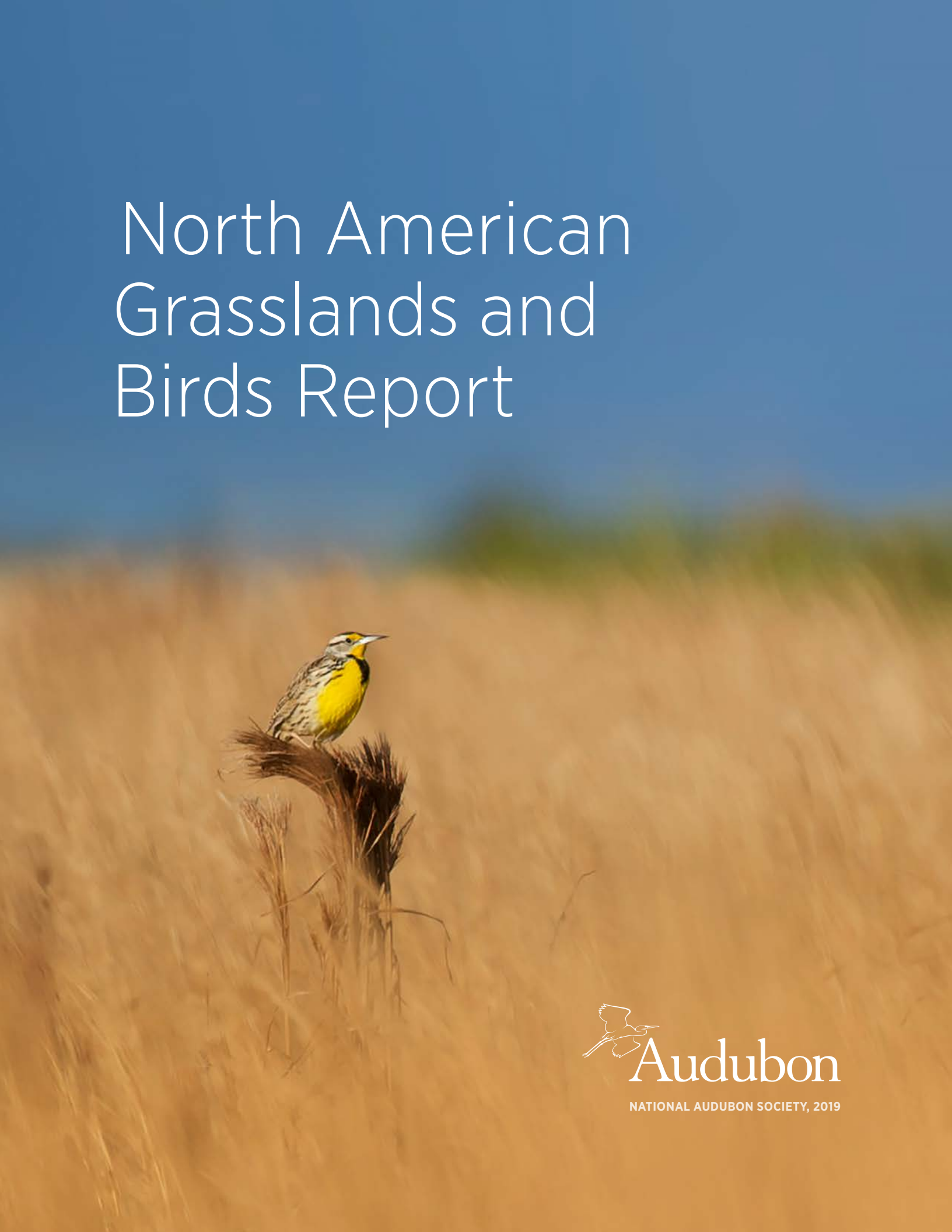
North American Grasslands and Birds Report



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North American Grasslands and Birds Report

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(Cover) Eastern Meadowlark

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David O'Neill
Chief Conservation Officer
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When National Audubon Society launched our study of grassland habitats and birds, we already knew that both the birds and the grasslands were in trouble. Our analysis confirmed this peril: only 11% of the tallgrass prairie, 24% of the mixed grass prairie, and 54% of the shortgrass prairie that once covered much of the continent remains. Furthermore, grassland conversion continues at a rate of millions of acres per year. Given these habitat conversion rates, it is not surprising that grassland birds are among the most vulnerable in North America. Total populations have declined more than 40% since 1966, and some species, like the Lesser Prairie-Chicken, hover at the brink of extinction. **The message is stark: we must act now to protect and restore these remaining grasslands before they are lost.**

The grassland story and the need for action does not end there. Audubon also assessed the vulnerability of representative grassland birds and their habitat to warming global temperatures. Our findings make it clear that in addition to protecting remaining grasslands, we must also advance solutions that reduce carbon emissions, and prioritize and direct resources and other investments to the places that will support grassland birds and other wildlife into the future.

Here is the good news: Audubon's North American Grasslands and Birds Report identifies the birds most vulnerable to climate change, and the places, or "climate strongholds," they will need to thrive as temperatures rise. It also points us to the sites most vulnerable to land conversion today, and highlights the specific conservation strategies that are part of Audubon's ambitious effort to protect grassland birds and prairies.

By partnering with key stakeholders in this working landscape, including farmers and ranchers, public agencies, and other stakeholders, we are finding balanced solutions that meet the needs of both birds and people. No one has a closer connection to the land than those who depend on its fertile soil, pollinating insects, or productive grazing lands for their livelihood. It is a way of living that forges a deep commitment to stewardship and to doing right by the environment. Growing up, I learned that first-hand from my father. I saw him and his fellow farmers in Maryland move from skepticism to enthusiastic adoption of a range of agricultural best management practices that improved soil quality, reduced labor and fuel costs, and improved water quality. The farming community where I grew up gained the knowledge that working with, and not against, nature is good for business and the environment.

Today, 65 ranches encompassing nearly two million acres are participating in Audubon's Conservation Ranching Initiative. They do not need to choose between economic prosperity and environmental stewardship. By adopting bird-friendly ranching practices, they are raising cattle in a way that both minimizes environmental impacts and also supports premium pricing for their beef. This initiative is gaining momentum throughout

the Great Plains and Intermountain West, with more acres of ranchlands in the pipeline. These practices have the added benefit of sequestering carbon, which may create additional market-based incentives for ranchers who apply bird-friendly ranching practices.

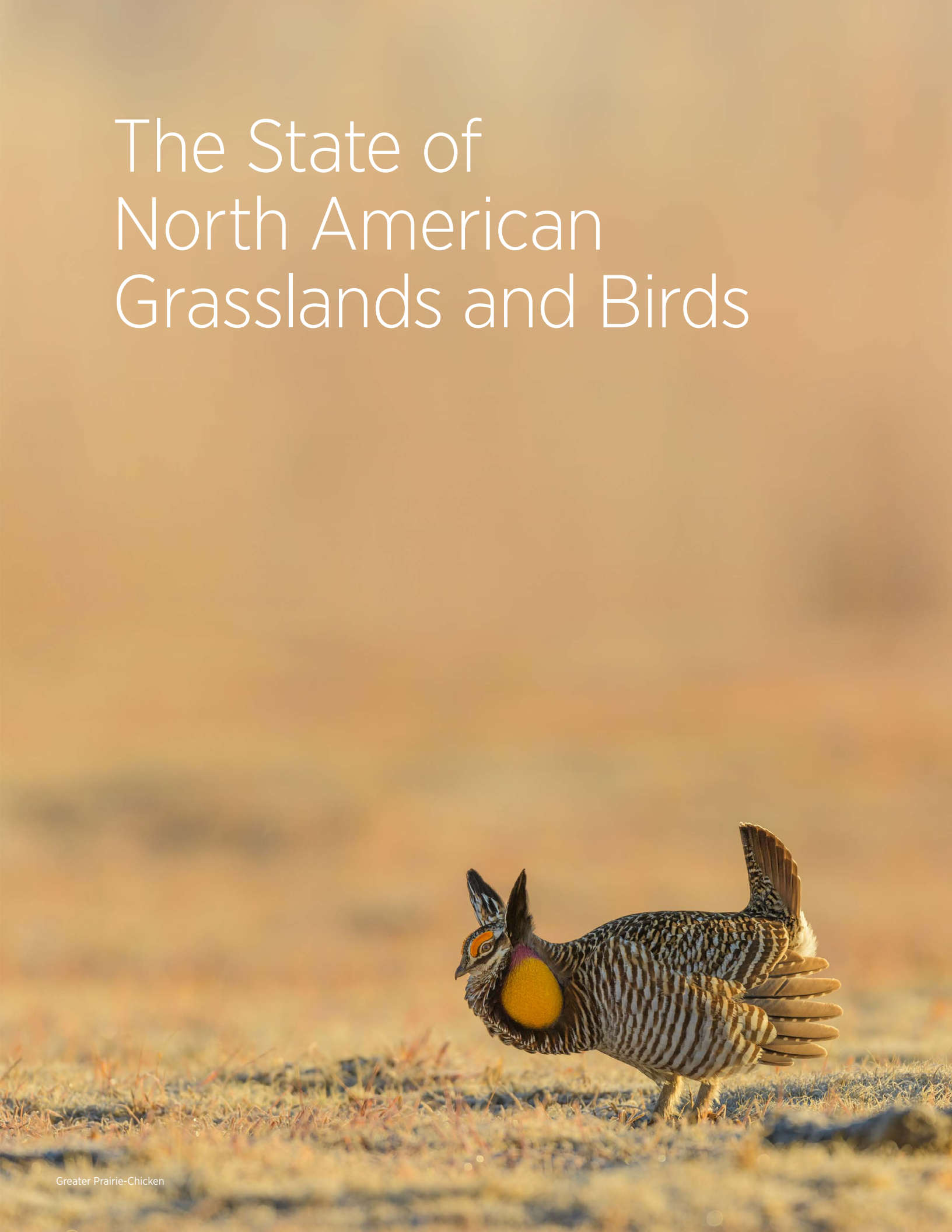
We are also mobilizing our network of Audubon advocates throughout the U.S. on behalf of policies that benefit farmers and ranchers, as well as grassland habitats and birds. We are making sure that legislation like the federal Farm Bill includes incentives for conservation—and helping bring together government agencies, private interests, tribes, non-governmental organizations, and others to collaborate around large-scale solutions that balance economic and ecological interests.

Despite their critical importance to economic growth, rural economies, and food security—as well as to birds and other wildlife—prairies and grasslands are a largely forgotten and misunderstood landscape. Through this report, Audubon is sounding an urgent alarm, and empowering and inspiring our network, our partners, and all who love birds to act now on behalf of grasslands and the birds, other wildlife, and communities that depend on them.

David O'Neill
Chief Conservation Officer
Audubon

Western Meadowlark

The State of North American Grasslands and Birds



Greater Prairie-Chicken

A Diverse Landscape

"The plain gives man new and novel sensations of elation, of vastness, of romance, of awe, and often nauseating loneliness."

- Walter Prescott Webb, The Great Plains (1931)

Vast, expansive grasslands once spread across central North America, appearing almost monotonous (Weaver 1968). These grasslands extended from southern Canada to northern Mexico, an area known as the Great Plains, and comprised the largest grassland region in North America (Fig. 1.1). Grasslands are herbaceous and grass-dominated landscapes with less than 10% cover from trees (Dixon et al. 2014). Topography (i.e., flat expansive plains) and climate are the primary drivers of native grasslands in the Great Plains region. The three primary types of grasslands, known more commonly as prairies, include tallgrass prairie, mixed prairie, and shortgrass prairie. The distribution of these grasslands reflects a moisture gradient from east to west (spanning a range of approximately 10 to 50 inches of precipitation per year; USGS 2017), with tallgrass prairie occurring in the wettest, mixed grass prairie in the intermediate, and shortgrass prairie occurring in the driest region. In addition, somewhat unpredictable droughts drive prairie composition and are more frequent in the shortgrass prairie and decrease in occurrence going east (Samson et al. 2004).

Prior to European settlement, the primary ecological drivers on the prairies were disturbance from

Figure 1.1. Historic grassland types of North America based on mapping data from the International Vegetation Classification and Terrestrial Ecoregions of the World. A grassland is defined as grass-dominated and having less than 10% tree cover. (Dixon et al. 2014).

grazing by large herbivores and drought, with natural fire also occurring in tall and mixed grass prairies (Nelson et al. 2006). Historically, bison moved nomadically throughout the Great Plains searching for the best forage, resulting in rest intervals of 1 to 8 years before being grazed again, allowing grasses plenty of time to recover (Knapp et al. 1999, Samson et al. 2004). Fire was a critical component of the prairie's natural disturbance regime and provided unique benefits; such as reducing aboveground biomass, releasing previously immobilized nutrients (Collins 2000), enhancing soil microbial activity (Ojima et al. 1994), and reducing woody and weedy species (Brockway et al. 2002). Fire-adapted prairie grasses have growing tissues at the bottom of the plant rather than the top, as forbs and woody plants do, and thus are much more resilient to burning (Reinking 2005). Vast root systems provide native prairie forbs the ability to survive and thrive after fire events. The interaction of fire and grazing also helped to promote a mosaic of plant communities as bison preferred to graze recently-burned patches due to their high-quality new growth, which allowed dead plant material to accumulate on unburned patches (Anderson 2006). The fuel-rich patches then burned, continuing the cycle and creating a mosaicked landscape (Fuhlendorf and Engle 2001). Thus, the Great Plains, despite its seeming homogeneity, was actually a dynamic landscape dependent on disturbance to maintain a diverse and resilient ecological community.

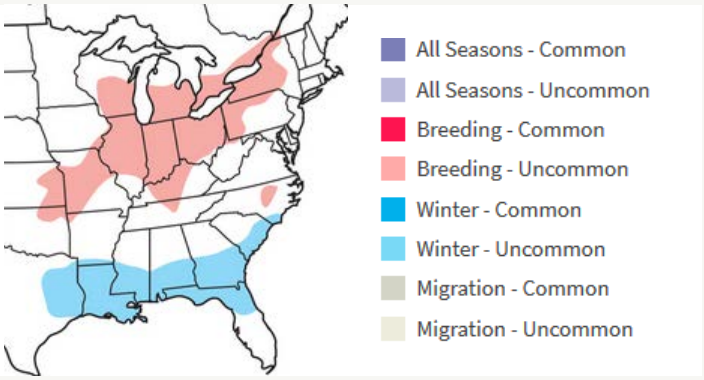
Tallgrass

Tallgrass prairie extended historically from southeastern Manitoba to southeastern Texas, and east through Indiana (Fig. 1.1; Askins et al. 2007), covering an area of 200 million acres (Dixon et al. 2014). As much as 98% of historic tallgrass prairie has been lost (Comer et al. 2018) as the region is particularly fertile and arable, and land-use conversion continues today (Lark et al. 2015).

Climate and fire are the primary ecological drivers in tallgrass prairie. Annual precipitation is around 40 to 50 inches per year (USGS 2017), with large summer thunderstorms (ranging from 1 to 10 thunderstorm days per year) interrupting extended dry periods (Changnon et al. 2002). Fire historically burned every 2 to 5 years (Abrams 1985, Collins 2000).

Tallgrass prairies have a rich floristic diversity, comprising over 500 species (NPS 2017) of grass, forb (wildflower), and sedges. Some species grow

Henslow's Sparrow



Did you know? **Perhaps no species of bird exemplifies tallgrass prairies better than the Henslow's Sparrow. Though it's been the focus of many conservation efforts, it is remarkably inconspicuous and delivers a song that is "least impressive" and described as a "feeble hiccup." The Henslow's Sparrow has shown significant declines over the past few decades. Its tallgrass habitat has almost been entirely converted to row crops, hay fields, and forage crops. On top of that, the Henslow's Sparrow has been shown by our new climate assessment to be highly vulnerable to the effects of climate change in summer, meaning it is projected to experience a great proportion of range loss with very little future expansion.**

six to more than eight feet tall (NPS 2017). The "big four" grasses are big bluestem (*Andropogon gerardi*), little bluestem (*Schizachyrium scoparius*), Indiangrass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*; Reinking 2005, NPS 2017). A large diversity of wildflower species are also found, including purple coneflower (*Echinacea* sp.), prairie blazing star (*Liatris punctata*), sunflowers (*Helianthus sp.*), aromatic aster (Aster oblongifolius), and button blazing star (*Liatris aspera*; NPS 2017).

Some of the most iconic grassland bird obligates associated with native tallgrass are Greater Prairie-Chicken (*Tympanuchus cupido*), Henslow's Sparrow (*Ammodramus henslowii*; Reinking 2005), and Short-eared Owl (*Asio flammeus*; Askins 2007). Bobolink (*Dolichonyx oryzivorus*) formerly nested in tall and mixed grass prairies, but displays more flexibility than the other species across the spectrum of prairie types (Renfrew et al. 2015). Tallgrass prairie birds subsist primarily on the insects and seeds, and in the owl's case, rodents, and nest among dense vegetation on the ground. All of these species have negative population trends or are of high conservation concern (Table 1.1).

Mixed Grass

Mixed grass prairie occurs in the transition between short and tallgrass prairies, with grasses of intermediate height being predominant (Askins et al. 2007). Historically, mixed grass prairie covered an area of 140 million acres (Fig. 1.1; Dixon et al. 2014), but approximately 76% has been converted (Comer et al 2018). Less wet than the tallgrass prairie, the climate of the mixed grass prairie is characterized by occasional rains, high temperatures, relatively low humidity, and high winds (Albertson 1937). Mean temperatures range from below zero degrees Fahrenheit in winter to over 100 ^{0}F in summer (Albertson 1937). The primary ecological driver that kept mixed grass prairies grass-dominated was the variability in and general lack of precipitation (Askins et al. 2007). Secondarily, intermittent grazing by bison (*Bison bison*), pronghorn (*Antilocapra americana*), elk (*Cervus canadensis*), hares/rabbits, Richardson's ground squirrels (*Spermophilus richardsonii*), and black-tailed prairie dogs (*Cynomys ludovicianus*), and periodic fire also contributed to sustaining mixed grass prairie (Askins et al. 2007). Fires were smaller and less frequent than in tallgrass prairies, occurring on average every six years in wetter areas and up to every 26 years in drier areas (Askins et al. 2007).

The mixed grass prairie contains the floral and faunal biodiversity of both tallgrass and shortgrass prairies. Common grass species are little bluestem (*Schizachyrium scoparius*), big bluestem (*Andropogon gerardi*), and wire grass (*Aristida purpurea; Albertson 1937*). Birds of this region sometimes forage in short grasses while hiding their nests in dense vegetation. Iconic birds of the mixed prairie are the Baird's Sparrow (*Ammodramus bairdii*), Sprague's Pipit (*Anthus spragueii*), Upland Sandpiper (*Bartramia longicauda*), Dickcissel (*Spiza americana*), Grasshopper Sparrow (*Ammodramus savannarum*), and Bobolink. All of these species except for the Upland Sandpiper have negative population trends (Sauer et al. 2013; Table 1.1), while the Upland Sandpiper populations began increasing recently (Sauer et al. 2013).

Shortgrass

Shortgrass prairie covered historically an area of 265 million acres (Fig. 1.1; Dixon et al. 2014). Approximately 46% of its historic area has been lost (Comer et al. 2018). Drought and grazing were key ecological drivers of shortgrass prairie. The most important herbivore was black-tailed prairie dogs, followed by bison and elk (Askins et al. 2007). Unlike its effect on tall and mixed grass prairies, fire is not a prominent driver for the shortgrass prairie. Endemic shortgrass prairie species include blue grama (*Bouteloua gracilis*) and buffalo grass (*Bouteloua dactyloides*), which are highly tolerant of drought and maintain 90% of their biomass below ground in root systems (Askins et al. 2007). Black-tailed prairie dogs existed historically in large colonies and clipped tall vegetation to maintain clear views (Askins et al. 2007). Their burrows also provide nesting habitat for Burrowing Owls (Athene cunicularia). Extensive prairie dog eradication has been associated with taller vegetation and expansion of non-native grasses (Copeland et al. 2011).

Birds of the shortgrass prairie tend to have habitat requirements that are quite different from those

that persist in the mixed and tallgrass prairies. They forage in much more open areas and often nest directly on the ground. Iconic birds of the shortgrass prairie include Chestnut-collared Longspur (*Calcarius ornatus*), McCown's Longspur (*Rhynchophanes mccownii*), Mountain Plover (*Charadrius montanus;* Askins et al. 2007), Lark Bunting (*Calamospiza melanocorys*), Horned Lark (*Eremophila alpestris*), Loggerhead Shrike (*Lanius ludovicianus;* Rosenberg et al. 2016), and Western Meadowlark (*Sturnella neglecta*). All of these species have shown substantial population declines since 1966 (Sauer et al. 2013).

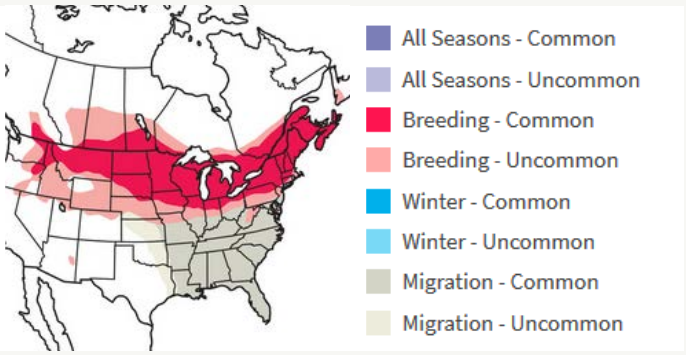
Chihuahuan Grasslands

Set apart from the three grassland types of the Great Plains in its climate patterns and geologic history, the Chihuahuan grasslands are a region of desert grasslands in northern central Mexico, southern New Mexico, and southern Arizona (Fig. 1.1; Askins et al. 2007, Dixon et al. 2014). These grasslands appeared as recently as 9,000 years ago, replacing mesquite shrublands (Cotera et al. 2004). Despite being a desert, the Chihuahuan Desert is wetter than other warm deserts of the world, averaging 9 inches of rainfall per year falling primarily in summer (Dinerstein et al. 2000). Ecological drivers included drought, grazing, and fire, with a fires occurring every 7 to 10 years (Askins et al. 2007). Bison, pronghorn antelope (*Antilocapra americana*), black-tailed prairie dogs (*Cynomys ludovicianus*) and Mexican prairie dogs (*C. mexicanus*) also helped to maintain grasslands by clipping mesquite and other shrubs to maintain an unobstructed view (Askins et al. 2007).

Grasslands comprised approximately 20% of the Chihuahuan Desert region historically (Dinerstein et al. 2000), or around 34.5 million acres (Cotera et al. 2004). Approximately 43% of the Chihuahuan grasslands has been lost (Comer et al. 2018). Fire limited shrub cover; however, fire suppression has resulted in grassland loss in recent decades due to shrub encroachment (Dinerstein et al. 2000).

The flora of the region is comprised of mostly desert species. Native grasses include side-oats grama (*Bouteloua curtipendula*), black grama (*Bouteloua eriopoda*), purple three-awn (*Aristida*

Bobolink



Did you know?

Bobolinks are in the blackbirds and orioles family, despite their similar appearances to sparrows. The male Bobolink has a striking black plumage with a yellow nape that he flaunts in a few different courtship displays. The species' name comes from the bubbling, tinkling song the male makes while fluttering over meadows and hayfields. Originally, their prime breeding habitat was damp meadows and natural prairies with dense growth of grass and weeds and a few low bushes. Such habitats are still favored but hard to find, and today most Bobolinks in eastern United States nest in hayfields. Bobolink is a priority bird for Audubon and highly vulnerable to climate change, facing threats on several fronts simultaneously.

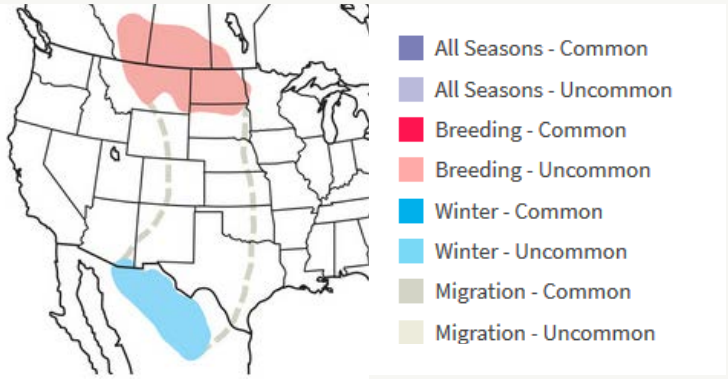
purpurea), tobosa (*Hilaria mutica*), lechuguilla (Agave lechuguilla), and big alkali sacaton (*Sporobolus wrightii*; Cotera et al. 2004). Tarbush (*Florensia cernua*), mesquite (*Prosopis glandulosa*), acacia, and cacti are common shrubs of the region (Cotera et al. 2004).

The Chihuahuan grasslands provide critical over-wintering habitat for many birds that breed in the northern grasslands, funneling millions of birds into a relatively small area. Eighty-five percent of the grassland-obligate bird species that breed in the Northern Great Plains spend their winters in the Chihuahuan grasslands, yet only 5% of the Chihuahuan Desert remains as suitable wintering habitat (Macías-Duarte et al. 2011). Grassland species that winter here include Chestnut-collared Longspur, McCown's Longspur, Baird's Sparrow, Sprague's Pipit, Horned Lark, Savannah Sparrow, Grasshopper Sparrow, and Mountain Plover (Askins et al. 2007, Rosenberg et al. 2016). Two near-endemic species of the Chihuahuan grasslands are Botteri's Sparrow (*Peucaea botterii*) and Rufous-winged Sparrow (*Peucaea carpalis*; Askins et al. 2007). Protection of this important over-wintering ground is critical to the conservation of North America's grassland birds.

Other significant grasslands of North America

Though this report focuses on the Great Plains and Chihuahuan grasslands, there are other significant grassland regions in North America (Fig. 1.1). The Western Gulf Coast grasslands of Louisiana and Texas, comprised of marshes, bays, tallgrass prairies, and live oak woodlands (Texas Parks & Wildlife 2017), provide important habitat for birds. The Edwards Plateau of Texas is an ecologically unique oak woodland/mesquite savannah grassland that ranges in elevation from 100 to 3,000 feet above sea level (Texas Parks & Wildlife 2017). The Montana Valley and Foothill grasslands is a biodiverse region along the Rocky Mountain front (WWF 2018a). The Basin Desert steppe is comprised of cold-tolerant shrub species such as sagebrushes, saltbrushes, and winterfat (WWF 2018a). The Palouse grasslands, in the rain shadow of the Cascade Cascade Mountains, were once dominated by native bluebunch wheatgrass and Idaho fescue, but are now more than 99% converted (WWF 2018a). Formerly comprised of a wide variety of perennial grasses, riparian forests, vernal pools, wetlands, chaparral shrub, and open oak woodlands, less than one percent of pre-settlement California grasslands remain following land use conversion (WWF 2018a).

Baird's Sparrow



Did you know?

The Baird's Sparrow was discovered by John James Audubon in 1843 and named for the young ornithologist Spencer Baird. The bird was then not seen for almost 30 years. This kind of disappearing act seems appropriate for Baird's Sparrow, which runs through the grass like a mouse, almost never perching up in the open. Though little is known about this elusive bird, it winters in the Chihuahuan grasslands, favoring dense and expansive grasslands with a minor shrub component. Both summer and winter habitat have been lost at drastic rates, which is further compounded by climate change; the Baird's Sparrow is highly vulnerable in both summer and winter and may lose much of its range due to the effects of climate change alone.

A Continental Resource

These diverse grassland landscapes also provide a suite of ecosystem services of local, regional, and continental significance. Ecosystem services are benefits that people receive from natural ecosystems (MEA, 2005). Grassland vegetation improves water infiltration and reduces runoff (Kim et al. 2016, Wilsey et al. 2016, Wilcox et al. 2017). This helps recharge aquifers critical for drinking water and irrigated agriculture (Kim et al. 2016, Wilcox et al. 2017), such as the Ogallala, that covers much of the central grassland region. Grasslands also filter agricultural runoff, reducing soil erosion and concentrations of nitrogen and phosphorus (Wilcox et al. 2017). These can have significant downstream effects. For example, high nutrient loads in agricultural runoff is a primary cause of the Gulf Coast Hypoxic Zone (HTF 2015) a ~3,400-acre area off the coast of Louisiana with low concentration of dissolved oxygen due an ecological cascade set off by unusually high nutrient levels. Conservation of intact grasslands and restoration of grassland-wetland complexes, particularly along rivers, tributaries and urban corridors, could potentially prevent 1.7 trillion gallons of surface runoff, 87 million pounds of total phosphorus, and 427 million pounds of total nitrogen (Flynn et al. 2017). Finally, the deep, perennial root systems of grasslands sequester carbon. Grasslands sequester carbon at rates comparable to some forest types and their broad continental extent implies a tremendous capacity to sequester carbon (Chambers et al. 2016).

Mountain Plover

A Landscape Under Threat

There is little debate that grasslands are one of the most imperiled ecosystems in North America (Samson and Knopf 1994). Across the vast North American landscape, 62% of tallgrass, mixed grass, shortgrass, and Chihuahuan grasslands have been lost. Conversion of grasslands in many localized areas exceed 80% (Samson and Knopf 1994, Brennan and Kuvlesky 2005). Tallgrass prairies in particular are most impacted, having incurred an 89% loss (Comer et al. 2018) since the 1800s, exceeding old-growth forests in the Pacific Northwest, temperate rainforests in British Columbia and Alaska, and hardwood forests in south-central United States (Samson and Knopf 1994).

The biggest threat to tall and mixed grass prairies is conversion to cropland agriculture, owing to their suitability for crop production, and because relatively little land set aside for conservation prior to development (Vickery et al. 2000, Hoekstra et al. 2004, Wimberley et al. 2018). Wholesale conversion of grasslands began with the Homestead Act of 1862, which allowed nearly 1.5 million people to acquire nearly 200 million acres of land in the Great Plains region (Samson et al. 2004). Most of this land was converted to cropland, particularly the wet, arable regions of the tallgrass prairies (Samson et al. 2004). Agricultural conversion has seen a slight uptick since the late 2000s. Cropland has expanded west into California, eastern Washington, Montana (Yu and Lu 2017), eastern Colorado, North and South Dakota (Stephens et al. 2008, Wimberley et al. 2018), southern Iowa and northern Missouri, western Kansas, and the Oklahoma and Texas panhandles (Lark et al. 2015). Even the patches of prairie that remain are sometimes too small to support viable bird populations, being fragmented and surrounded by low-quality habitat (Wimberly et al. 2018).

Conversion is ongoing. Since 2009, an estimated 57.4 million acres of land has been converted to cropland in the central Great Plains of the US and Canada (WWF 2018b). More recently, 2.5 million acres were converted to cropland in 2016 and 1.7 million acres in 2017 across the Great Plains (WWF, 2018b). These new croplands are typically less arable, marginal lands (Lark et al. 2015, Olimb and Robinson 2019). Because these marginal lands are less productive, the costs of recent conversions (e.g. loss of water filtration and recharge; pollination; pest suppression; and plant, animal, and microbial diversity) may actually be high relative to the benefit of increased cropland area (Lark et al. 2015, Olimb and Robinson 2019). Furthermore, total grassland conversion is higher than net grassland loss because some lands are returned grassland. In the US, 5.7 million acres of grasslands were converted, forming 77% of all new croplands; however, only 3 million acres of net cropland were added (Lark et al. 2015). Corn, wheat, and soy made up 75% of the primary crops added (Lark et al. 2015).

In the shortgrass prairies, energy development and range management are also major threats (Copeland et al. 2011). Wind energy development, crop production for ethanol and other biofuels, and shale oil and natural gas extraction are having a prominent impact on North American grasslands in the west (Copeland et al. 2011). Wind development in the Great Plains has accelerated, leading to direct mortality of birds and bats, as well as widespread habitat fragmentation due to power infrastructure (Kreuter et al. 2016). “Energy sprawl” results when a landscape is fragmented by roads, wind towers, and transmission lines (Copeland et al. 2011), which adds challenges to nesting and migrating wildlife. The Energy Independence and Security Act of 2007 has also promoted the expansion of ethanol refineries in the US, and within 50 miles of refineries, 2.7 million acres of central grasslands were converted to cropland between 2008 and 2012, with a net loss of 1.6 million grassland acres (Table S4 & S6 in Wright et al. 2017). Shale oil and gas extraction has also resulted in water contamination in the Great Plains (Kreuter et al. 2016).

Other threats across North America’s grasslands include replacement of native grasses with non-natives (McGranahan et al. 2012), fire suppression (Fedy et al. 2018), intensive incompatible grazing (Briggs et al. 2005), urbanization (Cook et al.2015, Fedy et al. 2018), as well as the declining water availability and increased drought (Cook et al.2015). The Great Plains are a difficult landscape to conserve, yet the failure to do so has manifested in the decline of many bird species (Table 1.1; Fig. 1.2).

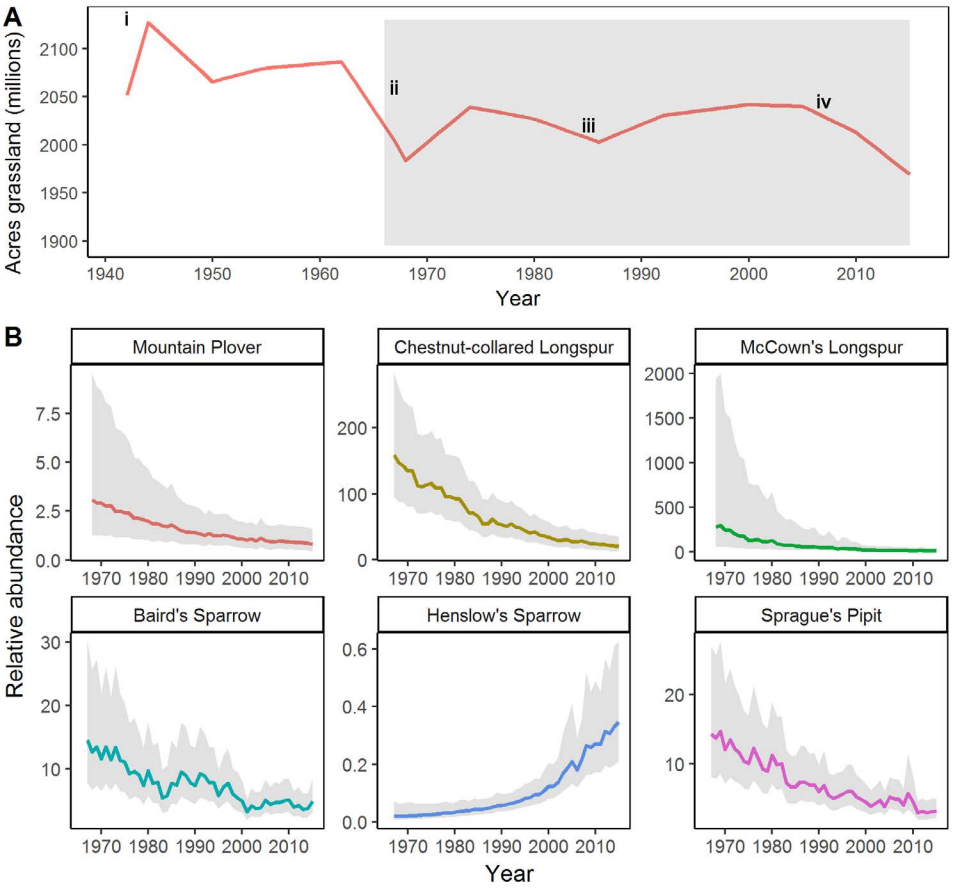


Figure 1.2. Change in grassland area from 1940 to 2015 and population trends for six focal species from 1966 to 2015. (A) Grassland area data are from USGS Landcover Modeling project (Sohl 2016), extracted from the same region as the BBS results. The gray shaded area corresponds to the time period shown in the six, lower panel plots. i: recovery of grasslands from the Great Drought of 1933-1940 (Weaver 1968); ii: grassland declines in this decade are likely due to a combination of factors, such as the innovation of the center pivot irrigation system (Mac et al. 1998, Spencer 2017), expiration of the Acreage Reserve Program in 1958 (Helms 1985), and conversion to range, pasture, and forest (Conner et al. 2001); iii: Conservation Reserve Program (CRP) instated in 1985; iv: peak enrollment of the CRP. (B) Relative abundance data for bird species are from Breeding Bird Survey (Sauer et al. 2017) results in the Central region, which overlaps with the majority of our grassland study area. All species shown exhibit a declining trend except for the Henslow's Sparrow, which has stabilized and begun to show increases since the Conservation Reserve Program's inception.

Trends of Grassland Birds

Perhaps not surprisingly, birds of North American grasslands have incurred drastic declines over the past 50 years. The plight of these birds is worrisome as they have shown "steeper, more consistent, and more geographically widespread declines than any other behavioral or ecological guild" (Knopf 1994). Analysis from North American Breeding Bird Survey data showed 57 of 77 (74%) of cropland-associated species decreased from 1966 to 2013 (Stanton et al. 2018). Grassland birds (42 species) incurred a 20% decline during this time, which was the second steepest decline, following aerial insectivores (six species of swallows and nighthawks) at a 40% decline (Stanton et al. 2018). The North American Bird Conservation Initiative documented a >40% decline since 1966 among 24 grassland species (NABCI 2017). Birds that breed in the Great Plains of Canada and the US and winter in the Chihuahuan grasslands have experienced especially drastic declines of nearly 70% (NABCI 2016). Grassland specialists, such as McCown's Longspur, Sprague's Pipit, and Baird's Sparrow, are also more likely to fare worse than more generalist birds (Correll et al. 2019). Of Audubon's 19 priority species (Table 1.1), 16 (84%) are declining. The exceptions are species that have rebounded in recent years but still merit conservation attention in parts of their range. The Greater Prairie-Chicken is threatened, endangered or extinct in portions of its range. Of its three subspecies, the Heath Hen (*T. c. cupido*) is extinct, Attwater's Prairie-Chicken (*T. c. attwateri*) is endangered, and the Greater Prairie-Chicken (*T. c. pinnatus*) is extirpated or threatened in 18 states and provinces, yet numerous enough to be hunted in six states (Johnson et al. 2010). The Henslow's Sparrow is a species of conservation concern to the North American Bird Conservation Initiative and Partners in Flight, but has shown steady population increases in the recent decades (Sauer et al. 2017). The Ferruginous Hawk has seen historic declines, but have rebounded in Colorado and Montana since the 1980s driving an increasing range-wide population trend (Sauer et al. 2017). Winter population trends for Ferruginous Hawk are positive (Soykan et al. 2016) perhaps because raptor prey, such as small birds and mammals, thrive in cropland during winter despite having reduced abundance in the summer (Steenhof 2013). Upland Sandpiper had a declining continental population trend through 1999, but now has a range-wide increasing trend (Sauer et al. 2013) driven by increases in the central Great Plains (Houston and Bowen, 2011). Long-billed Curlew had historically low abundance and declining trends through the 1990s, but more recently is considered stable (Sauer et al. 2013).

Table 1.1. Population trend of priority grassland species, conservation status, and a general description of their range. Information is from the Partners in Flight Landbird Conservation Plan (2016) unless otherwise stated. Climate Change Vulnerability is provided for summer and winter at the 3° C warming scenario.

Species	Population trend[1]	Range		Climate change vulnerability[3]	
		Summer	Winter	Summer	Winter
Baird's Sparrow	Declining[YD]	US & CAN	Chihuahuan	High	High
Bobolink	Declining[YD]	US & CAN	S. America	High	---
Burrowing Owl	Declining	US & CAN	Chihuahuan	Neutral	Neutral
Chestnut-collared Longspur	Declining[YD]	US & CAN	Chihuahuan	High	Moderate
Eastern Meadowlark	Declining[C]	US, CAN, & MEX	US & MEX	Moderate	Neutral
Ferruginous Hawk	Increasing	US & CAN		Moderate	Moderate
Grasshopper Sparrow	Declining[C]	US & CAN	Chihuahuan	Low	Neutral
Greater Prairie-Chicken	Declining[YD]	US	US	Neutral	Neutral
Henslow's Sparrow	Declining[YR]	US	US	High	Neutral
Horned Lark	Declining[C]	US & CAN	US & Chihuahuan	Low	Low
Lesser Prairie-Chicken	Declining[R]	US	US	Moderate	Low
Long-billed Curlew	Stable[2]	US & CAN	Chihuahuan	High	Neutral
McCown's Longspur	Declining[YD]	US & CAN	Chihuahuan	High	Moderate
Mountain Plover	Declining[2]	US	Chihuahuan	High	Low
Northern Bobwhite	Declining	US & CAN	US & CAN	Neutral	Neutral
Sprague's Pipit	Declining[YD]	US & CAN	Chihuahuan	High	Neutral
Upland Sandpiper	Increasing	US & CAN	Southern Cone	Neutral	---
Vesper Sparrow	Declining	US & CAN	Chihuahuan	Moderate	Neutral
Western Meadowlark	Declining	US & CAN	Chihuahuan	Low	Neutral

1 Population trend and watch list status are from Partners in Flight Landbird Conservation Plan (2016) unless otherwise noted. R = Red Watch List Species; YR = Yellow R Watch List Species (not declining but vulnerable due to small range/population, or facing threats); YD = Yellow D Watch List Species (population declines and facing threats); C = Common Birds in Steep Decline.

2 Population trend data from Sauer et al. (2013).

3 H = High, M = Moderate, L = Low, and N = Neutral vulnerability to climate change.

Protections and Policies

The decline of grasslands and habitats for birds is a prominent conservation issue, and numerous federal and state programs as well as non-profit conservation actions have attempted to conserve grassland habitats. In the United States, implementation of Farm Bill programs, including the Conservation Reserve Program (CRP), Agricultural Conservation Easement Program (ACEP), and Crop Production of Native Sod (Sodsaver) programs, have seemingly stabilized the decline in many grassland bird populations (NABCI 2017). This achievement is tenuous as recent expiration of enrolled lands from CRP is associated with a 30% conversion rate back to agriculture, amounting to 1.3 million acres from 2010-2013 (Morefield et al. 2016). North and South Dakota, areas we have identified as high conservation priority (see below), are likely to lose 60 and 66% of their CRP lands respectively (Warhurst 2012).

Within the Great Plains there are 17 National Grasslands administered by the US Department of Agriculture Forest Service, protecting nearly 4 million acres of grasslands (USFS 2018). The Tallgrass Prairie National Preserve in the Kansas Flint Hills region, at 11,000 acres, contains the majority of the remaining tallgrass prairie in public ownership (NPS 2017). The Sand Lake National

Wildlife Refuge in eastern South Dakota sets aside 21,498 acres of prairie pothole and tallgrass habitat, and actively restores cropland to native prairie habitat for waterbirds and grassland bird species (USFWS 2014). The Thunderbasin National Grasslands is 2-million-acre area of grasslands in northeastern Wyoming managed by the US Forest Service (USFS 2018). Other sources of perpetual or long-term grassland protection include federal conservation easements, national wildlife refuges, national preserves, and federal conservation programs such as the Conservation Reserve Program (CRP). Within the Prairie Pothole Region, 3.5 million acres are currently perpetually protected through the federal conservation easement program (USFWS 2018). CRP provides short-term land protection (10-15 years), for approximately 22.7 million acres across the United States. Texas, Kansas, Iowa, Colorado and North Dakota are the top five states for CRP enrollment with more than 10 million CRP acres. The term and perpetual protection efforts of the federal government account for 22.7 million acres protected as of June 2018 (www.fb.org).

Unlike other grassland regions, a relatively large component of the shortgrass prairie is public lands. However, in the absence of native grazers (i.e., prairie dogs), a unique conservation challenge public land managers face is public pressures against grazing, which can actually allow taller grasses to shade out native short grasses that would otherwise be dominant (Askins et al. 2007). Proper management to maintain the shortgrass prairie includes regenerative grazing practices that can restore ecosystem function by managing livestock in ways that mimic the historical movements and impacts of bison and other native grazers of the past.

The grasslands of North America are diverse and require a suite of heterogeneous varied management strategies tailored to each habitat type. Over much of the tallgrass prairie, land conservation and restoration back to native species may be most needed. Mixed grass prairie benefits from sustainable rotational grazing practices, as well as land conservation and native plant restoration. Shortgrass prairies provide a unique opportunity for sustainable ranching and bird habitat to coexist. There is increasing interest in the adoption of "regenerative" grazing practices that mimic the role of historical grazing animals by using animal density, rest, and rotation to restore the mosaic pattern that once characterized these landscapes, with additional benefits to soil health, carbon sequestration, and water retention.

Table 1.2. Lands owned or managed by Audubon, plus the short-term (2020) enrollment target for private ranches in Audubon's Conservation Ranching Initiative.

State	Grassland type	Property	Acres	Current or 2020 Target
Arizona	Chihuahuan	Appleton-Whittell Research Ranch	7,077	Current
California	California grasslands	Bobcat Ranch	6,800	Current
Colorado	Shortgrass	Kiowa Creek Ranch	1,500	Current
North Dakota	Mixed grass	Frederick L. Wicks Prairie Wildlife Sanctuary	800	Current
North Dakota	Mixed grass	Edward M. Bringham III Alkaki Lake Wild-life Sanctuary	2,000	Current
Minnesota	Tallgrass	Omdahl Homestead and Property	480	Current
Missouri	Tallgrass	Audubon Center at Riverlands	3,700	Current
Nebraska	Tallgrass	Spring Creek Prairie	850	Current
Multiple	All	Audubon Conservation Ranching Initiative	2,500,000	Target

National Audubon Society is active in grassland conservation in the Great Plains. Audubon owns 1,732 acres and leases additional 9,525 acres of grassland habitats located in major grassland regions (Table 1.2). We engage in grassland conservation, restoration, and stewardship on those lands. Several are described in greater detail throughout the report. Through Audubon's Conservation Ranching Initiative, Audubon partners with ranchers to incorporate bird-friendly practices into their operations so these working lands generate forage for cattle and habitat for grassland birds. Now, more than ever, it is critical to understand the threats to grassland ecosystems and what can be done to reverse the decline of grassland birds and grassland habitats across North America.

Long-billed Curlew

Audubon California's Bobcat Ranch

Emerging wildflowers at California Audubon's Bobcat Ranch, a 6,800 acre wildlife sanctuary, working cattle ranch, and living laboratory for rangeland research.

Nestled in the foothills on the Western edge of Coast Range in the Central Valley of California is Bobcat Ranch—a 6,800 acre blue oak woodland wildlife sanctuary and working cattle ranch. Bobcat Ranch hosts over 500 visitors a year, is engaged in several ongoing rangeland research projects, and is the first property in California to enroll in the Audubon Conservation Ranching Initiative. Bobcat Ranch is using grazing to improve habitat, increase biodiversity, protect water sources and riparian zones, and improve soil health with the goal of serving as a demonstration for conservation ranching practices in this landscape.

Climate Change Vulnerability of Grassland Birds

Chestnut-collared Longspur

Background

Grassland birds will experience exceptional rates of climate change: temperate grassland regions are projected to have some of the highest climate change velocities among biomes on Earth (Loarie et al. 2009). Climate velocity is a measure of the speed of travel needed to keep pace with climate change; therefore, grassland birds will need to move large distances in order to continue occurring in climates similar to those found where they currently live in the Great Plains. This could be difficult in part because of the degree of isolation and fragmentation of remaining grassland habitats (McGuire et al. 2016).

The success of international agreements on climate change may impact the future vulnerability of grassland bird populations. The Paris Agreement (United Nations 2015) includes 174 ratified parties (mostly nations) that pledged to reduce greenhouse gas emissions and increase carbon sequestration incrementally over time. The goal is to limit global mean temperature increases to less than 2 °C above pre-industrial levels, a level of warming above which the risks of climate change to human civilization and the natural world are greatly increased (IPCC 2013). However, current commitments under the Paris Agreement will lead to an estimated 2.7 to 3.7 °C increase in global mean temperature (Levin & Fransen 2015), suggesting that further policy actions will be needed.

In Wilsey et al. (2019), we assessed the vulnerability of 38 grassland bird species to climate change under three scenarios representing a 1.5, 2.0, and 3 °C increase in global mean temperature and including the 2 °C target of the Paris Agreement. We used temperature change to describe the scenarios and to place our results in a clear international policy context, but underlying these scenarios are the projections of three atmospheric-ocean general circulation models and a 15-model ensemble. These projections considered the impacts of greenhouse gas emissions on both temperature and precipitation. The general circulation models selected represent a range of temperature and precipitation extremes for North America. We defined vulnerability as a function of a species' exposure, sensitivity, and adaptive capacity (Fig. 2.1) and used projections of future species' ranges under a changing climate to estimate the proportions of future range loss and gain. In particular, we constructed statistical models for each species relating current observations to current environmental conditions including climate, vegetation type, land-use, and topography. Those present-day models captured the current range of environmental conditions inhabited by the species. We then mapped the future range of each species by substituting projected future climate and vegetation as inputs to the models. The estimated proportion of projected range loss and gain under each climate change scenario were then used to assess climate change exposure, sensitivity, and adaptive capacity. We assessed vulnerability in summer and winter separately. Summer projections also incorporated the potential dispersal distance of each species to limit range expansion as a measure of adaptive capacity. Each species was given a vulnerability

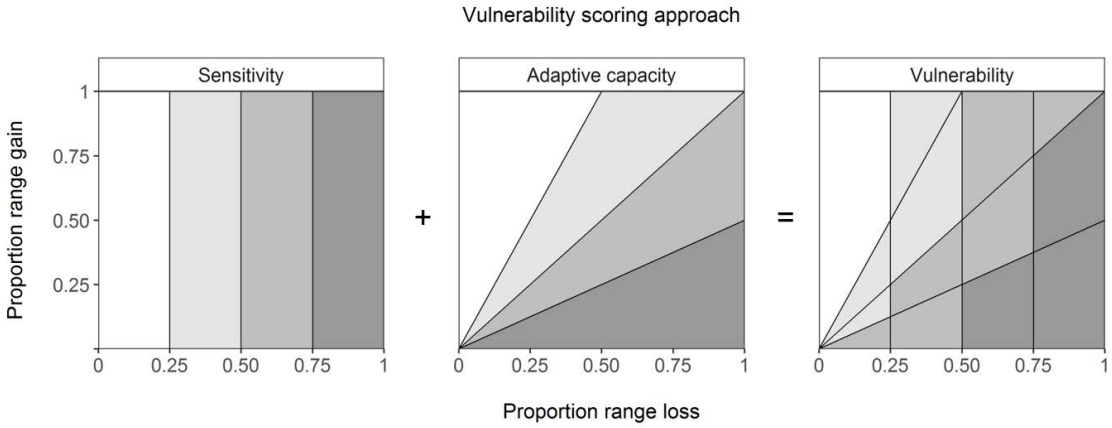


Figure 2.1. Conceptual diagram for assessing climate change vulnerability based on projected proportion of range loss as a measure of climate change exposure (1.5, 2.0, and 3° C increase in global mean temperature, not shown), climate sensitivity, and adaptive capacity. Darker colors equate to higher vulnerability. Projected summer range gains are limited by a species' estimated dispersal capacity.

score: neutral, low, moderate, and high. Highly vulnerable species were projected to experience the highest proportion of current range loss with limited opportunity for future expansion.

This assessment is an update to Audubon's 2014 Birds and Climate Change Report that assessed the climate change sensitivity of birds across North America (Langham et al. 2015). This new effort features more than 4 million bird records from >40 data sources as well as incorporating vegetation and land-use as predictors of species' ranges, and consideration of a species' ability to disperse as a component of its adaptive capacity to climate change. This work is the most comprehensive, model-based assessment of grassland birds' vulnerability to climate change to date.

Results

Nearly one half (42%) of grassland birds were highly vulnerable during the summer under a 3.0 °C increase in global mean temperature scenario (Fig. 2.2, Table 2.1). This proportion dropped to 13% with 2.0 °C increase and 8% with a 1.5 °C increase over pre-industrial global mean temperature (Appendix A). More than 70% of grassland birds had non-neutral vulnerability during the breeding season under the 3.0 °C (76%) and 2.0 °C and 1.5 °C (71%) scenarios, such that the number of neutral species remained relatively constant (24 to 29%). Climate change vulnerability was much lower in the winter season with 3 to 6% of species highly vulnerable and 41 to 44% classified as neutral across all scenarios.

Three species were highly vulnerable regardless of scenario: Henslow's Sparrow *(Ammodramus henslowii)* and McCown's Longspur *(Rhynchophanes mccownii)* in the summer and Baird's Sparrow *(Ammodramus bairdii)* in both seasons (Figure 2.2). Seven species were projected to lose more than 95% of their modeled current distribution, including those listed above plus Bobolink *(Dolichonyx oryzivorus)*, Chestnut-collared Longspur *(Calcarius ornatus),* LeConte's Sparrow *(Ammodramus leconteii),* and Sprague's Pipit *(Anthus spragueii)*.

We assessed the agreement in assigning climate change vulnerability classes between the multi-

Table 2.1. Species with high climate change vulnerability under a 3.0 °C increase in global mean temperature scenario.

Common Name	Scientific Name
Aplomado Falcon	*Falco femoralis*
Baird's Sparrow	*Ammodramus bairdii*
Bobolink	*Dolichonyx oryzivorus*
Botteri's Sparrow	*Peucaea botterii*
Chestnut-collared Longspur	*Calcarius ornatus*
Clay-colored Sparrow	*Spizella pallida*
Gray Partridge	*Perdix perdix*
Henslow's Sparrow	*Ammodramus henslowii*
Lark Bunting	*Calamospiza melanocorys*
Long-billed Curlew	*Numenius americanus*
McCown's Longspur	*Rhynchophanes mccownii*
Mountain Plover	*Charadrius montanus*
Nelson's Sparrow	*Perdix perdix*
Savannah Sparrow	*Ammodramus nelsoni*
Sprague's Pipit	*Anthus spragueii*

model ensemble and three individual global climate models representing a range of climate futures for North America. Agreement was generally high and increased with the magnitude of projected climate change. In the summer, 87 to 95% of species had medium-high or high agreement across all scenarios. In the winter, 97% of species had medium-high to high agreement regardless of scenario.

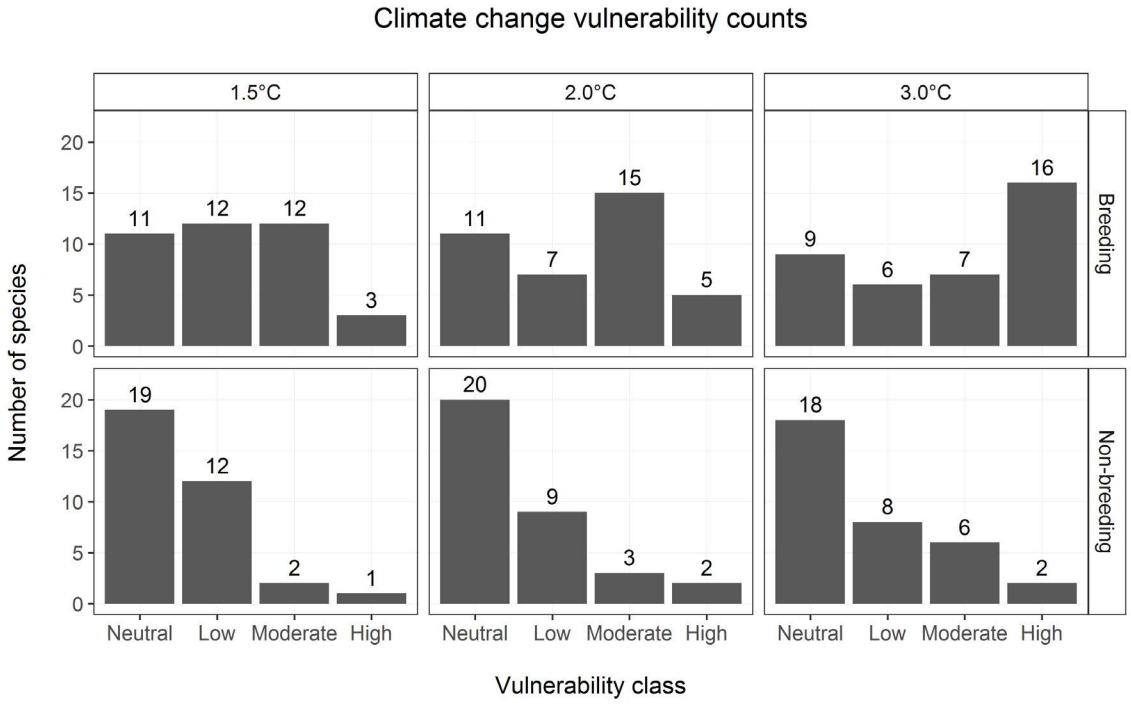


Figure 2.2. Climate change vulnerability assessment of 38 species of grassland birds under three scenarios for increases in mean global temperature.

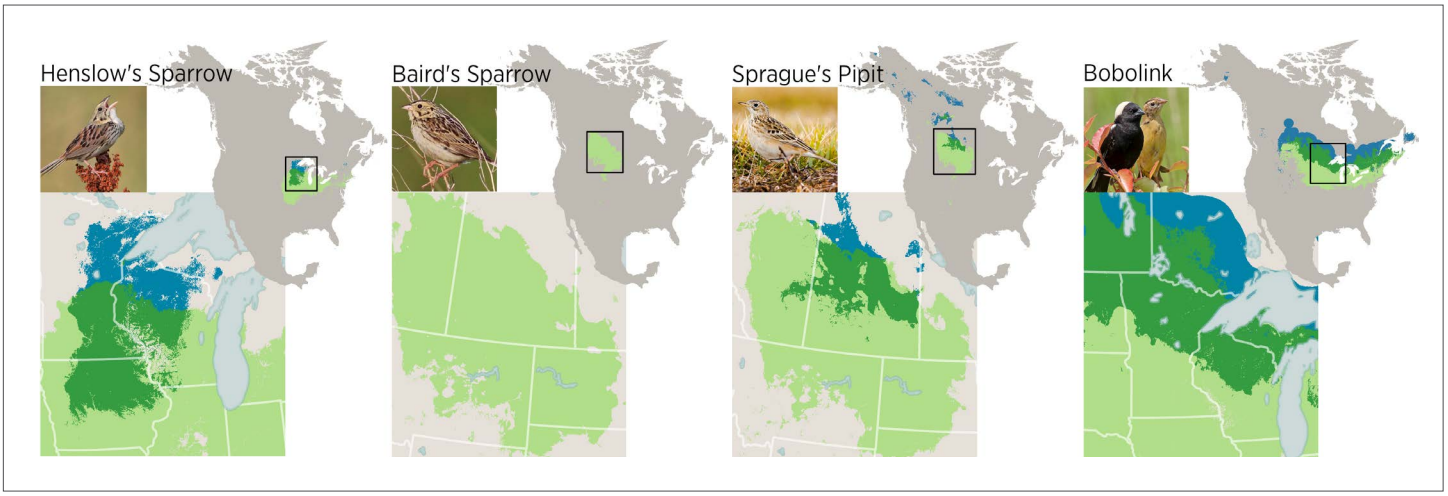


Figure 2.3. Projected summer range gain and loss under a 2.0 °C increase in global mean temperature scenario for four species classified as highly vulnerable.

Global Land and Air Ethic

Comprehensive action to reduce greenhouse gas emissions could reduce the number of species with high vulnerability to climate change from three in seven to fewer than one in twelve. Highly vulnerable species were projected to lose more than 50% of their current range with projected gains from range expansion (taking into account natal dispersal) unable to make up for those losses. Nine North American grassland bird species included in this analysis are species of continental conservation concern (Rosenberg et al. 2016). Of those, seven are highly vulnerable in at least one season under the scenario for a 3 °C increase in global mean temperature. That becomes six species with a 2 °C increase, and three species with a 1.5 °C increase. Thus, policies that reduce climate change will also benefit the most at-risk grassland species.

The future of grassland birds depends on a new land and air ethic. The land ethic includes support for federal programs that incentivize and expand grassland conservation and discourage the tilling of native prairie. Existing programs such as the Conservation Reserve Program (CRP), Environmental Quality Incentives Program (EQIP), Agricultural Conservation Easement Program (ACEP), Crop Production of Native Sod (Sodsaver) Program, and U.S. Fish and Wildlife Service Conservation Easement Program have demonstrated value for grassland birds (NABCI 2017). In addition, market-based conservation, such as Audubon's Conservation Ranching Initiative can help keep grasslands on the landscape providing habitats to these species and giving them greater capacity to adapt to the increasing threat of climate change. However, the estimated vulnerability of grassland birds to climate change suggests that land conservation will not be enough. Conservation of grassland bird populations requires that the Paris Accord be successful in keeping global mean temperature increases below 2 °C. Furthermore, energy policy must avoid traps, such as the renewable fuel standards, that accelerate grassland conversion in the name of emissions reductions (Wright et al. 2017).


Ferruginous Hawk

Grassland conservation and certain ranchland grazing practices, in particular, can help mitigate climate change by sequestering atmospheric carbon that would otherwise contribute to global warming (Blackburn et al. 2018). Regenerative grazing encompasses multiple grazing systems (e.g. prescribed grazing, intensive rotational grazing, holistic planned grazing, adaptive multi-paddock (AMP) grazing, patch-burn grazing) all of which focus on restoring the ecological function and productivity of degraded grasslands with the benefit of sequestering carbon in soils. Natural Resources Conservation Service (NRCS) estimates a net potential benefit of 0.01-0.20 tons C per acre per year from implementation of prescribed grazing on ranchlands (Chambers et al. 2016). This would equate to 1.1 to 20 million tons C per year if 100 million acres were managed with these practices. Over decades, continued efforts to increase carbon stocks by 0.04% per year could eventually lead to 83 million tons C per year by 2050, half the net greenhouse gas emissions of the agricultural sector in 2013 (Chambers et al. 2016). Estimated differently, if half of grasslands in the US were managed to improve carbon sequestration, they could capture 10 to 23% of CO_2 emissions annually (Blackburn et al. 2018). Thus, grassland conservation and restoration, through practices such as regenerative grazing, are valuable components of a comprehensive climate change mitigation strategy.

Grassland birds need creative solutions, like market-based conservation, that keep grasslands viable and support diverse bird communities, as well as sustained advocacy for federal and local programs that protect grasslands and reduce greenhouse gas emissions.

Measuring Impacts of Rangeland Management on Birds: The Bird Friendliness Index

Short-eared Owl

Background

Most metrics evaluating habitat quality or management response focus on individual species as indicators (Simberloff 1998). Yet, birds often exhibit a broad range of habitat preferences. For example, Horned Larks prefer open grasslands with bare ground or short grass, while Henslow's Sparrows prefer dense stands of tall grass. Consequently, single species rarely serve as effective proxies for entire communities (Landres et al. 1988, Carnigan and Villard 2002). Therefore, to evaluate effects of conservation actions on entire grassland bird communities it is necessary to develop multispecies metrics that evaluate the responses of the full suite of affected species (Nuttle et al. 2003, Goyert et al. 2016). These metrics allow for consideration of not only habitat preferences, but also foraging behavior, body size, and other life-history characteristics. By incorporating multiple species into conservation planning and adaptive management, we will support bird communities that are more resilient to change (Barbaro et al. 2014).

Multispecies metrics to evaluate conservation actions are particularly important in threatened habitats. Grasslands of the Northern Great Plains, are among the continent's most endangered habitats due to the loss of more than 80% of natural grassland since the 1800s (Samson et al. 2004, Brennan and Kuvlesky 2005). One consequence of this habitat loss has been the >40% decline in grassland bird populations since 1966 (NABCI 2017). Only 5% of the remaining grassland habitat is protected by government agencies, while 84% is held in private landownership (Askins et al. 2007). Moreover, seven obligate grassland-breeding bird species have more than 90% of their summer distribution on private lands, including the Eastern Meadowlark *(Sturnella magna)* and Dickcissel *(Spiza americana; NABCI 2013)*. As such, cooperation between government agencies, non-profit organizations and private landowners is essential to ensure conservation of these imperiled species in the future (Samson et al. 2004).

The National Audubon Society developed the Conservation Ranching Initiative in an effort to partner with private landowners to conserve grassland bird species. Audubon provides ranchers with guidelines for "bird-friendly" ranching management practices implemented through customized Habitat Management Plans. Ranches that implement these plans are certified as providers of bird-friendly products. Thus, the program utilizes market-based conservation solutions that benefit both ranchers and birds (www.audubon.org/conservation/ranching). In order to evaluate the success of Audubon's Conservation Ranching Initiative in maintaining or increasing grassland bird community resiliency on partner ranches, we developed a metric evaluating grassland bird community response to management practices. This metric, the Bird Friendliness Index (BFI), combines avian count data with remotely sensed environmental data to evaluate the capacity of a landscape to support an abundant, diverse, and resilient grassland bird community (Fig. 3.1).

The BFI takes into account species abundance, conservation status, and diversity of the entire community of grassland birds at a site. Because birds provide a variety of useful ecosystem functions including seed dispersal, pest control, and pollination (Şekercioğlu et al. 2017), the resiliency of bird communities influences the resiliency of the overall ecosystem (Fischer et al. 2007). Thus the BFI includes a measure of functional diversity to evaluate the intactness and resilience of both the grassland bird community and the suite of functional roles they fulfill (Fischer et al. 2007). The design of the BFI enables evaluation at the scale of an individual ranch, state, or region due to standardization methods that facilitate comparisons among North American grasslands spanning broad climatic and bird community gradients.

$$BFI = \sum_{species} (Density \times Conservation\ Status) \times Functional\ Diversity$$

Figure 3.1. The Bird Friendliness Index (BFI) is the sum product of estimated avian density and conservation status times a measure of functional diversity based on species traits (i.e., diet, foraging strata, and body mass).

Here we develop a case study in the Northern Great Plains to demonstrate the use of the BFI to investigate historical trends in bird community resilience and evaluate the effects of land management practices on grassland bird communities. We used Integrated Monitoring in Bird Conservation Regions (IMBCR) avian count data collected during 2009-2014 by Bird Conservancy of the Rockies (BCoR 2017) to estimate the avian densities used as inputs to the BFI. IMBCR consists of 16 replicate point counts within 1 km_2 cells distributed randomly across the region. We estimated occurrence (i.e. probability of presence) and density within each 1 km_2 cell for 34 grassland and aridland bird species (Appendix B) while correcting for imperfect detection using spatial replicates, distance estimates, and time of first observation (Sólymos et al. 2013). We then predicted densities of each focal species across the Northern Great Plains by relating the cell-level density estimates with 18 environmental variables (Hijmans et al. 2017). This resulted in continuous density maps covering the entire region at 1 km_2 resolution. The 34 bird species were also grouped into functional species based on traits (i.e., diet, foraging strata, and body mass [Wilman et al. 2014]; Appendix B), and functional diversity was calculated for each 1 km_2 cell from the density maps as a Shannon's Diversity Index by summing densities across species with similar function traits. Predicted species densities were weighted for conservation value by multiplying by the breeding season Combined Conservation Score (NABCI 2016).

We calculated the BFI for each 1 km_2 cell by multiplying conservation-weighted density by functional diversity for each grid cell, and standardized by scaling from zero to one. We used a logistic distribution for scaling to accommodate the lower limit of zero and the occasional, exceptionally high BFI value. The standardization process is a critical component of the BFI. Standardization expresses each cell's bird-friendliness relative to the surrounding BCR, producing a ranked index scaled from zero to one that is easily interpreted. Furthermore, it enables BFIs from ranches across North America in differing grassland types and climatic zones to be compared. Finally, standardizing relative to a relatively large geographic region beyond the ranch zeroes in on management effects by controlling for interannual variation due to large-scale processes, e.g. weather and density-dependent cycles. The BFI for an individual ranch or other landholding is estimated as the mean BFI value across all 1 km_2 cells occurring within the property. We then use simulation to demonstrate how changes in the BFI over time indicate grassland bird community response to simulated habitat management.

Results

Average BFIs across the Northern Great Plains were similar across years, ranging from 0.497 in 2009 and 2011 to 0.500 in 2012. Grassland bird densities responded most strongly to drought

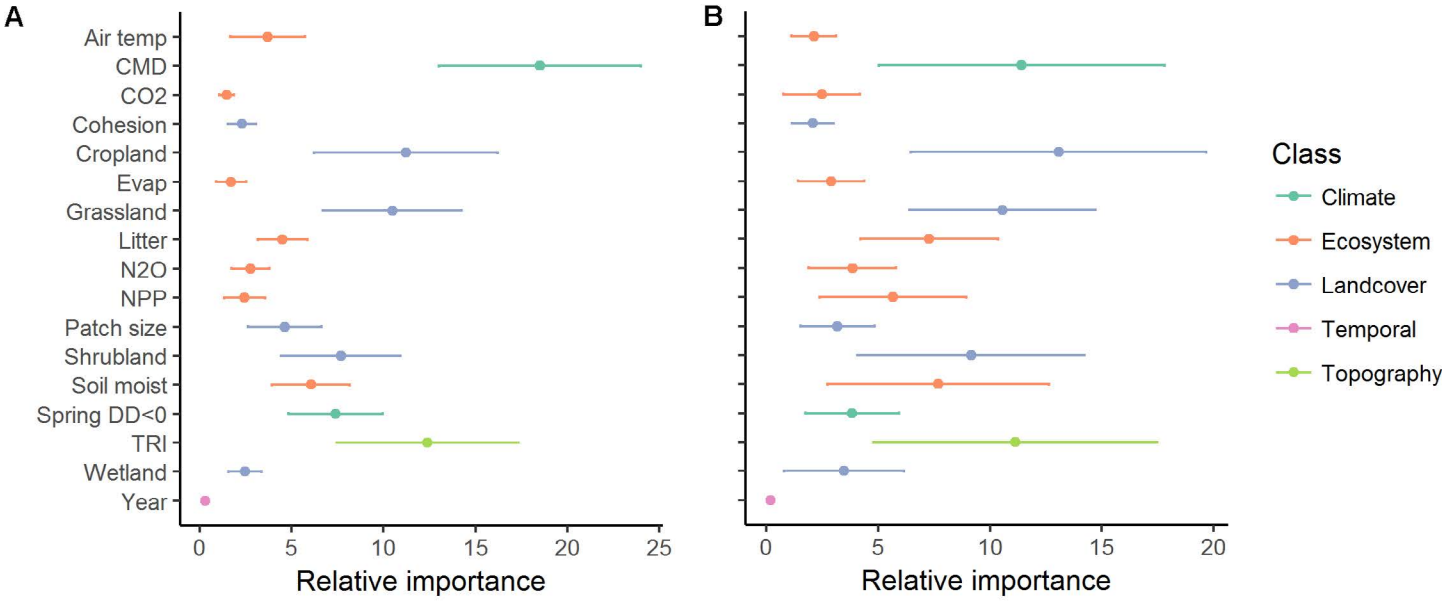


Figure 3.2. Relative importance for environmental covariates from bird-habitat models used to calculate the Bird Friendliness Index for the NGP. Mean relative importance with 95% confidence intervals from occurrence (A) and density (B) models averaged across 34 bird species are shown.

conditions as measured by climatic moisture deficit, explaining 18.5% of the variation in occurrence (± 2.8% SE), and cropland cover, explaining 13.1% of the variation in density (± 3.4% SE) on average across species (Fig. 3.2). Overall grassland birds responded most strongly to landcover variables, which together explained 38.3% of variation in occurrence and 41.5% of variation in density. Climate variables were the second most important class for occurrence, explaining 25.9% of the variation combined. For grassland bird density, ecosystem variables were the second most important class, explaining 31.9% of variation all together. Both occurrence and density of grassland birds responded more strongly to environmental variables than to year, indicating that most of the interannual fluctuations in grassland bird densities were explained by the covariates included in these models.

Sensitivity analyses revealed that changing species' densities had the largest relative impact on BFI values (effect size = 0.129 ± 0.004), followed by changing conservation scores (effect size = 0.061 ± 0.002), and changing functional diversity (effect size = 0.041 ± 0.001).

Evaluating Bird-Friendly Habitat Management on Conservation Ranches

To demonstrate the ability of the BFI to evaluate grassland bird community response to implementation of Bird-Friendly Habitat Management Plans on ranches enrolled in Audubon's Conservation Ranching Initiative, we simulated management action on an anonymous enrolled ranch within the Northern Great Plains. We used simulation because the Conservation Ranching Initiative is still relatively new. The first Habitat Management Plans were implemented in 2017, which is too recent to evaluate bird response to management. In these simulations, we assumed that management would reduce nearby cropland cover, CO_2, evapotranspiration, and N_2O, and increase litter, net primary productivity, soil moisture, proportion grassland, grassland cohesion, and grassland patch size. These changes were simulated to accumulate incrementally over time, with a compounding 10% increase or decrease each year (plus some random variation). These simulated environmental conditions were then used to re-calculate bird densities and functional diversity, and re-estimate the BFI each year within that ranch. We simulated habitat improvement beginning in 2011, and then compared changes in the BFI under simulated management practices to actual estimated BFI from 2009 to 2014 (Figure 3.3).

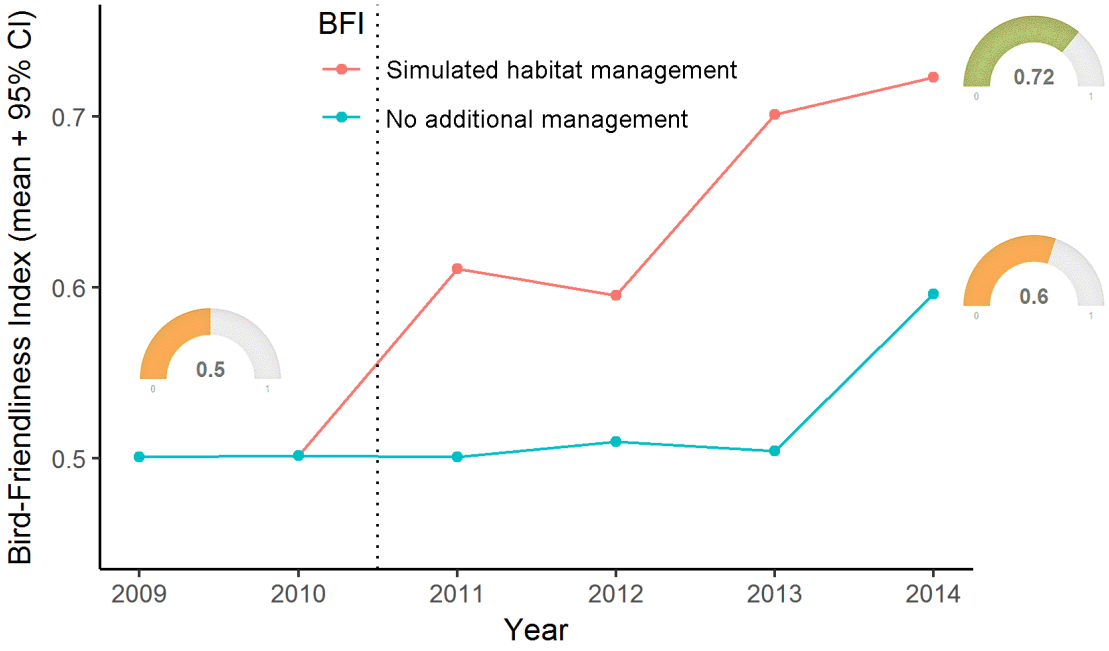


Figure 3.3. Estimated and simulated BFIs for an anonymous ranch enrolled in Audubon's Conservation Ranching Initiative within the Northern Great Plains. Simulated BFIs representing the response to hypothetical bird-friendly habitat management implemented during 2011-2014 – prior to actual implementation of Habitat Management Plans beginning in 2017 - were higher overall than estimated BFIs from observed data, and increased over time.

BFI values representing grassland bird community response to simulated Conservation Ranching Habitat Management Plans were 21% higher overall than BFIs estimated from observed data (Fig. 3.3). Additionally, BFI values with simulated bird-friendly habitat management significantly increased over the six-year period (slope = 0.05 ± 0.01 SE), while estimated BFI values (without bird-friendly habitat management) did not change during the same time period (slope = 0.01 ± 0.01 SE). This indicates that when practices commonly used in Habitat Management Plans do increase the abundance and resilience of the ranch's grassland bird community, the change will be detected using the Bird Friendliness Index.

Vesper Sparrow

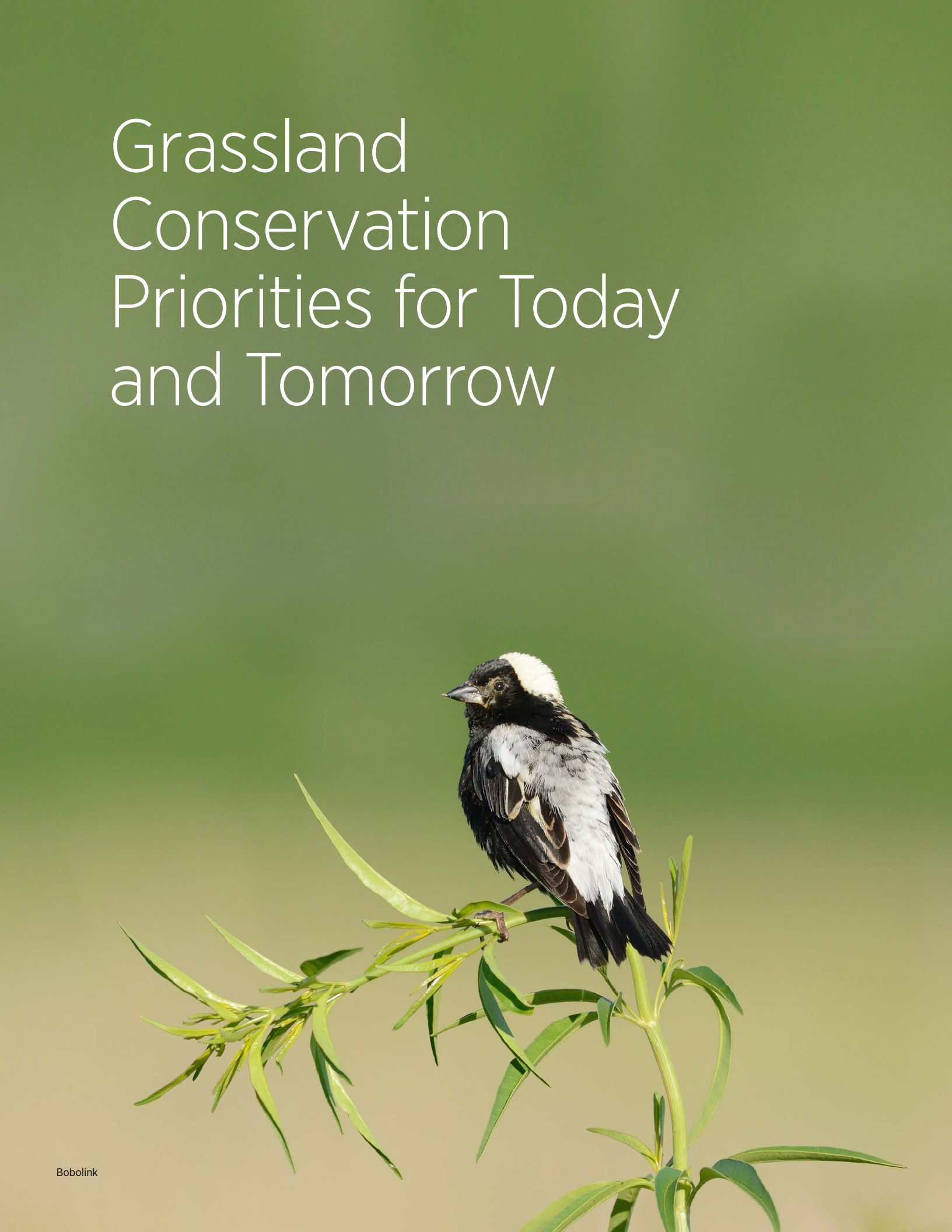
Accountable Conservation

Having quantitative metrics of impact is crucial to the success of any conservation program. The Bird Friendliness Index provides accountability and transparency for Audubon's Conservation Ranching Initiative. By incorporating individual species' density and functional diversity, Audubon can evaluate responses of the entire grassland bird community to habitat management on an annual basis, as well as information on individual species. This, in turn, can inform selection or adaptation of habitat management practices for the subsequent year through an adaptive management process. By identifying early on which species and communities are doing poorly, and where, we can potentially work with ranchers to modify conservation actions that will lead to population stabilization or even increasing abundance and distribution. To be able to do this effectively we are in dire need of indicators that are rigorous, repeatable, and easily understood (Balmford et al. 2005). The BFI is a tool by which Audubon and others can do accountable conservation now and into the future.

Audubon Great Lakes' State of the Grasslands Report

Audubon Great Lakes, in collaboration with Illinois Audubon Society and the Chicago Wilderness Grassland Bird Task Force, has published its inaugural State of the Grasslands Report in 2018. The report seeks to quantify, analyze, and illustrate the impact of management and stewardship on grasslands and grassland birds in the Chicago Wilderness region. Audubon and partners have mapped grasslands documenting a precise baseline of actively managed grasslands in various regimes of prescribed burning, haying, and mowing. An analysis of these land management activities along with grassland bird monitoring data compiled by landowners and volunteers is providing novel insights on how the collective impacts of local management are impacting regional grassland bird populations. The Chicago Wilderness region is now home to steady or increasing populations of grassland birds including Bobolink and Henslow's Sparrow, while much of Illinois and the broader region continues to suffer declines. Audubon, through this report and broad partnership, is shedding light on how we can maintain and expand these trends to reverse the plight of grassland birds in the Midwest and Great Lakes Region.

Grassland Conservation Priorities for Today and Tomorrow



Bobolink

Background

Bird conservation is challenging with limited resources (Myers et al. 2000); therefore, the conservation community is required to prioritize for protection or restoration those places that provide the greatest return on investment. Here we identify conservation priorities in three overlapping geographies: the entire central grasslands from Canada to Mexico, the Northern Great Plains and the Southern Great Plains. We identified continental and regional priorities to both meet the needs of a diverse stakeholder group that includes Audubon state, national, and international programs, as well as Audubon partners, and make use of higher resolution datasets available only for regional geographies.

Our priorities complement the Grassland Priority Conservation Areas (GPCAs) identified in 2005 by a multi-stakeholder partnership led by the Committee for Environmental Cooperation and The Nature Conservancy (Gauthier et al. 2003; Karl and Hoth 2005) and updated in 2010 by the Bird Conservancy of the Rockies (Pool and Panjabi 2011). These priority areas, hereafter referred to as 2010 GPCAs, are areas of tri-national importance due to their threatened status and ecological significance. The identification process involved integration of 120 spatial data layers, a priority-area gap analysis, assessment of 20 key grassland bird and mammal species, and a workshop with 36 Canadian, US, and Mexican experts from a variety of disciplines. The goal was to identify areas requiring immediate conservation action. In 2018, a new set of Grassland Potential Conservation Areas (hereafter referred to as 2018 GPCAs) were identified (Comer et al. 2018) that focused on representation of 12 major grassland types and their associated species of concern. Our work complements both sets of GPCAs by incorporating into the identification process the predicted impact of future climate and land-use change on grassland birds and their habitats at multiple spatial and temporal scales.

There are many emerging methods for developing climate-smart conservation plans that address both present and predicted future climate suitability for multiple species simultaneously (Carroll et al. 2010; Schuetz et al. 2015). We used the spatial conservation planning software Zonation (Moilanen et al. 2014) to identify multi-scale conservation priorities for suites of grassland birds based on species distributions and density; present and future projections of climate, land-use, and vegetation; and threats related to energy infrastructure development. We customized Zonation to produce a ranking of the landscape by aggregating the current and predicted future value of each cell for all species, while simultaneously accounting for the loss of value due to current and predicted land-use threats.

Upland Sandpiper

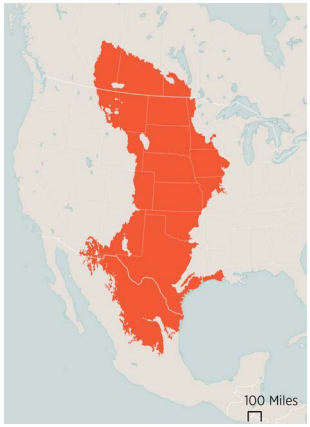


Figure 4.1. The tri-national extent for the continental prioritization.

Continental Priorities for Full Annual Cycle Conservation

To address full life cycle conservation and inform national and international policy, Grand et al. (2019) completed two prioritizations for the entire central North American grasslands extending from Canada to Mexico (Fig. 4.1). The region includes the Great Plains level I ecoregion (EPA 2013) plus the eastern Warm Deserts *(i.e. Chihuahuan Grasslands)* level II ecoregion, which is of critical importance to many wintering grassland bird species.

We prioritized areas for conservation based on present and projected future species ranges and land use under a changing climate (Fig. 4.2).

The first prioritization included climate change alone, and the second included both climate and land-use change. We included summer and winter ranges for 39 grassland birds; the same species included in the climate change vulnerability assessment with the addition of the Scaled Quail *(Callipepla squamata)*, a resident of the Chihuahuan grasslands and conservation target (see Part 2 for methods and Appendix C for a list of included species). The land-use projections were based on both climate and socioeconomic variables (Li et al. 2016) and we considered four decadal time steps (2010, 2030, 2060, 2090), each representing 30 year averages.

All projections assumed a climate change scenario of 3.0 °C increase in global mean temperature by the end of century. The 3.0 °C warming scenario is equivalent to the Intergovernmental Panel on Climate Change (IPCC) Representative Concentration Pathways very high emissions scenario (RCP 8.5; Moss et al. 2010; van Vuuren et al. 2011) that most closely resembles the trajectory of current international policy (United Nations 2015). Although, we use temperature to characterize the scenario, the RCPs are based on an ensemble of 15 general circulation models that simulate the impacts of greenhouse gas emissions on both temperature and precipitation.

We used Zonation spatial prioritization software (Moilanen et al. 2014) to rank every 1-km_2 cell in the landscape from 0 to 1 based on its climate and land-use suitability for grassland birds. We used the Core Area Zonation (CAZ) ranking method because it ensures that every species is represented in the final ranking. We gave preference to contiguous sites recognizing that connectivity is an essential climate change adaptation strategy. We generated separate landscape rankings for the summer and winter seasons to avoid bias related to the larger number of species breeding than wintering in North America. Finally, we combined the seasonal rankings into a single continental ranking by taking the maximum rank from either summer or winter for each cell in the landscape, and re-scaling all cells from 0 to 1.

The prioritization weights at-risk species higher than common species, and present conditions higher than future predictions. Species weights were derived from the State of the Birds conservation concern scores for summer and winter (NABCI 2016). We normalized the scores, which originally ranged from 1 to 20, using the formula: (X - X min)/(X max - X min). Weighting present conditions higher than future conditions reflects the increasing uncertainty of climate change predictions after approximately 2050 (Knutti and Sedláček 2013). To assign weights to time steps, we calculated the difference between the minimum and maximum model predictions at each time step (Knutti and Sedláček 2013) and used the inverse as the weight (Table 4.1). Final weights for each species' range map at each time step were the product of the normalized conservation concern score and the time-step weight (Appendix 1).

The ability (or inability) to disperse could influence a species' ability to move away from worsening climate or toward improving climate in order to adapt to climate change. We simulated dispersal potential in the prioritization via the ecological interactions function in Zonation (Moilanen et al. 2014) which down-weighted locations beyond which a species would be expected to disperse from its current distribution at each time period (Rayfield et al. 2009; Carroll et al. 2010). We used annual natal dispersal distances and generation time of each species derived by Partners in Flight to inform this function.

For the prioritization that included predicted land-use change, locations predicted to be grassland, pasture, shrub, wetland, or water were considered compatible with grassland bird use,

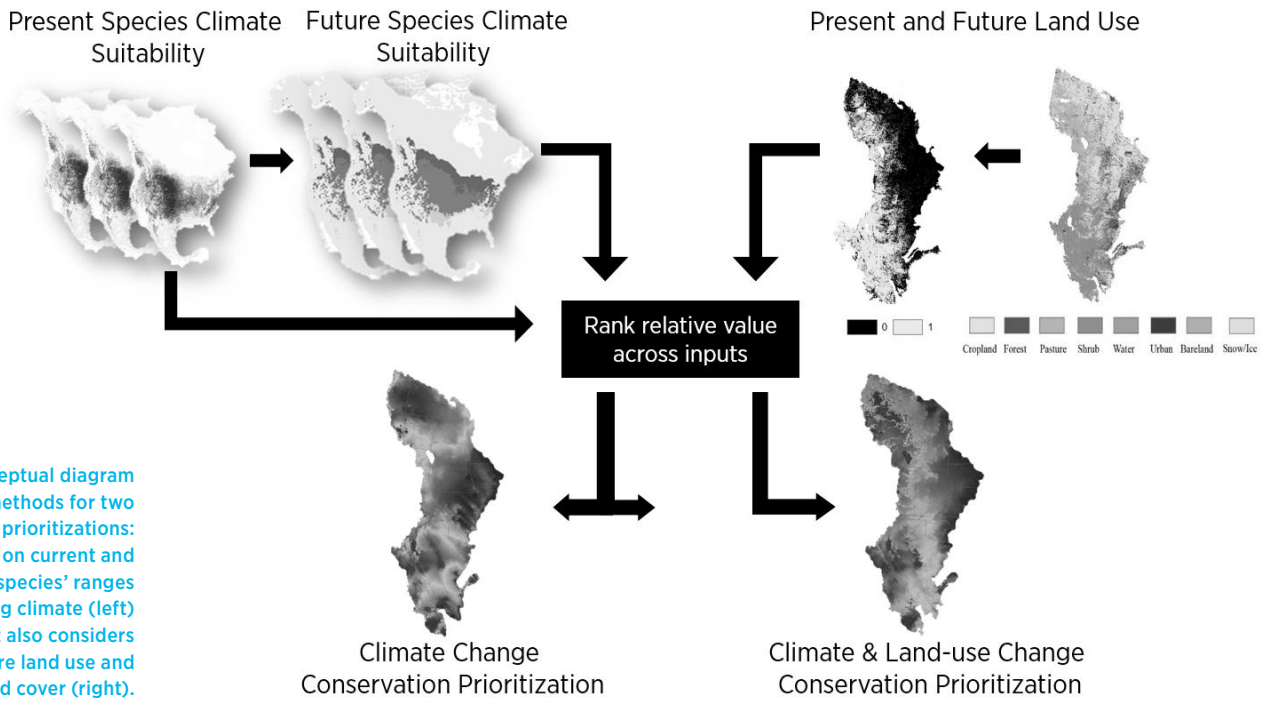


Figure 4.2. Conceptual diagram outlining methods for two continental spatial prioritizations: one based entirely on current and predicted future species' ranges under a changing climate (left) and a second that also considers predicted future land use and land cover (right).

while urban, cropland, forest, bare ground, and snow/ice were considered unsuitable. Only cells with compatible land use types were retained in the analysis and ranked based on the prioritization approach described above. Although shrublands provide marginal habitat for many grassland birds, we opted to retain them as they have high potential for restoration.

Table 4.1. Weighting scheme for time steps to account for increasing uncertainty of climate projections over time.

Time Step	Difference	Weight
2010	NA	3.0
2030	0.5	2.0
2060	0.9	1.1
2090	1.6	0.6

Lastly, we defined vulnerable grasslands as areas with a high climate stronghold rank and a high risk of conversion to incompatible land uses. We identified these areas by subtracting the climate and land-use change prioritization ranks from the climate change-only prioritization ranks. To create a comprehensive map of vulnerable priorities, we selected the top 20% of vulnerable grasslands and overlaid the 2010 and 2018 GPCAs predicted to have 20% or less of suitable grassland bird habitat in 2060.

Results

Areas with high conservation rank for grassland birds under a changing climate included the Southern Great Plains of New Mexico, Texas, the Oklahoma panhandle; the Chihuahuan desert; and the Northern Great Plains of North and South Dakota, Montana, Alberta, Saskatchewan, and Manitoba (Fig. 4.3a). When projected future land-use change was included, results suggested that virtually the entire eastern half of the region could be converted to incompatible land uses by 2100 (Fig. 4.3b). As a result of ongoing habitat loss in the east, a corridor of shortgrass prairie connecting the high-ranking northern and southern regions increased in conservation rank.

Grasslands vulnerable to land-use change included the Gulf Coast Prairie, Texas Blackland Prairie, portions of the Chihuahuan desert, much of the east-central Plains, and the Prairie Pothole Region and surrounding areas (Fig. 4.3c,d). What little remains of these unique ecological systems and the birds that depend on them will likely become extirpated without immediate protection. However, it remains to be seen whether these areas will prove to be too expensive to protect or restore due to increasing land conversion pressures.

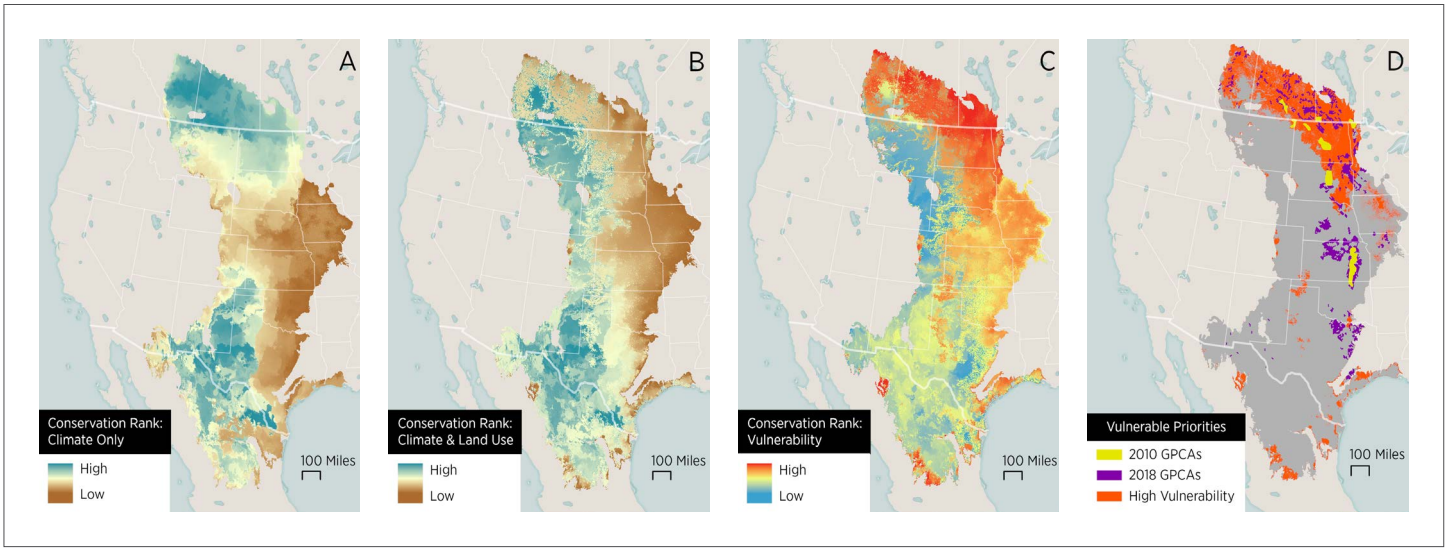


Figure 4.3. Conservation ranks based on: (A) present and future climate suitability for 39 grassland bird species; and (B) present and future climate and land-use suitability for 39 grassland bird species; (C) vulnerability, defined as the difference between the climate only scenario (Fig. 4.3a) and the climate and land-use scenario (Fig. 4.3b) where high vulnerability means a relative high climate-only conservation rank and a relatively low climate and land-use conservation rank; (D) vulnerable priorities have high vulnerability (from C) or are GPCAs (2010 or 2018) predicted to have 20% or less suitable grassland bird habitat by mid-century.

Approximately 27% of the area within 2010 GPCAs and 24% of the area within 2018 GPCAs was coincident with the top 20th percentile of our climate change prioritization, with average conservation ranks of all GPCAs ranging from 0.09 to 0.95. Approximately 16% of the area in global IBAs overlapped the top 20th percentile of the climate change prioritization. These overlapping areas were predicted to retain suitable climate conditions to accommodate the full annual cycle for species that breed and over-winter in the North American grasslands, and may become critical climate strongholds for grassland birds by the end of the century. They are also robust to differences in prioritization approach, suggesting that they should be given high priority in continental-scale conservation planning efforts.

Savannah Sparrow

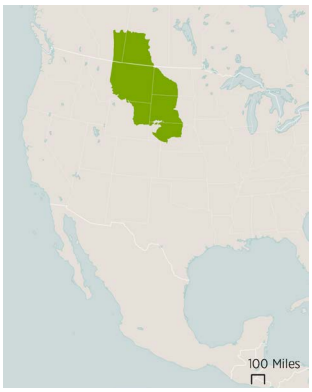


Figure 4.4. Extent of the Northern Great Plains prioritization

Northern Great Plains

The Northern Great Plains (Fig. 4.4) is a priority for Audubon and Canadian conservation partners, and the region emerged as having high importance in our continental prioritization (Grand et al. 2019). Setting priorities today that account for current and projected future changes in species distributions is essential for the long-term persistence of grassland birds in the region. When available, information of species abundances has been shown to improve the efficiency of spatial prioritization products (Veloz et al. 2015). In the Northern Great Plains, we used near present-day (2014) species density predictions for 25 grassland bird species based on the Integrated Monitoring in Bird Conservation Regions (IMBCR 2017) dataset (see Section III for detailed methods) and projected future ranges under a 3 °C increase in mean global temperature (see Section II for detailed methods) to prioritize areas for conservation. A second prioritization considered proximity to wind turbines and oil and gas infrastructure to mitigate these potential threats to grassland birds (Fig. 4.5).

Prioritization methods were similar to the continental prioritization described above. Again, we weighted at-risk species higher than common species, and projected future ranges under climate change lower than present species ranges. For this prioritization however, we focused on the breeding season, did not include dispersal limitations owing to the much smaller extent of analysis, and considered existing threats rather than projected land-use change.

Results

The Prairie Potholes Region, in particular the Dakotas, Montana, Alberta and Saskatchewan had the highest conservation rank for grassland birds under a changing climate (Fig. 4.6a). By including energy infrastructure, high-ranking sites shifted away from areas under development, most notably in Canada and northwest North Dakota (Fig. 4.6b).

Approximately 25% of 2010 GPCAs and 17% of 2018 GPCAs overlapped with cells ranked in the top 20th percentile of the climate change prioritization, with mean ranks of all GPCAs in the Northern Great Plains ranging from 0.03 to 0.89. Once again, IBAs had lower overlap than 2010 GPCAs, with approximately 17% of the IBA area co-occurring with cells ranked in the top 20th percentile. The lower coincidence of IBAs is indicative of the fact that grassland birds were not necessarily the focus of IBA identification efforts.

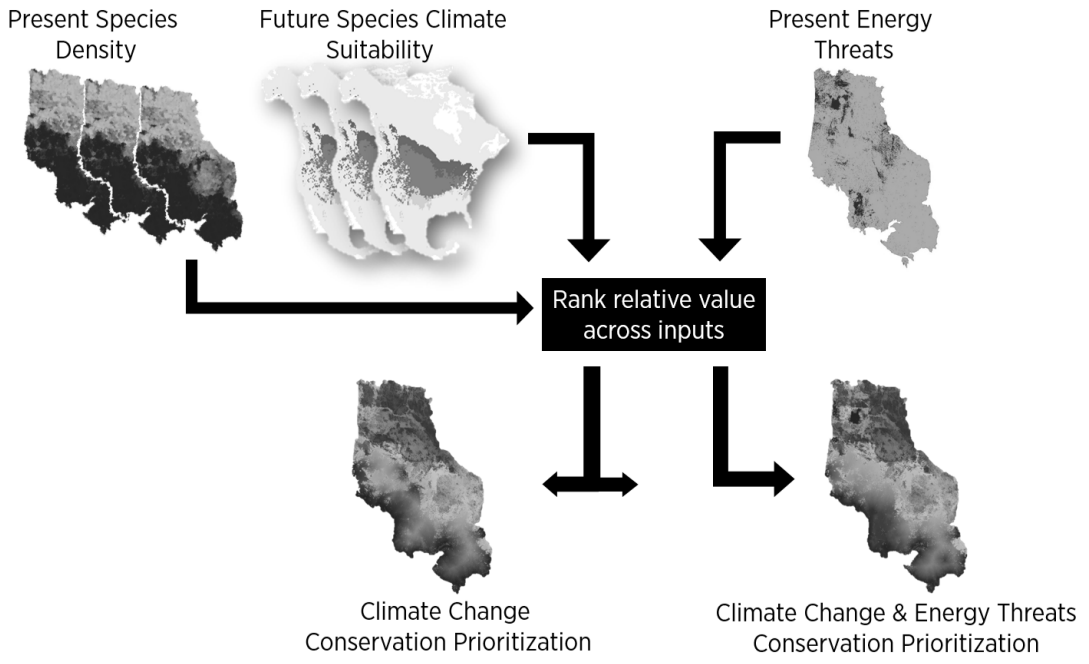


Figure 4.5. Conceptual diagram for the Northern Great Plains prioritization

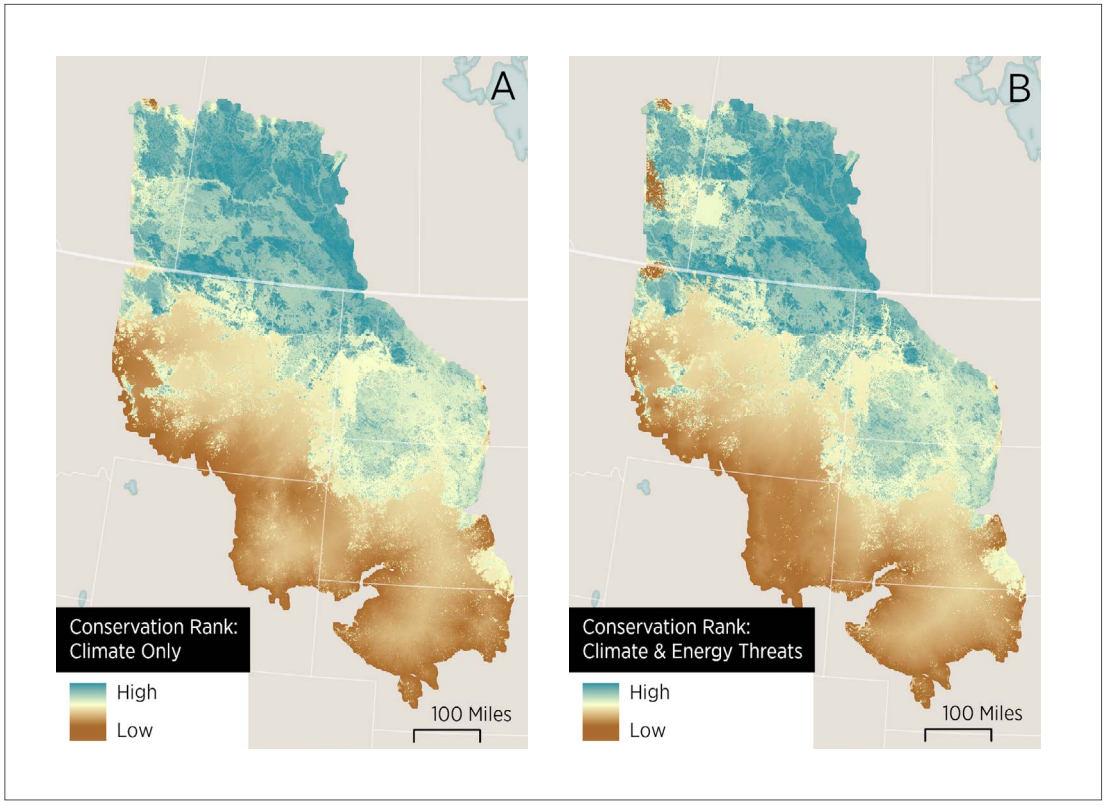


Figure 4.6. Conservation ranks based on: (A) present species density and future climate suitability for 25 grassland birds; and (B) present species density, future climate suitability, and energy infrastructure threats for 25 grassland birds

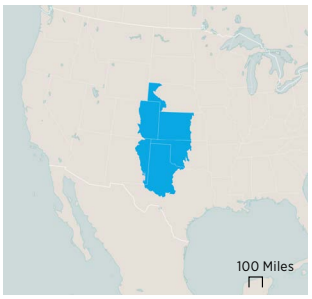


Figure 4.7. The extent of the Southern Great Plains prioritization

Southern Great Plains

The Southern Great Plains region is a priority for Audubon state offices in Nebraska, Colorado, New Mexico and Texas. We partnered with Playa Lakes Joint Venture (PLJV) to identify priorities for grassland conservation within the PLJV boundary, an area defined by the majority of Bird Conservation Regions 18 and 19 (Fig. 4.7). PLJV recently completed a Landscape Conservation Design for the implementation of Waterfowl Management Plan within this landscape (Bartuszevige et al. 2016), and is now applying the same design principles to grasslands. The process considers the potential of the landscape to support target populations of grassland birds and then designs strategies that will help achieve those population goals. Audubon scientists worked with the PLJV to incorporate spatial prioritization into the design process.

As in the Northern Great Plains prioritization, we used species density estimates to improve the potential efficiency of the regional prioritization (Veloz et al. 2016) under the assumption that high species density indicates high habitat suitability. The PLJV estimated density per acre for 14 grassland bird species (Appendix C) based on land-cover type, condition, state, and BCR.

To characterize impacts of future land-use change on bird densities, we used projections from the Global Change Assessment Model reference scenario, a climate change scenario consistent with a 3 °C or higher increase in mean global temperature. The Global Change Assessment Model addresses the complex interactions between energy, water, agriculture and other land use, socioeconomics, and climate change *(Capellán-Pérez et al. 2014)*. However, these global projections were quite coarse, so we worked with USGS scientists who have developed a model (FORE-SCE) that uses field-level data to create more realistic representations of the global land-use change projections at a 30 m resolution (Sohl et al. 2018). The model allowed climate change to influence both natural vegetation cover and human land-use (i.e. crop type), considering factors such as precipitation and aquifer depletion, for example.

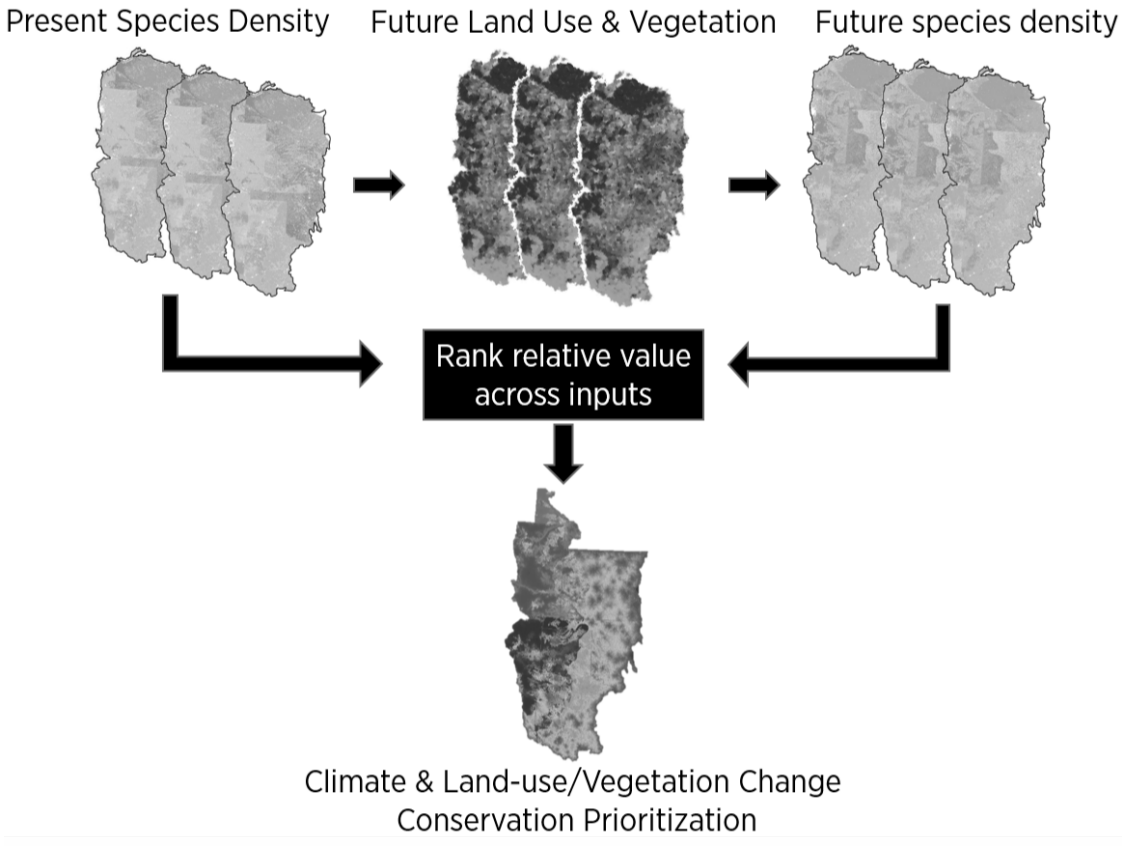


Figure 4.8. Conceptual diagram for the Southern Great Plains prioritization

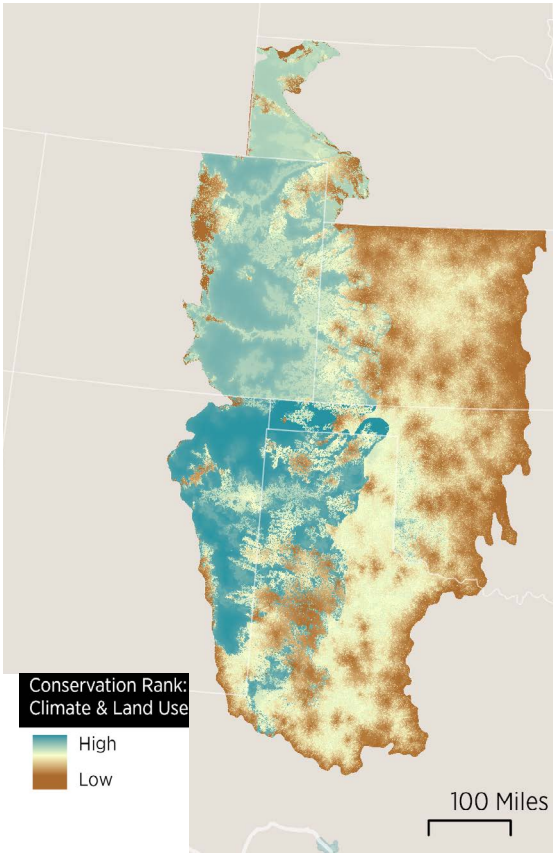


Figure 4.9. Conservation ranks based on estimated density of 14 grassland bird species, and present and predicted future climate and land use-land cover change.

To estimate grassland bird densities across the region, we reclassified the land-use/land-cover projections into five classes for which we had associated species density estimates: grassland (mixed grass, tallgrass, shortgrass), shrubland (shinnery oak, mesquite savannah, sand sage), wheat, row crops, and grass crops (pasture, fallow, alfalfa, hay). We then mapped the estimated densities for each of the 14 species at four decadal time steps (2014, 2040, 2070, 2100). We converted the species density maps to a 1 km_2 resolution (due to software constraints) and used them as inputs to Zonation to generate a spatial prioritization (Fig. 4.8).

Results

The western half of the Southern Great Plains region had the highest conservation ranks (Fig 4.9), while decreasing conservation ranks were projected for the eastern half of the region. These results are consistent with the continental climate and land-use prioritization results.

Overlap with GPCAs and IBAs was higher in the Southern Great Plains than the other regions.

Table 4.2: Examples of conservation strategies identified by the PLJV for implementation in the region, the philosophy behind engaging in each strategy, and the programs that can advance the strategy

Strategy	Philosophy	Programs/Practices
Retain and improve the condition of the current grass acreage in the short and mixed grass prairies	Grassland bird abundance can be increased through retaining grass and increasing the heterogenity of the grass structure on the landscape	• Support Audubon's Conservation Ranching Initiative • Work to retain CRP on the landscape through Farm Bill Programs that incentivize retention (e.g., EQIP, CRP Grasslands program) • Expand the GRIP program to the PLJV region
Increase area of grass in the PLJV region using Farm Bill Programs or other state and Federal conservation programs	Increasing grassland will increase habitat availability for grassland-breeding birds	• Invest in grassland restoration where vegetation and land-use projections agree it is likely to occur. • Increase acreage cap of CRP enrollment
Promote grasslands restoration in areas where aquifer depletion prohibits irrigated agriculture	Climate change combined with aquifer depletion may lead to changing land-use and opportunities for grassland expansion	• Invest in grassland restoration where vegetation and land-use projections agree it is likely to occur. • Support expansion of Audubon's Conservation Ranching Initiative into grassland restoration areas

Approximately 46% of the 2010 GPCA and 29% of the 2018 GPCA area co-occurred with the top 20th percentile, with mean ranks ranging from 0.06-0.96. Approximately, 33% of global IBAs overlapped with the top 20th percentile.

The Southern Great Plains prioritization showed high agreement with the continental prioritization incorporating land-use change. Both analyses suggest that the eastern half of the region is likely to become less suitable for grassland birds over time, likely due to higher precipitation and suitability for irrigated row crops. The fact that the majority of GPCAs in the area co-occur with the highest ranked sites in the western half of the region further validates our results. This prioritization suggests that regional-scale conservation efforts should target eastern New Mexico and Colorado, and northwestern Texas.

The output of the Landscape Conservation Design for the PLJV Grasslands Implementation Plan includes a table of conservation strategies that partners agreed to implement in pursuit of bird population targets (Table 4.2 provides an excerpt). Key strategies included retaining and improving the condition of short and mixed-grass prairie; increasing the area of grasslands through Farm Bill programs, and promoting grassland restoration in areas where aquifer depletion may prohibit irrigated agriculture in the future. Audubon's Conservation Ranching Initiative has the potential to advance one or more of those strategies. These conservation priorities identified in the Southern Great Plains prioritization incorporate existing grasslands as well as potential grassland expansion due to climate change.

Yellow-billed Magpie

Grassland Conservation Priorities

Our multiple spatial prioritizations incorporated the best available information on present and future bird ranges, bird density, and predicted land-use and land-cover change. We demonstrate substantial consensus across spatial scales regarding the most important areas for grassland birds in the central grasslands of North America. The results suggest that the most critical climate strongholds for grassland birds at the continental scale are located in southern Canada, northern Montana, the Dakotas, Arizona, New Mexico, Texas, the Oklahoma Panhandle, and the Chihuahuan Desert. Regional strongholds include southern Canada, the Dakotas, and Montana in the Northern Great Plains, and western Nebraska and Kansas, Colorado, New Mexico, and Texas in the Southern Great Plains.

Increasing pressure from competing land uses in the eastern half of the central grasslands makes this part of the region extremely vulnerable to land conversion. Urgent conservation action is required to protect or restore any unprotected tall- and mixed-grass prairie that remains; however, the cost may be higher given the value of the land in the region for irrigated agriculture. A less predictable factor that could reduce land conversion pressure is the depletion of aquifers, which could provide opportunities for grassland restoration as irrigated cropland is no longer viable.

To define a portfolio of high-priority sites for grassland conservation in North America, we identified areas of consensus across all of our continental and regional prioritizations, and both sets of GPCAs, in order to include and expand upon previous conservation planning efforts (Fig. 4.10). We mapped the top 20th percentile of conservation rank identified in each prioritization and tallied the number of prioritizations that overlapped. No single location was identified as a top priority by all prioritizations; however, all high-ranked sites are considered priorities for conservation action. Additionally, given the near total loss of native tallgrass prairie in the eastern half of the region, this area is poorly represented in our prioritizations. We therefore recommend that any remaining fragments of unprotected tallgrass prairie be iden-

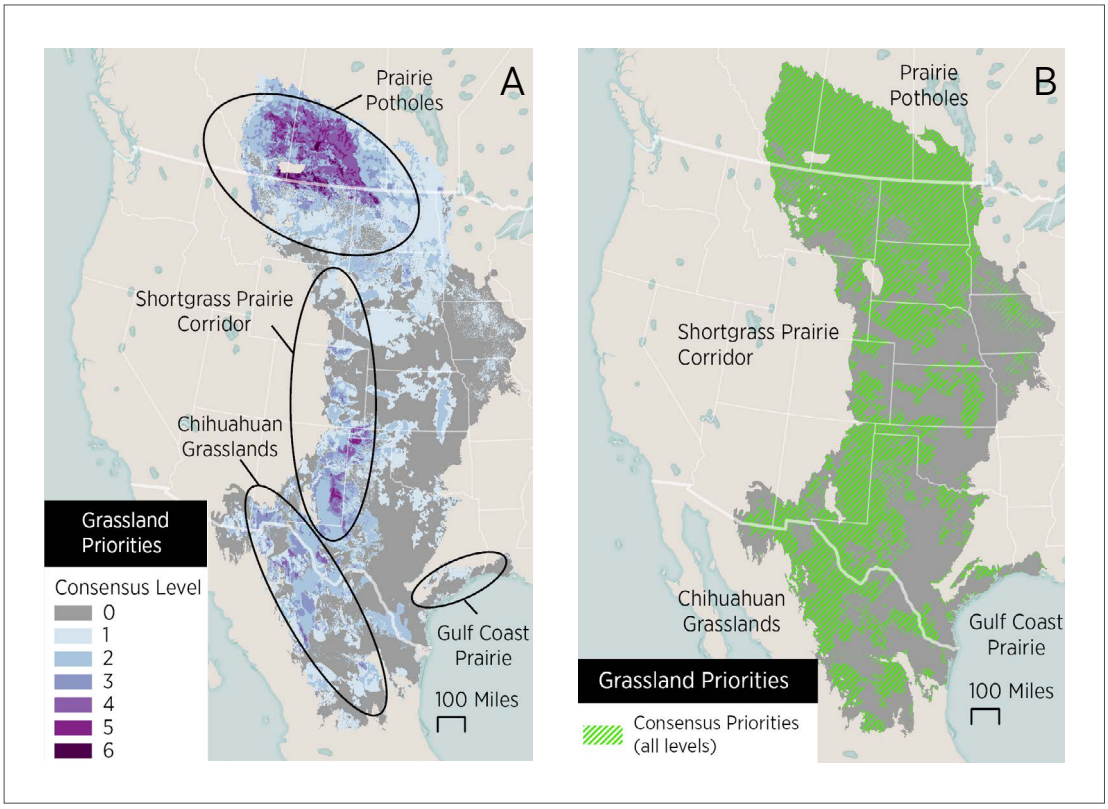


Figure 4.10. (A) Consensus Grassland Priorities across the top 20th percentile of all prioritizations and both sets of GPCAs. Audubon's regional priorities (black ovals) are also depicted. (B) All levels of consensus priorities including strongholds, GPCAs, and vulnerable areas.

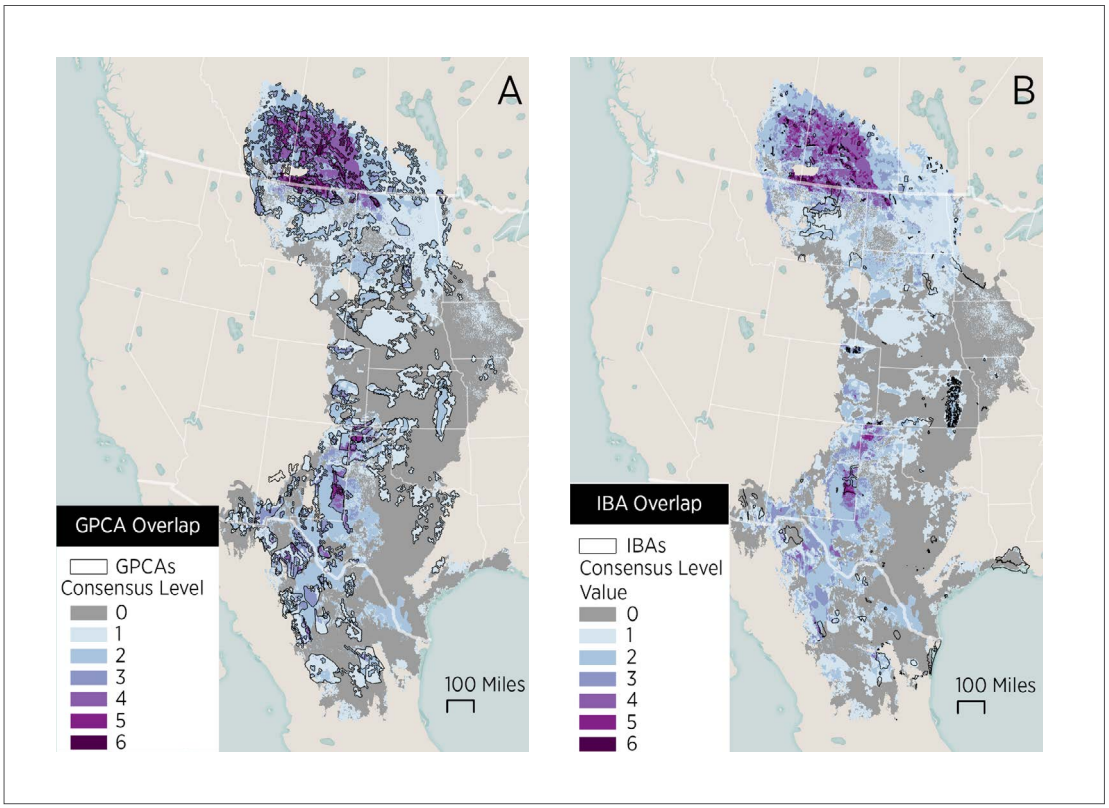


Figure 4.11. Consensus Priorities with (A) the union of Grassland Priority Conservation Areas (2010 [Pool and Panjabi 2011] and 2018 [Comer et al. 2018]) outlined in black, and (B) global Important Bird Areas.

tified as high priority for protection, restoration, or collection of genetic material for seed banks.

Many Grassland Priority Conservation Areas (2010 and 2018) and Important Bird Areas occur in highly ranked grassland priorities (Figs 4.11a and b respectively). For example, the Sage Creek Milk River, Monet, and Frenchman River – Bitter Creek GPCAs, and the North Valley Grasslands IBA in the Prairie Potholes Region, and the New Mexico Lesser-Prairie Chicken Complex and Pradera de Tokio IBAs in the southern Great Plains and Chihuahuan grasslands, respectively. These areas may provide high return on conservation investment, as they have been identified as important by several independent prioritization approaches. Furthermore, the substantial overlap of GPCAs in particular with our portfolio of climate-smart grassland priorities provides strong validation of our approach.

We calculated the proportion of each grassland type in the top 20% of grassland climate strongholds (GCS; Fig. 4.3a), grassland climate and land-use strongholds (GCLUS; Fig. 4.3b) and vulnerable grassland strongholds (VCGS; Fig. 4.3c), and the highest level of Consensus Priorities (CP; Fig. 4.11), as well as the proportion of each that is currently under some form of protection. The extent of each grassland type was identified based on NatureServe's Current Grassland Range Maps which were developed by extending the LANDFIRE biophysical settings products that correlate field observations with climate, landform, and soil (Rollins 2019) to Mexico and Canada, and thus provide complete and current distributions of the major grassland types in North America (Comer et al. 2018). We condensed the 12 grassland types to four (desert, shortgrass, mixed grass, tallgrass) prior to analysis. The Western Great Plains Sand Prairie did not fall neatly into one of these four classes as it shares characteristics with several of them. Consequently, we grouped sand prairie with mixed grass as the two ranges were highly spatially coincident. Proportions of the four major grassland types coincident with the top 20% of GCSs ranged from 0.2% of tallgrass prairie to 30% of desert grassland, GCLUSs ranged from 0.5% of tallgrass prairie to 33% of desert grassland, VGCSs ranged from 2% of shortgrass prairie to 29% of mixed grass prairie, and Consensus Priorities (value = 6) ranged from 0% of tall, desert, and shortgrass prairie to 0.8% of mixed grass prairie (Fig. 4.12).

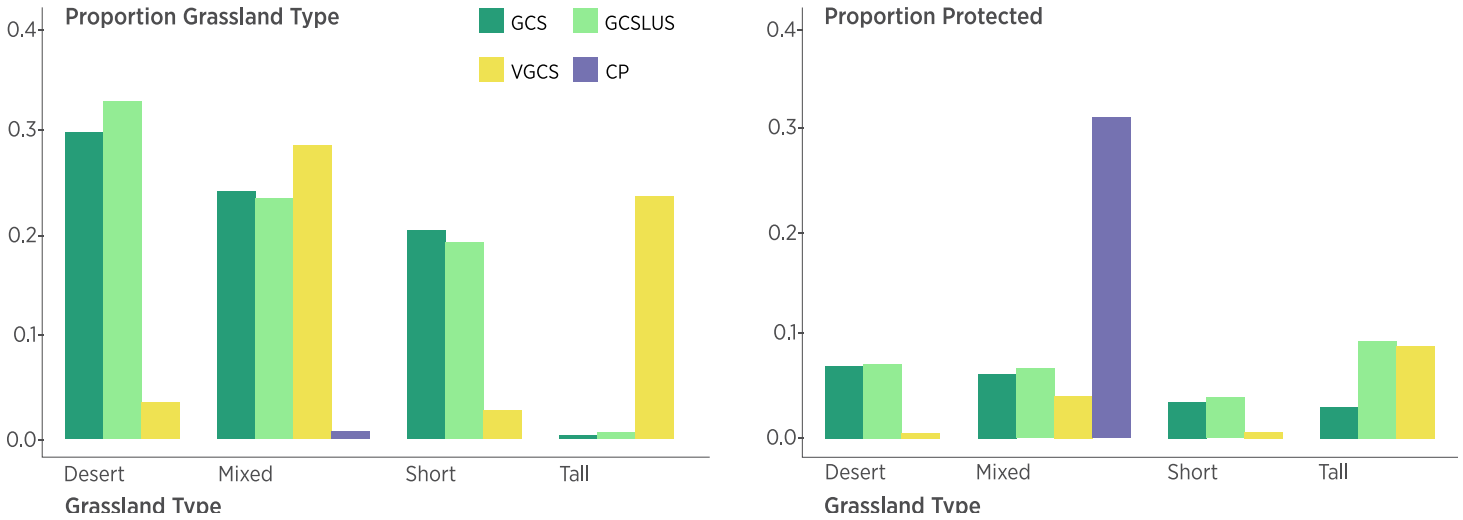


Figure 4.12. Bar graphs depicting the proportion of each grassland type coincident with Grassland Climate Strongholds (GCS), Grassland Climate and Land-use Strongholds (GCLUS), Vulnerable Grassland Climate Strongholds (VGCS), and Consensus Priorities (CP), and proportion of each coincident area currently protected.

Tallgrass prairie had the lowest level of protected GCSs (3%) and desert grasslands had the highest, with 7% having some form of protection. Protected GCLUSs ranged from 9% in tallgrass prairie to 4% in shortgrass prairie, and protected VGCSs ranged from 9% in tallgrass prairie to 0.3% in desert grassland. Approximately one third (30%) of the Consensus Priorities (value = 6) in mixed grass prairie were protected (Fig. 4.12).

Audubon's high-priority regions for grassland conservation and expansion of our Conservation Ranching Initiative include:

1. Prairie Potholes Region, mixed, and tallgrass prairies
2. Shortgrass prairie corridor
3. Gulf Coast prairie
4. Chihuahuan grasslands

Grasshopper Sparrow

Table 4.3. High-priority (top 20%) acreage according to all three continental prioritizations (Fig. 4.3a-c), the Northern Great Plains climate prioritization (Fig. 4.6a), and the Southern Great Plains climate and land-use change prioritization (Fig. 4.9). California and Nevada are excluded as they are outside of the study area boundaries.

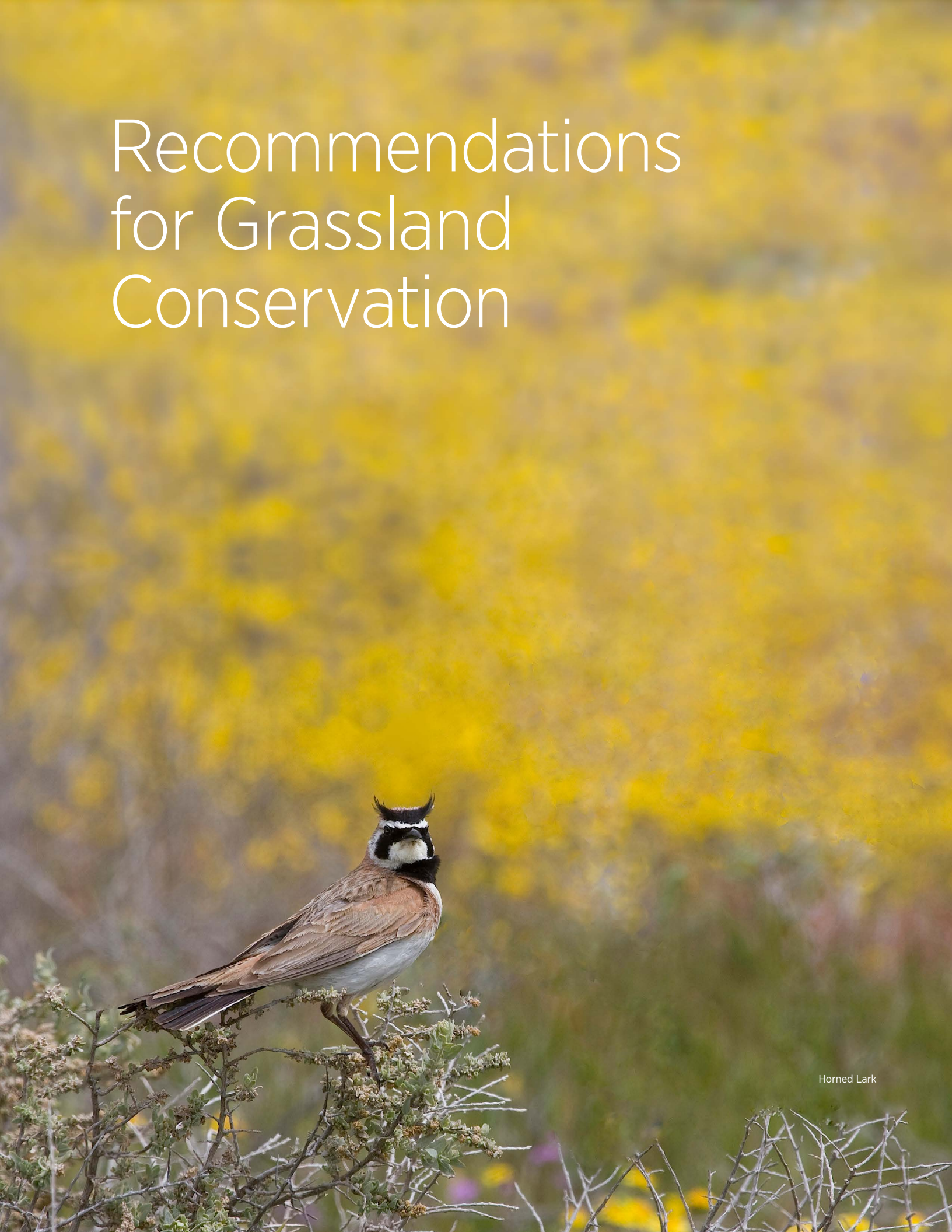
State	Continental Climate Only	Continental Climate & Land Use	Continental Vulnerable	Northern Great Plains	Southern Great Plains
Arizona	555,000	670,000	12,000	NA	NA
Colorado	239,000	390,000	958,000	NA	7,724,000
Kansas	481,000	522,000	655,000	NA	137,000
Missouri	0	0	1,911,000	NA	NA
Montana	5.611.00	42,363,000	1,616,000	5,073,000	NA
Nebraska	0	106,000	1,646,000	8,600	0
New Mexico	21,378,000	21,689,000	206,000	NA	12,089,000
North Dakota	5,549,000	5,193,000	32,743,000	3,605,000	NA
Oklahoma	1,609,000	938,000	1,008,000	NA	2,019,000
South Dakota	0	7,247,000	15,535,000	363,000	NA
Texas	33,241,000	30,833,000	7,671,000	NA	9,858,000
Wyoming	0	5,294,000	281,000	2,000	NA

The acreage of high-ranking cells in each state (Table 4.3) can be used as a guide for prioritizing outreach to and enrollment of new ranches in the initiative. Our results suggest that the top 20% of at least one prioritization encompasses sufficient area to grow the initiative within high-ranked sites in every state, with the caveat that all high-ranked sites are not necessarily available or suitable for enrollment.

In this section, we prioritized areas for grassland bird conservation across the central grasslands of North America. The priorities identified are areas predicted to be critical for many declining grassland birds that rely on North America's grasslands for their full annual cycle, and some are highly vulnerable to land-use conversion. These results will inform the expansion of Audubon's Conservation Ranching Initiative as well as the Playa Lakes Joint Venture grassland conservation implementation plan. Furthermore, these priorities complement existing Grassland Priority Conservation Areas by addressing the emerging threats of climate change in addition to the ongoing threat of agricultural conversion. This additional information can guide conservation action toward grasslands that are likely to persist over time and provide critical climate strongholds for grassland birds through the end of the century.

Mountain Plover

Recommendations for Grassland Conservation



Horned Lark

Overview

According the analyses presented above, by mid- to late-century, a significant percent of remaining grassland bird habitat will be lost or diminished due to the impacts of climate change and grassland conversion to cropland or development. The threats facing grassland conservation are as diverse and complex as the solutions to protect and restore them. Furthermore, 84% of central grasslands in the US are in private ownership (Gauthier et al. 2003), with the rest held largely by federal and state agencies. Thus, achieving conservation of grasslands at scale will require both broad stakeholder engagement and fundamental changes in the incentives that drive agricultural and other development in the region.

We found some grassland systems important to birds to be less susceptible to climate and conversion threats than others. These systems, including the Prairie Potholes Region, Short-grass Prairie Corridor, Gulf Coast Prairie, and Chihuahuan Grasslands, represent the best opportunities for preserving grassland birds by protecting the integrity and sustainability of these stronghold regions through collaborative efforts. Boundary organizations, such as migratory bird joint ventures and landscape conservation cooperatives, are building these collaborative partnerships between federal and state agencies; ranchers and other private interests; tribes; NGOs; and universities to deliver habitat for grassland bird conservation. It is only through cooperation that we can protect grasslands in the face of climate change and land conversion pressures.

Long-term, viable strategies to reduce threats must entail a diverse collection of solutions and involve many partners. The following recommendations provide a springboard for conservation action; they also lay the foundation for further development of innovative grassland management solutions that address the economic drivers that contribute substantially to conversion.

- **Increase public investments** in collaborative conservation efforts to restore and protect grassland ecosystems.
- **Create opportunities for private investment** in grassland conservation through mechanisms like market-based incentives and landscape-scale mitigation programs driven by development permitting approvals.

Audubon Appleton-Whittell Research Ranch

An hour outside of Tucson, Arizona, in the heart of the Sky Island mountains, the grasslands of Audubon Appleton-Whittell Research Ranch (AWRR) is one of the largest sanctuaries for native animals and plants in the southwestern United States. State and federal government agencies, private entities and non-profit organizations, as well as researchers from public and private universities and research institutes come together in a cooperative partnership to facilitate ecological research on this living laboratory. By fostering these relationships and the biological natural diversity of the land, AWRR contributes further understanding of this grassland ecosystem in hopes of advocating for the preservation and rehabilitation of grasslands everywhere.

- **Expand and strengthen existing policy solutions** like Sodsaver and other Farm Bill conservation programs or reduce subsidies for ethanol (i.e., reforms to the Renewable Fuel Standard) to further limit and/or remove incentives to convert grasslands to cropland or human and energy development.
- **Provide public and private funding to underwrite collaborative processes** that bring together government agencies, private interests, tribes, non-governmental organizations and others to collaborate on solutions across large landscapes that balance economic and ecological interests.
- **Prioritize public funding for projects to focus on the most critical landscapes**, like those identified in this report as grassland strongholds and grasslands that are highly vulnerable.
- **Improve land management agencies' grazing programs** to realize compatible economic and ecological goals on public lands.
- **Incorporate ecological outcomes** in criteria for technical assistance and producer certification programs that create mutual benefits with economic viability of the land manager.

Audubon is committed to hemispheric grasslands conservation through partnerships with Birdlife International, federal and state wildlife and agricultural conservation agencies, and other non-governmental organizations. Our grassland conservation strategy focuses on four key areas:

1. Technical support to private landowners and ranchers to assist their transition to bird-friendly management practices.
2. Enhancement and protection of critical grassland bird habitat through financial incentives and acquisition of voluntary term or permanent conservation easements.
3. Catalyze market-based incentives for grassland conservation by empowering consumers to invest in healthy grasslands through Audubon's Conservation Ranching Initiative certification and promote emerging markets that invest in natural climate solutions, like soil sequestration.
4. Align federal and state policies to incentivize grassland bird habitat protection and reduce threats to land use conversion.

Technical Assistance

Grazing animals have played a key role in grassland ecosystems for millennia, and grassland bird habitat is linked to the ecological impacts of grazers on the landscape. Vast herds of bison once were a primary influence on a shifting mosaic of habitat types by virtue of their movements and the natural disturbance they cause, and cattle can be managed in ways that mimic these important impacts. Grazing animal density and movements can be used to diversify habitat structure and composition, and research is confirming that these practices can rebuild soil organic matter, put carbon back into soils, increase water retention and infiltration ability of soils, increase plant diversity and nutrient density, and lead to more productive ranchlands (Teague et al 2016, Derner et al 2009). These regenerative grazing practices can make grasslands more resilient to changes in climate, especially extreme events such as heavy rainfall and drought.

Implemented best management practices utilize domestic livestock to benefit the grassland ecosystem. By mimicking the movements and pressure of historical grazers like bison, management can improve soil health and drive plant diversity and structure towards the habitat conditions of native prairie that grassland birds prefer. This technical assistance is a key partnership to create win-win solutions that strengthen economic vitality of rural communities and build healthy functioning grassland ecosystems.

Audubon staff and consultants work with ranchers to develop Habitat Management Plans (HMPs) tailored to address site-specific habitat and bird conservation opportunities on ranches participating in one of our programs. Desired outcomes of HMPs are guided by the habitat needs of a region-specific set of target grassland bird species, and they feature protocols that specify practices which, when adopted, ensure ranches are managed sustainably to benefit these species. In addition to habitat management practices, the protocols include a standardized set of criteria related to forage consumption, animal health & welfare, and environmental sustainability. The Bird Friendliness Index referenced in this report will help Audubon staff and consultants work with ranchers to modify their existing HMP, incorporating bird and ecosystem response over time to adaptively manage their lands for increasingly beneficial outcomes.

Conservation Incentives and Easements

Audubon will conserve 1 million acres of critically endangered grassland and wetland habitat by 2022 through a matrix of strategic grassland enhancement, restoration, and protection using conservation incentives and easements. Audubon will focus conservation efforts to support endangered and threatened grassland and wetland dependent species such as Whooping Crane, Sandhill Crane, Northern Pintail, Black Tern, Greater Prairie-Chicken, and Western Meadowlark. At the core of the Northern Great Plains, the Prairie Pothole Region (PPR) gets its name from the millions of shallow depressions left behind from ancient receding glaciers and associated tall and mixed grass prairies. These prairie potholes are wetlands rich in aquatic plants and wildlife, and support globally significant populations of breeding waterfowl, shorebirds, and grassland obligate birds. Since the vast majority of land within the PPR is privately owned, it is crucial that conservation organizations partner with landowners to protect this critical migratory and breeding habitat for Audubon's priority bird species. Additionally, the PPR also represents the most important monarch butterfly, honey bee, and native bee habitat in the US (Evans et al. 2018).

Piloted in North Dakota, Audubon provides cost-share opportunities to private landowners for grazing infrastructure (perimeter and cross fencing, water wells, pipelines, etc.), invasive species removal/control, and prairie restoration/reconstruction. Program enrollment requires landowners to conserve their grasslands between 5 to 10 years, depending on the conservation practices implemented. Site-specific data for avian and vegetation communities is collected and incorporated into HMPs that Audubon staff develop with landowners to determine the impacts of the applied land management. This program provides unique grassland management assistance not previously

The Wolsey Crane Stopover Important Bird Area

During fall migration, Sandhill Cranes stop for extended periods in the northern Prairie Pothole Region of North America before continuing southward to wintering grounds. During the months of September and October, cranes "stage" in areas of eastern Alberta, Saskatchewan, Manitoba, North Dakota, South Dakota and northwestern Minnesota. To protect fall migration habitat utilized by cranes in North Dakota, Audubon partnered with the US Fish and Wildlife Service Partners for Fish and Wildlife, ND Game and Fish Department, Ducks Unlimited, ND Wildlife Federation, and private donors. These partnerships have led to the protection of private acres that experience levels of high use by Sandhill Cranes during fall migration through the acquisition of conservation easements.

The Wolsey Crane Stopover Important Bird Area (IBA) covers 1.6 million acres in east central South Dakota. Almost a quarter of the world's population of Sandhill Cranes arrives and utilizes the high quality wetlands, grasslands, and croplands of the area to rest and forage each spring. Phase I & II of the South Dakota Wolsey IBA Habitat Conservation Project focus on protecting over 3,000 acres through perpetual easements on privately owned land within the Wolsey IBA. Partnerships with US Fish and Wildlife Service, Ducks Unlimited, and South Dakota Game, Fish, and Parks, and private donors have been central to receiving project funding through the North American Wetland Conservation Act.

supported by other conservation entities, which has encouraged program expansion into other parts of the Northern Great Plains.

To protect migration habitat of our priority bird species, partnerships are at the heart of Audubon's working lands conservation strategy. These partners include, but are not limited to, US Fish and Wildlife Service (USFWS), USFWS Partners for Fish and Wildlife, North and South Dakota Game and Fish Department, Ducks Unlimited, ND Wildlife Federation, and private donors. Audubon's conservation strategy will be implemented through grassland enhancement cost share programs, conservation easements, and incentive-based habitat programs.

Market-based Incentives

Audubon's Conservation Ranching Initiative uses an innovative, market-based approach to connect conservation-conscious consumers to ranchers who employ bird-friendly management practices in raising their livestock. The program addresses loss in ecosystem function and health through the conservation of focal bird species and the habitats they depend upon. It incentivizes bird-friendly livestock management practices, emphasizing regenerative grazing approaches that improve soil health, diversify habitat structure, and ensure environmental sustainability. These then benefit the livestock, birds, pollinators, and other wildlife that depend on grasslands.

When ranches demonstrate full compliance with Audubon-approved HMPs and other requirements specified in the protocols during third-party audits, they receive full certification and can use the "Grazed on Audubon-Certified Bird-Friendly Land" certification mark on product packaging, websites, or other promotional materials. Audubon staff assist in connecting certified ranches to branded companies, restaurants and retailers to encourage self-sustaining markets that will incentivize continued program participation into the future. Currently, nearly 2 million acres and 65 ranches across 11 states are participating in the program, with more in the pipeline. Audubon's goal is to have 2.5 million acres enrolled by the end of 2020. Products carrying the Audubon certification seal are currently available in 26 retailers and 12 restaurants across 7 states and 11 companies that sell online. This too is growing. By engaging and educating consumers, the program has the potential to change the way that we manage livestock on the land, providing a new, market-based path toward ecological sustainability.

Enrolling new ranches depends on several factors, primarily the willingness of ranchers to participate in this voluntary initiative and their ability to implement changes in their management. This often includes structural improvements to fencing and watering facilities to move cattle or bison in new or different ways. Access to financial assistance from NRCS programs like EQIP can provide critical support to enable ranchers to manage their lands to support bird habitat. Where possible, Audubon will prioritize bringing ranches under bird-friendly habitat management plans within the priority areas identified in this report. Currently, approximately 57% of the enrolled acres overlap with these priority areas in the central grassland region.

Markets are now emerging that pay ranchers to preserve and manage their grasslands and lock carbon into the soil. The agricultural sector represents 9% of global greenhouse gas emissions (www.epa.gov), but there is growing evidence that soils on agricultural lands, especially grasslands, can store considerable CO_2 and serve as an important solution to meeting climate change objectives (Chambers et al. 2016). This market is new, but methods and protocols have been developed to measure carbon sequestration rates, generate credits and verify results, and transactions have occurred whereby landowners sell carbon sequestration credits in voluntary markets. The management practices that sequester carbon into soils on ranches also have the co-benefits of delivering healthy habitats for wildlife and more nutrient-rich food for livestock. Audubon is exploring how it can best facilitate this market and provide landowners with an additional financial incentive that produces results beneficial to protecting grasslands.

By using market-based incentives, Audubon's Conservation Ranching Initiative can collaborate with ranchers to enhance and restore millions of acres

of grassland bird habitat by empowering consumers to participate in conservation efforts that keep ranchers on the land and healthy grasslands on the landscape. Audubon will prioritize enrolling ranches located as within the conservation priorities identified in this report (Figure 4.10D) that help protect existing grassland strongholds and vulnerable areas.

Federal and State Policies

Conversion to row crop agriculture, urban development, oil and gas development, and fire suppression accompanied by woody encroachment are the primary causes of native prairie habitat loss. In order to reduce future grassland conversion, Audubon will pursue a proactive policy strategy at the federal and state levels that incentivize grassland conservation and discourage excessive conversion practices. The primary levers for success is productive, conservation-minded Farm Bill policies and programs as well as funding to implement State Wildlife Action Plans.

Farm Bill

Birds thrive in places with abundant food and shelter, like national wildlife refuges, state forests, and other large, wild tracts of public land. With more than two-thirds of the contiguous US privately-owned, what happens on our nation's 914 million acres of farms and ranches and 300 million acres of private woodlands is critical for North American birds and other wildlife. The largest federal funding source for conservation on those lands is the Farm Bill. Every five years, Congress rewrites our nation's agriculture policy to set initial funding levels and make policy changes in the Farm Bill, which covers an array of farm-related programs including commodity, trade, nutrition, and more. Within the Farm Bill, the conservation and forestry titles consist of programs focusing on restoring soils, protecting waterways and enhancing wildlife habitat on private lands. Through these programs, billions of dollars go to agricultural producers and private landowners each year to incorporate conservation practices into their operations that improve water quality, soil health, air quality, and wildlife habitat. This assistance is critical to maintaining wetlands, grasslands, and other fragile lands available as habitat for

Lark Bunting

the birds and other wildlife that call them home. In 2015 alone, almost 9 million acres of wildlife habitat were improved. Audubon was successful in working to secure passage of the 2018 Farm Bill reauthorization in December 2018 that expands funding for, and improves access to several key programs that will benefit birds and other wildlife through Audubon partnerships across our Working Lands initiatives.

State Wildlife Action Plans

Unless a species is protected by the federal Endangered Species Act, each state has responsibility for oversight of the fish and wildlife within their borders. Each state's fish and wildlife agency has developed a State Wildlife Action Plan which identifies imperiled species in the state and describes actions to assist in their recovery and protection. More than 8,000 species are currently identified through these plans as in need of proactive conservation activities. These Action Plans assess the health of wildlife and habitat in the state so experts know which species are at risk, and outline steps needed to conserve the "species of greatest conservation need" before they become more rare and costly to protect. The State Wildlife Grants Program is currently the main source of federal funding for states and territories as they implement these plans; however, it currently provides only $70 million among all 50 states and territories, which is not nearly enough to take the actions necessary to recover and protect imperiled species. Adequately funding implementation of State Wildlife Action Plans across the Great Plains would provide critical support for grassland conservation for the birds and people who depend on this important landscape.

Final Conclusions

Prairies and grasslands are a largely forgotten and misunderstood landscape of the Americas, yet they are critically important to our nation's economic health, natural heritage, rural economies, and food security. There is no doubt that the challenges we face in protecting these grassland ecosystems are significant. The intent of this report and Audubon's recommendations is to bring light to this important issue and to inspire change that has meaningful impact on both our natural resources and future economic prosperity.

Aplomado Falcon

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Henslow's Sparrow

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Appendix A
Vulnerability scores by species.

Common Name	Scientific Name	Season	Vulnerability			Agreement		
			1.5° C	2.0° C	3.0° C	1.5° C	2.0° C	3.0° C
Aplomado Falcon	*Falco femoralis*	Summer	L	L	H	M-H	M-H	M-H
		Winter	M	M	M	H	M-H	M-H
Baird's Sparrow	*Ammodramus bairdii*	Summer	H	H	H	M-H	H	H
		Winter	H	H	H	H	H	H
Bobolink	*Dolichonyx oryzivorus*	Summer	M	M	H	M-H	H	M-H
Botteri's Sparrow	*Peucaea botterii*	Summer	M	M	H	H	H	M-H
		Winter	N	N	L	M-H	M-H	M-H
Burrowing Owl	*Athene cunicularia*	Summer	N	N	N	M-H	M-H	M-H
		Winter	N	N	N	M-H	H	M-H
Cassin's Sparrow	*Peucaea cassinii*	Summer	N	N	L	M-H	M-H	M-H
		Winter	L	M	M	M-H	M-H	M-H
Chestnut-collared Long-spur	*Calcarius ornatus*	Summer	M	H	H	L	M-H	H
		Winter	L	M	M	M-H	M-H	M-H
Clay-colored Sparrow	*Spizella pallida*	Summer	M	M	H	M-H	M-H	M-H
		Winter	N	N	N	H	H	H
Dickcissel	*Spiza americana*	Summer	N	N	N	H	H	H
		Winter	N	N	N	H	H	H
Eastern Kingbird	*Tyrannus tyrannus*	Summer	L	M	M	M-H	M-H	M-H
Eastern Meadowlark	*Sturnella magna*	Summer	L	L	M	H	M-H	H
		Winter	N	N	N	M-H	H	H
Ferruginous Hawk	*Buteo regalis*	Summer	L	M	M	M-L	M-L	M-H
		Winter	L	L	M	M-L	M-H	M-H
Grasshopper Sparrow	*Ammodramus savannarum*	Summer	N	N	L	M-H	M-H	M-H
		Winter	N	N	N	M-H	M-H	H
Gray Partridge	*Perdix perdix*	Summer	M	M	H	M-H	H	M-H
		Winter	L	L	L	M-H	M-H	M-H
Greater Prairie-Chicken	*Tympanuchus cupido*	Summer	M	L	N	H	M-H	M-H
		Winter	N	N	N	M-H	H	H
Henslow's Sparrow	*Ammodramus henslowii*	Summer	H	H	H	M-H	H	H
		Winter	N	N	N	H	H	H
Horned Lark	*Eremophila alpestris*	Summer	L	L	L	M-H	M-H	M-L
		Winter	L	L	L	H	H	H
Lark Bunting	*Calamospiza melanocorys*	Summer	L	M	H	M-H	M-H	M-H
		Winter	L	N	N	H	M-H	M-H
Le Conte's Sparrow	*Ammodramus leconteii*	Summer	M	M	H	M-H	M-H	M-H
		Winter	N	N	N	H	H	H
Lesser Prairie-Chicken	*Tympanuchus pallidicinctus*	Summer	L	L	M	M-H	H	H
		Winter	N	L	L	M-H	H	H

Loggerhead Shrike	*Lanius ludovicianus*	Summer	N	N	N	M-H	M-H	M-H
		Winter	N	N	N	H	M-H	M-H
Long-billed Curlew	*Numenius americanus*	Summer	M	M	H	M-H	M-H	M-H
		Winter	N	N	N	M-H	M-H	H
McCown's Longspur	*Rhynchophanes mccownii*	Summer	H	H	H	M-H	M-H	M-H
		Winter	L	L	M	H	H	H
Mountain Plover	*Charadrius montanus*	Summer	M	H	H	M-L	M-H	H
		Winter	L	L	L	H	H	H
Nelson's Sparrow	*Ammodramus nelsoni*	Summer	L	M	H	M-L	M-L	M-L
		Winter	M	H	H	M-H	M-L	M-H
Northern Bobwhite	*Colinus virginianus*	Summer	N	N	N	H	H	H
		Winter	N	N	N	M-H	M-H	H
Ring-necked Pheasant	*Phasianus colchicus*	Summer	N	N	L	M-H	H	M-H
		Winter	L	L	L	M-H	M-H	M-H
Savannah Sparrow	*Passerculus sandwichensis*	Summer	M	M	H	M-H	M-H	M-H
		Winter	L	L	L	H	H	H
Scaled Quail1	*Callipepla squamata*	Summer	L	L	M	H	H	M-H
		Winter	L	L	L	M-H	H	M-H
Scissor-tailed Flycatcher	*Tyrannus forficatus*	Summer	N	N	N	H	H	H
		Winter	N	N	N	H	H	H
Sedge Wren	*Cistothorus platensis*	Summer	M	M	M	M-H	M-H	M-H
		Winter	L	N	N	H	M-H	M-H
Sharp-tailed Grouse	*Tympanuchus phasianellus*	Summer	L	L	L	M-H	M-H	M-H
		Winter	L	L	M	H	H	M-L
Short-eared Owl	*Asio flammeus*	Summer	M	M	M	M-H	M-H	H
		Winter	N	N	L	H	H	M-H
Sprague's Pipit	*Anthus spragueii*	Summer	L	M	H	M-L	M-L	M-H
		Winter	N	N	N	M-H	H	H
Swainson's Hawk	*Buteo swainsoni*	Summer	N	N	N	M-H	M-H	M-H
Upland Sandpiper	*Bartramia longicauda*	Summer	N	N	N	H	H	M-H
Vesper Sparrow	*Pooecetes gramineus*	Summer	L	M	M	M-H	M-L	M-H
		Winter	N	N	N	H	H	M-H
Western Kingbird	*Tyrannus verticalis*	Summer	N	N	N	H	H	H
		Winter	N	N	N	M-H	M-H	M-H
Western Meadowlark	*Sturnella neglecta*	Summer	L	L	L	M-H	H	H
		Winter	N	N	N	M-H	H	H

1 Scaled Quail is included in this report but excluded from estimates of the proportion of grassland birds vulnerable to climate change because it is classified as an arid land species by the State of the Birds Report.

Appendix B

Grassland and aridland bird species included in Bird-Friendliness Index estimation for the NGP, their functional species grouping, and State of the Birds breeding season Combined Conservation Score (CCSb).

Common Name	Functional Species	CCSb
Baird's Sparrow	Ground-foraging invert- & granivores	15
Bell's Vireo	Mid- to upperstory foraging invertivores	11
Bobolink	Ground-foraging invert- & frugivores	12
Brewer's Sparrow	Ground-foraging invert- & granivores	11
Burrowing Owl	Large ground-foraging invert- & vertivores	12
Canyon Wren	Ground- or aerial-foraging invertivores	9
Chestnut-collared Longspur	Ground-foraging invert- & granivores	15
Clay-coloured Sparrow	Ground-foraging invert- & granivores	9
Dickcissel	Ground-foraging invert- & granivores	10
Eastern Kingbird	Understory-foraging invert-, frug- & granivores	10
Ferruginous Hawk	Large ground-foraging vertivores	10
Grasshopper Sparrow	Ground- or aerial-foraging invertivores	12
Greater Prairie-chicken	Ground-foraging invert- & granivores	16
Greater Sage-grouse	Large ground-foraging herbivores	15
Green-tailed Towhee	Ground-foraging invert- & frugivores	11
Horned Lark	Ground-foraging invert- & granivores	9
Lark Bunting	Ground-foraging invert- & granivores	12
Lark Sparrow	Ground-foraging invert- & granivores	9
Long-billed Curlew	Ground- or aerial-foraging invertivores	14
Loggerhead Shrike	Small ground-foraging invert-, vertivores & scavengers	11
McCown's Longspur	Ground-foraging invert- & granivores	15
Mountain Plover	Ground- or aerial-foraging invertivores	15
Northern Harrier	Large ground-foraging invert-, vertivores & scavengers	11
Rock Wren	Small ground-foraging invert- & vertivores	10
Sage Thrasher	Ground- or aerial-foraging invertivores	11
Savannah Sparrow	Ground-foraging invert- & frugivores	8
Sprague's Pipit	Ground- or aerial-foraging invertivores	14
Sharp-tailed Grouse	Midsized ground-foraging herb- & granivores	10
Swainson's Hawk	Large ground-foraging invert- & vertivores	9
Upland Sandpiper	Ground- or aerial-foraging invertivores	10
Vesper Sparrow	Ground-foraging invert- & granivores	10
Western Kingbird	Mid- to upperstory foraging invertivores	7
Western Meadowlark	Ground-foraging invert- & granivores	9
White-throated Swift	Ground- or aerial-foraging invertivores	11

Appendix C

Species included in each prioritization analysis, their normalized State of the Birds Concern Scores, and summer and winter geographic distributions. NA indicates the species is not native and therefore not included in the State of the Birds assessment. We assigned these species a weight of 0.01. *The analyses the species was included in (C = continental, S = Southern Great Plains, N = Northern Great Plains).

Common Name	Analysis*	Summer Norm. Concern Score	Winter Norm. Concern Score	Summer Range	Winter Range
Aplomado Falcon	C	0.63	0.58	US/Mexico	US/Mexico
Baird's Sparrow	C, N	0.74	0.74	US/Canada	Chihuahuan Grasslands
Bobolink	C, N	0.58	0.68	US/Canada	S. American Lowlands
Botteri's Sparrow	C	0.63	0.58	Chihuahuan Grass-lands	Chihuahuan Grasslands
Burrowing Owl	C, S, N	0.58	0.53	US/Canada	Chihuahuan Grasslands
Cassin's Sparrow	C, S	0.53	0.53	US	Chihuahuan Grasslands
Chestnut-collared Longspur	C, N	0.74	0.68	US/Canada	Chihuahuan Grasslands
Clay-colored Sparrow	C, N	0.42	0.47	US/Canada	Chihuahuan Grasslands
Dickcissel	C, N	0.47	0.53	US	S. American Lowlands
Eastern Kingbird	C, N	0.47	0.53	US/Canada	S. American Lowlands
Eastern Meadowlark	C, S	0.53	0.53	US/Canada	US/Canada
Ferruginous Hawk	C, N	0.47	0.47	US/Canada	US/Canada
Grasshopper Sparrow	C, S, N	0.58	0.58	US/Canada	US/Chihuahuan Grasslands
Gray Partridge	C	NA	NA	US/Canada	US/Canada
Greater Prairie-Chicken	C, N	0.79	0.79	US	US
Henslow's Sparrow	C	0.63	0.68	US	US
Horned Lark	C, N	0.42	0.42	US/Canada	US
Lark Bunting	C, S, N	0.58	0.58	US/Canada	Chihuahuan Grasslands
Lark Sparrow	S	0.42	0.47	US/Canada	US/Chihuahuan Grasslands
Le Conte's Sparrow	C	0.53	0.58	US/Canada	US/Canada
Lesser Prairie-Chicken	C, S	0.95	0.95	US	US
Loggerhead Shrike	C, S, N	0.53	0.53	US/Canada/Chihuahuan Grasslands	US/Chihuahuan Grasslands
Long-billed Curlew	C, N	0.68	0.68	US/Canada	Chihuahuan Grasslands
McCown's Longspur	C, N	0.74	0.74	US/Canada	US/Chihuahuan Grasslands
Mountain Plover	C, S, N	0.74	0.79	US	Chihuahuan Grasslands
Nelson's Sparrow	C	0.53	0.68	US/Canada	US
Northern Bobwhite	C, S	0.58	0.53	US/Chihuahuan Grasslands	US/Chihuahuan Grasslands
Ring-necked Pheasant	C, S	NA	NA	US/Canada	US/Canada
Savannah Sparrow	C, N	0.37	0.37	US/Canada	US/Chihuahuan Grasslands
Scaled Quail	C, S	0.58	0.58	US/Chihuahuan Grass-lands	US/Chihuahuan Grass-lands
Scissor-tailed Flycatcher	C, S	0.47	0.53	US	Pacific Lowlands
Sedge Wren	C, N	0.32	0.32	US/Canada	US/Chihuahuan Grasslands
Sharp-tailed Grouse	C, N	0.47	0.47	US/Canada	US/Canada
Short-eared Owl	C	0.58	0.58	US/Canada	US/Chihuahuan Grasslands
Sprague's Pipit	C, N	0.68	0.68	US/Canada	Chihuahuan Grasslands

Swainson's Hawk	C, S, N	0.42	0.58	US/Canada/Chihuahuan Grasslands	S. American Lowlands
Upland Sandpiper	C, N	0.47	0.47	US/Canada	Southern Cone
Vesper Sparrow	C, N	0.47	0.53	US/Canada	US/Chihuahuan Grasslands
Western Kingbird	C, N	0.32	0.42	US/Canada	Pacific Lowlands
Western Meadowlark	C, N	0.42	0.47	US/Canada	US/Chihuahuan Grasslands

Savannah Sparrow