2018

Adaptive Management in Native Grasslands Managed by the U.S. Fish and Wildlife Service—Implications for Grassland Birds

Lawrence D. Igl

Welsey E. Newton

Todd A. Grant

Cami S. Dixon

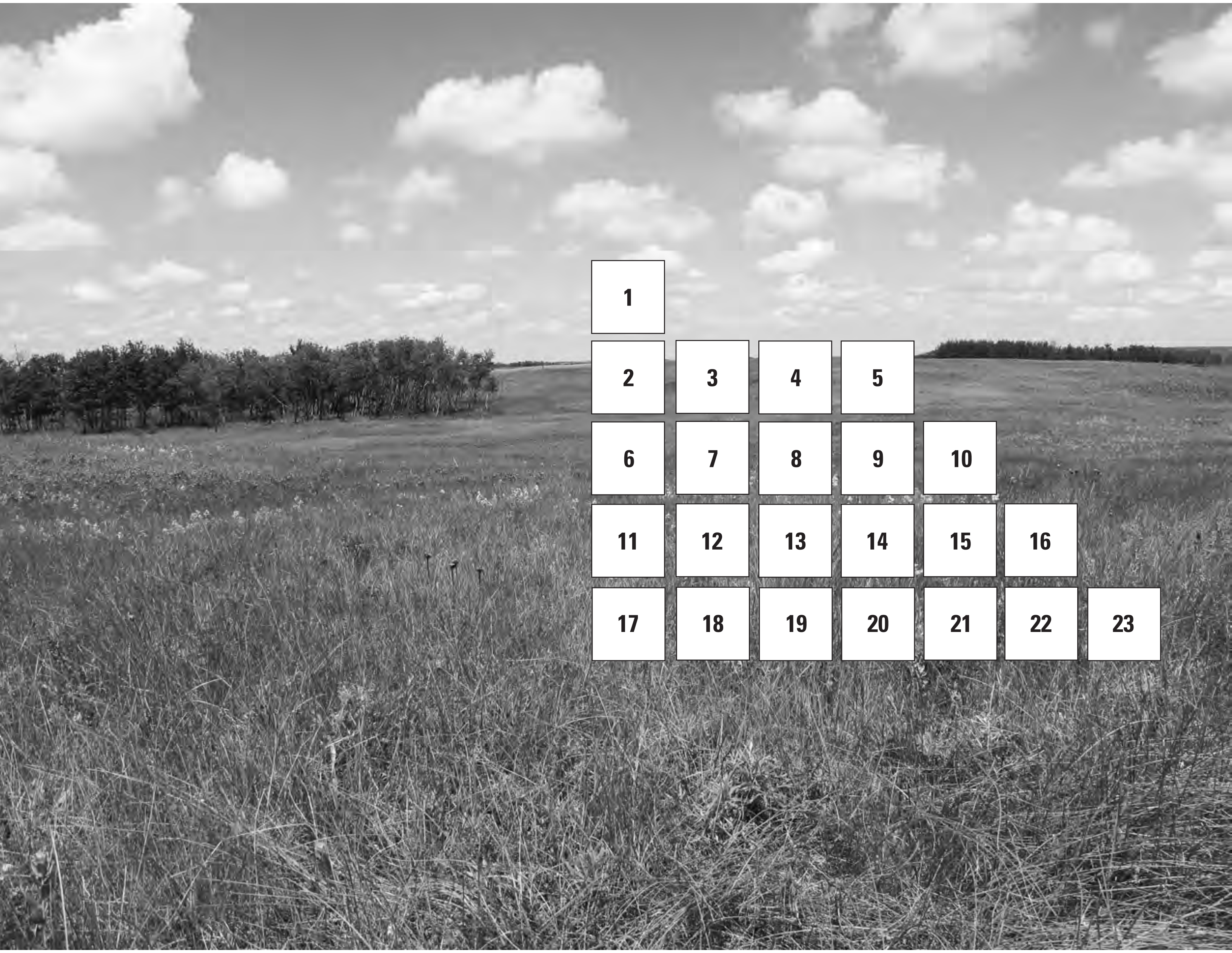
USGS
science for a changing world

Prepared in cooperation with the U.S. Fish and Wildlife Service

Adaptive Management in Native Grasslands Managed by the U.S. Fish and Wildlife Service—Implications for Grassland Birds

Open-File Report 2018–1152

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



Cover. Obligate and facultative grassland birds from top to bottom and left to right: 1, American goldfinch; 2, barn swallow; 3, bobolink; 4, Brewer's blackbird; 5, brown-headed cowbird; 6, chestnut-collared longspur; 7, clay-colored sparrow; 8, common grackle; 9, common yellowthroat; 10, eastern kingbird; 11, grasshopper sparrow; 12, killdeer; 13, mourning dove; 14, red-winged blackbird; 15, ring-necked pheasant; 16, Savannah sparrow; 17, sedge wren; 18, song sparrow; 19, tree swallow; 20, upland sandpiper; 21, western meadowlark; 22, yellow warbler; and 23, yellow-headed blackbird. Photographs by David O. Lambeth, used with permission. Background: Study Unit No. 2, Lostwood National Wildlife Refuge (Windmill South, west half), Burke County, North Dakota. Photograph by Brian J. Chepulis, U.S. Geological Survey.

Adaptive Management in Native Grasslands Managed by the U.S. Fish and Wildlife Service—Implications for Grassland Birds

By Lawrence D. Igl, Wesley E. Newton, Todd A. Grant, and Cami S. Dixon

Prepared in cooperation with the U.S. Fish and Wildlife Service

Open-File Report 2018–1152

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

U.S. Department of the Interior
RYAN K. ZINKE, Secretary

U.S. Geological Survey
James F. Reilly II, Director

U.S. Geological Survey, Reston, Virginia: 2018

Suggested citation:
Igl, L.D., Newton, W.E., Grant, T.A., and Dixon, C.S., 2018, Adaptive management in native grasslands managed by the U.S. Fish and Wildlife Service—Implications for grassland birds: U.S. Geological Survey Open-File Report 2018–1152, 61 p., https://doi.org/10.3133/ofr20181152.

ISSN 2331-1258 (online)

Contents

Figures

Tables

Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
decimeter (dm)	3.937	inch (in.)
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
hectare (ha)	2.471	acre
hectare (ha)	0.003861	square mile (mi2)
	Flow rate	
kilometer per hour (km/h)	0.6214	mile per hour (mi/h)

Datum

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Abbreviations

CI	confidence interval
FWS	U.S. Fish and Wildlife Service
GLMM	generalized linear mixed model
GPS	global positioning system
LCL	lower confidence limit
NPAM	Native Prairie Adaptive Management
NWR	National Wildlife Refuge
SD	standard deviation
SE	standard error
UCL	upper confidence limit
USGS	U.S. Geological Survey
VOR	vertical obstruction reading
WMD	Wetland Management District
WPA	Waterfowl Production Area

Acknowledgments

Funding for this study was provided by the U.S. Geological Survey's Science Support Partnership Program and Northern Prairie Wildlife Research Center. We thank the dedicated U.S. Geological Survey field biologists who collected data for this project, including Thomas K. Buhl, Brian J. Chepulis, Monica L. Daane, Colin M. Dovichin, Tyler J. Garwood, Robert L. Jones, Nicole M. Staton, and Dustin L. Toy.

We also thank many managers, biologists, and other personnel from the U.S. Fish and Wildlife Service for logistical and technical support, especially Stacy Adolf-Whipp, Kristine Askerooth, Kathy Baer, Michael Borgreen, Kim Bousquet, Justin Dupey, Michael Erickson, Rebecca Esser, Mark R. Fisher, Bridgette L. Flanders-Wanner, Todd Frerichs, David Gillund, Paul Halko, Todd Hauge, Roger Hollevet, Laura Hubers, Brent E. Jamison, Andy Jewett, Lloyd Jones, Kyle W. Kelsey, Edward Meendering, Connie Mueller, Michael J. Rabenberg, Edward Rodriguez, Brian Salem, William Schultze, Chris C. Swanson, Sara Vacek, and Jennifer Zorn. We thank Kim Bousquet, Bridgette L. Flanders-Wanner, Terry L. Shaffer, and Sara Vacek for their valuable contributions to the project as members of the Native Prairie Adaptive Management science team, and personnel from the U.S. Fish and Wildlife Service who collected vegetation composition data. We are grateful to David O. Lambeth for providing the color photographs of birds for this report. Earlier versions of this account benefitted from insightful comments from Jane E. Austin and Paulette Scherr.

Adaptive Management in Native Grasslands Managed by the U.S. Fish and Wildlife Service—Implications for Grassland Birds

By Lawrence D. Igl,[1] Wesley E. Newton,[1] Todd A. Grant,[2] and Cami S. Dixon[2]

Abstract

Burning and grazing are natural processes in native prairies that also serve as important tools in grassland management to conserve plant diversity, to limit encroachment of woody and invasive plants, and to maintain or improve prairies. Native prairies managed by the U.S. Fish and Wildlife Service (FWS) in the Prairie Pothole Region of the northern Great Plains have been extensively invaded by nonnative, cool-season species of grasses. These invasions were believed to reflect a common management history of long-term rest and little or no defoliation by natural processes (burning and grazing). To address the challenges associated with these invasive species, the FWS embraced a collaborative approach in 2008, in partnership with U.S. Geological Survey, to restore native prairies on lands managed by FWS. This approach is known as the Native Prairie Adaptive Management (NPAM) initiative and was based on the application of an adaptive decision-support framework to assist managers in selecting management actions despite uncertainty and in maximizing learning from management outcomes. The primary objective of this approach was to increase the composition of native grasses and forbs on native, unbroken sod while minimizing costs. The alternative management actions that were used to meet this objective include grazing, burning, burning and grazing, and rest (no action).

A major challenge for FWS resource managers participating in the NPAM initiative was the recognition that other taxa, besides native grasses and forbs, may be affected by the alternative management practices, thus complicating the adaptive-management cycle and deepening the uncertainty. Specifically, many grassland birds are sensitive to changes in vegetation composition and structure, and thus management that alters vegetation also may affect bird populations. The primary objectives of this study were to assess the effects of alternative management actions on grassland birds on FWS-owned grasslands that are managed under the adaptive-management framework, and to assess the association of vegetation structure and composition as mechanisms for triggering grassland bird responses to management.

We surveyed breeding birds and sampled vegetation on 89 native prairie NPAM units managed by the FWS during 2011–13, including 55 units in 2011, 87 units in 2012, and 87 units in 2013. The NPAM units were in 19 FWS refuge complexes and wetland management districts, including 14 complexes in FWS Region 6 (North Dakota, South Dakota, and Montana) and 5 complexes in FWS Region 3 (Minnesota). Generalized linear mixed models were used to evaluate the effects of management actions on vegetation structure, vegetation composition, and densities of common bird species. Vegetation structure and composition varied among study units and years, and many of these differences were linked to specific management activities or to the recency of those activities. We recorded 110 bird species in the 89 adaptive-management units. Models of bird abundance reflected not only disturbance-derived changes in vegetation structure and species-specific vegetation preferences but also the influence of defoliation treatments. Vegetation composition was less important to grassland birds than vegetation structure; in particular, mean vertical obstruction (vegetation height-density), bare-ground cover, and litter depth positively or negatively influenced densities of some grassland bird species. The diversity of bird responses to management in this study underscores the complexity of natural grassland systems and the need for heterogeneity management in grasslands in this region.

Introduction

Temperate grasslands are considered one of the most altered terrestrial ecosystems in the world and are recognized as having the lowest level of protection of the world's major biomes (Henwood, 2010). Grasslands in North America have undergone extensive changes since Euro-American settlement, and native grasslands are considered among the most endangered ecosystems on the continent (Samson and Knopf, 1994;

---

[1] U.S. Geological Survey.

[2] U.S. Fish and Wildlife Service.

Noss and others, 1995; Van Dyke and others, 2004; Stephens and others, 2008; Henwood, 2010). More than 95 percent of the original tallgrass prairies have been converted to agriculture or modified by management practices (Samson and Knopf, 1994; Noss and others, 1995), and the extent of mixed-grass prairies has declined by 70–90 percent across States and Provinces in the northern Great Plains (Samson and Knopf, 1994; Samson and others, 2004; Henwood, 2010). These declines continue unabated in North Dakota and South Dakota (Higgins and others, 2002; Stephens and others, 2008). The remaining prairies have been increasingly degraded by fragmentation, encroachment of woody and exotic plants, and suppression or misapplication of defoliation disturbances (for example, fire, grazing, haying) (Samson and Knopf, 1994; Grant and Murphy, 2005; Murphy and Grant, 2005; Grant and others, 2009). Uncertainty about future changes in the region's climate poses additional serious but unquantified threats to the integrity of remaining native prairies in the northern Great Plains.

More than 100,000 hectares (ha) of native (no history of cultivation) tallgrass and mixed-grass prairies are managed by the U.S. Fish and Wildlife Service (FWS) in the northern Great Plains (Grant and others, 2009). Although prairies in this region evolved with grazing, fire, and climatic variability, management of FWS grasslands often has been passive and involved extended periods of rest (that is, no disturbance) (Grant and others, 2009). Extended rest has been implicated as a contributing factor in large-scale invasions by woody vegetation, smooth brome (*Bromus inermis*), Kentucky bluegrass (*Poa pratensis*), and other introduced cool-season grasses on FWS-owned native grasslands (Grant and others, 2004, 2009).

The invasion of introduced cool-season grasses on FWS-owned prairies and the uncertainty about management actions has motivated collaborators in the U.S. Geological Survey (USGS) and the FWS to develop a structured framework for decision making. In 2008, these two Federal agencies initiated the collaborative effort called the Native Prairie Adaptive Management (NPAM) initiative. The focus of the NPAM initiative involves developing an adaptive decision-support system to guide and support FWS restoration efforts on FWS-owned prairies in the northern Great Plains (FWS Regions 3 and 6). The NPAM initiative includes multiple FWS refuges and complexes and employs the principles of adaptive management (iterative cycles of decision making, management action, and monitoring; Williams and others, 2009; Williams and Brown, 2012) to evaluate and improve management decisions on FWS prairies over time.

The FWS prairies in this region differ by degree of invasion, plant species composition, and other attributes (for example, precipitation, previous management), making management of these prairies a complex problem with many uncertainties. By explicitly addressing these uncertainties through application of adaptive management, FWS refuge biologists and managers (that is, the end users) can use iterative cycles of decision making, action, and monitoring to reduce uncertainty and thereby improve future management decisions. Each year, managers choose from one of several treatment options, including rest, fire, grazing, and fire with grazing. The framework of the NPAM effort rests on a set of models that express competing hypotheses about vegetation response to these management treatments. Decision models were developed that predict vegetation composition (for example, percent native grasses, percent smooth brome, and percent Kentucky bluegrass) in year t+1 from vegetation composition in year t and the treatment strategy between year t and year t+1 (Gannon and others, 2013). Based on monitoring feedback, predictive models are updated annually to reflect the current monitoring results and predictive performance of the decision models. Uncertainty about management is incrementally resolved as each model's ability to predict outcomes is either confirmed or repudiated.

Refinement of management strategies over time will develop a broader understanding of the complexity of FWS prairies and their future management. During the pilot field season in 2009, the NPAM project included 104 adaptive-management units from 22 FWS stations in North Dakota, South Dakota, Minnesota, and Montana. By 2010, the NPAM project was fully implemented; in that year, the effort included 118 adaptive-management units from 24 participating FWS stations. The average size of the units in FWS Region 6 (North Dakota, South Dakota, and Montana) in 2010 was 37.2 ha (range=5.5–240.7 ha).

The NPAM initiative represents one of the few fully implemented applications of adaptive management with the FWS (Gannon and others, 2013). A major focus of the NPAM program is structuring management strategies to enhance competition of native grasses and forbs on prairies that differ by geographic location, tract size, degree of invasion, exotic species present, and so on. The NPAM initiative has served as a springboard for other investigations (Bryant, 2015; Kobiela and others, 2017), including developing techniques to quantify phenological development of invasive grasses (Dupey, 2014), evaluating genotypic and genetic diversity of invasive grasses (Dennhardt and others, 2016), and improving methods of prairie restoration and data management (Hunt and others, 2015, 2016). The NPAM initiative also provided a unique opportunity to evaluate the success of adaptive-management strategies on vertebrate populations, particularly grassland breeding birds. Realistically, shifts in vegetation structure and composition through time may influence habitat quality and quantity for grassland birds, which have exhibited more rapid and widespread declines than those of other major groups of birds in North America (Igl and Johnson, 1997; Peterjohn and Sauer, 1999; McCracken, 2005; North American Bird Conservation Initiative, 2016; North American Bird Conservation Initiative, U.S. Committee, 2017). Changes in vegetation composition occur over a longer period than structural changes in prairies but are known to influence habitat use (Madden and others, 2000; Grant and others, 2004) and vital rates (Ludlow and others, 2015; Lloyd and Martin, 2005) of some endemic grassland birds of high conservation concern, including Sprague's pipit (*Anthus spragueii*), Baird's sparrow (*Centronyx bairdii*), and chestnut-collared longspurs (*Calcarius ornatus*). The decline of North American grassland bird populations is considered one of the most prominent conservation crises of the 21st century (Askins and others, 2007). In 2011–13, we included a grassland breeding-bird component to the NPAM effort. Specifically, under the adaptive-management decision framework, we developed models for the response of grassland breeding birds to management treatments (including rest, fire, livestock grazing, or grazing with fire) that are being used to restore floristic composition of native prairies on FWS-owned management units in the north-central United States.

Objectives

The primary objectives of this study were to (1) assess the effects of management actions on vegetation structure, vegetation composition, and other variables on FWS-owned grasslands within the framework of the NPAM effort; (2) assess the effects of management actions on grassland bird densities on FWS-owned grasslands; and (3) assess the association of vegetation structure and composition as mechanisms for triggering grassland bird responses to management. The full dataset used for analyses is available as a USGS data release (Igl and others, 2018a).

Study Area and Methods

Study Area

In 2011, the year that this bird study was initiated, the NPAM initiative included 120 adaptive-management units from 19 participating FWS refuge complexes and wetland management districts, including 14 complexes in FWS Region 6 (North Dakota, South Dakota, and Montana) and 5 complexes in FWS Region 3 (Minnesota). Specifically, these prairie tracts are (1) primarily native prairies invaded by introduced cool-season grasses (primarily smooth brome and Kentucky bluegrass) and often woody vegetation (Grant and others, 2009); (2) managed mainly by rest (that is, no disturbance), with periodic defoliation by fire, livestock grazing, or haying; (3) variable in size, with many tracts large enough to contain area-sensitive grassland bird species (Johnson and Igl, 2001; Davis, 2004); (4) characterized by scattered small wetlands or nearby, large seasonal or semipermanent wetlands (Stewart and Kantrud, 1971); and (5) bordered by annually tilled cropland or by grazed native prairie or nonnative grassland.

The NPAM units are stratified by grass types (mixed-grass and tallgrass prairies) and are typical of grasslands managed by the FWS in the northern Great Plains. The tallgrass prairies are in eastern North and South Dakota and western Minnesota, are the wettest of the two grass types, include a strong warm-season grass component, and support grass species that can attain heights of 100–300 centimeters (cm) (Risser and others, 1981; Gannon and others, 2013). The northern mixed-grass prairies are in western and central North and South Dakota and eastern Montana, are the driest of the two grass types, have a strong cool-season grass component, and support grasses that reach 60–122 cm in height (Risser and others, 1981; Gannon and others, 2013). Precipitation for both grass types falls primarily during the growing season (64–102 cm annually for tallgrass region; 40–50 cm for the mixed-grass region) (Risser and others, 1981; Gannon and others, 2013).

We surveyed 55 NPAM units in 2011, 87 units in 2012, and 87 units in 2013 (fig. 1). Site selection for this bird component was dictated by field size, grass type, and restoration in progress or planned for the area. During the initial year of this study (2011), we focused our efforts in mixed-grass prairie units that were greater than or equal to 20 ha and that were in North Dakota, South Dakota, or Montana (FWS Region 6). We surveyed the same units in 2012 and 2013, if they remained part of the NPAM initiative, but we also added additional NPAM units, including mixed-grass prairie units that were 16–20 ha in North Dakota, South Dakota, and Montana (Region 6), and tallgrass prairie units that were greater than or equal to 16 ha in Minnesota (FWS Region 3), North Dakota, and South Dakota. The FWS adaptive-management units that were not part of the NPAM study were not included in the study. Two NPAM units (both in Huron County, South Dakota) that were surveyed in 2011 were removed from the overall NPAM effort in 2012, and thus these units were not surveyed for birds or vegetation in 2012 and 2013.

Bird Surveys

On each NPAM adaptive-management unit, birds were surveyed by trained observers two times within a breeding season from late May to mid-July, which coincides with the peak breeding season of breeding birds in the northern Great Plains (Stewart and Kantrud, 1972; Igl and Johnson, 1997). The first visit occurred early in the breeding season between late May and mid-June, and the second visit occurred later in the season between mid-June and mid-July. The phenological advance in seasons during the spring and early summer is earlier in the southeastern part of the study area than in the northwestern part. To compensate for these differences, the sequence in which study units were covered progressed from southeast to northwest. After completing the first round of surveys, the observers began their second round in the southeastern-most study units and worked toward the northwest. In a few cases, the observers only completed a single survey within a season or only completed a partial survey due to aggressive or overly friendly cattle, the presence of American bison (*Bison bison*), or flooding of upland areas. When only a partial bird survey was conducted, breeding bird densities were adjusted to reflect the total area surveyed.

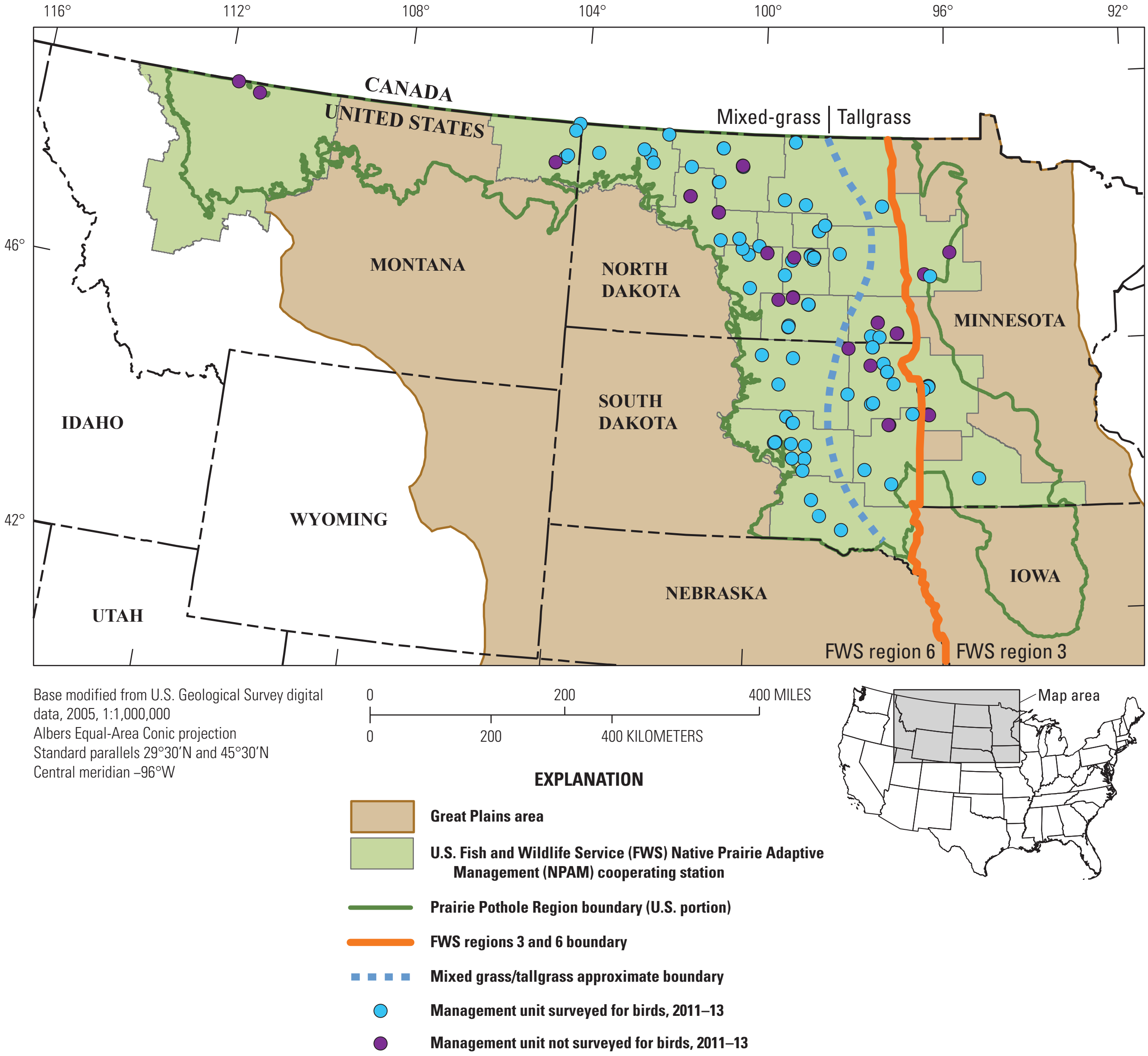


Figure 1. The Native Prairie Adaptive Management (NPAM) units on Federal lands owned by the U.S. Fish and Wildlife Service (Regions 3 and 6) and managed under an adaptive-management framework in mixed-grass and tallgrass prairies in North Dakota, South Dakota, Minnesota, and Montana. Map modified from Gannon and others (2013).

During each visit, observers estimated breeding bird abundance (breeding pairs per 100 ha) using a total-area count methodology that employs a series of line transect surveys. Line transects generally are considered more suitable and more efficient than point counts in open, uniform, or species-poor habitats, such as grasslands (Reynolds and others, 1980; Bollinger and others, 1988; Bibby and others, 2000). Before entering the field, observers determined the number, length, start and end points, and juxtaposition of bird survey transects in each grassland tract in a geographic information system (ARCMAP 10.1; Esri, Redlands, California). In general, the area covered by transects was roughly proportional to the grassland size, each transect was usually 200 meters (m) wide, and the first transect line was positioned at least 100 m from an edge habitat (for example, fencerow, forested area) (fig. 2). Start and end points of transects occurred at the boundaries of the adaptive-management units. Successive transects within the same grassland tract were parallel to the first transect. During surveys, observers were equipped with global position systems (Earthmate® PN-60 GPS, DeLorme, Inc., Yarmouth, Maine) and walked transect lines slowly on foot, assuming a speed of about 1.0–1.5 kilometers per hour. This slow rate of progress allowed an observer to efficiently cover a transect survey and is implicit in balancing the length of exposure to individual breeding pairs and avoiding/reducing duplication of counts. Breeding birds were surveyed between 0.5 hour before sunrise and the mid-morning lull in grassland bird activity, which varies from day to day but usually occurs in mid- to late morning. We avoided surveying birds in adverse weather conditions (for example, heavy precipitation, sustained winds stronger than 15 kilometers per hour), although surveying during light mist or drizzle was allowed if birds remained active. Breeding birds were identified from visual or aural observations of adults or the presence of an active nest. Counts of birds were based on the number of indicated breeding pairs on territories or home ranges. For most species, nearly all indicated pairs were observed as territorial males or as segregated pairs. Bird densities within each NPAM unit were averaged across the two visits within each year for all analyses. The average number of breeding pairs recorded during the two visits at a study unit was used as a measure of abundance for each species in the analyses.

Because the design of the bird surveys was tightly controlled, we believe that the probability of detection (given a species was present) was similar among treatments for species of grassland birds that we expected to record, so that comparisons of treatments were not biased by imperfect detectability. Therefore, we based our comparisons of treatments on actual counts of indicated pairs rather than estimates of absolute abundance, which would require species-specific estimates of detection probability and introduce additional sources of variability (Johnson, 2008). Methods for estimating absolute abundance from surveys have met with limited success, including in grasslands (Dale and Jardine, 2010; Leston and others, 2015), because necessary assumptions are difficult to meet in field studies involving multiple species over extensive areas (Johnson, 2008; Efford and Dawson, 2009; Etterson and others, 2009). Johnson (2008) argued that, although new analytical approaches (for example, distance sampling, removal models, double sampling, multiple-observer models) improve our understanding of the detection process, indices remain the best available option for many studies. Leston and others

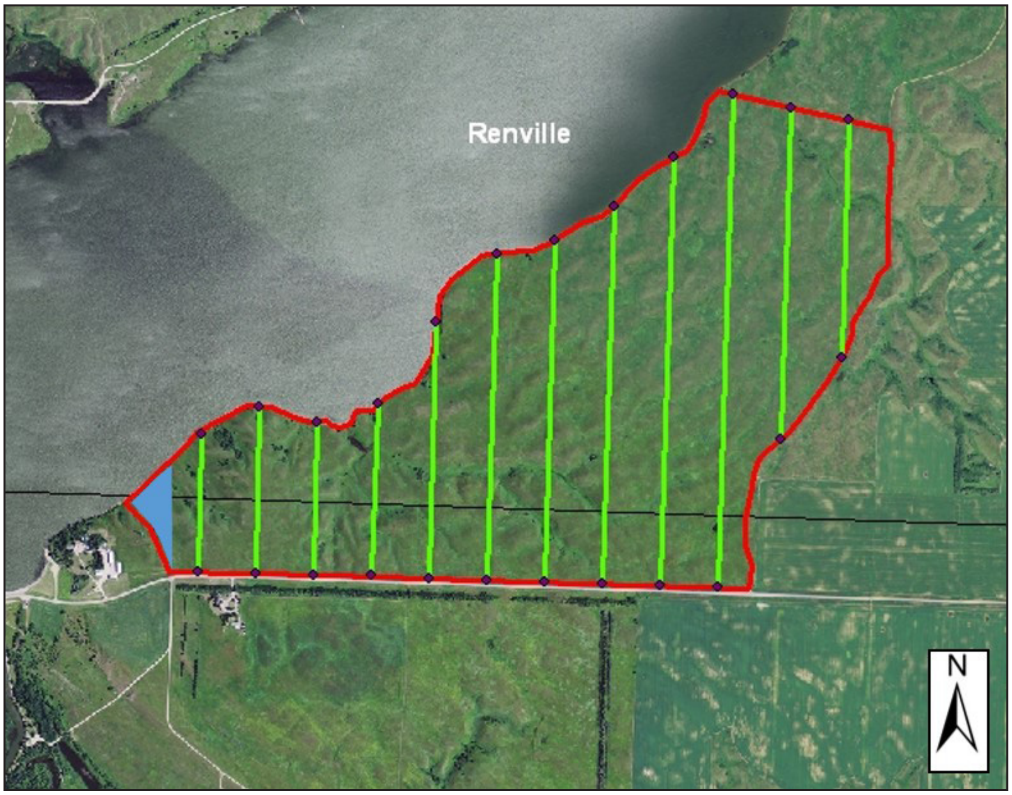


Figure 2. Example study unit (red line) showing bird-survey transect lines (green lines) and start and end points for each transect. This Native Prairie Adaptive Management unit is in Renville County in north-central North Dakota in the U.S. Fish and Wildlife Service's Souris River Basin National Wildlife Refuge Complex. Most of this 240.7-hectare mixed-grass prairie unit was surveyed for breeding birds, except in the area shown in blue in the western edge of the study unit.

(2015) showed that methods of accounting for imperfect detectability were unlikely to be met in grasslands and argued that unadjusted counts from abundance observations are more appropriate and optimal indices for estimating avian relative abundance in grasslands. Vernacular and scientific names of birds follow the Integrated Taxonomic Information System (https://www.itis.gov) and the 58th and 59th Supplements to the American Ornithological Society's Check-list of North American Birds (Chesser and others, 2017, 2018).

Vegetation Sampling

A driving force of the NPAM initiative is to increase native plant composition through various management strategies while minimizing management costs. As part of the NPAM monitoring effort, the NPAM science team adopted a vegetation monitoring protocol that was rapid, inexpensive, and familiar to cooperating FWS personnel (Grant and others, 2004; Gannon and others, 2013). FWS refuge biologists, managers, and biological technicians annually collected data on vegetation composition in July and August of each year along randomly selected transects, according to the modified belt-transect technique described by Grant and others (2004). This annual monitoring effort provided information about the state of each unit's vegetation composition. The number of vegetation-composition transects in each study unit was generally proportional to the area of the tract (1 transect for every 1.2–2.0 ha). Composition transects were placed in random orientations and were located at least 65 m from other composition transects and at least 5 m from fences, structures, and permanent wet areas. Each transect was divided into fifty 0.5-m long segments. At each segment, an observer made an ocular assessment of the dominant vegetation type in a 0.1-m wide strip that was bisected by the transect line. For this bird study, vegetation cover (percent) was summarized (mean and standard deviation) into several vegetation cover categories, including native grasses, nonnative grasses, native forbs, nonnative forbs, smooth brome, and Kentucky bluegrass.

Vegetation structure, however, often is considered a better predictor of grassland bird habitat than floristics (Wiens, 1974; Fletcher and Koford, 2002; Jones and Bock, 2005; Fisher and Davis, 2010). Based on a review of the literature, Fisher and Davis (2010) identified nine variables that were important predictors of habitat use by grassland birds, including coverage of bare ground, grass, dead vegetation, forbs, and litter, along with an index of vegetation density, vegetation volume, litter depth, and vegetation height. Of the nine variables, bare-ground cover, vegetation height, and litter depth were three of the most consistent predictors of habitat use by grassland birds in the literature. None of these three variables were sampled by the FWS. To identify associations between birds and vegetation structure, and as a supplement to the composition and cover variables collected by the FWS, USGS field personnel measured vegetation structure and other cover variables at fixed intervals along the same transects used for bird surveys. To avoid oversampling larger study units and undersampling smaller units, the interval between sampling points within each study unit was determined by calculating the square root of the total length of the transects (in meters) in that study unit. This interval value also was used as the starting distance from a study unit edge for each transect. Vegetation structure was not sampled in wetlands or flooded areas within a study unit or immediately after heavy precipitation.

To quantify vegetation structure and other variables that are important predictors of habitat used by grassland birds, in each study plot, the following vegetation measurements were collected at multiple sampling points per plot between late June and mid-July of each year. At the center of each sampling point, we measured vegetation height-density as a vertical (or visual) obstruction reading (VOR) to the nearest 0.5 decimeter using a Robel pole (Robel and others, 1970). These VORs can be useful to approximate vegetation density, biomass, and cover for breeding birds and other wildlife species in grasslands (Fisher and Davis, 2010). At each sampling point, four VOR measurements were recorded, with the observer standing 4 m from the graduated Robel pole and observing the pole at eye-level at a 1-m height (fig. 3) and moving in the four cardinal directions. The lowest visible numbered marking on the Robel pole was recorded. The four VOR measurements at a sampling point were averaged to obtain a single VOR measurement at each sampling point. Litter depth and maximum vegetation height were measured once at each sampling point (that is, location of the Robel pole) with a meter stick to the nearest centimeter. Litter depth was defined as the thickness of dead, unconsolidated, mostly horizontal, plant matter. Maximum vegetation height was defined as the tallest live or dead vegetation at the location of the Robel pole. To estimate percent canopy cover of standing dead vegetation and percent cover of bare ground, observers used a 20×50-cm Daubenmire frame that was placed 4 m east or west of the Robel pole. Estimates of cover were measured once and were recorded as percentages (5 percent increments) rather than categorical measures. Standing dead vegetation (or standing dead residual vegetation) was defined as accumulated dead plant material (phytomass) from previous years that is still standing and attached in the ground.

As with vegetation composition, the number of samples of vegetation structure in each grassland tract were proportional to the area of the grassland. Because vegetation samples collected within a study plot are not independent of each other, vegetation structure data were pooled and summarized as means and standard deviations for each study plot. Although vegetation structure was only sampled once during the breeding season, many grassland birds remain on their breeding territories throughout the nesting season (for example, Wiens, 1973b; Whitmore, 1979; Fletcher and Koford, 2002), and some studies have shown strong correlations between vegetation structure in the beginning of the breeding season (early May) and vegetation structure at the end of the breeding season (mid-July) (for example, Winter and Faaborg, 1999). For analyses, we considered vegetation variables collected by the

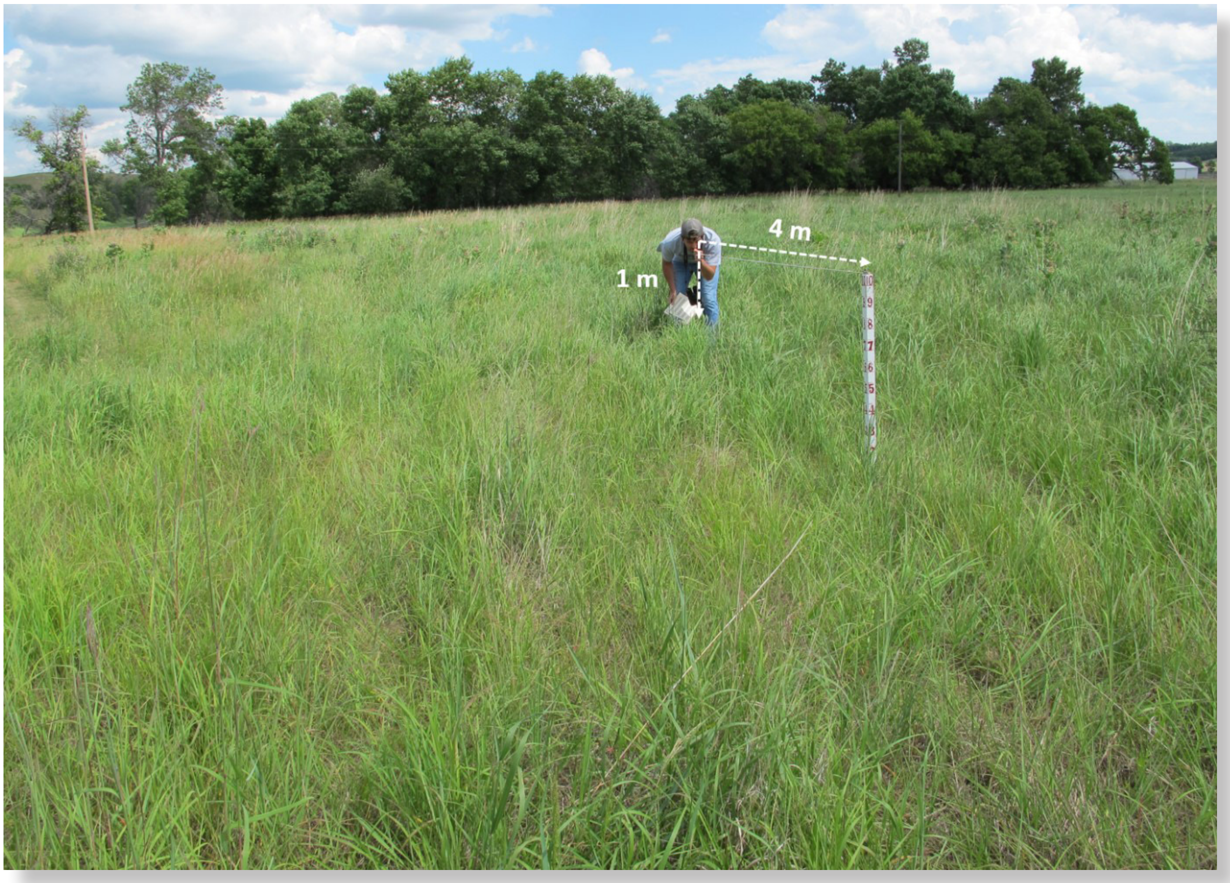


Figure 3. Sampling vertical obstruction (vegetation height-density) data using a Robel pole. The field observer is standing 4 meters from the graduated Robel pole and observing the pole at a 1-meter height. Photograph taken by Robert L. Jones, U.S. Geological Survey.

FWS as part of the overall NPAM effort as vegetation composition variables, and we considered vegetation variables collected during the bird study as vegetation structure variables, although we recognize that both sampling efforts included some vegetation cover variables. Vernacular and scientific names of plants follow the Integrated Taxonomic Information System (https://www.itis.gov)

Native Prairie Adaptive Management Alternative Management Actions

The NPAM initiative recognized four alternative management actions (that is, rest, grazed-only, burned-only, and burned-grazed) that were permitted under its adaptive-management framework (as described in Gannon and others, 2013). Management actions were applied during the management year, which was defined as September 1 of the previous calendar year to August 31 of the current calendar year. *Rest* was defined as the absence of any defoliation treatment (grazed-only, burned-only, or burned-grazed) applied to a management unit during a management year. Special targeted treatments, such as spot herbicide applications or clippings to control invasive or noxious weeds, were allowed (usually affecting only a small proportion of the unit) but the unit was still considered to have received the rest treatment. The *grazed-only* treatment was defined as the targeted use of grazing domestic livestock as the single form of defoliation treatment that was implemented within a management year. In the grazed-only treatment, NPAM guidelines permitted flexibility in the timing, duration, intensity (stocking rate), or species of domestic livestock that targeted the rapid growth phase of cool-season invasive plant species and that was considered consistent with best management practices for native prairie ecosystems. In 2011–13, most of the grazing treatments included domestic cattle; American bison were used on one NPAM study unit. The *burned-only* treatment was defined as the application of fire as the single form of defoliation that was carried out during a management year. In the burned-only treatment, NPAM guidelines permitted flexibility in the timing, intensity, or method of application that was considered consistent with best management practices for native prairie ecosystems. The *burned-grazed* treatment was defined as the use of both burned and grazed treatments, as defined above, in the course of a single management year. According to the NPAM guidelines, the burning and grazing management actions could both be applied in the fall or both applied in the spring, or they could be applied in different seasons within a management year. In most cases, the burn action preceded the graze action, but reversal of these actions also occurred infrequently and was acceptable under NPAM guidelines. Most of the burn actions occurred in the spring before the growing season or at the beginning of the growing season.

More than one management action was allowed on a management unit within a management year, including multiple grazing actions (Gannon and others, 2013). The defining factor was the type of action rather than the frequency with which it occurred. As an index to how intensively a unit was managed during the previous 7 years, the NPAM science team developed a defoliation index that takes into account the frequency of defoliation events during a 7-year window (that is, the number of management years within a 7-year window in which at least one defoliation event occurred) and the number of years since the last defoliation (Gannon and others, 2013). The index assigns a weighting scheme that reflects the importance of recentness to the number of defoliation actions executed during the 7-year window.

Assignment of Treatment Regimes and Post-Management Treatments

As described above, this study builds on an existing long-term and ongoing adaptive decision-support system and monitoring effort (that is, NPAM project). As such, we did not attempt to influence decisions to burn, graze, rest, or otherwise manage a FWS-owned prairie or influence how and when vegetation was monitored under the original NPAM framework. The breeding activity of grassland birds occurs largely within the growing season (that is, spring and summer) of a management year, whereas management actions could occur at any point in time throughout the management year. For this study, we defined two measures of grassland management to evaluate grassland bird response to NPAM management actions: post-management treatment and overall treatment regimes.

To account for any delayed effects of management on vegetation and bird densities, we initially assigned a post-management treatment for each of the two bird surveys in each year for each study unit (table 1). Post-management treatments were defined by the number of growing seasons post-disturbance (Grant and others, 2010; Igl, 2009) for each of the defoliation methods, including burned-only, grazed-only, and burned-grazed. These post-management assignments corresponded to lagged effects based on the number of growing seasons after the unit was burned, grazed, or burned-grazed, up to 5 years:

- B1, B2, B3, B4, and B5 = 1, 2, 3, 4, and 5 growing seasons after burning;
- G1, G2, G3, G4 and G5 = 1, 2, 3, 4, and 5 growing seasons after grazing;
- BG1, BG2, BG3, BG4, and BG5 = 1, 2, 3, 4, and 5 growing seasons after burned-grazed.

Because grazing is a prolonged management activity that often occurs during several weeks or across months, especially during the peak of the growing season, bird surveys often occurred at a study unit when the grazing treatment was occurring or ongoing. Thus, for study units involving active (that is, ongoing) grazing during the growing season when bird surveys were being conducted, we also included a post-management treatment assignment that reflected grazing within the growing season (that is, G0 or BG0, table 1). If post-management assignments were interrupted by another disturbance before the fifth growing season post-disturbance, post-management assignments began again from the first growing season post-disturbance or, in the case of units that included ongoing grazing, began again from the growing season during which grazing occurred (G0 or BG0). After five growing seasons from the initial disturbance, the study unit was treated as being rested, regardless of the management technique that had been used 5 years earlier. Note that our definition of rest (that is, greater than [>] five growing seasons since last disturbance) in the assignment of post-management treatments differs from the definition of rest used in the overall NPAM effort (that is, no defoliation during management year).

Each study unit in each of the 3 years was then assigned a single post-management designation (table 1) by combining the post-management treatments for the two bird surveys within a year. For most of the study units, we assigned the same post-management treatment to both of the bird surveys within each growing season, and thus the post-management assignment for that year was the same as the post-management assignment for the two bird surveys. In some cases, however, we had two different post-management treatments within a year—one for each of the two bird surveys. This occurred most often when a spring management action occurred after we completed the first of the two bird surveys within a growing season. In those cases, the post-management assignment was given a mixed code (G or BG) without a number indicating the number of growing seasons post-disturbance. Nearly all growing season/study unit combinations that were assigned a G code included G0 for one survey and G1 for another survey. We assumed that these units occurred between the G0 and G1 categories. Growing season/study unit combinations that were assigned a BG code were more difficult to categorize, because they included several different alternatives of grazing and burning. Sample sizes for some post-management treatments were small (table 2), which required us to combine data across several growing seasons (for example, G3-5=grazed 3–5 growing seasons prior to survey) or to drop them from the analyses.

After the final assignments of post-management treatments, each study unit was assigned an overall treatment regime, which we defined as the prevailing management activity at each unit across the 3 years. The treatment regime included four categories: burned-only, grazed-only, burned-grazed, and rest. For example, a study unit that was assigned post-management treatments of B1 in 2011, B2 in 2012, and B3 in 2013 was assigned a treatment regime of “burned-only,” and a study unit assigned post-management treatments of BG1

Table 1. Assignment of management treatments by year and designation of overall management regime for 89 Native Prairie Adaptive Management study units in two grass types (mixed-grass and tallgrass) in North Dakota, South Dakota, Minnesota, and Montana.

[NWR, National Wildlife Refuge; WPA, Waterfowl Production Area; WMD, Wetland Management District; B1, first growing season after burning; B2, second growing season after burning; B3, third growing season after burning; B4, fourth growing season after burning; B5, fifth growing season after burning; G0, grazed during the current growing season; G1, first growing season after grazing; G2, second growing season after grazing; G3, third growing season after grazing; G4, fourth growing season after grazing; and G5, fifth growing season after grazing; BG0, burned-grazed during the current growing season; BG1, first growing season after burning-grazing; BG2, second growing season after burning-grazing; BG3, third growing season after burning-grazing; BG4, fourth growing season after burning-grazing; BG5, fifth growing season after burning-grazing; G, grazing occurred between the two bird surveys in a single season; BG, grazing-burning occurred between the two bird surveys in a single season, --, no data]

Unit	Name	Management treatment[1]			Overall management regime[2]	Grass type
		2011	2012	2013		
1	Lostwood Complex: Lake Zahl NWR: Lake Zahl 7	B2	G0	G1	Burned-grazed	Mixed.
2	Lostwood Complex: Lostwood NWR: Windmill South - West half	B2	B3	B4	Burned	Mixed.
3	Lostwood Complex: Mountrail County WPA: Coteau Prairie - G2 West half	B1	G1	G	Burned-grazed	Mixed.
5	Lake Andes NWR: Aurora County WPA: Foster	G1	G1	G0	Grazed	Mixed.
6	Lake Andes NWR: Bon Homme County WPA: Hieb	G	G	G0	Grazed	Mixed.
7	Long Lake WMD: Burleigh County WPA: Rath WPA - #1 Grazing Unit	G1	G1	G1	Grazed	Mixed.
8	Long Lake WMD: Burleigh County WPA: Crimmins NE Grazing Unit	B1	B2	B3	Burned	Mixed.
9	Long Lake WMD: Long Lake NWR: G-12A East	G0	G1	G0	Grazed	Mixed.
14	Audubon Complex: Sheridan County WPA: Lasher Unit A	B1	B1	B2	Burned	Mixed.
15	Audubon Complex: McLean County WPA: Otis Unit 8N	--	G0	G1	Grazed	Mixed.
19	Audubon Complex: Sheridan County WPA: Lasher Unit B	B1	B1	B2	Burned	Mixed.
20	Audubon Complex: McLean County WPA: Koenig Section Line Slough Unit	B1	G1	G1	Burned-grazed	Mixed.
23	Tewaukon WMD: Tewaukon NWR: Tewaukon NWR	--	BG1	BG	Burned-grazed	Tall.
24	Tewaukon WMD: Sargent County WPA: Krause	--	B1	G0	Burned-grazed	Tall.
28	Arrowwood Complex: Stutsman County WPA: Woodworth Station Unit 7	G0	G0	G1	Grazed	Mixed.
29	Arrowwood Complex: Stutsman County WPA: Odegaard	B3	B4	G0	Burned-grazed	Mixed.
30	Arrowwood Complex: Wells County WPA: Frederick	Rest	Rest	Rest	Rested	Mixed.
32	Souris River Basin Complex: McHenry County WPA: Keller Unit 1	G	BG0	G0	Burned-grazed	Mixed.
33	Souris River Basin Complex: McHenry County WPA: Keller Unit 2	G2	BG0	BG1	Burned-grazed	Mixed.
35	Souris River Basin Complex: J. Clark Salyer NWR: Nelson Prairie 3	B1	B2	G	Burned-grazed	Mixed.
36	Souris River Basin Complex: J. Clark Salyer NWR: Nelson Prairie 4	G1	G2	G3	Grazed	Mixed.
38	Souris River Basin Complex: Upper Souris NWR: HB-24 Ekert Ranch South	B1	B2	B1	Burned	Mixed.
39	Souris River Basin Complex: Des Lacs NWR: HB7	B2	BG0	BG	Burned-grazed	Mixed.
40	Arrowwood Complex: Griggs County WPA: Wogsland	Rest	Rest	Rest	Rested	Mixed.
41	Arrowwood Complex: Arrowwood NWR: G28	B1	B2	B3	Burned	Mixed.
42	Arrowwood Complex: Arrowwood NWR: G14 Pasture 1	BG3	BG	B1	Burned-grazed	Mixed.
43	Arrowwood Complex: Arrowwood NWR: G14 Pasture 2	B3	B1	B1	Burned	Mixed.
44	Arrowwood Complex: Foster County WPA: Topp West Paddock	G2	B1	BG	Burned-grazed	Mixed.
45	Arrowwood Complex: Foster County WPA: Topp East Paddock	G	BG0	BG	Burned-grazed	Mixed.
46	Huron WMD: Jerauld County WPA: Winter	G0	G1	G0	Grazed	Mixed.
48	Huron WMD: Hand County WPA: VenJohn Unit 1	G0	BG	G0	Burned-grazed	Mixed.
49	Huron WMD: Hand County WPA: Millerdale Unit 2	G1	G2	G3	Grazed	Mixed.
50	Huron WMD: Buffalo County WPA: Mills Unit 2	--	G1	G	Grazed	Mixed.
51	Huron WMD: Hand County WPA: Campbell Unit 2	G3	G4	G5	Grazed	Mixed.
52	Huron WMD: Hyde County WPA: Harter Unit 6	G0	G0	G	Grazed	Mixed.
53	Huron WMD: Hyde County WPA: Cowan Unit 4	BG0	--	--	Burned-grazed	Mixed.

Table 1. Assignment of management treatments by year and designation of overall management regime for 89 Native Prairie Adaptive Management study units in two grass types (mixed-grass and tallgrass) in North Dakota, South Dakota, Minnesota, and Montana.—Continued

[NWR, National Wildlife Refuge; WPA, Waterfowl Production Area; WMD, Wetland Management District; B1, first growing season after burning; B2, second growing season after burning; B3, third growing season after burning; B4, fourth growing season after burning; B5, fifth growing season after burning; G0, grazed during the current growing season; G1, first growing season after grazing; G2, second growing season after grazing; G3, third growing season after grazing; G4, fourth growing season after grazing; and G5, fifth growing season after grazing; BG0, burned-grazed during the current growing season; BG1, first growing season after burning-grazing; BG2, second growing season after burning-grazing; BG3, third growing season after burning-grazing; BG4, fourth growing season after burning-grazing; BG5, fifth growing season after burning-grazing; G, grazing occurred between the two bird surveys in a single season; BG, grazing-burning occurred between the two bird surveys in a single season, --, no data]

Unit	Name	Management treatment[1]			Overall management regime[2]	Grass type
		2011	2012	2013		
54	Huron WMD: Hyde County WPA: Cowan Unit 6	G0	--	--	Grazed	Mixed.
55	Sand Lake Complex: McPherson County WPA: Charley-Harley	--	B1	G0	Burned-grazed	Mixed.
56	Sand Lake Complex: Edmunds County WPA: Mitzel	G0	G1	G2	Burned-grazed	Mixed.
57	Sand Lake Complex: Spink County WPA: Sanderson	--	B1	G0	Burned-grazed	Tall.
58	Devils Lake WMD: Grand Forks County WPA: Mekinock	--	B1	B2	Burned	Tall.
59	Devils Lake WMD: Sullys Hill National Game Preserve: Sullys Hill	B2	B3	B1	Burned	Mixed.
60	Devils Lake WMD: Benson County WPA: Melass South	G1	B1	B2	Burned	Mixed.
61	Waubay NWR Complex: Roberts County WPA: Wike Paddock 1	--	B1	B2	Burned	Tall.
62	Waubay NWR Complex: Codington County WPA: Roe F	--	B1	B2	Burned	Tall.
66	Kulm WMD: McIntosh County WPA: Geiszler 4	G2	BG	BG1	Burned-grazed	Mixed.
67	Kulm WMD: McIntosh County WPA: Geiszler 2	G	G1	G0	Grazed	Mixed.
68	Kulm WMD: McIntosh County WPA: Geiszler 1	B1	BG1	BG	Burned-grazed	Mixed.
69	Kulm WMD: McIntosh County WPA: Geiszler 3	B1	G	G2	Burned-grazed	Mixed.
70	Kulm WMD: Logan County WPA: Mayer 2	--	B1	B2	Burned	Mixed.
76	Sand Lake Complex: Campbell County WPA: Cooper North	B1	B2	B3	Burned	Mixed.
77	Souris River Basin Complex: J. Clark Salyer NWR: GLT Plot A	G1	BG1	BG2	Burned-grazed	Mixed.
78	Morris WMD: BIG STONE County WPA: Hillman A	--	B3	B4	Burned	Tall.
79	Morris WMD: BIG STONE County WPA: Hillman B	--	G0	G1	Burned	Tall.
80	Morris WMD: BIG STONE County WPA: Hillman C	--	G	G1	Grazed	Tall.
81	Morris WMD: BIG STONE County WPA: Hillman D	--	B2	B	Burned	Tall.
82	Morris WMD: Lac Qui Parle County WPA: Freeland B	--	G1	G	Grazed	Tall.
84	Big Stone NWR: Big Stone NWR: Laskowske	--	G2	G3	Grazed	Tall.
86	Souris River Basin Complex: J. Clark Salyer NWR: GLT Plot C	G1	BG1	BG2	Burned-grazed	Mixed.
88	Lake Andes NWR: Douglas County WPA: Denning	G	G1	G0	Grazed	Mixed.
90	Waubay NWR Complex: Clark County WPA: Warner Lake Paddock 5	--	G1	G2	Grazed	Tall.
91	Waubay NWR Complex: Roberts County WPA: Berward Paddock 4	--	G1	G2	Grazed	Tall.
92	Waubay NWR Complex: Roberts County WPA: Berward Paddock 5	--	Rest	G	Rest-Graze	Tall.
93	Waubay NWR Complex: Marshall County WPA: Buffalo Lake	--	Rest	Rest	Rested	Tall.
94	Waubay NWR Complex: Marshall County WPA: Buss Paddock 2	--	G1	G0	Grazed	Tall.
95	Waubay NWR Complex: Marshall County WPA: Buss Paddock 1	--	G1	G	Grazed	Tall.
97	DETROIT LAKES WMD: Clay County WPA of Minnesota: Hoykens WPA North	--	B2	B1	Burned	Tall.
101	Waubay NWR Complex: Codington County WPA: Roe E	--	G	G2	Grazed	Tall.
104	Kulm WMD: La Moure County WPA: Cornell 2	--	G1	G0	Grazed	Mixed.
107	Arrowwood Complex: Eddy County WPA: Haven Paddock 5	G	BG	BG	Burned-grazed	Mixed.
108	Arrowwood Complex: Arrowwood NWR: G26 Paddock 1	G	G	G0	Grazed	Mixed.
109	Arrowwood Complex: Arrowwood NWR: G26 Paddock 4	G	G	G0	Grazed	Mixed.

Table 1. Assignment of management treatments by year and designation of overall management regime for 89 Native Prairie Adaptive Management study units in two grass types (mixed-grass and tallgrass) in North Dakota, South Dakota, Minnesota, and Montana.—Continued

[NWR, National Wildlife Refuge; WPA, Waterfowl Production Area; WMD, Wetland Management District; B1, first growing season after burning; B2, second growing season after burning; B3, third growing season after burning; B4, fourth growing season after burning; B5, fifth growing season after burning; G0, grazed during the current growing season; G1, first growing season after grazing; G2, second growing season after grazing; G3, third growing season after grazing; G4, fourth growing season after grazing; and G5, fifth growing season after grazing; BG0, burned-grazed during the current growing season; BG1, first growing season after burning-grazing; BG2, second growing season after burning-grazing; BG3, third growing season after burning-grazing; BG4, fourth growing season after burning-grazing; BG5, fifth growing season after burning-grazing; G, grazing occurred between the two bird surveys in a single season; BG, grazing-burning occurred between the two bird surveys in a single season, --, no data]

Unit	Name	Management treatment[1]			Overall management regime[2]	Grass type
		2011	2012	2013		
110	Arrowwood Complex: Arrowwood NWR: G26 Paddock 3	--	G	G1	Grazed	Mixed.
111	Arrowwood Complex: Arrowwood NWR: G26 Paddock 2	G0	BG	G0	Burned-grazed	Mixed.
114	Medicine Lake NWR Complex: Sheridan County WPA: Anderson	G2	G0	G	Grazed	Mixed.
117	Medicine Lake NWR Complex: Medicine Lake NWR: East ML Bridgerman	B1	BG	G0	Burned-grazed	Mixed.
118	Medicine Lake NWR Complex: Sheridan County WPA: Gjesdal West	G	G0	G1	Grazed	Mixed.
119	Waubay NWR Complex: Roberts County WPA: Wike Paddock 2	--	B2	B3	Burned	Tall.
122	Medicine Lake NWR Complex: Medicine Lake NWR: East ML Lake 10	G	G1	G2	Grazed	Mixed.
125	Windom WMD: Cottonwood County WPA: Des Moines River WPA South	--	B1	B1	Burned	Tall.
127	Lake Andes NWR: Charles Mix County WPA: Trout	--	G1	G	Grazed	Mixed.
134	Huron WMD: HAND County WPA: Slunecka Unit 3	G0	G0	G1	Grazed	Mixed.
135	Huron WMD: HAND County WPA: Slunecka Unit 4	G0	G1	G	Grazed	Mixed.
456	Madison WMD: Minnehaha County WPA: Buffalo Lake 80	--	G1	G2	Grazed	Tall.
457	Madison WMD: Miner County WPA: Hepner WPA	--	G	G2	Grazed	Tall.
458	Madison WMD: Deuel County WPA: Miller	--	Rest	Rest	Rested	Tall.
459	Lostwood Complex: Burke County WPA: Swanson	B1	G0	G1	Burned-grazed	Mixed.
460	Devils Lake WMD: Towner County WPA: Towner	Rest	Rest	Rest	Rested	Mixed.
461	Kulm WMD: Dickey County WPA: Lazy M Unit 3	--	B1	G1	Burned-grazed	Mixed.

[1] Native Prairie Adaptive Management units were assigned management treatments depending upon whether the unit was rested, grazed, burned, or burned-grazed. To account for any delayed effects of management, the treatment assignments for NPAM units that were grazed, burned, or burned-grazed corresponded to the lagged effects based on the number of growing seasons after the treatment, up to five growing seasons. Because grazing is a protracted management treatment, which may occur during most or all of a growing season, treatment assignments that involved grazing during the growing season (that is, when bird surveys were being conducted) were designated as G0 or BGO. Finally, in some cases, bird surveyors encountered different management treatments during the two visits to a unit within the same growing season. In these cases of mixed management, the assigned treatment was a combination of the two treatments, but there was no numeral associated with the treatment (for example, G, BG, and so on).

[2] Native Prairie Adaptive Management units were assigned overall management regimes based on the prevailing management strategy during the study, including rested, grazing, burning, or burning-grazing.

in 2011, G0 in 2012, and G1 in 2013 was assigned a treatment regime of "burned-grazed" (table 1).

Statistical Analyses

Generalized linear mixed models (GLMMs; Stroup, 2013) were used to evaluate the effects of treatment regimes and post-management treatments on vegetation structure, vegetation composition, and breeding bird densities. For vegetation metrics, we evaluated both means and standard deviations; standard deviations were used as a measure of habitat heterogeneity or variation within study units. Analyses were done separately for treatment regimes and post-management treatments because they assess different aspects related to management actions on the NPAM units. Grass type (mixed-grass or tallgrass) was considered as a factor in the GLMM analyses involving both treatment regimes and post-management treatments. In the models involving treatment regimes, year (2011, 2012, and 2013) was included as a repeated-measures factor. In the models involving post-management treatments, the number of years (0, 1, 2, 3–5) after the management treatment was included as a repeated-measures factor. We accounted for serial correlation by assuming an autoregressive error structure for all models, and we used a Kenward-Roger adjustment to accommodate the repeated-measures nature

Table 2. Study-design matrix for post-management treatments and the number of unit-by-year combinations in mixed-grass and tallgrass units on Federal lands managed under an adaptive-management framework by the U.S. Fish and Wildlife Service in North Dakota, South Dakota, Minnesota, and Montana, 2011–13.

Treatment[1]	Description	Grass type	
		Mixed grass	Tallgrass[2]
B1	Burned 1 growing season prior	20	7
B2	Burned 2 growing seasons prior	13	6
B3-4	Burned 3–4 growing seasons prior	7	2
BG	Mixed burned-grazed	10	1
BG0	Burned-grazed during the growing season	5	0
BG1-3	Burned-grazed 1–3 growing seasons prior	6	1
G0	Grazed during the current growing season	26	4
G	Mixed grazed-only	19	6
G1	Grazed 1 growing season prior	27	8
G2	Grazed 2 growing seasons prior	9	6
G3-5	Grazed 3–5 growing seasons prior	3	1
Rest	Rested (idle) for more than 5 growing seasons	3	3
Total		**148**	**45**

[1] See table 1 for post-management treatments assigned to each of the 89 individual NPAM units surveyed in 2011–13. Some units were surveyed in more than 1 year.

[2] Treatments with less than or equal to two study units were not included in this analyses.

of the study design (Littell and others, 2006). Because some treatments were unavailable in each year or for each grass type, we used a means model approach for both analyses (Milliken and Johnson, 2009). For assessing the effects of either treatment regimes or post-management treatments on breeding bird densities, we did not include the vegetation metrics as specific covariates in either model because they are impacted by or confounded with treatments or management actions, violating one tenet of using analysis of covariance (Milliken and Johnson, 2002). Planned *a priori* contrasts were used to assess important effects when examining specific year by treatment regime effects (10 contrasts) or grass type by post-management effects (21 contrasts).

For variables involving percent data, we assumed a beta distribution (Gbur and others, 2012). For other continuous variables, we used a gamma distribution. We assumed a log-normal distribution when a model did not converge for the gamma distribution, and we assumed a normal distribution when a log-normal distribution did not converge (Gbur and others, 2012; Kiernan and others, 2012). For percent data, we converted percentages to proportions and then added 0.01 to zero values and subtracted 0.01 from 1.0 values. For all other continuous variables that followed gamma or log-normal distributions, we added 1.0 to accommodate zero values. We back-transformed the least squares means and 95-percent confidence intervals for reporting purposes. Given that the assignments of management treatments to specific study units within a management year were controlled or partially controlled (that is, manipulated) by FWS refuge managers as part of the NPAM effort, we viewed analyses of treatment regimes and post-management effects as being typical of a strict manipulative study design (that is, in which managers had control over assignment of treatments and controls; Burnham and Anderson, 2002). Therefore, we report *p*-values and used them as a guide to evaluate strong and moderate effects with respect to differences among means within planned contrasts using α=0.05 and α=0.1 as a guide, which is analogous to using 95-percent or 90-percent confidence intervals, respectively (Murtaugh, 2014).

As a followup to assessing treatment regimes and post-management effects, we modeled abundances of individual bird species as a function of vegetation and other relevant metrics. We first reduced the set of potential explanatory variables by identifying collinear variables using a correlation matrix and eliminating highly correlated variables or redefining various combinations of the variables using ratios (for example, native versus nonnative forbs). To account for regional gradients in grassland bird abundance and the area surveyed, we included the location (easting and northing, in kilometers) and area of the study unit in the modeling effort. We considered the design structure for this analysis to be a randomized block in-time with covariates, rather than considering this as a growth-curve type modeling in a repeated-measures context, because there are only 3 years of data. In all models, we first attempted to use a gamma distribution, but the models failed to converge for most species. Therefore, for consistency, we assumed a log-normal distribution for the all focal bird species and adjusted the distribution right by the value 1.0 to accommodate zero values.

We used an information-theoretic model-selection approach (Burnham and Anderson, 2002) to model individual bird species abundances with vegetation structure, vegetation composition, and other covariates. Bird-abundance models were conducted in a two-stage approach. Vegetation structural variables were evaluated in the first stage, because vegetation structural variables (for example, litter depth, bare-ground exposure, vegetation height) have been shown to be consistent predictors of grassland bird abundance (Wiens, 1969, 1974; Coppedge and others, 2008; Fisher and Davis, 2010). Vegetation composition and other variables were then added to the best vegetation structural model (with the lowest Akaike Information Criterion) to see if they improved the model fit. Year was included in all candidate models (except the null model), because grassland bird populations in this region are known to exhibit considerable annual variability in abundance (Igl and Johnson, 1997; Igl and others, 2008). All covariates were included in the candidate models only as interaction terms with year. Using the best model from the second stage, we then estimated the model parameters and assessed the fit of the model by correlating the observed and predicted values. All analyses were conducted using the PROC GLIMMIX procedure of SAS (SAS Institute, Inc., 2014).

Vegetation and Bird Responses to Adaptive Management

General Results

We surveyed breeding birds on 89 total NPAM units, including 55 mixed-grass units in 2011 and 87 (62 mixed-grass and 25 tallgrass) units in 2012 and 2013 (table 3). The total area surveyed ranged from 2,315 ha in 2011 to 3,148 ha in 2013. The average unit size was 42.1 ha in 2011, 35.3 ha in 2012, and 36.2 ha in 2013; the decline in average unit size in 2012 and 2013 reflected the inclusion of smaller NPAM units in those years.

Vegetation Responses to Management

In grasslands, disturbances shape vegetation structure and composition (Vinton and others, 1993; Tilman and Downing, 1994; Tilman, 1996; Coppedge and others, 1998). Descriptive statistics (that is, means, standard deviations, and minimum and maximum values) of vegetation structure, vegetation composition, and other explanatory variables for the 89 NPAM units across years and grass types (228 year-unit combinations) are summarized in table 4. Vegetation structure and composition varied among the NPAM units, and differences among the units were often linked to specific management actions.

Vegetation Structure

The results of the GLMMs that were used to evaluate the effects of treatment regimes and post-management treatments on vegetation structure are summarized in tables 5 and 6. Below we discuss only strong and moderate effects with respect to differences among means within planned contrasts using α=0.05 and α=0.1 as a guide. More detailed summaries of the GLMMs for vegetation structure are included in appendixes 1 and 2. These appendixes include figures showing the response of vegetation structure to treatment regimes and post-management treatments.

Bare-Ground Cover

The mean and standard deviation (that is, variation) of bare-ground cover (percent) were lower in management regimes that did not receive any treatment involving burning (that is, grazed-only and rest treatments) across the 3 years for both mixed-grass and tallgrass units (table 5, appendix 1). For both grass types, bare-ground cover in grazed-only study units was only slightly higher than bare-ground cover in study units that were rested for more than 5 years. In both the mixed-grass and tallgrass prairie units, post-management effects showed a linear decline in mean and standard deviation of bare-ground cover for burned-only units (table 6, appendix 2); that is, bare-ground cover was highest in the first growing season after a burn (B1) and declined in subsequent growing seasons (B2 and B3–4).

Table 3. Summary statistics of Native Prairie Adaptive Management units used during surveys of breeding birds in mixed-grass and tallgrass prairies on Federal lands managed under an adaptive-management framework by the U.S. Fish and Wildlife Service in North Dakota, South Dakota, Minnesota, and Montana, 2011–13.

[±, plus or minus]

	Year		
	2011	**2012**	**2013**
Total number of study units	55	87	87
Total area surveyed (hectares)	2,315	3,075	3,148
Average unit size (hectares)[1]	42.1 (±4.7)	35.3 (±29.1)	36.2 (±29.2)
Range in unit size (hectares)[1]	6.8–234.0	8.5–234.0	5.4–234.0
Total transect length (meters)	118,678	160,854	162,386
Average transect length (meters)	2,158 (±1,743)	1,849 (±1,461)	1,910 (±1,517)

[1] The size of the study unit reflects the area surveyed for breeding birds rather than the total area of the National Prairie Adaptive Management unit. Thus, the minimum unit size surveyed may have been smaller than the minimum unit size (20 hectares in 2011 and 16 hectares in 2012–13) required to be included in this study.

Table 4. Summary of mean vegetation structure, composition, and other variables and their standard deviations, minimums, and maximums sampled in Native Prairie Adaptive Management units in North Dakota, South Dakota, Minnesota, and Montana, 2011–13 (*n*=228 study units by year combinations; means are arithmetic means).

[ln, natural logarithm]

Description	Mean	Standard deviation	Minimum	Maximum
Vegetation structure variables				
Mean bare ground cover (percent)	8.82	13.43	0.00	60.13
Standard deviation of bare ground (percent)	9.26	9.00	0.00	33.40
Mean litter depth (centimeter)	2.78	2.43	0.00	13.70
Standard deviation of litter depth (centimeter)	2.04	2.22	0.00	21.36
Mean maximum vegetation height (centimeter)	66.37	19.56	15.37	149.58
Standard deviation of maximum vegetation height (centimeter)	19.30	8.56	4.04	84.61
Mean standing dead vegetation (percent)	8.01	10.92	0.00	61.52
Standard deviation of standing dead vegetation (percent)	8.56	7.92	0.00	31.81
Mean visual obstruction reading (decimeter)	2.31	1.27	0.23	5.83
Standard deviation of visual obstruction reading (decimeter)	1.07	0.55	0.14	3.39
Vegetation composition variables				
Mean smooth brome (*Bromus inermis*) occurrence (percent)	24.00	20.51	0.00	98.74
Standard deviation of smooth brome occurrence (percent)	21.25	10.55	0.00	41.16
Mean Kentucky bluegrass (*Poa pratensis*) (percent)	28.80	20.14	0.00	91.14
Standard deviation of Kentucky bluegrass (percent)	21.45	9.62	0.00	44.65
Mean native forbs (percent)	2.22	4.00	0.00	25.29
Standard deviation of native forbs (percent)	3.45	4.91	0.00	25.35
Mean native grasses (percent)	30.47	21.58	0.00	94.88
Standard deviation of native grasses (percent)	23.76	10.01	0.00	44.25
Mean nonnative forbs (percent)	3.32	5.18	0.00	34.18
Standard deviation of nonnative forbs (percent)	5.70	6.33	0.00	32.60
Mean nonnative grasses (percent)	58.15	22.59	4.88	99.26
Standard deviation of nonnative grasses (percent)	25.76	8.04	3.10	45.07
Defoliation Index[1]	3.71	1.81	0.00	6.67
Other variables				
Ratio: percent smooth brome to percent native grass[2]	−0.48	2.26	−6.86	6.70
Ratio percent Kentucky bluegrass to percent native grass[3]	−0.15	2.06	−6.46	6.76
Ratio: percent non-native forb to percent native forb[4]	0.67	2.06	−4.62	5.54
Study unit area (hectare)	37.3	30.6	5.4	234.0
Mean easting (kilometer)	−257.8	143.8	−623.7	60.57
Mean northing (kilometer)	2,623.0	185.3	2,240.5	2,913.0

[1] Defoliation Index takes into account the frequency of defoliation events during the previous 7 years (Gannon and others, 2013).

[2] ln[((percent mean smooth brome/100)+0.01)/((percent mean native grass/100)+0.01)].

[3] ln[((percent mean Kentucky bluegrass/100)+0.01)/((percent mean native grass/100)+0.01)].

[4] ln[((percent mean non-native forb/100)+0.01)/((percent mean native forb/100)+0.01)].

Table 5. Summary of generalized linear mixed models testing the influence of management regime and year on vegetation structure variables on mixed-grass and tallgrass prairies on Federal lands managed under an adaptive-management framework by the U.S. Fish and Wildlife Service in North Dakota, South Dakota, Minnesota, and Montana, 2011–13. For more detailed results, see appendix 1.

[Bare Ground, mean cover of bare ground (percent [%]); SD_Bare, standard deviation of bare ground cover (%); LitDepth, mean litter depth (cm); SD_Litter, standard deviation of litter depth (cm); Height, mean maximum vegetation height (cm); SD_Height, standard deviation of maximum vegetation height (cm); VOR, mean vertical obstruction reading; SD_VOR, standard deviation of vertical obstruction reading (dm); StandDead, mean cover of standing dead vegetation (%); SD_Dead, standard deviation of standing dead cover (%); %, percent; cm, centimeter; dm, decimeter; *, evidence for moderate effect ($0.05<p\leq 0.10$); **, evidence for strong effect ($p\leq 0.05$); --, nonsignificant ($p>0.10$)]

Model test	Vegetation structure variable									
	Bare Ground	SD_Bare	Lit Depth	SD_Litter	Height	SD_Height	VOR	SD_VOR	StandDead	SD_Dead
Overall test										
Regime × year × grass type	**	**	**	--	**	**	**	**	**	**
Contrasts										
Mixed: regime effect	**	**	**	--	*		**	**	--	--
Mixed: year effect	--	--	**	--	**	**	**	**	**	**
Mixed: interaction	--	*	--	--	*	--	*	--	--	--
Tall: regime effect	**	*	--	--	--	*	--	--	--	--
Tall: year effect	--	--	**	--	**	**	--	**	--	*
Tall: interaction	--	--	--	--	--	--	--	**	--	--
Mixed versus tall: burned only	--	--	--	--	*	--	--	--	--	--
Mixed versus tall: grazed only	--	--	--	--	**	--	**	*	--	--
Mixed versus tall: burned-grazed	--	--	--	--	--	**	*	**	--	*
Mixed versus tall: rest	--	--	--	--	--	--	--	--	--	--

Litter Depth

Mean litter depth (in centimeters) was consistently lower in mixed-grass units that received burned-only, grazed-only, and burned-grazed treatment regimes than those rested for more than 5 years (table 5, appendix 1). In both the tallgrass and mixed-grass prairies, mean litter depth tended to increase in study units receiving burned-only, grazed-only, and burned-grazed treatments across the 3 years. Variation in litter depth showed similar patterns but was not significant. In the model assessing the influence of post-management treatments, there was a linear increase in mean litter depth in mixed-grass and tallgrass units in the growing seasons after burning, and there was a linear increase in litter depth in mixed-grass units in the growing season after grazing (table 6, appendix 2). A similar pattern was noted for variation in litter depth, but the evidence was weak.

Maximum Vegetation Height

Mean maximum vegetation height (in centimeters) was only slightly lower in mixed-grass units than in tallgrass units. Vegetation heights were lower on mixed-grass units that were burned-only, grazed-only, and burned-grazed than in mixed-grass units that were rested for more than 5 years (table 5, appendix 1). Mean maximum vegetation heights were similar among treatment regimes in the tallgrass prairie units. Maximum vegetation heights increased between 2011 and 2012 and declined slightly between 2012 and 2013 in mixed-grass units that were burned-only, grazed-only, and rested. Mean vegetation height also declined between 2012 and 2013 in tallgrass units that were grazed-only, burned-grazed, and rested. Variation in vegetation height increased in all regimes in the mixed-grass units between 2011 and 2012, and declined in all regimes in both grass types between 2012 and 2013 (table 6, appendix 2). For the overall model assessing the influence of post-management treatments, mean maximum vegetation height tended to increase in both mixed-grass and tallgrass units following burned-only, grazed-only, and burned-grazed treatments, with lowest heights occurring immediately following the management activity (table 6, appendix 2). For models assessing treatment regimes, no patterns were evident in the variation of maximum vegetation height.

Vertical Obstruction Reading

The overall model testing the influence of grass type, management regime, and year on mean VORs (in decimeters) and its variation was significant (table 5, appendix 1). There was a strong regime and year effect for mean VOR and its

Table 6. Summary of generalized linear mixed models testing the influence of post-management treatments on vegetation structure variables and their standard deviations in two grass types (mixed-grass and tallgrass) on lands managed under an adaptive-management framework by the U.S. Fish and Wildlife Service in North Dakota, South Dakota, Minnesota, and Montana, 2011–13. For more detailed results, see appendix 2.

[Bare Ground, mean cover of bare ground (percent [%]); SD_Bare, standard deviation of bare ground cover (%); LitDepth, mean litter depth (cm); SD_Litter, standard deviation of litter depth (cm); Height, maximum vegetation height (cm); SD_Height, standard deviation of maximum vegetation height (cm); StandDead, Mean cover of standing dead vegetation (%); SD_Dead, standard deviation of standing dead cover (%); VOR, mean vertical obstruction reading; SD_VOR, standard deviation of vertical obstruction reading (dm); %, percent; cm, centimeter; dm, decimeter; *, evidence for moderate effect ($0.05<p\le0.10$); **, evidence for strong effect ($p\le0.05$); --, nonsignificant ($p>0.10$)]

Model test	Vegetation structure variables									
	Bare Ground	SD_Bare	Lit Depth	SD_Litter	Height	SD_Height	VOR	SD_VOR	StandDead	SD_Dead
Overall test										
Grass type × treatment	**	**	**	--	**	--	**	**	--	*
Contrasts										
Mixed: burned linear	**	**	**	--	*	--	**	--	--	**
Mixed: burned quadratic	--	--	--	--	--	--	--	**	--	--
Mixed: BG0 versus BG1-3	**	*	--	--	**	--	**	*	--	--
Mixed: grazed linear	--	--	*	--	--	--	**	--	--	--
Mixed: grazed quadratic	--	--	--	--	--	--	--	--	--	--
Tall: burned linear	**	**	**	--	--	--	--	**	--	--
Tall: grazed linear	--	--	--	--	**	--	**	--	--	--
Tall: grazed quadratic	--	--	*	--	--	--	--	**	--	--
B1: mixed versus tall	--	--	--	--	--	--	--	--	--	--
B2: mixed versus tall	--	--	--	--	--	--	--	--	--	--
G0: mixed versus tall	--	--	*	--	**	--	--	--	--	--
G: mixed versus tall	--	--	--	--	--	--	**	--	--	--
G1: mixed versus tall	--	--	--	--	**	--	**	--	--	--
G2: mixed versus tall	--	*	--	--	--	--	--	--	--	--
Mixed: burned versus rest	--	--	**	--	--	--	*	**	--	**
Mixed: grazed versus rest	--	--	--	--	*	--	**	*	--	**
Mixed: burned-grazed versus rest	*	**	**	--	**	--	**	**	--	**
Mixed: burned versus grazed	--	--	*	--	*	--	**	*	--	--
Tall: burned versus rest	--	*	*	--	--	--	--	--	--	--
Tall: grazed versus rest	--	--	--	--	--	--	--	**	--	--
Tall: burned versus grazed	**	**	**	--	--	--	--	--	--	--

standard deviation in mixed-grass prairie units. Mean VOR and its standard deviation tended to increase between 2011 and 2013, and VORs were lower in mixed-grass units that were burned-only, grazed-only, and burned-grazed than in units that were rested for more than 5 years. The overall model for assessing the influence of post-management treatments on mean VOR in tallgrass and mixed-grass prairies provided support that mean VOR differed among some grass type by treatment combinations (table 6, appendix 2). In the mixed-grass prairie units, there was a linear increase in mean VOR in the growing seasons after burned-only, grazed-only, and burned-grazed management. Mean VOR was lower, on average, in mixed-grass units that were burned-only, grazed-only, and burned-grazed than those that were rested for more than 5 years. In the tallgrass units, there was a linear increase in mean VOR after grazed-only management.

Standing Dead Cover

The overall model testing the influence of grass type, management regime, and year on standing dead cover (percent) and its variation was significant (table 5, appendix 1). There was a strong year effect in the mixed-grass prairie units; however, the mean and variation in percent standing dead cover fluctuated widely among the 3 years of the study for both grass types. Standing dead cover and its standard deviation were generally higher in 2012 than in 2011 or 2013; this pattern was consistent across grass types and treatment regimes. In the overall model assessing the influence of post-management treatments, none of the post-management treatments seemed to influence the standing dead cover nor were there any meaningful positive or negative trends following treatment for either grass type (table 6, appendix 2). However, in mixed-grass units, the amount of variation in standing dead cover tended to increase with the number of growing seasons after a burned-only management treatment.

Vegetation Composition

The results of the GLMMs that were used to evaluate the effects of treatment regimes and post-management treatments on vegetation composition are summarized in tables 7 and 8. More detailed summaries of the GLMMs are included in appendixes 3 and 4. Although the principle objective of the NPAM initiative is to increase the composition of native plant species on native prairies managed by the FWS (Gannon and others, 2013), our results related to vegetation composition should be viewed within the time constraints (3 years) of this study.

Smooth Brome Cover

The overall model testing the influence of the grass type, management regime, and year on smooth brome cover (percent) indicated no effect (table 7, appendix 3). Although the evidence was weak and nonsignificant, tallgrass units that rested for more than 5 years had, on average, the highest brome cover, and mean brome cover tended to increase across the 3 years in mixed-grass and tallgrass units that were grazed-only, burned-only, or burned-grazed (table 7, appendix 3). The overall model for assessing the influence of post-management treatments on smooth brome cover in tallgrass and mixed-grass prairies provided support that brome cover differed among some grass type by treatment combinations (table 8, appendix 4). In both the mixed-grass and tallgrass prairie units, there was a linear increase in smooth brome cover in the growing seasons after grazed-only management. No trends or patterns were noted in the variation in brome cover among post-management treatments.

Kentucky Bluegrass Cover

The overall models testing the influence of management regime and post-management treatments on mean Kentucky bluegrass cover (percent) and its variation (percent) on mixed-grass and tallgrass units indicated no effects (tables 7 and 8, appendixes 3 and 4).

Native Forb Cover

The overall model testing the influence of grass type, management regime, and year on mean native forb cover (percent) and its variation (percent) on mixed-grass and tallgrass units indicated differences among the management regime by year combinations (tables 7, appendix 3). Native forb cover was, on average, higher in tallgrass units that were rested for more than five growing seasons than in their mixed-grass counterparts. In models assessing the influence of post-management treatments, cover of native forbs tended to be higher in tallgrass units that were rested for more than 5 years than those that were burned-only or grazed-only (table 8, appendix 4). Native forb cover also tended to be higher, on average, in burned-only tallgrass units than in grazed-only tallgrass units.

Native Grass Cover

The overall model testing the influence of grass type, management regime, and year on mean native grass cover (percent) and its variation (percent) was significant (table 7, appendix 3). There was a regime effect in both the mixed-grass and tallgrass units. In mixed-grass prairies, native grass cover was higher in burned-only, burned-grazed, and rested units than in units that were grazed-only. In tallgrass prairies, native grass cover was higher, on average, in burned-only units than in units that were grazed-only, burned-grazed, or rested. Native grass cover was higher in burned-grazed units in mixed-grass prairies than in burned-grazed units in tallgrass prairies. The overall model testing the influence of the interaction of post-management treatment and grass type on native grass cover indicated no effect of grass type and post-management treatment (table 8, appendix 4).

Table 7. Summary of generalized linear mixed models testing the influence of management regime and year on vegetation composition variables on mixed-grass and tallgrass prairies on Federal lands managed under an adaptive-management framework by the U.S. Fish and Wildlife Service in North Dakota, South Dakota, Minnesota, and Montana, 2011–13. For more detailed results, see appendix 3.

[Brome, mean cover of smooth brome (percent [%]); SD_Brome, standard deviation of smooth brome cover (%); KYBlue, mean cover of Kentucky bluegrass (%); SD_KYBlue, standard deviation of Kentucky bluegrass cover (%); NatForb, mean cover of native forbs (%); SD+NatF, standard deviation of native forb cover (%); NatGrass, mean cover of native grasses (%); SD_NatG, standard deviation of native grass cover (%); NonNatF, mean cover of non-native forbs (%); SD_NonNF, standard deviation of non-native forb cover (%); NonNatG, mean cover of non-native grasses (%); SD_NonNG, standard deviation of non-native grass cover (%); DefIndex, Defoliation Index; %, percent; *, evidence for moderate effect ($0.05<p\leq0.10$); **, evidence for strong effect ($p\leq0.05$); --, nonsignificant ($p>0.10$)]

Model test	Vegetation composition variables												
	Brome	**SD_Brome**	**KYBlue**	**SD_KYBlue**	**NatForb**	**SD_NatF**	**NatGrass**	**SD_NatG**	**NonNatF**	**SD_NonNF**	**NonNatG**	**SD_NonNG**	**DefIndex**
							Overall test						
Regime × year × grass type	--	--	--	--	**	**	**	*	--	--	**	--	**
							Contrasts						
Mixed: regime effect	--	--	--	--	--	**	*	*	--	--	**	--	**
Mixed: year effect	--	--	--	--	--	--	--	*	--	--	--	--	--
Mixed: interaction	--	--	--	--	--	--	--	--	--	--	--	--	--
Tall: regime effect	--	--	--	--	**	--	*	--	--	--	**	--	*
Tall: year effect	--	--	--	--	--	--	--	--	--	--	--	--	--
Tall: interaction	--	--	--	--	--	--	--	--	--	--	--	--	--
Mixed versus tall: burned only	--	--	--	--	--	--	--	--	--	--	--	--	--
Mixed versus tall: grazed only	--	--	--	--	--	--	--	--	--	--	--	--	**
Mixed versus tall: burned-grazed	--	--	--	--	--	--	*	--	--	--	--	--	--
Mixed versus tall: rest	--	--	--	--	*	--	--	--	--	--	--	--	**

Table 8. Summary of generalized linear mixed models testing the influence of post-management treatments on vegetation composition variables and their standard deviations in two grass types (mixed-grass and tallgrass) on Federal lands managed under an adaptive-management framework by the U.S. Fish and Wildlife Service in North Dakota, South Dakota, Minnesota, and Montana, 2011–13. For more detailed results, see appendix 4.

[Brome, mean cover of smooth brome (percent [%]); SD_Brome, standard deviation of smooth brome cover (%); KYBlue, mean cover of Kentucky bluegrass (%); SD_KYBlue, standard deviation of Kentucky bluegrass cover (%); NatForb, mean cover of native forbs (%); SD+NatF, Standard deviation of native forb cover (%); NatGrass, Mean cover of native grasses (%); SD_NatG, standard deviation of native grass cover (%); NonNatF, mean cover of non-native forbs (%); SD_NonNF, standard deviation of non-native forb cover (%); NonNatG, mean cover of non-native grasses (%); SD_NonNG, standard deviation of non-native grass cover (%); DefIndex, Defoliation Index; B1, first growing season after burning; B2, second growing season after burning; BG0, burned-grazed during the current growing season; BG1-3, first, second, and third growing seasons after burning-grazing; G0, grazed during the current growing season; G, grazing occurred between the two bird surveys in a single season; G1, first growing season after grazing; G2, second growing season after grazing; Grasstype, type of grassland; %, percent; *, evidence for moderate effect ($0.05<p\le0.10$); **, evidence for strong effect ($p\le0.05$); --, nonsignificant ($p>0.10$)]

Model test	Vegetation composition variables												
	Brome	SD_Brome	KYBlue	SD_KYblue	NatForb	SD_NatF	NatGrass	SD_NatG	NonNatF	SD_NonNF	NonNatG	SD_NonNG	DefIndex
Overall test													
Grass type × treatment	*	--	--	--	**	**	--	--	--	--	--	--	**
Contrasts													
Mixed: burned linear	--	--	--	--	--	--	--	--	--	--	--	--	**
Mixed: burned quadratic	--	--	--	--	--	*	--	--	--	--	--	--	--
Mixed: BG0 versus BG1-3	--	--	--	--	--	--	--	--	--	--	--	--	--
Mixed: grazed linear	**	--	--	--	--	--	--	--	--	--	--	--	**
Mixed: grazed quadratic	--	--	--	--	--	--	--	--	--	--	--	--	**
Tall: burned linear	--	--	--	--	--	--	--	--	--	--	--	--	**
Tall: grazed linear	**	--	--	--	--	--	--	--	--	--	--	--	**
Tall: grazed quadratic	--	--	--	--	--	--	--	--	--	--	--	--	--
B1: mixed versus tall	--	--	--	--	--	--	--	--	--	--	--	--	**
B2: mixed versus tall	--	--	--	--	--	--	--	--	--	--	--	--	**
G0: mixed versus tall	--	--	--	--	--	--	--	--	--	--	--	--	**
G: mixed versus tall	--	--	--	--	--	--	--	--	--	--	--	--	**
G1: mixed versus tall	--	--	--	--	--	--	--	--	--	--	--	--	**
G2: mixed versus tall	*	--	--	--	--	--	--	--	--	--	--	--	**
Mixed: burned versus rest	--	--	--	--	--	--	--	--	--	--	--	--	**
Mixed: grazed versus rest	--	--	--	--	--	**	--	--	--	--	--	--	**
Mixed: burned-grazed versus rest	--	--	--	--	--	**	--	--	--	--	--	--	**
Mixed: burned versus grazed	--	--	--	--	--	--	--	--	--	--	--	--	**
Tall: burned versus rest	--	--	--	--	*	--	--	--	--	--	--	--	**
Tall: grazed versus rest	--	--	--	--	**	**	--	--	--	--	--	--	**
Tall: burned versus grazed	--	--	--	--	*	--	--	--	--	--	--	--	--

Nonnative Forb Cover

The overall models testing the influence of management regime and post-management treatments on mean nonnative forb cover (percent) and its variation (percent) on mixed-grass and tallgrass NPAM units indicated no effects (tables 7 and 8, appendixes 3 and 4).

Nonnative Grass Cover

The overall model testing the influence of grass type, management regime, and year on nonnative grass cover was significant (table 7, appendix 3). There was a strong regime effect in both the mixed and tallgrass grass types. In the mixed-grass prairies, nonnative grass cover was, on average, higher in grazed-only units than in burned-only, burned-grazed, and rested units. In the tallgrass prairies, nonnative grass cover was lower in burned-only tallgrass units than in grazed-only, burned-grazed, and rested units. The overall model testing the influence of management regime on the standard deviation of nonnative forb cover (percent) indicated no effect. The overall models testing the influence of the interaction of post-management treatment and grass type on mean nonnative grass cover and its variation indicated no effect (table 8, appendix 4).

Defoliation Index

The overall model testing the influence of grass type, management regime, and year on the Defoliation Index was significant (table 7, appendix 3). There was a strong regime effect in the mixed-grass units and a moderate regime effect in the tallgrass units. As expected, the Defoliation Index, which reflects the number of management years within a 7-year window in which at least one defoliation event occurred (Gannon and others, 2013), was highest for units that were burned-only, grazed-only, and burned-grazed than in units that were rested for more than 5 years. In units that were grazed-only, the mean Defoliation Index was higher in mixed-grass prairies than tallgrass prairies. For units that were rested for more than 5 years, the Defoliation Index was higher in tallgrass units than mixed-grass units. The overall model for assessing the influence of post-management treatments on the mean Defoliation Index in tallgrass and mixed-grass prairies provided support that the index differed among most grass type by treatment combinations (table 8, appendix 5). As expected, in both grass types, the Defoliation Index was lowest on rested units, and declined with time after the management treatments on units that were burned-only, grazed-only, or burned-grazed.

Correlation among Vegetation Variables

Correlations among vegetation structure variables and among composition variables were examined using Pearson product moment correlations (*r*; tables 9 and 10). In general, means were highly correlated with their standard deviations. Therefore, we reduced the number of explanatory variables by removing standard deviations from subsequent generalized linear models. All other variables were included in the models.

For structural variables (table 9), we found a positive correlation between mean litter depth and mean vertical obstruction (*r*=0.43) and mean maximum vegetation height and mean vertical obstruction (*r*=0.83). That is, as vertical obstruction increased, litter depth and vegetation height also increased. Mean bare-ground cover was negatively correlated with mean litter depth (*r*=−0.55), indicating that as bare-ground cover increased, litter depth decreased.

For composition variables (table 10), we found a negative correlation between mean native grass cover and both mean smooth brome cover (*r*=−0.51) and mean Kentucky bluegrass cover (*r*=−0.45), and a positive correlation between the mean nonnative grass cover and both smooth brome cover (*r*=0.55)

Table 9. Pearson correlation coefficients between vegetation structure variables measured at 228 unit-by-year combinations in mixed-grass and tallgrass prairies on Federal lands managed under an adaptive-management framework by the U.S. Fish and Wildlife Service in North Dakota, South Dakota, Minnesota, and Montana, 2011–13.

[Coefficients that are greater than 0.4 are shown in **bold**. BareGround, mean cover of bare ground (percent [%]); SD_Bare, standard deviation of bare ground cover (%); LitDepth, mean litter depth (cm); SD_Litter, standard deviation of litter depth (cm); Height, maximum vegetation height (cm); SD_Height, standard deviation of maximum vegetation height (cm); StandDead, mean cover of standing dead vegetation (%); SD_Dead, standard deviation of standing dead cover (%); VOR, mean vertical obstruction reading; SD_VOR, standard deviation of vertical obstruction reading (dm); %, percent; cm, centimeter; dm, decimeter]

	SD_Bare	LitDepth	SD_Litter	Height	SD_Height	StandDead	SD_Dead	VOR	SD_VOR
BareGround	**0.80**	**−0.55**	−0.31	−0.34	−0.05	−0.16	−0.23	−0.33	−0.06
SD_Bare		**−0.56**	−0.25	−0.29	0.10	−0.08	−0.14	−0.31	0.02
LitDepth			**0.68**	0.27	0.03	0.08	0.16	**0.43**	0.14
SD_Litter				0.20	0.18	0.14	0.21	0.30	0.17
Height					**0.42**	0.09	0.12	**0.83**	**0.63**
SD_Height						0.20	0.26	0.32	**0.52**
StandDead							**0.87**	−0.01	−0.05
SD_Dead								0.06	0.01
VOR									**0.74**

Table 10. Pearson correlation coefficients between vegetation composition variables measured at 228 unit-by-year combinations in mixed-grass and tallgrass prairies on Federal lands managed under an adaptive-management framework by the U.S. Fish and Wildlife Service in North Dakota, South Dakota, Minnesota, and Montana, 2011–13.

[Coefficients that are greater than 0.4 are shown in **bold**. Brome, mean cover of smooth brome (percent [%]); SD_Brome, standard deviation of smooth brome cover (%); KYBlue, mean cover of Kentucky bluegrass (%); SD_KYBlue, standard deviation of Kentucky bluegrass cover (%); NatForb, mean cover of native forbs (%); SD+NatF, standard deviation of native forb cover (%); NatGrass, mean cover of native grasses (%); SD_NatG, standard deviation of native grass cover (%); NonNatF, mean cover of non-native forbs (%); SD_NonNF, standard deviation of non-native forb cover (%); NonNatG, mean cover of non-native grasses (%); SD_NonNG, standard deviation of non-native grass cover (%); DefIndex, Defoliation Index; %, percent]

	SD_Brome	KYBlue	SD_KYBlue	NatForb	SD_NatF	NatGrass	SD_NatG	NonNatF	SD_NonNF	NonNatG	SD_NonNG	DefIndex
Brome	**0.64**	−0.36	−0.37	−0.04	−0.09	**−0.51**	−0.31	0.08	0.08	**0.55**	−0.16	−0.32
SD_Brome		−0.25	−0.14	0.00	0.00	−0.37	0.01	0.17	0.17	0.33	0.21	−0.23
KYBlue			**0.64**	−0.13	−0.18	**−0.45**	−0.29	−0.15	−0.16	**0.49**	−0.22	0.29
SD_KYBlue				−0.09	−0.12	−0.19	0.08	−0.17	−0.16	0.19	0.21	0.18
NatForb					**0.87**	0.01	−0.04	0.09	0.11	−0.16	0.05	−0.15
SD_NatF						0.09	0.03	0.08	0.11	−0.23	0.09	−0.20
NatGrass							**0.54**	−0.15	−0.14	**−0.90**	0.25	0.03
SD_NatG								−0.09	−0.04	**−0.53**	**0.81**	0.02
NonNatF									**0.91**	−0.10	0.07	−0.09
SD_NonNF										−0.12	0.10	−0.14
NonNatG											−0.33	0.02
SD_NonNG												0.02

and Kentucky bluegrass cover (*r*=0.49). As expected, the cover of native grass was strongly and negatively correlated with the cover of nonnative grass (*r*=−0.90).

Correlations between the vegetation structure and composition variables indicate that these two sets of variables are mostly weakly correlated (table 11). The two exceptions are mean litter depth (*r*=−0.40) and mean vertical obstruction (*r*=−0.47), which were negatively correlated with mean Defoliation Index, indicating that litter depth and vertical obstruction decreased with an increase in the number of management years within a 7-year window in which at least one defoliation event occurred.

Breeding Bird Responses to Management

Breeding Bird Community

We recorded a total of 110 bird species in the 89 adaptive-management units surveyed in 2011–13 (455 unit by year by visit combinations). Scientific names of all bird species are provided in table 12. The breeding bird community was dominated by obligate and facultative grassland birds (table 12; Vickery and others, 1999). The 10 most frequently occurring species at mixed-grass prairie units were Savannah sparrow (*Passerculus sandwichensis*; 100 percent of mixed-grass units surveyed), brown-headed cowbird (*Molothrus ater*; 100 percent), red-winged blackbird (*Agelaius phoeniceus*; 98.4 percent), grasshopper sparrow (*Ammodramus savannarum*; 98.4 percent), western meadowlark (*Sturnella neglecta*; 96.9 percent), bobolink (*Dolichonyx oryzivorus*; 96.9 percent), eastern kingbird (*Tyrannus tyrannus*; 87.5 percent), upland sandpiper (*Bartramia longicauda*; 82.8 percent), clay-colored sparrow (*Spizella pallida*; 78.1 percent), and common yellowthroat (*Geothlypis trichas*; 71.9 percent). The 10 most frequently occurring species at tallgrass prairie units were bobolink (100 percent of tallgrass units surveyed), common yellowthroat (100 percent), red-winged blackbird (100 percent), brown-headed cowbird (92 percent), grasshopper sparrow (92 percent), sedge wren (*Cistothorus platensis*; 92 percent), western meadowlark (92 percent), clay-colored sparrow (88 percent), Savannah sparrow (88 percent), and barn swallow (*Hirundo rustica*; 80 percent). Twenty-three species had rounded frequencies of 20 percent or more of the 455 unit by year by visit combinations (table 12). Two grassland species of highest conservation concern—Sprague's pipit and Baird's sparrow—in this region (FWS, 2008; South Dakota Game, Fish and Parks, 2014; Dyke and others, 2005; Minnesota Department of Natural Resources, 2015; Montana Fish, Wildlife and Parks, 2015) were relatively uncommon in this study and only occurred in 12.5 percent and 20.3 percent, respectively, of the mixed-grass NPAM units and were not recorded in any of the tallgrass units (table 12).

As mentioned above, in grasslands, disturbances shape vegetation or other variables if the species occurred in 20 percent or more of the 455 unit by year by visit combinations. The following sections summarize and discuss the results of the GLMMs for 23 bird species that had adequate number of occurrences to evaluate the effects of treatment regimes and post-management treatments on breeding bird densities. We discuss only strong and moderate effects with respect to differences among means within planned contrasts using α=0.05 and α=0.1 as a guide. The order of the species is based on the overall mean abundance of the species, across years and grass type.

More detailed results from these models are included in appendixes 5 and 6, including results for 12 additional but less common species. These appendixes include figures showing the response of birds to treatment regimes and post-management treatments. Models relating vegetation structure, vegetation composition, and other variables to breeding densities of the 23 focal breeding bird species are included in appendix 7.

Red-winged Blackbird (*Agelaius phoeniceus*)

Red-winged blackbirds were reported on 98.4 percent of mixed-grass NPAM units and 100 percent of the tallgrass units (table 12). The overall model testing the influence of grass type, management regime, and year on red-winged blackbird breeding densities was significant (table 13, appendix 5). There was a strong year effect in the mixed-grass and tallgrass grass types. Red-winged blackbird densities generally declined between 2012 and 2013 in all management regimes in both grass types. In the burned-grazed regime, densities tended to be lower, on average, in mixed-grass prairies than in tallgrass prairies.

The overall model assessing the influence of post-management treatments on red-winged blackbird densities provided support that grass type by management treatment effects existed (table 14, appendix 6). In particular, in the mixed-grass prairie units, there was a linear increase in red-winged blackbird densities after grazing; that is, densities were lowest in the growing season in which the grazing treatment occurred and increased in subsequent growing seasons. Densities were higher in tallgrass prairie units than in mixed-grass units that experienced a mixed grazing treatment within the same growing season (G).

For the red-winged blackbird, the best model relating vegetation structure to breeding densities included year and an interaction between year and mean VOR (table 15, appendix 7). Densities increased with increasing VOR (fig. 4). Floristic composition variables and other variables did not improve the vegetation structural model.

The red-winged blackbird is considered a wetland or marsh species, but during the breeding season, the species also uses a variety of upland habitats, including grasslands, hayland, active and retired cropland, shrublands, and road rights-of-way (Stewart, 1975; Sample, 1989; Johnson, 1997; Linz and others, 2017). Red-winged blackbird abundance varies dramatically among years (Johnson, 1997), as is demonstrated by the strong year effect in both tallgrass and mixed-grass

Table 11. Pearson correlation coefficients among vegetation structure and composition variables measured at 228 unit-by-year combinations in mixed-grass and tallgrass prairies on Federal lands managed under an adaptive-management framework by the U.S. Fish and Wildlife Service in North Dakota, South Dakota, Minnesota, and Montana, 2011–13.

[Coefficients that are greater than 0.4 are shown in **bold**. Brome, mean cover of smooth brome (percent [%]); SD_Brome, standard deviation of smooth brome cover (%); KYBlue, mean cover of Kentucky bluegrass (%); SD_KYBlue, standard deviation of Kentucky bluegrass cover (%); NatForb, mean cover of native forbs (%); SD_NatF, standard deviation of native forb cover (%); NatGrass, mean cover of native grasses (%); SD_NatG, standard deviation of native grass cover (%); NonNatF, mean cover of non-native forbs (%); SD_NonNF, standard deviation of non-native forb cover (%); NonNatG, mean cover of non-native grasses (%); SD_NonNG, standard deviation of non-native grass cover (%); DefIndex, Defoliation Index; BareGround, mean cover of bare ground (%); SD_Bare, standard deviation of bare ground cover (%); LitterDepth, mean litter depth (cm); SD_Litter, standard deviation of litter depth (cm); Height, mean maximum vegetation height (cm); SD_Height, standard deviation of maximum vegetation height (cm); Deadveg, mean cover of standing dead vegetation (%); SD_Dead, standard deviation of standing dead cover (%); VOR, mean vertical obstruction reading; SD_VOR, standard deviation of vertical obstruction reading (dm); %, percent; cm, centimeter; dm, decimeter]

Vegetation structure variables	Vegetation composition variables												
	Brome	SD_Brome	KYBlue	SD_KYBlue	NatForb	SD_NatF	NatGrass	SD_NatG	NonNatF	SD_NonNF	NonNatG	SD_NonNG	DefIndex
BareGround	−0.22	−0.13	−0.05	0.09	−0.02	−0.01	0.28	0.22	0.09	0.13	−0.25	0.20	0.17
SD_Bare	−0.23	−0.10	0.01	0.07	−0.03	−0.04	0.19	0.22	0.15	0.22	−0.19	0.22	0.24
LitterDepth	0.21	0.05	−0.04	−0.04	0.07	0.07	−0.15	−0.07	−0.10	−0.09	0.13	−0.07	**−0.40**
SD_Litter	0.04	0.07	−0.10	−0.07	0.00	0.04	0.03	0.06	−0.03	0.01	−0.07	0.05	−0.20
Height	0.13	0.06	−0.14	−0.12	0.09	0.09	−0.10	−0.14	0.00	−0.01	0.05	−0.08	−0.31
SD_Height	−0.08	0.07	−0.13	−0.01	0.03	0.03	0.11	0.10	0.03	0.01	−0.16	0.10	−0.07
DeadVeg	−0.02	−0.01	0.02	0.01	−0.09	−0.15	0.05	0.04	−0.11	−0.11	0.01	−0.01	−0.01
SD_Dead	0.01	0.01	0.02	0.00	−0.07	−0.11	0.03	0.03	−0.10	−0.06	0.03	−0.06	−0.12
VOR	0.15	0.09	−0.17	−0.08	0.15	0.22	−0.11	−0.06	0.02	0.02	0.03	0.01	**−0.47**
SD_VOR	0.02	0.11	−0.12	−0.02	0.08	0.15	−0.10	0.00	0.11	0.14	−0.03	0.06	−0.32

Table 12. Frequencies of occurrence (percent) for 110 breeding bird species (ordered alphabetically by species code) by grass type (mixed-grass and tallgrass) and year (2011, 2012, and 2013) on Federal lands managed under an adaptive-management framework by the U.S. Fish and Wildlife Service in North Dakota, South Dakota, Minnesota, and Montana, 2011–13.

[Numbers in parentheses indicate the number of Native Prairie Adaptive Management (NPAM) study units that were surveyed in each grass type in each year]

Code	Common name	Scientific name	Mixed grass				Tallgrass			Overall percent occurrence[1]
			2011 (55)	2012 (62)	2013 (62)	Overall (64)	2012 (25)	2013 (25)	Overall (25)	
AMAV	American avocet	*Recurvirostra americana*	1.8	4.8	1.6	6.3	0.0	0.0	0.0	1.1
AMBI	American bittern	*Botaurus lentiginosus*	10.9	4.8	8.1	15.6	4.0	4.0	8.0	4.0
AMCO	American coot	*Fulica americana*	0.0	1.6	1.6	3.1	0.0	0.0	0.0	0.4
AMCR	American crow	*Corvus brachyrhynchos*	1.8	1.6	0.0	3.1	0.0	0.0	0.0	0.4
AMGO	American goldfinch	*Spinus tristis*	27.3	40.3	27.4	43.8	64.0	40.0	68.0	26.8
AMKE	American kestrel	*Falco sparverius*	0.0	1.6	0.0	1.6	0.0	0.0	0.0	0.2
AMRE	American redstart	*Setophaga ruticilla*	1.8	0.0	0.0	1.6	0.0	0.0	0.0	0.2
AMRO	American robin	*Turdus migratorius*	7.3	16.1	6.5	18.8	12.0	8.0	20.0	5.9
AMWI	American wigeon	*Mareca americana*	0.0	1.6	1.6	3.1	0.0	0.0	0.0	0.4
BAEA	Bald eagle	*Haliaeetus leucocephalus*	0.0	0.0	1.6	1.6	0.0	0.0	0.0	0.2
BAIS	Baird's sparrow	*Centronyx bairdii*	18.2	9.7	8.1	20.3	0.0	0.0	0.0	7.3
BANS	Bank swallow	*Riparia riparia*	16.4	6.5	9.7	25.0	4.0	4.0	8.0	5.3
BAOR	Baltimore oriole	*Icterus galbula*	0.0	0.0	1.6	1.6	4.0	4.0	8.0	0.7
BARS	Barn swallow	*Hirundo rustica*	29.1	35.5	32.3	56.3	56.0	40.0	80.0	22.2
BBMA	Black-billed magpie	*Pica hudsonia*	1.8	0.0	1.6	3.1	0.0	0.0	0.0	0.4
BCNH	Black-crowned night-heron	*Nycticorax nycticorax*	1.8	4.8	0.0	6.3	0.0	0.0	0.0	0.9
BHCO	Brown-headed cowbird	*Molothrus ater*	94.5	90.3	95.2	100.0	84.0	68.0	92.0	74.9
BLTE	Black tern	*Chlidonias niger*	0.0	12.9	8.1	17.2	8.0	12.0	16.0	4.6
BOBO	Bobolink	*Dolichonyx oryzivorus*	83.6	74.2	87.1	96.9	92.0	100.0	100.0	70.5
BRBL	Brewer's blackbird	*Euphagus cyanocephalus*	47.3	45.2	25.8	64.1	12.0	4.0	16.0	21.8
BRTH	Brown thrasher	*Toxostoma rufum*	5.5	4.8	12.9	17.2	4.0	0.0	4.0	4.8
BWTE	Blue-winged teal	*Spatula discors*	29.1	33.9	30.6	53.1	40.0	36.0	60.0	18.2
CAEG	Cattle egret	*Bubulcus ibis*	0.0	0.0	1.6	1.6	4.0	4.0	8.0	0.7
CAGO	Canada goose	*Branta canadensis*	0.0	3.2	0.0	3.1	4.0	0.0	4.0	0.7
CAGU	California gull	*Larus californicus*	0.0	3.2	0.0	3.1	0.0	0.0	0.0	0.4
CCLO	Chestnut-collared longspur	*Calcarius ornatus*	38.2	32.3	30.6	42.2	0.0	0.0	0.0	22.0
CCSP	Clay-colored sparrow	*Spizella pallida*	58.2	67.7	79.0	78.1	84.0	88.0	88.0	68.8
CEDW	Cedar waxwing	*Bombycilla cedrorum*	9.1	14.5	9.7	17.2	4.0	0.0	4.0	5.5
CHSP	Chipping sparrow	*Spizella passerina*	5.5	0.0	0.0	4.7	4.0	0.0	4.0	0.9
CLSW	Cliff swallow	*Petrochelidon pyrrhonota*	21.8	17.7	25.8	46.9	36.0	56.0	60.0	17.1
COGR	Common grackle	*Quiscalus quiscula*	27.3	40.3	40.3	62.5	56.0	28.0	68.0	25.1
COHA	Cooper's hawk	*Accipiter cooperii*	0.0	3.2	0.0	3.1	0.0	0.0	0.0	0.4
CONI	Common nighthawk	*Chordeiles minor*	1.8	0.0	1.6	3.1	4.0	4.0	8.0	1.3
COTE	Common tern	*Sterna hirundo*	0.0	1.6	1.6	1.6	0.0	0.0	0.0	0.7
COYE	Common yellowthroat	*Geothlypis trichas*	49.1	50.0	59.7	71.9	92.0	100.0	100.0	47.5
DICK	Dickcissel	*Spiza americana*	10.9	37.1	11.3	39.1	76.0	40.0	76.	15.8
DOWO	Downy woodpecker	*Dryobates pubescens*	0.0	1.6	0.0	1.6	0.0	4.0	4.0	0.4
EABL	Eastern bluebird	*Sialia sialis*	3.6	0.0	0.0	3.1	0.0	0.0	0.0	0.4

Table 12. Frequencies of occurrence (percent) for 110 breeding bird species (ordered alphabetically by species code) by grass type (mixed-grass and tallgrass) and year (2011, 2012, and 2013) on Federal lands managed under an adaptive-management framework by the U.S. Fish and Wildlife Service in North Dakota, South Dakota, Minnesota, and Montana, 2011–13.—Continued

[Numbers in parentheses indicate the number of Native Prairie Adaptive Management (NPAM) study units that were surveyed in each grass type in each year]

Code	Common name	Scientific name	Mixed grass				Tallgrass			Overall percent occurrence[1]
			2011 (55)	2012 (62)	2013 (62)	Overall (64)	2012 (25)	2013 (25)	Overall (25)	
EAKI	Eastern kingbird	*Tyrannus tyrannus*	70.9	72.6	79.0	87.5	64.0	60.0	76.0	56.9
EAPH	Eastern phoebe	*Sayornis phoebe*	0.0	1.6	0.0	1.6	0.0	0.0	0.0	0.2
EUST	European starling	*Sturnus vulgaris*	3.6	0.0	0.0	3.1	0.0	0.0	0.0	0.4
FEHA	Ferruginous hawk	*Buteo regalis*	0.0	0.0	1.6	1.6	0.0	0.0	0.0	0.2
FISP	Field sparrow	*Spizella pusilla*	0.0	0.0	3.2	3.1	0.0	0.0	0.0	0.4
FRGU	Franklin’s gull	*Leucophaeus pipixcan*	1.8	4.8	3.2	9.4	0.0	0.0	0.0	1.3
GADW	Gadwall	*Mareca strepera*	20.0	19.4	22.6	39.1	12.0	20.0	28.0	11.2
GHOW	Great horned owl	*Bubo virginianus*	5.5	0.0	0.0	4.7	0.0	0.0	0.0	0.7
GPCH	Greater prairie-chicken	*Tympanuchus cupido*	9.1	0.0	0.0	7.8	0.0	0.0	0.0	1.3
GRCA	Gray catbird	*Dumetella carolinensis*	14.5	16.1	9.7	18.8	4.0	0.0	4.0	8.1
GRPA	Gray partridge	*Perdix perdix*	0.0	0.0	1.6	1.6	0.0	0.0	0.0	0.2
GRSP	Grasshopper sparrow	*Ammodramus savannarum*	89.1	83.9	85.5	98.4	72.0	76.0	92.0	73.0
GWTE	Green-winged teal	*Anas crecca*	1.8	1.6	1.6	4.7	0.0	0.0	0.0	0.7
HAWO	Hairy woodpecker	*Dryobates villosus*	1.8	0.0	0.0	1.6	0.0	0.0	0.0	0.2
HESP	Henslow’s sparrow	*Ammodramus henslowii*	0.0	0.0	0.0	0.0	8.0	8.0	12.0	1.3
HOLA	Horned lark	*Eremophila alpestris*	25.5	6.5	11.3	34.4	0.0	0.0	0.0	7.0
HOWR	House wren	*Troglodytes aedon*	12.7	4.8	0.0	10.9	0.0	0.0	0.0	3.1
KILL	Killdeer	*Charadrius vociferus*	34.5	43.5	14.5	60.9	40.0	12.0	44.0	19.8
LARB	Lark bunting	*Calamospiza melanocorys*	0.0	0.0	1.6	1.6	0.0	0.0	0.0	0.4
LASP	Lark sparrow	*Chondestes grammacus*	0.0	0.0	1.6	1.6	8.0	0.0	8.0	0.7
LCSP	Leconte’s sparrow	*Ammospiza leconteii*	9.1	17.7	1.6	23.4	20.0	12.0	24.0	6.2
LEFL	Least flycatcher	*Empidonax minimus*	18.2	16.1	16.1	23.4	4.0	0.0	4.0	10.3
LESC	Lesser scaup	*Aythya affinis*	0.0	0.0	1.6	1.6	0.0	0.0	0.0	0.2
LEYE	Lesser yellowlegs	*Tringa flavipes*	0.0	3.2	0.0	3.1	0.0	0.0	0.0	0.4
MAGO	Marbled godwit	*Limosa fedoa*	29.1	27.4	22.6	42.2	8.0	0.0	8.0	12.7
MALL	Mallard	*Anas platyrhynchos*	23.6	19.4	24.2	42.2	32.0	32.0	48.0	13.4
MAWR	Marsh wren	*Cistothorus palustris*	27.3	16.1	9.7	37.5	32.0	16.0	36.0	10.8
MOBL	Mountain bluebird	*Sialia currucoides*	1.8	0.0	0.0	1.6	0.0	0.0	0.0	0.2
MODO	Mourning dove	*Zenaida macroura*	43.6	33.9	37.1	56.3	20.0	32.0	52.0	22.0
NESP	Nelson’s sparrow	*Ammospiza nelsoni*	10.9	19.4	21.0	29.7	8.0	8.0	12.0	9.2
NOFL	Northern flicker	*Colaptes auratus*	9.1	8.1	4.8	15.6	4.0	0.0	4.0	3.5
NOHA	Northern harrier	*Circus hudsonius*	21.8	22.6	14.5	43.8	4.0	12.0	16.0	9.2
NOPI	Northern pintail	*Anas acuta*	10.9	3.2	14.5	23.4	4.0	4.0	8.0	4.4
NRWS	Northern rough-winged swallow	*Stelgidopteryx serripennis*	7.3	0.0	0.0	6.3	8.0	4.0	12.0	1.8
NSHO	Northern shoveler	*Spatula clypeata*	5.5	6.5	9.7	18.8	0.0	4.0	4.0	3.1
OROR	Orchard oriole	*Icterus spurius*	9.1	8.1	11.3	17.2	16.0	12.0	24.0	5.7
PUMA	Purple martin	*Progne subis*	0.0	0.0	1.6	1.6	0.0	0.0	0.0	0.2
RBGU	Ring-billed gull	*Larus delawarensis*	9.1	3.2	1.6	9.4	4.0	0.0	4.0	2.9

Table 12. Frequencies of occurrence (percent) for 110 breeding bird species (ordered alphabetically by species code) by grass type (mixed-grass and tallgrass) and year (2011, 2012, and 2013) on Federal lands managed under an adaptive-management framework by the U.S. Fish and Wildlife Service in North Dakota, South Dakota, Minnesota, and Montana, 2011–13.—Continued

[Numbers in parentheses indicate the number of Native Prairie Adaptive Management (NPAM) study units that were surveyed in each grass type in each year]

Code	Common name	Scientific name	Mixed grass				Tallgrass			Overall percent occurrence[1]
			2011 (55)	2012 (62)	2013 (62)	Overall (64)	2012 (25)	2013 (25)	Overall (25)	
REDH	Redhead	*Aythya americana*	1.8	0.0	0.0	1.6	0.0	0.0	0.0	0.2
ROPI	Rock pigeon	*Columba livia*	3.6	0.0	0.0	3.1	0.0	0.0	0.0	0.7
RPHE	Ring-necked pheasant	*Phasianus colchicus*	23.6	43.5	21.0	56.3	40.0	44.0	56.0	20.2
RTHA	Red-tailed hawk	*Buteo jamaicensis*	5.5	19.4	8.1	23.4	0.0	4.0	4.0	5.1
RTHU	Ruby-throated hummingbird	*Archilochus colubris*	0.0	0.0	1.6	1.6	0.0	0.0	0.0	0.2
RWBL	Red-winged blackbird	*Agelaius phoeniceus*	92.7	91.9	85.5	98.4	96.0	100.0	100.0	83.1
SAVS	Savannah sparrow	*Passerculus sandwichensis*	92.7	80.6	95.2	100.0	76.0	84.0	88.0	77.6
SEOW	Short-eared owl	*Asio flammeus*	0.0	1.6	3.2	4.7	0.0	0.0	0.0	0.7
SEWR	Sedge wren	*Cistothorus platensis*	38.2	46.8	43.5	70.3	80.0	76.0	92.0	38.5
SORA	Sora	*Porzana carolina*	34.5	8.1	3.2	31.3	4.0	0.0	4.0	7.0
SOSP	Song sparrow	*Melospiza melodia*	32.7	43.5	30.6	50.0	48.0	44.0	64.0	29.0
SPPI	Sprague's pipit	*Anthus spragueii*	9.1	8.1	9.7	12.5	0.0	0.0	0.0	4.8
SPSA	Spotted sandpiper	*Actitis macularius*	1.8	0.0	0.0	1.6	0.0	0.0	0.0	0.2
SPTO	Spotted towhee	*Pipilo maculatus*	1.8	0.0	0.0	1.6	0.0	0.0	0.0	0.2
STGR	Sharp-tailed grouse	*Tympanuchus phasianellus*	29.1	29.0	29.0	54.7	12.0	12.0	16.0	14.9
SWHA	Swainson's hawk	*Buteo swainsoni*	0.0	0.0	1.6	1.6	0.0	4.0	4.0	0.4
SWSP	Swamp sparrow	*Melospiza georgiana*	0.0	1.6	0.0	1.6	28.0	20.0	36.0	4.2
TRES	Tree swallow	*Tachycineta bicolor*	27.3	35.5	30.6	62.5	56.0	36.0	76.0	20.0
UPSA	Upland sandpiper	*Bartramia longicauda*	50.9	59.7	51.6	82.8	40.0	32.0	56.0	35.2
VEER	Veery	*Catharus fuscescens*	0.0	0.0	1.6	1.6	0.0	0.0	0.0	0.2
VESP	Vesper sparrow	*Pooecetes gramineus*	14.5	17.7	22.6	39.1	8.0	0.0	8.0	9.5
VIRA	Virginia rail	*Rallus limicola*	1.8	0.0	0.0	1.6	0.0	0.0	0.0	0.2
WAVI	Warbling vireo	*Vireo gilvus*	0.0	1.6	1.6	3.1	0.0	0.0	0.0	0.4
WEKI	Western kingbird	*Tyrannus verticalis*	18.2	21.0	22.6	43.8	12.0	4.0	16.0	11.0
WEME	Western meadowlark	*Sturnella neglecta*	87.3	87.1	90.3	96.9	80.0	88.0	92.0	76.3
WFIB	White-faced ibis	*Plegadis chihi*	0.0	1.6	0.0	1.6	0.0	0.0	0.0	0.2
WIFL	Willow flycatcher	*Empidonax traillii*	10.9	17.7	16.1	21.9	16.0	4.0	16.0	10.1
WILL	Willet	*Tringa semipalmata*	20.0	37.1	22.6	48.4	0.0	8.0	8.0	11.9
WIPH	Wilson's phalarope	*Phalaropus tricolor*	43.6	21.0	12.9	45.3	8.0	4.0	12.0	14.3
WISN	Wilson's snipe	*Gallinago delicata*	29.1	25.8	30.6	48.4	36.0	40.0	48.0	18.5
YBSA	Yellow-bellied sapsucker	*Sphyrapicus varius*	0.0	1.6	0.0	1.6	0.0	0.0	0.0	0.2
YERA	Yellow rail	*Coturnicops noveboracensis*	5.5	0.0	0.0	4.7	0.0	0.0	0.0	0.7
YHBL	Yellow-headed blackbird	*Xanthocephalus xanthocephalus*	50.9	35.5	19.4	62.5	36.0	16.0	48.0	20.9
YWAR	Yellow warbler	*Setophaga petechia*	21.8	24.2	27.4	26.6	32.0	44.0	52.0	22.9

[1] Overall percent occurrence is based on 455 unit × year × visit combinations.

Table 13. Summary of generalized linear mixed models testing the influence of management regime and year on breeding densities of 23 species of birds on mixed-grass and tallgrass prairies on Federal lands managed under an adaptive-management framework by the U.S. Fish and Wildlife Service in North Dakota, South Dakota, Minnesota, and Montana, 2011–13. For more detailed results, see appendix 5.

[RWBL, red-winged blackbird; CCSP, clay-colored sparrow; BOBO, bobolink; GRSP, grasshopper sparrow; SAVS, Savannah sparrow; WEME, western meadowlark; BHCO, brown-headed cowbird; SEWR, sedge wren; COYE, common yellowthroat; CCLO, chestnut-collared longspur; EAKI, eastern kingbird; YWAR, yellow warbler; BRBL, Brewer's blackbird; COGR, common grackle; YHBL, yellow-headed blackbird; SOSP, song sparrow; AMGO, American goldfinch; UPSA, upland sandpiper; KILL, killdeer; TRES, tree swallow; BARS, barn swallow; MODO, mourning dove; RPHE, ring-necked pheasant; *, evidence for moderate effect (0.05<*p*≤0.10); **, evidence for strong effect (*p*≤0.05); --, nonsignificant (*p*>0.10)]

Model test	Bird species												
	RWBL	CCSP	BOBO	GRSP	SAVS	WEME	BHCO	SEWR	COYE	CCLO	EAKI	YWAR	BRBL
Overall test													
Regime × year × grass type	**	--	**	**	**	**	**	**	**	**	--	**	**
Contrasts													
Mixed: regime effect	--	--	--	**	--	**	--	**	**	**	--	--	--
Mixed: year effect	**	--	--	--	--	--	*	--	**	--	--	**	**
Mixed: interaction	--	--	--	**	**	--	--	--	**	--	--	--	--
Tall: regime effect	--	--	--	**	**	--	--	--	--	--	--	--	--
Tall: year effect	**	--	--	--	*	--	--	--	--	--	--	**	--
Tall: interaction	--	--	--	**	**	*	**	--	--	--	--	--	**
Mixed versus tall: burned only	--	--	*	--	--	--	**	--	**	**	--	--	--
Mixed versus tall: grazed only	--	--	**	--	--	**	**	**	**	**	--	--	**
Mixed versus tall: burned-grazed	**	--	*	**	--	--	--	**	**	**	--	--	*
Mixed versus tall: rest	--	--	**	--	**	**	**	--	--	--	--	--	--

Model test	Bird species									
	COGR	YHBL	SOSP	AMGO	UPSA	KILL	TRES	BARS	MODO	RPHE
Overall test										
Regime × year × grass type	--	**	**	**	**	**	**	--	--	**
Contrasts										
Mixed: regime effect	--	**	--	--	--	--	--	--	--	--
Mixed: year effect	--	**	**	**	**	**	--	--	--	**
Mixed: interaction	--	**	--	--	**	--	--	--	--	--
Tall: regime effect	--	--	--	--	--	--	--	--	--	**
Tall: year effect	--	--	--	**	--	--	**	--	--	--
Tall: interaction	--	**	--	--	--	**	**	--	--	--
Mixed versus tall: burned only	--	*	--	--	--	--	--	--	--	--
Mixed versus tall: grazed only	--	*	--	--	--	--	**	--	--	--
Mixed versus tall: burned-grazed	--	--	--	--	--	--	--	--	--	**
Mixed versus tall: rest	--	--	--	--	--	--	--	--	--	--

Table 14. Summary of generalized linear mixed models testing the influence of post-management treatments on breeding densities of 23 species of birds on two grass types (mixed-grass and tallgrass) on Federal lands managed under an adaptive-management framework by the U.S. Fish and Wildlife Service in North Dakota, South Dakota, Minnesota, and Montana, 2011–13. For more detailed results, see appendix 6.

[RWBL, red-winged blackbird; CCSP, clay-colored sparrow; BOBO, bobolink; GRSP, grasshopper sparrow; SAVS, Savannah sparrow; WEME, western meadowlark; BHCO, brown-headed cowbird; SEWR, sedge wren; COYE, common yellowthroat; CCLO, chestnut-collared longspur; EAKI, eastern kingbird; YWAR, yellow warbler; BRBL, Brewer's blackbird; COGR, common grackle; YHBL, yellow-headed blackbird; SOSP, song sparrow; AMGO, American goldfinch; UPSA, upland sandpiper; KILL, killdeer; TRES, tree swallow; BARS, barn swallow; MODO, mourning dove; RPHE, ring-necked pheasant; B1, first growing season after burning; B2, second growing season after burning; BG0, burned-grazed during the current growing season; BG1-3, first, second, and third growing seasons after burning-grazing; G0, grazed during the current growing season; G, grazing occurred between the two bird surveys in a single season; G1, first growing season after grazing; G2, second growing season after grazing; *, evidence for moderate effect ($0.05<p\leq0.10$); **, evidence for strong effect ($p\leq0.05$); --, nonsignificant ($p>0.10$)]

Model test	Bird species												
	RWBL	CCSP	BOBO	GRSP	SAVS	WEME	BHCO	SEWR	COYE	CCLO	EAKI	YWAR	BRBL
Overall test													
Grass type × treatment	*	**	**	**	**	**	--	*	**	*	*	--	*
Contrasts													
Mixed: burned linear	--	**	*	**	**	--	--	--	--	--	--	--	**
Mixed: burned quadratic	--	--	*	**	--	--	--	--	--	--	--	--	--
Mixed: BG0 versus BG1-3	--	--	*	--	--	--	--	--	--	--	--	--	--
Mixed: grazed linear	*	--	**	--	--	--	--	--	--	--	--	--	--
Mixed: grazed quadratic	--	--	--	--	--	*	--	--	--	--	--	--	--
Tall: burned linear	--	**	**	*	**	--	--	*	--	--	--	--	**
Tall: grazed linear	--	--	*	--	--	--	--	--	--	--	--	--	--
Tall: grazed quadratic	--	--	--	--	*	--	--	--	--	--	**	--	--
B1: mixed versus tall	--	--	--	--	--	--	--	*	**	--	--	--	--
B2: mixed versus tall	--	**	--	**	--	--	--	**	**	--	--	--	--
G0: mixed versus tall	--	--	--	--	**	--	--	*	**	--	--	--	--
G: mixed versus tall	*	--	--	--	--	--	--	--	**	--	--	--	--
G1: mixed versus tall	--	--	**	--	--	--	--	**	**	--	--	--	--
G2: mixed versus tall	--	--	**	--	**	--	--	--	**	**	--	--	--
Mixed: burned versus rest	--	**	--	**	--	**	--	*	--	--	--	--	--
Mixed: grazed versus rest	--	**	--	**	--	**	--	**	*	--	--	--	--
Mixed: burned-grazed versus rest	--	**	--	**	--	**	--	*	--	**	--	--	--
Mixed: burned versus grazed	--	--	--	**	**	**	--	--	--	--	*	--	--
Tall: burned versus rest	--	--	--	--	**	--	--	--	--	--	--	--	--
Tall: brazed versus rest	--	--	--	**	**	*	--	--	--	--	--	--	--
Tall: burned versus grazed	--	--	--	**	--	--	--	--	--	--	--	--	*

Table 14. Summary of generalized linear mixed models testing the influence of post-management treatments on breeding densities of 23 species of birds on two grass types (mixed-grass and tallgrass) on Federal lands managed under an adaptive-management framework by the U.S. Fish and Wildlife Service in North Dakota, South Dakota, Minnesota, and Montana, 2011–13. For more detailed results, see appendix 6.—Continued

[RWBL, red-winged blackbird; CCSP, clay-colored sparrow; BOBO, bobolink; GRSP, grasshopper sparrow; SAVS, Savannah sparrow; WEME, western meadowlark; BHCO, brown-headed cowbird; SEWR, sedge wren; COYE, common yellowthroat; CCLO, chestnut-collared longspur; EAKI, eastern kingbird; YWAR, yellow warbler; BRBL, Brewer's blackbird; COGR, common grackle; YHBL, yellow-headed blackbird; SOSP, song sparrow; AMGO, American goldfinch; UPSA, upland sandpiper; KILL, killdeer; TRES, tree swallow; BARS, barn swallow; MODO, mourning dove; RPHE, ring-necked pheasant; B1, first growing season after burning; B2, second growing season after burning; BG0, burned-grazed during the current growing season; BG1-3, first, second, and third growing seasons after burning-grazing; G0, grazed during the current growing season; G, grazing occurred between the two bird surveys in a single season; G1, first growing season after grazing; G2, second growing season after grazing; *, evidence for moderate effect ($0.05<p\leq0.10$); **, evidence for strong effect ($p\leq0.05$); --, nonsignificant ($p>0.10$)]

Model test	**Bird species**									
	COGR	**YHBL**	**SOSP**	**AMGO**	**UPSA**	**KILL**	**TRES**	**BARS**	**MODO**	**RPHE**
Overall test										
Grass type × treatment	--	--	*	--	**	--	--	--	--	--
Contrasts										
Mixed: burned linear	--	--	--	--	**	--	--	--	--	--
Mixed: burned quadratic	--	--	--	--	--	--	--	--	--	--
Mixed: BG0 versus BG1-3	--	--	--	--	**	--	--	--	--	--
Mixed: grazed linear	--	--	--	--	--	--	--	--	--	--
Mixed: grazed quadratic	--	--	--	--	--	--	--	--	--	--
Tall: burned linear	--	--	--	--	--	--	--	--	--	--
Tall: grazed linear	--	--	--	--	--	--	--	--	--	--
Tall: grazed quadratic	--	--	--	--	--	--	--	--	--	--
B1: mixed versus tall	--	--	--	--	--	--	--	--	--	--
B2: mixed versus tall	--	--	--	--	--	--	--	--	--	--
G0: mixed versus tall	--	--	--	--	--	--	--	--	--	--
G: mixed versus tall	--	--	--	--	--	--	--	--	--	--
G1: mixed versus tall	--	--	--	--	--	--	--	--	--	--
G2: mixed versus tall	--	--	--	--	--	--	--	--	--	--
Mixed: burned versus rest	--	--	**	--	--	--	--	--	--	--
Mixed: grazed versus rest	--	--	**	--	--	--	--	--	--	--
Mixed: burned-grazed versus rest	--	--	**	--	--	--	--	--	--	--
Mixed: burned versus grazed	--	--	--	--	*	--	--	--	--	--
Tall: burned versus rest	--	--	--	--	--	--	--	--	--	--
Tall: brazed versus rest	--	--	--	--	--	--	--	--	--	--
Tall: burned versus grazed	--	--	--	--	--	--	--	--	--	--

Table 15. Final model terms, model diagnostics, and model fit for models relating vegetation structure, vegetation composition, and other variables to breeding densities (pairs per 100 hectares) of 23 breeding bird species on mixed-grass and tallgrass prairies managed under an adaptive-management framework by the U.S. Fish and Wildlife Service in North Dakota, South Dakota, Minnesota, and Montana, 2011–13. For more detailed results, see appendix 7.

[k, number of parameters considered in the model; AIC_c, Akaike Information Criterion corrected for small samples; ω_i, Akaike weights indicating the relative likelihood of each model; RWBL, red-winged blackbird; VOR, mean vertical obstruction reading; CCSP, clay-colored sparrow; LitDepth, mean litter depth (cm); BOBO, bobolink; GRSP, grasshopper sparrow; BareGround, mean cover of bare ground (%); SAVS, Savannah sparrow; NC, not computable; WEME, western meadowlark; BHCO, brown-headed cowbird; SEWR, sedge wren; COYE, common yellowthroat; CCLO, chestnut-collared longspur; EAKI, eastern kingbird; YWAR, yellow warbler; BRBL, Brewer's blackbird; COGR, common grackle; YHBL, yellow-headed blackbird; SOSP, song sparrow; AMGO, American goldfinch; UPSA, upland sandpiper; KILL, killdeer; TRES, tree swallow; BARS, barn swallow; MODO, mourning dove; RPHE, ring-necked pheasant; ln, natural logarithm; ha, hectare]

Species	Final model terms	Model diagnostics			Model fit (r)[1]		
		k	AIC_c	ω_i	2011	2012	2013
RWBL	Year, VOR	8	674.96	0.99800	0.16	0.40	0.47
CCSP	Year, VOR, LitDepth	11	715.96	0.99773	0.45	0.29	0.20
BOBO	Year, VOR	8	686.68	0.98717	0.57	0.55	0.52
GRSP	Year, VOR, BareGround	11	704.31	0.98942	0.44	0.53	0.64
SAVS	Year	5	675.88	0.99852	NC	NC	NC
WEME	Year	5	595.91	0.99698	NC	NC	NC
BHCO	Year	5	587.62	0.95842	NC	NC	NC
SEWR	Year, VOR, LitDepth	11	689.28	0.93628	0.37	0.56	0.68
COYE	Year, VOR	8	560.69	0.61490	0.54	0.71	0.66
CCLO	Year	5	625.54	0.99609	NC	NC	NC
EAKI	Year	5	582.80	0.99870	NC	NC	NC
YWAR	Year	5	438.07	0.99621	NC	NC	NC
BRBL	Year	5	654.63	0.99535	NC	NC	NC
COGR	Year	5	660.48	0.98705	NC	NC	NC
YHBL	Year	5	612.56	0.99457	NC	NC	NC
SOSP	Year	5	542.53	0.99969	NC	NC	NC
AMGO	Year, VOR	8	515.08	0.99953	0.21	0.30	−0.17
UPSA	Year, VOR, LitDepth	11	509.47	0.99958	0.31	0.51	0.36
KILL	Year, VOR	8	514.11	0.99958	0.26	0.35	0.15
TRES	Year	5	503.86	0.98803	NC	NC	NC
BARS	Year	5	510.94	0.99964	NC	NC	NC
MODO	Year	5	446.90	0.99715	NC	NC	NC
RPHE	Year	5	440.92	0.99976	NC	NC	NC

[1] Correlation between observed ln(pairs per 100 hectares) and predicted ln(pairs per 100 hectares) for each year.

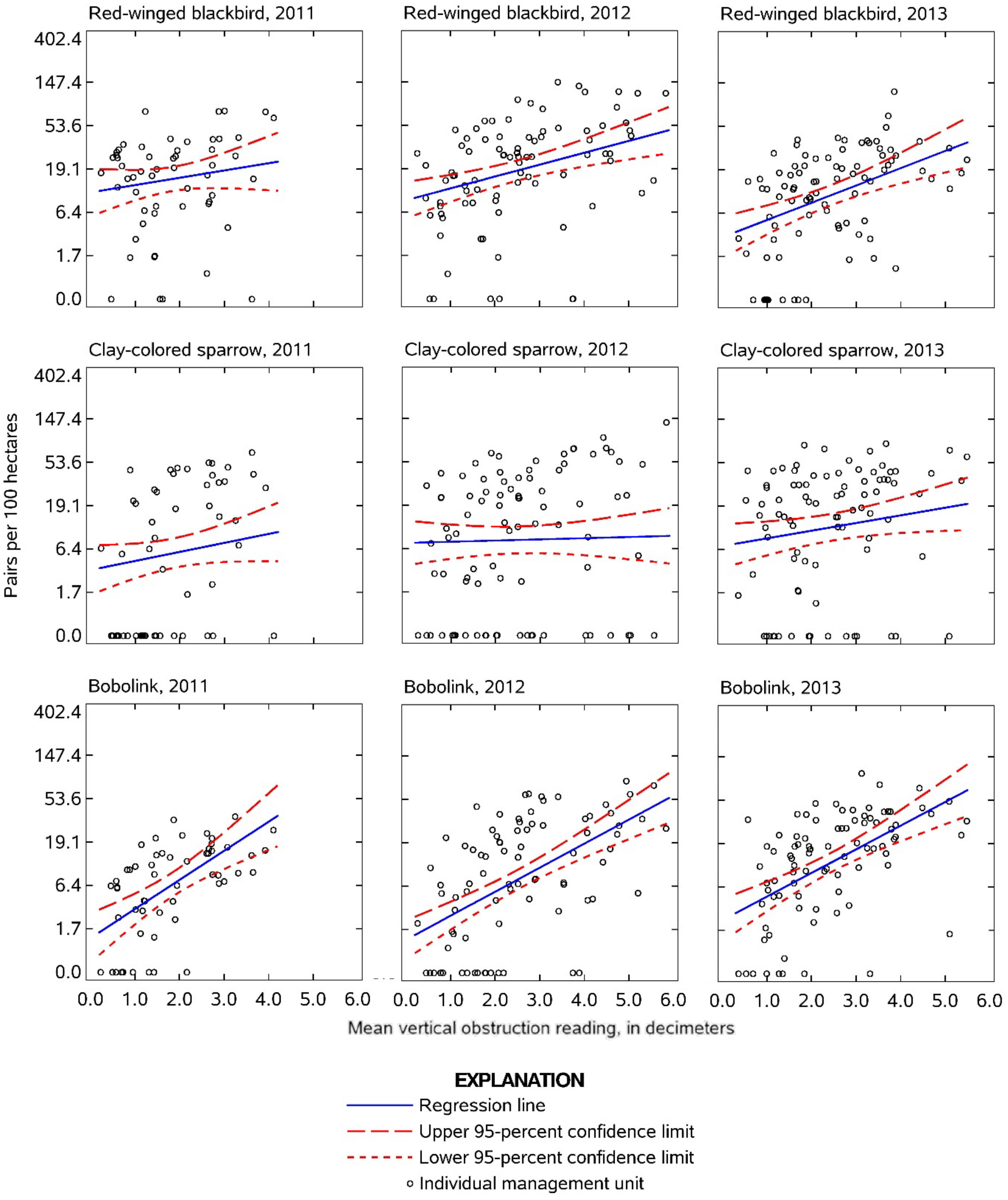


Figure 4. Results of vegetation-based models to predict red-winged blackbird (*Agelaius phoeniceus*), clay-colored sparrow (*Spizella pallida*), and bobolink (*Dolichonyx oryzivorus*), abundance in 2011–13 using simple least-squares regression. Plots show relationships (plus or minus 95-percent confidence limits) between numbers of breeding pairs (natural-log scale) and mean vertical obstruction readings.

prairies in this study. Renfrew and others (2008) reported that red-winged blackbird densities were higher on wet meadows in Nebraska with greater vertical obstruction, and Fletcher and Koford (2002) reported that densities were positively associated with vertical obstruction in native prairies and restored prairies in Iowa. Patterson and Best (1996) and Delisle and Savidge (1997), however, determined no relationship between abundance and vegetation structure or composition variables in Iowa and Nebraska grasslands enrolled in the Conservation Reserve Program. The species typically responds positively to moderate grazing in taller grasslands but negatively to heavier grazing in shorter grasslands (Bock and others, 1993). In North Dakota mixed-grass prairies, Salo and others (2004) reported that red-winged blackbird were more common in mixed-grass prairies that were idle than in mixed-grass prairies that were twice-over grazed, season-long grazed, or short-duration grazed.

Clay-colored Sparrow (*Spizella pallida*)

Clay-colored sparrows were reported on more than 78 percent of mixed-grass NPAM units and 88 percent of the tallgrass units (table 12). The overall model testing the influence of the grass type, management regime, and year on clay-colored sparrow densities was not significant (table 13, appendix 5).

The overall model for assessing the influence of post-management treatments on breeding densities of clay-colored sparrows in tallgrass and mixed-grass prairies provided support that densities differed among some grass type by treatment combinations (table 14, appendix 6). In both the mixed-grass and tallgrass prairie units, there was a linear increase in clay-colored sparrow densities in the growing seasons after burning; that is, densities were lowest in the first growing season after burning and increased in subsequent growing seasons. Densities were higher in tallgrass prairie units than in mixed-grass units in the second growing season after burning and were lower in mixed-grass prairie units that were burned-only, grazed-only, or burned-grazed than in units that were rested for more than five growing seasons.

The best vegetation model relating vegetation structure to clay-colored sparrow breeding densities included year, an interaction between year and mean vertical obstruction reading, and an interaction between year and mean litter depth (table 15, appendix 7). Clay-colored sparrow densities increased with increasing mean VOR and increasing mean Litter Depth (figs. 4 and 5). Floristic composition variables and other variables did not improve the vegetation structure model for the clay-colored sparrow.

Clay-colored sparrows prefer woody edges, grasslands intermixed with shrubs, or grasslands with thick, dense vegetation (Stewart, 1975; Johnson and others, 2004). The species uses both native and nonnative grasslands, and idle grasslands often support higher densities than grasslands that have been disturbed by burning, grazing, or haying (Renken, 1983; Messmer, 1990; Madden, 1996; Koford, 1999; Prescott and Murphy, 1999; Durán, 2009; Ranellucci, 2010; Igl and Johnson, 2016). Similar to this study, other studies have determined that burning often has an immediate negative effect on clay-colored sparrow abundance in the first growing season after burning, but their abundance increased in subsequent growing seasons (Madden, 1996; Johnson, 1997; Madden and others, 1999; Grant and others, 2010, 2011). Clay-colored sparrow abundance tends to be higher in tall, dense grasslands (Johnson and others, 2004); response to grazing, however, often varies and likely reflects the species response to changes in vegetation structure rather than responses to the grazing regime or intensity (Messmer, 1990; Bock and others, 1993; Johnson and others, 2004). Long-term rest favors this species (Madden, 1996; Johnson, 1997; Horn and Koford, 2000; Igl and Johnson, 2016), as do areas with higher litter depth, shrub cover, and vertical obstruction (Renken and Dinsmore, 1987; Madden, 1996; Schneider, 1998; Bakker and others, 2002; Winter and others, 2005, 2006; White, 2009; Thompson and others, 2014). In Manitoba, Canada, mixed-grass prairies, Richardson (2012) determined that clay-colored sparrow abundance was negatively associated with grazing and showed a significant interaction with year and grazed-only units.

Bobolink (*Dolichonyx oryzivorus*)

The bobolink was observed on more than 96 percent of the mixed-grass NPAM units and on 100 percent of the tallgrass units (table 12). The overall model testing the influence of the grass type, management regime, and year on bobolink densities was significant (table 13, appendix 5). On average, densities were higher in all treatment regimes in tallgrass prairie units than in mixed-grass units.

The overall model assessing the influence of post-management treatments on breeding densities of bobolinks in tallgrass and mixed-grass prairies provided support that densities differed among some grass type by post-management treatment combinations (table 14, appendix 6). In the mixed-grass and tallgrass prairie units, there was a linear increase in bobolink densities in the growing seasons after burned-only and grazed-only management actions. There was a quadratic trend in the burned-only mixed-grass prairie units, but the linear trend was stronger. There also was a linear increase in densities between the growing season during which the burned-grazed treatment occurred (BG0) and 1–3 years after the burned-grazed treatment. Bobolink densities were lower in mixed-grass prairie units than in tallgrass units during the first growing season after grazing occurred (G and G1).

The best model relating vegetation structure to bobolink densities included year and an interaction between year and VOR (table 15, appendix 7). Bobolink densities increased with increasing VOR (fig. 4). Floristic composition variables and other variables did not improve the vegetation structure model for the bobolink.

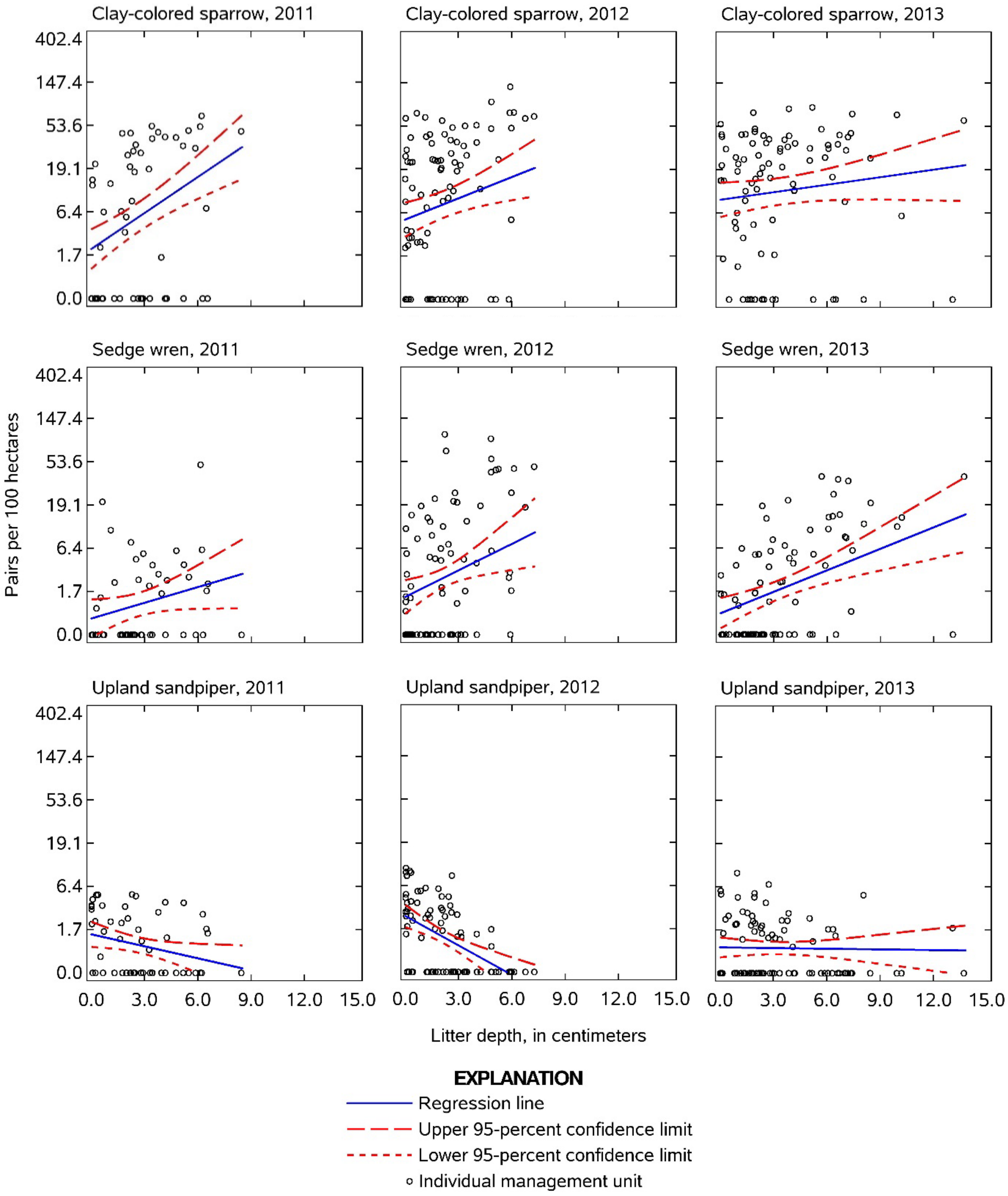


Figure 5. Results of vegetation-based models to predict clay-colored sparrow (*Spizella pallida*), sedge wren (*Cistothorus platensis*), and upland sandpiper (*Bartramia longicauda*) abundance in 2011–13. Plots show relationships (plus or minus 95-percent confidence limits) between numbers of breeding pairs (natural-log scale) and mean litter depth.

The bobolink is an obligate grassland species that prefers grasslands characterized by intermediate to tall vegetation that is somewhat dense, with some residual vegetation (Wiens, 1969; Sample, 1989). Habitats of the bobolink during the breeding season include mixed-grass and tallgrass prairies, wet-meadows, hayland, retired croplands (for example, Conservation Reserve Program grasslands), and some croplands (Stewart, 1975; Fritcher and others, 2004). The species uses native and nonnative grasslands during the breeding season (Dhol and others, 1994; Hartley, 1994; Johnson and others, 2004). Bobolink densities often are higher in grasslands dominated by nonnative species than in mixed-grass and tallgrass prairies (Renken, 1983; Renken and Dinsmore, 1987; Dhol and others, 1994; Hartley, 1994; Davis and others, 2013) and often are higher in tallgrass prairies than in mixed-grass prairies (Bock and others, 1999). Breeding abundance of this species tends to increase with vegetation height, vertical obstruction, and grassland and litter cover (Schneider, 1998; Fletcher and Koford, 2002; Winter and others, 2005, 2006; Nocera and others, 2007; Pillsbury, 2010; Ranellucci, 2010; Thompson and others, 2014). Ahlering and Merkord (2016), however, reported that bobolink abundance declined with increasing VOR and increased with increasing litter depth. Abundance may decline with long-term rest (Johnson, 1997; Olechnowski and others, 2009) or heavy grazing (Bock and others, 1993; Salo and others, 2004). In Wisconsin grasslands enrolled in the Conservation Reserve Program, Byers and others (2017) reported that bobolink nest densities were higher 1–3 years after a burn than in the year of the burn. In two North Dakota studies in mixed-grass prairies, bobolinks were absent from unburned areas, and abundance peaked one to three growing seasons after burning and then declined five growing seasons after burning (Madden, 1996; Johnson, 1997). In Illinois tallgrass prairie fragments, however, Herkert (1994) found that bobolinks showed a significant preference for recently burned areas. In Iowa and Missouri tallgrass prairies, Pillsbury (2010) determined that bobolink densities were highest in burned-only pastures, moderate in burned-grazed pastures, and lowest on grazed grasslands that were patch-burned, but Duchardt and others (2016) reported that densities were similar in burned-only, burned-grazed, and patch-burned tallgrass prairie fragments. In North Dakota, bobolink abundance was lowest the first growing season after burning and peaked three growing seasons after burning (Grant and others, 2010). In Missouri, bobolink abundance was highest in lightly to moderately grazed tallgrass prairies and were absent from idle tallgrass prairies (Skinner, 1974, 1975), but in Nebraska wet meadows and Manitoba mixed-grass prairies, bobolink densities were higher or similar in rested areas than in grazed areas (Kim and others, 2008; Durán, 2009).

Grasshopper Sparrow (*Ammodramus savannarum*)

The grasshopper sparrow was reported on 98 percent of the mixed-grass NPAM units and on 92 percent of the tallgrass units (table 12). The overall model testing the influence of the grass type, management regime, and year on grasshopper sparrow densities was significant (table 13, appendix 5). In both the mixed-grass and tallgrass prairie units, there was a strong treatment regime effect. On average, grasshopper sparrow densities were highest in units with a grazed-only treatment regime and lowest in units that were rested for more than five growing seasons. Also in both grass types, the model indicated that differences in grasshopper sparrow densities depended on year. In the mixed-grass prairies, densities generally increased between 2011 and 2013 for units that were burned-only, grazed-only, or burned-grazed but declined between 2011 and 2013 for units that were rested. Grasshopper sparrow densities also were higher in mixed-grass prairie units that had been burned-grazed than in tallgrass prairie units that had been burned-grazed.

The overall model assessing the influence of post-management treatments on breeding densities of grasshopper sparrows in two grass types indicated that densities differed among some grass type by post-management treatment combinations (table 14, appendix 6). In both the mixed-grass and tallgrass prairie units, there was a linear increase in grasshopper sparrow densities in the growing seasons after a burned-only management action. Grasshopper sparrow densities were higher in mixed-grass prairie units than in tallgrass units during the second growing season (B2) after a burned-only management action. On average, densities were higher in mixed-grass units that were burned-only, grazed-only, and burned-grazed than in mixed-grass units that were rested more than 5 years. Densities also were higher in mixed-grass units that were grazed-only than in mixed-grass units that were burned-only. In tallgrass units, densities were higher in study units that were grazed-only than in units that were burned-only or rested for more than 5 years.

The best model relating vegetation structure to grasshopper sparrow densities included year, an interaction between year and VOR, and an interaction between year and bare-ground cover (table 15, appendix 7). Densities declined with increasing VOR and increasing cover of bare ground (figs. 6 and 7). Floristic composition variables and other variables did not improve the vegetation structure model for the grasshopper sparrow.

During the breeding season, the grasshopper sparrow prefers grasslands that have an intermediate vegetation height and density, moderately deep litter, high grass cover, low shrub cover, and clumped vegetation interspersed with patches of bare ground (Whitmore, 1981; Skinner, 1982; Sample, 1989; Johnson and others, 2004). The species tends to avoid areas with tall, dense vegetation (Sample, 1989; Igl and others, 2008; Bakker and Higgins, 2009; Greer, 2009). Grasshopper sparrows can be found in both native and nonnative grasslands during the breeding season (Sample, 1989; Madden, 1996; Igl and others, 2008). Low vertical height-density or vertical obstruction has been identified as an important habitat feature for grasshopper sparrows and is consistent with the species' preference for shorter and clumped vegetation (Rotenberry

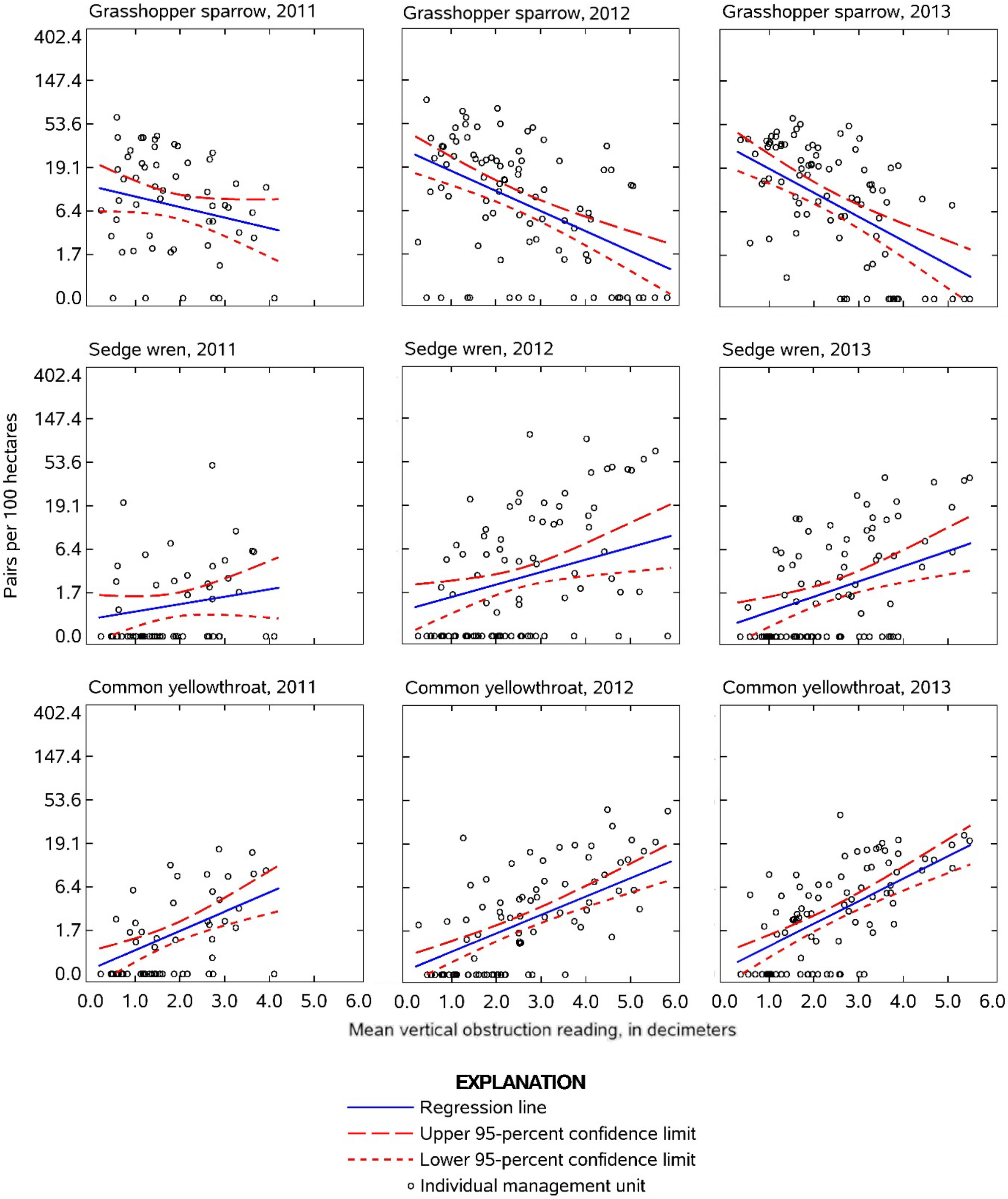


Figure 6. Results of vegetation-based models to predict grasshopper sparrow (*Ammodramus savannarum*), sedge wren (*Cistothorus platensis*), and common yellowthroat (*Geothlypis trichas*) abundance in 2011, 2012, and 2013. Plots show relationships (plus or minus 95-percent confidence limits) between numbers of breeding pairs (natural-log scale) and mean vertical obstruction readings.

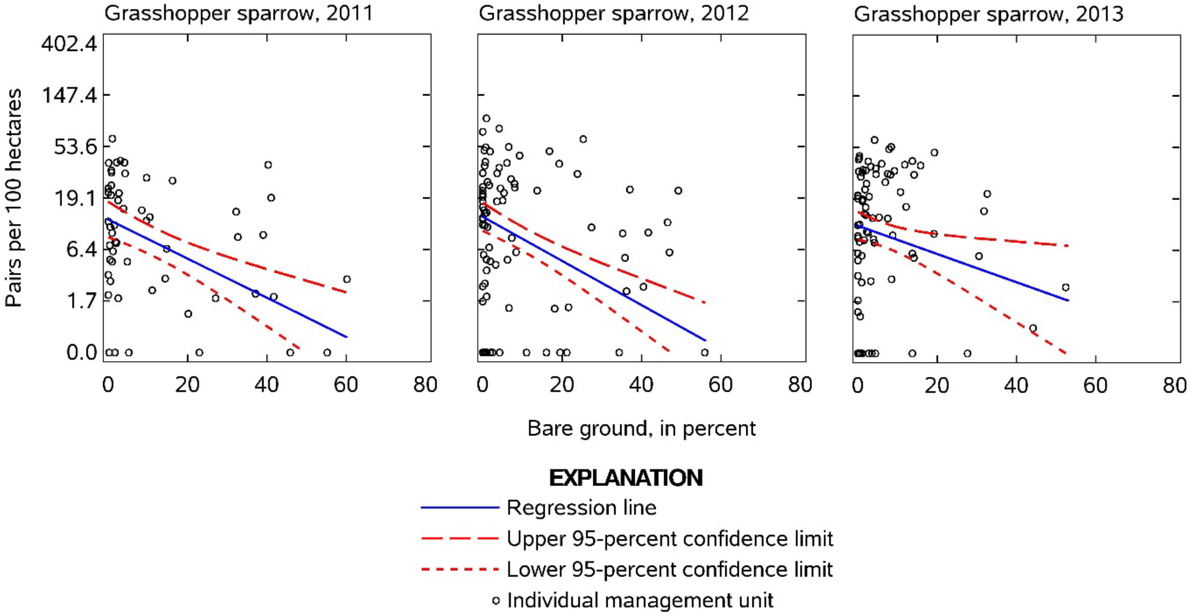


Figure 7. Results of vegetation-based models to predict grasshopper sparrow (*Ammodramus savannarum*) abundance in 2011, 2012, and 2013. Plots show relationships (plus of minus 95-percent confidence limits) between numbers of breeding pairs (natural-log scale) and mean cover of bare ground.

and Wiens, 1980; Sample, 1989; Patterson and Best, 1996; Delisle and Savidge, 1997; Madden and others, 2000; Bakker and others, 2002; Fletcher and Koford, 2002; Scott and others, 2002; Roth and others, 2005; Jacobs and others, 2012; Greer and others, 2016). As with this study, preference for grasslands with lower cover of bare ground was noted by Rotenberry and Wiens (1980), Schneider (1998), and Greer (2009). In North Dakota mixed-grass prairies, Schneider (1998) found that two of the strongest predictors of grasshopper sparrow presence were decreasing bare-ground coverage and increasing litter. Eddleman (1974) and Forde and others (1984) indicated that lack of litter and nesting cover will result in fewer nesting sites and a lack of nesting materials for this species immediately after a burn. Madden and others (1999) reported that grasshopper sparrow abundance was higher in mixed-grass prairies burned four times in the previous 15 years than in unburned mixed-grass prairies or prairies burned 1–2 times in the previous 15 years. Similar to our study, in mixed-grass prairies in North Dakota, Johnson (1997) reported that grasshopper sparrow abundance was reduced in the first year after a burn, but increased for the next 4 years after the burn and then slowly declined thereafter. Messmer (1990) in mixed-grass prairies and Jacobs and others (2012) in tallgrass prairies determined that grasshopper sparrow abundance was higher in prairies that were grazed than those that were rested. Jacobs and others (2012) reported that abundance was highest in grazed grasslands than in idle grasslands enrolled in the Conservation Reserve Program. In tallgrass prairies in Kansas, Powell (2006, 2008) determined that abundance was higher in areas grazed by cattle and areas that had been burned 1–3 years earlier than during the year of a burn. Duchardt and others (2016) reported higher densities of grasshopper sparrows in tallgrass prairie fragments that were burned and grazed than in fragments that were only burned.

Savannah Sparrow (*Passerculus sandwichensis*)

The Savannah sparrow was reported on 100 percent of the mixed-grass NPAM units and on 88 percent of the tallgrass units (table 12). The overall model testing the influence of grass type, management regime, and year on Savannah sparrow densities was significant (table 13, appendix 5). In the tallgrass prairie units, there were strong effects of treatment regime and year, and the differences among management regimes depended on year. On average, Savannah sparrow densities were higher in tallgrass units that were grazed-only, burned-only, or burned-grazed management and were lowest in units that were rested for more than 5 years. Densities were higher in 2012 than in 2013 in burned-only tallgrass units, and lower in 2012 than 2013 in burned-grazed tallgrass units. In mixed-grass prairies, the differences in densities among management regimes depended on year. For units that were rested more than 5 years, densities were higher in mixed-grass units than tallgrass units.

The overall model assessing the influence of post-management treatments on breeding densities of Savannah sparrows in tallgrass and mixed-grass prairies indicated that densities differed among some grass type by post-management treatment combinations (table 14, appendix 6). In the mixed-grass prairie units, there was a linear increase in Savannah sparrow densities in the growing seasons after burning. In the tallgrass prairie units, there was a linear decrease in densities in the growing seasons after grazing. Densities were lower in the first growing season after burning (B1) in mixed-grass units than in tallgrass units. Densities were higher in tallgrass units than in mixed-grass units during the growing season that grazing occurred (G0), but were higher in mixed-grass units in the second growing season after grazing (G2). In mixed-grass units, densities were higher in grazed units than burned units. In the tallgrass prairie units, densities were higher in burned-only and grazed-only treatments than in rested study units.

The best model relating vegetation structure to Savannah sparrow densities included only year (table 15, appendix 7). Floristic composition variables and other variables did not improve the vegetation structure model for the Savannah sparrow.

The Savannah sparrow uses a variety of grassland habitats during the breeding season. Although there was no evidence of vegetation effects for this species, other studies have reported that Savannah sparrows show a preference for grasslands with short or intermediate vegetation height, intermediate vegetation density, and a well-developed litter layer (Johnson and others, 2004). Information in the literature indicates that the species' response to burning and grazing is highly variable. For example, White (2009) and Richardson and others (2014) reported that grazing and burning treatments in mixed-grass prairies did not affect Savannah sparrow abundance, but in two studies in mixed-grass prairies in North Dakota, Savannah sparrows reached their highest densities 1–5 years post-burn (Johnson, 1997) and 6–8 years post-burn (Madden and others, 1999). Similar to this study, Grant and others (2010, 2011) found that Savannah sparrow abundance in mixed-grass prairies was lowest during the first growing season after a burn but continued to increase in subsequent seasons. Several studies have reported higher breeding densities of Savannah sparrows on idle or lightly grazed grasslands than moderately or heavily grazed grasslands (for example, Owens and Myres, 1973; Kantrud and Kologiski, 1982; Anstey and others, 1995; Salo and others, 2004). In mixed-grass prairies in South Dakota, Greer (2009) determined higher densities of male Savannah sparrows in idle mixed-grass prairies than in those that were grazed or hayed. In Illinois tallgrass prairies, Savannah sparrows preferred recently burned prairies, reached highest densities the first growing season after a burn, reached lower densities in the second growing season after a burn, and were not recorded more than 3 years after a burn (Herkert, 1994). In contrast to our study, Richardson (2012) found that Savannah sparrow abundance did not show a significant association with time since management treatment (burned-only, grazed-only, or burned-grazed) in mixed-grass prairies in Manitoba, Canada.

Western Meadowlark (*Sturnella neglecta*)

The western meadowlark was reported on more than 96 percent of the mixed-grass NPAM units and on 92 percent of the tallgrass units (table 12). The overall model testing the influence of grass type, management regime, and year on western meadowlark densities was significant (table 13, appendix 5). In the mixed-grass prairie units, there was a strong treatment regime effect. On average, meadowlark densities were highest in mixed-grass units that were grazed-only, moderate in burned-only and burned-grazed units, and lowest in study units that were rested for more than five growing seasons. In the tallgrass prairie units, the model indicated an interaction between management regime and year, indicating that the differences in meadowlark densities among management regimes depended on year. Western meadowlark densities were higher in 2012 than 2013 in grazed-only and burned-only tallgrass units and lower in 2012 than 2013 in burned-grazed and rested tallgrass units. On average, densities were higher in study units that were grazed-only in mixed-grass prairies than in tallgrass prairies, but meadowlark densities were lower in mixed-grass units that were rested than tallgrass units that were rested.

The overall model assessing the influence of post-management treatments on breeding densities of western meadowlarks in tallgrass and mixed-grass prairies indicated that densities differed among some grass type by post-management treatment combinations (table 14, appendix 6). Specifically, in the tallgrass prairie units, there was a linear decline in western meadowlark densities after burning. In the mixed-grass prairie units, densities were, on average, higher in units that were burned-only, grazed-only, and burned-grazed than in units that were rested for more than five growing seasons. Densities were higher in grazed-only than burned-only mixed-grass prairie units and were higher in grazed-only tallgrass units than units that were rested for more than five growing seasons.

The best model relating vegetation structure to western meadowlark densities included only year (table 15, appendix 7). Floristic composition variables and other variables did not improve the vegetation structure model for the western meadowlark.

The western meadowlark breeds in a variety of grasslands, including native and nonnative grasslands and tallgrass and mixed-grass prairies (Stewart, 1975; Johnson and Schwartz, 1993a, 1993b; Bakker and others, 2002; Johnson and others, 2004; Igl and others, 2008; Bakker and Higgins, 2009). The species prefers grasslands with a high grass and litter component and low to intermediate cover of forbs (Stauffer and Best, 1980; Sample, 1989; Hull and others, 1996; Johnson and others, 2004), and the species tends to avoid grasslands with exceptionally sparse or tall vegetation cover (Dale, 1983; Patterson and Best, 1996). Our study indicates that burning and grazing are important disturbances for maintaining grasslands used by western meadowlarks. In two studies in mixed-grass prairies in North Dakota, western meadowlarks reached their highest densities 2–4 years post-burn (Johnson, 1997) and 1–3 years post-burn (Madden and others, 1999). Western meadowlarks were absent from prairies that had not been burned for more than 80 years (Madden and others, 1999). Although western meadowlarks have shown a mixed response to grazing, several studies have reported that they respond positively to light to moderate grazing (Kantrud and Kologiski, 1982; Messmer, 1985; Bock and others, 1993) and, similar to our study, have higher abundances in grazed grasslands than in idle grasslands (Kantrud and Kologiski, 1982; Fondell and Ball, 2004; Durán, 2009; Ranellucci, 2010; Ranellucci and others, 2012). Some studies, however, have reported that western meadowlark abundances were unrelated to grazing or were higher in idle grasslands (Wiens, 1973a; Messmer, 1990; Logan, 2001; Kim and others, 2008; Smythe and Haukos, 2010). In a Manitoba, Canada, study in mixed-grass prairies, Richardson (2012) reported that western meadowlark abundance was positively associated with the number of years since a burned-grazed treatment, but abundance did not show any significant relationships with burned-only or grazed-only units.

Brown-headed Cowbird (*Molothrus ater*)

The brown-headed cowbird was reported on 100 percent of the mixed-grass NPAM units and on 92 percent of the tallgrass units (table 12). The overall model testing the influence of grass type, management regime, and year on brown-headed cowbird densities was significant (table 13, appendix 5). In the mixed-grass prairie units, there was a moderate year effect. On average, brown-headed cowbird densities declined between 2011 and 2013 in the mixed-grass prairie units. In the tallgrass prairie units, the model indicated an interaction between management regime and year, indicating that the difference in densities among management regimes depends on year. Densities were higher in 2012 than 2013 in grazed-only and burned-only tallgrass units and lower in 2012 than 2013 in burned-grazed tallgrass units. Densities in mixed-grass prairie units were higher, on average, in grazed-only, burned-only, and rest treatment regimes than in their tallgrass counterparts.

The overall model testing the influence of the interaction of post-management treatment and grass type on brown-headed cowbird densities indicated no effect of post-management treatment or year (table 14, appendix 6).

The best model relating vegetation structure to cowbird densities included only year (table 15, appendix 7). Floristic composition variables and other variables did not improve the vegetation structure model for the brown-headed cowbird.

The brown-headed cowbird is an obligate brood parasite that lays its eggs in nests of other songbird species and depends on these host species to incubate its eggs and rear its young. The brown-headed cowbird is a habitat generalist that evolved in the Great Plains; the species is considered a facultative grassland bird (Vickery and others, 1999). Brown-headed cowbirds and their hosts can be found in a variety of habitats, including both native and nonnative grasslands and in mixed-grass and tallgrass prairies (Sample, 1989; Madden, 1996; Johnson and others, 2004; Igl and Johnson, 2007). Brown-headed cowbird densities and brood parasitism vary considerably across space and time, and female densities are strongly related to densities and richness of other bird species in the breeding bird community (Igl and Johnson, 2007). In our study, brown-headed cowbird densities were lower in managed tallgrass prairies than in managed mixed-grass prairies, which may reflect that a lower number of potential hosts occur in tallgrass prairies or that tallgrass prairies are outside of the brown-headed cowbird's peak distribution in the mixed-grass prairies of the northern Great Plains. Similar to our study, several studies have reported no significant response in brown-headed cowbird abundance to burning (Zimmerman, 1993; Madden, 1996; Robel and others, 1998; Madden and others, 1999), and only a few studies have reported a strong effect of burning on abundance (Best, 1979; Camp and Best, 1993). In south-central North Dakota, densities were lowest in the first year after a burn but showed no longer-term response (Johnson, 1997). The species may be common in grasslands that are grazed (Kantrud and Kologiski, 1982; Klute, 1994; Shaffer and others, 2003; Johnson and others, 2004), and the species often is associated with livestock (Goguen and Mathews, 1999). In North Dakota, Messmer (1990) determined that densities did not differ significantly among idle mixed-grass prairies and those managed under several rotational grazing systems. Similar to our study, in Manitoba, Canada, brown-headed cowbirds did not show a significant association with time since management treatment (burned-only, grazed-only, or burned-grazed) in mixed-grass prairies (Richardson, 2012).

Sedge Wren (*Cistothorus platensis*)

The sedge wren was reported on more than 70 percent of the mixed-grass NPAM units and on 92 percent of the tallgrass units (table 12). The overall model testing the influence of grass type, management regime, and year on sedge wren densities was significant (table 13, appendix 5). In the mixed-grass prairie units, there was a strong management regime effect. On average, wren densities were lower in mixed-grass units experiencing burned-only, grazed-only, and burned-grazed management regimes than in units that were rested for more than five growing seasons. Wren densities were lower, on average, in grazed-only and burned-grazed mixed-grass prairie units than in their tallgrass counterparts.

The overall model assessing the influence of post-management treatments on breeding densities of sedge wrens in tallgrass and mixed-grass prairies indicated that densities differed among some grass type by post-management treatment combinations (table 14, appendix 6). In the tallgrass prairie units, there was a linear increase in sedge wren densities after burning. Densities were higher in the tallgrass units than in the mixed-grass units in the first (B1) and second (B2) growing seasons after burning, in the growing season that grazing occurred (G0), and in the first growing season after grazing (G1). In the mixed-grass prairie units, densities were, on average, lower on units that were burned-only, grazed-only, and burned-grazed than in units that were rested for five or more growing seasons.

The best model relating vegetation structure to sedge wren densities included year, an interaction between year and VOR, and an interaction between year and litter depth (table 15, appendix 7). Sedge wren densities increased with increasing VOR and increasing litter depth (fig. 6). Floristic composition variables and other variables did not improve the vegetation structure model for the sedge wren.

Sedge wren breeding habitat includes tall, dense vegetation and prostrate residual vegetation, which can be found in nonnative and native grasslands, dry marshes and wet meadows, and retired cropland (Stewart, 1975; Sample, 1989; Johnson and Schwartz, 1993b; Johnson, 1997; Igl and others, 2008; Bakker and Higgins, 2009; Robert and others, 2009; Begley and others, 2012). In this study, sedge wrens were more abundant in tallgrass and mixed-grass prairie units that were rested for more than five growing seasons than in managed NPAM units. Similar to this study, high vertical height-density or vertical obstruction was identified as an important habitat feature for sedge wrens by Sample (1989), Delisle and Savidge (1997), and Vogel (2011). Sedge wren preference for grasslands with greater litter depth also was noted by Delisle and Savidge (1997), Bakker and others (2002), Renfrew and Ribic (2002), Pillsbury (2010), and Vogel (2011). In two North Dakota studies, sedge wren abundance was reduced in the first year after burning (Johnson, 1997; Grant and others, 2010). In North Dakota, sedge wrens were more abundant on idle mixed-grass prairies than in mixed-grass pastures that were twice-over or season-long grazed (Messmer, 1985, 1990).

Common Yellowthroat (*Geothlypis trichas*)

The common yellowthroat was reported on about 72 percent of the mixed-grass NPAM units and on 100 percent of the tallgrass units (table 12). The overall model testing the influence of grass type, management regime, and year on common yellowthroat densities was significant (table 13, appendix 5). In the mixed-grass prairie units, there was a strong effect of year, management regime, and their interaction; on average, common yellowthroat densities generally increased between 2011 and 2013 in all management regimes except in burned-grazed units. Densities were higher in mixed-grass units experiencing rest than in units that were burned-only, grazed-only, or burned-grazed. Densities were higher, on average, in grazed-only, burned-only and burned-grazed tallgrass prairie units than in their mixed-grass counterparts.

The overall model assessing the influence of post-management treatments on breeding densities of common yellowthroats in tallgrass and mixed-grass prairies indicated that densities differed among some grass type by post-management treatment combinations (table 14, appendix 6). Common yellowthroat densities were higher in the tallgrass units than mixed-grass units in the first (B1) and second (B2) growing seasons after burning, in the growing season that grazing occurred (G0 and G), and in the first (G1) and second (G2) growing seasons after grazing. In the mixed-grass prairie units, densities were, on average, lower in units that were grazed-only than in units that were rested for more than 5 years.

The best model relating vegetation structure to common yellowthroat densities included year and an interaction between year and VOR (table 15, appendix 7). Densities increased with increasing vertical obstruction (fig. 6). Floristic composition variables and other variables did not improve the vegetation structure model for the common yellowthroat.

The common yellowthroat is a habitat generalist that breeds in mesic habitats characterized by tall, dense vegetation. Breeding habitats include grasslands with lush vegetation, emergent wetland vegetation, sedge meadows, shrublands, and woodland edges (Stewart, 1975; Kahl and others, 1985; Sample, 1989; Patterson and Best, 1996; Johnson, 1997). The selection of areas with taller, denser vegetation (that is, higher vertical obstruction) in this study is consistent with information reported in the literature for this species (Madden, 1996; Murray and Best, 2014). Madden (1996), for example, determined a similar preference for higher vertical height-density in mixed-grass prairies in northwestern North Dakota. In Iowa, Murray and Best (2014) emphasized the importance of unmanaged areas with denser and more senescent vegetation for nesting common yellowthroats. In Quebec, common yellowthroat abundance was higher on ungrazed wet prairies than grazed wet prairies, and abundance increased with higher vertical obstruction (Bélanger and Picard, 1999). Madden and others (1999) found that fire reduced the suitability of mixed-grass prairies for common yellowthroats, and that abundance was greatest on mixed-grass prairies that had not been burned for greater than 80 years. In Wisconsin, common yellowthroat densities were positively correlated with increasing vertical height-density (Sample, 1989).

Chestnut-collared Longspur (*Calcarius ornatus*)

The chestnut-collared longspur was reported on more than 42 percent of the mixed-grass NPAM units and on none of the tallgrass units (table 12). The overall model testing the influence of grass type, management regime, and year on chestnut-collared longspur densities was significant (table 13, appendix 5). In the mixed-grass prairie units, there was a strong effect of management regime. On average, chestnut-collared longspur densities were lowest in mixed-grass units that experienced rest for more than 5 years than in units that were burned-only, grazed-only, or burned-grazed. Densities were higher, on average, in mixed-grass prairie units that were grazed-only, burned-only, and burned-grazed than in their tallgrass counterparts.

The overall model assessing the influence of post-management treatments on breeding densities of chestnut-collared longspurs in tallgrass and mixed-grass prairies indicated that densities differed among some grass type by post-management treatment combinations (table 14, appendix 6). Chestnut-collared longspur densities were higher in the mixed-grass units than in tallgrass units in the second growing season after grazing (G2). In the mixed-grass prairie units, densities were, on average, higher in units that were burned-grazed than in units that were rested for more than 5 years.

The best model relating vegetation structure to chestnut-collared longspur densities included only year (table 15, appendix 7). Floristic composition variables and other variables did not improve the vegetation structure model for the chestnut-collared longspur.

The chestnut-collared longspur favors grasslands with short vegetation and sparse litter (Owens and Myres, 1973; Stewart, 1975; Kantrud, 1981; Fritcher and others, 2004; Johnson and others, 2004; Greer and others, 2016). The species uses native prairies, nonnative pastures, hayland, and active, fallow, and retired cropland fields, and the species tends to avoid grasslands that have tall, dense vegetation with dense litter (Renken, 1983; Renken and Dinsmore, 1987; Berkey and others, 1993; Johnson, 1997; Igl and others, 2008). The species has been largely extirpated from the tallgrass prairie region of North America (Wyckoff, 1986). Similar to our study, many other studies have reported that chestnut-collared longspurs prefer grazed, burned, or burned-grazed mixed-grass prairies to ungrazed prairies (Maher, 1973; Owens and Myres, 1973; Kantrud, 1981; Kantrud and Kologiski, 1982, 1983; Madden and others, 1999; Bleho, 2009; Lusk, 2009; White, 2009; Sliwinski, 2011; Ranellucci and others, 2012; Richardson, 2012; Lipsey, 2015; Davis and others, 2016). Richardson (2012) reported that the species showed a strong positive association with both burning and grazing, and the species' abundance declined over time in burned-only and burned-grazed mixed-grass prairie units.

Eastern Kingbird (*Tyrannus tyrannus*)

The eastern kingbird was reported on 87.5 percent of the mixed-grass NPAM units and on 76 percent of the tallgrass units (table 12). The overall model testing the influence of grass type, management regime, and year on eastern kingbird densities was not significant (table 13, appendix 5).

The overall model assessing the influence of post-management treatments on breeding densities of eastern kingbirds in tallgrass and mixed-grass prairies indicated that densities differed among some grass type by post-management treatment combinations (table 14, appendix 6). In the tallgrass prairie units that were grazed, there was a quadratic response in eastern kingbird densities; that is, densities in tallgrass units were lowest in the growing season in which grazing occurred (G0), highest in units that received a mixed grazing treatment (G), and then declined in subsequent growing seasons (G1 and G2). In mixed-grass prairie units, densities were, on average, higher in burned-only units than in grazed-only units.

The best model relating vegetation structure to eastern kingbird densities included only year (table 15, appendix 7). Floristic composition variables and other variables did not improve the vegetation structure model for the eastern kingbird.

The eastern kingbird is a facultative grassland bird (Vickery and others, 1999) that uses a variety of habitats during the breeding season, including savanna-like habitats, woodlands with open canopies, and open habitats with the presence of nearby tall, woody vegetation (Stewart, 1975; Arnold and Higgins, 1986; Sample, 1989; Igl and Johnson, 1997, 2018b; Johnson, 1997). In tallgrass prairies in Kansas, eastern kingbird abundance did not differ among management treatments that included rest, grazed-only, burned-only, and hay production (Powell and Busby, 2013), and Messmer (1990) and Ranellucci (2010) determined that eastern kingbird densities did not differ significantly among grazing regimes in mixed-grass prairies. In mixed-grass prairies, Johnson (1997) found that eastern kingbird densities were only slightly lower than average in the first 3 years after a burn, but in general, were unaffected by the recency of a burn. Robel and others (1998) reported that eastern kingbird abundance was nonsignificantly higher on burned Conservation Reserve Program fields than on unburned fields. In contrast to our study, in mixed-grass prairies in western North Dakota, Schmitt (2003) reported that eastern kingbirds were largely absent from burned-only units compared to undisturbed, grazed-only, and burned-grazed units. Salo and others (2004) reported that eastern kingbird densities declined with increasing grazing intensity in mixed-grass prairies in south-central North Dakota.

Yellow Warbler (*Setophaga petechia*)

The yellow warbler was reported on 26.6 percent of the mixed-grass NPAM units and on 52 percent of the tallgrass units (table 12). The overall model testing the influence of grass type, management regime, and year on yellow warbler densities was significant (table 13, appendix 5). In both the mixed-grass and tallgrass prairie units, there was a strong effect of year. On average, yellow warbler densities were lower in 2012 than in 2011 and 2013.

The overall model testing the influence of the interaction of post-management treatment and grass type on yellow warbler densities indicated no effect of post-management treatment or year (table 14, appendix 6).

The best model relating vegetation structure to yellow warbler densities included only year (table 15, appendix 7). Floristic composition variables and other variables did not improve the vegetation structure model for the yellow warbler.

The yellow warbler favors a variety of habitats during the breeding season, including woodlands with open canopies, open habitats with scattered trees or shrubs, thickets of small trees or shrubs, and open habitats with the presence of nearby tall, woody vegetation (Stewart, 1975; Dobkin, 1992; Igl and others, 1997, 2018b; Johnson, 1997). In this study, the yellow warbler occurred in low densities in all treatment regimes and post-management treatments; highest densities occurred in mixed-grass prairie units that were rested for more than five growing seasons. Johnson (1997) reported that yellow warbler densities showed no long-term pattern following a burn, and Bélanger and Picard (1999) determined significantly higher yellow warbler densities on ungrazed prairies than moderately grazed prairies.

Brewer's Blackbird (*Euphagus cyanocephalus*)

The Brewer's blackbird was reported on more than 64 percent of the mixed-grass NPAM units and on 16 percent of the tallgrass units (table 12). The overall model testing the influence of the interaction of grass type, management regime, and year on Brewer's blackbird densities was significant (table 13, appendix 5). In the mixed-grass prairie units, there was a strong year effect. On average, Brewer's blackbird densities were highest in 2011 and lowest in 2013. In the tallgrass prairie units, the difference in densities among management regimes depended on year. Densities were similar among management regimes in 2012 but were higher in burned-only units in 2013 compared to the other three management regimes. Densities in units that were grazed-only or burned-grazed were higher in mixed-grass prairie units than in the tallgrass counterparts.

The overall model assessing the influence of post-management treatments on breeding densities of Brewer's blackbirds in tallgrass and mixed-grass prairies indicated that densities differed among some grass type by post-management treatment combinations (table 14, appendix 6). In both the mixed-grass and tallgrass prairie units that were burned-only, there was a negative linear response in Brewer's blackbird densities in the growing seasons following burning; that is, densities were highest in the growing season after burning occurred (B1) and declined in subsequent years (B2 and B3-4). In the tallgrass prairie units, densities were, on average, higher in burned-only units than grazed-only units.

The best model relating vegetation structure to Brewer's blackbird densities included only year (table 15, appendix 7). Floristic composition variables and other variables did not improve the vegetation structure model for the Brewer's blackbird.

The Brewer's blackbird is a habitat generalist and a facultative grassland bird (Vickery and others, 1999). The species is associated with a wide variety of habitats, including grasslands, road and railroad rights-of-way, fencerows, residential areas, open woodlands, thickets of shrubs or trees, and brush piles from cut or fallen branches (Stewart, 1975; Sample, 1989). In this study, the species responded positively to burned-only treatments in both tallgrass and mixed-grass NPAM units, but densities declined in subsequent growing seasons. In burned coniferous forests in Montana, Brewer's blackbird densities were highest 1–4 years post-burn (Harris, 1982; Hutto, 1995; Saab and Powell, 2005). In Wisconsin, Brewer's blackbirds nested in dry marshes from which the previous year's vegetation had been burned (Schorger, 1934). Although not noted in our study, in riparian areas in the Intermountain West, the species responded positively to grazing (Bock and others, 1993).

Common Grackle (*Quiscalus quiscula*)

The common grackle was reported on 62.5 percent of the mixed-grass NPAM units and on 68 percent of the tallgrass units (table 12). The overall model testing the influence of the grass, type, management regime, and year on common grackle densities was not significant (table 13, appendix 5).

The overall model testing the influence of the interaction of post-management treatment and grass type on common grackle densities indicated no effect of post-management treatment or year (table 14, appendix 6).

The best vegetation structure model relating vegetation structure to common grackle densities included only year (table 15, appendix 7). Floristic composition variables and other variables did not improve the vegetation structure model for the common grackle.

The common grackle is an edge species that often forages in open habitats, such as grasslands and wetlands (Stewart, 1975; Peer and Bollinger, 2017). The species nests in short trees and tall shrubs, and the general lack of nest sites in the NPAM units likely limited the use of these adaptive-management units by common grackles. We did not detect differences in common grackle densities among treatment regimes or post-management treatments, which is a result also supported by Wood and others (2013).

Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*)

The yellow-headed blackbird was reported on 62.5 percent of the mixed-grass NPAM units and on 48 percent of the tallgrass units (table 12). The overall model testing the influence of grass type, management regime, and year on yellow-headed blackbird densities was significant (table 13, appendix 5). In the mixed-grass prairie units, there was a strong effect of year and management regime. In mixed-grass prairies, yellow-headed blackbird densities were highest in burned-only units, followed by grazed-only, burned-grazed, and rested units. The difference in densities among management regimes depended on year in both the mixed-grass units and the tallgrass units. In the mixed-grass units, densities declined between 2011 and 2013 in the grazed-only, burned-grazed, and rested units, whereas densities increased between 2011 and 2013 in the burned-only units. In the tallgrass prairie units, densities declined between 2012 and 2013 in the burned-only units but were similar across years in the other three management regimes (that is, grazed-only, burned-grazed, and rest). Densities in units that were burned-only or grazed-only were higher, on average, in mixed-grass prairie units than in tallgrass prairie units.

The overall model testing the influence of the interaction of post-management treatment and grass type on yellow-headed blackbird densities indicated no effect of post-management treatment or year (table 14, appendix 6).

The best vegetation structure model relating vegetation structure to yellow-headed blackbird densities included only year (table 15, appendix 7). Floristic composition variables and other variables did not improve the vegetation structure model for the yellow-headed blackbird.

The yellow-headed blackbird is an obligate marsh-nesting species that selects emergent vegetation in more deeply flooded areas of wetlands (Murkin and others, 1997; Twedt, 2017). Yellow-headed blackbird populations fluctuate dramatically among years in relation to rainfall variation and water levels in wetlands (Fletcher and Koford, 2004), as shown by the strong year effect in tallgrass and mixed-grass prairie units in this study. The species typically forages from vertical emergent vegetation (Orians and Horn, 1969) or on the ground in agricultural fields, pastures, and meadows (Dolbeer and Linz, 2016). In this study, yellow-headed blackbirds often were recorded while they were foraging on the ground in upland grasslands on NPAM units. Higher densities of yellow-headed blackbirds in burned-only prairie units may reflect exploitation of the most available food resources in nearby grasslands at that time of the breeding season (Twedt, 2017).

Song Sparrow (*Melospiza melodia*)

The song sparrow was reported on 50 percent of the mixed-grass NPAM units and on 64 percent of the tallgrass units (table 12). The overall model testing the influence of grass type, management regime, and year on song sparrow densities was significant (table 13, appendix 5). In the mixed-grass prairie units, there was a strong year effect. On average, song sparrow densities were higher in mixed-grass units in 2012 than in 2011 and 2013.

The overall model assessing the influence of post-management treatments on breeding densities of song sparrows in tallgrass and mixed-grass prairies indicated that densities differed among some grass type by post-management treatment combinations (table 14, appendix 6). Densities of song sparrows in burned-only, grazed-only, and burned-grazed mixed-grass prairie units were lower, on average, than those in units that had been rested for over five growing seasons.

The best vegetation structure model relating vegetation structure to song sparrow densities included only year (table 15, appendix 7). Floristic composition variables and other variables did not improve the vegetation structure model for the song sparrow.

The song sparrow is a habitat generalist. During the breeding season the species can be found in a variety of habitats, including mesic to wet habitats with tall, dense vegetation; shrublands; forest edges; woodlands with open canopies; retired cropland; and wetlands with tall, emergent vegetation (Stewart, 1975; Sample, 1989). Similar to this study, other studies have reported a preference for undisturbed habitats over those that had been managed by burning, grazing, or haying (Vogl, 1973; Bélanger and Picard, 1999; Zuckerberg and Vickery, 2006; Carragher and others, 2012; Igl and Johnson, 2016).

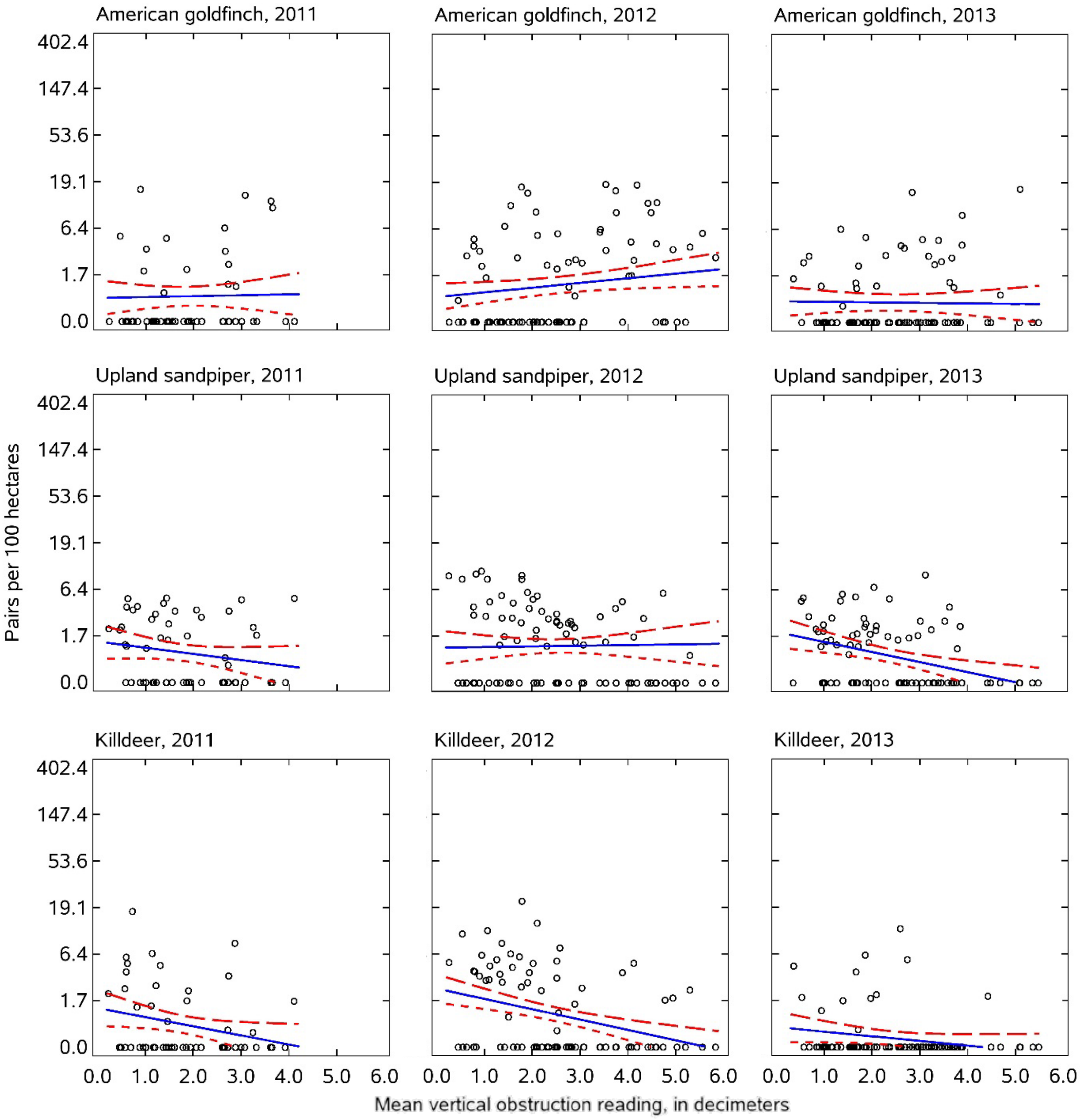
American Goldfinch (*Spinus tristis*)

The American goldfinch was reported on about 44 percent of the mixed-grass NPAM units and on 68 percent of the tallgrass units (table 12). The overall model testing the influence of grass type, management regime, and year on American goldfinch densities was significant (table 13, appendix 5). In the mixed-grass and tallgrass prairie units, there was a strong year effect. American goldfinch densities were higher in 2012 than in 2011 and 2013 in both grass types.

The overall model testing the influence of the interaction of post-management treatment and grass type on American goldfinch densities indicated no effect of post-management treatment or year (table 14, appendix 6).

The best vegetation structure model relating vegetation structure to American goldfinch densities included year and an interaction between year and VOR (table 15, appendix 7). Goldfinch densities increased with increasing VOR in 2011 and 2012 but slightly declined with increasing vertical obstruction in 2013, which indicates that this relationship is somewhat weak (fig. 8). Floristic composition variables and other variables did not improve the vegetation structure model for the American goldfinch.

The American goldfinch is a habitat generalist but prefers habitats and habitat edges with a somewhat high coverage of shrub or tree cover and moderate residual cover for nesting (Sample, 1989). During the breeding season, the species is found in open areas with trees and shrubs, marshes, shrublands, wet meadows, retired cropland, woodland edges, residential areas, and grasslands (Stewart, 1975; Sample, 1989). The availability of woody vegetation for nesting is probably a key habitat feature for American goldfinches in NPAM units; however, if small trees and shrubs are eliminated by grazing or burning, use of the area by American goldfinches will likely decline (Arnold and Higgins, 1986). In Wisconsin, the species preferred grasslands with intermediate vegetation height-density (Sample, 1989), and in Iowa tallgrass prairies, American goldfinch densities were positively associated with total vegetation cover and negatively associated with vertical visual obstruction (Fletcher and Koford, 2002).



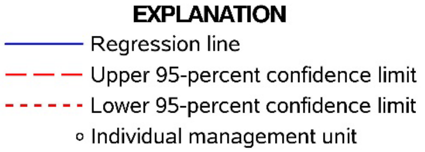


Figure 8. Results of vegetation-based models to predict American goldfinch (*Spinus tristis*), upland sandpiper (*Bartramia longicauda*), and killdeer (*Charadrius vociferus*) abundance in 2011, 2012, and 2013. Plots show relationships (plus or minus 95-percent confidence limits) between numbers of breeding pairs (natural-log scale) and mean vertical obstruction readings.

Upland Sandpiper (*Bartramia longicauda*)

The upland sandpiper was reported on 82.8 percent of the mixed-grass NPAM units and on 56 percent of the tallgrass units (table 12). The overall model testing the influence of grass type, management regime, and year on upland sandpiper densities was significant (table 13, appendix 5). In the mixed-grass prairie units, there was a strong year effect, and the differences in densities among management regimes depended on year. On average upland sandpiper densities were highest in 2012 and lowest in 2011 and 2013 in mixed-grass prairie units that were burned-only, burned-grazed, or rested. Densities in grazed-only mixed-grass prairie units increased between 2011 and 2013.

The overall model assessing the influence of post-management treatments on breeding densities of upland sandpipers in tallgrass and mixed-grass prairies indicated that upland sandpiper densities differed among some grass type by post-management treatment combinations (table 14, appendix 6). In the mixed-grass prairie units that were burned-only and burned-grazed, there was a linear response in upland sandpiper densities. In the burned-only mixed-grass units, densities were highest in the growing season after burning occurred (B1) and declined in subsequent growing seasons (B2 and B3-4). In the burned-grazed mixed-grass units, densities were highest in the growing season in which the burned-grazed treatment occurred (BG0) and declined in subsequent growing seasons (BG1-3). In the mixed-grass prairie units, densities were, on average, higher in the grazed-only units than in burned-only units.

The best vegetation structure model relating vegetation structure to upland sandpiper densities included year, an interaction between year and VOR, and an interaction between year and litter depth (table 15, appendix 7). Upland sandpiper densities declined with mean vertical obstruction readings in 2011 and 2013, but densities increased slightly with increasing VOR in 2012 (fig. 8). Densities also declined with increasing mean litter depth (fig. 5). Floristic composition variables and other variables did not improve the vegetation structure model for the upland sandpiper.

The upland sandpiper is an obligate grassland species that favors open grasslands with short to medium vegetation and little to no woody cover (Higgins and others, 1969; Stewart, 1975; Ailes, 1976; Sample, 1989; Kantrud and Higgins, 1992; Bowen and Kruse, 1993). The species prefers heavier cover for nesting than it does for foraging (Higgins and others, 1969; Ailes, 1976; Kantrud, 1981; Bowen and Kruse, 1993). Similar to this study, low vertical height-density has been identified as an important habitat feature by Renken and Dinsmore (1987), Sample (1989), Roth and others (2005), Murray and others (2008), and Ahlering and Merkord (2016). Preference for grasslands with lower litter depth also was reported by Renken and Dinsmore (1987) and Ahlering and Merkord (2016). Several studies have reported that the species typically reaches its highest abundance in disturbed habitats with intensive grazing or recent burning (Mong, 2005; Fuhlendorf and others, 2006; Powell, 2006; Coppedge and others, 2008; Sandercock and others, 2015). In tallgrass prairies, Sandercock and others (2015) showed that upland sandpipers selected disturbed sites that were grazed or recently burned. Mong (2005) reported that radio-marked upland sandpipers preferred tallgrass prairie sites that were recently burned and grazed, followed by burned-only, undisturbed, and grazed-only sites. Huber and Steuter (1984) also reported that this species used burned sites more than unburned sites. In North Dakota mixed-grassed prairies, Johnson (1997) reported that upland sandpipers had highest densities immediately after a burn and for about a year following a burn, which is consistent with results from this study.

Killdeer (*Charadrius vociferus*)

The killdeer was reported on 60.9 percent of the mixed-grass NPAM units and on 44 percent of the tallgrass units (table 12). The overall model testing the influence of grass type, management regime, and year on killdeer densities was significant (table 13, appendix 5). In the mixed-grass prairie units, there was a strong year effect, with higher densities, on average, in 2012 than in 2011 and 2013. In tallgrass prairie units, the differences in killdeer densities among management regimes depended on year. In grazed-only and burned-grazed tallgrass units, densities were higher in 2012 than 2013; densities were similar between the two years in burned-only and rested tallgrass units.

The overall model testing the influence of the interaction of post-management treatment and grass type on killdeer densities indicated no effect of post-management treatment or year (table 14, appendix 6).

The best vegetation structure model relating vegetation structure to killdeer densities included year and an interaction between year and VOR (table 15, appendix 7). Killdeer densities declined with an increase in mean VOR in all years (fig. 8). Floristic composition variables and other variables did not improve the vegetation structure model for the killdeer.

The killdeer prefers open habitats with bare ground or somewhat short vegetation, little residual cover, and no woody vegetation (Stewart, 1975; Kantrud, 1981; Sample, 1989; Best and others, 1995). The species is well adapted to nesting in cultivated fields, heavily grazed grasslands, exposed gravel and sand, and bare shorelines of lakes and ponds. Similar to this study, preference for grasslands with lower vertical obstruction readings was reported by Sample (1989) and George (2006). Previous research has shown that percent cover of bare ground had a positive influence on killdeer abundance (Coppedge and others, 2008)—a finding that was not noted in this study. Huber and Steuter (1984) reported that killdeer were absent from unburned areas. Fondell and Ball (2004) determined that killdeer nested at lower densities on ungrazed grasslands than grazed grasslands, and their nest densities were negatively correlated with vertical height-density (that is, vertical obstruction) at the plot level.

Tree Swallow (*Tachycineta bicolor*)

The tree swallow was reported on 62.5 percent of the mixed-grass NPAM units and on 76 percent of the tallgrass units (table 12). The overall model testing the influence of the grass type, management regime, and year on tree swallow densities was significant (table 13, appendix 5). In the tallgrass prairie units, there was a strong year effect, and the differences in tree swallow densities among management regimes depended on year. On average, densities were highest in 2012 and lowest in 2013 in grazed-only, burned-grazed, and rested tallgrass prairie units. Densities in burned-only tallgrass prairie units increased slightly between 2012 and 2013. Densities in grazed-only tallgrass prairie units were, on average, higher than those in mixed-grass units.

The overall model testing the influence of the interaction of post-management treatment and grass type on tree swallow densities indicated that densities were not related to grass type and treatment (table 14, appendix 6).

The best vegetation structure model relating vegetation structure to tree swallow densities included only year (table 15, appendix 7). Floristic composition variables and other variables did not improve the vegetation structure model for the tree swallow.

Tree swallows nest in abandoned tree cavities near forest and woodland edges and wetlands, and forage in open grasslands and wetlands (Winkler and others, 2011). The species also readily uses nest boxes in open areas and along habitat edges. Although we did not report a strong response to burning, several studies have reported that tree swallows often show a positive response to fire events in forested areas (Bock and Lynch, 1970; Gruell, 1980; Finch, 1996; Smith, 2000; Kotliar and others, 2002).

Barn Swallow (*Hirundo rustica*)

The barn swallow was reported on 56.3 percent of the mixed-grass NPAM units and on 80 percent of the tallgrass units (table 12). The overall model testing the influence of grass type, management regime, and year on barn swallow densities was not significant (table 13, appendix 5).

The overall model testing the influence of the interaction of post-management treatment and grass type on barn swallow densities indicated that densities were not related to grass type and treatment (table 14, appendix 6).

The best vegetation structure model relating vegetation structure to barn swallow densities included only year (table 15, appendix 7). Floristic composition variables and other variables did not improve the vegetation structure model for the barn swallow.

The barn swallow is a semicolonial passerine that nests on buildings, bridges, culverts, and highway overpasses, and forages in open habitats on many types of invertebrate prey (Stewart, 1975; Shahan and others, 2017). The general lack of potential nest sites in the NPAM units likely limited the breeding distribution of barn swallows in this study. We did not detect differences in barn swallow densities among treatment regimes or post-management treatments. Ambrosini and others (2002) showed that the current distribution of barn swallows may be influenced more by past ecological conditions, expanding over a time-span longer than the average life-span of this species, than by current ecological conditions. Shahan and others (2017) reported that the barn swallow's presence in mixed-grass and tallgrass prairies in Minnesota, North Dakota, and South Dakota was driven largely by landscape variables rather than local variables (for example, VOR, percent cover of grass and forbs, and so on).

Mourning Dove (*Zenaida macroura*)

The mourning dove was reported on 56.3 percent of the mixed-grass NPAM units and on 52 percent of the tallgrass units (table 12). The overall model testing the influence of the grass type, management regime, and year on mourning dove densities was not significant (table 13, appendix 5).

The overall model assessing the influence of post-management treatments and grass type on breeding densities of mourning doves in tallgrass and mixed-grass prairies indicated that grass type and post-management treatment did not affect mourning dove densities (table 14, appendix 6).

The best vegetation structure model relating vegetation structure to mourning dove densities included only year (table 15, appendix 7). Floristic composition variables and other variables did not improve the vegetation structure model for the mourning dove.

During the breeding season, the mourning dove favors areas with a mixture of forest, woodland edge, grassland, and cropland (Stewart, 1975; Tomlinson and others, 1994). The species prefers nesting in trees and shrubs along the edge of woodlands and grasslands, but doves will nest on the ground in grasslands and cropland where these edge habitats are absent or availability is limited, especially early in the breeding season (McNicholl, 1988; Drobney and others, 1998). The species occurs at higher densities in smaller grassland patches (Johnson and Igl, 2001). Although not reported in this study, previous research has shown that mourning dove abundance was positively associated with percent cover of bare soil (George, 2006; Coppedge and others, 2008). We did not detect differences in mourning dove densities among treatment regimes or post-management treatments. Holcomb and others (2014) also did not find differences in mourning dove densities between grazed-only and burned-grazed management regimes, but Duchardt and others (2016) reported higher densities in burned-only tallgrass prairie fragments than in fragments that were burned and grazed.

Ring-necked Pheasant (*Phasianus colchicus*)

The ring-necked pheasant was reported on about 56 percent of the NPAM units in the mixed-grass and tallgrass NPAM units (table 12). The overall model testing the influence of grass type, management regime, and year on ring-necked pheasant densities was significant (table 13, appendix 5). In mixed-grass prairie units, there was a strong year effect, with higher pheasant densities, on average, in 2012 than in 2011 and 2013. In tallgrass prairie units, there was a strong management regime effect. Densities were highest, on average, in burned-grazed tallgrass NPAM units, followed by grazed-only units, burned-only units, and rested units.

The overall model testing the influence of the interaction of post-management treatment and grass type on ring-necked pheasant densities indicated that densities were not related to grass type and post-management treatment (table 14, appendix 6).

The best vegetation structure model relating vegetation structure to pheasant densities included only year (table 15, appendix 7). Floristic composition variables and other variables did not improve the vegetation structure model for the ring-necked pheasant.

The ring-necked pheasant was introduced from Asia into North America in the early 1700s (Johnson and Knue, 1989) and into the northern Great Plains in the early 1900s (Stewart, 1975). Ring-necked pheasants flourish in areas of intensive agriculture where there is adequate nesting cover during the breeding season and protective woody cover and food during the winter (Igl and others, 2008). In contrast to our study, Duchardt and others (2016) observed ring-necked pheasants only in tallgrass prairie fragments that were burned every 3 years but did not observe the species in fragments that were grazed annually and burned every 3 years. Fondell and Ball (2004) determined that ring-necked pheasant nest densities were positively correlated with vertical obstruction readings and were higher on ungrazed plots than on grazed plots.

Implications for Grassland Birds

The U.S. Fish and Wildlife Service and other resource management agencies are faced with increased pressure to adopt adaptive management or ecosystem-based management approaches (Walters, 2007). The concept of adaptive management was first proposed four decades ago as an approach to deal with extreme uncertainty about the impacts of policy choices in renewable resource management (Walters and Hilborn, 1976, 1978; Holling, 1978). A central tenet of adaptive management is active learning through a long-term iterative process.

The Native Prairie Adaptive Management (NPAM) project, which began in 2008, is early in the adaptive-management process (Grant and others, 2009; Gannon and others, 2013). FWS-owned tracts of native prairie in the northern Great Plains were experiencing widespread invasion of introduced grasses and forbs, which was believed to reflect a common management history of long-term rest and little or no defoliation by natural processes (Murphy and Grant, 2005; Grant and others, 2009). Over many decades, the integrity of these lands under Federal protection had degraded, largely due to invasion of invasive cool-season grasses (Grant and others, 2009; Ellis-Felege and others, 2013). NPAM's central objective was simple but challenging—to increase the composition of native grasses and forbs on native sod while minimizing costs (Gannon and others, 2013). The alternative management actions that were allowed to meet this objective include grazing, burning, burning and grazing, and rest (no action). Burning and grazing are natural processes in native prairies that also serve as important tools in prairie management to conserve diversity, limit woody plant encroachment, and maintain or improve prairies. From its onset, the NPAM effort overcame the main causes of implementation failure that have plagued many other adaptive-management efforts, including lack of management resources for expanded monitoring, unwillingness of decision makers to embrace uncertainty, and lack of leadership in implementation (Walters, 2007). Moreover, there has been tremendous grassroots commitment and support for this collaborative long-term restoration effort, not only from FWS cooperators at the field level but also from the agency's decision makers.

From both a scientific and management standpoint, the challenge that faces FWS resource managers and biologists is that there are other taxa—beyond native forbs and grasses—on the NPAM units that complicate the adaptive-management cycle and deepen the uncertainty. Some grassland birds, for example, are sensitive to changes in vegetation composition, structure, and quality, and thus the alternative management actions under the NPAM adaptive-management framework also will influence bird populations by changing vegetation structure or altering the plant community.

Conservation strategies of the FWS in the northern Great Plains have traditionally relied on the establishment of refuges, waterfowl production areas, and other protected areas (for example, wetland and grassland easements) to conserve wildlife habitat. FWS managers and biologists (that is, the stewards of refuge lands) are faced with a major dilemma: can these degraded NPAM prairies play a useful role in the conservation of grassland birds? Can management actions improve the quality of these prairies for grassland birds? One of the difficulties in answering these questions concerning the effectiveness of these protected areas is that reliable data on occupancy and abundance of breeding birds have been largely unavailable for most of these refuge lands. In this study, 110 breeding-bird species were recorded on the 89 NPAM units that were surveyed, each with different amounts of native and nonnative vegetation. The list of bird species was dominated by both obligate and facultative grassland birds, but it also included many species that frequent wetlands, wet meadows, savannas, and woodland edges. Two obligate grassland species—Baird's sparrow and Sprague's pipit—that are endemic to the northern Great Plains and are species of high conservation concern (Jones and Green, 1998; Jones, 2010) were absent from most of the NPAM management units. Model performance for these species was generally lower because of the smaller number of NPAM units that supported these rarer species (for example, see appendixes 5 and 6), and models based on low occurrence or abundance generally are unsuitable for conservation planning and other complex applications (Wisz and others, 2008). Nonetheless, the Sprague's pipit and Baird's sparrow are habitat specialists that are known to require large patches of native grass cover throughout their life cycles (Johnson and others, 2004). Large-scale losses of critical prairie habitat (largely due to land conversion) highlight the importance of appropriate management and conservation measures for these species in remaining native prairie.

Grazing, fire, and climate were the principal drivers that historically maintained North American prairies. Grasslands evolved with a shifting mosaic of vegetation pattern across the landscape that included severely disturbed habitats, relatively undisturbed habitats, and a matrix of grassland patches that varied in time since the last disturbance (Fuhlendorf and Engle, 2004). Grassland birds, in turn, evolved within these disturbance-driven landscapes, and the disparate habitat requirements or preferences of grassland birds are an indication that these systems were historically highly heterogeneous in space and time (Fuhlendorf and Engle, 2001). The many different responses by grassland birds to management in this study reflect the individualistic nature of bird species' responses to disturbance-mediated changes in vegetation and their subtle preferences for vegetation characteristics. That is, grassland bird species exploit the same class of vegetation resources, but each species exploits those resources in different ways and combinations. In our study, some bird species were strongly influenced by specific structural characteristics, in particular vegetation height-density (or vertical obstruction) (appendix 7, fig. 9). Species that prefer shorter, sparser vegetation (for example, killdeer, horned lark, chestnut-collared longspur) were generally more common in prairies that had low vertical obstruction (for example, those that were recently defoliated by burning, grazing, or burning and grazing) and were less common in prairies that had higher vertical obstruction (for example, those that were rested for more than 5 years). Other species that prefer taller, denser vegetation (for example, sedge wren, common yellowthroat) were less common in prairies that had lower visual obstruction and more common in prairies with higher vertical obstruction.

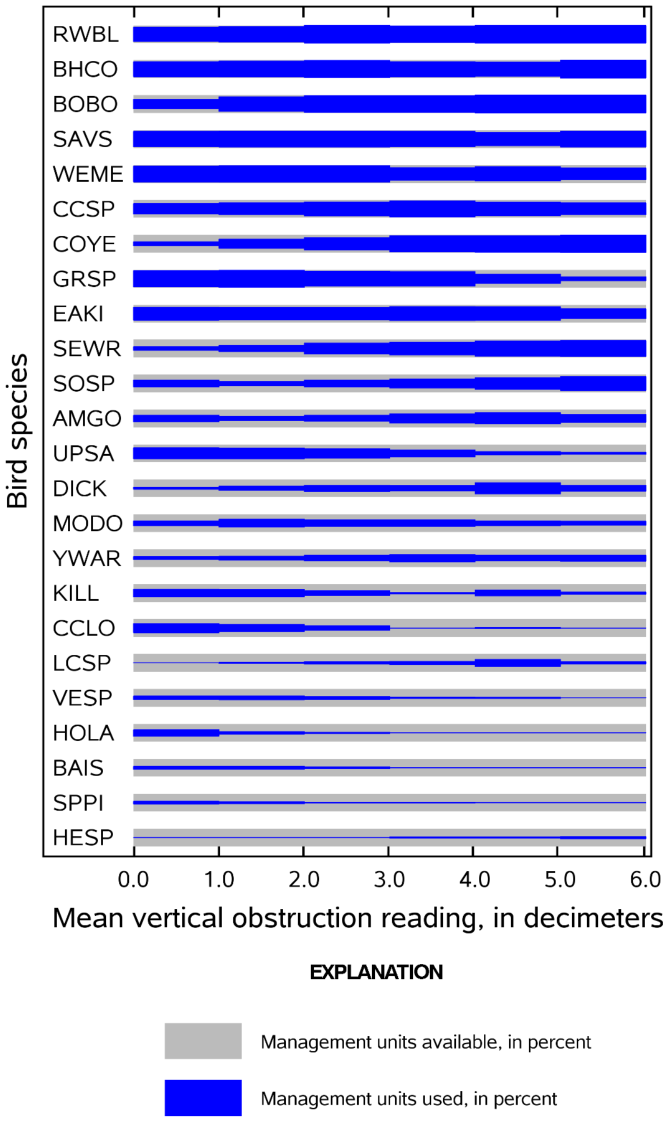


Figure 9. Occurrence of 24 obligate and facultative grassland bird species in relation to mean vertical obstruction readings on mixed-grass and tallgrass prairies managed under an adaptive-management framework by the U.S. Fish and Wildlife Service in North Dakota, South Dakota, Minnesota, and Montana, 2011–13. Four-letter species codes are defined in table 12.

A new paradigm is emerging for the management of native grasslands that considers heterogeneity as a fundamental aspect of a healthy, functioning ecosystem (Fuhlendorf and Engle, 2001). The diversity of breeding-habitat preferences among grassland birds and the range of their responses to management underscore the need for heterogeneity in managed grasslands in this region, including those that are not included in the NPAM effort (for example, Conservation Reserve Program grasslands and grasslands protected under conservation easements). The growing body of literature on management to benefit grassland birds emphasizes the importance of providing a mosaic of successional habitats across the landscape (Renken and Dinsmore, 1987; Madden, 1996; Prescott and Murphy, 1999; Dale and others, 1997; Johnson, 1997; Madden and others, 2000; Rohrbaugh and others, 1999; Fuhlendorf and Engle, 2001, 2004; Fuhlendorf and others, 2006, 2017; Ribic and others, 2009; Negus and others, 2010; Richardson, 2012; Igl and Johnson, 2016). Fuhlendorf and others (2006, 2017) highlighted the need for spatial and temporal heterogeneity in grassland landscapes to increase the variability in vegetation structure, which in turn results in greater variability at higher trophic levels (for example, birds). Historically, traditional grassland management promoted homogeneity-based approaches, simplifying ecosystem structure, and uniform disturbances across the landscape (Fuhlendorf and Engle, 2001, 2004). Restoration of habitat heterogeneity continues to be a major challenge and critical need for wildlife conservation in grasslands (Johnson and others, 2011; Fuhlendorf and others, 2017). A heterogeneity-based approach to grassland management has not been well studied in the northern Great Plains and clearly warrants further investigation. For grassland bird conservation, a variety of grassland conditions will be required; that is, no single grassland habitat type or alternative management approach will be adequate to conserve the entire suite of grassland birds in this region (McCracken, 2005; Ribic and others, 2009).

Summary

In summary, native tallgrass and mixed-grass prairies managed by the U.S. Fish and Wildlife Service (FWS) in the northern Great Plains have been extensively invaded by nonnative, cool-season grasses. These invasions were believed to reflect prolonged periods of rest and little or no defoliation by natural processes, such as fire and grazing. To address the challenges associated with the invasions of nonnative grasses and to improve the conditions of native prairies, the FWS embraced an adaptive-management approach to assist managers in selecting management actions despite uncertainty. The primary goal of this adaptive-management approach was to increase the composition of native grasses and forbs on native, unbroken sod while minimizing costs. The alternative-management actions that were used to meet this objective include grazing, burning, burning and grazing, and rest (no action). The primary objectives of our study were to assess the effects of these alternative-management actions on grassland birds on FWS-owned grasslands that are managed under the adaptive-management framework, and to assess the association of vegetation structure and composition as mechanisms for triggering grassland bird responses to management. We surveyed breeding birds and sampled vegetation on 89 native prairie units managed by the FWS during 2011–13 in North Dakota, South Dakota, Montana, and Minnesota. Generalized linear mixed models were used to evaluate the effects of management actions on vegetation structure, vegetation composition, and densities of common bird species. The models indicated that bird abundance reflected not only disturbance-derived changes in vegetation structure and species-specific vegetation preferences but also the influence of the alternative-management practices. The diversity of bird responses to management in this study underscores the complexity of natural grassland systems and the need for spatial and temporal heterogeneity in the management of grasslands in this region.

In this study, we only examined breeding bird responses to management during three growing seasons, whereas the endpoint of the NPAM effort may extend decades into the future. The data presented here on bird responses to management can serve as a baseline for future evaluations of bird responses to management on these grasslands. The FWS is committed to carrying out this adaptive-management process over the long term, with the primary objective being to increase the composition of native grasses and forbs and decrease the cover of cool-season invasive grass species. Although that primary objective does not consider breeding birds on these management units, clearly, adaptive-management actions are influencing grassland bird populations on these sites. As this restoration effort continues, there remains a role for monitoring birds on these management units, whether monitoring occurs annually, semiannually, or on a subset of the management units. Future efforts also should consider other factors that may influence grassland birds on these prairie units, including aspects of landscape at a broader scale (for example, edge proximity, fragmentation, patch size, and landscape context) or other important resources known to influence grassland birds (for example, food).

References

Ahlering, M.A., and Merkord, C.L., 2016, Cattle grazing and grassland birds in the northern tallgrass prairie: Journal of Wildlife Management, v. 80, no. 4, p. 643–654. [Also available at https://dx.doi.org/10.1002/jwmg.1049.]

Ailes, I.W., 1976. Ecology of the upland sandpiper in central Wisconsin: Stevens Point, Wis., University of Wisconsin, Master’s Thesis, 55 p.

Ambrosini, R., Bolzen, A.M., Canova, L., and Saino, N., 2002, Latency in response of barn swallow *Hirundo rustica* populations to changes in breeding habitat conditions: Ecology Letters, v. 5, no. 5, p. 640–647. [Also available at https://dx.doi.org/10.1046/j.1461-0248.2002.00363.x.]

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

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

Askins, R.A., Chávez-Ramírez, F., Dale, B.C., Haas, C.A., Herkert, J.R., Knopf, F.L., and Vickery, P.D., 2007, Conservation of grassland birds in North America—Understanding ecological processes in different regions: Ornithological Monographs, no. 64, p. 1–46. [Also available at https://dx.doi.org/10.2307/40166905.]

Bakker, K.K., and Higgins, K.F., 2009, Planted grasslands and native sod prairie—Equivalent habitat for grassland birds: Western North American Naturalist, v. 69, no. 2, p. 235–242. [Also available at https://dx.doi.org/10.3398/064.069.0212.]

Bakker, K.K., Naugle, D.E., and Higgins, K.F., 2002, Incorporating landscape attributes into models for migratory grassland bird conservation: Conservation Biology, v. 16, no. 6, p. 1638–1646. [Also available at https://dx.doi.org/10.1046/j.1523-1739.2002.01328.x.]

Begley, A.J.P., Gray, B.T., and Paszkowski, C.A., 2012, A comparison of restored and natural wetlands as habitat for birds in the Prairie Pothole Region of Saskatchewan, Canada: The Raffles Bulletin of Zoology, suppl. no. 25, p. 173–187.

Bélanger, L., and Picard, M., 1999, Cattle grazing and avian communities of the St. Lawrence River Islands: Journal of Range Management, v. 52, no. 4, p. 332–338. [Also available at https://dx.doi.org/10.2307/4003542.]

Berkey, G., Crawford, R., Galipeau, S., Johnson, D., Lambeth, D., and Kreil, R., 1993, A review of wildlife management practices in North Dakota—Effects on nongame bird populations and habitats—A report submitted to the U.S. Fish and Wildlife Service, Region 6: Bismarck, North Dakota, North Dakota Game and Fish Department, 69 p.

Best, L.B., 1979, Effects of fire on a field sparrow population: American Midland Naturalist, v. 101, no. 2, p. 434–443. [Also available at https://dx.doi.org/10.2307/2424609.]

Best, L.B., Freemark, K.E., Dinsmore, J.J., and Camp, M., 1995, A review and synthesis of habitat use by breeding birds in agricultural landscapes of Iowa: American Midland Naturalist, v. 134, no. 1, p. 1–29. [Also available at http://dx.doi.org/10.2307/2426479.]

Bibby, C.J., Burgess, N.D., Hill, D.A., and Mustoe, S.H., 2000, Bird census techniques, Second edition: New York, Academic Press, 302 p.

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

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

Bock, C.E., and Lynch, L.E., 1970, Breeding bird populations of burned and unburned conifer forest in the Sierra Nevada: Condor, v. 72, no. 2, p. 182–189. [Also available at https://dx.doi.org/10.2307/1366629.]

Bock, C.E., Saab, V.A., Rich, T.D., and Dobkin, D.S., 1993, Effects of livestock grazing on Neotropical migratory landbirds in western North America, *in* Finch, D.M., and Stangel, P.W., eds., Status and management of Neotropical migratory birds: Fort Collins, Colo., Rocky Mountain Forest and Range Experiment Station, U.S. Department of Agriculture Forest Service General Technical Report RM-229, p 296–309.

Bollinger, E.K., Gavin, T.A., and McIntyre, D.C., 1988, Comparison of transects and circular-plots for estimating bobolink densities: Journal of Wildlife Management, v. 52, no. 4, p. 777–876. [Also available at https://dx.doi.org/10.2307/3800946.]

Bowen, B.S., and Kruse, A.D., 1993, Effects of grazing on nesting by upland sandpipers in southcentral North Dakota: Journal of Wildlife Management, v. 57, no. 2, p. 291–301. [Also available at https://dx.doi.org/10.2307/3809426.]

Bryant, R.B., 2015, An assessment of the native invertebrate pollinator community and floral sources in grasslands of eastern North Dakota: Arcata, Calif., Humboldt State University, Master's Thesis, 89 p.

Burnham, K.P., and Anderson, D.R., 2002, Model selection and multimodel inferences—A practical information-theoretic approach (2d ed.): New York, Springer-Verlag, 488 p.

Byers, C.M., Ribic, C.A., Sample, D.W., Dadisman, J.D., and Guttery, M.R., 2017, Grassland bird productivity in warm season grass fields in southwest Wisconsin: American Midland Naturalist, v. 178, no. 1, p. 47–63. [Also available at https://doi.org/10.1674/0003-0031-178.1.47.]

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

Carragher, K.A., Clawges, R.M., Bunn, R.L., Pigage, H.K., and Pigage, J.C., 2012, Effects of grassland alteration from mowing and fire on bird activity at a Colorado airfield: Human-Wildlife Interactions, v. 6, no. 2, p. 298–310.

Chesser, R.T., Burns, K.J., Cicero, C., Dunn, J.L., Kratter, A.W., Lovette, I.J., Rasmussen, P.C., Remsen, J.V., Jr., Rising, J.D., Stotz, D.F., and Winker, K., 2017, Fifty-eighth supplement to the American Ornithological Society's *Check-list of North American Birds*: Auk, v. 134, no. 3, p. 751–773. [Also available at https://dx.doi.org/10.1642/AUK-17-72.1.]

Chesser, R.T., Burns, K.J., Cicero, C., Dunn, J.L., Kratter, A.W., Lovette, I.J., Rasmussen, P.C., Remsen, J.V., Jr., Stotz, D.F., Winger, B.M., and Winker, K., 2018, Fifty-ninth supplement to the American Ornithological Society's *Check-list of North American Birds*: Auk, v. 135, no. 3, p. 798–813. [Also available at https://dx.doi.org/10.1642/AUK-18-62.1.]

Coppedge, B.R., Engle, D.M., Toepfer, C.S., and Shaw, J.H., 1998, Effects of seasonal fire, bison grazing, and climatic variation on tallgrass prairie vegetation: Plant Ecology, v. 139, no. 2, p. 235–246. [Also available at https://dx.doi.org/10.1023/A:1009728104508.]

Coppedge, B.R., Fuhlendorf, S.D., Harrell, W.C., and Engle, D.M., 2008, Avian community response to vegetation and structural features in grasslands managed with fire and grazing: Biological Conservation, v. 141, no. 5, p. 1196–1203. [Also available at https://dx.doi.org/10.1016/j.biocon.2008.02.015.]

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

Dale, B., and Jardine, C., 2010, Are corrected bird counts useful in grasslands, *in* The Proceedings of the annual meeting of the Association of Field Ornithologists, Ogden, Utah, 2010: Ogden, Utah, Weber State University, p. 27.

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

Davis, S.K., 2004, Area sensitivity in grassland passerines—Effects of patch size, patch shape, and vegetation structure on bird abundance and occurrence in southern Saskatchewan: Auk, v. 121, no. 4, p. 1130–1145. [Also available at https://dx.doi.org/10.2307/4090481.]

Davis, S.K., Fisher, R.J., Skinner, S.L., Shaffer, T.L., and Brigham, R.M., 2013, Songbird abundance in native and planted grassland varies with type and amount of grassland in the surrounding landscape: Journal of Wildlife Management, v. 77, no. 5, p. 908–919. [Also available at https://dx.doi.org/10.1002/jwmg.537.]

Davis, S.K., Ludlow, S.M., and McMaster, D.G., 2016, Reproductive success of songbirds and waterfowl in native mixed-grass pasture and planted grasslands used for pasture and hay: Condor, v. 118, no. 4, p. 815–834. [Also available at https://dx.doi.org/10.1650/CONDOR-16-16.1.]

Delisle, J.M., and Savidge, J.A., 1997, Avian use and vegetation characteristics of Conservation Reserve Program fields: Journal of Wildlife Management, v. 61, no. 2, p. 318–325. [Also available at https://dx.doi.org/10.2307/3802587.]

Dennhardt, L.A., DeKeyser, E.S., Tennefos, S.A., and Travers, S.E., 2016, There is no evidence of geographical patterning among invasive Kentucky bluegrass (*Poa pratensis*) populations in the northern Great Plains: Weed Science, v. 64, no. 3, p. 409–420. [Also available at https://doi.org/10.1614/WS-D-15-00169.1.]

Dhol, S., Horton, J., and Jones, R.E., 1994, 1994 Non-waterfowl evaluation of Manitoba's North American Waterfowl Management Plan: Winnipeg, Manitoba, Wildlife Branch, Manitoba Department of Natural Resources, 12 p.

Dobkin, D.S., 1992, Neotropical migrant landbirds in the Northern Rockies and Great Plains—A handbook for conservation and management: Missoula, Mont., U.S. Department of Agriculture Forest Service, North Region, Publication No. R1-93-34, 144 p.

Dolbeer, R.A., and Linz, G.M., 2016, Blackbirds: Washington, D.C., U.S., Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, 16 p.

Drobney, R.D., Schulz, J.H., Sheriff, S.L., and Fuemmeler, W.J., 1998, Mourning dove nesting habitat and nest success in central Missouri: Journal of Field Ornithology, v. 69, no. 2, p. 299–305.

Duchardt, C.J., Miller, J.R., Debinski, D.M., and Engle, D.M., 2016, Adapting the fire-grazing interaction to small pastures in a fragmented landscape for grassland bird conservation: Rangeland Ecology and Management, v. 69, no. 4, p. 300–309. [Also available at https://doi.org/10.1016/j.rama.2016.03.005.]

Dupey, J., 2014, Developing techniques to quantify phenological development of smooth brome (*Bromus inermis* Leyss.)—Sampling variability: Brookings, S. Dak., South Dakota State University, Master's Thesis, 55 p.

Durán, S.M., 2009, An assessment of the relative importance of Wildlife Management Areas to the conservation of grassland songbirds in south-western Manitoba: Winnipeg, Manitoba, University of Manitoba, Master's Thesis, 92 p.

Dyke, S.R., Johnson, S., and Isakson, P., 2015, North Dakota State Wildlife Action Plan: Bismarck, N. Dak., North Dakota Game and Fish Department, accessed July 2018 at https://gf.nd.gov/sites/default/files/publications/swap-2015_0.pdf.

Eddleman, W.R., 1974, The effects of burning and grazing on bird populations in native prairie in the Kansas Flint Hills: Manhattan, Kans., National Science Foundation-Undergraduate Research Program, Kansas State University, 33 p.

Efford, M.G., and Dawson, D.K., 2009, Effect of distance-related heterogeneity on population size estimates from point counts: Auk, v. 126, no. 1, p. 100–111. [Also available at https://dx.doi.org/10.1525/auk.2009.07197.]

Ellis-Felege, S.N., Dixon, C.S., and Wilson, S.D., 2013, Impacts and management of invasive cool-season grasses in the northern Great Plains—Challenges and opportunities for wildlife: Journal of Wildlife Management, v. 37, no. 3, p. 510–516. [Also available at https://doi.org/10.1002/wsb.321.]

Etterson, M.A., Niemi, G.J., and Danz, N.P., 2009, Estimating the effects of detection heterogeneity and overdispersion on trends estimated from avian point counts: Ecological Applications, v. 19, no. 8, p. 2049–2066. [Also available at https://dx.doi.org/10.1890/08-1317.1.]

Finch, D.M., ed., 1996, Ecosystem disturbance and wildlife conservation in western grasslands—a symposium proceedings—General Technical Report RM-GTR-285: Fort Collins, Colo., U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, 82 p. [Also available at https://doi.org/10.2737/RM-GTR-285.]

Fisher, R.J., and Davis, S.K., 2010, From Wiens to Robel—A review of grassland-bird habitat selection: Journal of Wildlife Management, v. 74, no. 2, p. 265–273. [Also available at https://dx.doi.org/10.2193/2009-020.]

Fletcher, R.J., Jr., and Koford, R.R., 2002, Habitat and landscape associations of breeding birds in native and restored grasslands: Journal of Wildlife Management, v. 55, no. 4, p. 1011–1022. [Also available at https://dx.doi.org/10.2307/3802933.]

Fletcher, R.J., Jr., and Koford, R.R., 2004, Consequences of rainfall variation for breeding wetland blackbirds: Canadian Journal of Zoology, v. 82, no. 8, p. 1316–1325. [Also available at https://dx.doi.org/10.1139/z04-107.]

Fondell, T.F., and Ball, I.J., 2004, Density and success of bird nests relative to grazing on western Montana grasslands: Biological Conservation, v. 117, no. 2, p. 203–213. [Also available at https://dx.doi.org/10.1016/S0006-3207(03)00293-3.]

Forde, J.E., Sloan, N.F., and Shown, D.A., 1984, Grassland habitat management using prescribed burning in Wind Cave National Park, South Dakota: Prairie Naturalist, v. 16, no. 3, p. 97–110.

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

Fuhlendorf, S.D., and Engle, D.M., 2001, Restoring heterogeneity on rangelands—Ecosystem management based on evolutionary grazing patterns: BioScience, v. 51, no. 8, p. 625–632. [Also available at https://doi.org/10.1641/0006-3568(2001)051[0625:RHOREM]2.0.CO;2.]

Fuhlendorf, S.D., and Engle, D.M., 2004, Application of the fire–grazing interaction to restore a shifting mosaic on tallgrass prairie: Journal of Applied Ecology, v. 41, no. 4, p. 604–614. [Also available at https://dx.doi.org/10.1111/j.0021-8901.2004.00937.x.]

Fuhlendorf, S.D., Fynn, F.W.S., McGranahan, D.A., and Twidwell, D., 2017, Heterogeneity as the basis for rangeland management, *in* Briske, D.D., ed., Rangeland systems—Processes, management and challenges: New York, N.Y., Springer Nature, p. 169–196. [Also available at https://doi.org/10.1007/978-3-319-46709-2_5.]

Fuhlendorf, S.D., Harell, W.C., Engle, D.M., Hamilton, R.G., Davis, C.A., and Leslie, D.M., Jr., 2006, Should heterogeneity be the basis for conservation? Grassland bird response to fire and grazing: Ecological Applications, v. 16, no. 5, p. 1706–1716. [Also available at https://dx.doi.org/10.1890/1051-0761(2006)016%5B1706:SHBTBF%5D2.0.CO;2.]

Gannon, J.J., Shaffer, T.L., and Moore, C.T., 2013, Native Prairie Adaptive Management—A multi-region adaptive approach to invasive plant management on Fish and Wildlife Service owned native prairies: U.S. Geological Survey Open-File Report 2013–1279, 184 p. [Also available at https://dx.doi.org/10.3133/ofr20131279.]

Gbur, E.E., Stroup, W.W., McCarter, K.S., Durham, S., Young, L.J., Christman, M., West, M., and Krame, M., 2012, Analysis of generalized linear mixed models in the agricultural and natural resources sciences: Madison, Wis., American Society of Agronomy, Soil Science Society of America, and Crop Science Society of America, Inc., 298 p.

George, A.D., 2006, Avian response to Old World bluestem (*Bothriochloa ischaemum*) monocultures in mixed-grass prairie: Stillwater, Okla., Oklahoma State University, Master's Thesis, 63 p.

Goguen, C.B., and Mathews, N.E., 1999, Review of the causes and implications of the association between cowbirds and livestock, *in* Morrison, M.L., Hall, L.S., Robinson, S.K., Rothstein, S.I., Hahn, D.C., and Rich, T.D., eds., Research and management of the brown-headed cowbird in western landscapes: Studies in Avian Biology, v. 18. p. 10–17.

Grant, T.A., Flanders-Wanner, B., Shaffer, T.L., Murphy, R.K., and Knutsen, G.A., 2009, An emerging crisis across northern prairie refuges—Prevalence of invasive plants and a plan for adaptive management: Ecological Restoration, v. 27, no. 1, p. 58–65. [Also available at https://dx.doi.org/10.3368/er.27.1.58.]

Grant, T.A., Madden, E.M., Murphy, R.K., Smith, K.A., and Nenneman, M.P., 2004, Monitoring native prairie vegetation—The belt transect method: Ecological Restoration, v. 22, no. 2, p. 106–112. [Also available at https://dx.doi.org/10.3368/er.22.2.106.]

Grant, T.A., Madden, E.M., Shaffer, T.L., and Dockens, J.S., 2010, Effects of prescribed fire on vegetation and passerine birds in northern mixed-grass prairie: Journal of Wildlife Management, v. 74, no. 8, p. 1841–1851. [Also available at https://dx.doi.org/10.2193/2010-006.]

Grant, T.A., and Murphy, R.K., 2005, Changes in woodland cover on prairie refuges in North Dakota, USA: Natural Areas Journal, v. 25, no. 4, p. 359–368.

Grant, T.A., Shaffer, T.L., Madden, E.M., and Berkey, G.B., 2011, Ducks and passerines nesting in northern mixed-grass prairie treated with fire: Wildlife Society Bulletin, v. 35, no. 4, p. 368–376. [Also available at https://dx.doi.org/10.1002/wsb.65.]

Greer, M.J., 2009, An evaluation of habitat use and requirements for grassland bird species of greatest conservation need in central and western South Dakota: Brookings, S. Dak., South Dakota State University, Master's Thesis, 158 p.

Greer, M.J., Bakker, K.K., and Dieter, C.D., 2016, Grassland bird response to recent loss and degradation of native prairie in central and western South Dakota: Wilson Journal of Ornithology, v. 128, no. 2, p. 278–289. [Also available at https://dx.doi.org/10.1676/wils-128-02-278-289.1.]

Gruell, G.E., 1980, Fire's influence on wildlife habitat on the Bridger-Teton National Forest, Vol. II—Changes and causes, management implications: Ogden, Utah, U.S. Department of Agriculture, Forest Service Intermountain Forest and Range Experiment Station, General Technical Report INT-252, 35 p.

Harris, M.A., 1982, Habitat use among woodpeckers in forest burns: Missoula, Mont., University of Montana, Master's Thesis, 63 p.

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

Henwood, W.D., 2010, Toward a strategy for the conservation and protection of the world's temperate grasslands: Great Plains Research, v. 20, no. 1, p. 121–134.

Herkert, J.R., 1994, Breeding bird communities of midwestern prairie fragments—The effects of prescribed burning and habitat-area: Natural Areas Journal, v. 14, no. 2, p. 128–135.

Higgins, K.F., Duebbert, H.F., and Oetting, R.B., 1969, Nesting of the upland sandpiper on the Missouri Coteau: Prairie Naturalist, v. 1, no. 2, p. 45–48.

Higgins, K.F., Naugle, D.E., and Forman, K.J., 2002, A case study of changing land use practices in the northern Great Plains, U.S.A.: an uncertain future for waterbird conservation: Waterbirds, v. 25, Special Publication no. 2, p. 42–50.

Holcomb, E.D., Davis, C.A., and Fuhlendorf, S.D., 2014, Patch-burn management—Implications for conservation of avian communities in fire-dependent sagebrush ecosystems: Journal of Wildlife Management, v. 78, no. 5, p. 848–856. [Also available at https://doi.org/10.1002/jwmg.723.]

Holling, C.S., ed., 1978, Adaptive environmental assessment and management: New York, N.Y., John Wiley, 377 p.

Horn, D.J., and Koford, R.R., 2000, Relation of grassland bird abundance to mowing of Conservation Reserve Program fields in North Dakota: Wildlife Society Bulletin, v. 28, no. 3, p. 653–659.

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

Hull, S.D., Robel, R.J., and Kemp, K.E., 1996, Avian abundance, invertebrate biomass, and forbs in Kansas CRP: Prairie Naturalist, v. 28, no. 1, p. 1–12.

Hunt, V.M., Jacobi, S.K., Gannon, J.J., Zorn, J.E., Moore, C.T., and Lonsdorf, E.V., 2016, A decision support tool for adaptive management of native prairie ecosystems: Interfaces Articles in Advance, v. 46, no. 4, p. 334–344. [Also available at https://doi.org/10.1287/inte.2015.0822.]

Hunt, V.M., Jacobi, S.K., Knutson, M.G., Lonsdorf, E.V., Papon, S., and Zorn, J., 2015, A data management system for long-term natural resource monitoring and management projects with multiple cooperators: Wildlife Society Bulletin, v. 39, no. 3, p. 463–471. [Also available at https://dx.doi.org/10.1002/wsb.547.]

Hutto, R.L., 1995, Composition of bird communities following stand-replacement fires in northern Rocky Mountain (U.S.A.) conifer forests: Conservation Biology, v. 9, no. 5, p. 1041–1058. [Also available at https://dx.doi.org/10.1046/j.1523-1739.1995.9051041.x.]

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

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

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

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

Igl, L.D., Johnson, D.H., and Kantrud, H.A., 2008, A historical perspective: changes in grassland breeding bird densities within major habitats in North Dakota between 1967 and 1992–1993, *in* Springer, J.T. and Springer, E.C., eds., Prairie invaders: Proceedings of the 20th North American Prairie Conference, Kearney, Nebr., University of Nebraska, p. 275–295.

Igl, L.D., Newton, W.E., Grant, T.A., and Dixon, C.S., 2018a, Adaptive management in native grasslands managed by the U.S. Fish and Wildlife Service: implications for grassland birds, 2011–2013 data release: U.S. Geological Survey data release, https://doi.org/10.5066/P9OHS27F.

Igl, L.D., Newton, W.E., and Kantrud, H.A., 2018b, Bird population changes following the establishment of a diverse stand of woody plants in a former crop field in North Dakota, 1975–2015: Great Plains Research, v. 28, no. 1, p. 73–90. [Also available at https://dx.doi.org/10.1353/gpr.2018.0006.]

Jacobs, R.B., Thompson, F.R., III, Koford, R.R., La Sorte, F.A., Hardwood, H.D., and Fitzgerald, J.A., 2012, Habitat and landscape effects on abundance of Missouri's grassland birds: Journal of Wildlife Management, v. 76, no. 2, p. 372–381. [Also available at https://dx.doi.org/10.1002/jwmg.264.]

Johnson, D.H., 1997, Effects of fire on bird populations in mixed-grass prairie, *in* Knopf, F.L., and Samson, F.B., eds., Ecology and conservation of Great Plains vertebrates: New York, N.Y., Springer-Verlag, p. 181–206. [Also available at https://doi.org/10.1007/978-1-4757-2703-6_8.]

Johnson, D.H., 2008, In defense of indices—The case of bird surveys: Journal of Wildlife Management, v. 72, no. 4, p. 857–868. [Also available at https://dx.doi.org/10.2193/2007-294.]

Johnson, D.H., and Igl, L.D., 2001, Area requirements of grassland birds—A regional perspective: Auk, v. 118, no. 1, p. 24–34. [Also available at https://dx.doi.org/10.2307/4089756.]

Johnson, D.H., Igl, L.D. and Shaffer J.A., eds., 2004, Effects of management practices on grassland birds: Jamestown, North Dakota, U.S. Geological Survey, Northern Prairie Wildlife Research Center, accessed July 2018 at https://www.npwrc.usgs.gov/Effects-of-Management-Practices-on-Grassland-Birds-links.

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

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

Johnson, M.D., and Knue, J., 1989, Feathers from the prairie—A short history of upland game birds (2d ed.): Bismarck, North Dakota, North Dakota Game and Fish Department, 240 p.

Johnson, R.J., Jedlicka, J.A., Quinn, J.E., and Brandle, J.R., 2011, Global perspectives on birds in agricultural landscapes, *in* Campbell, W.B., and López Ortíz, S., eds., Integrating agriculture, conservation and ecotourism—Examples from the field: New York, N.Y., Springer, p. 55–140. [Also available at https://doi.org/10.1007/978-94-007-1309-3_3.]

Jones, S.L., 2010, Sprague's pipit (*Anthus spragueii*) conservation plan: Washington, D.C., U.S. Department of Interior, Fish and Wildlife Service, 44 p.

Jones, S.L., and Green, M.T., 1998, Baird's sparrow status assessment and conservation plan: Denver, Colo., U.S. Department of Interior, Fish and Wildlife Service, Administrative Report, 85 p.

Jones, Z.F., and Bock, C.E., 2005, The Botteri's sparrow and exotic Arizona grasslands—An ecological trap or habitat regained?: Condor, v. 107, no. 4, p. 731–741. [Also available at https://dx.doi.org/10.1650/7741.1.]

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

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

Kantrud, H.A., and Higgins, K.F., 1992, Nest and nest site characteristics of some ground-nesting, non-passerine birds of northern grasslands: Prairie Naturalist, v. 24, no. 2, p. 67–84.

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

Kantrud, H.A., and Kologiski, R.L., 1983, Avian associations of the northern Great Plains grasslands: Journal of Biogeography, v. 10, no. 4, p. 331–350. [Also available at https://dx.doi.org/10.2307/2844742.]

Kiernan, K., Tao, J., and Gibbs, P., 2012, Tips and strategies for mixed modeling with SAS/STAT procedures: SAS Global Forum Paper 332–2012, 18 p.

Kim, D.H., Newton, W.E., Lingle, G.R., and Chavez-Ramirez, F., 2008, Influence of grazing and available moisture on breeding densities of grassland birds in the central Platte River Valley, Nebraska: Wilson Journal of Ornithology, v. 120, no. 4, p. 820–829. [Also available at https://dx.doi.org/10.1676/07-153.1.]

Klute, D.S., 1994, Avian community structure, reproductive success, vegetative structure, and food availability in burned Conservation Reserve Program fields and grazed pastures in northeastern Kansas: Manhattan, Kans., Kansas State University, Master's Thesis, 168 p.

Kobiela, B., Quast, J., Dixon, C., and DeKeyser, E.S., 2017, Targeting introduced species to improve plant community composition on USFWS-managed prairie remnants: Natural Areas Journal, v. 37, no. 2, p. 150–160. [Also available at https://doi.org/10.3375/043.037.0204.]

Koford, R.R., 1999, Density and fledging success of grassland birds in Conservation Reserve Program fields in North Dakota and west-central Minnesota, *in* Vickery, P.D., and Herkert, J.R., eds., Ecology and conservation of grassland birds of the Western Hemisphere: Studies in Avian Biology, v. 19, p. 187–195.

Kotliar, N.B., Hejl, S., Hutto, R.L., Saab, V.A., Melcher, C.P., and McFadzen, M.E., 2002, Effects of fire and post-fire salvage logging on avian communities in conifer-dominated forests of the western United States, *in* George, T.L., and Dobkin, D.S., eds., Effects of habitat fragmentation on birds in western landscapes: contrasts with paradigms from the eastern United States: Studies in Avian Biology, v. 25, p. 49–64.

Leston, L., Koper, N., and Rosa, P., 2015, Perceptibility of prairie songbirds using double-observer point counts: Great Plains Research, v. 25, no. 1, p. 53–61. [Also available at https://dx.doi.org/10.1353/gpr.2015.0021.]

Linz, G.M., Klug, P.E., and Dolbeer, R.A., 2017, Ecology of and management of red-winged blackbirds, *in* Linz, G.M., Avery, M.L., and Dolbeer, R.A., eds., Ecology and management of blackbirds (Icteridae) in North America: Boca Raton, Fla., CRC Press, p. 17–41.

Lipsey, M.K., 2015, Cows and plows: science-based conservation for grassland songbirds in agricultural landscapes: Missoula, Mont., University of Montana, Ph.D. Dissertation, 137 p.

Littell, R.C., Milliken, G.A., Stroup, W.W., Wolfinger, R.D., and Schabenberger, O., 2006, SAS® for mixed models (2d ed.): Cary, N.C., SAS Institute, Inc., 814 p.

Lloyd, J.D., and Martin, T.E., 2005, Reproductive success of chestnut-collared longspurs in native and exotic grassland: Condor, v. 107, no. 2, p. 363–374. [Also available at https://dx.doi.org/10.1650/7701.]

Logan, B.D., 2001, Avian community composition and nesting productivity relative to cattle grazing in north-central Montana: Missoula, Mont., University of Montana, Master's Thesis, 60 p.

Ludlow, S.M., Brigham, R.M., and Davis, S.K., 2015, Oil and natural gas development has mixed effects on density and reproductive success of grassland songbirds: Condor, v. 117, no. 1, p. 64–75. [Also available at https://dx.doi.org/10.1650/CONDOR-14-79.1.]

Lusk, J., 2009, The effects of grazing on songbird nesting success in Grasslands National Park of Canada: Winnipeg, Manitoba, University of Manitoba, Master's Thesis, 78 p.

Madden, E.M., 1996, Passerine communities and bird-habitat relationships on prescribe-burned, mixed-grass prairie in North Dakota: Bozeman, Mont., Montana State University, Master's Thesis, 153 p.

Madden, E.M., Hansen, A.J., and Murphy, R.K., 1999, Influence of prescribed fire history on habitat and abundance of passerine birds in northern mixed-grass prairie: Canadian Field Naturalist, v. 113, no. 4, p. 627–640.

Madden, E.M., Murphy, R.K., Hansen, A.J., and Murray, L., 2000, Models for guiding management of prairie bird habitat in northwestern North Dakota: American Midland Naturalist, v. 144, no. 2, p. 377–392. [Also available at https://dx.doi.org/10.1674/0003-0031(2000)144%5B0377:MFGMOP%5D2.0.CO;2.]

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

McCracken, J.D., 2005, Where the bobolinks roam—The plight of North America's grassland birds: Biodiversity (Nepean), v. 6, no. 3, p. 20–29. [Also available at https://dx.doi.org/10.1080/14888386.2005.9712771.]

McNicholl, M.K., 1988, Ecological and human influences on Canadian populations of grassland birds, *in* Goriup, P.D., ed., Ecology and conservation of grassland birds: Cambridge, United Kingdom, International Council for Bird Preservation, Technical Publication No. 7, p. 1–25.

Messmer, T.A., 1985, Effects of specialized grazing systems on upland nesting birds in southcentral North Dakota: Fargo, N. Dak., North Dakota State University, Master's Thesis, 112 p.

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

Milliken, G.A., and Johnson, D.E., 2002, Analysis of messy data, Volume III—Analysis of covariance: Boca Raton, Fla., Chapman and Hall & CRC Press, 624 p.

Milliken, G.A., and Johnson, D.E., 2009, Analysis of messy data, Volume I—Designed experiments: Boca Raton, Fla., Chapman and Hall & CRC Press, 674 p. [Also available at https://doi.org/10.1201/EBK1584883340.]

Minnesota Department of Natural Resources, 2015, Minnesota's Wildlife Action Plan: St. Paul, Minn., Division of Ecological Services, Minnesota Department of Natural Resources. [Also available at https://files.dnr.state.mn.us/assistance/nrplanning/bigpicture/mnwap/wildlife-action-plan-2015-2025.pdf.]

Mong, T.W., 2005, Using radio-telemetry to determine range and resource requirements of upland sandpipers at an experimentally managed prairie landscape: Manhattan, Kans., Kansas State University, Master's Thesis, 66 p.

Montana Fish, Wildlife and Parks, 2015, Montana's State Wildlife Action Plan: Helena, Mont., Montana Fish, Wildlife and Parks, 444 p. [Also available at http://fwp.mt.gov/fishAndWildlife/conservationInAction/swap2015Plan.html.]

Murkin, H.R., Murkin, E.J., and Ball, J.P., 1997, Avian habitat selection and prairie wetland dynamics—A 10-year experiment: Ecological Applications, v. 7, no. 4, p. 1144–1159. [Also available at https://doi.org/10.1890/1051-0761(1997)007[1144:AHSAPW]2.0.CO;2.]

Murphy, R.K., and Grant, T.A., 2005, Land management history and floristics in mixed-grass prairie, North Dakota, USA: Natural Areas Journal, v. 25, no. 4, p. 351–358.

Murray, L.D., and Best, L.B., 2014, Nest-site selection and reproductive success of common yellowthroats in managed Iowa grasslands: Condor, v. 116, no. 1, p. 74–83. [Also available at https://doi.org/10.1650/CONDOR-13-047-R1.1.]

Murray, L.D., Ribic, C.A., and Thogmartin, W.E., 2008, Relationship of obligate grassland birds to landscape structure in Wisconsin: Journal of Wildlife Management, v. 72, no. 2, p. 463–467. [Also available at https://doi.org/10.2193/2006-556.]

Murtaugh, P.A., 2014, In defense of *P* values: Ecology, v. 95, no. 3, p. 611–617. [Also available at https://dx.doi.org/10.1890/13-0590.1.]

Negus, L.P., Davis, C.A., and Wessel, S.E., 2010, Avian response to mid-contract management of Conservation Reserve Program fields: American Midland Naturalist, v. 164, no. 2, p. 296–310. [Also available at https://dx.doi.org/10.1674/0003-0031-164.2.296.]

Nocera, J.J., Forbes, G., and Milton, G., 2007, Habitat relationships of three grassland breeding bird species—Broadscale comparisons and hayfield management implications: Avian Conservation & Ecology, v. 2, no. 1, article 7. [Also available at https://dx.doi.org/10.5751/ACE-00127-020107.]

North American Bird Conservation Initiative, 2016, The State of North America's birds 2016: Ottawa, Ontario, Environmental and Climate Change Canada, 7 p. [Also available at http://www.stateofthebirds.org/2016/wp-content/uploads/2016/05/SoNAB-ENGLISH-web.pdf.]

North American Bird Conservation Initiative, U.S. Committee, 2017, The State of the birds 2017—A Farm Bill special report: Ithaca, N.Y., Cornell Lab of Ornithology, 4 p. [Also available at http://www.stateofthebirds.org/2017/wp-content/uploads/2016/04/2017-state-of-the-birds-farm-bill.pdf.]

Noss, R.F., LaRoe, E.T., and Scott, J.M., 1995, Endangered ecosystems of the United States—A preliminary assessment of loss and degradation: Washington, D.C., U.S. Department of the Interior, National Biological Service, Biological Report 28, 95 p. [Also available at https://dx.doi.org/10.3996/022015-JFWM-008.S5.]

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

Orians, G.H., and Horn, H.S., 1969, Overlap in foods and foraging of four species of blackbirds in the potholes of central Washington: Ecology, v. 50, no. 5, p. 930–938. [Also available at http://dx.doi.org/10.2307/1933716.]

Owens, R.A., and Myres, M.T., 1973, Effects of agriculture upon populations of native passerine birds of an Alberta fescue grassland: Canadian Journal of Zoology, v. 51, no. 7, p. 697–713. [Also available at https://dx.doi.org/10.1139/z73-104.]

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

Peer, B.D., and Bollinger, E.K., 2017, Ecology and management of the common grackle, *in* Linz, G.M., Avery, M.L., and Dolbeer, R.A., eds., Ecology and management of blackbirds (Icteridae) in North America: Boca Raton, Fla., CRC Press, p. 65–76.

Peterjohn, B.G., and Sauer, J.R., 1999, Population status of North American grassland birds from the North American Breeding Bird Survey, 1966–1996, *in* Vickery, P.D., and Herkert, J.R., eds., Ecology and conservation of grassland birds of the Western Hemisphere: Studies in Avian Biology, v. 19, p. 27–44.

Pillsbury, F.C., 2010, Grassland bird responses to a fire-grazing interaction in a fragmented landscape: Ames, Iowa, Iowa State University, Iowa, Ph.D. Dissertation, 118 p.

Powell, A.F.L.A., 2006, Effects of prescribed burns and bison (*Bos bison*) grazing on breeding bird abundances in tallgrass prairie: Auk, v. 123, no. 1, p. 183–197. [Also available at https://dx.doi.org/10.1642/0004-8038(2006)123%5B0183:EOPBAB%5D2.0.CO;2.]

Powell, A.F.L.A., 2008, Responses of breeding birds in tallgrass prairie to fire and cattle grazing: Journal of Field Ornithology, v. 79, no. 1, p. 41–52. [Also available at https://dx.doi.org/10.1111/j.1557-9263.2008.00144.x.]

Powell, A.F.L.A., and Busby, W.H., 2013, Effects of grassland management on breeding birds at the western edge of the tallgrass prairie ecosystem in Kansas: Natural Areas Journal, v. 33, no. 2, p. 130–138. [Also available at https://doi.org/10.3375/043.033.0202.]

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

Ranellucci, C.L., 2010, Effects of twice-over rotation grazing on the relative abundances of grassland birds in the mixed-grass prairie region of southwestern Manitoba: Winnipeg, Manitoba, University of Manitoba, Master’s Thesis, 144 p.

Ranellucci, C.L., Koper, N., and Henderson, D.C., 2012, Twice-over rotational grazing and its impacts on grassland songbird abundance and habitat structure: Rangeland Ecology and Management, v. 65, no. 2, p. 109–118. [Also available at https://dx.doi.org/10.2111/REM-D-11-00053.1.]

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

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

Renfrew, R.B., Johnson, D.H., Lingle, G.R., and Robinson, W.D., 2008, Avian response to meadow restoration in the central Great Plains, *in* Springer, J.T. and Springer, E.C., eds., Prairie invaders: Proceedings of the 20th North American Prairie Conference, Kearney, Nebr., University of Nebraska, p. 313–324.

Renfrew, R.B., and Ribic, C.A., 2002, Influence of topography on density of grassland passerines in pastures: American Midland Naturalist, v. 147, no. 2, p. 315–325. [Also available at https://dx.doi.org/10.1674/0003-0031(2002)147%5B0315:IOTODO%5D2.0.CO;2.]

Reynolds, R.T., Scott, J.M., and Nussbaum, R.A., 1980, A variable circular-plot method for estimating bird numbers: Condor, v. 82, no. 3, p. 309–313. [Also available at https://dx.doi.org/10.2307/1367399.]

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

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

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

Risser, P.G., Birney, E.C., Blocker, H.D., May, S.W., Parton, W.J., and Wiens, J.A., 1981, The true prairie ecosystem: Stroudsburg, Pa., Hutchinson Ross Publishing Company, 557 p.

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

Robel, R.J., Hughes, J.P., Hull, S.D., Kemp, K.E., and Klute, D.S., 1998, Burning—Resulting avian abundance and nesting in Kansas CRP: Journal of Range Management, v. 51, no. 2, p. 132–138. [Also available at https://dx.doi.org/10.2307/4003197.]

Robert, M., Jobin, B., Latendresse, C., Giguere, S., and Shaffer, F., 2009, Habitat use by sedge wrens in southern Quebec: Wilson Journal of Ornithology, v. 121, no. 2, p. 347–358. [Also available at https://dx.doi.org/10.1676/08-057.1.]

Rohrbaugh, R.W., Jr., Reinking, D.L., Wolfe, D.H., Sherrod, S.K., and Jenkins, M.A., 1999, Effects of prescribed burning and grazing on nesting and reproductive success of three grassland passerine species in tallgrass prairie, *in* Vickery, P.D., and Herkert, J.R., eds., Ecology and conservation of grassland birds of the Western Hemisphere: Studies in Avian Biology, v. 19, p. 165–170.

Rotenberry, J.T., 1985, The role of habitat in avian community composition—Physiognomy or floristics?: Oecologia, v. 67, no. 2, p. 213–217. [Also available at https://dx.doi.org/10.1007/BF00384286.]

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

Roth, A.M., Sample, D.W., Ribic, C.A., Paine, L., Undersander, D.J., and Bartelt, G.A., 2005, Grassland bird response to harvesting switchgrass as a biomass energy crop: Biomass and Bioenergy, v. 28, no. 5, p. 490–498. [Also available at https://dx.doi.org/10.1016/j.biombioe.2004.11.001.]

Saab, V.A., and Powell, H.D.W., 2005, Fire and avian ecology in North America—Process influencing pattern, *in* Saab, V., and Powell, H., eds., Fire and avian ecology in North America: Studies in Avian Biology, v. 30, p. 1–13.

Salo, E.D., Higgins, K.F., Patton, B.D., Bakker, K.K., Barker, W.T., Kreft, B., and Nyren, P.E., 2004, Grazing intensity effects on vegetation, livestock and non-game birds in North Dakota mixed-grass prairie: Proceedings of the North American Prairie Conference, v. 19, p. 205–215.

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

Samson, F.B., and Knopf, F.L., 1994, Prairie conservation in North America: BioScience, v. 44, no. 6, p. 418–421. [Also available at https://dx.doi.org/10.2307/1312365.]

Samson, F.B., Knopf, F.L., and Ostlie, W.R., 2004, Great Plains ecosystems—Past, present, and future: Wildlife Society Bulletin, v. 32, no. 1, p. 6–15. [Also available at https://doi.org/10.2193/0091-7648(2004)32[6:GPEPPA]2.0.CO;2.]

Sandercock, B.K., Alfaro-Barrios, M., Casey, A.E., Johnson, T.N., Mong, T.W., Odom, K.J., Strum, K.M., and Winder, V.L., 2015, Effects of grazing and prescribed fire on resource selection and nest survival of upland sandpipers in an experimental landscape: Landscape Ecology, v. 30, no. 2, p. 325–337. [Also available at https://dx.doi.org/10.1007/s10980-014-0133-9.]

SAS Institute, Inc., 2014, SAS/STAT® 13.2 user's guide—The GLIMMIX procedure: Cary, N.C., SAS Institute, Inc., 338 p.

Schmitt, R.A., 2003, Effects of fire and grazing on breeding birds in a mixed-grass prairie: Missoula, Mont., University of Montana, Master's Thesis, 78 p.

Schneider, N.A., 1998, Passerine use of grasslands managed with two grazing regimes on the Missouri Coteau in North Dakota: Brookings, S. Dak., South Dakota State University, Master's Thesis, 94 p.

Schorger, A.W., 1934, Notes on the distribution of some Wisconsin birds—II. Brewer's blackbird (*Euphagus carolinus*): Auk, v. 51, no. 4, p. 482–486. [Also available at https://dx.doi.org/10.2307/4077812.]

Scott, P.E., DeVault, T.L., Bajema, R.A., and Lima, S.L., 2002, Grassland vegetation and bird abundances on reclaimed midwestern coal mines: Wildlife Society Bulletin, v. 30, no. 4, p. 1006–1014.

Shaffer, J.A., Goldade, C.M., Dinkins, M.F., Johnson, D.H., Igl, L.D., and Euliss, B.R., 2003, brown-headed cowbirds in grasslands—Their habitats, hosts, and response to management: Prairie Naturalist, v. 35, no. 3, p. 145–186.

Shahan, J.L., Goodwin, B.J., and Rundquist, B.C., 2017, Grassland songbird occurrence on remnant prairie patches is primarily determined by landscape characteristics: Landscape Ecology, v. 32, no. 5, p. 971–988. [Also available at https://dx.doi.org/10.1007/s10980-017-0500-4.]

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

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

Skinner, R.M., 1982, Vegetation structure and bird habitat selection on Missouri prairies: Columbia, Missouri, University of Missouri, Ph.D. Dissertation, 108 p.

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

Smith, J.K., ed., 2000, Wildland fire in ecosystems: effects of fire on fauna: General Technical Report RMRS-GTR-42-volume 1, Ogden, Utah, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, 83 p.

Smythe, L.A., and Haukos, D.A., 2010, Response of grassland birds in sand shinnery oak communities restored using Tebuthiuron and grazing in eastern New Mexico: Restoration Ecology, v. 18, no. 2, p. 215–223. [Also available at https://doi.org/10.1111/j.1526-100X.2008.00443.x.]

South Dakota Game, Fish and Parks, 2014, South Dakota Wildlife Action Plan, Wildlife Division Report 2014-03: Pierre, S. Dak., South Dakota Department of Game, Fish and Parks. [Also available at https://gfp.sd.gov/UserDocs/nav/SD_Wildlife_Action_Plan_Revision_Final.pdf.]

Stauffer, D.F., and Best, L.B., 1980, Habitat selection by birds of riparian communities—Evaluating effects of habitat alterations: Journal of Wildlife Management, v. 44, no. 1, p. 1–15. [Also available at https://doi.org/10.2307/3808345.]

Stephens, S.E., Walker, J.A., Blunck, D.R., Jayaraman, A., Naugle, D.E., Ringelman, J.K., and Smith, A.J., 2008, Predicting risk of habitat conversion in native temperate grasslands: Conservation Biology, v. 22, no. 5, p. 1320–1330. [Also available at https://dx.doi.org/10.1111/j.1523-1739.2008.01022.x.]

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

Stewart, R.E., and Kantrud, H.A., 1971, Classification of natural ponds and lakes in the glaciated prairie region: Washington, D.C., U.S. Department of Interior, Bureau of Sport Fisheries and Wildlife, Resource Publication 92, 57 p.

Stewart, R.E., and Kantrud, H.A., 1972, Population estimates of breeding birds in North Dakota: Auk, v. 89, no. 4, p. 766–788. [Also available at https://dx.doi.org/10.2307/4084108.]

Stroup, W.W., 2013, Generalized linear mixed models—Modern concepts, methods, and applications: Boca Raton, Fla., CRC Press, 555 p.

Thompson, S.J., Arnold, T.W., and Amundson, C.L., 2014, A multiscale assessment of tree avoidance by prairie birds: Condor, v. 116, no. 3, p. 303–315. [Also available at https://dx.doi.org/10.1650/CONDOR-13-072.1.]

Tilman, D., 1996, Biodiversity—Population versus ecosystem stability: Ecology, v. 77, no. 2, p. 350–363. [Also available at https://dx.doi.org/10.2307/2265614.]

Tilman, D., and Downing, J.A., 1994, Biodiversity and stability in grasslands: Nature, v. 367, p. 363–367. [Also available at https://dx.doi.org/10.1038/367363a0.]

Tomlinson, R.E., Dolton, D.D., George, R.R., and Mirarchi, R.E., 1994, Mourning dove, *in* Tacha, T.C., and Braun, C.E., eds., Migratory shore and upland game bird management in North America: Washington, D.C., International Association of Fish and Wildlife Agencies, p. 5–26.

Twedt, D.J., 2017, Ecology of yellow-headed blackbirds, *in* Linz, G.M., Avery, M.L., and Dolbeer, R.A., eds., Ecology and management of blackbirds (Icteridae) in North America: Boca Raton, Fla., CRC Press, p. 43–63.

U.S. Fish and Wildlife Service [USFWS], 2008, Birds of conservation concern 2008: Arlington, Virginia, U.S. Department of Interior, Fish and Wildlife Service, Division of Migratory Bird Management, 85 p. [Also available at https://www.fws.gov/migratorybirds/pdf/grants/BirdsofConservationConcern2008.pdf.]

Van Dyke, F., Van Kley, S.E., Page, C.E., and Van Beek, J.G., 2004, Restoration efforts for plant and bird communities in tallgrass prairies using prescribed burning and mowing: Restoration Ecology, v. 12, no. 4, p. 575–585. [Also available at https://dx.doi.org/10.1111/j.1061-2971.2004.00352.x.]

Vickery, P.C., Tubaro, P.L., Cardoza da Silva, J.M., Peterjohn, B.G., Herkert, J.R., and Cavalcanti, R.B., 1999, Conservation of grassland birds in the Western Hemisphere, *in* Vickery, P.D., and Herkert, J.R., eds., Ecology and conservation of grassland birds of the Western Hemisphere: Studies in Avian Biology, v. 19, p. 2–26.

Vinton, M.A., Hartnett, D.C., Finck, E.J., and Briggs, J.M., 1993, Interactive effects of fire, bison (*Bison bison*) grazing and plant community composition in tallgrass prairie: American Midland Naturalist, v. 129, no. 1, p. 10–18. [Also available at https://dx.doi.org/10.2307/2426430.]

Vogel, J.A., 2011, Grassland bird response to enhanced vegetation diversity in restoration planting in the Spring Run Complex of northwestern Iowa: Ames, Iowa, Iowa State University, Ph.D. Dissertation, 161 p.

Vogl, R.J., 1973, Effects of fire on the plants and animals of a Florida wetland: American Midland Naturalist, v. 89, no. 2, p. 334–347. [Also available at https://dx.doi.org/10.2307/2424038.]

Walters, C., and Hilborn, R., 1976, Adaptive control of fishing systems: Journal of the Fisheries Research Board of Canada, v. 33, no. 1, p. 145–159. [Also available at https://dx.doi.org/10.1139/f76-017.]

Walters, C.J., 2007, Is adaptive management helping to solve fisheries problems?: Ambio, v. 36, no. 4, p. 304–307. [Also available at https://doi.org/10.1579/0044-7447(2007)36[304:IAMHTS]2.0.CO;2.]

Walters, C.J., and Hilborn, R., 1978, Ecological optimization and adaptive management: Annual Review of Ecology and Systematics, v. 9, no. 1, p. 157–188. [Also available at https://dx.doi.org/10.1146/annurev.es.09.110178.001105.]

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

Whitmore, R.C., 1979, Temporal variation in the selected habitats of a guild of grassland sparrows: Wilson Bulletin, v. 91, no. 4, p. 592–598.

Whitmore, R.C., 1981, Structural characteristics of grasshopper sparrow habitat: Journal of Wildlife Management, v. 45, no. 3, p. 811–814. [Also available at https://dx.doi.org/10.2307/3808729.]

Wiens, J.A., 1969, An approach to the study of ecological relationships among grassland birds: Ornithological Monographs 8, p. 1–93. [Also available at https://dx.doi.org/10.2307/40166677.]

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

Wiens, J.A., 1973b, Interterritorial habitat variation in grasshopper and Savannah sparrows: Ecology, v. 54, no. 4, p. 877–883. [Also available at https://dx.doi.org/10.2307/1935683.]

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

Wiens, J.A., 1997, The emerging role of patchiness in conservation biology, in Pickett, S.T.A., Ostfeld, R.S., Shachak, M., and Likens G.E., eds., The ecological basis for conservation: Heterogeneity, ecosystems, and biodiversity: New York, Chapman & Hall, p. 93–107

Williams, B.K., and Brown, E.D., 2012, Adaptive management: the U.S. Department of the Interior applications guide: Washington, D.C., Adaptive Management Working Group, U.S. Department of the Interior, 120 p.

Williams, B.K., Szaro, R.C., and Shapiro, C.D., 2009, Adaptive management—The U.S. Department of the Interior technical guide: Washington, D.C, Adaptive Management Working Group, U.S. Department of the Interior, 72 p.

Winkler, D.W., Hallinger, K.K., Ardia, D.R., Robertson, R.J., Stutchbury, B.J., and Cohen, R.R., 2011, Tree swallow (*Tachycineta bicolor*), *in* Poole, A., ed., The birds of North America online: Ithaca, N.Y., Cornell Lab of Ornithology, accessed July 2018 at https://doi.org/10.2173/bna.11.

Winter, M., and Faaborg, J., 1999, Patterns of area sensitivity in grassland-nesting birds: Conservation Biology, v. 13, no. 6, p. 1424–1436. [Also available at https://dx.doi.org/10.1046/j.1523-1739.1999.98430.x.]

Winter, M., Johnson, D.H., and Shaffer, J.A., 2005, Variability in vegetation effects on density and nesting success of grassland birds: Journal of Wildlife Management, v. 69, no. 1, p. 185–197. [Also available at https://dx.doi.org/10.2193/0022-541X(2005)069%3C0185:VIVEOD%3E2.0.CO;2.]

Winter, M., Johnson, D.H., and Shaffer, J.A., 2006, Does body size affect a bird's sensitivity to patch size and landscape structure?: Condor, v. 108, no. 4, p. 808–816. [Also available at https://dx.doi.org/10.1650/0010-5422(2006)108%5B808:DBSAAB%5D2.0.CO;2.]

Wisz, M.S., Hijmans, R.J., Li, J., Peterson, A.T., Graham, C.H., and Guisan, A., 2008, Effects of sample size on the performance of species distribution models: Diversity & Distributions, v. 14, no. 5, p. 763–773. [Also available at https://dx.doi.org/10.1111/j.1472-4642.2008.00482.x.]

Wood, T.J., Essner, R.L., Jr., and Minchin, P.R., 2013, Effects of prescribed burning on grassland avifauna at Riverlands Migratory Bird Sanctuary: Polymath—An Interdisciplinary Arts and Sciences Journal, v. 3, no. 1, p. 19–38.

Wyckoff, A.M., 1986, A relict population of chestnut-collared longspurs in western Minnesota: Loon, v. 58, no. 1, p. 3–11.

Zimmerman, J.L., 1993, The Birds of Konza—The avian ecology of the tallgrass prairie: Lawrence, Kans., University of Kansas Press, 216 p.

Zuckerberg, B., and Vickery, P.D., 2006, Effects of mowing and burning on shrubland and grassland birds on Nantucket Island, Massachusetts: Wilson Journal of Ornithology, v. 118, no. 3, p. 353–363. [Also available at https://dx.doi.org/10.1676/05-065.1.]

Appendixes 1–7

Appendix 1. Testing the influence of management regime and year on vegetation structure variables on two grass types on Federal lands managed under an adaptive-management framework by the U.S. Fish and Wildlife Service in North Dakota, South Dakota, Minnesota, and Montana, 2011–13. Available for download at https://doi.org/10.3133/ofr20181152.

Appendix 2. Testing the influence of post-management treatments on vegetation structure variables on Federal lands managed under an adaptive-management framework by the U.S. Fish and Wildlife Service in North Dakota, South Dakota, Minnesota, and Montana, 2011–13. Available for download at https://doi.org/10.3133/ofr20181152.

Appendix 3. Testing the influence of management regime and year on floristic composition variables collected on two grass types on Federal lands managed under an adaptive- management framework by the U.S. Fish and Wildlife Service in North Dakota, South Dakota, Minnesota, and Montana, 2011–13. Available for download at https://doi.org/10.3133/ofr20181152.

Appendix 4. Testing the influence of post-management treatments on vegetation composition variables on Federal lands managed under an adaptive-management framework by the U.S. Fish and Wildlife Service in North Dakota, South Dakota, Minnesota, and Montana, 2011–13. Available for download at https://doi.org/10.3133/ofr20181152.

Appendix 5. Testing the influence of management regime and year on breeding densities (pairs per 100 ha) of 35 common bird species and grassland bird species of conservation concern on two grass types on Federal lands managed under an adaptive-management framework by the U.S. Fish and Wildlife Service in North Dakota, South Dakota, Minnesota, and Montana, 2011–13. Available for download at https://doi.org/10.3133/ofr20181152.

Appendix 6. Testing the influence of post-management treatments on breeding densities (pairs per 100 ha) of 35 common breeding bird species and grassland species of conservation concern on Federal lands managed under an adaptive-management framework by the U.S. Fish and Wildlife Service in North Dakota, South Dakota, Minnesota, and Montana, 2011–13. Available for download at https://doi.org/10.3133/ofr20181152.

Appendix 7. Model selection results for candidate sets of models relating vegetation structure and vegetation composition and other variables to breeding densities (pairs per 100 ha) of 23 common breeding birds species and grassland species of conservation concern on Federal lands managed under an adaptive-management framework by the U.S. Fish and Wildlife Service in North Dakota, South Dakota, Minnesota, and Montana, 2011–13. Available for download at https://doi.org/10.3133/ofr20181152.

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

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

Publishing support provided by the
Rolla Publishing Service Center

Igl and others—**Adaptive Management in Native Grasslands Managed by the U.S. Fish and Wildlife Service—Implications for Grassland Birds**—OFR 2018–1152

ISSN 2331-1258 (online)
https://doi.org/10.3133/ofr20181152