to October) at moderate grazing intensity (that is, about 43 percent utilization). Two measures of vegetation patchiness (that is, heterogeneity) were evaluated: standard deviation (SD) and coefficient of variation (CV). At the plot level, Horned Lark abundance was positively associated with percentage cover of bare ground and shrubs, the SD-derived measure for patchiness of bare ground coverage, and the CV-derived measure for patchiness of vegetation height-density and litter coverage. Abundance at the plot level was negatively associated with vegetation height-density and the CV-derived measure for patchiness of bare ground and exposed moss and lichen (no species provided) coverage. At the pasture level, Horned Lark abundance was positively associated with percent coverage of bare ground and the SD-derived measure for patchiness of bare ground coverage. Within that same study area, White (2009) evaluated songbird response to burning on grazed and ungrazed mixed-grass prairies. In the first-year postburn, Horned Lark abundance was positively associated with visual obstruction and negatively associated with litter depth. In the second-year postburn, Horned Lark abundance was positively associated with percentage of exposed bare ground and percentage of forb cover and negatively associated with maximum vegetation height and visual obstruction. Also in southern Saskatchewan, Horned Lark abundance was negatively associated with shrubs and dead vegetation 20–100 cm tall (Anstey and others, 1995). In mixed-grass prairies in southwestern Saskatchewan, Gaudet (2013) reported that Horned Lark densities increased with an increase in cover of lichen (no species provided) and small clubmoss (*Selaginella densa*). In grazed mixed-grass prairies in southwestern Saskatchewan, Henderson and Davis (2014) reported that Horned Lark abundance increased with increasing cover of bare ground, and abundance decreased with increasing litter mass and increasing vegetation height-density. In mixed-grass prairies in south-central Saskatchewan, Horned Lark abundance increased in areas where vegetation was characterized by poor vigor and greater variation in standing dead vegetation and decreased in areas with increased frequency of standing dead vegetation and forbs (Davis and others, 2014).

In native grasslands in Saskatchewan, Horned Lark occurrence was related to vegetation at nest sites; occurrence was positively associated with number of contacts of narrow-leaved (<5 millimeters [mm] wide) grasses ≤10 cm tall and was negatively associated with vegetation height (Saskatchewan Wetland Conservation Corporation, 1997).

In north-central North Dakota, mixed-grass prairies occupied by Horned Larks had lower litter depth, taller vegetation, and less coverage of shrubs than unoccupied prairies; occurrence was not related to total live vegetation cover (Grant and others, 2004). In mixed-grass prairies in western North Dakota, Horned Lark densities declined with increasing litter depth (Chepulis, 2016). In south-central North Dakota, DNC grasslands occupied by Horned Larks had less grass and forb coverage than unoccupied DNC grasslands (Renken, 1983). In mixed-grass prairies in south-central North Dakota, Horned Larks preferred silty range sites that were characterized by loamy soils, 1–15 percent slope, moderate grass coverage, less shrub cover, and moderate-to-high litter cover (Messmer, 1990). Horned Larks also were present at sites that were characterized by shallow, coarse-textured soil, sparse cover, and reduced litter. In another study in mixed-grass prairies in south-central North Dakota, Horned Lark densities were higher in pastures with <10 percent coverage of western snowberry and silverberry (*Elaeagnus commutata*) than in pastures with 30–80 percent coverage of these shrubs (Arnold and Higgins, 1986). The largest densities of Horned Larks were on survey transects with the lowest height and density of vegetation, regardless of the presence or absence of shrubs. In South Dakota mixed-grass prairies, Horned Larks were more abundant in early than in late seral stages, and densities were negatively related to litter depth (Fritcher and others, 2004). In South Dakota, Montana, Colorado, Oklahoma, New Mexico, and Texas, Horned Larks preferred sites with short grass, emergent vegetation, and moderate vegetation heterogeneity (Wiens, 1973). At the Colorado site, the species occupied areas where forbs and woody vegetation were sparse and where vertical aspect of vegetation was not very well-developed. In Colorado, Kansas, Montana, Nebraska, Oklahoma, Texas, and Wyoming, Horned Lark abundance was negatively correlated with percentage of forb cover, maximum vegetation height, height of emergent forb and shrub cover, horizontal variation in forb and shrub height, and variation in the distance to the nearest forb or shrub (Rotenberry and Wiens, 1980). In Colorado, Horned Larks were significantly more abundant on plots of upland mixed-grass prairies than in plots of lowland tallgrass prairies or irrigated tame hayland (Bock and others, 1999). In shortgrass prairies in Nebraska, Colorado, Kansas, and Oklahoma, Horned Lark occurrence was greatest where <25 percent of the grass was taller than 15 cm and where shrub cover was <1 percent (McLachlan, 2007). In sagebrush habitats in eastern Washington, Horned Larks were most likely to be at sites with shorter shrub height and higher coverage of perennial grasses (Vander Haegen and others, 2000). In an Illinois study, Horned Larks only used pastures and alfalfa (*Medicago sativa*) hayland in early spring (before May 5), when vegetation was short and sparse (Gremaud, 1983). In Iowa, Horned Lark abundance in road rights-of-way increased with forb coverage (Camp and Best, 1993).

Horned Larks use cropland with bare ground; crop residue or stubble; or short, sparse vegetation. In Alberta, vegetation height in cropland was negatively correlated with Horned Lark abundance; stubble count (total number of cut plant stems) and percentage of bare ground were positively correlated with Horned Lark abundance (Martin and Forsyth, 2003). In Wisconsin agricultural areas, Horned Lark densities were negatively associated with percentage cover of woody cover 0–3 m tall, total percentage of woody cover, number of dead stems 0–3 m tall, total number of dead stems, maximum vegetation height, percentage cover of standing residual vegetation, percentage cover of prostrate residual vegetation, high density of prostrate residual vegetation (that is, proportion of quadrats with high density of prostrate residual vegetation was 0.1), and plant species richness (Sample, 1989). Densities were positively associated with percentage cover of low-density prostrate residual vegetation (that is, proportion of quadrats with low-density prostrate residual was 0.5) and bare ground. In Iowa, Horned Larks were common in strip-intercropped fields (that is, planting rowcrops, legumes, and small grains in a series of adjacent, narrow strips) (Stallman and Best, 1996), and their use of rowcrop fields significantly increased as the proximity to woody habitats decreased (Gremaud, 1983). In Wisconsin, Horned Larks were recorded in strip-crop fields (that is, areas subject to erosion that were planted in contour strips such that the rows were approximately perpendicular to the slope to reduce erosion) more than in CRP grasslands, remnant prairie, pasture, and hay fields; Horned Larks were considered an indicator species for strip-crop habitat based on the species' abundance and presence in this habitat (Ribic and others, 2009). In Nebraska, however, Horned Larks were absent from areas of extensive corn production, possibly because the timing of planting disrupted nesting activity (Faanes and Lingle, 1995).

Horned Larks use native and tame grasslands but have shown no clear preference for either of the two grassland types. Anstey and others (1995) in Saskatchewan and Prescott (1997) and Prescott and Murphy (1996) in Alberta reported that Horned Larks preferred mixed-grass pastures more than tame pastures. In other studies from Saskatchewan and Alberta, however, Horned Larks exhibited no preference between mixed-grass pastures and tame pastures (Sutter and Brigham, 1998; Davis and Duncan, 1999). In northern mixed-grass prairies in North Dakota, Grant and others (2004) determined that Horned Larks were present in grasslands with lower coverage of tame grasses (Kentucky bluegrass [*Poa pratensis*], smooth brome [*Bromus inermis*], and quackgrass [*Elymus repens*]), and with higher coverage of native grass and forb species than in unoccupied grasslands. Occurrence was not related to coverage of tame legumes. In native pastures in Alberta, ordination analysis indicated that the species used areas with moderate vegetation cover diversity, short grass, and grass moderately uniform in height

(Prescott and Murphy, 1996). Principal component analysis indicated that in native pastures the species reached highest abundance in areas of short grass with small forb-to-grass ratios. In tame pastures, highest abundances were in areas with low herbaceous biomass and uniform herbaceous height. In Washington shrubsteppe dominated by sagebrush, Earnst and Holmes (2012) reported Horned Larks were more common in native bunchgrasses and sagebrush-bunchgrass cover types than in cheatgrass (*Bromus tectorum*) associated cover types.

Horned Larks build nests on the ground and commonly place nests near tufts of grass, cow dung, rocks, small shrubs, mounds of dirt, or other objects in barren areas (Beason and Franks, 1974; Porter and Ryder, 1974; Ryder, 1980; With and Webb, 1993; Hartman and Oring, 2003). In Colorado, Horned Lark nests were nearly completely exposed to solar radiation during midday and were shaded about 45 percent of the day; most nests had a northeast orientation relative to vegetation or the structure near the nest (With and Webb, 1993). In California, nests were placed on the north side of objects (for example, tuft of grass, shrub, or rock); nests received shading from the objects, cooling from prevailing northeasterly daytime winds, and protection from prevailing southerly nighttime winds (Hartman and Oring, 2003). In Colorado, nests were not concealed by vegetation in one study (Creighton, 1974) but were concealed in another study (Boyd, 1976). In North Dakota, nests typically were in shallow depressions on bare or sparsely vegetated ground (Stewart, 1975). In a study in Idaho fescue (*Festuca idahoensis*)-dominated bunchgrass prairies in Oregon, Kennedy and others (2009) reported no significant relationships between average clutch size or nest concealment and average cover of nonnative vegetation of pastures.

Seasonal moisture levels, temperature, or extreme weather events may affect the occurrence, abundance, or productivity of Horned Larks. In native mixed-grass prairies of southeastern Alberta, Wiens and others (2008) reported that the best model of Horned Lark occurrence included a negative relationship with conserved soil moisture, which is an estimate of soil moisture on May 1 using a weighted combination of precipitation data from the previous 2 years. In an assessment of BBS data for the conterminous United States, O'Connor and others (1999) reported a negative relationship between Horned Lark abundance and average annual precipitation. Using BBS data from the Badlands and Prairies Bird Conservation Regions, Gorzo and others (2016) reported that Horned Lark abundance did not respond significantly to within- and between-year standardized precipitation and temperature indices. In an assessment of 13 BBS routes in North Dakota, Niemuth and others (2008) examined associations between two indices of regional moisture (that is, the number of prairie potholes containing water during annual May waterfowl surveys and the Palmer Drought Severity Index) and populations of Horned Larks and other grassland birds. Niemuth and others (2008) determined that Horned Lark abundance was negatively associated with the number of prairie potholes containing water in May of the same year. In mixed-grass prairies in western North Dakota, Horned Larks abruptly ended nesting in mid-June during an extreme drought; however, of the eight most common species in this study, the Horned Lark was the only species to increase in abundance during the drought (George and others, 1992). In shortgrass prairies in northeastern Colorado, nest survival for grassland songbirds that place their nests on the ground in short, sparse vegetation (Horned Lark and Thick-billed Longspur [*Rhynchophanes mccownii*] combined) were more strongly and negatively affected by daily storms and the number of dry days than grassland songbirds that place their nests on the ground in taller grasses (Lark Bunting [*Calamospiza melanocorys*], Chestnut-collared Longspur [*Calcarius ornatus*], and Western Meadowlark [*Sturnella neglecta*] combined) (Conrey and others, 2016). Weather also affected clutch sizes, with larger clutches associated with cooler springs and with wet and warmer conditions the week before egg laying. In another study in Colorado shortgrass prairies, overall nest success for Horned Larks was higher in a year of average precipitation than in a year of drought (Skagen and others, 2018). Horned Larks exhibited greater nesting effort in patch-burned pastures and lesser nesting effort in unburned prairies in the year of average precipitation, whereas the opposite was exhibited during the drought year. In shortgrass prairies in Texas, Horned Lark densities were relatively large during a dry year, nearly doubled in the next year after the drought intensified and became more widespread, and then declined by about one-third of the previous year's densities after the area received more than 6 cm of precipitation and vegetation increased (Wiens, 1974).

Area Requirements and Landscape Associations

The male Horned Lark has a multipurpose territory (that is, a defended area in which feeding, mating, and rearing of young occur) (Beason, 1995). Territory sizes of male Horned Larks are somewhat larger than those of other smaller grassland bird species (for example, wrens and sparrows); size of territories depends on habitat and population densities (Beason, 1995). In Colorado, Horned Lark territories in lightly grazed shortgrass pastures varied from 0.3 to 1.5 hectares (ha) and averaged 0.7 ha (Boyd, 1976). Territories in idle and grazed mixed-grass prairies averaged 1.1 and 1.6 ha, respectively (Wiens, 1971). In another Colorado study, territories in shortgrass pastures that were heavily summer- and winter-grazed varied from 1.0 to 1.7 ha and averaged 1.5 ha (Wiens, 1970, 1971). In shrubsteppe habitat in Oregon, average male territory sizes were similar in control plots (1.8 ha; range 1.5–2.0 ha) and in manipulated plots that experienced a 31.8-percent reduction in shrub coverage (1.9 ha; range 1.3–2.7 ha) (Wiens and others, 1986). In midwestern cropland, territory sizes varied from 0.6 to 3.1 ha and averaged 1.6 ha (Beason and Franks, 1974). Territories in disked cropland and tame hayland varied in size from 1.0 to 2.5 ha (Beason, 1970). Bent (1942) reported a Horned Lark territory in Illinois that was only 0.008 ha.

Horned Larks have shown a variable response to the size of grassland patches; some studies have indicated that the species is area sensitive (that is, preferring large grassland areas over small grassland areas; for example, Riffell and others, 2010). In Saskatchewan, Horned Lark abundance was not related to grassland patch size (Davis, 2003, 2004); however, in 1 of 2 years, Horned Lark occurrence was positively related to the distance to habitat patch edge and negatively related to patch edge-to-area ratio. In Colorado, Horned Larks were more frequently found on interior plots (that is, 200 m from edge) than on edge plots (that is, the interface between suburban development and upland or lowland habitat), but the difference was not significant because of high variation in the numbers of Horned Larks among plots (Bock and others, 1999). In Nebraska, Kansas, and Missouri, Riffell and others (2010) concluded that the Horned Lark was area sensitive and was negatively associated with a fragmentation gradient. In Illinois, Horned Larks were found in small prairie fragments <10 ha in size (Herkert, 1991). In oak barren and dry sand prairies in Wisconsin, Vos and Ribic (2011, 2013) reported Horned Larks and their nests only were on large patches (greater than [>] 45 ha) and were absent from small patches (<10.5 ha).

Grassland size also may affect Horned Lark productivity. In a Colorado study, Skagen and others (2005) reported that nest survival decreased with increasing grassland patch size; nest survival was not related to distance from an edge or vegetation structure. Of 46 Horned Lark nests, 6 were found within 50 m of an edge between shortgrass prairies and agricultural fields, which were fewer than expected if nest distribution was random or uniform relative to habitat edges. Skagen and others (2005) speculated that these unexpected results reflect the structure of the predator communities in their study area and the ways in which individual predators respond to nests. No studies were identified that investigated a relationship between patch size and rates of brood parasitism by Brown-headed Cowbirds (Molothrus ater).

Landscape-level habitat characteristics (for example, distance to wetlands, woodland, or cropland) may affect Horned Lark abundance and occurrence. In Saskatchewan, the presence of Horned Larks was negatively related to the number of wetlands within 2.8 square kilometers of point counts and negatively related to the area of woody vegetation; the species was not detected in wetlands or wetland margins (Shutler and others, 2000). In mixed-grass prairies in southern Alberta, relative abundance of Horned Larks increased as the distance to water increased; abundance was not related to distance to cropland or forage crops (Koper and Schmiegelow, 2006). In the same study area, Sliwinski and Koper (2012) reported that Horned Lark abundance increased with distance to water edge and distance to cropland edge. In northern mixed-grass prairies in North Dakota, Grant and others (2004) evaluated Horned Lark response to woody encroachment at both the territory (within 100-m radius) and landscape (within 500-m radius) scales; the species' occurrence declined with increasing coverage of tall shrubs (>1 m in height) and brush (≤1 m in height) within a 100-m radius. Horned Lark occurrence was not related to the percentage of quaking aspen (Populus tremuloides) woodland within 500 m of survey points, and Grant and others (2004) concluded that the species was not woodland sensitive. In another North Dakota study, Horned Larks were positively associated with the amount of cropland and negatively associated with the amount of grassland within 200 and 400 m from survey points (Browder and others, 2002). In shortgrass prairies in Colorado, Nebraska, Kansas, and Oklahoma, Horned Larks responded positively to the amount of grassland within 2,400 m of survey points and negatively to the amount of woodland within 300, 600, 1,200, or 2,400 m of survey points (McLachlan, 2007). In Nebraska, Kansas, and Missouri, Riffell and others (2010) reported that Horned Lark abundance was positively related to the amount of native grass in the surrounding landscape and was negatively related to patch density of CRP habitat, indicating a potential preference for more clumped arrangements of CRP grasslands. In Iowa, Horned Lark abundance was positively correlated with larger amount of rowcrops and small amounts of pasture, alfalfa hayland, and herbaceous fencerows in the landscape (Best and others, 2001). In Illinois, Horned Larks used more cropland as the amount of cropland in the landscape increased (Graber and Graber, 1963).

Brood Parasitism by Cowbirds and Other Species

The Horned Lark is considered an uncommon host of the brood parasitic Brown-headed Cowbird, although Horned Lark nests may be moderately to heavily parasitized by cowbirds in some regions or later in the breeding season (Friedmann, 1963; Hill, 1976). Shaffer and others (2019) summarized rates of cowbird brood parasitism in grassland bird nests from the literature; rates of cowbird parasitism for Horned Lark nests varied from 0 percent (Maher, 1973; Vander Haegen and Walker, 1999; Gaudet, 2013; Mahoney and Chalfoun, 2016) to 60 percent of 84 nests (Koford and others, 2000). Horned Lark nests may be multiply parasitized (that is, contain two or more cowbird eggs) by one or more female cowbirds (Peabody, 1899; Robbins, 1949; Friedmann, 1963; Saskatchewan Wetland Conservation Corporation, 1997; Koford and others, 2000; Igl and Johnson, 2007).

Cowbird parasitism rates of the first clutches of Horned Larks may be smaller than those in subsequent clutches because first Horned Lark clutches may have been laid before the onset of the Brown-headed Cowbird breeding season, which generally extends from early May to late July and peaks from late May to mid-July (Stewart, 1975; Hill, 1976; Igl and Johnson, 1997; Ortega, 1998; Koford and others, 2000). In North Dakota, no parasitism was observed in 24 clutches laid before May 15, but 60 percent of 84 clutches found after May 15 were parasitized (Koford and others, 2000). In western Kansas, no parasitism was observed in eight initial clutches laid from mid-March to mid-April, but 64 percent of 22 second clutches were parasitized from mid-May to mid-June (Hill, 1976).

Breeding-Season Phenology and Site Fidelity

Migratory Horned Larks begin to arrive on their breeding grounds in large numbers as early as February (later in the northern portions of the species' range) and depart from late October to late November (Maher, 1973; Stewart, 1975; Salt and Salt, 1976; Faanes, 1981; Janssen, 1987). Peak nesting in North Dakota is from late April to late July (Stewart, 1975). DuBois (1935) noted two peaks in Horned Lark nesting activity in Montana: one at the end of April and another in early June. Peak nesting activity in Colorado is from April to early May (Creighton, 1974). Horned Larks raise as many as three broods per season (Peabody, 1899; George, 1952; Maher, 1973, 1974; Porter and Ryder, 1974; Boyd, 1976; Salt and Salt, 1976). In Saskatchewan, the average number of clutches produced per female was estimated at two or three; some individuals produced as many as five clutches (Maher, 1973). Renesting is common after the failure of an initial nesting attempt (George, 1952; Maher, 1973; Beason, 1995).

Horned Larks have exhibited between-year fidelity to mates and to previous breeding areas (George, 1952; Ryder, 1972; Boyd, 1976). In Colorado, 40 percent of 15 banded adults were recaptured at the banding site the following year (Ryder, 1972). Two banded males returned to the same study area the year following banding but defended different territories. In another Colorado study, 66 percent of 35 females and 64 percent of 36 males returned the year following banding (Boyd, 1976). An additional two males were present on their previous year's territories in February and March but may have perished in a March snowstorm. Only one of the 23 returning males did not use the same territory that was used the previous year. Nearly one-half of the 23 returning females paired with the same mate the year following banding. Six of 136 Horned Larks marked as juveniles returned to breed on the study area (Boyd, 1976). Also in Colorado, a male Horned Lark was resighted in the same general area in which he was banded 6 years earlier (Clapp and others, 1983). In Michigan, 50 percent of 12 banded adults returned as breeders the year following banding (George, 1952).

Species' Response to Management

Horned Larks typically show a positive response to the early seral stages created or maintained by prescribed and natural fires, which reflects the species' selection of short and sparse vegetative conditions (Knick and others, 2005). In native rough fescue (*Festuca campestris*) grasslands in Saskatchewan, Horned Larks were present in small densities (ranging from 0.02 to 0.06 birds per ha) in a plot burned the previous fall and in an unburned plot (Pylypec, 1991). In a mixed-grass prairie in Saskatchewan that was burned in late summer, peak densities of Horned Larks were recorded 2 years postburn (Maher, 1973). Also in Saskatchewan mixed-grass prairies, White (2009) reported that Horned Lark abundance was positively affected by burning. During the first year postburn, Horned Lark abundance was smaller in both unburned-grazed and unburned-ungrazed plots than in the burned-grazed pastures. During the second year postburn, Horned Lark abundance was no longer significantly affected by treatment, suggesting that burned pastures became more similar to unburned pastures. Within the same Saskatchewan mixed-grass prairies, Richardson (2012) and Richardson and others (2014) also reported that abundance of Horned Larks was positively associated with burning and grazing; abundance decreased over time in burned-ungrazed pastures. Horned Larks were present in South Dakota mixed-grass areas 1 month postburn but were absent from unburned areas (Huber and Steuter, 1984). In shortgrass prairies in northeastern Colorado, Horned Lark abundance was unaffected by recent burns or time since burning and did not increase in response to patch-burn grazing (Augustine and Derner, 2015). In Nebraska, relative abundance of Horned Larks did not differ between an area managed with grazing by American bison and fire and an area managed with grazing by cattle; within a large bison pasture, Horned Lark abundances were not significantly different between burned and unburned areas (Griebel and others, 1998). In shortgrass prairies in Texas, Horned Lark abundance was almost two times larger on postburned plots than unburned plots; abundance declined through time as burned areas revegetated and litter increased (Roberts and others, 2012).

In Wyoming shrubsteppe, Kerley and Anderson (1995) observed Horned Larks in shrubsteppe that was burned to remove sagebrush. In Oregon shrubsteppe, Horned Lark abundance was higher in postburned areas where shrubs had been removed by prescribed fire (Holmes, 2007). In Washington shrubsteppe, Horned Lark abundance exhibited no trends before a prescribed fire, but abundance increased significantly and steadily after the fire, indicating a positive effect of fire in this habitat (Earnst and others, 2009). In Idaho shrubsteppe, Horned Larks only used experimental plots after these plots had been burned; the species was apparently attracted to the openness or reduced vertical structure of burned patches

(Petersen and Best, 1987). In Nevada, Horned Larks were most abundant in recently burned (8–9 years postburn) mountain big sagebrush (*Artemisia tridentata* subspecies [ssp.] *vaseyana*) communities, and abundance declined with the number of years since a burn (11–20 years postburn) (Holmes and Robinson, 2013).

As with burning, Horned Larks may respond positively to the early seral stages created or maintained by mowing or haying, but this response may be short term and tempered by the regrowth of the vegetation. In Saskatchewan, Horned Larks were common in hayland that was mowed once annually in July; birds were surveyed just before mowing (Dale and others, 1997). Igl and Johnson (2016) assessed the effects of haying on grassland breeding birds in 483 CRP grasslands in 9 counties in 4 States in the northern Great Plains between 1993 and 2008. Horned Larks were recorded in CRP fields in all 9 counties but were most common in the 3 westernmost counties. Compared to breeding densities in CRP grasslands that had been idled for 5 or more years, Horned Lark densities were higher in the first year after haying, but the species' densities returned to idle levels or lower in the second through fourth years after haying. In North Dakota, Horned Larks were absent from mixed-grass prairies that had been hayed during the previous year (Kantrud, 1981). In Colorado, Horned Larks were not present in hayland that had been flood-irrigated during spring and early summer, mowed during July, and occasionally grazed by cattle during fall and winter (Bock and others, 1995, 1999). Horned Larks were the most common breeding bird nesting in mowed and burned plots at a small (260 ha) military airport in Colorado; the species did not nest in unmanaged areas (Carragher and others, 2012). In Minnesota and Wisconsin, Horned Larks were observed in tame hayland (Faanes, 1981). In Illinois, Horned Larks were present in hayland consisting of a mixture of native and tame vegetation (Graber and Graber, 1963). In another Illinois study, Horned Larks were common in a tame hayfield (vegetation height was <10 cm) early (March through May) in the breeding season but abandoned the hayfield by early June, presumably because of the growth of vegetation (Beason, 1970). Horned Larks became abundant in the hayfield after the vegetation was cut (vegetation height after cutting was 10–15 cm) in mid-June, although no territories seemed to have been established. By early July, vegetation in the hayfield had grown to 40 cm tall, and Horned Larks abandoned the field.

Horned Larks also may respond positively to the changes in vegetation associated with grazing. In Saskatchewan, Horned Lark densities were three times larger in grazed than ungrazed grasslands (Maher, 1973). In mixed-grass prairies in Saskatchewan, Bleho (2009) reported that Horned Lark abundance was more than twice as large in grazed pastures as in ungrazed pastures. Within these same pastures, Sliwinski (2011) determined that the relative abundance of Horned Larks increased 0.1 bird per plot with an increase in stocking rate. Sliwinski (2011) also reported that Horned Lark abundance was more than twice as large in bison-grazed plots as in cattle-grazed plots, a result that was consistent with Griebel and others (1998) in Nebraska. Conversely, in mixed-grass prairies in southwestern North Dakota, Lueders and others (2006) reported that Horned Larks were common in cattle-grazed plots with moderate stocking rates but were absent from bison-grazed plots with low stocking rates that were sporadically burned. In that same study, Horned Lark densities decreased with distance from cattle water developments (Fontaine and others, 2004). Vegetation height-density and litter depth increased, and cow-dung coverage and vegetation structural variability decreased with distance from water, presumably because of reduced grazing pressure. In mixed-grass prairie in south-central North Dakota, Horned Larks were found on twice-over rotation pastures (grazing a number of pastures twice per season with about a 2-month rest in between grazing), short-duration pastures (rotating through a grazing schedule of about 1 week grazed and 1 month ungrazed repeated throughout the season), and season-long grazing pastures (Messmer, 1990). Within those same pastures, Salo and others (2004) reported that Horned Larks were observed only in heavily and extremely grazed sites (3.4 animal unit months [AUMs] per ha and 5.8 AUMs per ha, respectively) that were characterized by low visual obstruction, low litter depth, and short vegetation height; the species was not recorded in sites that were lightly or moderately grazed (2.0 AUMs per ha and 2.9 AUMs per ha, respectively). Also in south-central North Dakota, areas grazed by sheep or mowed had fewer shrubs than areas not mowed or grazed; Horned Larks preferred these grazed or mowed areas because of reduced shrub density (Higgins, 1986). In the northern Great Plains of the United States, Kantrud and Kologiski (1982) reported that Horned Lark densities were highest on heavily grazed mixed-grass prairie on borollic aridisol soils; densities were lowest under light grazing for all soil types. In the Nebraska Sandhills, Horned Lark densities were higher on medium-duration pastures (that is, simple rotation between 7 and 9 pastures) than on short-duration pastures (that is, intensive grazing) and long-duration pastures (that is, continuous grazing) (Kempema, 2007). In Colorado, Horned Lark nests were observed in moderately to heavily grazed shortgrass prairies (Strong, 1971). In grazed shortgrass prairies in Colorado, Horned Larks preferred heavily grazed over lightly or moderately grazed pastures (Giezentanner and Ryder, 1969; Ryder and Cobb, 1969; Giezentanner, 1970a, 1970b; Ryder, 1980). In Colorado, Wiens (1970) reported that breeding Horned Larks preferred heavily winter-grazed sites more than heavily summer-grazed sites. In Missouri, Horned Larks were most common in heavily grazed native or tame pastures, followed by moderately grazed pastures; the species was absent from idle grasslands and haylands (Skinner, 1974, 1975; Skinner and others, 1984). Vegetation that was >30 cm tall was avoided. In bunchgrass prairies in Oregon, Johnson and others (2012) reported that daily nest survival rates for Horned Larks were not related to variation in cattle stocking rates.

Horned Larks may be present in newly seeded grasslands during the breeding season (Prescott and Murphy, 1999), but few if any Horned Larks are observed in planted grasslands with well-established vegetation (Renken and Dinsmore, 1987; Dale, 1992, 1993; Johnson and Schwartz, 1993a, 1993b; Hartley 1994a, 1994b; Johnson and Igl, 1995; Patterson and Best, 1996; Best and others, 1997; Herkert, 2009; Igl and others, 2008; Igl, 2009). In Alberta, Horned Larks were present in newly seeded DNC grasslands (Prescott and Murphy, 1999). In Saskatchewan, Horned Larks were absent, or present at smaller densities, in DNC grasslands than in grasslands with short nesting cover (bluegrass-fescue mixture) and idle mixed-grass prairie (Dale, 1992, 1993; Hartley, 1994a, 1994b). In Alberta, Saskatchewan, and Manitoba, Horned Larks were common in PCP grasslands, but occurrence was significantly greater in cropland (McMaster and Davis, 1998, 2001). The frequency of occurrence of Horned Larks in PCP grasslands was significantly greater in grazed PCP sites than in hayed PCP sites. In North Dakota, Horned Larks were absent from tame DNC grasslands and idle mixed-grass prairies (Renken and Dinsmore, 1987). In North Dakota, South Dakota, Montana, and Minnesota, Horned Lark densities were significantly higher in CRP grasslands planted to native grasses than those planted to introduced grasses and forbs (Johnson and Schwartz, 1993b). Horned Larks were absent from wildlife food plots and tree plantings associated with CRP grasslands. In Indiana, Iowa, Kansas, Michigan, Missouri, and Nebraska, Horned Larks were not observed in CRP grasslands (Patterson, 1994; Best and others, 1997). In Iowa, Horned Larks were observed in former cropland that was restored to tallgrass prairie vegetation, but only in the first year after restoration (Olechnowski and others, 2009). In CRP grasslands in Nebraska, Kansas, and Missouri, Horned Lark abundance was negatively related to vegetation characteristics of CRP grasslands planted to exotic grasses (Riffell and others, 2010). In Missouri, Horned Larks were present at low densities in CRP fields that were planted to either cool-season or warm-season grasses (McCoy and others, 2001). Using BBS data from 12 States in the north-central United States, Herkert (2009) reported that Horned Lark populations declined after the establishment of CRP grasslands in the region, indicating that the species did not benefit from planting perennial grassland cover on former cropland. In Kansas, Horned Larks were found in CRP grasslands and grasslands planted to yellow bluestem (*Bothriochloa ischaemum*) but were not found in native mixed-grass prairies (Hickman and others, 2006). In Texas, Horned Larks were 157 percent more abundant in CRP grasslands seeded with mixes of native grasses than in grasslands seeded with monocultures of introduced grasses (Thompson and others, 2009).

Horned Larks nest in cultivated fields and commonly use croplands and recently disturbed habitats. In several studies, Horned Larks were more common in cropland than in CRP grasslands (Johnson and Schwartz, 1993a; Patterson, 1994; Johnson and Igl, 1995; Best and others, 1997; Ryan and others, 1998; McLachlan, 2007). In Alberta, Horned Larks were more abundant in summer fallow fields than in spring cereal or winter wheat (*Triticum* spp.) crops (Martin and Forsyth, 2003). The species showed no preference for minimum tilled fields (that is, planting directly into the previous year's stubble) or conventionally tilled fields (that is, multiple cultivations and other mechanical disturbances before planting). In 1 of 2 years, Horned Larks using winter wheat were more productive in minimum than in conventionally tilled fields (Martin and Forsyth, 2003). In Saskatchewan, Horned Lark occurrence was greater on organic and minimum-tillage cropland fields, followed by conventionally tilled fields; the species was least abundant in DNC grasslands (Shutler and others, 2000). In North Dakota, Horned Larks were the most common breeding bird nesting in organic, minimum-tillage, and conventional cropland fields (Lokemoen and Beiser, 1997). Johnson and Igl (1995) estimated that the North Dakota population of Horned Larks would increase by nearly 10 percent if CRP grasslands in North Dakota reverted back to cropland; similarly, Drum and others (2015) reported that Horned Lark populations would increase by 11.5 percent if all CRP is converted to cropland in the Prairie Pothole Region of the United States. In western South Dakota, DeJong and others (2004) reported that Horned Larks were more abundant in cropland fields than in native mixed-grass prairie or fallow cropland fields. In Nebraska, Colorado, Kansas, and Oklahoma, Horned Lark abundance was largest in dryland agriculture crops, followed by shortgrass prairies and CRP grasslands (McLachlan, 2007). In Illinois, Horned Lark densities were highest in plowed agricultural fields, followed by fields of alfalfa, red clover (*Trifolium pratense*), soybeans (*Glycine* spp.), corn, yellow sweetclover (*Melilotus officinalis*), small-grain stubble, oats (*Avena* spp.), ungrazed grassland, fallow, pastures, and hayland (Graber and Graber, 1963). In another Illinois study, territory densities were higher in hay stubble or corn stubble fields than in plowed fields (Beason and Franks, 1974); Beason (1970) reported that Horned Lark territories were densest in disked cropland and recently cut hayfields with vegetation heights of about 10 cm. In Indiana, Horned Larks preferred conventionally tilled corn and soybean fields (that is, fields tilled in the spring before planting) over no-tillage corn and soybean fields (that is, fields untilled between harvests with seeds planted directly into crop residue) (Castrale, 1985). Tews and others (2013) estimated the annual incidental take of young birds resulting from mechanically induced agricultural operations (including seeding, tillage, harvest, and mowing) in agriculture-dominated Bird Conservation Areas in Canada. Horned Larks were considered the species least likely to be killed by farming operations among the five species examined; the total annual estimated incidental take of young Horned Larks was about 43,000 birds.

Some pesticides may have deleterious effects on Horned Lark abundance or productivity. In Ontario corn fields, Horned Lark abundance did not differ between pre- and post-applications of the granular insecticides fonofos and terbufos, which were used to control corn rootworm (*Diabrotica* spp.), or between treated fields and control fields (Knapton and Mineau, 1995). In Canadian canola (*Brassica napus* and *Brassica rapa*) fields, Mineau and others (2005) determined that Horned Lark abundance was negatively correlated with the use of granular insecticides carbofuran and terbufos to control flea beetles (*Phyllotreta* spp.); Mineau and others (2005) found evidence to suggest that Horned Larks were experiencing regional population-level effects from applications of granular insecticides. In Montana, applications of chlorpyrifos (applied at rates of 0.56 and 1.0 kilogram [kg] in 18.9 liters [L] of water per ha) to control cutworms (Noctuidae) in wheat fields resulted in reduced cholinesterase activity in the brains of Horned Larks compared to a control group (McEwen and others, 1986). In Wyoming, Horned Lark mortality was observed after fenthion, a chemical used to control mosquitoes (Culicidae), was aerially applied at a rate of 47 grams (g) per ha to an irrigated meadow (DeWeese and others, 1983). In Colorado, Idaho, North Dakota, Utah, and Wyoming, Horned Lark densities were not affected by the use of malathion, carbaryl applied in oil formulation, and carbaryl bait for grasshopper (Acrididae) control (George and others, 1995). At the Pawnee National Grassland in Colorado, malathion and toxaphene were applied at rates of 0.6 kg per ha and 1.1 kg per ha, respectively (McEwen and Ells, 1975). Horned Lark densities on toxaphene plots were about 1 pair per ha before application of insecticides and declined by about 30 percent 17 days after application; densities remained stable on malathion and untreated plots. Nestlings were killed by toxaphene applications. Average toxaphene level of 13 Horned Larks collected 1–28 days postspray for analysis of residue was 5.4 parts per million (ppm). At 58 days, two birds had toxaphene residues of 4.1 and 4.6 ppm. At 85 days, two birds had toxaphene residues of 2.3 and 2.9 ppm. On malathion plots, only Horned Larks collected within 31 hours of spraying contained measurable (greater than or equal to 0.4 ppm) whole-body residues. Four Horned Larks from the untreated area contained 0.5 to 2.0 ppm toxaphene, indicating insecticide drift. No malathion residues were found in two birds from untreated plots.

In a multi-State study, McEwen and others (1972) evaluated the effect of several pesticides used for grasshopper control on Horned Larks and other birds. In Montana, numbers of Horned Larks were unaffected by an application rate of 175 g per ha of BAY 77488 (phenylglyoxylonitrile oxime *O*,*O*-diethyl phosphorothioate). Rates of 322 and 651 g per ha caused significant declines in Horned Lark abundance between pre- and post-spray censuses. Horned Lark numbers declined significantly on areas sprayed with fenitrothion at application rates of 441 and 672 g per ha. In Wyoming, diazinon applied at 350–560 g per ha caused Horned Lark mortalities and a significant decline in abundance. No significant declines in Horned Larks were reported for Mobam® (benzo [b]thien-4-yl methyl-carbamate) applied at a rate of 210 g per ha. In Montana and Wyoming, Horned Lark abundance did not decline significantly with Baygon® (*o*-isopropoxyphenyl methyl-carbamate) application rates of 140, 210, or 280 g per ha. In New Mexico, toxaphene applied at 1.1 kg per ha caused mortalities in Horned Larks and a decline in abundance. No effects were observed from applications of 448 g per ha carbaryl or 476 g per ha malathion. Horned Lark numbers declined significantly on plots treated with Guthion® (*O*,*O*-dimethyl *S*-[(4-oxo-1,2, 3-benzotriazin-3(4H)-yl)methyl] phosphorodithioate) at the application rate of 280 g per ha (McEwen and others, 1972).

Repellents have been used to deter Horned Larks from consuming seeds and seedling leaves (that is, cotyledons) and from uprooting seedlings (Werner and others, 2015; Schwillinger and Werner, 2016). Anthraquinone-based repellents have been tested or used to repel Horned Larks from lettuce (*Lactuca sativa*) and canola crops in the United States (Werner and others, 2015; Schwillinger and Werner, 2016). Werner and others (2015) observed 38–100 percent feeding repellency among Horned Larks offered wheat (*Triticum* spp.) seeds treated with 168–3,010 ppm anthraquinone.

Herbicides applied to control weed or shrub species can indirectly affect Horned Larks by changing vegetation structure and composition. Numbers of Horned Larks in Wyoming shrubsteppe were significantly larger in areas that were treated 20–22 years earlier with the herbicide 2,4–D to remove sagebrush than in areas that were not burned or treated with herbicides (Kerley and Anderson, 1995). Untreated areas contained larger shrub densities, higher percentage of shrub cover, and taller shrubs than treated areas. Grazing intensity also was lower on untreated areas. In areas managed for lowbush blueberries (*Vaccinium angustifolium*) in Maine, Horned Larks were present only in areas recently sprayed with the herbicide hexazinone at a rate of 4 kg per ha (Vickery, 1993). Horned Larks preferred the sparse vegetation cover.

Urbanization may limit the abundance of Horned Larks (Haire and others, 2000). In Colorado, Horned Lark abundance was significantly and negatively associated with an urban index, which was calculated by summing the percentage of urban vegetation and percentage of buildings and paved area within a landscape consisting of the city of Boulder, Colorado, and 1 km surrounding the Boulder Open Space (Haire and others, 2000). In a second study around Boulder, Lenth and others (2006) evaluated differences in avian density between clustered and dispersed housing developments; Horned Lark densities were significantly higher in undeveloped areas than in clustered developments or dispersed developments. In Colorado, the Horned Lark is struck by military and civilian aircraft more frequently than any other species (Carragher and others, 2012).

Several studies have evaluated Horned Lark response to roads and trails. In mixed-grass prairies in southern Alberta, Horned Lark abundance was not related to distance to roads (Koper and Schmiegelow, 2006; Sliwinski and Koper, 2012). In lightly to moderately grazed mixed-grass prairies in Saskatchewan, Horned Lark abundance was not significantly different along trails (that is, single pair of wheel ruts visually indistinct from surrounding habitat in terms of plant structure and composition) than along roads (that is, traveling surfaces with adjacent drainage ditches planted to smooth brome and ending with a fence 11–18 m from the traveling surface) (Sutter and others, 2000). In Wyoming shrubsteppe, Horned Larks were more abundant within 100 m of gas-well access roads than 100–200 m from the roads, ostensibly because of reduced shrub cover along the road edge (Ingelfinger and Anderson, 2004). Clark and Karr (1979) studied the effects of roads and interstate highways on the density of Horned Larks in central Illinois. Densities of Horned Larks increased with distance from the road for both county highways and interstate highways; Horned Lark densities were higher along county highways than along interstate highways.

Horned Larks typically are tolerant of oil and gas development, especially in recently disturbed areas. In mixed-grass prairies in southern Alberta, Horned Lark densities were not significantly affected by shallow gas-well densities or by distance to shallow gas wells, oil wells, or roads (Daniel, 2015). In Saskatchewan and Alberta, Horned Lark abundance tended to increase near oil and gas development, but the trend was not significant (Linnen, 2008). In mixed-grass pastures in Saskatchewan, Horned Lark abundance was highest at a northern study site with higher natural gas well densities, shorter vegetation, sparser litter and grass cover, and fewer forbs (Kalyn Bogard, 2011; Kalyn Bogard and Davis, 2014). Horned Larks did not respond to natural gas well density in a southern study site, apparently because the southern site provided more suitable habitat (that is, short, sparse vegetation with a litter depth of 6 mm) than the northern site. In southeastern Alberta, Horned Lark abundance decreased with an increase in natural gas well density and an increase in the percentage of live grasses and forbs; Horned Lark abundance increased at low percent coverage of crested wheatgrass (Rodgers, 2013; Rodgers and Koper, 2017). In southwestern Saskatchewan, Gaudet (2013) evaluated the effects of natural gas development on density and productivity of Horned Larks. Horned Lark densities declined as distance to compressor stations increased and as percent plot disturbance increased. Average distance of Horned Lark nests to the nearest gas well was significantly greater than average distance to random points. Horned Larks fledged more young per successful nest closer to compressor stations. In mixed-grass prairies in western North Dakota, Horned Lark densities were not related to densities of unconventional oil wells or roads within 1.6 km of study plot boundaries (Chepulis, 2016). In shrubsteppe habitat in western Wyoming, Gilbert and Chalfoun (2011) evaluated songbird abundance across gradients of oil and natural gas development at three locations. At the youngest site, Gilbert and Chalfoun (2011) determined that Horned Lark abundance increased with increasing well density. At the oldest site, which contained the least amount of human activity (that is, drilling rigs and vehicle traffic), Horned Larks had the smallest overall abundance.

Optimal sites for wind-energy development generally overlap with Horned Lark habitat. In Wyoming, Mahoney and Chalfoun (2016) examined reproductive success of Horned Larks at three wind facilities in mixed-grass and shortgrass prairies. Size-adjusted mass of Horned Lark nestlings was weakly negatively related to turbine density. In 1 of 2 years, nest survival decreased 55 percent as turbine density increased from 10 to 39 turbines within 2 km of a nest. In the second year, nest survival was best predicted by a combination of vegetation height, distance to shrub edge, and turbine density. The average number of Horned Lark fledglings from successful nests, however, was slightly larger at wind farms, averaging one additional fledging for every two nests (Mahoney and Chalfoun, 2016). Erickson and others (2014) summarized data from 116 studies from the United States and Canada on bird fatalities caused by collision with turbines at wind-energy facilities. Horned Larks constituted the largest proportion of small-passerine fatalities, with fatalities being nearly twice as high as any other species. Zimmerling and others (2013) analyzed 43 published and unpublished reports on the impacts from development and operation of wind turbines in Canada; the most frequently reported fatalities were Horned Larks. Most fatalities were in the spring, when male Horned Larks sing during aerial courtship displays as high as 250 m above the ground, potentially bringing them into contact wind-turbine blades. 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; Horned Larks were one of the most common species discovered during bird mortality surveys at monopole wind turbines. At a large wind facility in Washington and Oregon, Erickson and others (2004) reported that Horned Larks were the most commonly observed fatality for an individual bird species, with an estimated fatality rate of 0.89 bird per turbine; Erickson and others (2004) reported no apparent displacement from turbines for this species during the breeding season. Beston and others (2016) developed a prioritization system to identify avian species 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. The Horned Lark scored a 2.55 out of nine based on 428 species evaluated; 6.18 percent of the Horned Lark breeding population in the United States are exposed to wind facilities.

Management Recommendations from the Literature

Habitat use by Horned Larks is affected by local and landscape features. McLachlan (2007) recommended that natural resource managers should recognize the potential effect of landscape features along with local habitat conditions when developing conservation plans and prescribing management activities. Some studies have indicated that the Horned Lark is an area sensitive species, preferring larger grasslands over smaller ones (for example, McLachlan, 2007; Riffell and others, 2010). Other studies did not report area sensitivity for this species (for example, Davis, 2003, 2004). Given the Horned Lark's propensity to use sparsely vegetated grasslands and agricultural lands, the amount of cropland in the landscape may have a positive effect on Horned Lark occurrence and abundance in some portions of the species' breeding range (Graber and Graber, 1963; Best and others, 2001).

Burning, mowing, grazing, or herbicide applications can be used interchangeably to create or maintain short, sparse vegetation in grasslands that Horned Larks prefer (Skinner, 1974, 1975; Huber and Steuter, 1984; Skinner and others, 1984; McLachlan, 2007; White, 2009; Richardson, 2012). The benefits of these management practices may be short term because of the regrowth of the vegetation within the breeding season or in the following breeding season (Beason, 1970; Holmes and Robinson, 2013; Igl and Johnson, 2016). In Saskatchewan mixed-grass prairies, prescribed fire intervals of 5 years would maintain some habitat suitable for Horned Larks, although annual patch-burns would increase habitat heterogeneity (Richardson, 2012).

Livestock grazing intensity may be managed through stocking rates and season of use. In Saskatchewan mixed-grass prairies, Sliwinski (2011) suggested that pastures that are moderately grazed by cattle will create habitat heterogeneity; continuously applied moderate stocking rates will result in habitat similar to that created by high stocking rates favored by Horned Larks. In the same Saskatchewan mixed-grass prairies, Bleho (2009) suggested that light-to-moderate grazing can improve habitat for Horned Larks. In a North Dakota study in mixed-grass prairies, however, Horned Larks were not found in light-to-moderate grazing treatments and were only found in heavily grazed or extremely grazed areas (Salo and others, 2004). In northeast Oregon, Johnson and others (2012) found no evidence that increased stocking rates increased risk of nest predation, suggesting grasslands managed with livestock grazing may be compatible with grassland bird conservation. In tallgrass prairies and other mesic areas, moderate grazing may increase habitat patchiness and bird diversity (Skinner, 1974, 1975; Ryder, 1980; Skinner and others, 1984).

The Horned Lark tends to avoid areas with extensive woody vegetation but will tolerate the presence of some woody cover (Sample, 1989). The proximity to woody vegetation and other habitats within the landscape or the amount of woody vegetation within grasslands may negatively affect Horned Lark occurrence and abundance (Davis, 2003, 2004; Koper and Schmiegelow, 2006; McLachlan, 2007; Sliwinski and Koper, 2012), and thus limiting the planting of trees and shrubs on the edges of grasslands and limiting the encroachment of woody vegetation into grasslands will benefit Horned Larks. In mixed-grass prairies that have experienced heavy woody encroachment, Grant and others (2004) suggested that managers focus initial restoration efforts on grasslands with <20 percent woodland encroachment because these grasslands would have the most immediate and lasting conservation benefit for grassland birds. Management practices, such as mowing or grazing by sheep, which modify shrub coverage, may benefit Horned Larks (Arnold and Higgins, 1986). Rosenstock and Van Riper (2001) suggested that removal or reduction of invasive oneseed juniper (*Juniperus monosperma*) will improve breeding habitat for Horned Larks in northeast Arizona; Horned Larks were most abundant at study sites that had not been invaded by juniper. In shrubsteppe habitats, the removal of shrubs with prescribed fires may increase Horned Lark abundance (Holmes, 2007). In Missouri tallgrass prairies, Skinner and others (1984) recommended spring burns to reduce coverage of woody vegetation.

Pesticides may indirectly or directly affect Horned Larks. Herbicides applied to control weeds or shrubs may indirectly affect Horned Larks by changing vegetation structure and composition. For example, in a sandplain grassland in southern Maine (Vickery and others, 1999) and shrubsteppe in Wyoming (Kerley and Anderson, 1995), Horned Lark abundance increased after herbicide use. Insecticides, however, may have deleterious, direct effects (for example, higher mortality or lower productivity) on Horned Larks (McEwen and Ells, 1975; DeWeese and others, 1983; McEwen and others, 1972, 1986; Mineau and others, 2005). When invertebrate pest management is required, McEwen and others (1972) highlighted the importance of applying only rapidly degrading chemicals of low toxicity to nontarget organisms at the smallest application rates possible. Pest outbreaks can be avoided by maintaining rangeland in good condition; overgrazed and drought-affected areas tend to be more prone to insect outbreaks.

Studies on the effects of roads and road development on Horned Larks have shown that the impacts may be either positive or negative for Horned Larks or show no impact (Clark and Karr, 1979; Ingelfinger and Anderson, 2004; Koper and Schmiegelow, 2006; Sliwinski and Koper, 2012). Bock and others (1999) recommended reducing the amount of grassland edge near suburban interfaces. Clark and Karr (1979) indicated that future road construction programs should consider the effects of roads on Horned Larks and other wildlife in highway rights-of-way and within 500 m from the rights-of-way.

The number of Horned Lark fatalities associated with wind-energy developments typically is larger than fatalities of other small passerines at these developments (Loss and others, 2013; Zimmerling and others, 2013; Erickson and others, 2014). Zimmerling and others (2013) recommended that in situations where the rate of mortality is high, mitigation may be required. Mitigation examples include feathering of wind-turbine blades (that is, turbine blades are pitched parallel with the wind direction and spin at very low rotation rate or not at all) or periodic shutdown of select turbines during high-risk periods (for example, during spring aerial courtship displays).

References

Agnew, W., Uresk, D.W., and Hansen, R.M., 1986, Flora and fauna associated with prairie dog colonies and adjacent ungrazed mixed-grass prairie in western South Dakota: Journal of Range Management, v. 39, no. 2, p. 135–139. [Also available at http://dx.doi.org/10.2307/3899285.]

Anstey, D.A., Davis, S.K., Duncan, D.C., and Skeel, M., 1995, Distribution and habitat requirements of eight grassland songbird species in southern Saskatchewan: Regina, Saskatchewan, Saskatchewan Wetland Conservation Corporation, 11 p.

Arnold, T.W., and Higgins, K.F., 1986, Effects of shrub coverages on birds of North Dakota mixed-grass prairies: Canadian Field-Naturalist, v. 100, no. 1, p. 10–14.

Augustine, D.J., and Baker, B.W., 2013, Associations of grassland bird communities with black-tailed prairie dogs in the North American Great Plains: Conservation Biology, v. 27, no. 2, p. 324–334. [Also available at https://dx.doi.org/10.1111/cobi.12013.]

Augustine, D.J., and Derner, J.D., 2015, Patch-burn grazing management, vegetation heterogeneity, and avian responses in a semi-arid grassland: The Journal of Wildlife Management, v. 79, no. 6, p. 927–936. [Also available at https://doi.org/10.1002/jwmg.909.]

Beason, R.C., 1970, The annual cycle of the Prairie Horned Lark in west central Illinois: Macomb, Ill., Western Illinois University, Master's Thesis, 160 p.

Beason, R.C., 1995, Horned Lark (*Eremophila alpestris*) (ver. 2.0), *in* Poole, A.F., and Gill, F.B., eds., The birds of North America: Ithaca, N.Y., Cornell Lab of Ornithology, accessed March 2019 at https://birdsna.org/Species-Account/bna/species/horlar. [Also available at https://doi.org/10.2173/bna.195.]

Beason, R.C., and Franks, E.C., 1974, Breeding behavior of the Horned Lark: The Auk, v. 91, no. 1, p. 65–74. [Also available at https://doi.org/10.2307/4084662.]

Bent, A.C., 1942, Life histories of North American flycatchers, larks, swallows, and their allies. Order Passeriformes—Families Cotingidae, Tyrannidae, Alaudidae, and Hirundinidae: New York, N.Y., Dover Publications, Inc., 555 p. [Also available at https://doi.org/10.5479/si.03629236.179.i.]

Best, L.B., 2001, Temporal patterns of bird abundance in cornfield edges during the breeding season: American Midland Naturalist, v. 146, no. 1, p. 94–104. [Also available at https://dx.doi.org/10.1674/0003-0031(2001)146%5B0094:TPOBAI%5D2.0.CO;2.]

Best, L.B., Bergin, T.M., and Freemark, K.E., 2001, Influence of landscape composition on bird use of rowcrop fields: The Journal of Wildlife Management, v. 65, no. 3, p. 442–449. [Also available at https://dx.doi.org/10.2307/3803096.]

Best, L.B., Campa, H., III, Kemp, K.E., Robel, R.J., Ryan, M.R., Savidge, J.A., Weeks, H.P., Jr., and Winterstein, S.R., 1997, Bird abundance and nesting in CRP fields and cropland in the Midwest—A regional approach: Wildlife Society Bulletin, v. 25, no. 4, p. 864–877.

Best, L.B., and Hill, B.J., 1983, Fencerows are for the birds: Iowa Bird Life, v. 53, no. 1, p. 16–21.

Best, L.B., Whitmore, R.C., and Booth, G.M., 1990, Use of cornfields by birds during the breeding season—The importance of edge habitat: American Midland Naturalist, v. 123, no. 1, p. 84–99. [Also available at https://doi.org/10.2307/2425762.]

Beston, J.A., Diffendorfer, J.E., Loss, S.R., and Johnson, D.H., 2016, Prioritizing avian species for their risk of population-level consequences from wind energy development: PLoS One, v. 11, no. 3, p. e0150813 [Also available at https://doi.org/10.1371/journal.pone.0150813.]

Bleho, B., 2009, Passerine relationship with habitat heterogeneity and grazing at multiple scales in northern mixed-grass prairie: Winnipeg, Manitoba, University of Manitoba, Master's Thesis, 124 p.

Bock, C.E., Bock, J.H., and Bennett, B.C., 1995, The avifauna of remnant tallgrass prairie near Boulder, Colorado: Prairie Naturalist, v. 27, no. 3, p. 147–157.

Bock, C.E., Bock, J.H., and Bennett, B.C., 1999, Songbird abundance in grasslands at a suburban interface on the Colorado High Plains, *in* Vickery, P.D., and Herkert, J.R., eds., Ecology and conservation of grassland birds of the Western Hemisphere: Studies in Avian Biology, v. 19, p. 131–136.

Bock, C.E., and Webb, B., 1984, Birds as grazing indicator species in southeastern Arizona: The Journal of Wildlife Management, v. 48, no. 3, p. 1045–1049. [Also available at https://doi.org/10.2307/3801466.]

Boyd, R.L., 1976, Behavioral biology and energy expenditure in a Horned Lark population: Fort Collins, Colo., Colorado State University, Ph.D. Dissertation, 194 p.

Browder, S.F., Johnson, D.H., and Ball, I.J., 2002, Assemblages of breeding birds as indicators of grassland condition: Ecological Indicators, v. 2, no. 3, p. 257–270. [Also available at https://doi.org/10.1016/S1470-160X(02)00060-2.]

Bryan, G.G., and Best, L.B., 1991, Bird abundance and species richness in grassed waterways in Iowa rowcrop fields: American Midland Naturalist, v. 126, no. 1, p. 90–102. [Also available at https://dx.doi.org/10.2307/2426153.]

Camp, M., and Best, L.B., 1993, Bird abundance and species richness in roadsides adjacent to Iowa rowcrop fields: Wildlife Society Bulletin, v. 21, no. 3, p. 315–325.

Campbell, T.M., III, and Clark, T.W., 1981, Colony characteristics and vertebrate associates of white-tailed and black-tailed prairie dogs in Wyoming: American Midland Naturalist, v. 105, no. 2, p. 269–276. [Also available at https://doi.org/10.2307/2424745.]

Carragher, K.A., Clawges, R.M., Bunn, R.L., Pigage, H.K., and Pigage, J.C., 2012, Effects of grassland alteration from mowing and fire on bird activity at a Colorado airfield: Human-Wildlife Interactions, v. 6, p. 2, p. 298–310. [Also available at https://doi.org/10.26077/akef-9h40.]

Cassel, J.F., 1952, Breeding bird populations at various altitudes in north central Colorado: Boulder, Colo., University of Colorado, Ph.D. Dissertation, 147 p.

Castrale, J.S., 1985, Responses of wildlife to various tillage conditions: Transactions of the North American Wildlife and Natural Resources Conference, v. 50, p. 142–149.

Chepulis, B.J., 2016, Grassland bird response to landscape-level and site-specific variables in the Little Missouri National Grassland: Fargo, N. Dak, North Dakota State University, Master's Thesis, 139 p.

Clapp, R.B., Klimkiewicz, M.K., and Futcher, A.G., 1983, Longevity records of North American birds—Columbidae through Paridae: Journal of Field Ornithology, v. 54, no. 2, p. 123–137.

Clark, T.W., Campbell, T.W., III, Socha, D.G., and Casey, D.E., 1982, Prairie dog colony attributes and associated vertebrate species: The Great Basin Naturalist, v. 42, no. 4, p. 572–582.

Clark, W.D., and Karr, J.R., 1979, Effects of highways on Red-winged Blackbird and Horned Lark populations: The Wilson Bulletin, v. 91, no. 1, p. 143–145.

Conrey, R.Y., Skagen, S.K., Yackel Adams, A.A., and Panjabi, A.O., 2016, Extremes of heat, drought and precipitation depress reproductive performance in shortgrass prairie passerines: The Ibis, v. 158, no. 3, p. 614–629. [Also available at https://doi.org/10.1111/ibi.12373.]

Creighton, P.D., 1974, Habitat exploitation by an avian ground-foraging guild: Fort Collins, Colo., Colorado State University, Ph.D. Dissertation, 154 p.

Dale, B., 1992, North American waterfowl management plan implementation program related to non-game studies within the Prairie Habitat Joint Venture area, Annual report 1991–1992: Saskatoon, Saskatchewan, Canadian Wildlife Service, 66 p.

Dale, B., 1993, 1992 Saskatchewan non-game bird evaluation of North American Waterfowl Management Plan—DNC and short grass cover–1992: Edmonton, Alberta, Canadian Wildlife Service; Regina, Saskatchewan, Saskatchewan Wetland Conservation Corporation, 23 p.

Dale, B.C., 1983, Habitat relationships of seven species of passerine birds at Last Mountain Lake, Saskatchewan: Regina, Saskatchewan, University of Regina, Master's Thesis, 119 p.

Dale, B.C., Martin, P.A., and Taylor, P.S., 1997, Effects of hay management regimes on grassland songbirds in Saskatchewan: Wildlife Society Bulletin, v. 25, no. 3, p. 616–626.

Daniel, J., 2015, Landscape scale effects of oil and gas development on grassland passerines in southern Alberta: Winnipeg, Manitoba, University of Manitoba, Master's Thesis, 128 p.

Davis, S.K., 2003, Habitat selection and demography of mixed-grass prairie songbirds in a fragmented landscape: Regina, Saskatchewan, University of Regina, Ph.D. Dissertation, 131 p.

Davis, S.K., 2004, Area sensitivity in grassland passerines—Effects of patch size, patch shape, and vegetation structure on bird abundance and occurrence in southern Saskatchewan: The Auk, v. 121, no. 4, p. 1130–1145. [Also available at https://academic.oup.com/auk/article/121/4/1130/5562398.]

Davis, S.K., Dale, B.C., Harrison, T., and Duncan, D.C., 2014, Response of grassland songbirds to grazing system type and range condition: Proceedings of the North American Prairie Conference, v. 23, p. 110–119.

Davis, S.K., and Duncan, D.C., 1999, Grassland songbird occurrence in native and crested wheatgrass pastures of southern Saskatchewan, *in* Vickery, P.D., and Herkert, J.R., eds., Ecology and conservation of grassland birds of the Western Hemisphere: Studies in Avian Biology, v. 19, p. 211–218.

DeJong, J.R., Naugle, D.E., Bakker, K.K., Quamen, F.R., and Higgins, K.F., 2004, Impacts of agricultural tillage on grassland birds in western South Dakota, *in* Egan, D., and Harrington, J.A., eds., Proceedings of the nineteenth North American Prairie Conference: Madison, Wis., University of Wisconsin, p. 76–80.

DeWeese, L.R., McEwen, L.C., Settimi, L.A., and Deblinger, R.D., 1983, Effects on birds of fenthion aerial application for mosquito control: Journal of Economic Entomology, v. 76, no. 4, p. 906–911. [Also available at https://doi.org/10.1093/jee/76.4.906.]

Dickerman, R.W., 1964, Notes on the Horned Larks of western Minnesota and the Great Plains: The Auk, v. 81, no. 3, p. 430–432. [Also available at https://dx.doi.org/10.2307/4082698.]

Drum, R.G., Loesch, C.R., Carrlson, K.M., Doherty, K.E., and Fedy, B.C., 2015, Assessing the biological benefits of the USDA-Conservation Reserve Program (CRP) for waterfowl and grassland passerines in the Prairie Pothole Region of the United States—Spatial analyses for targeting CRP to maximize benefits for migratory birds: Bismarck, N. Dak., U.S. Fish and Wildlife Service, Final Report for USDA–FSA Agreement: 12-IA-MRE-CRP-TA, 98 p.

DuBois, A.D., 1935, Nests of Horned Larks and longspurs on a Montana prairie: The Condor, v. 37, no. 2, p. 56–72. [Also available at https://dx.doi.org/10.2307/1363878.]

Ducey, J., and Miller, L., 1980, Birds of an agricultural community: Nebraska Bird Review, v. 48, no. 3, p. 58–68.

Earnst, S.L., and Holmes, A.L., 2012, Bird-habitat relationships in interior Columbia basin shrubsteppe: The Condor, v. 114, no. 1, p. 15–29. [Also available at https://doi.org/10.1525/cond.2012.100176.]

Earnst, S.L., Newsome, H.L., LaFramboise, W.L., and LaFramboise, N., 2009, Avian response to wildfire in interior Columbia basin shrubsteppe: The Condor, v. 111, no. 2, p. 370–376. [Also available at https://doi.org/10.1525/cond.2009.080109.]

Erickson, W.P., Jeffrey, J., Kronner, K., and Bay, K., 2004, Stateline Wind Project wildlife monitoring final report July 2001–December 2003: Cheyenne, Wyo., Western EcoSystems Technology, Inc., and Pendleton, Oreg., Northwest Wildlife Consultants, Inc., 98 p.

Erickson, W.P., Wolfe, M.M., Bay, K.J., Johnson, D.H., and Gehring, J.L., 2014, A comprehensive analysis of small-passerine fatalities from collision with turbines at wind energy facilities: PLoS One, v. 9, no. 9, e107491. [Also available at https://doi.org/10.1371/journal.pone.0107491.]

Faanes, C.A., 1981, Birds of the St. Croix River Valley—Minnesota and Wisconsin: Washington, D.C., U.S. Fish and Wildlife Service, North American Fauna, no. 73, 196 p. [Also available at https://dx.doi.org/10.3996/nafa.73.0001.]

Faanes, C.A., and Lingle, G.R., 1995, Breeding birds of the Platte River Valley of Nebraska: Jamestown, N. Dak., U.S. Geological Survey, Northern Prairie Wildlife Research Center, 412 p.

Fontaine, A.L., Kennedy, P.L., and Johnson, D.H., 2004, Effects of distance from cattle water developments on grassland birds: Journal of Range Management, v. 57, no. 3, p. 238–242. [Also available at https://dx.doi.org/10.2307/4003790.]

Friedmann, H., 1963, Host relations of the parasitic cowbirds: Washington, D.C., Smithsonian Institution, U.S. National Museum, Bulletin 233, 276 p. [Also available at https://dx.doi.org/10.5479/si.03629236.233.]

Fritcher, S.C., Rumble, M.A., and Flake, L.D., 2004, Grassland bird densities in seral stages of mixed-grass prairie: Journal of Range Management, v. 57, no. 4, p. 351–357. [Also available at https://dx.doi.org/10.2307/4003858.]

Gaudet, C.A., 2013, The effects of natural gas development on density, reproductive success and nest survival of grassland songbirds in south-western Saskatchewan: Regina, Saskatchewan, University of Regina, Master's Thesis, 113 p.

George, J.L., 1952, The birds on a southern Michigan farm: Ann Arbor, Mich., University of Michigan, Ph.D. Dissertation, 413 p.

George, T.L., Fowler, A.C., Knight, R.L., and McEwen, L.C., 1992, Impacts of a severe drought on grassland birds in western North Dakota: Ecological Applications, v. 2, no. 3, p. 275–284. [Also available at https://doi.org/10.2307/1941861.]

George, T.L., McEwen, L.C., and Peterson, B.E., 1995, Effects of grasshopper control programs on rangeland breeding bird populations: Journal of Range Management, v. 48, no. 4, p. 336–342. [Also available at https://doi.org/10.2307/4002486.]

Giezentanner, J.B., 1970a, Avian distribution and population fluctuations on the shortgrass prairie of north central Colorado: Fort Collins, Colo., Colorado State University, Master's Thesis, 113 p.

Giezentanner, J.B., 1970b, Avian distribution and population fluctuations on the shortgrass prairie of north central Colorado: Fort Collins, Colo., Colorado State University, U.S. International Biological Program, Grassland Biome Technical Report 62, 112 p.

Giezentanner, J.B., and Ryder, R.A., 1969, Avian distribution and population fluctuations at the Pawnee site: Fort Collins, Colo., Colorado State University, U.S. International Biological Program, Grassland Biome Technical Report 28, 29 p.

Gilbert, M.M., and Chalfoun, A.D., 2011, Energy development affects populations of sagebrush songbirds in Wyoming: The Journal of Wildlife Management, v. 75, no. 4, p. 816–824. [Also available at https://dx.doi.org/10.1002/jwmg.123.]

Gorzo, J.M., Pidgeon, A.M., Thogmartin, W.E., Allstadt, A.J., Radeloff, V.C., Heglund, P.J., and Vavrus, S.J., 2016, Using the North American Breeding Bird Survey to assess broad-scale response of the continent's most imperiled avian community, grassland birds, to weather variability: The Condor, v. 118, no. 3, p. 502–512. [Also available at https://doi.org/10.1650/CONDOR-15-180.1.]

Graber, R.R., and Graber, J.W., 1963, A comparative study of bird populations in Illinois, 1906–1909 and 1956–1958: Illinois Natural History Survey Bulletin, v. 28, no. 3, p. 383–528.

Grant, T.A., Madden, E., and Berkey, G.B., 2004, Tree and shrub invasion in northern mixed-grass prairie—Implications for breeding grassland birds: Wildlife Society Bulletin, v. 32, no. 3, p. 807–818. [Also available at https://doi.org/10.2193/0091-7648(2004)032[0807:TASIIN]2.0.CO;2.]

Greer, R.D., 1988, Effects of habitat structure and productivity on grassland birds: Laramie, Wyo., University of Wyoming, Ph.D. Dissertation, 129 p.

Gremaud, G.K., 1983, Factors influencing nongame bird use of rowcrop fields: Ames, Iowa, Iowa State University, Master's Thesis, 56 p.

Griebel, R.L., Winter, S.L., and Steuter, A.A., 1998, Grassland birds and habitat structure in sandhills prairie management using cattle or bison plus fire: Great Plains Research, v. 8, no. 2, p. 255–268.

Haire, S.L., Bock, C.E., Cade, B.S., and Bennett, B.C., 2000, The role of landscape and habitat characteristics in limiting abundance of grassland nesting songbirds in an urban open space: Landscape and Urban Planning, v. 48, no. 1–2, p. 65–82. [Also available at https://dx.doi.org/10.1016/S0169-2046(00)00044-X.]

Hartley, M.J., 1994a, Passerine abundance and productivity indices in grasslands managed for waterfowl nesting cover: Transactions of the North American Wildlife and Natural Resources Conference: v. 59, p. 322–327.

Hartley, M.J., 1994b, Passerine abundance and productivity indices in grasslands managed for waterfowl nesting cover in Saskatchewan, Canada: Baton Rouge, La., Louisiana State University, Master's Thesis, 42 p.

Hartman, C.A., and Oring, L.W., 2003, Orientation and microclimate of Horned Lark nests—The importance of shade: The Condor, v. 105, no. 1, p. 158–163. [Also available at https://academic.oup.com/condor/article/105/1/158/5563333.]

Henderson, A.E., and Davis, S.K., 2014, Rangeland health assessment—A useful tool for linking range management and grassland bird conservation?: Rangeland Ecology and Management, v. 67, no. 1, p. 88–98. [Also available at https://doi.org/10.2111/REM-D-12-00140.1.]

Herkert, J.R., 1991, Study suggests increases in restored prairie fragments to conserve breeding bird communities: Restoration and Management Notes, v. 9, no. 2, p. 107.

Herkert, J.R., 2009, Response of bird populations to farmland set-aside programs: Conservation Biology, v. 23, no. 4, p. 1036–1040. [Also available at https://dx.doi.org/10.1111/j.1523-1739.2009.01234.x.]

Hickman, K.R., Farley, G.H., Channell, R., and Steier, J.E., 2006, Effects of Old World bluestem (*Bothriochloa ischaemum*) on food availability and avian community composition within the mixed-grass prairie: The Southwestern Naturalist, v. 51, no. 4, p. 524–530. [Also available at https://doi.org/10.1894/0038-4909(2006)51[524:EOOWBB]2.0.CO;2.]

Higgins, K.F., 1986, A comparison of burn season effects on nesting birds in North Dakota mixed-grass prairie: Prairie Naturalist, v. 18, no. 4, p. 219–228.

Hill, R.A., 1976, Host-parasite relationships of the Brown-headed Cowbird in a prairie habitat of west-central Kansas: The Wilson Bulletin, v. 88, no. 4, p. 555–565.

Holmes, A.L., 2007, Short-term effects of a prescribed burn on songbirds and vegetation in mountain big sagebrush: Western North American Naturalist, v. 67, no. 2, p. 292–298. [Also available at https://dx.doi.org/10.3398/1527-0904(2007)67%5B292:SEOAPB%5D2.0.CO;2.]

Holmes, A.L., and Robinson, W.D., 2013, Fire mediated patterns of population densities in mountain big sagebrush bird communities: The Journal of Wildlife Management, v. 77, no. 4, p. 737–748. [Also available at https://doi.org/10.1002/jwmg.540.]

Huber, G.E., and Steuter, A.A., 1984, Vegetation profile and grassland bird response to spring burning: Prairie Naturalist, v. 16, no. 2, p. 55–61.

Igl, L.D., 2009, Breeding bird use of grasslands enrolled in the Conservation Reserve Program in the northern Great Plains: Fargo, N. Dak., North Dakota State University, Ph.D. Dissertation, 199 p.

Igl, L.D., and Johnson, D.H., 1997, Changes in breeding bird populations in North Dakota: 1967 to 1992–93: The Auk, v. 114, no., 1, p. 74–92. [Also available at https://dx.doi.org/10.2307/4089067.]

Igl, L.D., and Johnson, D.H., 2007, Brown-headed Cowbird, *Molothrus ater*, parasitism and abundance in the northern Great Plains: Canadian Field-Naturalist, v. 121, no. 3, p. 239–255. [Also available at https://dx.doi.org/10.22621/cfn.v121i3.471.]

Igl, L.D., and Johnson, D.H., 2016, Effects of haying on breeding birds in CRP grasslands: The Journal of Wildlife Management, v. 80, no. 7, p. 1189–1204. [Also available at https://dx.doi.org/10.1002/jwmg.21119.]

Igl, L.D., Johnson, D.H., and Kantrud, H.A., 2008, A historical perspective—Changes in grassland breeding bird densities within major habitats in North Dakota between 1967 and 1992–1993, *in* Springer, J.T., and Springer, E.C., eds., Prairie invaders: Proceedings of the twentieth North American Prairie Conference: Kearney, Nebr., University of Nebraska, p. 275–295.

Ingelfinger, F., and Anderson, S., 2004, Passerine response to roads associated with natural gas extraction in a sagebrush steppe habitat: Western North American Naturalist, v. 64, no. 3, p. 385–395.

Janssen, R.B., 1987, Birds in Minnesota: Minneapolis, Minn., University of Minnesota Press, 352 p.

Johnson, D.H., and Igl, L.D., 1995, Contributions of the Conservation Reserve Program to populations of breeding birds in North Dakota: The Wilson Bulletin, v. 107, no. 4, p. 709–718.

Johnson, D.H., and Schwartz, M.D., 1993a, The Conservation Reserve Program and grassland birds: Conservation Biology, v. 7, no. 4, p. 934–937. [Also available at https://dx.doi.org/10.1046/j.1523-1739.1993.740934.x.]

Johnson, D.H., and Schwartz, M.D., 1993b, The Conservation Reserve Program—Habitat for grassland birds: Great Plains Research, v. 3, no. 2, p. 273–295.

Johnson, T.N., Kennedy, P.L., and Etterson, M.A., 2012, Nest success and cause-specific nest failure of grassland passerines breeding in prairie grazed by livestock: The Journal of Wildlife Management, v. 76, no. 8, p. 1607–1616. [Also available at https://dx.doi.org/10.1002/jwmg.437.]

Kahl, R.B., Baskett, T.S., Ellis, J.A., and Burroughs, J.N., 1985, Characteristics of summer habitats of selected nongame birds in Missouri: Columbia, Mo., University of Missouri-Columbia, Research Bulletin 1056, 155 p.

Kalyn Bogard, H.J., 2011, Natural gas development and grassland songbird abundance in southwestern Saskatchewan—The impact of gas wells and cumulative disturbance: Regina, Saskatchewan, University of Regina, Master's Thesis, 154 p.

Kalyn Bogard, H.J., and Davis, S.K., 2011, Grassland songbirds exhibit variable responses to the proximity and density of natural gas wells: Journal of Wildlife Management, v. 78, no. 3, p. 471–482. [Also available at: https://dx.doi.org/10.1002/jwmg.684.]

Kantrud, H.A., 1981, Grazing intensity effects on the breeding avifauna of North Dakota native grasslands: Canadian Field-Naturalist, v. 95, no. 4, p. 404–417.

Kantrud, H.A., and Kologiski, R.L., 1982, Effects of soils and grazing on breeding birds of uncultivated upland grasslands of the northern Great Plains: Washington, D.C., U.S. Fish and Wildlife Service, Wildlife Research Report 15, 33 p.

Kempema, S.L.F., 2007, The influence of grazing systems on grassland bird density, productivity, and species richness on private rangeland in the Nebraska Sandhills: Lincoln, Nebr., University of Nebraska, Master's Thesis, 178 p.

Kennedy, P.L., DeBano, S.J., Bartuszevige, A.M., and Lueders, A.S., 2009, Effects of native and non-native grassland plant communities on breeding passerine birds—Implications for restoration of northwest bunchgrass prairie: Restoration Ecology, v. 17, no. 4, p. 515–525. [Also available at https://dx.doi.org/10.1111/j.1526-100X.2008.00402.x.]

Kerley, L.L., and Anderson, S.H., 1995, Songbird responses to sagebrush removal in a high elevation sagebrush steppe ecosystem: Prairie Naturalist, v. 27, no. 3, p. 129–146.

King, J.W., and Savidge, J.A., 1995, Effects of the Conservation Reserve Program on wildlife in southeast Nebraska: Wildlife Society Bulletin, v. 23, no. 3, p. 377–385.

Knapton, R.W., and Mineau, P., 1995, Effects of granular formulations of terbufos and fonofos applied to cornfields on mortality and reproductive success of songbirds: Ecotoxicology, v. 4, no. 2, p. 138–153. [Also available at https://dx.doi.org/10.1007/BF00122173.]

Knick, S.T., Holmes, A.L., and Miller, R.F., 2005, The role of fire in structuring sagebrush habitats and bird communities, *in* Saab, V.A., and Powell, H.D.W., eds., Fire and avian ecology in North America: Studies in Avian Biology, v. 30, p. 63–75.

Koford, R.R., Bowen, B.S., Lokemoen, J.T., and Kruse, A.D., 2000, Cowbird parasitism in grassland and cropland in the northern Great Plains, *in* Smith, J.N.M., Cook, T.L., Rothstein, S.I., Robinson, S.K., and Sealy, S.G., eds., Ecology and management of cowbirds and their hosts: Austin, Tex., University of Texas Press, p. 229–235.

Koper, N., and Schmiegelow, F.K.A., 2006, A multi-scaled analysis of avian response to habitat amount and fragmentation in the Canadian dry mixed-grass prairie: Landscape Ecology, v. 21, p. 1045–1059. [Also available at https://dx.doi.org/10.1007/s10980-006-0004-0.]

Kotliar, N.B., Baker, B.W., Whicker, A.D., and Plumb, G., 1999, A critical review of assumptions about the prairie dog as a keystone species: Environmental Management, v. 24, no. 2, p. 177–192. [Also available at http://dx.doi.org/10.1007/s002679900225.]

Lenth, B.A., Knight, R.L., and Gilgert, W.C., 2006, Conservation value of clustered housing developments: Conservation Biology, v. 20, no. 5, p. 1445–1456. [Also available at https://doi.org/10.1111/j.1523-1739.2006.00491.x.]

Linnen, C.G., 2008, Effects of oil and gas development on grassland birds: Saskatoon, Saskatchewan, Northern EnviroSearch Ltd., Report prepared for Petroleum Technology Alliance Canada, 26 p.

Lokemoen, J.T., and Beiser, J.A., 1997, Bird use and nesting in conventional, minimum-tillage, and organic cropland: The Journal of Wildlife Management, v. 61, no. 3, p. 644–655. [Also available at https://dx.doi.org/10.2307/3802172.]

Loss, S.R., Will, T., and Marra, P.P., 2013, Estimates of bird collision mortality at wind facilities in the contiguous United States: Biological Conservation, v. 168, p. 201–209. [Also available at https://dx.doi.org/10.1016/j.biocon.2013.10.007.]

Lueders, A.S., Kennedy, P.L., and Johnson, D.H., 2006, Influences of management regimes on breeding bird densities and habitat in mixed-grass prairie—An example from North Dakota: The Journal of Wildlife Management, v. 70, no. 2, p. 600–606. [Also available at https://dx.doi.org/10.2193/0022-541X(2006)70%5B600:IOMROB%5D2.0.CO;2.]

Maher, W.J., 1973, Matador Project—Birds I. Population dynamics: Saskatoon, Saskatchewan, University of Saskatchewan, Canadian Committee for the International Biological Programme, Matador Project, Technical Report 34, 56 p.

Maher, W.J., 1974, Matador Project—Birds II. Avifauna of the Matador area: Saskatoon, Saskatchewan, University of Saskatchewan, Canadian Committee for the International Biological Programme, Matador Project, Technical Report 58, 31 p.

Mahoney, A., and Chalfoun, A.D., 2016, Reproductive success of Horned Lark and McCown's Longspur in relation to wind energy infrastructure: The Condor, v. 118, no. 2, p. 360–375. [Also available at https://doi.org/10.1650/CONDOR-15-25.1.]

Martin, P.A., and Forsyth, D.J., 2003, Occurrence and productivity of songbirds in prairie farmland under conventional versus minimum tillage regimes: Agriculture, Ecosystems & Environment, v. 96, no. 1–3, p. 107–117. [Also available at https://dx.doi.org/10.1016/S0167-8809(02)00234-7.]

McCoy, T.D., Ryan, M.R., and Kurzejeski, E.W., 2001, Grassland bird conservation—CP1 vs. CP2 plantings in Conservation Reserve Program fields in Missouri: American Midland Naturalist, v. 145, no. 1, p. 1–17. [Also available at https://dx.doi.org/10.1674/0003-0031(2001)145%5B0001:GBCCVC%5D2.0.CO;2.]

McEwen, L.C., DeWeese, L.R., and Schladweiler, P., 1986, Bird predation on cutworms (Lepidoptera: Noctuidae) in wheat fields and chlorpyrifos effects on brain cholinesterase activity: Environmental Entomology, v. 15, no. 1, p. 147–151. [Also available at https://doi.org/10.1093/ee/15.1.147.]

McEwen, L.C., and Ells, J.O., 1975, Field ecology investigations of the effects of selected pesticides on wildlife populations: Fort Collins, Colo., Colorado State University, U.S. International Biological Program, Grassland Biome Technical Report 289, 36 p.

McEwen, L.C., Knittle, C.E., and Richmond, M.L., 1972, Wildlife effects from grasshopper insecticides sprayed on short-grass range: Journal of Range Management, v. 25, no. 3, p. 188–194. [Also available at https://dx.doi.org/10.2307/3897053.]

McLachlan, M.M., 2007, Habitat use by birds in the northern shortgrass prairie of North America—A local and landscape approach: Stillwater, Okla., Oklahoma State University, Master's Thesis, 87 p.

McMaster, D.G., and Davis, S.K., 1998, Non-game evaluation of the Permanent Cover Program: Regina, Saskatchewan, Saskatchewan Wetland Conservation Corporation, 75 p.

McMaster, D.G., and Davis, S.K., 2001, An evaluation of Canada's Permanent Cover Program—Habitat for grassland birds?: Journal of Field Ornithology, v. 72, no. 2, p. 195–210. [Also available at https://dx.doi.org/10.1648/0273-8570-72.2.195.]

Messmer, T.A., 1990, Influence of grazing treatments on nongame birds and vegetation structure in south central North Dakota: Fargo, N. Dak., North Dakota State University, Ph.D. Dissertation, 164 p.

Mineau, P., Downes, C.M., Kirk, D.A., Bayne, E., and Csizy, M., 2005, Patterns of bird species abundance in relation to granular insecticide use in the Canadian prairies: Ecoscience, v. 12, no. 2, p. 267–278. [Also available at https://doi.org/10.2980/i1195-6860-12-2-267.1.]

National Geographic Society, 2011, Field guide to the birds of North America (6th ed.): Washington, D.C., National Geographic Society, 576 p.

Niemuth, N.D., Solberg, J.W., and Shaffer, T.L., 2008, Influence of moisture on density and distribution of grassland birds in North Dakota: The Condor, v. 110, no. 2, p. 211–222. [Also available at https://dx.doi.org/10.1525/cond.2008.8514.]

O'Connor, R.J., Jones, M.T., Boone, R.B., and Lauber, T.B., 1999, Linking continental climate, land use, and land patterns with grassland bird distribution across the conterminous United States, *in* Vickery, P.D., and Herkert, J.R., eds., Ecology and conservation of grassland birds of the Western Hemisphere: Studies in Avian Biology, v. 19, p. 45–59.

Olechnowski, B.F.M., Debinski, D.M., Drobney, P., Viste-Sparkman, K., and Reed, W.T., 2009, Changes in vegetation structure through time in a restored tallgrass prairie ecosystem and implications for avian diversity and community composition: Ecological Restoration, v. 27, no. 4, p. 449–457. [Also available at https://dx.doi.org/10.3368/er.27.4.449.]

Ortega, C.P., 1998, Cowbirds and other brood parasites: Tucson, Ariz., University of Arizona Press, 371 p.

Patterson, M.P., 1994, Bird species abundance, composition, and vegetation characteristics, and bird productivity in Conservation Reserve Program land in central Iowa: Ames, Iowa, Iowa State University, Master's Thesis, 54 p.

Patterson, M.P., and Best, L.B., 1996, Bird abundance and nesting success in Iowa CRP fields—The importance of vegetation structure and composition: American Midland Naturalist, v. 135, no. 1, p. 153–167. [Also available at https://dx.doi.org/10.2307/2426881.]

Peabody, P.B., 1899, The Prairie Horned Lark: Osprey, v. 3, no. 8, p. 118–119.

Petersen, K.L., and Best, L.B., 1987, Effects of prescribed burning on nongame birds in a sagebrush community: Wildlife Society Bulletin, v. 15, no. 3, p. 317–329.

Porter, D.K., and Ryder, R.A., 1974, Avian density and productivity studies and analyses on the Pawnee Site in 1972: Fort Collins, Colo., Colorado State University, U.S. International Biological Program, Grassland Biome Technical Report 252, 77 p.

Prescott, D.R.C., 1997, Avian communities and NAWMP habitat priorities in the northern prairie biome of Alberta: St. Albert, Alberta, Land Stewardship Centre of Canada, NAWMP-029, 41 p.

Prescott, D.R.C., and Murphy, A.J., 1996, Habitat associations of grassland birds on native and tame pastures of the aspen parkland in Alberta: Edmonton, Alberta, Alberta NAWMP Centre, NAWMP-021, 36 p.

Prescott, D.R.C., and Murphy, A.J., 1999, Bird populations in seeded nesting cover on North American Waterfowl Management Plan properties in the aspen parkland of Alberta, *in* Vickery, P.D., and Herkert, J.R., eds., Ecology and conservation of grassland birds of the Western Hemisphere: Studies in Avian Biology, v. 19, p. 203–210.

Pylypec, B., 1991, Impacts of fire on bird populations in a fescue prairie: Canadian Field-Naturalist, v. 105, no. 3, p. 346–349.

Renken, R.B., 1983, Breeding bird communities and bird-habitat associations on North Dakota waterfowl production areas of three habitat types: Ames, Iowa, Iowa State University, Master's Thesis, 90 p.

Renken, R.B., and Dinsmore, J.J., 1987, Nongame bird communities on managed grasslands in North Dakota: Canadian Field-Naturalist, v. 101, no. 4, p. 551–557.

Ribic, C.A., Guzy, M.J., and Sample, D.W., 2009, Grassland bird use of remnant prairie and Conservation Reserve Program fields in an agricultural landscape in Wisconsin: American Midland Naturalist, v. 161, no. 1, p. 110–122. [Also available at https://dx.doi.org/10.1674/0003-0031-161.1.110.]

Richardson, A.N., 2012, Changes in grassland songbird abundances through time in response to burning and grazing in the northern mixed-grass prairie: Winnipeg, Manitoba, University of Manitoba, Master's Thesis, 73 p.

Richardson, A.N., Koper, N., and White, K.A., 2014, Interactions between ecological disturbances—Burning and grazing and their effects on songbird communities in northern mixed-grass prairies: Avian Conservation and Ecology, v. 9, no. 2, article 5. [Also available at https://dx.doi.org/10.5751/ACE-00692-090205.]

Riffell, S., Scognamillo, D., Burger, L.W., Jr., and Bucholtz, S., 2010, Broad-scale relations between Conservation Reserve Program and grassland birds—Do cover type, configuration, and contract age matter?: The Open Ornithology Journal, v. 3, p. 112–123. [Also available at https://dx.doi.org/10.2174/1874453201003010112.]

Robbins, S.D., Jr., 1949, The 1948 nesting season: The Passenger Pigeon, v. 11, no. 1, p. 21–28.

Robel, R.J., Briggs, J.N., Dayton, A.D., and Hulbert, L.C., 1970, Relationships between visual obstruction measurements and weight of grassland vegetation: Journal of Range Management, v. 23, no. 4, p. 295–297. [Also available at https://dx.doi.org/10.2307/3896225.]

Roberts, A.J., Boal, C.W., Wester, D.B., Rideout-Hanzak, S., and Whitlaw, H.A., 2012, Grassland bird community response to large wildfires: The Wilson Journal of Ornithology, v. 124, no. 1, p. 24–30. [Also available at https://doi.org/10.1676/10-177.1.]

Rodgers, J.A., 2013, Effects of shallow gas development on relative abundances of grassland songbirds in a mixed-grass prairie: Winnipeg, Manitoba, University of Manitoba, Master's Thesis, 178 p.

Rodgers, J.A., and Koper, N., 2017, Shallow gas development and grassland songbirds—The importance of perches: The Journal of Wildlife Management, v. 81, no. 3, p. 406–416. [Also available at https://dx.doi.org/10.1002/jwmg.21210.]

Rosenstock, S.S., and Van Riper, C., III, 2001, Breeding bird responses to juniper woodland expansion: Journal of Range Management, v. 54, no. 3, p. 226–232. [Also available at https://dx.doi.org/10.2307/4003238.]

Rotenberry, J.T., and Wiens, J.A., 1980, Habitat structure, patchiness, and avian communities in North American steppe vegetation—A multivariate analysis: Ecology, v. 61, no. 5, p. 1228–1250. [Also available at https://dx.doi.org/10.2307/1936840.]

Ryan, R.M., Burger, L.W., and Kurzejeski, E.W., 1998, The impact of CRP on avian wildlife—A review: Journal of Production Agriculture, v. 11, no. 1, p. 61–66. [Also available at https://dx.doi.org/10.2134/jpa1998.0061.]

Ryder, R.A., 1972, Avian population studies on the Pawnee Site, 1968–1971: Fort Collins, Colo., Colorado State University, U.S. International Biological Program, Grassland Biome Technical Report 171, 62 p.

Ryder, R.A., 1980, Effects of grazing on bird habitats, *in* DeGraff, R.M., and Tilghman, N.G., compilers, Management of western forests and grasslands for nongame birds: Ogden, Utah, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, General Technical Report INT-86, p. 51–66.

Ryder, R.A., and Cobb, D.A., 1969, Birds of the Pawnee National Grasslands in northern Colorado: Journal of the Colorado-Wyoming Academy of Science, v. 6, p. 5.

Salo, E.D., Higgins, K.F., Patton, B.D., Bakker, K.K., and Barker, W.T., 2004, Grazing intensity effects on vegetation, livestock and non-game birds in North Dakota mixed-grass prairie, *in* Egan, D., and Harrington, J.A., eds., Proceedings of the nineteenth North American Prairie Conference: Madison, Wis., University of Wisconsin, p. 205–215.

Salt, W.R., and Salt, J.R., 1976, The birds of Alberta: Edmonton, Alberta, Hurtig Publishers, 498 p.

Sample, D.W., 1989, Grassland birds in southern Wisconsin—Habitat preference, population trends, and response to land use changes: Madison, Wis., University of Wisconsin, Master's Thesis, 588 p.

Sauer, J.R., Hines, J.E., Fallon, J.E., Pardieck, K.L., Ziolkowski, D.J., Jr., and Link, W.A., 2014, The North American Breeding Bird Survey, results and analysis 1966–2012 (ver. 02.19.2014): Laurel, Md., U.S. Geological Survey, Patuxent Wildlife Research Center, accessed March 2019 at https://www.mbr-pwrc.usgs.gov/bbs/bbs2012.shtml.

Saskatchewan Wetland Conservation Corporation, 1997, Grassland bird conservation through Saskatchewan's native prairie stewardship program: Regina, Saskatchewan, Saskatchewan Wetland Conservation Corporation, 25 p.

Schwillinger, W.F., and Werner, S.J., 2016, Horned Lark damage to pre-emerged canola seedlings: Industrial Crops and Products, v. 89, p. 465–467. [Also available at https://dx.doi.org/10.1016/j.indcrop.2016.05.045.]

Shaffer, J.A., Igl, L.D., and Johnson, D.H., 2019, The effects of management practices on grassland birds—Rates of Brown-headed Cowbird (*Molothrus ater*) parasitism in nests of North American grassland birds, chap. PP *of* Johnson, D.H., Igl, L.D., Shaffer, J.A., and DeLong, J.P., eds., The effects of management practices on grassland birds: U.S. Geological Survey Professional Paper 1842, 24 p., accessed on June 2019 at https://doi.org/10.3133/pp1842PP.

Shutler, D., Mullie, A., and Clark, R.G., 2000, Bird communities of prairie uplands and wetlands in relation to farming practices in Saskatchewan: Conservation Biology, v. 14, no. 5, p. 1441–1451. [Also available at https://dx.doi.org/10.1046/j.1523-1739.2000.98246.x.]

Skagen, S.K., Augustine, D.J., and Derner, J.D., 2018, Semi-arid grassland bird responses to patch-burn grazing and drought: The Journal of Wildlife Management, v. 82, no. 2, p. 445–456. [Also available at https://doi.org/10.1002/jwmg.21379.]

Skagen, S.K., Yackel Adams, A.A., and Adams, R.D., 2005, Nest survival relative to patch size in a highly fragmented shortgrass prairie landscape: The Wilson Bulletin, v. 117, no. 1, p. 23–34. [Also available at https://doi.org/10.1676/04-038.]

Skinner, R.M., 1974, Grassland use patterns and prairie bird populations in Missouri: Columbia, Mo., University of Missouri, Master's Thesis, 53 p.

Skinner, R.M., 1975, Grassland use patterns and prairie bird populations in Missouri, *in* Wali, M.K., ed., Prairie—A multiple view: Grand Forks, N. Dak., University of North Dakota Press, p. 171–180.

Skinner, R.M., Baskett, T.S., and Blendon, M.D., 1984, Bird habitat on Missouri prairies: Jefferson City, Mo., Missouri Department of Conservation, Terrestrial Series 14, 37 p.

Sliwinski, M.S., 2011, Changes in grassland songbird abundance and diversity in response to grazing by bison and cattle in the northern mixed-grass prairie: Winnipeg, Manitoba, University of Manitoba, Master's Thesis, 156 p.

Sliwinski, M.S., and Koper, N., 2012, Grassland bird response to three edge types in a fragmented mixed-grass prairie: Avian Conservation and Ecology, v. 7, no. 2, article 6. [Also available at https://dx.doi.org/10.5751/ACE-00534-070206.]

Smith, G.A., and Lomolino, M.V., 2004, Black-tailed prairie dogs and the structure of avian communities on the shortgrass plains: Oecologia, v. 138, no. 4, p. 592–602. [Also available at https://dx.doi.org/10.1007/s00442-003-1465-3.]

Speirs, J.M., and Orenstein, R., 1967, Bird populations in fields of Ontario County, 1965: Canadian Field-Naturalist, v. 81, no. 3, p. 175–183.

Stallman, H.R., and Best, L.B., 1996, Bird use of an experimental strip intercropping system in northeast Iowa: The Journal of Wildlife Management, v. 60, no. 2, p. 354–362. [Also available at https://dx.doi.org/10.2307/3802235.]

Stewart, R.E., 1975, Breeding birds of North Dakota: Fargo, N. Dak., Tri-College Center for Environmental Studies, 295 p.

Strong, M.A., 1971, Avian productivity on the shortgrass prairie of northcentral Colorado: Fort Collins, Colo., Colorado State University, Master's Thesis, 70 p.

Sutter, G.C., and Brigham, R.M., 1998, Avifaunal and habitat changes resulting from conversion of native prairie to crested wheatgrass—Patterns at songbird community and species levels: Canadian Journal of Zoology, v. 76, no. 5, p. 869–875. [Also available at https://doi.org/10.1139/z98-018.]

Sutter, G.C., Davis, S.K., and Duncan, D.C., 2000, Grassland songbird abundance along roads and trails in southern Saskatchewan: Journal of Field Ornithology, v. 71, no. 1, p. 110–116. [Also available at https://dx.doi.org/10.1648/0273-8570-71.1.110.]

Tews, J., Bert, D.G., and Mineau, P., 2013, Estimated mortality of selected migratory bird species from mowing and other mechanical operations in Canadian agriculture: Avian Conservation and Ecology, v. 8, no. 2, article 8. [Also available at https://dx.doi.org/10.5751/ACE-00559-080208.]

Thompson, T.R., Boal, C.W., and Lucia, D., 2009, Grassland bird associations with introduced and native grass Conservation Reserve Program fields in the southern High Plains: Western North American Naturalist, v. 69, no. 4, p. 481–490. [Also available at https://dx.doi.org/10.3398/064.069.0408.]

Tyler, J.D., and Shackford, J.S., 2002, Vertebrate associates of black-tailed prairie dogs in Oklahoma: Proceedings of the Oklahoma Academy of Science, v. 82, p. 41–47.

Vander Haegen, W.M., Dobler, F.C., and Pierce, D.J., 2000, Shrubsteppe bird response to habitat and landscape variables in eastern Washington, U.S.A.: Conservation Biology, v. 14, no. 4, p. 1145–1160. [Also available at https://doi.org/10.1046/j.1523-1739.2000.99293.x.]

Vander Haegen, W.M., and Walker, B.L., 1999, Parasitism by Brown-headed Cowbirds in the shrubsteppe of eastern Washington, *in* Hahn, D.C., Hall, L.S., Morrison, M.L., Robinson, S.K., Rothstein, S.I., and Rich, T.D., eds., Research and management of the Brown-headed Cowbird in western landscapes: Studies in Avian Biology, v. 18, p. 34–40.

Vickery, P.D., 1993, Habitat selection of grassland birds in Maine: Orono, Maine, University of Maine, Ph.D. Dissertation, 124 p.

Vickery, P.D., Hunter, M.L., Jr., and Wells, J.V., 1999, Effects of fire and herbicide treatment on habitat selection in grassland birds in southern Maine, *in* Vickery, P.D., and Herkert, J.R., eds., Ecology and conservation of grassland birds of the Western Hemisphere: Studies in Avian Biology, v. 19, p. 149–159.

Vos, S.M., and Ribic, C.A., 2011, Grassland bird use of oak barrens and dry prairies in Wisconsin: Natural Areas Journal, v. 31, no. 1, p. 26–33. [Also available at https://doi.org/10.3375/043.031.0104.]

Vos, S.M., and Ribic, C.A., 2013, Nesting success of grassland birds in oak barrens and dry prairies in west central Wisconsin: Northeastern Naturalist, v. 20, no. 1, p. 131–142. [Also available at https://doi.org/10.1656/045.020.0110.]

Werner, S.J., DeLiberto, S.T., Mangan, A.M., Pettit, S.E., Ellis, J.W., and Carlson, J.C., 2015, Anthraquinone-based repellent for Horned Larks, Great-tailed Grackles, American Crows and the protection of California's specialty crops: Crop Protection, v. 72, p. 158–162. [Also available at https://dx.doi.org/10.1016/j.cropro.2015.03.020.]

White, K., 2009, Songbird diversity and habitat use in response to burning on grazed and ungrazed mixed-grass prairie: Winnipeg, Manitoba, University of Manitoba, Master's Thesis, 88 p.

Wiens, J.A., 1969, An approach to the study of ecological relationships among grassland birds: Ornithological Monographs, no. 8, p. 1–93. [Also available at https://dx.doi.org/10.2307/40166677.]

Wiens, J.A., 1970, Avian populations and patterns of habitat occupancy at the Pawnee site, 1968–1969: Fort Collins, Colo., Colorado State University, U.S. International Biological Program, Grassland Biome Technical Report 63, 57 p.

Wiens, J.A., 1971, Avian ecology and distribution in the comprehensive network, 1970: Fort Collins, Colo., Colorado State University, U.S. International Biological Program, Grassland Biome Technical Report 77, 49 p.

Wiens, J.A., 1973, Pattern and process in grassland bird communities: Ecological Monographs, v. 43, no. 2, p. 237–270. [Also available at https://doi.org/10.2307/1942196.]

Wiens, J.A., 1974, Climatic instability and the "ecological saturation" of bird communities in North American grasslands: The Condor, v. 76, no. 4, p. 385–400. [Also available at https://dx.doi.org/10.2307/1365813.]

Wiens, J.A., Rotenberry, J.T., and Van Horne, B., 1986, A lesson in the limitations of field experiments—Shrubsteppe birds and habitat alteration: Ecology, v. 67, no. 2, p. 365–376. [Also available at https://dx.doi.org/10.2307/1938579.]

Wiens, T.S., Dale, B.C., Boyce, M.S., and Kershaw, G.P., 2008, Three way *k*-fold cross-validation of resource selection functions: Ecological Modelling, v. 212, no. 3–4, p. 244–255. [Also available at https://doi.org/10.1016/j.ecolmodel.2007.10.005.]

With, K.A., and Webb, D.R., 1993, Microclimate of ground nests—The relative importance of radiative cover and wind breaks for three grassland species: The Condor, v. 95, no. 2, p. 401–413. [Also available at https://doi.org/10.2307/1369363.]

Zimmerling, J.R., Pomeroy, A.C., d'Entremont, M.V., and Francis, C.M., 2013, Canadian estimate of bird mortality due to collisions and direct habitat loss associated with wind turbine developments: Avian Conservation and Ecology, v. 8, no. 2, article 10. [Also available at https://dx.doi.org/10.5751/ACE-00609-080210.]

Table U1. Measured values of vegetation structure and composition in Horned Lark (*Eremophila alpestris*) 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; <, less than; --, no data; DNC, dense nesting cover; spp., species]

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)
Beason, 1970	Illinois	Tame grassland, cropland	Multiple	<10	--	--	--	--	--	--	--
Bleho, 2009	Saskatchewan	Mixed-grass prairie	Ungrazed	--	7.4[a]	15.6	4.5	6.2	4.7	60.9	--
Bleho, 2009	Saskatchewan	Mixed-grass prairie	Cattle-grazed	--	4[a]	17.9	6.9	3.6	8.4	45.2	--
Bock and Webb, 1984	Arizona	Semi-desert grassland	Grazed, ungrazed	18.7[b]	--	58.5	4.7	1.1	38.8	--	--
Creighton, 1974	Colorado	Shortgrass prairie	Grazed	7.2	--	67	7	0.8	17	--	--
Dale, 1983	Saskatchewan	Mixed-grass prairie	Grazed, ungrazed	--	--	--	3.4	20.5[c]	9.8	--	0.5
Fritcher and others, 2004[d,e]	South Dakota	Mixed-grass prairie	--	26.6–45	5.8–14.5[a]	85.7–91.3	18–26.1	--	7.1–12.9	80.7–87.2	0.9–2.5
Giezentanner, 1970a	Colorado	Shortgrass prairie	Heavy summer-grazing intensity	2.5–5.1	--	--	--	--	--	--	--
Grant and others, 2004	North Dakota	Mixed-grass prairie	--	63	--	--	--	7.1	--	--	2.1
Greer, 1988[e] (territories)	Wyoming	Mixed-grass prairie	Multiple	--	--	49	8	7	37	15	--
Holmes, 2007	Oregon	Sagebrush steppe	Unburned	--	--	--	--	--	--	25.3	--
Holmes, 2007	Oregon	Sagebrush steppe	Burned	--	--	--	--	--	--	6.4	--
Kahl and others, 1985 (territories)	Missouri	Multiple	Multiple	<10	--	--	--	0	--	<25	<0.4
Kalyn Bogard, 2011	Saskatchewan	Mixed-grass prairie	Grazed	10.3	--	44.7	9.5	--	43.7	--	0.2
Kennedy and others, 2009	Oregon	Bunchgrass prairie	Grazed	--	8[a]	63	--	--	20.2	29.5	--
Lueders and others, 2006	North Dakota	Mixed-grass prairie	Cattle-grazed	--	8[a]	29.1[f]	11	0.6	24.7	25.9	1.5
Messmer, 1990	North Dakota	Mixed-grass prairie	Multiple	50–70	--	17–65	--	--	--	--	3.8–9.1
Renken, 1983[g]	North Dakota	Tame grassland (DNC)	Idle, grazed	--	5[a]	45	13	0.7	1	99	1.6

Table U1. Measured values of vegetation structure and composition in Horned Lark (*Eremophila alpestris*) 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; <, less than; --, no data; DNC, dense nesting cover; spp., species]

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)
Rodgers, 2013[g]	Alberta	Mixed-grass prairie	--	22.8[b]	--	35.8	11.1	--	2.9	--	0.2
Salo and others, 2004	North Dakota	Mixed-grass prairie	Heavy grazing intensity	27.1[b]	22.9[a]	--	--	--	--	--	2
Salo and others, 2004	North Dakota	Mixed-grass prairie	Extreme grazing intensity	17.5[b]	7.9[a]	--	--	--	--	--	0.9
Sample, 1989	Wisconsin	Multiple	--	57.3	25.5[a]	--	69.9[h]	0.4	20.5	7.8	--
Skinner, 1974	Missouri	Tallgrass prairie	Multiple	<30	--	--	--	--	--	--	--
Skinner and others, 1984	Missouri	Tallgrass prairie	Multiple	--	--	--	5–70	--	--	--	--
Sliwinski, 2011	Saskatchewan	Mixed-grass prairie	Bison- and cattle-grazed	30.8	--	29.9	4.9	--	1.4	34.3	4.7
White, 2009	Saskatchewan	Mixed-grass prairie	Burned and cattle-grazed	37.2	3.5[a]	30.7	6.1	0.7	19.5	14.9	1.6
White, 2009	Saskatchewan	Mixed-grass prairie	Burned and ungrazed	39.4	4[a]	31.4	6.8	0.5	15.4	10.4	1.1
White, 2009	Saskatchewan	Mixed-grass prairie	Unburned and cattle-grazed	41.4	3.4[a]	17.3	7.8	0.4	3.2	47.3	2.1
White, 2009	Saskatchewan	Mixed-grass prairie	Unburned and un-grazed	41.7	7.2[a]	14.8	5.1	2.1	1.6	62.8	5.1
Wiens, 1970[g] (territories)	Colorado	Shortgrass prairie	Summer-grazed	--	0.3[i]	81	0	0	18.5	19.1	0.19
Wiens, 1970[g] (territories)	Colorado	Shortgrass prairie	Winter-grazed	--	1.1[i]	79.5	2	2.5	17.5	27.2	0.33
Wiens, 1973[g]	Colorado	Shortgrass prairie	Heavy winter-grazing intensity	8[j]	0.7[i]	82	10	3	16	23	0.3

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

[b]Grass height.

[c]Dwarf shrub cover.

[d]Range of averages across seral stages within study area.

[e]The sum of the percentages is greater than 100%, based on methods described by the author(s).

[f]Grass and sedge (*Carex* spp.) combined.

[g]The sum of the percentage is greater than 100%, based on the modified point-quadrat technique of Wiens (1969).

[h]Herbaceous vegetation cover.

[i]Effective vegetation height.

[j]Emergent vegetation height.

For more information about this publication, contact:
Director, USGS Northern Prairie Wildlife Research Center
8711 37th Street Southeast
Jamestown, ND 58401
701–253–5500

For additional information, visit: https://www.usgs.gov/centers/npwrc

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