The Effects of Management Practices on Grassland Birds—Bobolink (*Dolichonyx oryzivorus*)

Chapter LL of

The Effects of Management Practices on Grassland Birds

Professional Paper 1842–LL

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

Cover. Bobolink. Photograph by Grayson Smith, U.S. Fish and Wildlife Service, used with permission. Background photograph: Northern mixed-grass prairie in North Dakota, by Rick Bohn, used with permission.

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By Jill A. Shaffer,[1] Lawrence D. Igl,[1] Douglas H. Johnson,[1] Marriah L. Sondreal,[1] Christopher M. Goldade,[1,2] Amy L. Zimmerman,[1] Travis L. Wooten,[1,3] and Betty R. Euliss[1]

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

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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square meter (m^2)	0.0002471	acre
hectare (ha)	2.471	acre
square kilometer (km^2)	247.1	acre
square meter (m^2)	10.76	square foot (ft^2)
hectare (ha)	0.003861	square mile (mi^2)
square kilometer (km^2)	0.3861	square mile (mi^2)
	Mass	
kilogram (kg)	2.205	pound (lb)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32$$

Abbreviations

AUM	animal unit month
BBS	Breeding Bird Survey
CREP	Conservation Reserve Enhancement Program
CRP	Conservation Reserve Program
DNC	dense nesting cover
n.d.	no date
PCP	Permanent Cover Program
PDSI	Palmer Drought Severity Index
sp.	species (an unspecified species within the genus)
spp.	species (applies to two or more species within the genus)
WMA	wildlife management area
WPA	Waterfowl Production Area

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Capsule Statement

Keys to Bobolink (*Dolichonyx oryzivorus*) management are providing large areas of suitable habitat (for example, native or tame grasslands of moderate vegetative height and density, low shrub density, and moderate litter and forb cover), and protecting nesting habitat from disturbance during the breeding season. Bobolinks have been reported to use habitats with 10–166 centimeters (cm) average vegetation height, 6–75 cm visual obstruction reading, 17–65 percent grass cover, 3–50 percent forb cover, less than or equal to (≤) 22 percent shrub cover, ≤38 percent bare ground, 5–39 percent litter cover, and ≤9 cm litter depth. The descriptions of key vegetation characteristics are provided in table LL1 (after the "References" section). Vernacular and scientific names of plants and animals follow the Integrated Taxonomic Information System (https://www.itis.gov).

Breeding Range

Bobolinks breed from southern British Columbia across southern Canada to Nova Scotia, and south to eastern Oregon, central Colorado, central Illinois, and northern Virginia (National Geographic Society, 2011). The relative densities of Bobolinks in the United States and southern Canada, based on North American Breeding Bird Survey (BBS) data (Sauer and others, 2014), are shown in figure LL1 (not all geographic places mentioned in report are shown on figure).

[1]U.S. Geological Survey.

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

[3]Marine Corps Base Camp Pendleton (current).

Bobolink. Illustration by Christopher M. Goldade, U.S. Geological Survey.

Suitable Habitat

Bobolinks prefer habitats with moderately tall vegetation, moderately dense vegetation, and moderately deep litter (Tester and Marshall, 1961; Bent, 1965; Wiens, 1969; Harrison, 1974; Messmer, 1990; Bollinger, 1995; Renfrew and Ribic, 2008), moderate forb cover (Bollinger, 1995), and sparse woody vegetation (Sample, 1989; Messmer, 1990; Bollinger and Gavin, 1992). Bobolinks breed in a variety of habitats, including shortgrass, mixed-grass, and tallgrass prairies that are idle, burned, hayed, or grazed (for example, Silloway, 1904; George, 1952; Tester and Marshall, 1961; Bent, 1965; Speirs and Orenstein, 1967; Wiens, 1969; Birkenholz, 1973; Stewart, 1975; Joyner, 1978; Johnsgard, 1979, 1980; Faanes, 1981; Kantrud and Kologiski, 1982; Huber and Steuter, 1984; Volkert, 1992; Madden, 1996; DeJong and others, 2004; Igl and others, 2008, 2018; Ahlering and Merkord, 2016). Haylands are a preferred habitat for Bobolinks (for example, Harrison, 1974; Skinner, 1974, 1975; Kantrud, 1981; Bollinger, 1995; Faanes and Lingle, 1995; Perlut and others, 2006; Fromberger and others, 2020). Bobolinks also use planted

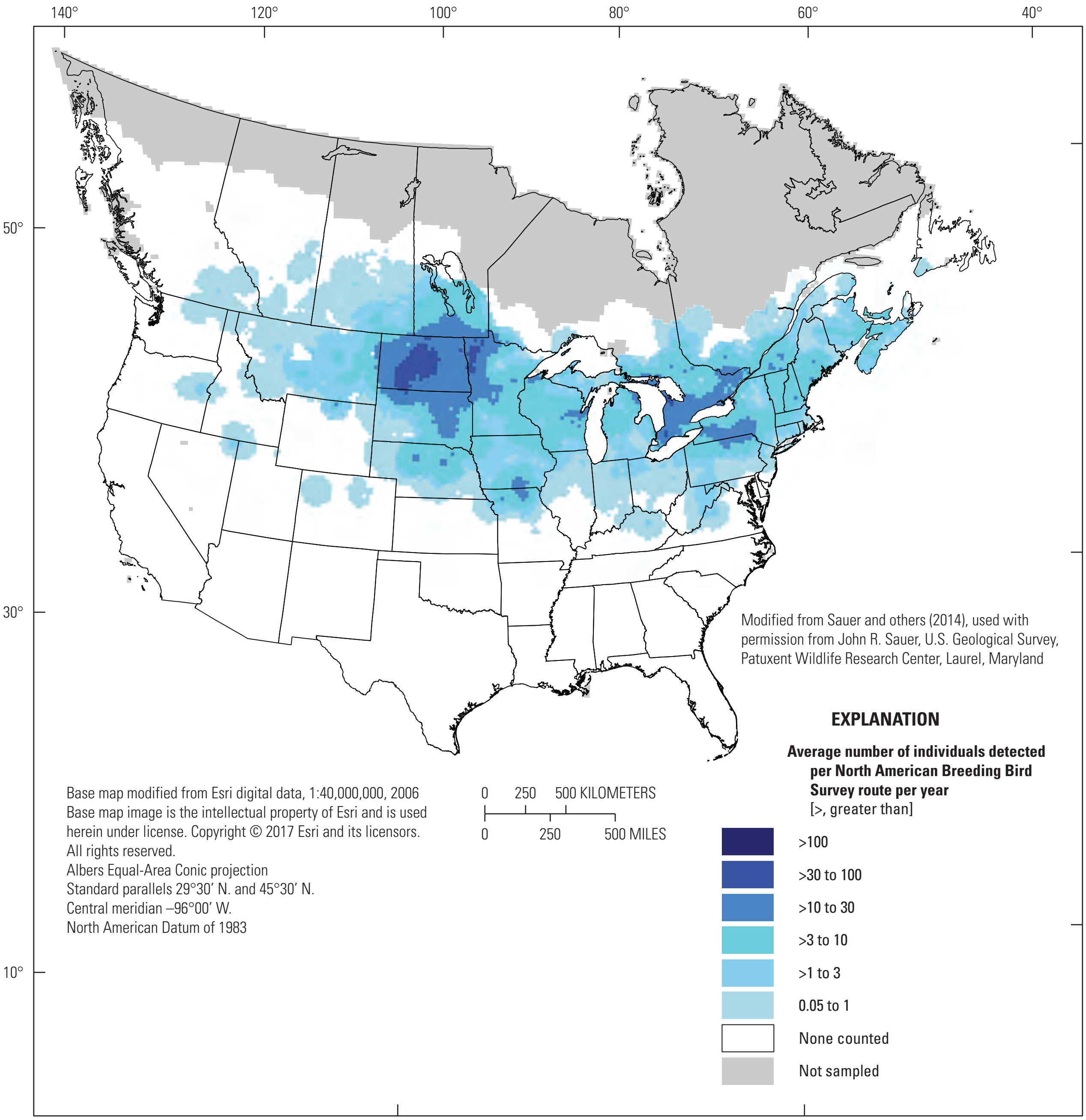

Figure LL1. Breeding distribution of the Bobolink (*Dolichonyx oryzivorus*) in the United States and southern Canada, based on North American Breeding Bird Survey (BBS) data, 2008–12. The BBS abundance map provides only an approximation of breeding range edges.

grasslands, such as Conservation Reserve Program (CRP) fields, Conservation Reserve Enhancement Program (CREP) fields, Permanent Cover Program (PCP) fields, and dense nesting cover (DNC) in Waterfowl Production Areas (WPAs), wildlife management areas (WMAs), and wildlife production areas (for example, Renken and Dinsmore, 1987; Johnson and Schwartz, 1993; Dhol and others, 1994; Hartley, 1994; King and Savidge, 1995; Best and others, 1997; Delisle and Savidge, 1997; McMaster and Davis, 1998; Koford, 1999; McCoy and others, 2001; Fletcher and Koford, 2002; Hull, 2002; Igl and others, 2008; Wentworth and others, 2010). On reclaimed coal mines in Indiana, Bobolinks occurred in low numbers in open grasslands (Galligan and others, 2006).

Bobolinks occupy mesic prairies, wet meadows, sedge (*Carex* species [spp.]) meadows, the peripheries of natural and restored wetlands, peatlands, and moist roadsides with cattails (*Typha* spp.) (Silloway, 1904; Bent, 1965; Stewart, 1975; Johnsgard, 1979, 1980; Wittenberger, 1980; Faanes, 1981; Niemi, 1985; Faanes and Lingle, 1995; Kim and others, 2008; Renfrew and others, 2008; Safratowich and others, 2008; Igl and others, 2017). In a survey of breeding birds in 1,190 wetlands throughout the Prairie Pothole Region of North Dakota and South Dakota, Bobolinks were associated with 216 wetlands ranging from fresh to saline and varying widely in size and permanence (Igl and others, 2017). The species was observed primarily in permanent wetlands and in lower and nearly equal proportions regardless of other wetland types (alkali, semipermanent, seasonal, or temporary; wetland classification based on Stewart and Kantrud, 1971), management (natural or restored), or ownership (private or public). Wetlands inhabited by Bobolinks were characterized as having an average of 41 percent open water, 26 percent emergent vegetation, 31 percent wet meadow, and 2.5 percent shore/mudflat (Igl and others, 2017). In the northern Great Plains, Niemuth and others (2017) found that the occurrence of Bobolinks was positively associated with the area of emergent herbaceous wetlands within the surrounding landscape (that is, areas where herbaceous vegetation accounted for greater than [>] 80 percent of vegetative cover and the soil or substrate was periodically saturated with water).

Bobolinks occasionally inhabit no-tillage cropland and small-grain fields (for example, Johnsgard, 1979, 1980; Basore and others, 1986; Sample, 1989; DeJong and others, 2004), although the species was absent from cropland in Saskatchewan and Manitoba (Hartley, 1994; Jones, 1994; Mozel, 2010) and wheat (*Triticum aestivum*) fields were avoided in Saskatchewan (Hartley, 1994). In south-central Manitoba, Bobolinks were not recorded in cropland (McDonald and Koper, 2022). In North Dakota, Bobolink densities were higher in cropland (defined as land used for the production of annual field crops, land under summer fallow, and land cleared for annual field crops), hayland, and planted cover than in native grasslands (Igl and others, 2008), and Bobolink densities in CRP grasslands were higher than those in cropland (Johnson and Igl, 1995). In South Dakota, Bobolink abundance was higher in fallow fields than in cropland (primarily wheat, corn [*Zea mays*], and soybeans [*Glycine max*]) or native prairie (primarily wheatgrass [primarily *Pascopyrum smithii*] and needlegrass [*Stipa* spp.]), and abundance in native prairie was higher than in cropland (DeJong, 2001; DeJong and others, 2004). In Wisconsin, a few Bobolinks were found in small-grain fields, but none were found in rowcrops (Sample, 1989). In Wisconsin, Bobolinks did not occur in corn fields with 10-meter (m) wide ungrazed grassy buffer strips (Renfrew and Ribic, 2001). In Iowa, Bobolinks nested at low densities in untilled fields of corn that were idle in the fall and spring and contained year-round crop residue, rather than in tilled fields or strip cover (Basore and others, 1986).

Planted Cover

Several researchers have compared Bobolink use of fields planted to native and tame species of grasses relative to other habitats such as native prairies. In Manitoba and Saskatchewan, Bobolinks were found in DNC fields planted to native and tame species of vegetation and in idle mixed-grass prairies (Dhol and others, 1994; Hartley, 1994); no differences in abundance or productivity were found among grassland types (Dhol and others, 1994). In southern Manitoba, Mozel (2010) reported that Bobolink densities were similar between planted grasslands (pasture, hayland, and idle land) that included both native and tame grass species and tallgrass prairies; Bobolinks did not occur in agricultural fields. In southern Alberta and Saskatchewan, Bobolinks occurred almost exclusively within tame grasslands and infrequently within native mixed-grass prairies, but suitability of tame grasslands was affected by proximity to native grasslands (Davis and others, 2013). In Alberta, Bobolinks were found in tame pastures but not in native mixed-grass prairie pastures (Prescott and Murphy, 1996). In North Dakota, higher densities of Bobolinks were found in DNC fields planted to alfalfa (*Medicago sativa*) and wheatgrass (formerly *Agropyron* spp.) than in idle mixed-grass prairies (Renken, 1983; Renken and Dinsmore, 1987). In seeded grasslands and tallgrass prairies in eastern South Dakota and western Minnesota, Bobolink densities were 51 percent lower in fields planted to tame cool-season grass species than in fields planted to monocultures of native switchgrass (*Panicum virgatum*); densities were 68 percent lower in fields planted to monocultures of tame intermediate wheatgrass (*Thinopyrum intermedium*) than in switchgrass fields (Bakker and Higgins, 2009). Bobolink densities in switchgrass fields were similar to densities in native tallgrass prairies and to fields planted to warm-season native grass species. In eastern South Dakota, Bobolinks reached their highest occurrence and density in old (10–13 years of age) rather than in new (1–3 years of age) CRP grasslands (Bakker and others, 2004). In western Minnesota and northwestern Iowa, Bobolinks had higher densities and occupancy rates in grasslands than in hayland or cropland, and equal densities in cropland and hayland (Quamen, 2007). Grasslands included native tallgrass prairie pastures, tame pastures, and CRP, whereas hayland included alfalfa or alfalfa intermixed with tame grass species. In Wisconsin, Bobolink densities occurred in all of the evaluated habitats, which were cool-season CRP grasslands, remnant tallgrass prairies, heavily grazed cattle pastures, grass-and-alfalfa haylands, and strip crops (that is, corn or soybeans alternated with alfalfa hayland, oats, or wheat) (Ribic and others, 2009a). Densities were highest in hayfields, followed by CRP fields, and densities in hayfields were five times greater than in strip crops. Throughout Wisconsin, Bobolink abundance was highest in cool-season grasslands, followed by wet pastures, bluegrass (*Poa* spp.)-quackgrass (*Elymus repens*) communities, and alfalfa-grass hayfields (Sample, 1989). In central Iowa, Bobolinks occurred in CRP fields planted to tame grass species and alfalfa and did not occur in rowcrop fields (Patterson and Best, 1996). Although few Bobolink nests were found in CRP fields during their study, Patterson and Best (1996) surmised that Bobolinks nested in the habitat, as many preflight fledglings were observed. In restored grasslands in northwestern Iowa, Bobolink densities were significantly greater in grasslands planted to cool-season grass species than in grasslands planted to warm-season grass species or a high-diversity species mixture (Vogel, 2011). In northern Iowa, Fletcher and Koford (2003) found that Bobolink densities were similar between tallgrass prairies and WPA and WMA grasslands restored with native warm-season and tame cool-season species. Fletcher and others (2006) projected that Bobolink populations in restored grasslands, which were embedded in landscapes dominated by row crops, could only remain stable if annual juvenile or adult survival was high. Seasonal fecundity and nestling growth rates were low when nest predation was high and brood parasitism was moderate; however, other habitats were not studied to serve as comparisons. Near a tallgrass prairie preserve in northern Illinois, Bobolinks occurred only in patches of Kentucky bluegrass (*Poa pratensis*) and were absent from tallgrass prairies (Birkenholz, 1973).

In southeastern Nebraska, Bobolinks occurred in tallgrass prairies and in CRP fields planted to cool-season grasses but not in CRP fields planted to warm-season grasses (King and Savidge, 1995). In another Nebraska study, abundance was significantly higher in CRP fields planted to cool-season grasses than in CRP fields planted to warm-season grasses, possibly because of shorter vegetation in cool-season fields (Delisle and Savidge, 1997). In Colorado, Bobolinks were significantly more abundant in tame hayland and tallgrass prairies than in mixed-grass prairies (Bock and others 1999). In northern and western Missouri grasslands, Jacobs and others (2012) found no statistical support for a relationship between Bobolink abundance and grassland type (that is, hayed and grazed native and tame grasslands and idle CRP fields), vegetation structure, or landscape attributes. In north-central Missouri CRP fields, Bobolinks were present in grasslands planted to either cool-season or warm-season grasses in abundances too low to permit statistical comparison (McCoy and others, 2001). In central Ohio, Bobolink abundance was significantly higher in Wildlife Production Areas planted to switchgrass, a native warm-season grass, than those planted to timothy (*Phleum pratense*), a tame cool-season grass (Hull, 2002). In Pennsylvania CREP grasslands, Bobolinks occurred in grasslands planted to cool-season grass species but not in fields planted to warm-season grass species (Wentworth and others, 2010). In another Pennsylvania study, Bobolink abundance was not statistically different between pastures and hayland planted to either cool- or warm-season grass species (Giuliano and Daves, 2002). In New York, fields planted to dense stands of switchgrass as waterfowl nesting cover were infrequently used by Bobolinks (Norment and others, 1999).

Biomass (Bioenergy) Fields

CRP fields planted to switchgrass as a biomass fuel are harvested to provide a domestic energy source; switchgrass fields for biomass fuel differ from more traditional hayfields in that the former are typically harvested after the avian breeding season (Murray and Best, 2003). In southwestern Wisconsin, Roth and others (2005) examined Bobolink use of five August-harvested switchgrass fields and five unharvested control fields. The species used both harvested and unharvested CRP fields (Roth and others, 2005). In southern Wisconsin, Blank and others (2014) evaluated Bobolink use of cropland and biomass plantings, including biomass grassland monocultures of warm-season grass species, grass-dominated conservation grasslands (that is, Federal, State, and nonprofit wildlife areas with >50 percent live vegetation cover in warm-season grass species), and forb-dominated conservation grasslands (that is, less than [<] 50 percent live vegetation cover in grass species). Bobolinks were not present in cropland, grass monocultures, or forb-dominated grasslands and occurred at low densities in grass-dominated grasslands, which contained an average of 11 percent forbs (Blank and others, 2014). In Iowa switchgrass CRP fields, Murray and Best (2003) evaluated Bobolink abundance and nest success among fields that were completely mowed, fields in which 60 percent was mowed in strips with alternate unmowed strips, and fields that were completely unmowed. Harvesting occurred between November and March; switchgrass was cut to a height of 9 cm with a disc mower, baled, and removed from the field. Bobolinks were more abundant in harvested plots than in unharvested plots, a finding that approached statistical significance (Murray and Best, 2003). In a later model, Murray and others (2003) predicted that Bobolink abundance would increase in biomass fields converted from rowcrop fields. In southern Ontario, MacDonald (2014) surveyed for Bobolinks in three different biomass energy crop types (*Miscanthus* species, switchgrass, and tallgrass prairie), which are harvested in late summer or fall after nesting has been completed for most grassland birds. Bobolinks were not present in any of the crop types, perhaps because vegetation was poorly established in the spring when male Bobolinks were establishing territories.

Vegetation Structure and Composition

Vegetative structure is more important to Bobolink occurrence and abundance than vegetation composition. Bobolinks prefer grasslands characterized by a moderate percentage of forb cover and a high percentage of grass cover that is tall and relatively dense (Wiens, 1969; Skinner, 1974; Renken, 1983; Renken and Dinsmore, 1987; Sample, 1989; Herkert, 1994a; Madden, 1996). In Oregon, territories of bachelor males had significantly lower forb cover than those of mated males, and forb cover differed between territories of polygynous and monogamous males in 1 of 3 years (Wittenberger, 1980). In Manitoba mixed-grass prairies, abundance of Bobolinks was positively associated with percentage cover of standing grass and with vegetation height (Durán, 2009). Within mixed-grass prairies in the same general area as Durán (2009), Ranellucci (2010) found that Bobolink abundance was positively associated with vegetation height, visual obstruction, and percentage cover of forbs in 1 of 2 years; abundance was negatively associated with percentage cover of shrubs in 1 of 2 years.

In Manitoba tallgrass prairies, abundance of Bobolinks was positively associated with vegetation density and negatively associated with percentage water cover on prairie patches (Bruinsma, 2012). In another study in Manitoba tallgrass prairies, Bobolink density was positively associated with litter depth (Mozel, 2010).

In grasslands managed by the U.S. Fish and Wildlife Service in Montana, North Dakota, South Dakota, and Minnesota, Bobolink densities increased with increasing visual obstruction in each of the 3 years of the study; floristic composition (for example, percent cover of native or nonnative forbs or grass) and other variables, did not improve the vegetation structure model (Igl and others, 2018). In mixed-grass prairies in northwestern North Dakota, Madden and others (2000) found that the best predictors of Bobolink occurrence were increasing amounts of forb and grass cover, increasing frequency of broad-leaved exotic grasses, decreasing amounts of shrub cover, and decreasing frequency of native grasses. In north-central North Dakota mixed-grass prairies, Bobolinks were present in grasslands with higher litter depth, taller vegetation, lower percentage cover of live vegetation, higher percentage cover of smooth brome (*Bromus inermis*) and quackgrass, and lower percentage cover of native grass and forb species than in unoccupied areas (Grant and others, 2004). Occurrence was not related to year, percentage cover of shrubs <1 m tall, or percentage cover of Kentucky bluegrass and tame legumes. Within grazed mixed-grass prairies in North Dakota, abundance of Bobolinks was positively associated with percentage cover of grass, litter depth, density of low-growing shrubs (western snowberry [*Symphoricarpos occidentalis*] and silverberry [*Elaeagnus commutata*]), vegetation density, and plant communities dominated by Kentucky bluegrass and native grass species (*Nassella viridula, Hesperostipa comata*, *Bouteloua* spp., *Koeleria macrantha*, and *Schizachyrium scoparium*) (Schneider, 1998). Abundance was negatively associated with percentage cover of small clubmoss (*Selaginella densa*), percentage bare ground, and plant communities dominated solely by native grass species. Strongest vegetational predictors of the presence of Bobolinks were increasing vegetation density, increasing litter depth, and decreasing percentage bare ground. In south-central North Dakota, Bobolinks occurred in grazed areas that had moderate-to-deep litter and few shrubs (Messmer, 1990). In DNC in WPAs in North Dakota, territories were in areas with greater grass and forb cover than unused areas, and Bobolink abundance was positively correlated with effective height of vegetation (Renken, 1983). In tallgrass prairies in southeastern North Dakota, Bobolink abundance increased with litter depth and decreased with visual obstruction reading (Ahlering and Merkord, 2016). Bobolink abundance was highest in hummocky sandhills dominated by prairies and wetlands and lower in the deltaic plains landform dominated by tallgrass prairies or the choppy high sand dunes dominated by oak (*Quercus* spp.) savannas (Ahlering and Merkord, 2016). In North Dakota and Minnesota tallgrass prairies, density of Bobolinks increased with increasing vegetation height; the magnitude of this increase varied slightly among regions, from 0.43 to 1.23 pairs per 100 hectares (ha) for each centimeter increase in vegetation height (Winter and others, 2005, 2006a). In a Minnesota tallgrass prairie, abundance was positively correlated with litter depth, although areas with very high amounts of litter seemed to be avoided (Tester and Marshall, 1961). In fragmented grasslands of either native or tame grasses in Minnesota, Thompson and others (2014) found that Bobolink density increased with increasing litter depth, grass height-density (visual obstruction readings), and grass extent. In remnant tallgrass prairies in Minnesota, Elliott and Johnson (2017) reported that Bobolink density increased with increasing litter depth to about 5 or 10 cm, and possibly declined thereafter. Although the range in height was limited, there is some suggestion that Bobolink density may increase to about 35 cm. Bobolink density increased up to about 2 percent bare ground, then decreased to about 4 percent bare ground, after which density remained constant. Bobolink density decreased with increasing dead vegetation to about 15 percent dead vegetation, after which the density was relatively stable. Bobolink density was unaffected by percentage cover of grass and forbs. In Minnesota, Montana, North Dakota, and South Dakota CRP fields, Bobolink density was positively associated with percentage cover of grass (Johnson and Schwartz, 1993). In western Minnesota and northwestern Iowa, Bobolink density within 100-m avian point-count circles was positively related to the percentage of survey stops for which the dominant vegetation was grasses, average (of 20 stops) leaf height, and litter depth; density was negatively related to percentage of woodland within the 100-m count area (Quamen, 2007).

In South Dakota mixed-grass and tallgrass prairies, Bobolink occurrence was positively related to vegetation height-density and negatively related to height of tallest forb (Bakker and others, 2002). In South Dakota mixed-grass prairies, Bobolinks were more abundant in late than in early seral stages, and density was positively related to litter depth and bare ground (Fritcher and others, 2004). In another South Dakota study in mixed-grass prairies, occurrence of Bobolinks and male density of Bobolinks were positively associated with percentage cover of tame grass and with vegetation height-density; occurrence was negatively associated with the amount of bare ground and grass cover, and male density was positively associated with forb height (Greer, 2009; Greer and others, 2016). In Nebraska, Bobolink abundance in CRP fields planted to cool-season grasses was significantly and positively correlated with percentage cover of litter and negatively correlated with vertical density of vegetation (Delisle and Savidge, 1997). In natural and restored meadows in the Platte River Valley of Nebraska, Bobolink densities were higher on sites with less exposed soil, lower vegetation height-density, and less lying litter cover (Renfrew and others, 2008).

In Wisconsin grasslands, Bobolink density was positively correlated with plant species richness and negatively correlated with total number of dead stems per square meter, maximum vegetation height, height-density, and proportion of plots burned (Sample, 1989). In Wisconsin pastures, Bobolinks occurred more frequently away from streams than along them, possibly because of homogenous vegetation structure near streams (Renfrew and Ribic, 2001). In restored grasslands in Iowa, Bobolink density was positively associated with percentage cover of grass (Vogel, 2011). In tame CRP grasslands in Iowa, Bobolink abundance was positively correlated with percentage cover of the grass canopy and litter and negatively correlated with forb cover and the horizontal patchiness of vegetation (Patterson and Best, 1996). In restored grasslands in Iowa, Bobolink density was positively correlated with vertical vegetation density and percentage cover of standing dead vegetation (Fletcher and Koford, 2002). In tallgrass prairies in Iowa and Missouri, Bobolink density was positively associated with vegetation height-density and litter cover (Pillsbury, 2010). In Missouri, the highest Bobolink densities occurred when grass heights were 10–30 cm (Skinner, 1974). In Michigan, Bobolink occupancy was positively related to areas of high plant diversity (that is, 14 plant species) (Harrison, 1974). In Illinois tallgrass prairie fragments, the best predictors of Bobolink occurrence were mean number of live forb contacts, mean vegetation height, and mean grass height (Herkert, 1994a). In a second study within Illinois tallgrass prairie fragments, Bobolink density was negatively related to height of dead vegetation (Buxton and Benson, 2016). In Maine, Bobolink abundance was positively correlated with high grass and forb cover, greater patchiness, and larger area of habitat patch (Vickery and others, 1994). In Nova Scotia hayfields, the abundance, occurrence, and reproductive activity of Bobolinks were positively related to vegetation height-density (Nocera and others, 2007).

Forbs are an important component in grasslands used by breeding Bobolinks as they provide song and lookout perches and nesting cover. In Wisconsin, heavy-stemmed forbs were an important substrate for singing, and medium-stemmed forbs seemed to be important as lookout perches (Wiens, 1969). In New York, Bollinger (1988, 1995) found that Bobolinks preferred hayland with high grass-to-forb ratios, although a forb component was beneficial for nesting cover. In Nova Scotia, however, occupancy of Bobolinks in hayfields was negatively related to forb coverage (Nocera and others, 2007). In Ontario and Quebec, nonnest sites had about half of the overhead concealment compared to nest sites, and forb cover was 25 percent greater at nest than nonnest sites (Frei, 2009). Successful nests had higher concealment and percentage of forbs than unsuccessful nests. Most nests were placed at the base of a large forb.

Woody Vegetation

Bobolink occurrence and abundance typically are lower in grasslands containing woody vegetation than in open grasslands (Madden and others, 2000; Grant and others, 2004). In North Dakota northern mixed-grass prairies, Grant and others (2004) classified the Bobolink as a woodland-sensitive species. The species reached its maximum probability of occurrence (80 percent) in open, treeless grasslands, and the probability of occurrence declined to 50 percent at about 10–25 percent woodland cover. Bobolinks were present in grasslands with lower percentage cover of shrubs >1 m tall than in unoccupied grasslands. Bobolinks were present in grasslands with lower percentage cover of quaking aspen (*Populus tremuloides*) woodland within 100 and 500 m than in unoccupied grasslands; shrubs <1 m tall had no effect on occurrence (Grant and others, 2004). In mixed-grass prairies in northwestern North Dakota, Madden and others (2000) found that a predictor of Bobolink occurrence was decreasing amounts of shrub cover. Within grazed mixed-grass prairies in North Dakota, abundance of Bobolinks was positively associated with density of low-growing shrubs (western snowberry and silverberry) (Schneider, 1998). In North Dakota tallgrass prairies, Bobolink occurrence was negatively associated with grassland and woodland cover at the 100-m scale (Cunningham and Johnson, 2006). In a statewide study in North Dakota, Igl and others (2008) reported that the Bobolinks avoided using areas with woody vegetation (defined as all native and artificially stocked tree and shrub stands). In grasslands managed by the U.S. Fish and Wildlife Service in North and South Dakota, Quamen (2007) reported that Bobolink abundance was lower in grasslands with trees than in treeless grasslands. In restored grasslands in Iowa, Bobolinks were in low abundance; the authors surmised that the species was deterred by the many wooded areas dispersed throughout the grasslands (Olechnowski and others, 2009). In remnant tallgrass prairies in Minnesota, Elliott and Johnson (2017) reported that Bobolink density was unaffected by percentage cover of shrubs within 4 m of the vegetation sampling point. However, Bobolink densities declined as the proportion of trees within 100 m of survey points increased up to 10 percent tree cover, and densities increased with increasing distance to the nearest tree up to about 200 m. Remnant prairies with Bobolinks were significantly farther from trees than prairies without Bobolinks. In Wisconsin grasslands, Bobolink density was negatively correlated with percentage cover of woody vegetation 1–3 m and 3–6 m tall (Sample, 1989). In Missouri grasslands, Jacobs and others (2012) found no statistical support for a relationship between Bobolink abundance and percentage shrub cover. Across a gradient of graminoid- to shrub-dominated wetlands in the Upper Peninsula of Michigan, Austin and Buhl (2021) modeled the relationship between Bobolink probability of occurrence and habitat variables measured within 100-square-meter segments from survey belt transects and within 200 m of segments. Bobolink probability of occurrence increased with percentage cover of low shrubs within 50 m of segments and with percentage cover of shrubs (cover density of 50–80 percent of scrub-shrub [lowland], speckled alder [*Alnus incana* subspecies *rugosa*], tamarack [*Larix laricina*], and willow [*Salix* spp.]) within 200 m of segments. The probability of occurrence was bimodal for percentage cover of sedge (cover density of 50–80 percent of sedge-bluejoint reedgrass [*Carex* and *Calamagrostis canadensis*]) within 200 m of survey segment, showing maximum occurrence at about 32 percent and a secondary peak at 9 percent (Austin and Buhl, 2021). Highest probability of occurrence occurred in areas with <40 percent low shrubs and >40 percent sedge cover.

Nests and Nest Sites

Bobolink nests typically are well concealed beneath vegetation. In Minnesota and North Dakota tallgrass prairies, Bobolinks placed nests on the ground within thick litter (Winter and others, 2004). Bobolinks do not seem to be affected by infestations of leafy spurge (*Euphorbia esula*), an invasive forb. In leafy spurge-infested tallgrass prairies in southeastern North Dakota, Bobolink densities did not differ among plots designated as high-, medium-, or low-infestation of leafy spurge (Scheiman and others, 2003). Nest success was not related to cover of leafy spurge, and nest sites did not differ in vegetation characteristics from random sites. In North Dakota mixed-grass prairies, Kerns and others (2010) found no relationship between nest survival and vegetation height or vegetation density. In tallgrass prairies of North Dakota and Minnesota, Winter and others (2005) also found no relationship between nest success and vegetation variables measured around nests; however, nest success increased as density of Bobolinks increased. In Wisconsin CRP fields, Byers and others (2017) reported that daily survival rates for Bobolink nests were higher when nests were placed in areas with low vegetation height-density. In Iowa, Bobolinks nested under or near native species of bluestem (*Andropogon gerardii*, *Schizachyrium scoparium*) or Kentucky bluegrass (Kendeigh, 1941). In Wisconsin, nests were built at bases of dense grasses or clumps of forbs (Wiens, 1969; Martin, 1971). Vegetation structure around nests averaged 77 cm height of nearest forb (meadowrue [*Thalictrum* spp.] or golden alexander [*Zizia* aurea]), 2 m distance to nearest forb, and heavy cover around nests (11 total vertical contacts at nest site compared to 9 vertical contacts at random points) (Martin, 1971).

In Ontario, nests in a weedy meadow near a wetland were built in the litter layer, had a canopy of dead grasses, and were surrounded by living vegetation 33–41 cm tall (Boyer and Devitt, 1961; Joyner, 1978). In southeastern Ontario, Pintaric and others (2019) found that female Bobolinks built nests in areas with high forb, grass, and thatch coverage and low alfalfa cover. Nests in hayfields had significantly taller vegetation cover and lower thatch cover than nests in pastures. Bobolinks chose nest sites with higher soil moisture content than the average soil moisture in pastures and hayfields; hayfield nest sites had higher soil moisture content than pasture nest sites (Pintaric and others, 2019). In Ontario and Quebec, Bobolinks nested primarily in a mixture of grasses and forbs (Frei, 2009). The predominant grass species was timothy, and forb species included white clover (*Trifolium repens*) and red clover (*Trifolium pratense*), birdsfoot trefoil (*Lotus corniculatus*), common dandelion (*Taraxacum officinale*), and American purple vetch (*Vicia americana*). Of 53 nests, 35 (66 percent) were placed at the base of or within a cluster of forbs. In grasslands (that is, fallow fields, pastures, hayfields) planted to cool-season plant species mixtures, Bobolink nest success was higher in pastures and hayfields than in fallow fields (Norment and others, 2010).

Climate

Spatial and temporal variation in precipitation and temperature may affect the timing of spring arrival and the occurrence, abundance, and distribution of Bobolinks. Moisture levels may affect the distribution and abundance of Bobolinks, but as Niemuth and others (2017) pointed out, the biological meaning of climate variables in models characterizing bird-environment relationships is unclear; climate variables are likely correlates of other factors (for example, plant community composition, primary and secondary productivity) that more directly affect species occurrence, likely in concert with other factors such as soils and landform. Under projected greenhouse gas emission scenarios described by the Intergovernmental Panel on Climate Change (2000), Langham and others (2015) categorized the Bobolink as a climate-threatened species, indicating that the species will lose >50 percent of its current distribution by 2080 across all Intergovernmental Panel on Climate Change scenarios, with possible net gain from potential range expansion. Using a combination of BBS, eBird (https://www.ebird.org; Sullivan and others, 2009), and point-count data, Nixon and others (2016) modeled the effect of future climate change scenarios on Bobolink breeding distribution along the boreal forest–prairie ecotone in Alberta. Nixon and others (2016) predicted that the Bobolink's breeding range would expand by 42 percent and that expansion largely would occur northward, originating in the Parkland Region of Alberta, with little southward expansion. To evaluate the role of global climate change scenarios in affecting bird distributions, Hitch and Leberg (2007) compared the distribution of Bobolinks east of the Rocky Mountains over two 5-year periods with a 27-year span between them and concluded that the species exhibited a significant shift south. Wilsey and others (2019) compiled avian occurrence data from 40 datasets to project climate vulnerability scores under scenarios in which global mean temperature increases 1.5, 2, or 3 degrees Celsius (ºC). Bobolinks ranked medium in vulnerability during the breeding season at 1.5 ºC and 2 ºC increases and ranked high at a 3 ºC increase. Culp and others (2017) assessed the vulnerability of Bobolinks to changes in climatic factors (that is, changes in temperature and moisture) across the species' full annual cycle in the Upper Midwest and Great Lakes regions. The assessment considered factors such as background risk (that is, factors unrelated to climate change that could affect resiliency to climate change), climate change exposure (that is, exposure to temperature and moisture changes throughout the annual life cycle), and climate sensitivity and adaptability (that is, the ability of a species to physiologically and evolutionarily tolerate change). Bobolinks ranked moderate in the relative total vulnerability score (Culp and others, 2017).

Using BBS data for seven States that constitute the northern Great Plains, Niemuth and others (2017) developed spatially explicit models of Bobolink distribution from a suite of candidate predictor variables that characterized landscape, weather and climate, bird activity and detectability, topography, and survey structure. The authors reported that the occurrence of Bobolinks exhibited a quadratic relationship with mean long-term (30-year) precipitation and August temperature. Bobolink occurrence also was negatively related to the current-year precipitation anomaly, which was described as the subtraction of current-year March–June precipitation from the long-term mean to create a variable reflecting the deviation in precipitation for each examined time period. From an analysis of BBS data from Minnesota, Wisconsin, Michigan, Illinois, and Iowa, Thogmartin and others (2006) found that variations in annual precipitation and temperature were important factors influencing Bobolink abundance. In another assessment of BBS data, O'Connor and others (1999) reported a negative relationship between Bobolink abundance and January climate, and between Bobolink abundance and longitude. Using point-count data from five States in the northern Great Plains representing the area of the Upper Missouri River Basin and 20 environmental predictors, Baltensperger and others (2020) modeled the potential effect of seven future land-cover and climate scenarios on Bobolink abundance; the largest declines (14.5 individuals per square kilometer [km^2]) were predicted to occur in the agricultural lands of western North Dakota, with more moderate losses throughout northern Wyoming and central Montana. The largest increases in abundance (60 individuals per km^2) were predicted in western North Dakota and South Dakota (Baltensperger and others, 2020).

In Oregon, polygyny occurred only on territories with moist soil; a higher proportion of territories in wet habitat attracted two females than either mesic or dry habitats (Wittenberger, 1980). In the tallgrass prairies of Minnesota and North Dakota, Winter and others (2005) found that inclusion of conserved soil moisture (an index that indicates the weighted average of precipitation during the 21 months preceding May of a particular year) improved the model relating Bobolink density to vegetation variables; inclusion of the Palmer Drought Severity Index (PDSI) improved the model relating nest success to Bobolink density. Niemuth and others (2008) incorporated the PDSI and the number of prairie potholes containing water during annual May waterfowl surveys into models and reported that the abundance of Bobolinks along 13 BBS routes in northern North Dakota was positively associated with the number of prairie potholes in May of the same year and in May of the previous year. In wet-meadow pastures in Nebraska, Bobolink density declined with increasing PDSI values (Kim and others, 2008). In tallgrass prairies along the Platte River of Nebraska, adult Bobolink abundance and numbers of juveniles increased with increasing minimum January temperature and increasing January precipitation (Kaplan and others, 2021). Juvenile numbers were positively correlated with the interaction of August PDSI. In a 6-year study in northern North Dakota, Grant and others (2010) showed that Bobolink abundance peaked in the year with the highest annual precipitation. In southeastern North Dakota, Ahlering and Merkord (2016) reported an interaction between precipitation and management treatment, in that Bobolink abundance was greatest at intermediate levels of grazing in the driest year and at burned sites in the driest year. Travers and others (2015) compared historical bird data on species' spring-arrival dates on their breeding grounds in eastern North Dakota in the early to mid-20th century to dates in the early 21st century and concluded that Bobolinks were arriving later in the recent period than in the historical period. Swanson and Palmer (2009) examined spring-arrival dates of Bobolinks in South Dakota (1971–2006) and Minnesota (1964–2005); Bobolinks did not show a significant trend toward earlier or later spring arrival over the time periods examined. Butler (2003) found that the average spring arrival date for Bobolinks in New York and Massachusetts significantly changed between the time periods 1903–50 and 1951–93, with Bobolinks arriving earlier in the latter period than in the former period. In Vermont, McGowan and others (2021) related interannual variation in nest-initiation dates to climate conditions on breeding and migratory stopover areas. Variation was best explained by the interaction between breeding-ground precipitation and average temperature at fall stopover sites. McGowan and others (2021) found that Bobolinks were unlikely to respond to phenological shifts of a changing climate, even though management activities, such as haying, have advanced on the breeding grounds.

Area Requirements and Landscape Associations

Territory Size

Territories include both foraging and nesting areas (Martin, 1967). Average Bobolink territory sizes ranged from 0.38 to 1.67 ha in an Ontario hayfield (Diemer and Nocera, 2014), 0.45 to 0.69 ha in a mixed-species hayland on a floodplain in Wisconsin (Martin, 1967, 1971), 0.49 ha in six tame hayfields in New York (Bollinger, 1988), 1.4 ha in a tame hayfield in Michigan (Raim, 1975), and 2.5 ha in a dry, sparsely vegetated pasture in Wisconsin (Wiens, 1969). Herkert (1991a) reported that the minimum patch area on which Bobolinks were found ranged from 10 to 30 ha in Illinois tallgrass prairie fragments. The minimum patch size requirement for Bobolinks in wet meadows in Nebraska was 46 ha, with a perimeter-to-area ratio of about 0.01 (Helzer, 1996; Helzer and Jelinski, 1999). In southern Minnesota, Bobolink presence was negatively associated with perimeter-to-area ratio and percent of perimeter that was wooded (Cooper, 2005). In Ontario hayfields, Bobolink territory size was affected by patch size, vegetation structure, and prey abundance (Diemer and Nocera, 2014).

Bobolinks had smaller (<1 ha) territories in smaller hayfields (range of hayfield sizes was 4–14 ha), and small territories were characterized by taller and denser vegetation, deeper litter, less bare soil, and more abundant prey items than large (>1 ha) territories. In rotationally grazed pastures in Vermont, the minimum pasture size to accommodate one female Bobolink was 70×70 m (0.49 ha), allowing a nesting female to stay within a pasture and move approximately 50 m between nesting attempts (Perlut and Strong, 2011).

Area Sensitivity

Several studies have reported that Bobolinks are area sensitive (that is, show a preference for larger grasslands over smaller grasslands) (Bollinger and Gavin, 1992; Herkert and others, 1993; Herkert, 1994b; Vickery and others, 1994; Helzer, 1996; Helzer and Jelinski, 1999; O'Leary and Nyberg, 2000; Renfrew and Ribic, 2002; Ribic and others, 2009b; Bruinsma, 2012; Buxton and Benson, 2016; Guttery and others, 2017). In Nebraska, occurrence of Bobolinks was positively correlated with patch area and inversely correlated with perimeter-to-area ratio (Helzer, 1996; Helzer and Jelinski, 1999). In Wisconsin, Bobolink patch occupancy was positively associated with patch area (Guttery and others, 2017). In Ontario, abundance of male Bobolinks was positively associated with pasture size (Pintaric and others, 2019). In New York, Norment and others (1999) found that fields larger than 10 ha supported an average of three or more individual Bobolinks per bird survey per survey point and relatively high nest success. Within a rural/suburban interface near Boston, Massachusetts, the presence of Bobolinks was positively related to the area of open patches (that is, 84 patches varying from 2 to 34 ha and 100 m average width) (Forman and others, 2002). Bobolinks were present in 29 percent of the patches. Regular breeding (evidence of breeding observed in 3 or more years) occurred in 11 percent of the patches, and only on patches greater than or equal to (≥) 7.2 ha. Bobolink presence was unaffected by distance to nearest open patch. In comparing the relative importance of open-patch area to quality habitat (that is, hayfield, pasture, oldfield [that is, idle or neglected arable lands that have naturally reverted back to perennial cover]), area of quality habitat was a better predictor for both presence and use for breeding than was area of open patches (Forman and others, 2002). In hayfields of New York and Vermont, Bobolink abundance was positively correlated with area (Shustack and others, 2010).

A small number of researchers have not found evidence for area sensitivity in Bobolinks. Neither DeJong and others (2004) nor Mozel (2010), working in South Dakota and Manitoba prairies, respectively, found a relationship between Bobolink density or abundance and patch area. In another Manitoba study, Ranellucci (2010) reported that Bobolinks used small grassland patches (study patches ranged from 65 to 260 ha) but showed a preference for large areas of open grassland.

Two studies have indicated that area sensitivity in Bobolinks may vary regionally or annually. In North Dakota and Minnesota tallgrass prairies, Winter and others (2006a) found that patch-size effects varied among regions and years. Within CRP fields in nine counties in North Dakota, South Dakota, Minnesota, and Montana, Bobolinks exhibited area sensitivity, favoring larger contiguous patches of grassland; in models relating occurrence, frequency, and density to area of contiguous grassland, grassland patch size was positively associated with Bobolink presence in three of the nine counties, with Bobolink frequency in two counties, and with Bobolink density in two counties (Johnson and Igl, 2001). Using BBS data from western North Dakota and eastern Montana, Bohannon and Blinnikov (2019) examined the relationship between Bobolink abundance on BBS routes and habitat fragmentation caused by oil-extraction activities. The local population did not significantly decline with increasing edge density (that is, the amount of linear edge per total landscape area).

Bobolinks avoid habitat edges. In eight Bobolink territories in Wisconsin, mean distance from territory boundary to woods was 100 m, to fenceline was 0 m, and to cultivated field was 59.4 m (Wiens, 1969). All territories included posts and fencelines, 25 percent contained wire bales or tangles, and 50 percent contained trees. In Iowa, Bobolink density increased with distance to habitat edges, regardless of edge type (agricultural, forest, or road) (Fletcher and Koford, 2003). In contrast, territory size decreased with distance from road edges, increased with distance from woodland edges, and stayed constant with distance from agricultural edges, indicating that factors causing edge avoidance in Bobolinks may vary among edge types. In restored tallgrass prairies in Iowa, Bobolink density was negatively correlated with the percentage of agricultural edge in the surrounding landscape (Fletcher and Koford, 2002). In Nebraska, Bobolink abundance was lower near woody edges (<100 m) than far (>100 m) from woody edges (Helzer, 1996). In Colorado, Bobolinks were significantly more abundant on interior plots (200 m from edge) than on edge plots (the interface between suburban development and upland or lowland habitat) (Bock and others, 1999).

Habitat edges also may affect Bobolink nest-site selection, productivity, and brood parasitism by Brown-headed Cowbirds (*Molothrus ater*). In New York hayfields, nest densities were much lower than expected within 25 m of forest edges (Bollinger and Gavin, 2004). Nests within 50 m of forest or wooded hedgerow edges had lower daily survival rates compared with nests >100 m from any habitat edge. Females that renested after failure of initial nests placed their nests farther from the edge type in which the initial nest had been unsuccessful. Bobolinks avoided nesting near road edges (whereby roads were paved or graveled two-lane country roads with mowed grass borders), even though nest survival rates were not lower near road edges. Nest densities were lower than expected out to 50 m from the nearest road at one site and out to 100 m at another site. However, Bobolinks did not avoid nesting near edges of oldfields or pastures. Nest survival near these types of edges was similar to or higher than survival of nests >100 m from any habitat edge (Bollinger and Gavin, 2004). In hayfields and pastures in the Champlain Valley of Vermont and New York, Bobolinks avoided placing their nests near edges and placed their nests in open locations more than expected by chance (Keyel and others, 2013). In four grassland types (early, mid-, and late-hayed hayfields, and rotationally grazed pastures) in the Champlain Valley of Vermont, Bobolinks placed their nests farther than expected from field edges but distance to edge had no detectable consequence on reproductive success (Perkins and others, 2013). In Minnesota tallgrass prairies, nest depredation and Brown-headed Cowbird brood parasitism decreased farther from woody edges, and nest depredation rates were lower on large (130–486 ha) than on small (16–32 ha) grasslands (Johnson and Temple, 1990). Nest productivity was highest for nests in habitats far (>45 m) from forest edges (Johnson and Temple, 1986). In contrast to the above two nesting studies, Bobolink nest placement in tame pastures in Wisconsin did not seem to be affected by edge type (Renfrew and others, 2005). Although nest density was lower near edges, the relationship between nest density and distance to edge was not significant. The type of edge (wooded or nonwooded [cropland or grassland]) was not a significant predictor of density within 50 or 100 m. However, sample sizes did not allow the researchers to separate edge types for each bird species. Because of low sample sizes, nests of Grasshopper Sparrows (*Ammodramus savannarum*) and Bobolinks were combined in analyses of nest predation. During incubation, predation was higher for nests that were closer to edges. There was no difference in nest predation rates within 50 or 100 m of wooded or nonwooded edges (Renfrew and others, 2005). In another Wisconsin study, male Bobolink density and number of nests increased near edges after removal of tree rows; daily nest survival increased after the first year of tree removal, but decreased the second year, possibly because of redistribution of the predator community (Ellison and others, 2013). In Wisconsin CRP fields, daily survival rate of Bobolink nests depended on the type of edge; nest survival was lower when nests were placed close to woody/agricultural edges and was unaffected by grassy edges (Byers and others, 2017). Nest depredation was not related to field edge type. In southwestern Manitoba, the relative abundance of grassland-obligate species, including the Bobolink, 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).

Landscape Effects

The distribution and abundance of Bobolinks may be affected by characteristics of the surrounding landscape. Within the Prairie Pothole Region of Canada, Fedy and others (2018) examined the effect of grassland, cropland, shrubland, woodland, and wetland habitats at four scales (within 400; 800; 1,600; and 3,200 m of BBS stops) on the relative probability of occurrence of Bobolinks. The best model for predicting occurrence indicated the species' preference for landscapes consisting of annually seeded cropland and an abundance of wetland basins within 3,200 m; the model indicated avoidance of landscapes with shrubland or tame grasslands and other perennial cropland grown for hay, pasture, or seed, as well as a high wetland area count within 3,200 m of BBS stops (Fedy and others, 2018). In southern Saskatchewan, Bobolink abundance in tame grasslands increased as amount of native grassland within 400 m increased (Davis and others, 2013). In Manitoba mixed-grass prairies, abundance of Bobolink was positively associated with the amount of forest in the landscape at the 1,200- and 4,800-m scales; abundance was negatively associated with the amount of grass cover at the 1,600-m scale and with edge density from 1,600 to 4,000 m (Durán, 2009). In contrast to Durán (2009), Mozel (2010), who also worked in Manitoba, reported that Bobolink density decreased with more forest in the landscape, measured from within 500 m of prairie edges. In south-central Manitoba, McDonald and Koper (2022) reported that Bobolink abundance was positively related to the amount of open cover, which was defined as native and tame grasslands, forage and annual cropland, and vegetated wetlands. Amount of open cover ranked higher in importance than did patch size or proximity to edge. Bobolink abundance was correlated with open cover amount at small (100–200 m) and very large (2,000–5,000 m) spatial extents. Throughout Ontario, amount of hayfield and latitude were positively correlated to Bobolink population trend (Ethier and others, 2017).

In a study encompassing seven States of the northern Great Plains, Dreitz and others (2017) demonstrated that occupancy of Bobolinks was positively related to latitude and percentage of grassland habitats within 1-km^2 survey plots lands and negatively related to lands in public ownership and the percentage of sagebrush habitats within 1-km^2 survey plots. Niemuth and others (2017) investigated the relationship between Bobolink occurrence and land use within a 400-m landscape of BBS points throughout the northern Great Plains; Bobolink occurrence was positively associated with percent coverage of grasslands (native and tame), pasture and hayland (native and tame), CRP fields, alfalfa, and emergent wetlands, but was negatively associated with percent coverage of shrubland, forest, open water, and developed land. In restored grasslands in North Dakota and South Dakota, Bobolinks avoided woodland edges up to 220 m, the farthest distance considered by Tack and others (2017). In North Dakota and South Dakota, Bobolinks were associated with 216 wetlands that averaged 7 ha in size (Igl and others, 2017). Landscape composition within 800 m of these wetlands was 59 percent grassland, 21 percent agricultural, and 15 percent wetland; the average number of wetlands within 800 m of these wetlands was 27. In the Prairie Pothole Region of North Dakota, Bobolinks were positively associated with the total area of grassland within 200 and 400 m of roadside survey points and negatively associated with the area of cropland and woodland within 200 and 400 m of survey points (Browder, 1998). In North Dakota tallgrass prairies, 25 percent of 68 Bobolink nests were parasitized, but rates decreased with increased tree cover; Bobolink nests were 5 percent less likely to be parasitized with every 1 percent increase in tree cover within 2 kilometers (km) of nests (Pietz and others, 2009). In another study in North Dakota tallgrass prairies, Bobolink occurrence was negatively associated with tree cover at the 1,600-m scale (Cunningham and Johnson, 2006). In South Dakota mixed-grass prairies, Bobolink occurrence was negatively associated with the amount of grassland surrounding the patch up to 1,600 m and increasing amount of habitat edge relative to area (Greer and others, 2016). In North Dakota and Minnesota tallgrass prairies, density of Bobolinks decreased in two of the three regions studied and as percentage of shrubs and trees within 200 m of grassland plots increased (Winter and others, 2006a, 2006b). However, the magnitude of this decrease differed among regions and years. Nesting success was not consistently higher in large (>100 ha) or treeless prairie patches (<10 percent shrubs and trees) than in small (<65 ha) patches or patches with trees (>10 percent shrubs and trees). Patch size, distance to the nearest tree, or the percentage of trees and shrubs within 200 m of study plots did not have a strong or consistent effect on nesting success. In fragmented grasslands of native or tame grasses in Minnesota, Bobolink density was negatively related to woodland covariates (that is, the proportion of tree cover within 100, 500, and 1,000 m of point counts) and was positively related to grass covariates (that is, the proportion of grassland cover within 100, 500, and 1,000 m of point counts) (Thompson and others, 2014). Bobolinks were predicted to increase from 0.30 to 0.98 bird per ha as grass-related covariates increased from the 10th to 90th percentile. Bobolinks were predicted to decrease from 0.86 to 0.21 bird per ha as woody vegetation covariates increased from the 10th to 90th percentile. In western Minnesota and northwestern Iowa, Bobolink density was positively related to the percentage of grasslands within 400 m of avian point-count surveys (Quamen, 2007).

Using BBS data from Wisconsin, Michigan, Minnesota, Iowa, and Illinois, Thogmartin and others (2006) reported that Bobolink abundance was sensitive to grassland patch size at finer (800 ha) and intermediate (8,000 ha) scales, but not at 80,000 ha. Abundance differed based on patch size and the proportion of the landscape in forest; Bobolinks were more abundant in grasslands surrounded by forest when grassland patches were large. In Wisconsin, Bobolink patch occupancy was positively related to pasture (mostly tame cool-season grass species), hayland, and idle grasslands (including agricultural set-aside fields, oldfields, and retired pastures, with vegetation consisting of tame cool-season or native warm-season grasses), with positive effects occurring at closer scales (300–1,100 m) than farther distances (out to 3,000 m); patch occupancy was negatively related to cropland and forest at all scales (from 100 to 3,000 m from avian point-count surveys) (Guttery and others, 2017). In another Wisconsin study, the density of Bobolinks along grassland transects was positively correlated with cover-type diversity, the area of woodlots, and the number of patches within 800-m buffers around transects (Ribic and Sample, 2001). Along Wisconsin roadside survey routes, Bobolink abundance was positively correlated to proportions of hayland, idle grassland, pasture, strip-crop, and forest (Murray and others, 2008). Also in Wisconsin, Bobolink density within a site increased as proportion of grass and hedgerows within 200 m of the site increased (Ribic and others, 2009a). In a study encompassing a wide range of terrestrial and aquatic habitats throughout Iowa, Harms and others (2017) reported that Bobolink occupancy was positively correlated to the percentage of the landscape in grassland within 500 m of sampled sites, whereas Bobolink colonization was positively correlated to the largest patch of grassland within 500 m standardized by the total landscape area. In tame grasslands in Iowa, the occurrence of Bobolinks was positively associated with amount of grassland within 300 and 800 m of grassland patches (Robles, 2010). In Iowa and Missouri tallgrass prairies, density of Bobolinks was negatively associated with wooded edge density within 1,000 m (Pillsbury, 2010). In fragmented Illinois tallgrass prairies, Buxton and Benson (2016) found that Bobolink density was positively related to the percentage of forested land within a 1.6-km radius of point counts. In Illinois, a decline in Bobolink abundance over a 41-year period was significantly correlated with declines in the areal amount of alfalfa, oats (*Avena sativa*), and pasture in the northern one-third of the State (Herkert, 1997). In Missouri grasslands, Jacobs and others (2012) found no statistical support for a relationship between Bobolink abundance and grassland type (that is, hayed and grazed native and tame grasslands and idle CRP fields), vegetation structure, or landscape attributes. In New York and Vermont hayfields, Bobolink 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 (Shustack and others, 2010). In late-cut and uncut hayfields in eastern and central Massachusetts, openness (that is, an index based on visual perception of the landscape immediately adjacent to a habitat patch) provided greater explanatory power for site occupancy and population density of male Bobolinks than did physical patch size (Keyel and others, 2012a). Behavioral responses to predators, however, did not explain patterns of settlement of male Bobolinks relative to openness or patch area (Keyel and others, 2012b).

Brood Parasitism by Cowbirds and Other Species

Bobolinks generally are considered a common host of the Brown-headed Cowbird with moderate to heavy parasitism in the midwestern and western portion of their range and an uncommon or rare host in the eastern portion of their breeding range (Hicks, 1934; Friedmann, 1963; Martin, 1967; Friedmann and others, 1977; Davis, 1994; Strausberger and Ashley, 1997; Igl and Johnson, 2007; Shaffer and others, 2019a; Renfrew and others, 2020). Rates of cowbird brood parasitism are summarized in Shaffer and others (2019a) and varied from 0 percent (several studies) to 51 percent of 839 nests in Nebraska (D. Kim, pers. commun. [n.d.] in Renfrew and others, 2020). Bobolinks may be multiply parasitized (Silloway, 1917; Roberts, 1932; Friedmann, 1963; Davis and Sealy, 2000; Igl and Johnson, 2007). In the northern Great Plains, 8 of 15 parasitized Bobolink nests were multiply parasitized; parasitized nests contained an average of 2.2 cowbird eggs (Igl and Johnson, 2007).

Breeding-Season Phenology and Site Fidelity

In Iowa, Michigan, Minnesota, Nebraska, and Wisconsin, Bobolinks arrive on the breeding grounds from late April to mid-May and depart from July to September (George, 1952; Bent, 1965; Martin, 1967, 1971; Harrison, 1974; Johnsgard, 1980; Faanes, 1981; Kent and Dinsmore, 1996; Renfrew and others, 2013). In Alberta and Saskatchewan, Bobolinks arrive in early June and depart around early September (Maher, 1974; Salt and Salt, 1976). In New York, male Bobolinks arrive in late April or early May (Bollinger and Gavin, 2004). In Oregon, Bobolinks arrive in mid-May (Wittenberger, 1980).

Females may renest if their first nest is destroyed and will occasionally attempt to renest a third time (Martin, 1971; Gavin, 1984; Fletcher and others, 2006; Frei, 2009; Renfrew and others, 2020). Female Bobolinks are usually single-brooded (Johnsgard, 1979; Winter and others, 2004), but double-brooding has been reported (Martin, 1971; Gavin, 1984; Bollinger and Gavin, 2004; Renfrew and others, 2020).

Bobolinks exhibit fidelity to breeding sites (George, 1952; Martin, 1971; Bollinger, 1988; Fajardo and others, 2009). In Oregon, 96 percent of 27 banded adult males and 92 percent of 13 banded adult females returned to within 1,000 m of where they bred the previous year (Wittenberger, 1980). One of eight males and six of nine females banded as nestlings returned to within 1,000 m of their natal territories (Wittenberger, 1980). In tallgrass prairies in Nebraska, of 717 adult Bobolinks, 58 were recaptured in subsequent years, 81 percent of which occurred at the same site as initial capture (Kaplan and others, 2021). In restored grasslands in Iowa, return rates of marked Bobolinks were 48 percent of 109 males and 5 percent of 110 females (Fletcher and others, 2006). In Indiana hayfields and pastures, Bobolink return rates were 21 percent of 143 males and 0 percent of 58 females (Scheiman and others, 2007). Of those 30 returning marked male Bobolinks, 80 percent returned to previous breeding sites. In tame hayfields in New York, 44 percent of 59 males and 25 percent of 71 females returned to previous breeding sites in subsequent years (Bollinger, 1988). In Vermont and New York, Bobolink dispersal averaged 1,522 m for 31 1-year-old birds and 370 m for 115 adults (Fajardo and others, 2009). About 30 percent of the natal dispersers and 80 percent of the adults nested within 300 m from where they hatched or nested in previous years. In Vermont, Perlut and Strong (2016) reported that 22 percent of 83 Bobolinks banded as nestlings returned to their natal field. Cava and others (2016) indicated that natal philopatry and short-distance natal dispersal in Bobolinks seem to be affected by factors that are difficult to manage, and thus, land managers should attempt to keep management consistent across time to reduce misinformation in dispersal cues. Denny and others (2021) recorded 70 of 842 nests that belonged to Bobolinks exhibiting natal-site fidelity and 214 nests that belonged to adult birds that returned to the general area where they were banded.

Species' Response to Management

Typical management of grassland ecosystems involves burning, grazing, haying, or a combination of these practices (Shaffer and DeLong, 2019). In the northern Great Plains, the combination of burning and grazing of rangelands is a common management practice implemented by public land managers, such as those on Federal wildlife refuges and grasslands, and by private livestock producers (Danley and others, 2004; Lueders and others, 2006; Ahlering and others, 2019). In eastern grasslands, the combination of grazing and haying may be more prevalent (MacDonald and Nol, 2017; Pintaric and others, 2019; Fromberger and others, 2020). Differences in grazing systems, seasonality of burns, timing and intensity of livestock grazing, and timing of haying across geographical regions make comparisons among studies difficult. For this reason, we are deviating from the standard format in this series (Johnson and others, 2019), which has been to examine fire, grazing, fire-grazing as a combination, and haying separately. For the Bobolink account, we take a regional approach, beginning with the northern Great Plains, followed by the Midwest, and finishing with eastern grasslands; however, there are some general commonalities among regions. One is that grazing can be beneficial to Bobolinks, although scant evidence exists for advantages of rotational grazing systems over traditional season-long grazing in the northern Great Plains (Messmer, 1990; Schneider, 1998; Temple and others, 1999; Buskness and others, 2001; Renfrew and Ribic, 2001; Ranellucci and others, 2012). In eastern grasslands, rotationally grazed pastures may support higher Bobolink productivity, as the number of young fledged per female Bobolink was higher in rotationally grazed pastures compared to hayfields cut early in the breeding season, but lower than in hayfields cut late in the season (Perlut and others, 2006). Another commonality among regions is that trampling of nests by cattle is a concern. In Wisconsin, trampling of Bobolink nests by cattle was the second most common cause of nest failure after predation (Renfrew and others, 2005). In Ontario, 13 percent of 31 nests were trampled by cattle in 1 year and 28 percent of 65 nests in the subsequent year (Campomizzi and others, 2019). In another Ontario study of 75 nests in which 30 nests failed, eight were trampled by cattle (MacDonald, 2014). In a third Ontario study, three of 58 nests were trampled by cattle (Pintaric and others, 2019). Fromberger and others (2020) reported on 463 nests monitored over 6 years from three regions across southern and eastern Ontario. Of this sample, 17 percent of 193 nests were trampled, with 53 percent of 53 nests in rotationally grazed pastures and 10 percent of 40 nests in continuously grazed pastures. In the Champlain Valley of New York and Vermont, Perlut and others (2006) reported that cattle caused 39 percent of 38 nests to fail as a result of cattle eating the nest contents or trampling them. A third commonality across regions is that haying during the breeding season may cause high rates of nest failure for Bobolinks. Tews and others (2013) examined effect of mechanical operations on mortality of Bobolinks in southern Canada. Operations included mowing, tilling, seeding, and harvesting. Tews and others (2013) estimated that 321,000 Bobolinks would annually fledge successfully in the absence of mechanical disturbances. In an Ontario study of 75 nests in which 30 nests failed, four nests were destroyed by mowing (MacDonald, 2014). In a New York hayfield, mowing accounted for 51 percent of Bobolink nest losses (Bollinger and others, 1990). In the Champlain Valley of New York and Vermont, Perlut and others (2006) reported that haying in early hayed fields accounted for 99.2 percent of failure of 130 nests, with 78 percent of failure owing to the machinery. In New Jersey, the only two Bobolink nests active during hay harvesting were destroyed (Allen and others, 2019).

Northern Great Plains Grasslands

Fire

Within mixed-grass prairies in Lostwood National Wildlife Refuge in northwestern North Dakota, Madden (1996) applied knowledge of the refuge’s fire history to evaluate the effect of burning on Bobolink abundance. Abundance was highest in grasslands that had been burned four times in the previous 15 years, compared to unburned areas and areas burned 1–2 times in the previous 15 years (Madden and others, 1999). In mixed-grass prairies in J. Clark Salyer National Wildlife Refuge in north-central North Dakota, the number of indicated pairs of Bobolinks was lowest the first year postburn, peaked the second year postburn, and declined during the 3-year postburn and ≥4-year postburn periods (Grant and others, 2010). Abundance was not associated with any measured habitat feature. Nesting density followed a similar pattern; Bobolink nest density was 7.2 nests per 100 ha during the first postburn growing season, increased to 17.5 nests per 100 ha during the second postburn growing season, and declined during the 3-year postburn and ≥4-year postburn periods (Grant and others, 2011). In mixed-grass prairies dominated by smooth brome and Kentucky bluegrass and ungrazed for at least 5 years at Des Lacs National Wildlife Refuge in northwestern North Dakota, Bobolink abundance was weakly but positively related to fire history (Ludwick and Murphy, 2006). In a combination of restored and native grasslands in east-central North Dakota historically subjected to various burning and grazing treatments, Johnson (1997) examined the effect of prescribed burns on Bobolink density over a 14-year period. Prescribed burns occurred in either spring or fall. Bobolinks were absent in unburned areas, and abundance peaked the first through third year postburn; abundance declined the fifth year postburn (Johnson, 1997).

In Saskatchewan and Manitoba, Davis and others (2017) investigated the effects of burning and haying on Bobolink densities in grasslands converted from cropland to native or tame grass-forb mixtures at least 4 years before the 2-year study. In Manitoba, Bobolinks reached their highest densities 4–5 years postmanagement and their lowest densities in the first and eighth years postmanagement; the treatment effect was stronger in 1 of the 2 years of the study. In Saskatchewan, Bobolink density varied with year. In 1 year, Bobolinks reached their highest densities 8 years postmanagement, which declined linearly to the lowest densities 1 year postmanagement. In another year, the relationship was reversed. However, vegetation structure was a better predictor of Bobolink densities or occurrence than management treatment (burning or haying) or years postmanagement (Davis and others, 2017).

Fire and Grazing

In mixed-grass and tallgrass prairies managed by the U.S. Fish and Wildlife Service in Montana, North Dakota, South Dakota, and Minnesota, Bobolink densities were significantly higher in tallgrass prairie units that were idle, burned, grazed, or burned-grazed than in mixed-grass prairie units that experienced the same management treatments (Igl and others, 2018). In mixed-grass prairies on National Wildlife Refuges in northwestern North Dakota, Danley and others (2004) compared the occurrence of singing male Bobolinks in burned-only plots (prescribed burning schedules on plots varied from three to six burns that occurred 1–8 years since last burn; burns were conducted either in late spring or in summer [Madden and others, 1999]) to plots both burned and rotationally grazed (each of three cells per plot were grazed for 14 days from late May through mid-August; two of three cells were grazed at 0.6–1.2 animal unit months [AUMs] per ha for a second 14-day period after a 28-day rest; grazing occurred 1–4 years after the last of the prescribed burns). Bobolink occurrence was similar in burned-only and in burned-and-grazed plots. In mixed-grass prairies in South Dakota, unburned pastures were lightly grazed (0.2 AUM per ha) in the dormant season by American bison (*Bison bison*) and burned pastures were rested from grazing during the year before a spring burn; Bobolinks preferred lightly grazed pastures over spring-burned areas (Huber and Steuter, 1984).

Grazing

Several studies in the northern Great Plains have evaluated the response of Bobolinks to grazing regimes. Generally, throughout the Great Plains, Bobolinks responded positively to moderate grazing in tallgrass prairies and negatively to heavy grazing in shortgrass prairies (Bock and others, 1993). In Manitoba mixed-grass prairies, Ranellucci and others (2012) and Carnochan and others (2018) examined the effects of twice-over rotational grazing (grazing twice from June to mid-October at an average 1.87 AUMs per ha with about a 2-month rest between grazing and cattle rotated between 3–6 pastures), and season-long grazing (continuous grazing from May through October at an average 2.17 AUMs per ha). In a 2-year study, Bobolink abundance was higher on season-long grazed pastures and idle pastures than twice-over rotational grazed pastures (Ranellucci, 2010; Ranellucci and others, 2012). In another 2-year study conducted 2 years later on the same pastures, Carnochan and others (2018) reported only one Bobolink nest, and that nest was in season-long grazed pastures. In Manitoba mixed-grass prairies, abundance of Bobolinks was the same in idle grasslands as in grazed or hayed grasslands (Durán, 2009). In North Dakota mixed-grass prairies, grazing seemed to have no effect on nest survival, but nest survival was so low (3.5 percent) that grazing effects may have been difficult to detect (Kerns and others, 2010).

In northwestern and central North Dakota, Schneider (1998) examined the effect of two grazing systems on Bobolink abundance. Within the twice-over rotational grazing system, pastures were divided into cells through which cattle were rotated twice during the typical June–October grazing season (although some pastures received cattle in May and still contained cattle in November). Season-long grazing allowed cattle to graze continuously from May through early November. Schneider (1998) reported no difference in Bobolink abundance between rotational twice-over and season-long grazing systems. In south-central and northwestern North Dakota, Bobolink abundances were similar between rotationally grazed pastures and season-long pastures in both years of a 2-year study (Buskness and others, 2001). Rotationally grazed pastures consisted of 4–8 cells that were grazed from May 26 to November 10 at 0.6–2.5 AUMs per ha; season-long pastures were grazed from May 15 to November 1 at 0.9–2.7 AUMs per ha. In mixed-grass prairies in south-central North Dakota, Bobolinks were found only in moderately grazed pastures (2.4 AUMs per ha; 50 percent of forage produced in an average year remained) and not in lightly (65 percent of forage remained), heavily (35 percent of forage remained), or extremely grazed pastures (20 percent of forage remained) (Salo and others, 2004). In the same study area, Messmer (1990) compared Bobolink abundance in idle mixed-grass prairies to three grazing systems of short-duration pastures (that is, pastures rotated through a grazing schedule of about 1 week grazed and 1 month ungrazed), twice-over rotation pastures (that is, pastures grazed twice per season, with about a 2-month rest between grazing), and season-long pastures (that is, pastures grazed continuously). Messmer (1990) found no difference in Bobolink density among grazing systems. Bobolinks preferred short-duration pastures over idle mixed-grass prairies and preferred silty range sites over other soil communities such as shallow-to-gravel and reseeded sites. In southeastern South Dakota, Bobolinks preferred lightly grazed areas on typic ustoll soils (Kantrud and Kologiski, 1982). In grasslands managed by the U.S. Fish and Wildlife Service in Montana, North Dakota, South Dakota, and Minnesota, Bobolink densities increased linearly in the growing seasons after grazed-only, burned-only, and burned-grazed management actions occurred (Igl and others, 2018). Bobolink densities were lower in mixed-grass prairie units than in tallgrass prairie units during the first growing season after grazing. In Nebraska wet meadows, Bobolink densities were higher on ungrazed than grazed plots (Kim and others, 2008). In tallgrass prairies along the Platte River of Nebraska, Kaplan and others (2021) examined Bobolink abundance in patch-burn grazed pastures (system not described; grazing done by cattle) and rotationally grazed pastures (system also not described). Bobolink adult abundance and numbers of juveniles peaked immediately after burning and thereafter declined with time since burning. In rotationally grazed grasslands, Bobolink abundance peaked after the departure of cattle and then declined with time since grazing. Number of juvenile Bobolinks was negligible in the presence of active cattle grazing and increased over time with the departure of cattle (Kaplan and others, 2021).

Livestock type may affect Bobolink abundance (Lueders and others, 2006; Kaplan and others, 2021). In mixed-grass prairies on National Grasslands in southwestern North Dakota, Bobolink densities were lower in cattle-grazed pastures (0.74–1.76 AUMs per ha) without fire than bison-grazed (0.28–0.31 AUM per ha) pastures that also had been managed by fire (Lueders and others, 2006). Cattle-grazed pastures had lower vegetation structure and habitat heterogeneity and higher stocking rates, whereas bison-grazed pastures had higher vegetation structure and habitat heterogeneity and lower stocking rates. In tallgrass prairies along the Platte River of Nebraska, Kaplan and others (2021) examined the effect of bison grazing on Bobolink abundance and productivity. Bison were introduced at rate of about 1 bison per 3 ha on pastures previously grazed by cattle. Compared to an earlier 7-year period in which pastures were grazed by cattle, Bobolink abundance declined over a 3-year period (representing the third to fifth years after the introduction of bison). The annual average number of adult Bobolinks in the 8-ha study site dropped from 12.15 to 4.66, a 62 percent decline. The annual average number of juvenile Bobolinks declined from 1.53 to 0.25, an 84 percent decline. Compared to adjacent grasslands where bison were not introduced but in which haying or cattle grazing occurred, Bobolink abundances remained stable. Compared to hayed grasslands, by the end of the 18-year study, Bobolink abundance was higher in hayed grasslands than in grazed grasslands (Kaplan and others, 2021).

Haying

Haylands in the northern Great Plains provide breeding habitat for Bobolinks. In Saskatchewan, Dale and others (1997) reported that Bobolink abundance was higher in annually or periodically (idle for 4–8 years) mowed tame hayland than in idle native grasslands. Also in Saskatchewan, Bobolinks were more abundant in tame hayfields mowed during drought years (under emergency-mowing allowances) than in native grasslands, tame grasslands, or annually mowed tame hayland (Dale, 1992). Igl and Johnson (2016) 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. Bobolink densities were higher in CRP grasslands that had been hayed 1, 2, 3, and 4 years earlier than in CRP grasslands that had been idled for more than 5 years. In North Dakota, Kantrud (1981) found the highest Bobolink densities in mixed-grass hayland mowed the previous year, with lightly grazed mixed-grass prairies containing the second highest densities and heavily grazed mixed-grass pastures containing the lowest densities. In another North Dakota study, there was no difference in abundance between hayed and idled portions of CRP fields in the year following haying (Horn and Koford, 2000). In Nebraska, Bobolinks occurred more frequently in tallgrass hayland than in tallgrass pastures (Helzer, 1996).

Midwestern Grasslands

Fire

A Wisconsin field that was burned in April in each of 2 years was occupied by Bobolinks in early June in both years; in a year that the field was not burned, it was occupied by mid-May (Martin, 1971). In southern Wisconsin CRP fields, Byers and others (2017) reported that Bobolink nest density was higher in 1–3 years after burning than in the year of the burn, with peak nest density occurring in the second year after burning. Nest density was best explained by litter cover or deeper litter, and the model with litter cover was five times better in explaining nest density than the number of years since the burn. Daily nest survival rate was not affected by the number of years since the burn. In Minnesota, Bobolinks were absent from tallgrass prairies the first year postburn but were present the second year postburn (Tester and Marshall, 1961). Also in Minnesota tallgrass prairies, nest productivity and the probability of encountering Bobolinks were highest the first year postburn than 2–3 years and at least 4 years postburn (Johnson and Temple, 1986). In Illinois tallgrass prairie fragments, Bobolinks preferred recently burned or mowed (burned or mowed 1–4 months before the breeding season) sites over areas burned >1 year previous or unmowed areas (Herkert, 1991b, 1994b).

Fire and Grazing

In western Minnesota and northwestern Iowa, Ahlering and others (2019) examined the effect of management history (time since fire or grazing), grassland type (remnant prairie or restored grassland), and land ownership (public or private ownership) on Bobolink abundance after habitat and landscape variables had been considered. Fire and grazing history best explained additional variation in the abundance of Bobolinks. Bobolinks were more abundant on sites burned within 1 year of the survey year than on sites burned 2 or more years before the survey year. Bobolinks had higher abundances on sites grazed in the survey year and the previous 2 years, and on public than on private lands (Ahlering and others, 2019). In State- and privately owned rangelands in the Grand River Grasslands of southern Iowa and northern Missouri, Pillsbury (2010), Pillsbury and others (2011), and Duchardt and others (2016) evaluated the response of Bobolinks to management treatments of patch-burn grazing (that is, spatially discrete spring fires and free access by cattle at 1.7–3.1 AUMs per ha from May 1 to October 1), grazed-and-burned (that is, free access by cattle and a single complete burn), and burned-only (that is, single complete burn with no cattle). Bobolink densities were highest on burned-only pastures, half as high on grazed-and-burned pastures, and lowest on patch-burn-grazed pastures (Pillsbury, 2010; Pillsbury and others, 2011). Duchardt and others (2016) reported that Bobolinks were most common on patch-burn-grazed pastures and about equally as common on burned-only pastures and grazed-and-burned pastures.

Grazing

In Wisconsin, Bobolink densities did not differ between continuously and rotationally grazed pastures (not described) (Renfrew and Ribic, 2001). Higher densities of Bobolinks were found in pastures under a short-duration grazing treatment (which involved a system of pastures rotated through a grazing schedule of about 1 week grazed and 1 month ungrazed) than in idle areas. In southwestern Wisconsin, Bobolinks were nearly equally abundant in rotationally grazed pastures, continuously grazed pastures, and ungrazed pastures (Temple and others, 1999). Ungrazed grasslands were neither mowed nor grazed from May 15 to July 1. Continuously grazed sites were grazed throughout the summer at levels of 2.5–4 animals per ha. Rotationally grazed pastures, stocked with 40–60 animals per ha, were grazed for 1–2 days and then left undisturbed for 10–15 days before being grazed again; pastures averaged 5 ha. All sites were composed of 50–75 percent cool-season grasses, 7–27 percent legumes, and 8–23 percent forbs (Temple and others, 1999). In Missouri, Bobolinks were most abundant in lightly to moderately grazed tallgrass prairies and were not present in idle prairies (Skinner, 1974, 1975).

Haying

Traditional hayland management that involves an early initial cutting date and one or more subsequent harvests within a growing season may be detrimental to nesting Bobolinks; however, the effects of haying depend on the timing and frequency of the disturbance. Using North American BBS data from Minnesota, Wisconsin, and Michigan, Corace and others (2009) examined the relationship between Bobolink population response and values from an index of mowing intensity that incorporated the date of first harvest, number of harvests, and weeks between harvests. The authors reported that Bobolinks have moderate-to-high affinity for hayfields but found no relationship between haying intensity and population trends for Bobolinks. On a military training facility in Iowa in which hayfields were planted either to tame cool-season grass species or native warm-season grass species, McMullen and Harms (2020) reported no difference in the number of detections of Bobolinks in hayfields mowed during the nesting season (mid-July) than in hayfields mowed after the nesting season (mid-August). In Michigan and Wisconsin, Bobolinks were common in hayfields before mowing but deserted these fields after the fields were mowed (Harrison, 1974; Sample, 1989). In Missouri, however, Skinner (1974) indicated that Bobolinks were present in hayfields before and after haying.

Eastern Grasslands

Grazing

As the application of fire to eastern grasslands is uncommon, this subsection on eastern grasslands will focus mainly on grazing, haying, and the combination of the two practices, with the exception of the Vickery (1993) study. In Maine, Bobolink abundance declined in the year of a burn but peaked the first and second year postburn (Vickery, 1993). Most eastern researchers compare Bobolink abundance or productivity between pastures and hayfields, although Campomizzi and others (2019), Campomizzi and Lebrun-Southcott (2022), and Cassidy and Kleppel (2017) conducted grazing-only studies. In southern Ontario, Campomizzi and others (2019) compared Bobolink fledging success between pastures left ungrazed in 1 year to those same pastures that were grazed in another year; the authors also examined fledging success under an experimental light spring grazing regime (that is, grazed lightly from 4–8 days between May 21 and June 3 and then not again until July 2, early in the season). The grazing system was rotational, in which 5–17 pastures were rotated through during the Bobolink breeding season described as from May through July 15. Although AUMs were not reported, stocking rate was recorded as number of cattle multiplied by days grazed and then divided by area grazed; median stocking rate was 107 cattle-days per ha in 1 year and 111 cattle-days per ha in the second year of the study. Of 28 Bobolink territories, 54 percent fledged young in pastures when the pastures were left ungrazed compared to 16 percent of 25 territories containing fledged young when the pastures were grazed in another breeding season. Of 12 territories in the light spring grazing system, 67 percent fledged young from pastures grazed with a low stocking rate. A predictive model indicated that the probability of young fledging from a territory decreased from 0.53 to 0.04 when mid-season stocking rates increased from zero to 174 cattle-days per ha. Pastures on rotationally grazed beef cattle farms that are ungrazed until the Bobolink breeding season is finished or grazed lightly for a brief duration soon after territories are established can provide areas that enable Bobolink to fledge young. In another study in southern Ontario, Campomizzi and Lebrun-Southcott (2022) examined Bobolink abundance in rotationally grazed and ungrazed fields. Temporary fencing within permanent pastures enabled rotational grazing. Pastures were grazed once or twice by the end of July, were grazed 1–12 days each grazing period, and were grazed 4–7 weeks before being grazed a second time, depending on year; AUMs were not reported. Mean number of male Bobolinks was lower in grazed fields than in ungrazed fields. Observed abundance of Bobolinks decreased by 73 percent in fields after grazing, compared to stable abundance in ungrazed fields. Evidence of nesting was higher in ungrazed than in grazed fields. In east-central New York, Bobolink abundance did not differ among minimally rotated pastures, continuously grazed pastures, and holistic-resource managed 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 days) 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).

Grazing and Haying

Several studies in the eastern grasslands of Ontario and New York compared Bobolink density and reproductive success between pastures and hayfields, so these dual-focused studies will be covered in this section. In southeastern Ontario, MacDonald and Nol (2017) compared reproductive success between cattle-grazed pastures and hayfields on four farms in southeastern Ontario. Over the 2-year study, 62 and 61 pastures were monitored, respectively, with herds of 25 beef cattle rotated among 2–9 pastures annually throughout the grazing season at average stocking rates of 248.62 animal units × days per hectare for 1 year of the study and 206.74 animal units × day per hectare in the second year of the study. The effect of the intensity of grazing within pastures on reproductive success (the proportion of pastures that produced at least one

Bobolink young) was assessed by categorizing herds into three categories based on the proportion of pastures grazed before July 1, with the lowest category indicating that herds grazed 30–65 percent of the pastures available, 80–90 percent of the pastures available, and 100 percent of the pastures. Over the 2 years, 27 and 31 hayfields were studied, respectively. Pastures and hayfields that were grazed or cut before July 1 were categorized as managed, whereas pastures and hayfields that remained ungrazed or uncut until after July 1 were categorized as untouched. A behavioral index measured the level of reproductive activity. Pastures in which cattle grazed a lower proportion of pasture area during the breeding season were more likely to produce ≥1 Bobolink young. In 1 year of the 2-year study, no young were produced in pastures grazed at ≥80 percent, whereas the mean proportion of pastures producing ≥1 Bobolink young grazed at 30–65 percent was 0.29. In the second year, the mean proportions of pastures producing ≥1 Bobolink young grazed at 30–65 percent, 80–90 percent, and 100 percent were 0.63, 0.17, and 0.08, respectively. There was a significant difference in the proportion of pastures producing ≥1 Bobolink young between grazing categories between the 2 years. The primary factor influencing reproductive success of Bobolinks was the date that cattle entered a pasture; Bobolinks experienced higher reproductive success when the entry date was later in the nesting season or after the nesting season (MacDonald, 2014). Bobolink abundance was significantly higher in hayfields than in the rotationally grazed pastures (MacDonald, 2014; MacDonald and Nol, 2017). The behavioral index indicated that untouched fields contained nestlings and that managed fields contained at least one Bobolink pair for more than 3 weeks (a lower measure of reproductive activity). Reproductive activity was negatively associated with managed fields and pastures. Of the total of 75 nests found in fields (33 in pastures and 42 in hayfields), 84 percent were found in untouched pastures and hayfields. Bobolinks nesting in managed fields had lower daily survival rates than birds nesting in untouched fields. Bobolinks did not recolonize or renest in pastures that were grazed early (before June 2) and then left to rest until after July 1. The behavioral index indicated that hayfields cut before July 1 still contained nestlings or fledglings, as mean fledging date was June 16 and June 22, respectively, over 2 years. In both years, with each additional day without hay cutting, the probability of Bobolink producing at least one young increased by more than 20 percent. Several studies have evaluated the use of reproductive indices, such as the ones used by MacDonald (2014) and MacDonald and Nol (2017), as an alternative to nest searching and monitoring of grassland birds and found that reproductive indices often lack the ability to predict nest fate or provide reliable estimates of reproductive performance at the territory or plot level (Rivers and others, 2003; Althoff and others, 2009; Morgan and others, 2010). Results from MacDonald (2014) and MacDonald and Nol (2017) related to productivity should be evaluated within the context and caveats of the growing body of literature on this topic.

In a second Ontario study, Pintaric and others (2019) compared the abundance and reproductive success of Bobolinks between continuously grazed pastures (that is, cattle at a stocking density of 0.31–1.24 animal units per ha have unrestricted access to pastures for most or all of the growing season that ranged from May 10 to June 3 and from September 30 to November 23) and late-cut hayfields (that is, hayed after July 15). Abundances of both male and female Bobolinks were significantly higher in hayfields than in pastures, which had lower vegetation cover and alfalfa cover than did hayfields. However, as vegetation height increased in hayfields, the abundance of both sexes decreased. For female Bobolinks in pastures, abundance increased with vegetation height; male abundance increased as pasture size increased (Pintaric and others, 2019). No relationship was detected between cattle stocking density and Bobolink abundance. Daily nest survival rate was higher in hayfields than in pastures. Nest survival in hayfields was higher with higher vegetation around the nest. Nest survival in pastures was best explained by the interaction between caterpillar (Lepidopteran, Hymenopteran, and Coleopteran larvae) biomass and year, with higher biomass indicating lower nest survival (Pintaric and others, 2019). In southern and eastern Ontario, Fromberger and others (2020) assessed Bobolink nest survival across land-cover types and uses. Nests were monitored in rotationally grazed pastures, continuously grazed pastures, ungrazed pastures, restored grasslands, fallow fields, and late-cut hayfields. Rotationally grazed pastures were those in which cattle were moved through and grazed ≥3 fields of subdivided pastures during the Bobolink breeding season (that is, beginning in May to July 15). Continuously grazed pastures had cattle with unrestricted access to ≥1 field throughout the Bobolink breeding season. Ungrazed pastures were not grazed during the Bobolink breeding season. Restored grasslands were seeded with various species of native seed mixes. Fallow fields were not farmed in any manner and were all former hayfields or cropland. Late-cut hayfields were cut after July 15. A total of 463 nests were monitored over 6 years from three regions across southern and eastern Ontario. Daily survival rate decreased across the nesting season. Stocking rate was negatively associated with daily survival rate, which decreased from 0.96 to 0.69 as stocking rate increased from 0 to 243 cattle-days per ha. At a stocking rate of 40 cattle-days per ha, 64 percent of 33 nests in rotationally grazed pastures were trampled by cattle. Daily survival rate was not related to field type, field area, distance to forest edge, or landscape composition (Fromberger and others, 2020).

In the Champlain Valley of New York and Vermont, Perlut and others (2006, 2008a, 2008b) compared Bobolink density, nest success (daily nest survival), 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 (hayed between June 21 and July 10), late-hayed fields (hayed after August 1), and rotationally grazed fields (cattle rotated through a matrix of pastured and moved after all grass was eaten to a farm-specific height). Density and reproductive success were greatest on late-hayed fields, followed by middle-hayed fields (Perlut and others, 2006, 2008b). Early hayed and grazed fields acted as population sinks because nest success and reproductive success were low. Both the initial cutting date and time between cuttings affected renesting behavior. Bobolinks using late-hayed fields had >25 percent higher apparent survival than those on the early and middle-hayed fields and grazed fields (Perlut and others, 2008a). However, low adult survival resulted in strongly declining populations in all categories of fields. The authors further examined the effect of alternative strategies on increasing the viability of Bobolink populations (Perlut and others, 2008b). Those strategies were (1) modeling how changes in adult and juvenile survival on the nonbreeding grounds increased survivorship for all birds; (2) increasing the total amount of high-quality habitats (that is, middle- and late-hayed fields), such as by converting corn to grassland; (3) decreasing the amount of high-quality habitats by increasing low-quality habitats (that is, early hayed and grazed fields); (4) changing parameters for early hayed fields to those of grazed fields; (5) changing parameters for early hayed fields to those of middle-hayed fields; and (6) increasing the attractiveness of late-hayed fields by decreasing the amount of thatch. The strongest positive response to the management changes occurred when the early hayed fields were converted to middle-hayed or grazed fields; Bobolink survivorship increased. Substituting middle-hayed fields for early hayed fields resulted in a slowing of population declines by 11 percent, compared to baseline declines, whereas increasing the attractiveness of late-hayed fields decreased population declines by 3–4 percent. Increasing the area of high-quality habitats by 5–25 percent marginally slowed population declines; increasing the area of low-quality habitats by 5–25 percent marginally hastened population declines. Based on these scenarios, the authors concluded that current land-management practices in the Champlain Valley will not sustain Bobolink populations (Perlut and others, 2008b). In that same region, Perlut and others (2011) evaluated an incentive program that ensured farmers a high-protein, first hay harvest followed by a 65-day delayed second harvest of greater quantity but decreased quality. Compared to the normal 35–40 day cutting cycle, Bobolink reproductive rates under this incentive program improved from 0.0 to 2.8 fledglings per female per year. In an evaluation of first-year survival of Bobolinks in early versus late-harvested fields, timing of mowing did not explain apparent survival, which was best explained by the interaction between date of fledging and body mass (Perlut and Strong, 2016). Shustack and others (2010) examined occupancy patterns of Bobolinks in Champlain Valley hayfields during a series of three visits. Bobolinks generally vacated fields after cutting and infrequently colonized newly cut fields and fields exhibiting regrowth. Also in the Champlain Valley, Masse and others (2008) conducted an artificial-nest experiment to examine nest success in uncut patches (that is, patches inadvertently missed by haying machinery or avoided purposefully because of saturated soils or debris) within early hayed fields; only one of the 29 artificial nests was depredated, suggesting that uncut patches might reduce nest predation in hayed fields. Denny and others (2021) used a 17-year dataset to evaluate the effect of grassland management type (that is, early hayed, early delayed hayed, middle hayed, late hayed, and rotationally grazed) on daily nest survival of Bobolinks in the Champlain Valley of Vermont. Early hayed fields were cut between May 16 and June 11 and generally again 35 to 52 days later; early delayed fields were cut between May 16 and May 29 and had a 65-day window between the first and second cuts (July 20 to August 2); middle-hayed fields were hayed between June 21 and July 11; late-hayed fields were cut after July 15, typically after most birds have ended their reproductive season; and rotationally grazed pastures supported cattle for various lengths of time during the growing season. Daily nest survival was greater on late-hayed fields than early hayed and early delayed fields and rotationally grazed pastures, and daily nest survival between late-hayed fields and middle-hayed fields was similar. Scott and others (2022) used an 18-year dataset to evaluate the effect of grassland management type (that is, early hayed, early delayed hayed, middle-hayed, late-hayed, and rotationally grazed) on daily nest survival of Bobolinks in the Champlain Valley of Vermont. Grassland management was not found to explain daily nest survival, but Bobolinks fledged fewer young on early hayed fields than other field types. DiMaggio and others (2020) examined the effect of grassland management type on Bobolink divorce (that is, the selection of a different mate in a subsequent nest attempt while the original mate is available). Bobolinks were more likely to divorce after nest failure, but haying management did not affect divorce rate; grazing management was not evaluated. In National Wildlife Refuges in western New York, the timing of the combination of grazing and haying as implemented was beneficial to Bobolinks (Norment and others, 1999). Cattle were grazed from mid-July through October at stocking rates of 0.60 to 0.83 cattle per ha and hayed in August or September. This timing allowed Bobolinks to raise at least one brood with no mechanical or livestock disturbance.

Haying

In southwestern Quebec and eastern Ontario, Frei (2009) examined Bobolink nest success between late-harvested (July 1–15) and uncut hayfields. Mean fledging date was June 24, and 91 percent of young fledged before July 1. July 15 was identified as the optimal date to delay hay cutting to allow Bobolinks to fledge (Frei, 2009). In southern Ontario, Diemer and Nocera (2016) examined Bobolink reproductive success in hayfields cut at traditional times (that is, average harvest data of June 23), late-harvested fields (that is, harvest on or after July 15), and early harvested fields (that is, harvest before June 1 and again after 65 days). Most Bobolinks dispersed from breeding sites before July 15 and had high reproductive success, although forage quality had declined. No Bobolinks renested on early harvested fields. In central Ontario, Brown and Nocera (2017) compared Bobolink fledgling phenology to hay quality over time and concluded that a slightly delayed (early or mid-July) hay harvest would benefit Bobolinks without jeopardizing forage nutrient quality. Similarly, Nocera and others (2005) concluded that delaying cutting of hayfields by 1 week in late June or early July in Nova Scotia would not diminish forage nutrient quality but increased Bobolink fledging rate. A delay of 1.5 weeks (from June 20 to July 1) increased fledging rate from 0 to 20 percent. In Ohio, Bobolink densities were nonsignificantly higher on unmowed than mowed portions of reclaimed strip-mine grasslands. Bobolinks seemed to nest only in unmowed areas, although return rates of banded birds were higher in mowed areas (Ingold, 2002; Ingold and others, 2010). In New York tame hayfields, Bobolinks increased in abundance as the hayfields aged (Bollinger, 1988, 1995). Older hayfields (>3 years old) were characterized by sparse, patchy, grass-dominated vegetation and high litter cover. In New Jersey, Allen and others (2019) evaluated the effect of leaving unmowed portions of hayfields on Bobolink density. Bobolink use of unharvested portions of hayfields increased after haying. Bobolink density on two completely hayed fields averaged 1.1 individuals per ha over 3 years but dropped to zero in all years after mowing. On hayfields that had unhayed portions remaining, Bobolink densities dropped by an average of 57 percent (from 1.8 to 0.8 individual per ha over 3 years).

Planted Cover

Bobolinks commonly use planted grasslands during the breeding season. Bobolinks nested or occurred in CRP fields in Iowa, Michigan, Minnesota, Montana, Nebraska, North Dakota, and South Dakota (Patterson and Best, 1996; Best and others, 1997; Delisle and Savidge, 1997; Roth and others, 2005; Igl, 2009; Negus and others, 2010). In a 12-State study of the north-central Plains, Bobolink populations increased after the establishment of CRP fields (Herkert, 2009). Veech (2006) used BBS data to characterize the landscape within a 30-km radius of populations of Bobolinks throughout the Great Plains that were increasing or decreasing; CRP and rangeland composed a greater proportion of the landscape for increasing populations than for decreasing populations, and urban land composed a greater proportion for decreasing populations. Between 1990 and 2008, Igl (2009) recorded 149 species of breeding birds on several hundred CRP grasslands in nine counties in North Dakota, South Dakota, Minnesota, and Montana; of those species, Bobolinks had the fourth highest average density of indicated breeding pairs. In Minnesota and North Dakota, Koford (1999) reported that Bobolink abundance was equal or nearly equal between CRP fields and WPAs. Bobolinks also were found in PCP grasslands in Canada (McMaster and Davis, 1998). In Canadian aspen parkland, Bobolinks occurred more frequently in PCP grasslands than in cropland (McMaster and Davis, 1998). However, their frequency of occurrence did not differ between hay and pasture sites within the parkland PCP grasslands. In North Dakota, Bobolinks were present in areas seeded to native grasses 1 year after seeding had occurred (Higgins and others, 1984), and Johnson and Igl (1995) estimated that the North Dakota population of Bobolinks would decline by nearly 11 percent if CRP grasslands in the State reverted to cropland.

In Nebraska, Bobolink abundance was higher in undisturbed CRP fields than in CRP fields that were disked and interseeded with legumes (Negus and others, 2010). Undisturbed CRP fields were characterized by higher amounts of grass and litter and lower percentages of bare ground cover than disked and interseeded CRP fields. In the Platte River valley of south-central Nebraska, Bobolink nest densities were higher in six remnant mixed-grass prairies than in six planted grasslands that were formerly cropland (Ramírez-Yáñez and others, 2011). In the Rainwater Basin of Nebraska, Uden and others (2015) evaluated the effect of four scenarios of land-use change on Bobolink abundance. The first scenario was a baseline condition in which some rowcrops were converted to switchgrass under current conditions of climate, irrigation limitations, commodity prices, ethanol demand, and continuation of CRP. The second scenario converted more rowcrops to switchgrass. The third scenario converted all CRP fields to switchgrass, and the fourth scenario converted all CRP fields to rowcrops. Bobolink abundance decreased under all scenarios, but especially under third and fourth scenarios, indicating that replacing CRP fields with either switchgrass or rowcrops would not be beneficial to Bobolinks.

In Wisconsin, Bobolinks occurred in a restored native tallgrass prairie site 3 years after seeding (Volkert, 1992). In northwestern Illinois, Shew and Nielsen (2021) examined the effects of midcontract management (that is, light strip disking, strip herbicidal spray, or strip herbicidal spray with a forb interseeding) on Bobolink presence in CRP fields planted either to brome or to a seed mix of native plant species. Bobolink presence was positively associated with brome fields and negatively associated with native-seeded CRP fields, but presence declined on brome fields with increasing cumulative management and increased on native-seeded fields.

Woody Vegetation

If grasslands are not maintained through periodic disturbances (for example, burning, grazing, haying), Bobolink use declines substantially, possibly because of the accumulation of litter and encroachment of woody vegetation (Johnson, 1997; Olechnowski and others, 2009). In Minnesota grasslands, Thompson and others (2016) evaluated the effect of tree and shrub removal on Bobolinks and other grassland birds. Initial efforts to remove woody vegetation via cutting and shearing were ineffective at controlling woody regrowth, and thus, burning and herbicide applications also were necessary. Mean count of Bobolinks declined in both control and treatment sites, with a lower count occurring in treatment sites in the second year after removal of woody vegetation. In the third through sixth year after removal of woody vegetation, mean Bobolink counts increased to levels similar to control sites, but counts on treated sites never did reach pretreatment levels. Removal of woody vegetation via burning caused a loss of litter layer that may have negatively affected Bobolink numbers (Thompson and others, 2016). In North Dakota and South Dakota, Quamen (2007) and Tack and others (2017) also evaluated the effect of removal of trees from grasslands on breeding bird abundance. Before tree removal, Bobolink abundance was highest at distances farthest from trees; after removal, no distance effect was apparent. Despite this response to tree removal, Bobolink abundance in grasslands with tree removal remained at or below levels observed in treeless grasslands.

Pesticides

Insecticides and herbicides may have direct effects (for example, mortality or reduced productivity) or indirect effects (for example, alterations in habitat or food resources) on Bobolinks. Few studies have evaluated the effects of pesticides on Bobolink populations during the breeding season, although intentional poisoning of Bobolink flocks has been reported on the wintering grounds in Venezuela (Basili, 1997). Mineau and Whiteside (2013) indicated that Bobolinks have died during pesticide-impact studies but found no evidence to suggest that Bobolinks were experiencing regional population-level effects from applications of granular insecticides (Mineau and others, 2005). Quinn and others (2017) examined the response of grassland birds to multiple measures of agricultural change over a 40-year period along the 41st parallel within Colorado, Wyoming, Nebraska, and Iowa. Within this region and time period, total land area planted to cropland increased 40 percent, biomass yield increased 100 percent, and chemical use increased 500 percent. The abundance of Bobolinks declined with increased area farmed, with chemical use, and with more intensive biomass production, although the latter measure was not statistically significant. In Maine, territory density of Bobolinks decreased for 2–5 years following the application of the herbicide hexazinone at a rate of 4 kilograms per ha on lowbush blueberries (*Vaccinium angustifolium*) (Vickery, 1993; Vickery and others, 1994).

Urban Development

Bobolinks seem to be fairly tolerant of urban development. Urbanization may impose limits on the abundance of Bobolinks (Haire and others, 2000). In Colorado, Bobolink abundance was highest at <5 percent urban index, as measured by summing the percentage urban vegetation and percentage buildings and paved area within a landscape composed of the city of Boulder, Colorado, and 1 km surrounding the Boulder Open Space (Haire and others, 2000). In patches of tallgrass prairie of varying sizes in Illinois, Bobolink density was unaffected by the amount of urban development within 1.6 km of point counts (Buxton and Benson, 2016). Within a suburban/rural interface near Boston, Mass., Bobolink presence was not affected by percent-built area (primarily houses with yards) adjacent to survey patches, but the presence of Bobolinks was positively related to the distance from roads used by 15,000–30,000 vehicles per day (Forman and others, 2002). Presence was not affected by roads with 3,000–15,000 vehicles per day, although breeding may be reduced within 400 m from roads with 8,000–15,000 vehicles per day and out to 1,200 m for roads with ≥30,000 vehicles per day. In six northeastern States, Perlut (2014) found that Bobolinks declined by 36 percent over a 41-year period and determined that the most important predictor of this decline was human population growth. In Ontario, Ethier and others (2017) used BBS data to examine the relationship between Bobolink population trends over 25 years and amount of hayfield, pasture, indices of cattle density and hayfield composition, total amount of pesticides used, and change in human population size within Ontario agricultural census division within 5-year sampling periods. Unlike the findings of Perlut (2014), Ethier and others (2017) found that Bobolink growth rates were positively related to human population growth. Loss and others (2014) estimated species vulnerability to building collisions from 23 studies on avian fatalities caused by collisions with buildings in the United States. The Bobolink was recorded as a fatality in three studies and its risk of collision was less than the average collision risk for all species documented as a collision in at least two studies.

Airfields

Schmidt and others (2013) compared bird use in native warm-season grasslands and tame cool-season airfield grasslands in Ohio. Bobolinks were more abundant in the native warm-season grasslands than in the airfield grasslands. Because of the species' small body size, tendency for nonflocking behavior, and other factors, Schmidt and others (2013) categorized the Bobolink into a very low hazard level, indicating a very low probability of being struck by an aircraft.

Energy Development

Bobolinks seem to avoid energy development and related infrastructure. In northwestern North Dakota, Bobolink density was reduced within 150 m of roads associated with unconventional oil extraction sites (that is, hydraulic fracturing and horizontal drilling) (Thompson and others, 2015). The estimated avoidance distances for Bobolinks at single-bore and multibore well sites were 250 and 200 m, respectively. Wind-energy development may negatively impact Bobolink distribution and abundance. Beston and others (2016) developed a prioritization system to identify avian species most likely to experience population declines in the United States from wind facilities based on the species' current conservation status and the species' expected risk from wind turbines. At a score of 4.2, the Bobolink was among 40 of 428 species evaluated with an average priority score of at least a four or above out of nine. Beston and others (2016) estimated that 7.72 percent of the Bobolink breeding population in the United States is 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; 27 Bobolink mortalities were reported at six wind facilities. Erickson and others (2014) compiled data from 116 studies on small-passerine fatalities caused by collisions with turbines at 71 wind-energy facilities in the United States and Canada. The Bobolink was among the 25 most common species of small passerines that were found as a fatality caused by a collision during a 17-year period. The effect of wind facilities on Bobolinks was examined in mixed-grass prairies in North Dakota and South Dakota (Shaffer and Buhl, 2016). The species exhibited displacement at two of three wind facilities. Displacement occurred within 200 m at one facility and at all evaluated distances (0 to >300 m) at the second facility. Displacement was most obvious at the wind facility where Bobolink density was highest, but also where many small wetlands contained nesting pairs of Icterids. Therefore, density-dependent factors and intra- or interspecific competition may have been factors at this facility.

Management Recommendations from the Literature

Grassland Protection and Restoration

Throughout the Bobolink's breeding range, the protection, maintenance, and restoration of large tracts of grassland habitat that support stands of tall, dense grasses and forbs will benefit Bobolink adults and fledglings (Bakker and Higgins, 2009; Herkert, 2009; McCracken and others, 2013; Uden and others, 2015). Bobolinks will use planted, restored, and native grasslands, but most effective management efforts may be in landscapes where native grasslands still exist. In eastern South Dakota and western Minnesota, native grasslands provided the most suitable habitat for grassland birds, and the authors cautioned against planting tame grass species, as these plantings had the lowest density of Bobolinks (Bakker and Higgins, 2009). In restored tallgrass prairies embedded in cropland-dominated landscapes in Iowa, conservation strategies that focus on increasing juvenile and adult survival will be important in maintaining Bobolink populations (Fletcher and others, 2006). Efforts to decrease nest predation may include managing the predator community, increasing grassland patch size, and increasing the amount of grassland habitats available in the landscape. In cropland-dominated landscapes, conversion of cropland to perennial grassland cover will be beneficial to Bobolinks (Davis and others, 2013). Habitats such as hayfields harvested after the Bobolink breeding season and grasslands enrolled in the CRP may be especially beneficial in maintaining Bobolink populations (Perlut and others, 2006; Ribic and others, 2009a; Uden and others, 2015). Maintaining complexes of grasslands and wetlands will ensure suitable habitat for Bobolinks under different moisture regimes (Niemuth and others, 2008).

Grassland patch area and configuration are important factors in decisions about what grasslands to protect, maintain, or restore (Helzer and Jelinski, 1999). Creating large patches (>10–50 ha) of habitat and minimizing woody edges may increase Bobolink densities and decrease Brown-headed Cowbird parasitism (Johnson and Temple, 1990; Bollinger and Gavin, 1992; Helzer, 1996; Helzer and Jelinski, 1999; O'Leary and Nyberg, 2000; Cunningham and Johnson, 2006; Quamen, 2007; Ellison and others, 2013; Tack and others, 2017). Shape, as well as area, of management units must be taken into consideration for management purposes; perimeter-area ratio strongly affected occurrence of Bobolinks in Nebraska (Helzer and Jelinski, 1999). Greer and others (2016) reported that as patch shape became more complex (that is, greater edge-to-area ratio) in South Dakota, the density of Bobolinks decreased. Bock and others (1999) recommended reducing the amount of grassland edge near suburban interfaces (Bock and others, 1999). Fletcher and others (2006) indicated that increasing grassland patch size and the total area of grasslands in the landscape may ameliorate the negative effect of nest predation. Prioritizing the protection of grassland parcels embedded in a landscape matrix with a high proportion of other grasslands may satisfy the Bobolink's apparent preference for large, contiguous grasslands (Helzer and Jelinski, 1999; Veech, 2006; Quinn and others, 2017). Quinn and others (2017) cautioned that conservation efforts focused on local remnant or restored patches, without consideration of the matrix of land uses within the surrounding landscapes, may be counterproductive, especially in landscapes dominated by intense agriculture. Guttery and others (2017) suggested that the surrounding landscape matrix can include multiple grassland habitat types, including but not limited to idle grasslands, pastures, and hayland. In urban or cropland-dominated landscapes, the only existing grasslands may be small patches (Ribic and others, 2009a). Bakker and others (2002) and Greer (2009) emphasized the importance of conserving remaining small grassland patches embedded within landscapes with a high proportion of grassland habitat.

McCracken and others (2013) and Renfrew and others (2019) summarized conservation actions that include the continuation, expansion, and creation of protected landscapes and of policies and programs aimed at reversing the rangewide decline of the Bobolink population. In areas where fragmentation is high because of urbanization and agriculture, or where unchecked vegetation succession eventually degrades Bobolink habitats, public lands protect imperiled habitats upon which Bobolinks rely. Examples include the U.S. Forest Service's Sheyenne National Grassland for tallgrass prairie and oak savanna in southeastern North Dakota (Ahlering and

Merkord, 2016), the J. Clark Salyer National Wildlife Refuge for mixed-grass prairies in north-central North Dakota (Grant and others, 2010), and the Open Space of Boulder, Colo., for shortgrass prairies (Haire and others, 2000). Federal policies that protect grassland types on public land, such as the hayfields found on military installations like Camp Dodge Joint Military Training Facility in Johnston, Iowa, may be key to preserving habitats inhabited by Bobolinks (McMullen and Harms, 2020). Federal policies that protect grasslands on private land, such as CRP grasslands or conservation easements, provide avian habitat (McCracken and others, 2013), although Quamen (2007) cautioned that protected areas in western Minnesota and northwestern Iowa did not overlap with areas of projected highest avian richness. Quamen (2007) advocated for the application of conservation planning maps to guide placement of grassland restoration—such as CRP—or grassland protection in the form of easements, and where placement optimizes benefits to grassland birds.

Because over 70 percent of the United States is held in private ownership (Ciuzio and others, 2013), privately owned lands (especially hayfields and pastureland generally referred to as "working lands") can provide habitat and protect native ecosystems. Guttery and others (2017) found that, of the grassland types that they studied, all four of their focal species, including Bobolinks, were positively associated with pasturelands, and Veech (2006) found that rangeland constituted a greater proportion of the landscape for increasing Bobolink populations than for decreasing populations. Guttery and others (2017) stated that multiple-use management aimed at livestock production and bird conservation may present the greatest opportunity for improving grassland bird population trends if wildlife management and land conservation agencies can establish meaningful incentives for, and cooperative agreements (for example, conservation easements) with, private landowners. McCracken and others (2013) and Renfrew and others (2019) provide examples of several such incentive and cost-share programs. Grassbanks are another example of conservation partnerships between Federal, State, and Tribal agencies; nongovernmental organizations; and private landowners. Gripne (2005) described a grassbank as a conservation tool that exchanges the value of a given amount of forage for conservation benefits. Bobolinks benefit from grassbanks for the grassland habitat protected and, in some cases, the higher abundances on private grasslands than on public lands (Ahlering and others, 2019). In addition, the ability to manipulate factors such as stocking rate that affect Bobolink demographics requires good relationships and agreements with private individuals (Salo and others, 2004).

Some of the widest-ranging examples of public/private partnerships are the PCP in Canada and the CRP in the United States (McMaster and Davis, 1998; Igl, 2009; Igl and Johnson, 2016), both of which provide habitat for Bobolinks and other grassland birds by converting cropland to perennial grassland cover. Federal landowner incentive programs like the CRP can provide valuable conservation benefits to a myriad of wildlife, and the effectiveness of this program in providing breeding habitat for the Bobolink has been well established (Herkert, 2009). The Bobolink population in the north-central United States showed growth after initiation of the CRP, demonstrating the effectiveness of this program (Herkert, 2009). Disturbances to planted CRP fields should be kept to a minimum; Bobolink abundance was highest in CRP fields that had been undisturbed for >10 years and was lowest in fields that had been disked and interseeded (Negus and others, 2010). Igl and Johnson (2016) suggested that land managers maintain a mosaic of CRP grasslands, including some that have been idled long-term and others that have been hayed or disturbed periodically at 3–5-year intervals. Davis and others (2017) suggested that the type of management (for example, burning or haying) on planted grasslands may be less important than tailoring the frequency, timing, and type of management to local environmental conditions in a given region and year, with less frequent management in arid environments and more frequent management in mesic environments. Davis and others (2017) further recommended that managers establish a mosaic of grasslands that vary from 1 to 6 years since the last management treatment and that treatments occur outside of the breeding season to reduce avian mortality or nest destruction from haying or burning. Blank and others (2014) reported that newer programs to establish grasslands as sources for bioenergy create more preferred habitat for Bobolinks than corn fields; thus, incentives to convert grasslands to corn fields would be detrimental to the species (Blank and others, 2014; Uden and others, 2015). Blank and others (2014) suggested that establishing bioenergy grasslands in a landscape of other grassland parcels maximizes the benefit to Bobolinks but cautioned that the timing of biomass harvests to minimize nest loss will be an important consideration. Decreasing herbicide use on bioenergy fields would increase forb abundance, which would benefit Bobolinks (Murray and Best, 2003). McCoy and others (2001) cautioned that recommendations about planting cool-season or warm-season grass species should be evaluated with considerations to how fields are managed and whether the fields are monocultures or of multispecies seedings. Bobolinks can be found in both cool-season and warm-season plantings and the value of the grasslands may depend as much on habitat structure and management history as plant species composition (McCoy and others, 2001). Former coal mines that are eligible for reclamation may be good targets for grassland creation and preservation, as they often are large (>2,000 ha), owned by a single entity, and are not desirable for agricultural uses (Galligan and others, 2006).

Woody Vegetation

Grasslands fragmented by trees or roads may be unsuitable to Bobolinks. Bollinger and Gavin (2004) considered the following habitats as poor habitats for Bobolinks: small grasslands (especially those <10 ha) that are surrounded by forests, larger sites that are dissected by wooded hedgerows, and grasslands bordered by roads. 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. Grasslands bordered by pastures or oldfields, even if the grassland patches are relatively small, may provide suitable habitat; nest success in New York hayfields was as high near pasture and oldfield edges as in the interiors of the hayfields (Bollinger and Gavin, 2004). Quamen (2007) discouraged conservation programs from including provisions that support the planting of trees and tall shrubs within grasslands. Removal of tree rows may increase Bobolink abundance and nest densities near edges and possibly create larger grassland patches (Quamen, 2007; Ellison and others, 2013; Tack and others, 2017). Quamen (2007) recommended that resource managers remove tree belts from grasslands where conservation of Bobolinks and other native grassland songbirds is a primary management objective. Given that grassland bird abundance is lower within 220 m of a woody edge, Quamen (2007) extrapolated that one tree belt on an average-sized (87 ha) Federal tract of land in North Dakota would reduce habitat benefits for Bobolinks and other grassland birds on 25 percent of Federal public lands. Thompson and others (2014) recommended focusing tree removal on linear features because they create more edge than a woodlot, and to target woody features that are isolated from other wooded habitats to maximize the percent reduction in woodland for a grassland patch. Once woody vegetation is established, successful, long-term removal is expensive, challenging, and may require management treatments that are not immediately beneficial to Bobolinks (Thompson and others, 2016). Quamen (2007) and Tack and others (2017) recommended that land managers remove shelterbelts from grasslands where conservation of grassland songbirds is a primary management goal. In southwestern Manitoba, WMAs would provide more suitable habitat for grassland songbirds if grasslands were managed with haying or grazing to help curtail encroachment of woody vegetation (Durán, 2009).

Management Timing

Regardless of geographic location within the Bobolink breeding range, it is important to avoid disturbing (for example, burning, haying, or moderately or heavily grazing) Bobolink nesting habitat during the breeding season (Bollinger, 1991; Brown and Nocera, 2017; MacDonald and Nol, 2017). Where possible, treatments should be conducted in early spring (several weeks before the arrival of adult Bobolinks on the breeding grounds) or in the fall after the breeding season (Renfrew and others, 2020). For agricultural producers to implement management practices that benefit Bobolinks, the timing of treatments may need to be compatible with meeting the nutritional quality of hay used for livestock forage or the nutritional requirements of grazing livestock (Nocera and others, 2005; Perlut and others, 2006; Perlut and Strong, 2011; Brown and Nocera, 2017).

Fire

Prescribed fire is an effective management tool for restoring native grasslands invaded by woody vegetation and nonnative plant species (Johnson, 1997; Madden and others, 2000, Grant and others, 2010, 2011; Murphy and others, 2017). Grant and others (2010) warned that burning as a management tool may be applied too infrequently in the northern Great Plains, and that the extent and frequency of prescribed burns need to increase above current levels to maintain and restore the ecological integrity of native prairie. Burning large grassland areas on a rotational basis, burning portions of the total grassland area each year, or burning small grassland areas periodically are all useful approaches to create a variety of successional stages (Renken, 1983; Renken and Dinsmore, 1987; Madden, 1996; Johnson, 1997). Although burning at >10-year intervals might increase nest density for some bird species in the short term, such a lengthy interval allows prairies to become encroached upon by invasive plant species, thus degrading prairie quality in the long term (Grant and others, 2011). Recommended fire-return intervals vary from 3–12 years (Grant and others, 2011; Grant and Knapton, 2020) to 5–10 years (Madden and others, 1999) for mixed-grass prairies threatened with invasion by aspen and nonnative grass species and 4–6 years in created grasslands within the aspen parkland ecoregion of Canada (Davis and others, 2017). In tallgrass prairies and eastern grasslands, more frequent burns may be warranted, as Bobolink productivity and occurrence peaked on recently burned (year of burn to 2 years) postburn than beyond 2 years postburn (Tester and Marshall, 1961; Johnson and Temple, 1986; Herkert 1991b; Vickery, 1993; Ahlering and others, 2019). In some areas, controlled burns may be necessary on CRP fields every 3–5 years to reduce dense vegetation (King and Savidge, 1995). In southwestern Wisconsin, Byers and others (2017) found that Bobolink nest density in CRP fields was higher 1–3 years postburn than the year of the burn, peaking at 2 years postburn, although daily nest survival was not affected by number of years postburn.

Rotating treatments over time on several adjacent prairie fragments will make a variety of successional stages available (Herkert, 1994b). Large areas (>80 ha) should be burned using a rotational system. Subunits of ≥30 ha in area, or about 20–30 percent of the total area, should be treated in a year (Herkert, 1994b). In small, isolated prairie fragments, it may be beneficial to burn ≤50–60 percent of the total area at a time (Herkert, 1994b). Haying or burning patches every 2–3 years will prevent excessive encroachment of woody vegetation (Bollinger and Gavin, 1992; Herkert, 1994b).

Fire and Grazing

Combination treatments, such as grazing and burning, are frequently applied in certain regions or habitats, such as the tallgrass prairies. In tallgrass prairies from Minnesota to northern Missouri, Bobolinks may tolerate some degree of grazing and burning (Pillsbury, 2010; Pillsbury and others, 2011; Duchardt and others, 2016; Ahlering and others, 2019). In western Minnesota and northwestern Iowa, Ahlering and others (2019) found that Bobolink abundance was highest in pastures grazed in the survey year and the previous 2 years and burned areas within 1 year of the burn, suggesting that habitat preferred by the species could be established by promoting grazing on public lands that currently are not being grazed and maintaining burning practices. In the Grand River Grasslands of southern Iowa and northern Missouri, Bobolink abundance was highest on burn-only pastures compared to patch-burn/grazed and complete burn/grazed pastures, presumably because vegetation growth after burning created tall and dense structure preferred by the species (Pillsbury, 2010; Pillsbury and others, 2011; Duchardt and others, 2016). Patch-burn grazing was not well-tolerated by Bobolinks, and patch-burn grazing did not produce the vegetative structural heterogeneity that provided suitable habitat for multiple avian species. High livestock stocking rates likely diminished the expected advantage of patch-burn grazing in terms of providing vegetation heterogeneity and thus avian diversity (Pillsbury, 2010). There was no difference in measures of vegetation heterogeneity between pastures in which distinct patches were burned and then grazed to pastures that underwent a complete burn and had free access by cattle; pastures that were burned but not grazed had the highest structural heterogeneity, and Bobolink densities were highest in these pastures (Pillsbury, 2010). Building on the study by Pillsbury and others (2011), Duchardt and others (2016) discovered that lowering stocking rates on small and fragmented patch-burned grazed pastures allowed avian diversity to increase. They suggested that stocking rates be adjusted annually based on the residual vegetation remaining in pastures, but that there may be a small margin of error in this adjustment in small grassland pastures (Duchardt and others, 2016). Similar to Ahlering and others (2019), Pillsbury and others (2011) concluded that the stark reductions in livestock stocking rate that would have created heterogeneity would best be achieved on public lands and recreational private lands where revenues from livestock production would be of secondary importance.

Grazing

From a study conducted in grazed and hayed native mixed-grass prairies in North Dakota, Kantrud (1981) recommended light grazing for Bobolinks; grazing was a subjective measure based on percentage bare soil, amount of standing and fallen dead vegetation, and average vegetation height compared to adjacent ungrazed areas. For northern mixed-grass prairies generally, Salo and others (2004) recommended moderate grazing (that is, 50 percent of the forage produced in an average year remained, about 2.4 AUMs per ha). In areas in Missouri where the average height of vegetation is 20–30 cm, grazing at moderate levels may provide diverse grass heights and densities and maintain plant vigor of warm-season grasses in tallgrass prairies, especially if they are not grazed to a height of <25 cm during the growing season (Skinner, 1974, 1975). In eastern grasslands, Campomizzi and others (2019) suggested light grazing (that is, a stocking rate of 31–40 cattle-days per ha [similar to 15 cattle for 5 days in a 2-ha pasture]) during the last week of May when rotational grazing is going to be used. Fromberger and others (2020) offered 40 cattle-days per ha as the threshold above which the daily survival rate of Bobolink nests rapidly decreases.

Several researchers in the northern Great Plains and the Midwest have reported that Bobolink abundance is similar between season-long grazing systems and rotationally grazed systems (Messmer, 1990; Schneider, 1998; Temple and others, 1999; Buskness and others, 2001; Renfrew and Ribic, 2001; Ranellucci and others, 2012). Ranellucci and others (2012) suggested implementing several grazing systems, and not promoting any one over another, to increase grassland bird diversity and to be mindful of the role that grazing plays in curbing woody species encroachment, which is a threat to grassland bird habitats. Pastures that were grazed season-long had higher species richness and diversity of obligate grassland birds and had spatially heterogeneous areas and temporally stable areas of high and low livestock use within any given pasture, thus increasing the diversity of microhabitats. Little evidence was found that twice-over grazing contributed to the conservation of grassland songbirds. Buskness and others (2001) and Renfrew and Ribic (2001) pointed out factors other than, or in addition to, type of grazing system that may impact avian abundance—namely, annual differences between temperature, precipitation, the date that cattle are turned out, past grazing intensity, and differences between pasture types (for example, upland vs. lowland pastures). Kaplan and others (2021) cautioned that bison grazing may have detrimental impacts on Bobolink abundance, especially if bison are allowed to overgraze pastures. Where bison were grazed at lower rates than cattle, Bobolink abundance was higher on the bison-grazed pastures, but this result may be confounded by burning (Lueders and others, 2006). Cattle pastures were not burned, whereas bison pastures were burned (Lueders and others, 2006).

In eastern grasslands, grazing system may be less of a factor than grazing intensity in determining pasture suitability for Bobolinks. In east-central New York, Cassidy and Kleppel (2017) found no difference in Bobolink abundance among grazing systems. In comparing ungrazed fields to rotationally grazed fields in eastern Ontario, Campomizzi and others (2019) and Campomizzi and Lebrun-Southcott (2022) concluded that ungrazed fields yielded higher Bobolink productivity and abundance. MacDonald and Nol (2017), Campomizzi and others (2019), and Fromberger and others (2020) all reported that increased stocking rates decreased Bobolink productivity. Campomizzi and others (2019) suggested several ways to make rotational grazing compatible with Bobolink productivity: (1) do not graze until after July 15, (2) target pastures with multiple Bobolink territories as the pastures that will not be grazed, and (3) graze lightly (that is, a stocking rate of 31–40 cattle-days per ha [similar to 15 cattle for 5 days in a 2-ha pasture]) during the last week of May on pastures where grazing is necessary. Campomizzi and Lebrun-Southcott (2022) recommended allowing a rest period of 6 weeks or more between grazing bouts to allow renesting adults time for the second nests to fledge young. MacDonald and Nol (2017) stated that early grazed (before June 2) pastures with a rest period are not sufficient to support Bobolinks and suggested maximizing the number of pastures that remain ungrazed through at least July 1. They suggested that the best time to select such fields would be mid-May, when Bobolinks have established territories so that the fields with the most territories are selected. Perlut and Strong (2011) recommended that land managers using rotational grazing systems in the northeastern United States balance grazing objectives and birds' breeding requirement by resting pastures 42–45 days before the second grazing. Similar to Buskness and others (2001), MacDonald (2014) concluded that Bobolinks produced more fledglings when the date that cattle entered pastures was later in the nesting season (after July 1), or even after the nesting season. On National Wildlife Refuges in western New York, the practice of not allowing cattle to graze until after mid-July allows Bobolinks to successfully rear young (Norment and others, 1999).

Haying

Throughout the Bobolink breeding range, haylands provide important habitat for nesting. Numerous studies have shown that Bobolinks prefer hayland over pastures and idle grasslands, from the northern Great Plains (Kantrud, 1981; Dale, 1992; Helzer, 1996; Dale and others, 1997; Kantrud, 1981; Horn and Koford, 2000; Igl and Johnson, 2016) to eastern grasslands (Perlut and others, 2006, 2008b; Ethier and others, 2017; MacDonald and Nol, 2017; Pintaric and others, 2019). However, conventional management of hayland is generally detrimental to grassland bird species as traditional mowing dates occur within the avian breeding season when nests, eggs, and juvenile and adult birds can be destroyed or killed (Frawley and Best, 1991). Renfrew and others (2019) described several practices to develop economically viable haying schedules that allow Bobolinks to produce young, including ideas like developing markets for late-cut hay and financial-incentive programs that pay agricultural producers to delay haying. Because mid-season haying may result in high nest and fledgling mortality, haying later in the breeding season will benefit Bobolinks (Herkert and others, 1993). For Canadian prairie provinces, Dale and others (1997) recommended delaying haying until after July 15, by which date the authors estimate that at least 70 percent of Bobolink nestlings will have fledged in years of normal breeding phenology; haying should be delayed further if nesting is hampered by inclement spring weather or drought. Based on nest-initiation dates for northwestern North Dakota, Grant and Shaffer (2015) estimated that delaying haying until August 1 would allow all Bobolink nests to be completed. For midwestern grasslands, managers can reduce disturbances to nesting birds in hayfields by delaying haying 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; Durán, 2009). When haying cannot be delayed, Dale and others (1997) and Herkert and others (1993) recommended that large fields can be divided in half with each half hayed in alternate years, which will ensure some productivity in individual fields as well as provide protective cover for fledglings in the unhayed half of the field. 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 eastern grasslands, harvesting hay as late in the breeding season as possible would be beneficial to Bobolink fledglings and late-nesting females (Bollinger, 1991). Although Harrison (1974) suggested that delaying haying until the end of June was sufficient time to allow young Bobolinks time to fledge, Bollinger (1991) advocated for late July or August. In Ontario, Frei (2009) recommended that harvesting be delayed until at least July 1, which was a minimal date, as fledglings at least have enough mobility to leave the area being harvested. To dissuade Bobolinks from nesting in hayfields that will be hayed during the Bobolink breeding season, Frei (2009) recommended grazing or haying those fields late in the previous year or early in the spring to create vegetation conditions that Bobolinks would not settle in for breeding. If haying during the Bobolink breeding season before mid-July is necessary, setting aside small portions of marginal land would be better than total-coverage haying; some government programs are available for such systems (Fajardo and others, 2009). Adjacent patches of alternative habitat may provide refuge for fledglings to escape from hayed areas and refuge for late-nesting attempts (Bollinger and others, 1990). Allen and others (2019) recommended leaving portions of hayfields unharvested to act as refugia that Bobolinks can use after the remainder of the hayfield is harvested. For Nova Scotia hayfields, Nocera and others (2007) recommended that an optimal harvest window to benefit Bobolinks would be early July to late August.

Delaying the cutting of hayland requires a balance between maintaining nutritional quality for cattle and maximizing songbird fledging rate (Nocera and others, 2005; Diemer and Nocera, 2016). Delaying the first harvest allows for successful fledging, whereas foregoing a late (for example, after late August) cutting would allow for the extra growth and height in vegetation in the subsequent year that is preferred by Bobolinks in the spring. In cases where late-season harvesting is a necessity, staggering harvests across a farm so that some fields are cut but some fields remain uncut would still maintain some suitable habitat. In Nova Scotia, delaying the first cutting until July 1 translated to a decrease in the percentage crude protein, the measure of nutritional quality of hay, by 2.1 percent, but an increase in fledging rate from 0 to 20 percent for Bobolinks (Nocera and others, 2005). Postponing cutting to July 7 allowed for peak fledging rates to be obtained, but the percentage crude protein decreased by 3.5 percent. A decreased percentage crude protein content of 2.1 percent would provide the energy maintenance levels necessary for nonlactating beef cows; a decreased percentage crude protein content of 3.5 percent would require supplementation. In central and southern Ontario, Diemer and Nocera (2016) and Brown and Nocera (2017) recommended a modest delay in the first harvest of hayfields to early or mid-July to balance the needs of agricultural producers and breeding Bobolinks. Implementation of this recommendation resulted in small declines in hay quality but substantial increases in Bobolink reproductive success; however, both peak Bobolink fledging and the maintenance of necessary levels of crude protein content were 1 to 2 weeks later than found by Nocera and others (2005) in Nova Scotia.

For eastern grasslands, Perlut and others (2006, 2008b) recommended decreasing the number of fields hayed in late May and early June and increasing the number of fields that are hayed after August 1 but removing thatch on these fields before the following nesting season. Because that strategy may not be feasible for the needs of producers of livestock forage, a secondary recommendation is to delay second cuts on early hayed fields, and by completing the first cut before May 31 to lessen the investment of adult Bobolinks before nest failure. 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 (Perlut and others, 2006, 2008b, 2011). However, Diemer and Nocera (2016) found that this strategy was unsuccessful in Ontario because Bobolinks did not nest on early cut fields during the 65-day interim.

Planting or maintaining patches of relatively sparse, grass-dominated vegetation that resembles old (that is, >8 years since planted) hayfields is recommended (Bollinger and Gavin, 1992). Scattered forbs (for example, clover [*Trifolium* spp.]) should be encouraged for nest-site cover. Although Bobolinks preferred eastern haylands with high grass-to-forb ratios, Bollinger (1988, 1995) found that a minimal forb component for nesting cover was beneficial. In Ontario, Frei (2009) suggested that monoculture fields of alfalfa and timothy would likely support few Bobolinks, so such fields could be harvested early to allow more fields with more suitable mixes of grass, and forb species could be cut late to benefit the Bobolink nesting cycle.

The high site fidelity of Bobolinks to breeding habitats, regardless of quality, may be problematic from a management perspective (Fajardo and others, 2009). Bobolinks exhibit high site fidelity to early hayed fields where annual fledging rates for the population were less than replacement values (Fajardo and others, 2009). The high site fidelity may constrain the species' ability to select fields that would provide higher reproductive success. Bobolinks that nested in fields that were managed for several years as late-hayed fields could experience lower reproductive success if these fields are changed to early hayed fields or to pastures; 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).

In contrast to the timing of haying of conventional hayfields, fall harvesting of CRP switchgrass fields may be beneficial to some grassland bird species (Roth and others, 2005), although Bobolinks may prefer unharvested fields. Thus, providing some unharvested fields each year would provide habitat for a larger number of bird species (Roth and others, 2005). Similarly, Murray and Best (2003) and Murray and others (2003) stated that a mixture of total-harvested, strip-harvested fields, and unharvested fields would provide habitat for numerous avian species; Bobolinks used all three management types in Iowa. To increase habitat diversity in switchgrass fields to benefit multiple avian species, Uden and others (2015) recommended harvesting switchgrass fields at different times and at varying heights, as well as investigating how switchgrass hybrids affect stand structure.

Targeted outreach with land managers and adoption of bird-friendly haying schedules may improve the conservation status of Bobolinks and other imperiled grassland-nesting birds (Gruntorad and others, 2021). Gruntorad and others (2021) reported that 60 percent of 229 landowners surveyed in the Nebraska Sandhills were willing to delay hay harvest for the conservation of both gamebirds and songbirds (including the Bobolink) to allow birds to successfully nest and raise young.

Energy Development

Thompson and others (2015) stated that the footprint of oil development could be minimized by clustering oil wells along corridors and on bore pads rather than placing numerous single-bore well pads throughout the landscape. 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 anthropogenic developments such as wind, oil, and natural gas facilities and related road infrastructure. The avian-impact offset method calculates the biological value (measured in terms of avian density) lost when Bobolinks and other species avoid otherwise suitable breeding habitat owing to the presence of the infrastructure. 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 implemented in the form of conservation easements or grassland reconstruction at the local, regional, or landscape scales (Shaffer and others, 2022). To this end, Shaffer and others (2019b) applied the models of Niemuth and others (2017) to develop a geospatial tool that identifies locations for placement of compensatory offset sites with equivalent biological value as impact sites. Additionally, the tool can be used before the construction of facilities to identify locations that would require little compensatory mitigation if developed, relative to other potential locations.

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[cm, centimeter; %, percent; <, less than; --, no data; CRP, Conservation Reserve Program; DNC, dense nesting cover; n.d., no date]

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	Native	96[a]	20[b]	--	--	--	--	--	2.6
Bakker and Higgins, 2009	Minnesota, South Dakota	Tame grassland	Seeded to intermediate wheatgrass (*Thinopyrum intermedium*)	135[a]	36[b]	--	--	--	--	--	3.1
Bakker and Higgins, 2009	Minnesota, South Dakota	Tame grassland	Seeded to switch-grass (*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
Bollinger, 1988	New York	Multiple	Hayed	18	--	28	--	--	--	5–25	--
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
Frei, 2009 (nests)	Ontario, Quebec	Tame grassland	Hayed	--	43[b]	--	50.1	--	--	--	1.3
Fritcher and others, 2004[c,d]	South Dakota	Mixed-grass prairie	Grazed	26.6–51.8	5.8–17[b]	85.7–91.6	18–26.1	--	1.8–12.9	80.7–94.6	0.9–3.1
Giuliano and Daves, 2002	Pennsylvania	Tame grassland	Warm-season seeding mixture	43.6–133.5	--	--	--	--	--	--	--
Giuliano and Daves, 2002	Pennsylvania	Tame grassland	Cool-season seeding mixture	26.1–82.6	--	--	--	--	--	--	--
Grant and others, 2004	North Dakota	Mixed-grass prairie	--	58	--	--	--	10.2	--	--	4.7
Greer, 2009[d]	South Dakota	Mixed-grass prairie	Multiple	86[a]	23[b]	61.3	14.6	1.5	2.3	21.4	2.1
Harrison, 1974 (territories)[d]	Michigan	Tame grassland	Hayed	56	--	--	--	--	--	60.1	--
Joyner, 1978 (nests)	Ontario	Tame grassland	Idle	33–41	--	--	--	--	--	--	--

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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)
Lueders and others, 2006	North Dakota	Mixed-grass prairie	Cattle-grazed	--	7[b]	35.3[e]	11.7	0.4	22.4	24.6	1.2
Lueders and others, 2006	North Dakota	Mixed-grass prairie	American bison (*Bison bison*)-grazed	--	15[b]	29.2[e]	14.7	18.5	10.3	25.9	2.1
MacDonald and Nol, 2017	Ontario	Tame grassland	Hayed	31.6	18.0[b]	31.4	26.6	--	10.3	17.7	1.5
MacDonald and Nol, 2017	Ontario	Tame grassland	Grazed	26.6	13.8[b]	43.4	30.1	--	7.5	15.6	1.5
Madden, 1996	North Dakota	Mixed-grass prairie	Burned	--	17[b]	40.8	25.9	22.1	--	--	3.4
Martin, 1971 (nests)[f]	Wisconsin	Tallgrass prairie, tame grassland	Idle, burned	--	--	30	83	<1	--	--	0.9
Messmer, 1990	North Dakota	Mixed-grass prairie	Multiple	70	--	17–65	--	--	--	--	3.9–9.1
Murray and Best, 2003	Iowa	Tame grassland (CRP)	Total-harvested switchgrass	80.9	71[b]	51.6	19.6	0.4	5	23.2	1.9
Murray and Best, 2003	Iowa	Tame grassland (CRP)	Strip-harvested switchgrass	81.7	75[b]	53.3	17.5	0.1	2.8	29.6	3.5
Murray and Best, 2003	Iowa	Tame grassland (CRP)	Unharvested switchgrass	78.1	71[b]	32.9	25.4	2.1	2.9	22.9	5.5
Negus and others, 2010[d]	Nebraska	Tame grassland (CRP)	Disked and interseeded	65.7	35.8[b]	41.8	23.8	--	14.5	25.2	1.8
Negus and others, 2010[d]	Nebraska	Tame grassland (CRP)	Idle	55.9	29.4[b]	63.9	1.4	--	1.4	39.3	3.1
Niemi, 1985	Minnesota	Peatland	--	80	--	--	--	--	--	--	--
Pillsbury, 2010[d]	Iowa, Missouri	Restored native grassland	Multiple	--	44.6[b]	21.7	24.8	2.3	--	32.1	--
Pintaric and others, 2019	Ontario	Tame grassland	Hayed	26.5	--	31.4	23.1	--	--	31.7	--
Pintaric and others, 2019	Ontario	Tame grassland	Grazed	28.1	--	29.9	28.1	--	--	37.3	--

Table LL1. Measured values of vegetation structure and composition in Bobolink (*Dolichonyx oryzivorus*) 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.—Continued

[cm, centimeter; %, percent; <, less than; --, no data; CRP, Conservation Reserve Program; DNC, dense nesting cover; n.d., no date]

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)
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[f]	North Dakota	Tame grassland (DNC)	Idle, grazed	--	22[b]	75	34	2	0.1	99	3.2
Roth and others, 2005	Wisconsin	Tame grassland (CRP)	Unharvested switchgrass	--	50[b]	--	34.4	--	--	--	5.3
Roth and others, 2005	Wisconsin	Tame grassland (CRP)	Harvested switchgrass	--	12.4[b]	--	33.2	--	--	--	1.4
Salo and others, 2004	North Dakota	Mixed-grass prairie	Moderate grazing intensity	48.3[a]	45.8[b]	--	--	--	--	--	4.6
Sample, 1989	Wisconsin	Multiple	--	63	22.4[b]	--	77.7[g]	2.2	5.4	12.4	--
Scheiman and others, 2003 (nests)	North Dakota	Tallgrass prairie	Multiple	--	22[b]	41.7	18.6	--	3.8	29.8	2.7
Schneider, 1998	North Dakota	Mixed-grass prairie	Grazed	--	14.7[b]	48.7	14.9	--	1	--	3.5
Skinner, 1974	Missouri	Tallgrass prairie	Multiple	10–30	--	--	--	--	--	--	--
Vogel, 2011	Iowa	Tame grassland	Cool-season grassland	--	34.9[b]	60.3	2.7	0.03	2.7	30.3	2.2
Vogel, 2011	Iowa	Tame grassland	Younger warm-season grassland	--	22[b]	42.8	15	0	24.6	15.9	0.4
Vogel, 2011	Iowa	Tame grassland	Older warm-season grassland	--	44.3[b]	49.6	13.3	0.2	5.5	28.3	2.4

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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)
Vogel, 2011	Iowa	Tame grassland	High-diversity grassland	--	42.7[b]	32.1	33.4	0.1	18.5	13.8	1
Wiens, 1969 (nests)[f]	Wisconsin	Tame grassland	Multiple	--	--	97	20	--	0	--	--
Wiens, 1969 (territories)[f]	Wisconsin	Tame grassland	Multiple	--	--	96	28	--	3	--	--
Winter and others, 2004 (nests)	Minnesota, North Dakota	Tallgrass prairie	Multiple	39.1	21[b]	35.3	22.6	2.6	0.3	38.6	4.8
M. Winter, WissenLeben e.V., Raisting, Germany, written commun. [n.d.]	Minnesota, North Dakota	Tallgrass prairie	Multiple	43.8	26[b]	38.5	19.4	2	3.9	34.9	4.5

[a]Mean grass height.

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

[c]Ranges represent averages across seral stages within study area.

[d]The sum of the percentages is greater than 100%, based on methods described by the authors.

[e]Grass and sedge combined.

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

[g]Herbaceous vegetation cover.

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