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The Effects of Management Practices on Grassland Birds—Savannah Sparrow (*Passerculus sandwichensis*)

Chapter FF of

The Effects of Management Practices on Grassland Birds

Professional Paper 1842–FF
Version 1.1, May 2023

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

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The Effects of Management Practices on Grassland Birds—Savannah Sparrow (*Passerculus sandwichensis*)

By David A. Swanson,[1,2] Jill A. Shaffer,[3] and Lawrence D. Igl[3]

Chapter FF of

The Effects of Management Practices on Grassland Birds

Edited by Douglas H. Johnson,[3] Lawrence D. Igl,[3] Jill A. Shaffer,[3] and John P. DeLong[3,4]

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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
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)
	Mass	
gram (g)	0.03527	ounce (oz)
kilogram (kg)	2.202	pound (lb)

Abbreviations

AUM	animal unit month
BBS	Breeding Bird Survey
CRP	Conservation Reserve Program
DNC	dense nesting cover
n.d.	no date
NWR	National Wildlife Refuge
PCP	Permanent Cover Program
SD	standard deviation
SNG	Sheyenne National Grasslands
spp.	species (applies to two or more species within the genus)
VOR	visual obstruction reading

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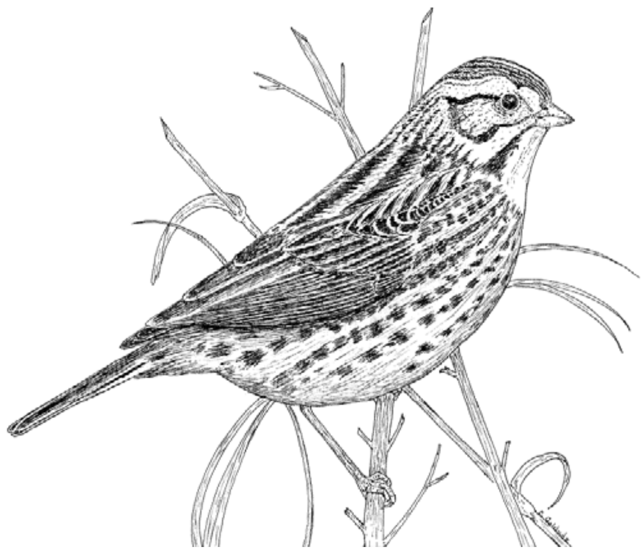
The Effects of Management Practices on Grassland Birds—Savannah Sparrow (*Passerculus sandwichensis*)

By David A. Swanson,[1,2] Jill A. Shaffer,[3] and Lawrence D. Igl[3]

Capsule Statement

Keys to Savannah Sparrow (*Passerculus sandwichensis*) management are providing extensive grasslands of intermediate height and density with a well-developed litter layer, controlling succession, and protecting nesting habitat from disturbance during the breeding season. Savannah Sparrows have been reported to use habitats with 11–190 centimeters (cm) average vegetation height, 4–50 cm visual obstruction reading (VOR), 15–66 percent grass cover, 4–45 percent forb cover, less than (<) 29 percent shrub cover, <38 percent bare ground, 10–63 percent litter cover, and less than or equal to (≤) 21 cm litter depth. The descriptions of key vegetation characteristics from the literature are provided in table FF1 (after the "References" section). Vernacular and scientific names of plants and animals follow the Integrated Taxonomic Information System (https://www.itis.gov).



Savannah Sparrow. Illustration by Christopher M. Goldade, used with permission.

Breeding Range

Savannah Sparrows breed across Alaska and most of continental Canada; south to southern California, eastern Arizona, New Mexico, and Nebraska; and east through Missouri, West Virginia, and Nova Scotia (National Geographic Society, 2011). The relative densities of Savannah Sparrows in the United States and southern Canada, based on North American Breeding Bird Survey (BBS) data (Sauer and others, 2014), are shown in figure FF1 (not all geographic places mentioned in this report are shown on figure).

Suitable Habitat

Savannah Sparrows prefer grassy habitats with short to intermediate vegetation height, intermediate vegetation density, and a well-developed litter layer. These preferred habitats cover a wide range of vegetation types, from grasslands and alpine and arctic tundra to coastal salt marshes and sedge bogs (Wheelwright and Rising, 2020). Savannah Sparrows use tallgrass, mixed-grass, and shortgrass prairies; bunchgrass prairies; dry sand prairies; oak barrens; and parkland (Rand, 1948; Dixon, 1972; Stewart, 1975; Salt and Salt, 1976; Skeel and others, 1995; Fondell and Ball, 2004; Koper and Schmiegelow, 2006; Jones and others, 2007; Bakker and Higgins, 2009; Kennedy and others, 2009; Ranellucci, 2010; Davis and others, 2013; Vos and Ribic, 2013; Igl and others, 2018). The species inhabits hayed, burned, and grazed grasslands (Graber and Graber, 1963; Harrison, 1974; Kantrud and Kologiski, 1982; Skinner and others, 1984; Dale, 1993; Corace and others, 2009; Grant and others, 2010; Davis and others, 2013, 2017). Planted cover, such as Conservation

[1]Ohio Division of Wildlife.

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[3]U.S. Geological Survey.

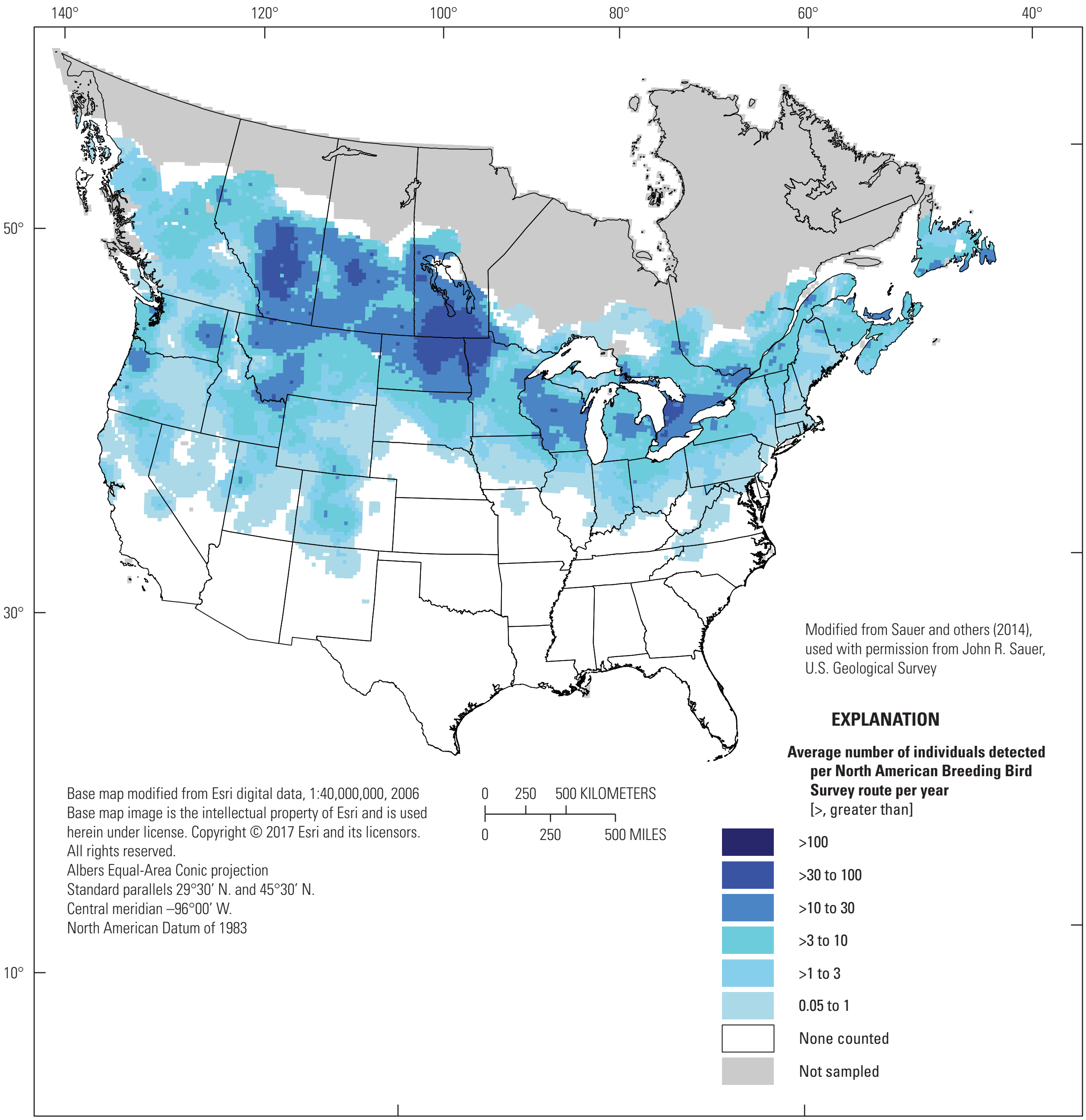

Figure FF1. The breeding distribution of the Savannah Sparrow (*Passerculus sandwichensis*) in the United States and southern Canada, based on North American Breeding Bird Survey (BBS) data, 2008–12. The BBS abundance map provides only an approximation of breeding range edges.

Reserve Program (CRP) fields, Permanent Cover Program (PCP) fields, dense nesting cover (DNC), Waterfowl Production Areas, and switchgrass (*Panicum virgatum*) fields, also provide suitable habitat (Renken, 1983; Hartley, 1994a; Johnson and Igl, 1995; Koford, 1999; Prescott and Murphy, 1999; Roth and others, 2005; Igl and others, 2008, 2018; Bakker and Higgins, 2009; Durán, 2009). Savannah Sparrows occasionally inhabit cropland, fallow fields, weedy areas, rowcrop terraces, shelterbelts, and reclaimed surface mines (Whitmore, 1979; Dale, 1993; Prescott and Murphy, 1999; Hultquist and Best, 2001; Igl and others, 2008; Ingold and others, 2010; van Vliet and others, 2020). In Alberta, Savannah Sparrows were not found in extensively cultivated land unless there was rank vegetation at the field edges (Owens and Myres, 1973). In Colorado, Savannah Sparrows used willow (*Salix* species [spp.]) shrub habitats in river flood plains (Knopf and others, 1988) and were significantly more abundant on lowland tallgrass prairie plots and tame hayland plots than on upland mixed-grass prairie plots (Bock and others, 1999).

Savannah Sparrows commonly are associated with wetlands or wetland peripheries. In Alberta mixed-grass prairies, Savannah Sparrows were attracted to wetlands; abundance increased by 25 percent within 1.08 kilometers (km) of wetland edges (Sliwinski and Koper, 2012). In Saskatchewan, Savannah Sparrows were observed in wetlands or wetland margins within all farmland types and within DNC fields (Shutler and others, 2000). In a study throughout the Prairie Pothole Region of North Dakota and South Dakota, the Savannah Sparrow was among the 10 most common species encountered on 1,190 wetlands (Igl and others, 2017). Savannah Sparrows were observed on 311 of the 1,190 wetlands, including 55 percent of the alkali wetlands, 40 percent of the permanent wetlands, 25 percent of the semipermanent wetlands, 23 percent of the seasonal wetlands, and 27 percent of the temporary wetlands (wetland classification followed Stewart and Kantrud, 1971). The 311 wetlands in which Savannah Sparrows were present were characterized as having an average of 43 percent open water, 21 percent emergent vegetation, 32 percent wet meadow, and 3 percent shore/mudflat, and an average size of 8 hectares (ha). Landscape composition within 800 meters (m) of the 311 wetlands was 61 percent grassland, 20 percent agricultural, 14 percent wetland, and 6 percent other; the average number of wetlands within 800 m of occupied wetlands was 27 (Igl and others, 2017). In the northern Great Plains, Niemuth and others (2017) determined that the occurrence of Savannah Sparrows within 800 m of survey points was positively associated with the area of emergent herbaceous wetlands (that is, areas where herbaceous vegetation accounts for greater than [>] 80 percent of vegetative cover and the soil or substrate is periodically saturated with water).

Vegetation Structure and Composition

Many studies have reported associations between abundance or occurrence of Savannah Sparrows and grass cover, vegetation height-density, and measures of litter (that is, litter cover and litter depth); however, consistent relationships between Savannah Sparrow abundance or occurrence and vegetation structure are not readily apparent, as indicated in several studies in the mixed-grass prairies in Saskatchewan. Dale (1983) reported that areas occupied by Savannah Sparrows had denser vegetation in the first 10 cm from the ground, greater forb height (average 7.4 cm), and shorter distance to nearest forb (average 16.8 cm) than unoccupied areas. Davis and Duncan (1999) reported that occurrence was positively associated with standing dead vegetation, vegetation height, sedges (*Carex* spp.), and alfalfa (*Medicago sativa*). Sutter and Brigham (1998) reported that numbers of Savannah Sparrows were positively related to litter depth; vertical vegetation density; and grass, sedge, and litter cover. Numbers of Savannah Sparrows were negatively correlated with forb density and bare ground. In fields of crested wheatgrass (*Agropyron cristatum*), numbers of Savannah Sparrows were positively correlated with grass and sedge cover, litter depth, and maximum vegetation height. Anstey and others (1995) stated that abundance was positively associated with dead vegetation 20–100 cm tall and with distance to nearest shrub. Dale (1992) determined that abundance was positively correlated with litter depth; Savannah Sparrow abundance was negatively correlated with the coefficient of variation of standing dead vegetation, indicating that the amount of residual vegetation is consistent in areas occupied by the species. Kalyn Bogard and Davis (2014) reported that Savannah Sparrow abundance was greatest in areas with tall vegetation and greater litter depth. Henderson and Davis (2014) reported that Savannah Sparrow probability of occurrence increased with litter mass (kilograms per hectare) and vegetation height-density, whereas abundance increased with litter mass and shrub cover and decreased with bare ground cover. Bleho (2009) evaluated the relationship between Savannah Sparrow abundance and vegetation structure at the plot and pasture levels, whereby plots were circular areas of 100-m radii within pastures that were grazed season-long (June to October). Two measures of vegetation patchiness (that is, heterogeneity), standard deviation (SD) and coefficient of variation, were evaluated. At the plot level, Savannah Sparrow abundance was positively associated with the SD-based measure of patchiness of vegetation height-density and negatively associated with the SD-based measure of percentage of exposed moss (no species provided) and lichen (no species provided). At the pasture level, Savannah Sparrow abundance was negatively associated with percentage shrub cover.

Within PCP grasslands in Saskatchewan, Alberta, and Manitoba, Savannah Sparrow presence was positively associated with clumped grass contacts 20–30 cm above the ground, forb contacts 10–20 cm above the ground, litter depth, ecoregion, the interaction between ecoregion and narrow-leaved grass contacts ≤10 cm above the ground, and land use (McMaster and Davis, 2001). In south-central Alberta, Savannah Sparrow abundance in cropland was positively correlated with vegetation height, vegetation contacts ≤10 cm above ground, and percentage weed cover; density was negatively correlated with percentage bare ground (Martin and Forsyth, 2003). In southern Alberta mixed-grass prairies, Savannah Sparrow distribution was positively related to litter depth, vegetation density, and vegetation height, and negatively related to percentage bare ground (Koper and Schmiegelow, 2006). In southeastern Alberta, Savannah Sparrow abundance was positively related to litter depth (Rodgers and Koper, 2017). In a 2-year study in Manitoba tallgrass prairies, Savannah Sparrow densities were higher in prairies with greater overall plant species richness in the first year and higher in prairies with a lower percentage of litter cover in the second year (Mozel, 2010). In Nova Scotia hayfields, the abundance, occurrence, and reproductive activity of Savannah Sparrows were negatively related to vegetation height-density, and occurrence and reproductive activity were negatively related to forb cover (Nocera and others, 2007).

Within grazed mixed-grass prairies in North Dakota, abundance of Savannah Sparrows was positively associated with percentage grass cover, litter depth, VOR, vegetation density, and density of low-growing shrubs (western snowberry [*Symphoricarpos occidentalis*] and silverberry [*Elaeagnus commutata*]) (Schneider, 1998). Abundance was negatively associated with the percentage cover of small clubmoss (*Selaginella densa*). In a study in grazed mixed-grass prairies in North Dakota, Savannah Sparrows were present in areas with thicker litter and lower percentage live vegetation than in unoccupied areas; occurrence was not related to maximum height of vegetation (Grant and others, 2004). In tallgrass prairies in North Dakota and Minnesota, density of Savannah Sparrows tended to be highest with intermediate levels of litter depth (Winter and others, 2005). In DNC fields in North Dakota, Savannah Sparrow abundance was positively correlated with percentage grass cover (Renken, 1983; Renken and Dinsmore, 1987). In South Dakota mixed-grass prairies, occurrence of Savannah Sparrows was positively associated with vegetation height-density, percentage litter cover, and litter depth, and negatively associated with percentage bare ground (Greer, 2009). Densities of male Savannah Sparrows were positively associated with vegetation height-density and percentage cover of litter and forbs and negatively associated with percentage cover of grass. In eastern South Dakota, Savannah Sparrow occurrence was negatively correlated with average vegetation height-density in tallgrass prairies and average effective leaf height in mixed-grass prairies (Bakker and others, 2002). In the northern Great Plains, Savannah Sparrows were most abundant in CRP fields with high percentage grass cover and low percentage legume cover (Johnson and Schwartz, 1993). In fragmented grasslands of either native or tame grasses in Minnesota, Savannah Sparrow density was negatively related to grass and woody vegetation covariates (that is, the proportion of grassland or tree cover within 100, 500, and 1,000 m of point counts) (Thompson and others, 2014). Savannah Sparrows were predicted to decrease from 0.52 to 0.47 birds per ha as grass-related covariates increased from the 10th to the 90th percentile, and to decrease from 0.70 to 0.12 birds per ha as woody vegetation covariates increased from the 10th to the 90th percentile. Savannah Sparrow density was predicted to decrease with attempts to improve grass quality by increasing litter depth, grass height, and grass extent (Thompson and others, 2014). In restored tallgrass prairies in Iowa, Savannah Sparrow density was negatively correlated with percentage total vegetation cover (Fletcher and Koford, 2002). In Wisconsin grasslands, Savannah Sparrow abundance was positively correlated with percentage herbaceous vegetation cover, maximum vegetation height, and vegetation height-density (Sample, 1989). In Illinois tallgrass prairie fragments, density was negatively related to litter depth (Buxton and Benson, 2016). In a study evaluating the relationship between bird density and nest-predator activity in urban-grassland and early successional parks near Chicago, Illinois, Savannah Sparrow densities at the local scale (2-ha plots) were more strongly linked to habitat characteristics than to mesopredator activity; Savannah Sparrow densities were reduced in dense ground cover. At the landscape (park) scale, Savannah Sparrow densities increased moderately with mesopredator activity (Thieme and others, 2015). In Ohio, abundance was negatively correlated with percentage herbaceous vegetation cover (Swanson and others, 1999). In Oregon and Nevada, Savannah Sparrow abundance was positively associated with percentage forb cover (Rotenberry and Wiens, 1980). In New York, density was negatively correlated with total percentage grass cover (Bollinger, 1988).

The relationship between Savannah Sparrow occurrence or abundance and vegetation characteristics may vary by year and locality. In mixed-grass pastures in southern Saskatchewan, Savannah Sparrow occurrence was related to different vegetation measurements in each year of a 2-year study (Davis, 2003a, 2004). In the first year, occurrence was negatively related to the density of live grass ≤10 cm above ground and 30–40 cm above ground and the percentage bare ground. In the second year, occurrence was positively related to the density of live grasses 30–40 cm above ground and negatively related to the density of standing dead vegetation 20–30 cm above ground. In native and tame grasslands in southern Saskatchewan, abundance was positively associated with taller vegetation and reduced coverage of cow dung (Davis and others, 2016). In Saskatchewan mixed-grass prairies, abundance was not related to any measured vegetation variables in the first year postburn but was positively associated with maximum vegetation height in the second year postburn (White, 2009). In mixed-grass prairies in Manitoba, Savannah Sparrow abundance was positively associated with vegetation height and percentage bare ground in 1 of 2 years and negatively associated with percentage shrub cover in both years and with litter depth and percentage forb cover in 1 of 2 years (Ranellucci, 2010).

In North Dakota and Minnesota tallgrass prairies, densities of Savannah Sparrows did not vary among years but varied greatly among three study areas, with the highest density occurring at the northern-most area and the lowest density occurring at the southern-most area (Winter and others, 2005). In Saskatchewan, vegetation associations depended on site characteristics (Sutter, 1996). Within a moderately moist native prairie site, Savannah Sparrow abundance was positively correlated with bare ground cover, maximum height, and horizontal heterogeneity and negatively correlated with grass and sedge cover. Within a more arid site with tame vegetation, abundance was positively correlated with grass and sedge cover, maximum height, and litter depth. Within a more arid site with native vegetation, abundance was positively correlated with litter depth and with litter, grass, and sedge cover, and negatively correlated with bare ground and forb density.

Native and Tame Vegetation

Savannah Sparrow use of native and tame grasslands varies by study. In a DNC study in Alberta, Savannah Sparrows were more abundant in DNC fields planted to tame grasses than in DNC fields planted to native grasses (Prescott and others, 1995). In another Alberta study, the species was equally abundant in a landscape of 99 percent native grassland and 1 percent cultivated land as in a landscape of 66 percent cultivated land, 4 percent land seeded to nonnative grasses, and 30 percent native grassland (Owens and Myres, 1973). In Saskatchewan, Savannah Sparrows were more abundant in tame pastures and hayland than in native pastures and were detected least frequently in cropland (Anstey and others, 1995). In another Saskatchewan study, however, Savannah Sparrows were observed more frequently on native pastures than on pastures seeded to pure crested wheatgrass; no difference was reported in Savannah Sparrow frequency of occurrence between native pastures and tame pastures of crested wheatgrass, smooth brome (*Bromus inermis*), and Kentucky bluegrass (*Poa pratensis*), or tame pastures of crested wheatgrass and alfalfa (Davis and Duncan, 1999). In a Saskatchewan study evaluating grassland bird abundance and reproductive success in native pastures compared to pastures and hayfields planted to alfalfa and tame grass species, Davis and others (2016) reported that Savannah Sparrow abundance was higher in hayfields and native pastures than in planted pastures; daily nest survival rate did not vary by grassland type. Davis and others (2013) reported inconsistent results in Saskatchewan and Alberta. In Saskatchewan, Savannah Sparrow abundance was similar on native and planted grasslands, whereas in Alberta, abundance was greater in planted than native grasslands. In native pastures within Alberta aspen parkland, the species preferred moderate-to-tall grass and low-to-moderate cover diversity; in tame pastures, the species preferred high herbaceous biomass (Prescott and Murphy, 1996). Within mixed-grass prairies in southeastern Alberta, Savannah Sparrow density declined by 50 percent, but the number of young that fledged increased by 25 percent, as crested wheatgrass cover increased from 0 to 60 percent (Ludlow and others, 2015). In Manitoba, abundance was positively correlated with native vegetation and negatively correlated with tame vegetation (Wilson and Belcher, 1989). In a DNC study in Manitoba, Savannah Sparrows were equally abundant in DNC fields planted to native or tame grasses and in native grasslands (Dhol and others, 1994); however, the species was more productive in DNC fields planted to native grasses than in native grasslands. In another Manitoba study, Savannah Sparrow densities were similar on tallgrass prairies and other grassland types that included native and tame grass species; densities were lower in agricultural fields (Mozel, 2010). In Iowa, agricultural lands restored to native tallgrass vegetation harbored higher densities of Savannah Sparrows than did native, unaltered tallgrass prairies (Fletcher and Koford, 2002). Koford (1999) reported that Savannah Sparrows were nearly equally abundant in Waterfowl Production Areas as in CRP grasslands in North Dakota, but the species was more abundant in Waterfowl Production Areas than in CRP grasslands in Minnesota.

Within grazed mixed-grass prairies in North Dakota, Savannah Sparrow abundance was positively associated with plant communities dominated by Kentucky bluegrass and native grasses (green needlegrass [*Nassella viridula*], needle and thread [*Hesperostipa comata*], grama [*Bouteloua* spp.], junegrass [*Koeleria macrantha*], and little bluestem [*Schizachyrium scoparium*]) and negatively associated with plant communities dominated by native grasses alone (Schneider, 1998). In another study in northern mixed-grass prairies in North Dakota, Grant and others (2004) determined that Savannah Sparrows were present in grasslands with a lower percentage cover of native grass and forb species, lower percentage cover of tame legumes, higher percentage cover of Kentucky bluegrass, and higher percentage cover of smooth brome and quackgrass (*Elymus repens*) than in unoccupied areas. Madden (1996) also reported a positive association with smooth brome and quackgrass in North Dakota mixed-grass prairies. In leafy spurge (*Euphorbia esula*)-infested tallgrass prairies in North Dakota, Savannah Sparrows were less common on high-infestation plots than on low- or medium-infestation plots (Scheiman and others, 2003). Nest success was not related to cover of leafy spurge but was positively associated with percentage forb and grass cover. Nest sites had higher percentage grass cover, lower percentage of bare ground, and thicker litter than did random sites (Scheiman and others, 2003). In eastern South Dakota and western Minnesota, Savannah Sparrow densities were highest in tallgrass prairies and fields planted to monocultures of native switchgrass than in fields planted to tame cool-season or native warm-season grass species or to monocultures of intermediate wheatgrass (*Thinopyrum intermedium*) (Bakker and Higgins, 2009). In Wisconsin, Savannah Sparrow densities were 5–10 times higher in pastures and hayfields than in CRP fields and remnant prairie patches (Ribic and others, 2009a). In Pennsylvania, Savannah Sparrow abundance was not statistically different between pastures and hayland planted to either cool- or warm-season grass species (Giuliano and Daves, 2002).

Nests and Nest Sites

Savannah Sparrows place their nests on the ground beneath clumps of grass or other low vegetation (Shields, 1935; George, 1952; Welsh, 1975; Weatherhead, 1979). Grass-dominated habitats with little forb cover are preferred (Wiens, 1969, 1973; Welsh, 1975; Knight, 1989; Vickery and others, 1992). In Alberta mixed-grass prairies, Savannah Sparrows selected nest sites with 30–40 percent denser grass, 5–20 percent more grass cover, and 9–35 percent taller grass compared to vegetation structure in available habitat (Yoo and Koper, 2017). Nests also were in areas with less bare ground, greater litter depth, and less lichen (no species provided) or moss (no species provided) than available habitat; presence of crested wheatgrass and shrub cover did not differ. Nest success was higher at nests with greater live grass cover and more bare ground (Yoo and Koper, 2017). In Saskatchewan, Savannah Sparrows nested in or near clumps of sparse western snowberry shrubs (Lein, 1968). Savannah Sparrow nest-site locations in mixed-grass pastures in Saskatchewan were positively related to the density of live grasses, forbs, and standing dead vegetation (10–20 cm and 30–60 cm above the ground) and negatively related to bare ground (Davis, 2003a). In another Saskatchewan study, Davis (2005) reported almost all of the 61 Savannah Sparrow nests near cow dung; nest-site selection was positively associated with density of dead vegetation within 30 cm of the ground, litter depth, and reduced bare ground cover. In Saskatchewan mixed-grass prairies, nest locations were positively associated with vegetation height, vegetation height-density, litter cover, and litter depth and were negatively associated with percent cover of biocrust and bare ground (Pipher, 2011). In North Dakota mixed-grass prairies, vegetation height-density and grass height were lower and vegetation was more heterogeneous at nest sites than expected based on availability (Nenneman, 2003). In the first year post-burn, Savannah Sparrows selected nest sites that had greater litter depth and more residual vegetation than was expected based on availability. Litter depth and residual vegetation were generally higher 2 and 3 years postburn, and Savannah Sparrows seemed to be less selective for these characteristics during those years. Nest sites had less Kentucky bluegrass and more native grass and shrubs than expected (Nenneman, 2003). In tallgrass prairies in North Dakota and Minnesota, nest success tended to increase with nest cover and vegetation height (Winter and others, 2005). The model that best predicted nest success indicated that nesting success tended to increase with Savannah Sparrow density. Climate had no clear effect on Savannah Sparrow density or nest success. In Montana, nest sites were characterized by well-developed litter and low cover of small clubmoss and bare ground compared to random areas (Dieni and Jones, 2003). The species frequently selected western wheatgrass (*Pascopyrum smithii*) as a nesting substrate. In tame grasslands in Montana, Savannah Sparrow nest densities were correlated with a moderate range of plot VOR; successful nests had higher VOR compared to depredated nests, and VOR and percentage forb cover were higher at nest sites than at random sites (Fondell and Ball, 2004). In Oregon, Kennedy and others (2009) reported no relationships between percentage of nonnative grass species and clutch size, number of young fledged, daily nest survival, nest concealment, or nestling size.

In Wisconsin, Wiens (1969, 1973) reported that Savannah Sparrows required shorter, dense vegetation and deeper litter for nest sites. In another Wisconsin study, Savannah Sparrows avoided habitats with tall, dense vegetation and nested primarily in managed or disturbed habitats such as pastures and hayfields (Sample, 1989). In Michigan, Savannah Sparrows nested within clumps of grass near cow dung in overgrazed pastures (George, 1952). In Maine, Savannah Sparrows nesting in areas dominated by forbs and shrubs experienced lower reproductive success than those nesting in predominantly grass cover (Vickery and others, 1992). In Quebec, vegetation height did not differ between Savannah Sparrow nest sites and random points, but successful nests were surrounded by taller vegetation than unsuccessful nests (Bedard and LaPointe, 1984a).

Woody Vegetation

The Savannah Sparrow avoids heavily wooded or shrubby areas and was classified by Grant and others (2004) to be a woodland-sensitive species. In mixed-grass pastures in Saskatchewan, Savannah Sparrow nest-site locations were farther from shrubs than were random sites (Davis, 2003a). In Saskatchewan agricultural areas, Savannah Sparrow presence was negatively related to percentage of woody vegetation and diversity of habitats around wetland margins (Shutler and others, 2000). In mixed-grass prairies in Manitoba, abundance of Savannah Sparrows was negatively associated with percentage of shrub cover (Durán, 2009). In mixed-grass prairies in northwestern North Dakota, the species reached its maximum probability of occurrence (80 percent) in open, treeless grasslands (Grant and others, 2004). Savannah Sparrow occurrence also declined with increasing cover of tall shrubs and quaking aspen (*Populus tremuloides*) at the territory scale (<100 m) (Grant and others, 2004). In another North Dakota study, Savannah Sparrows were found only on shrubless transects (Arnold and Higgins, 1986). In mixed-grass prairies in southwestern North Dakota, Savannah Sparrow densities were almost five times higher in cattle-grazed areas with low percentage (<1 percent) shrub cover than in American bison (*Bison bison*)-grazed areas with a high percentage (10 percent) of shrub cover (Lueders and others, 2006). In tallgrass prairies in Minnesota and North Dakota, Winter and others (2005) determined that the amount of woody cover within three study areas had no discernible negative effect on Savannah Sparrow density, which likely reflected that the amount of woody ground cover within the study sites was too low to have a negative effect on Savannah Sparrow density. In montane meadows in Montana and Wyoming, Savannah Sparrow occurrence was positively associated with distance to nearest tree line in 2 years, percentage of willow cover in 1 year, and percentage of woody cover in 1 year (Saveraid and others, 2001). In Wyoming sagebrush steppe, Savannah Sparrows were observed only on burned and herbicide-treated areas with fewer shrubs and more grass and forb cover than untreated areas (Kerley and Anderson, 1995). In Wisconsin, Savannah Sparrow abundance was negatively correlated with percentage of shrub cover (Sample, 1989).

Despite a general aversion to woodlands and woodland edges, male Savannah Sparrows commonly use elevated perches in grasslands for singing. Lein (1968) indicated that small trees or shrubs may be important as song perches for male Savannah Sparrows. In east-central Saskatchewan, Savannah Sparrows were associated with fallow fields that had song perches on the edges of the fallow fields (Dale, 1993). In Wisconsin, male territories sometimes included posts, fencelines, wire bales, or trees (Wiens, 1969, 1973); male Savannah Sparrows commonly used forbs as perches for songs and displays (Wiens, 1973). Although total woody cover was low (<1 percent) in habitats used by Savannah Sparrows in Wisconsin for nesting, Sample (1989) reported that the birds commonly used small trees and shrubs (<2 m tall); fence posts and wire; and tall, herbaceous stems as song perches. In West Virginia, Savannah Sparrow territories commonly included small trees, shrubs, and fence posts within the nesting territory (Shields, 1935).

Climate

Moisture levels may affect Savannah Sparrow productivity, occurrence, and abundance. In subalpine meadows of British Columbia, daily survival of Savannah Sparrow nests was lower in colder years than in warmer years; most weather-related nest failures occurred during extended periods of precipitation (Martin and others, 2017). Compared to Horned Larks (*Eremophila alpestris*), Savannah Sparrows delayed the onset of their breeding season and experienced more benign breeding-season conditions and fewer weather events during their nesting period (Martin and others, 2017). In southeastern Alberta mixed-grass prairies, however, Ludlow and others (2014) reported no effect of precipitation or temperature on nest survival. In Saskatchewan agricultural areas, presence of Savannah Sparrows was positively related to the area of water within wetlands and negatively related to water depth in late July (Shutler and others, 2000). Using BBS data for seven States that constitute the northern Great Plains, Niemuth and others (2017) reported that the occurrence of Savannah Sparrows was negatively related to long-term (30-year) precipitation and August temperature. Using 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), Niemuth and others (2008) determined that the abundance of Savannah Sparrows along 13 BBS routes in northern North Dakota was positively associated with the number of prairie potholes containing water in May of the same year and in May of the previous year. Dispersion (that is, percentage of 13 BBS routes on which the species was detected) was positively associated with the current-year wetland numbers (Niemuth and others, 2008). In another northern North Dakota study, Savannah Sparrow abundance was greatest in the year that precipitation reached its maximum, but then abundance declined as annual precipitation declined (Grant and others, 2010). In tallgrass prairies in North Dakota and Minnesota, Winter and others (2005) reported no relationship between Savannah Sparrow density or nest success and Conserved Soil Moisture (that is, an index that indicates the weighted average of precipitation during the 21 months preceding May of a particular year).

Area Requirements and Landscape Associations

Territory Size

During the breeding season, male Savannah Sparrows defend all-purpose territories that are used for nesting and foraging, although some males may spend considerable time foraging outside of their territories (Wheelwright and Rising, 2020). Females forage primarily within males' territories but also will occasionally forage in undefended feeding areas. Savannah Sparrow territories are small, ranging from 0.05 to 1.25 ha (George, 1952; Lein, 1968; Wiens, 1969; Potter, 1972; Welsh, 1975; Piehler, 1987; O'Leary and Nyberg, 2000; Wheelwright and Rising, 2020). Polygynous males typically defend larger territories than monogamous males (Wheelwright and Rising, 2020). In a Wisconsin tame pasture, interior territories were smaller than exterior territories, and occupied territories had deeper and more variable litter than unoccupied areas; the sizes of the territories varied with population size (Wiens, 1969).

Area Sensitivity

Area sensitivity (that is, a preference for larger grasslands over smaller grasslands) in Savannah Sparrows varies by region and study. In a literature review, Ribic and others (2009b) reported five studies indicating a positive effect of increasing grassland patch size on Savannah Sparrow occurrence or abundance, whereas one study exhibited a negative association and two studies had mixed results. In mixed-grass pastures in southern Saskatchewan, Davis (2003a, 2004) reported no overall indication of area sensitivity based on Savannah Sparrow abundance or occurrence, but the survival of Savannah Sparrow nests increased with increasing grassland patch size (Davis and others, 2006). In another Saskatchewan study in mixed-grass prairie pastures, Savannah Sparrow occurrence was negatively associated with grassland area (Saskatchewan Wetland Conservation Corporation, 1997). In Manitoba mixed-grass prairies, Ranellucci (2010) reported that the abundance of Savannah Sparrow increased as the proportion of open area increased. In another Manitoba study, Bruinsma (2012) reported that abundance of Savannah Sparrow was positively associated with large tallgrass prairie patches with lower edge:interior ratios than smaller patches with higher edge:interior area ratios. In a third Manitoba study, Savannah Sparrow densities were higher in large tallgrass prairies with minimal fragmentation than in fragmented prairies (Mozel, 2010). In southwestern Manitoba, Savannah Sparrow abundance was more strongly affected by grassland configuration than grassland amount; the relative abundance of Savannah Sparrows showed a strong negative response to a landscape shape index, which quantified the amount of edge for a given land-cover class relative to that of a maximally compact and simple shape (that is, a circle) of the same area (Lockhart and Koper, 2018). In Montana, Lipsey (2015) reported that Savannah Sparrows were not affected by the amount of grassland habitat at four spatial extents (0.7, 2.6, 93, and 1,492 square kilometers [km^2]). In Minnesota and North Dakota tallgrass prairies, the effect of grassland patch size on density was not consistent (Winter and others, 2006a). Among three study areas, patch size differentially affected Savannah Sparrow density, but the direction of the effect was not consistent. Patch size effects were not affected by landscape composition (that is, landscape metrics within 200-m and 1-km buffer zones surrounding the study plots), and patch size had no effect on nest success of Savannah Sparrows (Winter and others, 2006a). In South Dakota, Savannah Sparrows were area sensitive in the tallgrass prairies but not in mixed-grass prairies (Bakker and others, 2002). In South Dakota mixed-grass prairies, Berman (2007) reported that Savannah Sparrow density was not related to grassland patch size. In CRP grasslands in North Dakota, South Dakota, Minnesota, and Montana, Savannah Sparrows exhibited no overall area sensitivity (Johnson and Igl, 2001). Likewise, density was not related to patch area in Wisconsin tame pastures (Renfrew and Ribic, 2002). In another Wisconsin study, Vos and Ribic (2011) found Savannah Sparrows in large (>45 ha) grassland patches but not small (<10.5 ha) patches; relative abundance increased as patch size increased. In Illinois, Savannah Sparrows were highly sensitive to habitat fragmentation (Herkert and others, 1993). No Savannah Sparrows were found on grassland tracts smaller than 10 ha; the species was significantly more likely to be observed on large than on small grasslands and reached 50 percent occurrence at 40 ha. In another Illinois study, Buxton and Benson (2016) reported that Savannah Sparrow density was positively related to patch size. In a third Illinois study, Walk and Warner (1999) determined that Savannah Sparrows require a minimum of 75 ha of grassland habitat for nesting. In Michigan, Savannah Sparrows may occupy small (<5 ha) areas of suitable habitat (Potter, 1972). In New York hayfields, Savannah Sparrow density was positively correlated with field size (Bollinger, 1988, 1995). In hayfields of New York and Vermont, Savannah Sparrow abundance was positively correlated with area of the hayfields (Shustack and others, 2010). In Maine grassland barrens, Savannah Sparrow incidence increased with area and reached 50 percent occurrence at about 10 ha (Vickery and others, 1994).

Savannah Sparrows tend to avoid habitat edges during the breeding season. In Alberta mixed-grass prairies, Savannah Sparrow abundance increased as the distance to cropland edge increased; however, the null model (that is, relative abundance equals the intercept) for the effect of cropland edges was equally as plausible as the exponential model (Sliwinski and Koper, 2012). In mixed-grass prairie pastures in southern Saskatchewan, occurrence was negatively associated with distance to patch edge in 1 of 2 years (Davis, 2003a); Savannah Sparrow abundance was affected more by vegetation structure than by patch area, patch shape, edge:area ratio, or distance to woodland edges, although no consistent patterns emerged (Davis, 2004). In mixed-grass prairies in Manitoba, abundance of Savannah Sparrows was negatively associated with edge density (that is, total edge length between a grassland and any other habitat within a landscape divided by the total area of the grassland) (Durán, 2009). In restored grasslands in North Dakota and South Dakota, Tack and others (2017) reported that Savannah Sparrows avoided woodland edges up to 220 m (that is, the greatest distance considered). In South Dakota mixed-grass prairies, densities of male Savannah Sparrows were negatively associated with the percentage of wooded edge surrounding the grasslands (Greer, 2009). In eastern South Dakota mixed-grass and tallgrass prairies, occurrence of Savannah Sparrows was negatively associated with an increase in patch edges with trees (Bakker and others, 2002). In Colorado grasslands, Savannah Sparrows were more abundant on interior (more than 200 m from edge) plots than on edge (suburban habitat interface) plots (Bock and others, 1999). In Minnesota tallgrass prairies, Savannah Sparrow abundance was higher, and nest depredation and Brown-headed Cowbird (*Molothrus ater*) brood parasitism rates were lower, as distance to wooded edges increased; nest depredation rates were lower on large (130–486 ha) than on small (16–32 ha) grassland fragments (Johnson and Temple, 1986, 1990). In Wisconsin, most Savannah Sparrow breeding territories were in the center of grassland habitats (Wiens, 1969, 1973). In Wisconsin tame grasslands, nest density increased with distance from edges when all edge types (wooded, grass, crop, human-related structures) were combined (Renfrew and others, 2005). Nest predation did not differ between distances <50 and >50 m from edges. In Illinois, Savannah Sparrows usually nested and defended territories in field interiors rather than in the 50 m between the field interiors and the wooded boundaries (O'Leary and Nyberg, 2000). In restored tallgrass prairies in Iowa, Savannah Sparrow density was negatively correlated with the density of patch edges in the landscape (Fletcher and Koford, 2002). In New York hayfields, Savannah Sparrow density was negatively associated with the percentage of the fields that were bordered by woods (Bollinger, 1988). In New York and Vermont hayfields, Savannah Sparrow abundance was negatively correlated with the proportion of field area bordered by woods (Shustack and others, 2010).

Landscape Effects

Savannah Sparrow abundance and nest success may be affected by landscape-level factors, such as the composition of surrounding habitats. In hayfields in southern Saskatchewan, the number of Savannah Sparrow pairs was not affected by the area of croplands or wetlands within 1.6 km of study areas (McMaster and others, 1999). In Saskatchewan, Savannah Sparrow abundance increased in native grassland parcels when surrounded by native grasslands within 400 m, whereas abundance in planted grassland parcels increased when surrounded by planted grasslands (Davis and others, 2013, 2016). Savannah Sparrow abundance declined with the amount of cropland surrounding grassland parcels (Davis and others, 2016). In Manitoba, Leston and Koper (2017) reported no relationship between Savannah Sparrow occupancy in powerline rights-of-way (strips of grassland at least 30 m wide planted under power transmission lines) and the amount of grassland or urban land within 100 m. Niemuth and others (2017) investigated the relationship between Savannah Sparrow occurrence and land use within an 800-m landscape of BBS points throughout the northern Great Plains; occurrence was positively associated with percent coverage of CRP grasslands, alfalfa, pasture and hayland (native and tame), and emergent wetlands, but was negatively associated with percent coverage of forest, shrubland, open water, developed land, and topographic variation. Occurrence also was negatively related to the number of disjunct patches of grassland, wetland, and forest in the landscape, a measure of habitat fragmentation. The species exhibited a quadratic relationship with percentage coverage of cropland, indicating that the species typically was present at intermediate values of this variable (Niemuth and others, 2017). Veech (2006) used BBS data from throughout the Great Plains to characterize the landscape within a 30-km radius of populations of Savannah Sparrows that were increasing or decreasing; CRP grasslands and rangeland constituted a greater proportion of the landscape for increasing populations than for decreasing populations, whereas urban land constituted a greater proportion for decreasing populations. In South Dakota mixed-grass prairies, Savannah Sparrow occurrence and density were positively associated with the amount of grassland in the surrounding landscape up to 3,200 m (Greer, 2009; Greer and others, 2016). Probability of occurrence was <20 percent when the surrounding landscape contained <5 percent grassland habitat within 3,200 m; probability of occurrence increased to 40 percent when grassland habitat occupied >80 percent of the surrounding landscape (Greer and others, 2016). In another study within South Dakota mixed-grass prairies, Berman (2007) reported that Savannah Sparrow densities were not related to percentage of grass cover in the surrounding landscape. In eastern South Dakota tallgrass prairies, Savannah Sparrow occurrence was correlated with local-scale habitat variables rather than landscape-scale variables (Bakker and others, 2002). In Wisconsin, the density of Savannah Sparrows along transects was positively correlated with pasture and alfalfa hayland and was negatively correlated with the area of residential development and cover-type diversity within 800-m buffers around transects (Ribic and Sample, 2001). In New York and Vermont hayfields, Savannah Sparrow abundance was positively correlated with the proportion of the landscape within 500 and 2,500 m of survey stations that was not forested or developed, as well as the proportion of the landscape within 500 m that was in pasture, hayfield, fallow field, or old field (Shustack and others, 2010).

Savannah Sparrows show an aversion to woodlands and woodland edges (Grant and others, 2004; Igl and others, 2008; Niemuth and others, 2017). In Saskatchewan agricultural areas, the presence of Savannah Sparrows was negatively related to the amount of woody vegetation within a legal quarter-section (0.65 km^2) on which bird survey points were located (Shutler and others, 2000). In mixed-grass prairies in Manitoba, abundance of Savannah Sparrows was positively associated with distance to forest in the landscape at all scales measured (800–4,800 m) and with percentage forest cover from 1,600 to 4,800 m (Durán, 2009). In mixed-grass prairies within the same general area as Durán (2009), Ranellucci (2010) reported that the abundance of Savannah Sparrows was negatively associated with the proportion of trees in the landscape. In another Manitoba study, Savannah Sparrow occupancy in powerline rights-of-way decreased as the amount of woodland within 100 m of rights-of-way increased (Leston and Koper, 2017). In Minnesota tallgrass prairies and the tallgrass prairies of the Sheyenne National Grassland (SNG) in North Dakota, Savannah Sparrow density decreased with increasing percentage of woody vegetation within a study area and a 200-m buffer surrounding a study area (which was highly correlated with percentage of woody vegetation within 1 km); the magnitude of the response differed among the three study areas (Winter and others, 2006a, 2006b). Also in SNG prairies, Cunningham and Johnson (2006, 2019) reported that the occurrence of Savannah Sparrows decreased with increasing percentage of trees in the landscape. The probability of observing Savannah Sparrows on a survey transect decreased from nearly 30 percent to <10 percent as the amount of tree cover within 200 m increased from 0 to 18 percent, and occurrence was negatively associated with tree cover at the 1,200-m scale (Cunningham and Johnson, 2006). Savannah Sparrow occurrence dropped to zero above 10 percent tree cover (Cunningham and Johnson, 2019). In a third study within the SNG, parasitism rates decreased with increased tree cover within 2 km of the nest (Pietz and others, 2009). Savannah Sparrow nests were found in landscapes with 2–15 percent tree cover, and 92 percent of parasitized nests had 2–3 percent tree cover within 2 km. In mixed-grass prairies in north-central North Dakota, the percentage of woodland in the surrounding landscape was an important predictor of Savannah Sparrow occurrence; Savannah Sparrows were present in grasslands that had a lower percentage cover of woodland within 500 m than in unoccupied areas (Grant and others, 2004). The probability of occurrence declined to 50 percent at about 10 percent woodland cover within 500 m.

Brood Parasitism by Cowbirds and Other Species

The Savannah Sparrow is a common host of the Brown-headed Cowbird (Friedmann and others, 1977). Rates of cowbird brood parasitism for Savannah Sparrow are summarized in Shaffer and others (2019a). Parasitism rates varied from 0 percent in three studies (Southern and Southern, 1980; Pipher, 2011; Yoo and Koper, 2017) to 37 percent of 46 nests in a study in tallgrass prairie fragments in Minnesota (Johnson and Temple, 1990). Savannah Sparrow nests may be multiply parasitized (Knapton, 1979; Saskatchewan Wetland Conservation Corporation, 1997; Davis and Sealy, 2000; Davis, 2003b; Igl and Johnson, 2007). In Manitoba, the average number of host young that fledged from successful, unparasitized nests was significantly higher than from successful, parasitized nests; the cost of cowbird parasitism to Savannah Sparrows was 2.2 young per successful nest (Davis and Sealy, 2000). In Montana tame pastures, nest parasitism was affected more by nest density than by host density (Fondell and Ball, 2004). In Saskatchewan, distance to cowbird perches and amount of concealment cover were not significantly different between parasitized and unparasitized nests (S.K. Davis, Canadian Wildlife Service, Regina, Saskatchewan, written commun. [n.d.]). Also in Saskatchewan, clutch size, the number of host eggs hatched, the number of host eggs incubated full term that hatched, the number of host young fledged per nest, and the number of host young fledged per successful nest were lower in parasitized than unparasitized nests (Davis, 2003b). In Saskatchewan, 700–1,600 ha of grassland may be required to halve rates of brood parasitism (Saskatchewan Wetland Conservation Corporation, 1997). In North Dakota, Murphy and others (2017) did not find evidence for an effect of nest parasitism on Savannah Sparrow nest survival. The researchers also did not find a relationship between the probability of a nest being parasitized and the distance of a nest to the nearest patch of woody cover, the amount of tall woody vegetation within 100 m, or the coverage of low shrubs within 5 m of nests.

Breeding-Season Phenology and Site Fidelity

Savannah Sparrows arrive on the breeding grounds between late March and early May, and begin nesting in May (George, 1952; Baird, 1968; Lein, 1968; Maher, 1973; Harrison, 1974; Welsh, 1975; Salt and Salt, 1976; Knapton, 1979; Bedard and LaPointe, 1984b; Jones and others, 2010; Wheelwright and Rising, 2020). In North Dakota and Minnesota, Savannah Sparrows breed from mid-May through late July, with peak breeding from late May to mid-July (Stewart, 1975; Winter and others, 2004). In Montana mixed-grass prairies, Savannah Sparrows exhibited two peak breeding periods, one in late May and the second in late June (Jones and others, 2010). If the first nesting attempt fails, Savannah Sparrows will renest, and many females produce a second clutch after a successful first nest (George, 1952; Lein, 1968; Taber, 1968; Wiens, 1969; Harrison, 1974; Weatherhead, 1979; Wheelwright and Rising, 2020). In northern areas, Savannah Sparrows may be limited to a single brood during a breeding season (Maher, 1973; Weatherhead, 1979). In Saskatchewan, Savannah Sparrows departed from breeding territories in early August, but remained in the area, foraging in weedy fields, along road edges, and along the margins of lakes and sloughs (Lein, 1968). Fall migration extends from mid-September to October (George, 1952; Maher, 1973; Knapton, 1979).

Male and female Savannah Sparrows may be philopatric (Bedard and LaPointe, 1984b; Wheelwright and Rising, 2020). Of 83,892 Savannah Sparrows banded in North America, 546 were recovered, and 91 percent of those recoveries were found within about 20 km of where the birds had been banded (Wheelwright and Rising, 2020). In Michigan, a banded adult was recaptured 6 years later at the site where it had been banded (Klimkiewicz and Futcher, 1987). On reclaimed surface mines in Ohio, the return rate was 29 percent of 138 banded individuals (Ingold and others, 2010). Of 27 individuals, 44 percent were observed during multiple years, and two individuals were observed in four consecutive years. Return rates of Savannah Sparrows banded during a 7-year period in mixed-grass prairies of north-central Montana were 5.4 percent of 37 adult males and 1.6 percent of 193 1-year-old birds that were banded as nestlings (Jones and others, 2007). Of 169 Savannah Sparrows banded in Minnesota, 10 males and 6 females returned the year following banding; both male and female members of four pairs returned (M. Winter, WissenLeben e.V., Raisting, Germany, written commun. [n.d.]). In Vermont and New York, Fajardo and others (2009) banded 883 nestling and 553 adult Savannah Sparrows during a 5-year period. Site fidelity was high for returning Savannah Sparrows, with about 30 percent of the 36 detected natal dispersers and 80 percent of the 226 detected adults returning to the same field in subsequent years. Savannah Sparrow dispersal averaged 913 m for the 36 1-year-old birds and 113 m for 226 adults. Adult Savannah Sparrows were more likely than expected to make an unfavorable decision related to management practices, with 53 percent of the 226 detected adults moving to or remaining in low-quality habitats (Fajardo and others, 2009).

Species' Response to Management

Fire

Savannah Sparrow response to burning of grasslands is highly variable. Prescribed fire may improve, worsen, or have no effect on habitat suitability for Savannah Sparrows. In

Saskatchewan mixed-grass prairies, White (2009), Richardson (2012), and Richardson and others (2014) reported no effects of fire and grazing treatments on Savannah Sparrow abundance. In a native grassland in Saskatchewan, fire reduced Savannah Sparrow abundance for 3 years postburn (Pylypec, 1991). In east-central North Dakota mixed-grass prairies, Savannah Sparrows reached their highest densities 1–5 years postburn (Johnson, 1997). Within mixed-grass prairies in Lostwood National Wildlife Refuge (NWR) in northwestern North Dakota, density peaked between 6 and 8 years postburn, but the species exhibited no significant response to fire (Madden and others, 1999). Within J. Clark Salyer NWR in north-central North Dakota, Grant and others (2010, 2011) reported that the abundance (that is, the number of indicated pairs) of Savannah Sparrows increased about 0.5 pair per plot during the second growing season postfire and stabilized or slightly increased 2–3 years postfire. Savannah Sparrow abundance was positively associated with increasing standing dead vegetation, which increased by 39 percent during the second growing season after fire, suggesting that Savannah Sparrows responded to changes in vegetation structure induced by fire (Grant and others, 2010). At Des Lacs NWR in northwestern North Dakota, Murphy and others (2017) reported that Savannah Sparrow nest survival was not related to number of breeding seasons postfire (that is, 2, 3, or 4–5 seasons), or to proximity of nests to woody vegetation.

In Minnesota, Savannah Sparrow abundance was significantly correlated with litter cover and litter depth, and the species may require >2 years of litter accumulation postburn before using burned grasslands for nesting (Tester and Marshall, 1961). In western Minnesota and northwestern Iowa, Savannah Sparrow abundance was highest on remnant and reconstructed tallgrass prairies that were burned 2 or more years before the survey year (Ahlering and others, 2019). In Minnesota, Wisconsin, and South Dakota, higher densities of nesting Savannah Sparrows were in unburned (for longer than 12 months) than burned grasslands (Tester and Marshall, 1961; Martin, 1967; Halvorsen and Anderson, 1983; Huber and Steuter, 1984). In east-central Wisconsin, however, highest densities were in recently burned restored tallgrass prairies (Volkert, 1992). Halvorsen and Anderson (1983) attributed the difference in nesting densities between burned and unburned areas in central Wisconsin to the lack of litter in burned areas. In Illinois, Savannah Sparrows preferred recently burned grasslands for nesting (Herkert, 1994a, 1994b). Savannah Sparrow densities were highest in grasslands the first growing season postburn, were lower on grasslands in the second growing season postburn, and were not encountered beyond three growing seasons postburn.

Haying

Savannah Sparrows may use tame or native hayland provided that the disturbed (hayed) vegetation has time to grow before or during the breeding season. In Alberta, nesting densities of Savannah Sparrows were highest in undisturbed (more than three growing seasons since last mowing) grasslands, but Savannah Sparrows also nested in grasslands that had been mowed the previous summer (Owens and Myres, 1973). In another Alberta study, the species preferred haylands in which the field was mowed once after July 15 the previous summer to haylands managed with a conventional cutting regime (that is, mowed before July 15 of the current summer) (Prescott and others, 1995). In Saskatchewan, Savannah Sparrows were more abundant in tame haylands idled for longer than 3 years than in annually hayed, tame vegetation or in idle native prairies (Dale, 1992; Dale and others, 1997). In Manitoba, Savannah Sparrows were most abundant and most productive (as measured with a reproductive behavior index) in haylands compared to native grasslands and tame grasslands (Jones, 1994). In another Manitoba study, Savannah Sparrows were more abundant in hayfields than idle fields or grazed pastures (Durán, 2009). In a third Manitoba study, Savannah Sparrows exhibited a year-dependent, nonlinear response to management; the species reached its highest densities 4–5 years after haying (native mixed-grass prairie and tame grasslands) or burning (native mixed-grass prairie) (Davis and others, 2017). In a 3-year study evaluating grassland bird response to management of transmission-line rights-of-way in Manitoba, Leston and Koper (2017) determined that Savannah Sparrow densities were not affected by vegetation management during the first 2 years, but in the third year, densities increased along rights-of-way that were mowed more frequently and within hayed rights-of-way relative to unhayed rights-of-way; management treatments included mowing and herbicide spraying once or twice per year without haying, mowing and haying once per year, or tree removal with no mowing (Leston and Koper, 2017). In Alberta, Manitoba, and Saskatchewan, frequency of Savannah Sparrow occurrence was higher in hayed than in grazed PCP areas (McMaster and Davis, 2001). In North Dakota, Savannah Sparrows were significantly more abundant in the year after mowing in mowed portions of CRP fields compared to idled portions (Horn and Koford, 2000). Igl (2009) assessed the effects of emergency and managed haying on grassland breeding birds in 483 CRP grasslands in nine counties in four States in the northern Great Plains between 1993 and 2008. Savannah Sparrow densities in CRP grasslands that had been idled for more than 5 years did not differ from densities in CRP grasslands that had been hayed 1 to 4 years earlier. In switchgrass CRP fields in Wisconsin, Savannah Sparrows were only found in fields harvested the previous August and not in unharvested fields (Roth and others, 2005). In Michigan, Savannah Sparrow abundance was reduced after hayfields were mowed, and mowing exposed nests and young to predators (George, 1952). In another Michigan study, Savannah Sparrows continued breeding following mowing operations in late June but stopped breeding after a second mowing operation in early August (Harrison, 1974). On seven rural Illinois airports, mowing destroyed 44 percent of 188 grassland bird nests (multiple species included), and only 23 percent of 21 Savannah Sparrow nests were successful (Kershner and Bollinger, 1996). Also in Illinois, Savannah Sparrow abundance was highest in recently (within 4 months of May 1) mowed grasslands, which provided the low-to-medium vegetation height preferred by this species (Herkert, 1991a). In Ohio reclaimed coal-mine grasslands, Savannah Sparrows were as common, and return rates of marked individuals were similar, on spring-mowed (mowed in April) areas as in unmowed areas (Ingold, 2002; Ingold and others, 2010).

In the Champlain Valley of New York and Vermont, Perlut and others (2006, 2008a, 2008b) compared Savannah Sparrow density, nest success, reproductive success (number of female fledglings per adult female), and adult apparent survival and recruitment among early hayed fields (hayed between May 27 and June 11 and again in early to mid-July), middle-hayed fields (hayed between June 21 and July 10), late-hayed fields (hayed after August 1), and grazed fields. Densities were similar among grazed and hayed fields, whereas reproductive success was greatest on middle-hayed fields, followed by late-hayed fields (Perlut and others, 2006, 2008b). Early hayed and grazed fields acted as population sinks because nest and reproductive success were low. Savannah Sparrows using late-hayed fields had >25 percent higher apparent survival than those on the more intensively managed early and middle-hayed fields and grazed fields (Perlut and others, 2008a). High adult survival resulted in stable or near-stable populations in late-hayed and grazed fields. Late-hayed fields provided high-quality habitat in which Savannah Sparrows produced more offspring, adults survived longer, and the species had higher field-level philopatry than individuals from low-quality habitats. First-time breeders and emigrants settled more frequently in the low- and moderate-quality fields (that is, the early and middle-hayed fields and the grazed fields) (Perlut and others, 2008a).

Perlut and others (2008b) further examined the effectiveness of six management strategies to increase the viability of Savannah Sparrow populations. Those six strategies were modeling how changes in adult and juvenile survival on the nonbreeding grounds increased survivorship for all birds; increasing the total amount of high-quality habitats (that is, middle- and late-hayed fields), such as by converting corn (*Zea mays*) to grassland; decreasing amount of high-quality habitats by increasing low-quality habitats (that is, early hayed fields and grazed fields); changing parameters for early hayed fields to those of grazed fields; changing parameters for early hayed fields to those of middle-hayed fields; and increasing the attractiveness of late-hayed fields by decreasing the amount of thatch. The strongest positive response to the management changes followed the conversion of the early hayed fields to middle-hayed or grazed fields; survivorship increased. Substituting middle-hayed fields for early hayed fields resulted in population growth of 124 percent over 10 years, compared to baseline declines; increasing the attractiveness of late-hayed fields also increased Savannah Sparrow population growth. Increasing high-quality habitats by 5–25 percent marginally slowed population declines; increasing low-quality habitats by 5–25 percent marginally increased population declines. Based on these scenarios, Perlut and others (2008b) concluded that current land-management practices in the Champlain Valley will possibly maintain current Savannah Sparrow populations or result in a slight decline.

In another study in New York's Champlain Valley, Zalik and Strong (2008) reported that haying reduced total invertebrate biomass by 28–82 percent compared to unhayed fields. The reduction in invertebrate biomass caused decreased chick provisioning by adult Savannah Sparrows in hayed fields, but the reduction was insufficient to induce food limitation. Savannah Sparrows possibly compensated for lower invertebrate biomass by increasing total time spent foraging. Average clutch size of first and second nests, average size of second broods, and average nestling mass did not differ between cut and uncut fields. Number of young fledged per successful nest was lower on cut fields than on uncut fields for second nests but not for first nests (Zalik and Strong, 2008).

Shustack and others (2010) examined occupancy patterns in Champlain Valley hayfields during a series of three visits. Savannah Sparrows remained in fields after cutting and colonized newly cut fields and fields exhibiting regrowth. During three visits, field characteristics and landscape features at 500 m affected the distribution of Savannah Sparrows. The amount of available habitat and the openness of the landscape most affected Savannah Sparrow distribution on the first visit, whereas field characteristics affected Savannah Sparrow distribution on the second and third visits. In Nova Scotia hayfields, Nocera and others (2007) recommended that an optimal harvest window for Savannah Sparrows would be early July to late August. Delaying the first harvest allows for fledging of young from the first nests, whereas cutting after August maintains suitable habitat for Savannah Sparrows in the following year. Delaying the first cutting until July 1 translated to a decrease in crude protein, the measure of nutritional quality of hay, by 2.1 percent, but an increase in fledging success from 0 to 56 percent for Savannah Sparrows (Nocera and others, 2005). Postponing cutting to July 7 allowed for peak fledging rates to be obtained, but crude protein levels were reduced by 3.5 percent. A reduction in crude protein level of 2.1 percent would maintain the energy maintenance levels necessary for nonlactating beef cows; a reduction of 3.5 percent would require mineral supplementation (Nocera and others, 2005).

Grazing

Grazing may affect Savannah Sparrow abundance and productivity. Several studies in the Great Plains reported higher densities of Savannah Sparrows on idle or lightly grazed grasslands compared to heavily grazed areas (Rand, 1948; Owens and Myres, 1973; Maher, 1974, 1979; Kantrud, 1981; Kantrud and Kologiski, 1982; Anstey and others, 1995; Salo and others, 2004; Pipher, 2011). In Canadian shortgrass and mixed-grass prairies, moderately and heavily grazed areas did not provide the dense ground cover required by nesting

Savannah Sparrows (Dale, 1983). In Saskatchewan, Savannah Sparrows foraged most frequently in grazed grasslands, but the number of nesting pairs was consistently lower in grazed than ungrazed areas (Dale, 1984). Also in Saskatchewan, Savannah Sparrows were common in lightly grazed mixed-grass prairies and lightly grazed crested wheatgrass pastures (Sutter and Brigham, 1998). In tame grasslands in Montana, nesting densities were higher on grazed than ungrazed grasslands; however, nest success was lower on the grazed grasslands because of higher nest parasitism and trampling by cattle (Fondell and Ball, 2004). In a study in mixed-grass prairies in Montana, where stocking rates were experimentally manipulated, Savannah Sparrows were infrequently observed, preferred denser than average cover, and were not affected by grazing utilization (defined as the proportion of dry biomass removed by grazing animals over the course of the growing season) (Lipsey, 2015; Lipsey and Naugle, 2017). In south-central North Dakota, Savannah Sparrow density was highest in a field in its first year of rest after grazing, followed by DNC, grazed prairies, and idle fields (Renken, 1983). In mixed-grass prairies in eastern South Dakota, Greer (2009) reported that Savannah Sparrows selected grasslands that were idle or lightly grazed. In Idaho, Savannah Sparrows used grazed and ungrazed riparian habitats, but the species was more abundant in ungrazed areas (Medin and Clary, 1990). In tallgrass prairies in Minnesota, eastern North Dakota, and eastern South Dakota, Savannah Sparrow densities were higher in prairies that were grazed, burned, or burned and grazed than in tallgrass prairies that were rested for more than 5 years (Igl and others, 2018). Igl and others (2018) reported a linear decrease in Savannah Sparrow densities in the growing seasons after grazing. In western Minnesota and northwestern Iowa, Savannah Sparrow abundance was highest on remnant and reconstructed tallgrass prairies that were grazed in the survey year and the previous 2 years (Ahlering and others, 2019).

Grazing Intensity

Grazing intensity, grazing system, and livestock type may influence Savannah Sparrow nesting success or abundance. In a meta-analysis of grazing studies in the prairie Provinces of Canada, Bleho and others (2014) reported that the rate of cattle-induced nest destruction or abandonment for Savannah Sparrows was similar among grazing intensities (that is, <33 percent of available forage used [light], 33–65 percent used [moderate], and >65 percent used [heavy]). Nest destruction increased with stocking rates but remained constant with grazing intensities. Bleho and others (2014) considered nest destruction by livestock to be too low to have a strong effect on nest survival or avian productivity. Nest survival and probability of nests not being depredated were higher in moderately grazed pastures than in ungrazed pastures. In a series of phased studies conducted in the mixed-grass prairies of Grasslands National Park in southwestern Saskatchewan, the effects of cattle grazing on nest success and abundance were examined (Bleho, 2009; Molloy, 2014; Sliwinski and Koper; 2015; Pipher and others, 2016; Fischer and others, 2020). Avian nest success, avian abundance, or vegetation were measured for 2 years before the reintroduction of cattle, for the 4 years after cattle were grazed at stocking rates varying from very low (0.25 animal unit month [AUM] per ha) to very high (0.83 AUM per ha), and for 3 years after cattle were removed from pastures. Pasture units contained upland and lowland areas; upland areas were dominated by perennial graminoids, and lowland areas had more shrubs and taller forbs than upland areas. Molloy (2014), Sliwinski and Koper (2015), Pipher and others (2016), and Fischer and others (2020) also included ungrazed control pastures to implement a before-after control-impact evaluation. Bleho (2009), Molloy (2014), and Pipher and others (2016) included additional light-to-moderate grazed (0.25–0.55 AUM per ha) pastures in the Mankato Community Pastures adjacent to the Grasslands National Park. Pipher (2011) and Pipher and others (2016) determined that neither grazing intensity nor the number of years that a site had been grazed influenced nest success in 1 of the 2 years studied; sample sizes were too low for analysis in the second year. Bleho (2009) determined that Savannah Sparrow abundance was not significantly different between grazed and ungrazed pastures, between upland and lowland portions of pastures, or between ungrazed and grazed lowland portions of pastures, but abundance was 2.67 times higher in ungrazed lowland pastures than in grazed lowland pastures. In upland pastures, Molloy (2014) reported that Savannah Sparrow abundance began to decline at stocking rates between 0.2 and 0.5 AUM per ha; in lowland pastures, Savannah Sparrow abundance began to decline at stocking rates between 0.2 and 0.4 AUM per ha. Sliwinski and Koper (2015) reported that Savannah Sparrow abundance was unaffected by stocking rates within the first month that cattle were reintroduced to pastures after an absence of 16 to 21 years but declined after the first and second year of grazing above 0.4 AUM per ha, by one and two birds per pasture, respectively. Fischer and others (2020) reported that Savannah Sparrow abundance on upland pastures decreased as stocking rates increased, and abundance returned to pregrazing levels following a single year of rest. On lowland sites, the abundance of Savannah Sparrow decreased as stocking rates increased, and abundance required 2 years of rest to recover.

In other research conducted on the effects of grazing intensity, Salo and others (2004) examined Savannah Sparrow densities in mixed-grass prairies in south-central North Dakota; they determined that densities were highest in lightly and moderately grazed pastures (defined as 1.1 AUMs per ha and 65 percent of forage produced in an average year remaining and 2.4 AUMs per ha and 50 percent forage remaining, respectively), very low in heavily (4.2 AUMs per ha; 35 percent forage remaining) grazed pastures, and absent from extremely (6.8 AUMs per ha; 20 percent forage remaining) grazed pastures. In Oregon bunchgrass prairies, Johnson and others (2012) reported no evidence that cattle stocking rates (varying from 0 to 43.2 AUMs) affected daily nest survival for Savannah Sparrows. Stocking rates did not impact nest density; however, Savannah Sparrow density was negatively related to higher stocking rates, but only after grazing had ceased (Johnson and others, 2011).

Grazing Systems

In the Prairie Provinces of Canada, Bleho and others (2014) concluded that the rate of cattle-induced nest destruction and abandonment for Savannah Sparrows remained constant for season-long (May–September) and rotational (that is, rest rotation and deferred) grazing systems. In Alberta, Savannah Sparrow occurrence did not differ among four grazing treatments: early season tame (grazed from late April to mid-June), early season native (grazed in early summer), deferred-grazed native (grazed after July 15), and continuously grazed native (Prescott and Wagner, 1996). In another Alberta study, however, densities of Savannah Sparrows were higher in deferred-grazed tame pastures than in deferred-grazed mixed-grass or continuously grazed mixed-grass prairies (Prescott and others, 1995). In a Manitoba study of mixed-grass prairies in which the effects of twice-over rotational grazing (grazing twice per season, with about a 2-month rest in between grazing), season-long grazing (continuously grazed), and idling were examined, abundance of Savannah Sparrows was higher in twice-over rotationally grazed pastures than in idle grasslands during the 2-year study and was higher in twice-over rotationally grazed than season-long grazed pastures in 1 year (Ranellucci, 2010; Ranellucci and others, 2012).

In mixed-grass prairies in south-central North Dakota, Savannah Sparrow densities did not differ among twice-over rotationally grazed, season-long, or short-duration (pastures rotated through a grazing schedule of about 1 week grazed and 1 month ungrazed) grazing treatments (Messmer, 1990). In mixed-grass prairies in northwestern North Dakota, frequency of occurrence of singing male Savannah Sparrows was similar in plots that were prescribe-burned only and plots that were burned and then rotationally grazed 1–2 years later (each of three cells per plot were grazed for 14 days from late May through mid-August; two of three cells were grazed for a second 14-day period after a 28-day rest); in all treatments and years, Savannah Sparrows were detected at >80 percent of sample plots (Danley and others, 2004). In another study in northwestern North Dakota mixed-grass prairies, cattle were grazed at 0.20–0.28 AUM per ha on a 2-week rotation; grazing negatively affected nesting success of Savannah Sparrows (Kerns and others, 2010). In southwestern Wisconsin, Savannah Sparrows were significantly more territorial in ungrazed grasslands than in rotationally or continuously grazed pastures (Temple and others, 1999). Nesting success was highest on ungrazed grasslands (not mowed or grazed from May 15 to July 1), intermediate on continuously grazed grasslands (grazed throughout the summer at levels of 2.5–4 animals per ha), and lowest on rotationally grazed grasslands (40–60 animals per ha were grazed for 1–2 days and then left undisturbed for 10–15 days before being grazed again). Ungrazed grasslands and rotationally grazed pastures produced more young than continuously grazed pastures. In another southwestern Wisconsin study, Savannah Sparrows were equally abundant in lightly grazed fields that bordered riparian areas under continuous grazing and rotational grazing regimes (neither regime was defined in the study) (Renfrew and Ribic, 2001). Higher densities of Brown-headed Cowbirds were observed in summer-grazed pastures compared to winter-grazed pastures in Colorado; Knopf and others (1988) cautioned that summer grazing could reduce reproductive success of Savannah Sparrows. In New York, Savannah Sparrow abundance was higher on holistic resource management pastures than on minimally rotated or continuously grazed pastures (Cassidy and Kleppel, 2017). Holistic resource management was defined as a comprehensive, adaptive-management framework used by farmers to make decisions that promote ecosystem health by mimicking the behavior of wild grazers with high stocking densities, frequent (<1–3 day) rotations, and long periods (up to 60 days) of rest. Minimal rotation was defined as infrequent pasture rotation with little attention to stock density, in which only vegetation height was used to determine when the livestock were moved. Continuous grazing was defined as grazing without rest at relatively low stocking densities for the entire study, which resulted in the highest number of animal days on pastures (Cassidy and Kleppel, 2017).

Livestock Type

In Saskatchewan pastures, Sliwinski (2011) examined the effects of American bison and cattle grazing on Savannah Sparrow abundance and reported that abundance decreased as American bison grazing intensity increased. Savannah Sparrow abundance slightly increased with moderate cattle stocking rates and then began to decline at 0.4 AUM per ha, declining by about 0.5 bird per plot as cattle grazing intensity increased. In North Dakota mixed-grass prairies, density of Savannah Sparrows was higher on cattle-grazed plots than on bison-grazed plots managed with fire (Lueders and others, 2006). In that same study, Savannah Sparrow density did not change with distance from cattle water developments despite increases in vegetation height-density and litter depth and decreases in cow dung cover and vegetation structural variability associated with reduced grazing pressure (Fontaine and others, 2004). In Alberta, Yoo and Koper (2017) reported that nest success was not affected by distance to sources of water for cattle, but clutch sizes were higher farther from water sources.

Cropland

Although Savannah Sparrows occasionally nest in cropland, the species typically is more abundant in native prairies, DNC grasslands, and CRP grasslands (Hartley, 1994b; Johnson and Igl, 1995; Patterson and Best, 1996; McMaster and Davis, 2001; Igl and others, 2008). In east-central Saskatchewan, Savannah Sparrows were as common in fallow cropland as in two kinds of planted cover, that of DNC and short grass (red fescue [*Festuca rubra*] and Kentucky bluegrass) cover types (Dale, 1993). Hartley (1994b), however, reported that Savannah Sparrows in east-central Saskatchewan were more common in DNC fields and native grasslands than in wheat (*Triticum* spp.) fields. In southwestern Ontario, daily survival of Savannah Sparrow nests was lower on agricultural study sites (that is, monocultures of corn, soybeans [*Glycine max*], or winter wheat) than on nonagricultural study sites (that is, open areas with grasses and herbaceous plants) (van Vliet and others, 2020).

In Alberta, Savannah Sparrows preferred minimum-tilled cropland fields (planted directly into the previous year's stubble) to conventional-tilled cropland fields (multiple cultivations before planting) in 1 of 2 years, and their response to tilling practices varied by crop type (Martin and Forsyth, 2003). In spring cereal plots, Savannah Sparrows were denser and more productive in minimum-tilled than in conventional-tilled fields. In winter wheat plots, Savannah Sparrows occupied more territories and more productive territories in minimum-tilled than in conventional-tilled fields in 1 of 2 years. The species was most abundant in winter wheat fields. Martin and Forsyth (2003) reported no differences in territory number or productivity between minimum-tilled and conventional-tilled summer fallow fields. In Saskatchewan, Savannah Sparrows were more abundant in DNC fields than in cropland on organic, conventional-tilled, or minimum-tilled farmland (Shutler and others, 2000). In North Dakota, very few Savannah Sparrows were found nesting in any type of cropland (conventional-tilled, minimum-tilled, and organic fields in fallow, sunflowers, or wheat) (Lokemoen and Beiser, 1997). Minimum-tilled and organic fields had more vegetation and attracted greater numbers and species of birds, but predation and mechanical activities resulted in low reproductive success. In Iowa, Savannah Sparrows nested in no-tillage corn fields with sod residue (Basore and others, 1986). In another Iowa study, Savannah Sparrows were present in low numbers, and no nests were detected, in strip-intercropped fields (that is, planting rowcrops, legumes, and small grains in a series of adjacent, narrow strips) (Stallman and Best, 1996).

Pesticides

Some pesticides may have deleterious effects on Savannah Sparrows. In Wyoming, mortality of Savannah Sparrows 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). Fenthion is a cholinesterase inhibitor, and activity of brain cholinesterase was lower for 5 days after spraying in Savannah Sparrows collected from treated areas than in Savannah Sparrows from control areas. In Ontario corn fields, the average number of Savannah Sparrows 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 Maine, territory density of Savannah Sparrows decreased for 2–6 years following the application of the herbicide hexazinone at a rate of 4 kilograms per ha on lowbush blueberries (*Vaccinium* spp.) (Vickery, 1993).

Urban Development

Savannah Sparrows seem to be fairly tolerant to urbanization, although tolerance may vary with infrastructure type (Bernath-Plaisted and Koper, 2016; Warrington and others, 2018). In Colorado, the maximum abundance of Savannah Sparrows was only at the lowest levels (<7 percent) of an urban index, which was measured by summing the percentage of urban vegetation and the percentage of buildings and paved area in the open space surrounding the city of Boulder (Haire and others, 2000). Within patches of tallgrass prairies of various sizes in Illinois, however, Savannah Sparrow density increased with amount of urban development (Buxton and Benson, 2016).

Roads

Several studies have examined the impact of roads on Savannah Sparrows in southeastern Alberta (Linnen, 2008; Ludlow and others, 2015; Bernath-Plaisted and Koper, 2016; Bernath-Plaisted and others, 2017; Yoo and Koper, 2017; Daniel and Koper, 2019). The response of Savannah Sparrows to roads and trails was not consistent among studies. Linnen (2008) reported that Savannah Sparrows in Alberta were observed more frequently within 50 m of oil-well access roads than at farther distances, whereas in Saskatchewan, the species tended to avoid trails associated with wells, although neither relationship was statistically significant. Ludlow and others (2015) determined that distance to gravel roads or trails associated with oil and gas development did not affect the density or reproductive success of Savannah Sparrows. Bernath-Plaisted and Koper (2016) examined the effect on nesting success of gravel- or dirt-packed roads associated with oil and gas development and reported no relationship between nesting success and roads. During that same study, however, Bernath-Plaisted and others (2017) reported that the densities of Brown-headed Cowbirds and brood parasitism rates of Savannah Sparrow nests increased with proximity to roads. Yoo and Koper (2017) reported that nest success increased farther from roads and trails. Daniel and Koper (2019) reported that Savannah Sparrow abundance declined up to 1,120 m from roads, but clutch sizes were higher adjacent to roads. In addition to the above studies in Alberta, several researchers have examined the impact of roads on Savannah Sparrow abundance in Saskatchewan and North Dakota. In lightly to moderately grazed native prairies in Saskatchewan, abundance of Savannah Sparrows was significantly higher 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) than along trails (that is, single pair of wheel ruts in which the vegetation is visually indistinct from surrounding habitat in terms of plant structure and composition) (Sutter and others, 2000). In another Saskatchewan study, Kalyn Bogard (2011) reported similar results, with Savannah Sparrow abundance increasing in areas with more roads and crested wheatgrass but decreasing in areas with more trails. In northwestern North Dakota, Savannah Sparrow density was not reduced within 150 m of roads associated with unconventional oil extraction sites (that is, hydraulic fracturing and horizontal drilling) (Thompson and others, 2015).

Energy Development

Several studies in southeastern Alberta have examined the impact of oil and gas extraction on Savannah Sparrow abundance, distribution, productivity, and vocalizations (Linnen, 2008; Dale and others, 2009; Hamilton and others, 2011; Rodgers, 2013; Ludlow and others, 2015; Bernath-Plaisted and Koper, 2016; Curry and others, 2017; Rodgers and Koper, 2017; Yoo and Koper, 2017; Antze and Koper, 2018, 2019; Warrington and others, 2018; Daniel and Koper, 2019). Savannah Sparrows exhibited responses varying from no response to a weak negative response, to a strongly negative response to energy infrastructure. Hamilton and others (2011) reported that Savannah Sparrows were significantly more abundant in areas with high densities of natural gas wells (6.2 wells per km^2) than areas with low well densities (3.5 wells per km^2). Ludlow and others (2015) reported that Savannah Sparrow density was twice as high within 600 m of oil and gas wells than beyond 600 m, and fledging success was 40 percent higher compared with nests located 700 m away. Dale and others (2009) suggested that an increase in natural gas wells from 4 wells to 16 wells per 2.59 km^2 would increase Savannah Sparrow abundance by 249 percent. Rodgers (2013) and Rodgers and Koper (2017) reported similar results as Linnen (2008), with Savannah Sparrow abundances having a weak negative association with increasing density of natural gas wells. Yoo and Koper (2017) reported that nest success was not affected by distance to gas-well structures, and this effect did not vary with the age of the well; nest success also was independent of well density. Clutch size increased as distance to gas wells increased, and clutch sizes were greater by one egg near new (<15 years old) wells compared to wells of intermediate (15–30 years old) age. Clutch sizes were independent of well density, and a slight nonlinear effect of well age was detected (Yoo and Koper, 2017). Bernath-Plaisted and Koper (2016) examined the effect on nest success of several types of oil and gas infrastructure (that is, pumpjacks, screwpumps, and compressors), the level of activity (that is, active or inactive), the power source (that is, grid-powered or generator-powered), and noise intensity. Savannah Sparrow nest success was 15 percent lower at infrastructure sites than at control sites, although nest success did not differ between active and inactive sites. Nest success was 17 percent lower at screwpump sites than at control sites, whereas no significant reduction in nest success was detected between pumpjack or compressor stations and controls, and nest density was unaffected by proximity to infrastructure. Nest success was 28 percent lower at grid-powered sites than at generator-powered sites; noise intensity did not affect nest success (Bernath-Plaisted and Koper, 2016). Bernath-Plaisted and others (2017) measured relative abundance of Brown-headed Cowbirds and brood parasitism rates of Savannah Sparrow nests in relation to the presence of oil and natural gas infrastructure features and proximity to potential perches and edge habitat; the presence of oil and natural gas infrastructure increased Brown-headed Cowbird relative abundance by a magnitude of four times, which resulted in four times greater brood parasitism rates of Savannah Sparrow nests at infrastructure sites. Daniel and Koper (2019) compared the cumulative effects of energy-related infrastructure (oil wells, shallow gas wells, and roads) on habitat use and productivity. Savannah Sparrow productivity increased above 1,190 m from oil wells. Clutch sizes were higher adjacent to oil wells and shallow gas wells, but clutch sizes declined above 15 gas wells per legal section. Nesting success was lowest next to oil wells but declined with increasing distance to shallow gas wells; this effect extended to 2,167 m from gas wells (Daniel and Koper, 2019).

Curry and others (2017) examined the effects of noise from energy infrastructure on Savannah Sparrow song and syllable variability; male Savannah Sparrows shifted their songs to higher frequencies in the presence of low-frequency drilling noise. Curry and others (2017) concluded that grassland birds that evolved in acoustically heterogeneous environments may be capable of adjusting their songs in response to variable ambient noise. Warrington and others (2018) examined the effect of anthropogenic noise on acoustic properties of Savannah Sparrow song at four types of oil and gas infrastructure: natural gas compressor stations, generator-powered oil-well pumpjacks, power grid-powered oil-well screwpumps, and generator-powered oil-well screwpumps. Changes in acoustic song properties were detected and varied with syllable and with infrastructure type, with most effects being detected at the loudest type of infrastructure (that is, generator-powered screwpump sites). Antze and Koper (2018) evaluated acoustic playback experiments to determine whether Savannah Sparrows responded to conspecific alarm calls by delaying feeding visits, and whether this response was impaired by noise-producing natural gas compressor stations, generator- or grid-powered screwpump oil wells, and noise amplitude. Feeding latency was shortened at the noisiest treatment (that is, natural gas compressor stations) compared with control sites, which may have exposed nests to greater predation risk (Antze and Koper, 2018). Savannah sparrows also altered the structure of their alarm calls in the presence of natural gas compressor stations (Antze and Koper, 2019). Savannah Sparrows called at lower peak frequencies close to natural gas compressor stations, but their call structure did not differ with proximity to natural gas compressor stations or grid-powered or generator-powered screwpump oil wells, or in response to ambient noise levels (Antze and Koper, 2019).

In Saskatchewan mixed-grass prairies, Kalyn Bogard (2011) examined avoidance to gas wells. Savannah Sparrow abundance was higher near gas wells, but only in areas where well density was ≤9 wells per 1.6 km^2; abundance did not vary with distance in areas with greater well densities (Kalyn Bogard and Davis, 2014). Abundance also was affected by vegetation structure (Kalyn Bogard and Davis, 2014). In another Saskatchewan study, Savannah Sparrows tended to avoid minimal-disturbance gas wells, although the relationship was not statistically significant (Linnen, 2008). In northwestern North Dakota, Thompson and others (2015) estimated avoidance distance for Savannah Sparrows at single-bore well sites at 228 m and indicated little or no avoidance at multibore well pads.

Wind-energy development may affect Savannah Sparrow distribution and abundance. Savannah Sparrows may avoid wind facilities during the breeding season; at two wind facilities in North Dakota mixed-grass prairies, Savannah Sparrows exhibited displacement 100–300 m from turbines (Shaffer and Buhl, 2016). Beston and others (2016) developed a prioritization system to identify avian species (among 428 species evaluated) most likely to experience population declines in the United States from wind facilities based on their current conservation status and their expected risk from wind turbines. In the overall prioritization, the Savannah Sparrow had an average priority score of 2.39 out of nine; 5.83 percent of the Savannah Sparrow breeding population in the United States are estimated to be exposed to wind facilities. Loss and others (2013) reviewed published and unpublished reports on collision mortality at monopole wind turbines (that is, with a solid tower rather than a lattice tower) in the contiguous United States; 33 Savannah Sparrow mortalities were reported at 14 wind facilities. Erickson and others (2014) compiled data from 116 studies on small-passerine fatalities caused by collisions with turbines at wind-energy facilities in the United States and Canada. The Savannah Sparrow was among the 25 most common small-passerine species that were found as a fatality during a 17-year period. Wulff and others (2016) examined diurnal flight heights of Savannah Sparrows and determined that the species' mean flight height was 10.9 m, which is not within the rotor-swept zone (32–124 m) of wind turbine blades.

Management Recommendations from the Literature

Grassland Protection and Restoration

The Savannah Sparrow may be area sensitive in some regions, preferring larger grasslands over smaller grasslands (Ribic and others, 2009b). Thus, efforts to conserve contiguous native prairie or to restore agricultural fields to grasslands will be beneficial to this species (Herkert, 1991a, 1991b; Veech, 2006; Bakker and Higgins, 2009; Lipsey, 2015; Lockhart and Koper, 2018). Lipsey (2015) recommended that successful efforts to maintain productive rangelands, manage grazing, and control invasive plants in native grasslands should be rewarded and incentivized as a means of also contributing to the conservation of grassland birds. Slowing the conversion of native prairie to crop production will reduce further habitat loss and the negative effects of edges (Sliwinski and Koper, 2012). Maintenance of CRP grasslands, especially newer plantings, will provide suitable habitat (Veech, 2006). Acquisition and management of large grassland tracts with minimal woody vegetation will help maintain the contiguous nature of grassland parcels (Wray and others, 1982; Johnson and Temple, 1986, 1990; Burger and others, 1994). Maintaining complexes of grasslands and wetlands will ensure suitable habitat for Savannah Sparrows under different moisture regimes (Niemuth and others, 2008). Lipsey (2015) emphasized that managers of public land and private conservation areas should recognize that their management units are not isolated islands of grassland habitat but instead these areas form a basis for leveraging conservation in surrounding grassland landscapes.

Protection of large and small grassland patches embedded within landscapes with a high proportion of grassland habitat and with little or no woodland will benefit Savannah Sparrows (Bakker and others, 2002; Greer, 2009). Greer (2009) suggested conserving grasslands 250 ha or larger. Herkert and others (1993) suggested restoring grasslands that are larger than 50 ha and preferably larger than 100 ha. Where grassland restorations that are larger than 30 ha are not possible, Herkert and others (1993) recommended establishing several small grasslands, each at least 6–8 ha, within 0.4 km of each other, and using adjacent grassland habitats (for example, pastures, hayland, waterways) as corridors among tracts. Davis (2004) and Winter and others (2006b) also advocated the conservation of small grassland patches if patches are within grassland landscapes. Davis and others (2013) recommended converting cropland to tame or native grasslands near existing parcels of native grassland in cropland-dominated landscapes.

Woody Vegetation

Encroachment of woody vegetation and invasion of nonnative plant species into grasslands may negatively impact Savannah Sparrows and other grassland birds (Cunningham and Johnson, 2006, 2019; Durán, 2009; Greer, 2009; Ranellucci, 2010; Ranellucci and others, 2012). Tack and others (2017) recommended removing shelterbelts within and adjacent to grasslands to reduce woody edges. Reduction of woody vegetation within and along the periphery of grassland fragments may discourage predators that use woody vegetation as travel corridors (O'Leary and Nyberg, 2000; Greer, 2009). 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; Grant and others (2004) also discouraged programs that promoted the planting of trees and tall shrubs within grasslands. Idled grasslands need to be actively managed to control the invasion and encroachment of woody and invasive species (Ranellucci, 2010). Lipsey (2015) suggested that shrublands are unlikely to support a diverse grassland bird community despite grazing management and that shrublands should be managed to benefit shrub-obligate birds, such as the Greater Sage-Grouse (*Centrocercus urophasianus*) or the Brewer's Sparrow (*Spizella breweri*), rather than grasslands specialists, such as the Savannah Sparrow. Invasion of exotic nonwoody vegetation into native grasslands also may negatively affect Savannah Sparrows; for example, leafy spurge can increase overall vegetation density and cause a reduction in Savannah Sparrow density (Scheiman and others, 2003).

Creating a mosaic of successional stages within large blocks of grasslands is beneficial to Savannah Sparrows and other grassland birds. Portions of large areas can be treated (burned, grazed, mowed, or disked) on a rotational schedule to provide such a mosaic (Renken and Dinsmore, 1987; Madden, 1996; Prescott and Murphy, 1996; Richardson, 2012). In restored or native grasslands that are larger than 40 ha, Herkert and others (1993) recommended that 20–30 percent of the grassland should be burned annually to provide habitat for species that prefer recently burned areas and for species that do not. Grazing systems that allow for a diversity of vegetation structure will be beneficial to the grassland bird community (Ranellucci, 2010).

Fire

Management practices (for example, burning, mowing, moderate or heavy grazing) may be used to improve grassland habitats, but these same practices may be detrimental during the breeding season (about May 1 to August 1) (Swanson, 1996). Burning in early spring (March to April) or late fall (October to November) will reduce fledgling and nest mortality (Herkert and others, 1993; Swanson, 1996). On U.S. Fish and Wildlife Service lands, Grant and others (2010) cautioned that burning as a management tool is used too infrequently in the northern Great Plains, and that the extent and frequency of prescribed fires need to increase above current levels (that is, long-term rest) to maintain and restore the ecological integrity of native prairies. Burning reduces the encroachment of scattered patches of tall, woody cover without negatively impacting nest survival (Murphy and others, 2017). In northern mixed-grass prairies, a fire-return interval of 5–10 years is recommended (Madden and others, 1999; Grant and others, 2011). Although burning at intervals of >10 years might increase nest density for some bird species in the short term, long intervals between burns allow invasive plant species to encroach in native prairies, thus degrading prairie quality in the long term (Grant and others, 2011). Davis and others (2017) recommended that the frequency of management should depend on local environmental conditions; some form of management of planted grasslands should occur at least once every 4–6 years to maintain habitat for the Savannah Sparrow and other generalist grassland bird species.

Haying

Mid-season mowing may result in high nest and fledgling mortality; mowing later in the breeding season will benefit Savannah Sparrows (Herkert and others, 1993). Managers can reduce disturbances to nesting birds in hayfields by delaying mowing until mid- or late July or early August, which would allow birds to raise at least one brood in years with normal breeding phenology (Herkert and others, 1993; Dale and others, 1997; Durán, 2009). When mowing during the breeding season, hayfields can be managed on a rotational system, with some subunits remaining idle in each year (Herkert and others, 1993). Haying one-half of a field 1 year and the other half in the next year is an option to provide refuge for fledglings (Dale and others, 1997; Durán, 2009). Herkert and others (1993), however, cautioned against haying very late in the growing season, because late haying may adversely affect plant species composition and regrowth and encourage invasion of exotic grasses in the following growing season.

In New York and Vermont hayfields that were first cut in May, a 65-day interval between mowing would provide enough time for Savannah Sparrows to successfully fledge young (Perlut and others, 2006). Perlut and others (2006, 2008b) recommended decreasing the number of fields mowed in late May and early June, increasing the number of fields that are mowed after August 1, and removing thatch on these fields before the following nesting season. Because that strategy may not be feasible for the needs of forage producers, Perlut and others (2006, 2008b) provided a secondary recommendation that emphasized completing the first cut before May 31 to lessen the reproductive investment of adult Savannah Sparrows before nest failure and delaying second cuts on early hayed fields. A 65-day cutting interval would allow farmers to produce a moderate volume, high-protein first crop and a high volume, low-protein second crop. Long-term maintenance of the higher-quality middle- and late-hayed fields will enable Savannah Sparrows to disperse, either between or within years, from the lower quality early cut or grazed fields to the higher-quality fields (Fajardo and others, 2009). In eastern Canada, delaying cutting until early July requires a balance between maintaining nutritional quality of livestock forage and maximizing fledging rates (Nocera and others, 2007).

The high site fidelity of Savannah Sparrows to breeding habitats, regardless of quality, may be problematic from a management perspective (Fajardo and others, 2009). Savannah Sparrows exhibit strong site fidelity to early hayed fields where annual fledging rates for the population were less than replacement values (Fajardo and others, 2009). The strong site fidelity may constrain the species' ability to select fields that would provide higher reproductive success. Savannah Sparrows that nested in fields that were managed for several years as late-hayed could experience lower reproductive success if these fields are changed to early hayed or pasture; however, the species' propensity to return to former breeding areas provides an opportunity for land managers to focus conservation efforts on high-quality habitats, given that breeding adults are likely to return to the same fields in subsequent years (Fajardo and others, 2009).

On small airports, where all or most of the available grassland must be mowed to meet Federal Aviation Administration standards, Kershner and Bollinger (1996) recommended that vegetation should be mowed short enough (<4 cm) to discourage nesting by Savannah Sparrows and other grassland birds. This may cause birds to select higher-quality alternative nesting areas where nesting success would be higher (Kershner and Bollinger, 1996). In switchgrass fields harvested for biofuel production, habitat conditions with short- to moderate-height vegetation may provide habitat otherwise unavailable for Savannah Sparrows (Roth and others, 2005).

Grazing

Grazing Intensity

Managing stocking rates to achieve optimal grazing intensity for Savannah Sparrows depends on several factors, such as grassland type, variability in precipitation, and soil productivity (Sliwinski and Koper, 2015; Lipsey and Naugle, 2017). Herkert (1991a) suggested that light grazing (that is, leaving more than 40 percent vegetation cover >25 cm tall) can be used to create the intermediate vegetation height and density preferred by Savannah Sparrows. Salo and others (2004) and Sliwinski and Koper (2015) recommended light-to-moderate grazing in grasslands managed for Savannah Sparrows. Salo and others (2004) determined that Savannah Sparrow densities were higher in lightly and moderately grazed pastures than heavily and extremely heavily grazed pastures and recognized that grasslands grazed at low-to-moderate intensity had greater biomass reserves that benefitted the suite of grassland bird species while maintaining acceptable daily rates of gain for individual cattle. The suite of grassland bird species was best maintained on average at 2.4 AUMs per ha, whereas livestock production and economic benefits to operators were best achieved on average at stocking rates from 2.4 to 4.2 AUMs per ha, adjusted for annual precipitation and soil moisture reserves. Sliwinski and Koper (2015) indicated that Savannah Sparrows would benefit from periodic rest from grazing and that decisions about stocking rates be based on annual precipitation levels. Fischer and others (2020) recommended that grazing at lower stocking rates and allowing for periods of rest from grazing would allow grasslands to recover from grazing effects. To benefit a suite of grassland birds that includes Savannah Sparrows, Sliwinski and Koper (2015) and Pipher and others (2016) recommended that land managers use different stocking rates as a means to increase heterogeneity in vegetation structure, which can be achieved by using low stocking rates or rest on some pastures and heavy stocking rates on others; the specific stocking rates used will depend on the region and precipitation within a given year. Lipsey and Naugle (2017) suggested that land managers who use grazing management should evaluate current cover conditions and provide the cover that is most limiting for birds at the time of the evaluation. Lipsey and Naugle (2017) further emphasized that, when grassland species are rare in an area, such as the Savannah Sparrow in mixed-grass prairies in Montana, these species should not be discounted in grassland management because these species might benefit the most from increased habitat heterogeneity. Ahlering and others (2019) underscored that native grasslands are disturbance dependent systems and require varied and recurring disturbances, such as grazing, to create the mosaic of habitats necessary to support Savannah Sparrows and the full suite of grassland bird species.

Grazing Systems

Several studies indicated that Savannah Sparrows have higher nest success in grazing systems that use light grazing or that provide periods of rest from grazing (Temple and others, 1999; Kern and others, 2010; Cassidy and Kleppel, 2017). Temple and others (1999) recommended implementing a grassland management regime in which areas of ungrazed grassland and rotationally grazed pastures are maintained in a 1:2 ratio during the peak of the nesting season to allow refuge for adults and fledglings. Messmer (1990), Prescott and Wagner (1996), and Bleho and others (2014) reported that rotational grazing systems did not confer greater advantages, in terms of bird productivity or vegetation structure, than continuous grazing systems (Bleho and others, 2014). Bleho and others (2014) cautioned that grazing systems that produce uniform vegetation structure, such as rotational grazing systems, may not adequately preserve nesting habitat. As with stocking rate, the effect on vegetation of abiotic factors, such as interannual variability in precipitation levels and soil type, may be as important in governing the abundance and distribution of bird species as the type of grazing system (Ranellucci and others, 2012; Lipsey and Naugle, 2017). Davis and others (2014) recommended that greater effort be taken to improve range condition in pastures categorized as low-to-fair and in maintaining pastures in good condition, rather than focus on grazing systems.

Energy Development

Bernath-Plaisted and Koper (2016) provided several recommendations for reducing the impact of oil and gas infrastructure on nesting Savannah Sparrows, including replacing screwpumps with pumpjacks and replacing grid-powered wells with generator-powered wells. Management actions that reduce noise and human activity may not be as effective as actions that reduce the abundance and density of aboveground infrastructure, including roads (Bernath-Plaisted and Koper, 2016; Daniel and Koper, 2019). Such mitigation activities include reclaiming abandoned wells and access roads and using horizontal drilling techniques that allow well heads to be clustered to eliminate the need for new roads and surface infrastructure (Bernath-Plaisted and Koper, 2016; Daniel and Koper, 2019). Antze and Koper (2018) recommended decreasing the spatial extent, visual impact, and acoustic disturbance of oil and gas infrastructure to reduce the distraction of Savannah Sparrows from their reproductive activities. Warrington and others (2018) indicated that quieter infrastructure for energy extraction may have fewer acoustic impacts on Savannah Sparrows; mufflers and sound-dampening barrier walls may be effective tools to reduce effects of noise amplitude from oil wells.

To reduce negative impacts from wind turbines, Loss and others (2013) stressed the importance of considering species-specific and location-specific risks and making multiscale decisions about where to site wind facilities and individual wind turbines in the context of risks to individual bird species. Shaffer and others (2019b) developed an avian-impact offset method to guide compensatory mitigation of habitat loss associated with energy development. The avian-impact offset method calculates the biological value (measured in terms of avian numbers) lost when Savannah Sparrows and other species avoid otherwise suitable breeding habitat because of energy development (for example, wind turbines). The method converts biological value to the traditional unit of measure (that is, hectares of grassland) in which land is purchased or sold, so that compensatory mitigation can be undertaken in the form of conservation easements or grassland reconstruction at the local regional or landscape scales (Shaffer and others, 2019b). Alternatively, the tool can be used before development of energy facilities to identify locations that would require little compensatory mitigation if developed, relative to other potential locations.

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Table FF1. Measured values of vegetation structure and composition in Savannah Sparrow (*Passerculus sandwichensis*) breeding habitat by study. The parenthetical descriptors following authorship and year in the "Study" column indicate that the vegetation measurements were taken in locations or under conditions specified in the descriptor; no descriptor implies that measurements were taken within the general study area.

[cm, centimeter; %, percent; --, no data; <, less than; ha, hectare; >, greater than; DNC, dense nesting cover; CRP, Conservation Reserve Program; n.d., no date; 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)
Bakker and Higgins, 2009	Minnesota, South Dakota	Tallgrass prairie	--	96[a]	20[b]	--	--	--	--	--	2.6
Bakker and Higgins, 2009	Minnesota, South Dakota	Tame grassland	Seeded to intermediate wheatgrass	135[a]	36[b]	--	--	--	--	--	3.1
Bakker and Higgins, 2009	Minnesota, South Dakota	Tame grassland	Seeded to switchgrass (*Panicum virgatum*)	107[a]	37[b]	--	--	--	--	--	1.6
Bakker and Higgins, 2009	Minnesota, South Dakota	Tame grassland	Cool-season seeding mixture	124[a]	36[b]	--	--	--	--	--	3.4
Bakker and Higgins, 2009	Minnesota, South Dakota	Tame grassland	Warm-season seeding mixture	166[a]	27[b]	--	--	--	--	--	4.1
Berman, 2007	South Dakota	Mixed-grass prairie	<50 ha; <40% grassland landscape	62	17[b]	--	--	--	--	--	0.7
Berman, 2007	South Dakota	Mixed-grass prairie	<50 ha; >50% grassland landscape	73	20[b]	--	--	--	--	--	1.2
Berman, 2007	South Dakota	Mixed-grass prairie	>100 ha; <40% grassland landscape	53	10[b]	--	--	--	--	--	1.1
Berman, 2007	South Dakota	Mixed-grass prairie	>100 ha; >50% grassland landscape	77	12[b]	--	--	--	--	--	0.6
Bleho, 2009	Saskatchewan	Mixed-grass prairie	Ungrazed	--	7.4[b]	15.6	4.5	6.2	4.7	60.9	--
Bleho, 2009	Saskatchewan	Mixed-grass prairie	Grazed	--	4[b]	17.9	6.9	3.6	8.4	45.2	--
Bollinger, 1988	New York	Tame grassland	Hayed	26.3	--	23.9	--	--	--	--	--
Dieni and Jones, 2003 (nests)	Montana	Mixed-grass prairie	Idle	34.3	17[b]	65.5	13.7	0.5	0.6	13.4	21.2
Dieni and Jones, 2003 (nest vicinity)	Montana	Mixed-grass prairie	Idle	31.6	13[b]	--	--	--	--	--	--
Fletcher and Koford, 2002	Iowa	Tallgrass prairie	--	91.7	--	45.6	33.4	--	0.9	9.9	3.4
Fletcher and Koford, 2002	Iowa	Restored grassland	Cool- and warm-season seeding mixture	91.6	--	51.8	20.6	--	3.6	13.7	2.5
Fondell and Ball, 2004[c]	Montana	Tame grassland	Idle	--	16[b]	25.1	11.7	0	--	71	4.1
Fondell and Ball, 2004[c]	Montana	Tame grassland	Grazed	--	6.5[b]	31	25.6	0.5	--	43.3	1.3
Giuliano and Daves, 2002	Pennsylvania	Tame grassland	Cool-season seeding mixture	26.1–82.6	--	--	--	--	--	--	--

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[cm, centimeter; %, percent; --, no data; <, less than; ha, hectare; >, greater than; DNC, dense nesting cover; CRP, Conservation Reserve Program; n.d., no date; 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)
Giuliano and Daves, 2002	Pennsylvania	Tame grassland	Warm-season seeding mixture	43.6–133.5	--	--	--	--	--	--	--
Grant and others, 2004	North Dakota	Mixed-grass prairie	Multiple	55	--	--	--	9.5	--	--	4.6
Greer, 2009[c]	South Dakota	Mixed-grass prairie	Multiple	85[a]	20[b]	55.4	17.8	0.8	1.8	27.4	2.4
Harrison, 1974 (territories)	Michigan	Tame grassland	Hayed	48.2	--	--	--	--	--	57.9	--
Kalyn Bogard, 2011	Saskatchewan	Mixed-grass prairie	Grazed	11.1	--	58.5	11.1	--	27.6	--	0.2
Kennedy and others, 2009	Oregon	Bunchgrass prairie	Grazed	--	13[b]	63	--	--	20.2	29.5	--
Lueders and others, 2006	North Dakota	Mixed-grass prairie	Cattle-grazed	--	7[b]	35.3[d]	11.7	0.4	22.4	24.6	1.2
Lueders and others, 2006	North Dakota	Mixed-grass prairie	Bison-grazed	--	15[b]	29.2[d]	14.7	18.5	10.3	25.9	2.1
Madden, 1996	North Dakota	Mixed-grass prairie	Burned	--	20[b]	34.2	23.1	29	--	--	4.2
Nenneman, 2003 (nests)	North Dakota	Mixed-grass prairie	Burned	41.6[a]	31.3[b]	50.7	4.8	--	--	--	2.7
Nenneman, 2003 (fields)	North Dakota	Mixed-grass prairie	Burned	46.1[a]	34.3[b]	61.8	4.2	--	--	--	2.4
Niemi, 1985 (territories)	Minnesota	Mixed-grass prairie	Burned	190	--	--	--	--	--	--	--
Piehler, 1987[e] (territories)	Pennsylvania	Reclaimed mine grassland	--	84.4	106.5[f]	25	34.9	0.3	20.9	79.2	2.8
Pipher, 2011 (nests)	Saskatchewan	Mixed-grass prairie	Grazed	59.6	--	--	--	--	--	--	3.8
Renfrew and Ribic, 2002	Wisconsin	Tame lowland grassland	Grazed	--	8.4[b]	--	--	--	34.9	--	1
Renfrew and Ribic, 2002	Wisconsin	Tame upland grassland	Grazed	--	9.9[b]	--	--	--	26.1	--	1.1
Renfrew and Ribic, 2008	Wisconsin	Tame grassland	Grazed	--	9.0[b]	--	31.8	--	37.6	--	--
Renken, 1983[e]	North Dakota	Tame grassland (DNC)	Idle, grazed	--	17[b]	66.1	28	2.8	0.4	99	2.8
Rodgers, 2013	Alberta	Mixed-grass prairie	--	22.8[a]	--	35.8	11.1	--	2.9	--	0.2
Roth and others, 2005	Wisconsin	Tame grassland (CRP)	Idle	--	12.4[b]	--	33.2	--	--	--	1.4

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[cm, centimeter; %, percent; --, no data; <, less than; ha, hectare; >, greater than; DNC, dense nesting cover; CRP, Conservation Reserve Program; n.d., no date; 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)
Salo and others, 2004	North Dakota	Mixed-grass prairie	Light grazing intensity	52.9[a]	50.3[b]	--	--	--	--	--	5.3
Salo and others, 2004	North Dakota	Mixed-grass prairie	Moderate grazing intensity	48.3[a]	45.8[b]	--	--	--	--	--	4.6
Salo and others, 2004	North Dakota	Mixed-grass prairie	Heavy grazing intensity	27.1[a]	22.9[b]	--	--	--	--	--	2
Sample, 1989	Wisconsin	Multiple	--	53.9	17.4[b]	--	75[g]	1	8.6	12.7	--
Scheiman and others, 2003 (nests)	North Dakota	Tallgrass prairie	Multiple	--	19[b]	44.2	7.8	--	0.8	37.7	2.7
Schneider, 1998	North Dakota	Mixed-grass prairie	Grazed	--	9.8[b]	43.3	14.8	--	3.6	--	2.5
Skinner and others, 1984	Missouri	Tallgrass prairie	Multiple	--	--	--	15–45	--	--	--	--
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 grazed	37.2	3.5[b]	30.7	6.1	0.7	19.5	14.9	1.6
White, 2009	Saskatchewan	Mixed-grass prairie	Burned and ungrazed	39.4	4[b]	31.4	6.8	0.5	15.4	10.4	1.1
White, 2009	Saskatchewan	Mixed-grass prairie	Unburned and grazed	41.4	3.4[b]	17.3	7.8	0.4	3.2	47.3	2.1
White, 2009	Saskatchewan	Mixed-grass prairie	Unburned and ungrazed	41.7	7.2[b]	14.8	5.1	2.1	1.6	62.8	5.1
Whitmore, 1979[h] (territories)	West Virginia	Reclaimed mine grassland	Early breeding season	8[i]	25[f]	34.2	7.9	--	14.7	64.4	1.3
Whitmore, 1979[h] (territories)	West Virginia	Reclaimed mine grassland	Peak breeding season	10[i]	65.6[f]	9.4	12.9	--	28.6	71	1.1
Wiens, 1969[e] (nests)	Wisconsin	Tame grassland	Multiple	--	--	98	29	--	0	--	--
Wiens, 1969[e] (territories)	Wisconsin	Tame grassland	Multiple	--	--	96	30	--	2	--	--
Winter and others, 2004 (nests)	Minnesota, North Dakota	Tallgrass prairie	Multiple	33.2	17[b]	35.1	20.2	1.3	1.7	41.5	4
M. Winter, written commun. [n.d.]	Minnesota, North Dakota	Tallgrass prairie	Multiple	43.2	25.6[b]	38.3	19.3	1.8	4.3	35.2	4.6

[a]Mean grass height.

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

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

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

[e]The sum of the percentages is >100%, based on the modified point-quarter technique of Wiens (1969).

[f]Effective vegetation height.

[g]Herbaceous vegetation cover.

[h]The sum of the percentages is >100%, based on unclear methods.

[i]Forb height.

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