Journal for Nature Conservation 45 (2018) 48–57

Contents lists available at ScienceDirect

Journal for Nature Conservation

journal homepage: www.elsevier.com/locate/jnc

Using Structured Decision Making to prioritize species assemblages for conservation

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ARTICLE INFO

Keywords:
Conservation planning
Grasslands
Priority species
Prioritization
Structured decision making

ABSTRACT

Species prioritization efforts are a common strategy implemented to efficiently and effectively apply conservation efforts and allocate resources to address global declines in biodiversity. These structured processes help identify species that best represent the entire species community; however, these methods are often subjective and focus on a limited number of species characteristics. We developed an objective, transparent approach using a Structured Decision Making (SDM) framework to identify a group of grassland bird species on which to focus conservation efforts that considers biological, social, and logistical criteria in the Northern Great Plains of North America. The process quantified these criteria to ensure representation of a variety of species and habitats and included the relative value of each criterion to the working group. These SDM methods provide a unique roadmap for prioritization of grassland bird species and offer an objective, transparent, and repeatable method of selection for priority species in other well-studied ecosystems.

1. Introduction

Global declines in biodiversity have led to increased focus on how to halt or reverse these trends (Butchart et al., 2010; Diamond, Ashmole, & Purves, 1989). As funding for conservation is limited, it is necessary to prioritize conservation targets that best represent the interests of managers, policy makers, scientists, and the public. Extensive work in the development of conservation planning methods has yielded conservation prioritization schemes that help users identify single species, communities, or entire ecosystems as targets for conservation (Arponen, Moilanen, & Ferrier, 2008; Brooks et al., 2006; Nicholson & Possingham, 2006). Of these options, focal species selection is perhaps the most commonly used approach (Lambeck, 1997; Roberge & Angelstam, 2004).

Focal species are often expected to serve as surrogates for other species of interest, though there is conflicting evidence as to whether they are effective in this context (Fleishman, Blair, & Murphy, 2001; Lindenmayer et al., 2002; Roberge & Angelstam, 2004). Indicator, umbrella, and other surrogate species concepts each have inherent strengths and shortcomings (Lindenmayer et al., 2015); however, the need remains across the majority of environmental science sub-disciplines and conservation initiatives to select some type of focal species to prioritize and allocate limited conservation resources (e.g. Elliot & Johnson, 2018). Attempts to provide a transparent method for selecting focal species have mainly focused on only one characteristic of the species (Lambeck, 1997), used subjective measures of selection criteria (Beazley & Cardinal, 2004), or assumed that all selection criteria were equally important (Coppolillo, Gomez, Maisels, & Wallace, 2004). However, systematic, objective approaches to selecting species can serve as a prioritization tool for allocating resources towards a group of selected species to drive conservation of a particular resource or ecosystem (Regan et al., 2008). Because financial resources are limited and management for one species may not fully benefit other species, prioritization can help ensure that resources are focused on species reflecting the concerns of stakeholders and potentially provide benefits to lower-priority species when making conservation decisions (Nicholson, Lindenmayer, Frank, & Possingham, 2013; Roberge & Angelstam, 2004).

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https://doi.org/10.1016/j.jnc.2018.08.003
Received 15 November 2017; Received in revised form 6 July 2018; Accepted 7 August 2018
1617-1381/

Grasslands of North America present an ideal case study for the objective selection of a prioritization species group to help drive conservation of an imperiled resource. Grassland ecosystems are declining rapidly throughout the world (Brookshire & Weaver, 2015), and this decline is well documented through historical records (Gage, Olimb, & Nelson, 2016). Fewer than half of these grasslands, once continuous across Canada, the United States, and Mexico, persist today across these three countries (Hoekstra, Boucher, Ricketts, & Roberts, 2005; Fig. 1). Grassland birds as an assemblage are particularly threatened due to this habitat loss. Of the 28 grassland bird species included in Breeding Bird Survey (BBS) analyses, 75% have seen significant population declines since 1966, while none have shown significant increases (Sauer et al., 2017). In addition, grassland specialists such as the Baird's sparrow (see Table 2 for scientific names) and Sprague's pipit are increasingly vulnerable in the face of climate change and conversion of grasslands to agriculture on the wintering grounds (Gorzo et al., 2016; Pool, Panjabi, Macias-Duarte, & Solhjem, 2014).

Due to these population declines, grassland birds have been identified as a priority group for conservation in the Northern Great Plains (NGP) by the National Fish and Wildlife Foundation's (NFWF) mission to organize and prioritize conservation actions across priority landscapes in the United States. These conservation plans identify 10-year priority conservation goals and actions, resource needs, and performance measures through consensus across federal, state, and private organizations based on preexisting work, expert knowledge, and pointed collaboration examining the landscape in question (Andres et al., 2015). While some conservation plans use individual focal species as indicators of progress toward conservation goals, no one species equally occupies the full range of habitat used by grassland birds (Kukkala & Moilanen, 2013). Thus, the selection of a suite of species to act as a focal resource for grassland bird conservation is not only appropriate but necessary for effective conservation planning in this context (Roberge & Angelstam, 2004). NFWF will use the results of this analysis to allocate limited conservation resources toward implementation and evaluation of on-the-ground management actions affecting these species.

We used a Structured Decision Making (SDM) approach (Conroy & Peterson, 2013; Lyons, Runge, Laskowski, & Kendall, 2008; Nichols & Williams, 2006; Williams, Nichols, & Conroy, 2002) to develop a transparent framework to prioritize species for inclusion in the NFWF NGP business plan as a case study. We selected a suite of priority species that represented the priorities identified by NFWF for the receipt of elevated conservation concern and funding from this organization. SDM involves a process of 1) breaking a decision down into its basic elements, 2) analyzing those elements separately, and 3) integrating all the elements to find a solution. Our objective was to apply this formal decision-making framework to facilitate the quantitative, transparent, and defensible justification for the prioritization of species by the working group on which NFWF can focus resources. The working group included administrators and biologists from NFWF, the Bird Conservancy of the Rockies (Bird Conservancy), the Northern Great Plains Joint Venture, and World Wildlife Fund (hereafter, the working group; Appendix A). Through the SDM process, this working group identified measurable criteria (e.g. characteristics of species' populations, natural history, etc.) to then transparently evaluate potential focal species. Our methods provide an objective approach to incorporating subjective values of a working group into a transparent decision-making process, using the NFWF working group as a case study. The methods we developed are repeatable within an SDM context and can provide a framework for selection of priority species assemblages in other ecosystems.

2. Materials and methods

2.1. Study area

The Northern Great Plains (NGP) is a large area of North American grasslands spanning the north-central United States and south-central Canada comprised of short, mixed, and tall-grass prairies. These grasslands are open landscapes with little topographic variation or tree cover that experienced periodic disturbance in the form of episodic grazing by herds of wild herbivores, particularly the American bison (*Bison bison*), as well as disturbance from prairie fire (Axelrod, 1985). Both fire and grazing historically facilitated seed dispersal and activation of native grasses as well as spatial heterogeneity of grassland microhabitat across the landscape (Bragg & Hulbert, 1976). Much of the historical extent of this grassland landscape has now been converted to shrublands (through overgrazing and infrequent burning, Briggs et al., 2005) or other land cover types (e.g. urban cover and cultivated agriculture, World Wildlife Fund, 2017). On the grasslands that remain the ecological niche once held by the American bison is now filled by domestic cattle which are managed by ranchers across the NGP. In 2015, NFWF defined a specific spatial extent for the NGP based on known ecological boundaries to facilitate focused conservation effort in the area (Fig. 1). We use this delineation of the NGP to inform our focal species selection process.

2.2. Structured Decision Making

The first step in the SDM process is identifying explicit objectives. Objectives are chosen by the working group, and it is crucial that these objectives accurately reflect the desired outcomes of all stakeholders in the decision to be made. These objectives then describe the criteria with which different decisions are evaluated. The working group identified 11 characteristics judged as important in identifying priority species for the region, which we combined (see methods below) to evaluate potential priority species and assemblages (Table 1). Our criteria described biological characteristics (e.g. measures of population vulnerability due to threats, population size/trend, geographic range), as well as stakeholder interest in each species (e.g. ability to monitor the species, ability to detect changes in their populations, each species' utility as an umbrella species).

For each criterion, we developed or identified a measurable attribute that provided a quantitative measure of that criterion (Table 1) and then assessed each criterion for all bird species that are associated with grasslands within the NGP and for which we had data on our criteria ($n = 27$, Table 2). We used several data sets to quantify these measurable attributes for each species, including the Partners in Flight (PIF) Species Assessment Database (Partners in Flight Science Committee, 2012); the Breeding Bird Survey (BBS; Sauer et al., 2017); and the Bird Conservancy's Integrated Monitoring in Bird Conservation Regions (IMBCR) program (Pavlacky et al., 2017), a US-based multiyear, large-scale avian monitoring program. The PIF database provides range size and population size based on BBS data, which we used to quantify the global population size and the proportion of a species' population within the region, defined as the North American Bird Conservation Initiatives' Prairie Potholes and Badlands and Prairies Bird Conservation Regions (i.e., BCRs 11 and 17). The PIF database also provides a qualitative, 1–5 score describing the potential threats to each species (Panjabi, Blancher, Dettmers, & Rosenberg, 2012); we used the breeding ground threat score to assess the potential for future declines within the NGP. The PIF database does not yet include shorebirds, so for

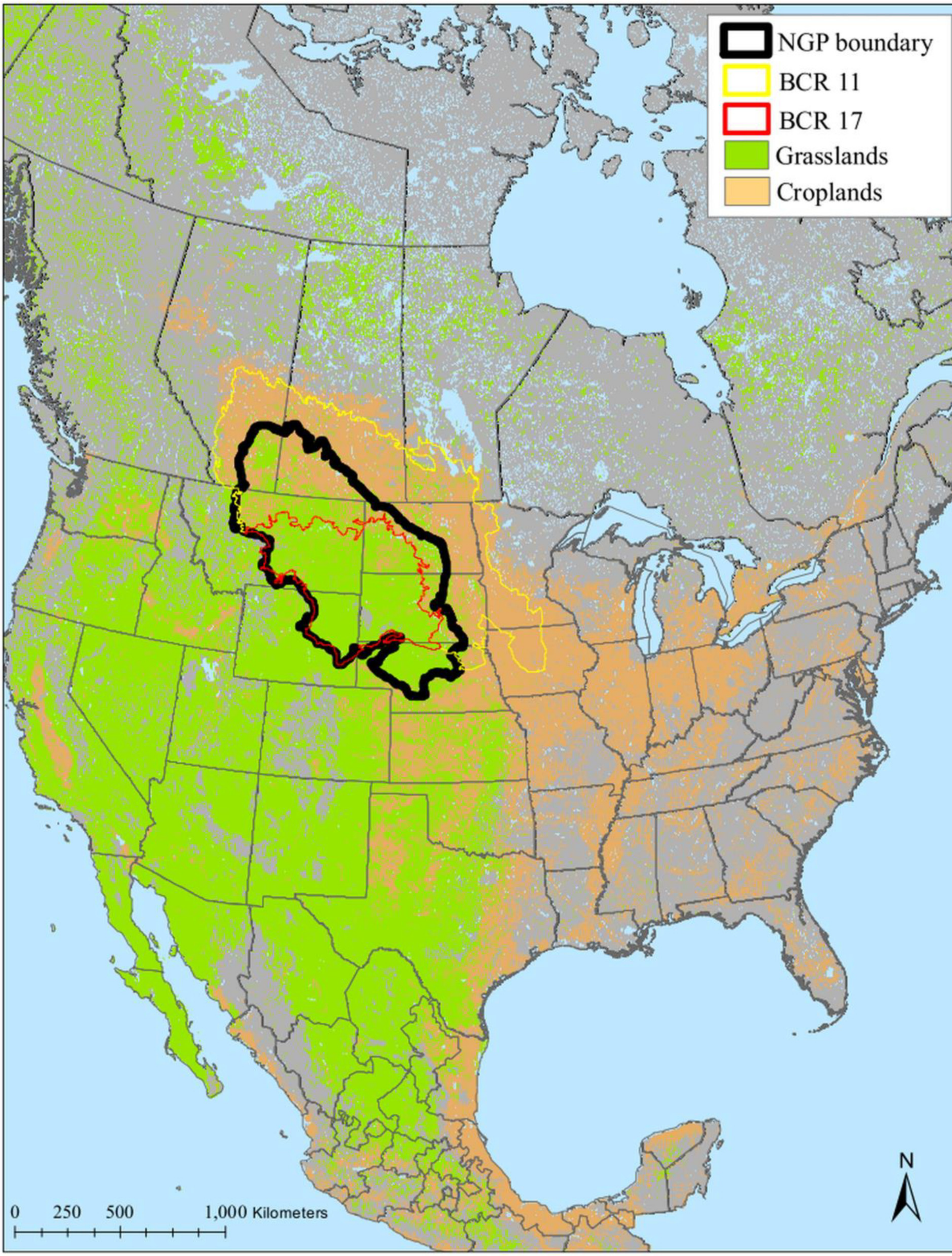

Fig. 1. Map of Northern Great Plains (NGP, black outline) study area in context of grassland (Gage et al., 2016) and cropland (Canada Center for Remote Sensing, 2013) landscapes of North America. Bird Conservation Regions (BCRs) are shown in red and yellow outline (11 and 17, respectively). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

the three shorebirds evaluated, we obtain estimates of these metrics from other sources (Table 1). We used survey-wide BBS trends from 1966 to 2013 to evaluate all species' trends (Sauer et al., 2017).

We developed metrics internally to measure attributes as identified by the working group when they were not readily available from an existing resource. To assess our ability to monitor each species, we averaged the coefficient of variation ($CV = \sigma/\mu$) in density estimates from 2010 to 2015 based on point count data across the NGP following

Table 1
Description of criteria and measurable attributes used to identify focal species for the Northern Great Plains ecosystem of the US. Prioritization function is the function we applied to each measurable attribute that resulted in the best score for that criterion.

Criterion	Measurable attribute	Prioritization function	Data source
Grassland specialization and diversity	Habitat requirements	Maximize	VerCauteren and Gillihan (2004)
Global breeding range size	Area (km^2) of breeding range	Minimize	PIF[a], BLI[b]
Global population size	Total breeding population size	Minimize	BBS[c], Andres and Stone (2009), Andres et al. (2012)
Population trend	BBS survey-wide trend, 1966–2013	Minimize	BBS
Threats to the breeding population	Threats to breeding, continental score	Maximize	PIF, Donaldson, Hyslop, Morrison, Dickson, and Davidson (2000), Brown, Hickey, Harrington, and Gill (2001)
Importance of NGP	Proportion of population in Bird Conservation Regions 11 and 17	Maximize	BBS
Ability to monitor	Mean coefficient of variation in density estimates	Minimize	IMBCR[d]
Stakeholder interest	Number of Species of Concern lists including the species of interest	Maximize	State, federal, and IUCN[e] reports
Ability to serve as umbrella species	Correlation in counts between species	Maximize	IMBCR
Ability to impact populations through management	Qualitative 1–5 score	Maximize	expert opinion
Landowner recognition	Qualitative 1–5 score	Maximize	expert opinion

[a] Partners in Flight Science Committee (2012).
[b] Bird Life International (2016).
[c] Breeding Bird Survey (Sauer et al., 2017).
[d] Integrated Monitoring in Bird Conservation Regions (Pavlacky et al., 2017).
[e] International Union for Conservation of Nature (2016).

standard sampling protocols from the IMBCR program (Pavlacky et al., 2017); we assume a lower CV indicates a greater ability to monitor that species. We quantified stakeholder interest by tallying the number of times each species was listed in US State Wildlife Action Plans, Canada's Species At Risk Act and Committee on the Status of Endangered Wildlife in Canada, US Forest Service Sensitive Species Region 1 and Region 2 lists, US Fish and Wildlife Service Birds of Conservation Concern, and the International Union for the Conservation of Nature Red List (International Union for Conservation of Nature, 2016); we assumed a larger score in this attribute reflected a greater stakeholder interest in the species.

We assessed the ability of each species to serve as an umbrella species for the other species in the analysis by calculating the Spearman correlation coefficients (ρ) for the counts of each species from the IMBCR data set for all 2-species combinations. Each species then received a score corresponding to the number of species with which it was positively correlated (i.e., $\rho \geq 0.33$), indicating species that were more often seen concurrently.

The working group identified landowner recognition as an important criterion in choosing priority species to help facilitate conservation action, interest, and impact on privately-owned land, which makes up much of the NGP. We developed a criterion to measure the ability of landowners to recognize a species by asking members of the working group to assign each species a score of landowner recognition, with a score of 1 representing no landowner recognition and no ability to impact, respectively, and a score of 5 representing high landowner recognition and a very high ability to impact the species. We took the mean of all responses to get a single landowner recognition score for each species.

NFWF has a broad focus in the NGP. It is, therefore, necessary for this organization to focus their resources on a subset of the taxa present in this area that use a wide variety of habitat conditions within the delineated area. Rather than attempt to monitor all grassland-obligate bird species, NFWF staff and the working group decided to focus on a manageable number of species for this analysis. We developed a metric to prioritize heterogeneity of habitat use within a priority species assemblage by identifying four vegetation types within grasslands of the NGP to represent the diversity of grassland vegetation in this area: 1) low herbaceous height, 2) moderate herbaceous height, 3) high herbaceous height, and 4) shrub cover. We assume that the use of these broad habitat categories by potential focal species also ensures some benefit to other species that also use this type of grasslands as habitat. We then calculated a score of habitat use within each of these defined vegetation types for each grassland bird species based on literature review of their habitat requirements (Table 4 in VerCauteren & Gillihan, 2004). VerCauteren and Gillihan defined the importance of each habitat component for each species as "used", "required", and "indicator species/required." We replaced these labels with numeric values of 1 ("used"), 2 ("required"), and 3 ("indicator species/required") for each species, respectively, and assigned unused habitat components a score of 0 for each species. For shrub cover, we only considered moderate and high shrub cover (i.e., > 1% cover at the species' territory scale) and used the same scoring system described above to reclassify the maximum value in those two categories.

After quantifying all criteria identified by the working group, we converted values for each criterion into a common scale (Table B1). We directly compared criteria to one another by rescaling values, with the "worst" and "best" values being rescaled to 0 and 1, respectively (Conroy & Peterson, 2013):

$$U_j = \frac{x_j - \text{worst}(x_j)}{\text{best}(x_j) - \text{worst}(x_j)}.$$

Here U_j is the rescaled score for species j, x_j is the measurement on the original scale, and worst(x_j) and best(x_j) are the least and most desired outcomes of the attribute over the range of that attribute's values. We used this method to rescale all criteria not already on a 0–1 scale. We rescaled all herbaceous height scores to sum to 1 for each species to calculate the relative importance of each category to the species of interest. We did not include shrub cover when we rescaled the other vegetation categories because any of the height categories could also have a shrub component. Therefore, a species could represent a height category and shrub cover simultaneously.

After scoring all criteria, the next step in the SDM process is to evaluate trade-offs between conflicting criteria. We asked all working group members to assign weights to each criterion reflecting their professionally informed value of the criterion in identifying a priority species, such that the weights sum to 1. We then took an average of the weights across working group participants to calculate final criteria weights (Table 2).

Because an ordinal scale may not be appropriate for representing the relative values of each habitat type to the species (Game, Kareiva, &

Table 2
Values of measurable attributes used to quantify criteria to identify focal grassland bird species in the Northern Great Plains (NGP). "Weight" indicates the relative importance of each criterion to the working group in determining a focal species. The weight for the habitat components was applied to the group habitat score when calculating overall group scores. Information on habitat requirements were not available for four species. Criteria included (measures of uncertainty included when possible): breeding range area (km^2); global population size; survey-wide Breeding Bird Survey (BBS) trend from 1966 to 2013 (95% credible interval in parentheses); Partners In Flight breeding ground threat score (Breeding threats); the proportion of the breeding population within the NGP (Prop. pop. in NGP); coefficient of variation of density estimates from the Bird Conservancy's Integrated Monitoring in Bird Conservation Regions (IMBCR) program (Density CV; standard deviation in parentheses); the number of state, federal, and International Union for Conservation of Nature species of concern lists on which the species is found (Number of SOC lists); the number of species with correlated IMBCR counts (Correlated species); expert opinion scores for the ability to impact the species through management (Ability to impact) and landowner recognition; and qualitative scores of the importance of low, moderate, and high herbaceous cover and shrub cover.

Common name	Scientific name	Breeding range (km^2)	Global population	BBS trend	Breeding threats
American Kestrel	*Falco sparverius*	24,137,348	4,000,000	−1.65 (−2.53, −1.22)	3
Baird's Sparrow	*Ammodramus bairdii*	827,483	2,000,000	−2.93 (−4.52, −1.31)	4
Bobolink	*Dolichonyx oryzivorus*	3,873,291	8,000,000	−2.04 (−3.07, −1.70)	3
Burrowing Owl	*Athene cunicularia*	14,203,527	2,000,000	−1.08 (−2.19, −0.22)	4
Chestnut−collared Longspur	*Calcarius ornatus*	797,094	3,000,000	−4.35 (−5.30, −3.33)	3
Common Nighthawk	*Chordeiles minor*	13,162,934	16,000,000	−2.06 (−7.16, −1.69)	3
Dickcissel	*Spiza americana*	3,458,339	20,000,000	−0.62 (−1.13, −0.20)	3
Ferruginous Hawk	*Buteo regalis*	2,435,600	80,000	0.73 (−0.20, 1.52)	4
Golden Eagle	*Aquila chrysaetos*	23,242,678	300,000	−0.12 (−1.00, 0.54)	3
Grasshopper Sparrow	*Ammodramus savannarum*	5,209,138	31,000,000	−2.83 (−3.76, −2.32)	3
Greater Sage-Grouse	*Centrocercus urophasianus*	1,407,633	150,000	−3.30 (−6.94, −0.71)	4
Horned Lark	*Eremophila alpestris*	20,824,080	120,000,000	−2.38 (−2.82, −1.92)	2
Lark Bunting	*Calamospiza melanocorys*	1,825,915	9,100,000	−4.10 (−6.16, −2.46)	3
Loggerhead Shrike	*Lanius ludovicianus*	8,849,539	5,800,000	−3.20 (−3.49, −2.91)	3
Long-billed Curlew	*Numenius americanus*	1,831,989	140,000	0.34 (−1.17, 1.20)	4
McCown's Longspur	*Rhynchophanes mccownii*	684,343	600,000	−6.18 (−8.90, −2.85)	3
Mountain Plover	*Charadrius montanus*	671,992	18,000	−3.11 (−7.82, −0.80)	4
Northern Harrier	*Circus cyaneus*	24,607,876	1,400,000	−1.21 (−1.74, −0.81)	3
Prairie Falcon	*Falco mexicanus*	3,793,485	80,000	0.80 (−0.27, 1.66)	3
Savannah Sparrow	*Passerculus sandwichensis*	13,727,335	180,000,000	−1.27 (−1.58, −0.97)	2
Sharp-tailed Grouse	*Tympanuchus phasianellus*	3,021,798	600,000	0.16 (−1.79, 1.67)	3
Short-eared Owl	*Asio flammeus*	62,415,997	3,000,000	−3.26 (−7.71, −1.11)	3
Sprague's Pipit	*Anthus spragueii*	1,157,665	900,000	−3.51 (−4.83, −2.34)	4
Swainson's Hawk	*Buteo swainsoni*	5,226,232	580,000	0.62 (0.20, 0.99)	3
Upland Sandpiper	*Bartramia longicauda*	3,283,142	750,000	0.49 (−0.02, 0.96)	2
Vesper Sparrow	*Pooecetes gramineus*	6,346,442	28,000,000	−0.89 (−1.24, −0.61)	3
Western Meadowlark	*Sturnella neglecta*	6,708,072	85,000,000	−1.30 (−1.59, −1.05)	3
Weight		**0.047**	**0.055**	**0.102**	**0.076**

Prop. Pop. In NGP	Density CV	Number of SOC lists	Correlated species	Ability to impact	Landowner recognition	Low herb	Mod herb	High herb	Shrub
0.06	0.49 (0.19)	1	0	3.0	3	–	–	–	–
1.00	0.36 (0.11)	8	6	3.7	1	0	2	3	1
0.43	0.36 (0.06)	4	4	4.0	3	0	2	2	0
0.02	1.03 (0.17)	9	0	4.0	4	2	1	1	0
0.97	0.35 (0.08)	10	7	2.3	1	1	3	1	0
0.07	0.45 (0.10)	2	0	1.7	3	–	–	–	–
0.09	0.87 (0.20)	4	0	3.7	2	0	2	2	0
0.48	1.14 (NA[a])	9	0	2.3	3	1	1	1	1
0.05	1.02 (0.18)	4	0	1.0	3	–	–	–	–
0.33	1.14 (NA)	4	8	3.7	1	0	1	3	1
0.26	0.14 (0.02)	9	0	4.0	4	2	3	3	3
0.18	0.18 (0.06)	0	8	1.7	2	3	1	0	1
0.59	0.22 (0.03)	2	4	2.7	3	3	1	1	3
0.10	0.49 (0.04)	7	0	2.0	2	2	1	0	2
0.33	0.55 (0.22)	9	1	2.3	4	2	2	1	0
0.60	0.59 (0.17)	8	0	2.7	1	3	0	0	0
0.08	1.06 (0.15)	9	0	3.7	2	3	1	0	1
0.20	0.44 (0.10)	2	2	2.0	2	1	1	2	0
0.12	1.14 (NA)	2	0	2.0	2	1	1	1	1
0.17	0.29 (0.08)	1	5	2.0	1	–	–	–	–
0.76	1.14 (NA)	3	1	4.0	4	2	2	2	1
0.03	0.42 (0.20)	7	0	2.7	3	0	2	1	1
0.96	0.89 (0.31)	9	1	2.7	1	2	2	0	0
0.34	0.69 (0.19)	2	1	3.0	3	1	1	1	1
0.84	0.33 (0.07)	3	3	2.0	3	2	2	2	1
0.50	0.12 (0.02)	0	0	1.7	1	2	2	1	2
0.38	0.07 (0.01)	0	4	1.7	3	0	3	2	1
0.157	**0.113**	**0.096**	**0.061**	**0.100**	**0.103**	**0.092**			

[a] NA means density estimates were not available for that species, and the maximum observed CV across species was assigned.

Possingham, 2013), we performed a sensitivity analysis to determine whether the relative values of habitat use influenced the top species group. In addition to equal weighting (i.e., use category 0 = score 0, 1 = 0.33, 2 = 0.67, 3 = 1), we also considered scenarios, where 1) indicator status received much more weight than other statuses (0 = 0, 1 = 0.1, 2 = 0.2, 3 = 1), 2) used and required statuses were more equally weighted (0 = 0, 1 = 0.45, 2 = 0.55, 3 = 1), 3) indicator and required statuses received substantially more weight (0 = 0, 1 = 0.1, 2 = 0.9, 3 = 1), and 4) any use was weighted substantially more than no use (0 = 0, 1 = 0.8, 2 = 0.9, 3 = 1). We then calculated overall scores as described above.

Finally, we combined the criteria scores and weights to evaluate how well different groups of species collectively met all the objectives identified at the beginning of the process. Species assemblage groups totaled five species, which NFWF determined as a manageable number for the purposes of supporting an ongoing monitoring effort. For each species, we multiplied non-habitat criteria scores, c, by their respective weights, w, and summed those values to get an overall score for each species, i,

$$s_i = \sum_{k=1}^{K} c_{ik} w_k$$

where c_{ik} and w_k are the species-specific rescaled score and weight for criterion k, respectively. We then evaluated each group of species to determine how well it represented a diversity of habitats. Group-specific scores, s_g, were calculated as

$$s_g = \sum_{i \epsilon g} s_i + 5 \times w \times \sum_{k=1}^{K} \max_{i \epsilon g} c_{ik},$$

where c_{ik} are the species-specific rescaled scores for all species in group, g, for habitat criterion, k, and w is the objective weight for habitat (i.e., 0.092, Table 2).

3. Results

The working group identified 11 evaluation criteria (Table 1. The importance of the NGP region to a species was assigned the most weight of any of the criteria by the working group (15.7%, Table 2), followed by ability to monitor (11.3%), landowner recognition (10.3%), population trend (10.2%), the ability to impact populations through conservation efforts (10.0%), stakeholder interest (9.6%), and diverse habitat representation (9.2%).

The 10 best species groups all included Baird's Sparrow, Chestnut-collared Longspur, Lark Bunting, and McCown's Longspur, with the fifth species differing across each grouping. The species assemblage that best balanced all criteria identified by the working group included these four species, as well as Sprague's Pipit (Table 3). The second-highest ranked assemblage included Bobolink (instead of Lark Bunting); the third-highest ranked assemblage included Long-billed Curlew, the fourth-highest included Sharp-tailed Grouse, and the fifth-highest included Burrowing Owl.

Results from the sensitivity analysis suggest that the optimal species group was mostly insensitive to changes in weights on habitat use (Table B2). As with equal weightings, the top groupings for all scenarios included Baird's Sparrow, Chestnut-collared Longspur, McCown's Longspur, and Lark Bunting. The fifth species in the top species group for each scenario included Grasshopper Sparrow (scenarios 1 and 3), Western Meadowlark (scenario 2), and Sprague's Pipit (scenario 4).

4. Discussion

In a world with declining natural resources and limited financial resources for conservation, prioritization of species and/or habitats is necessary to determine how to allocate conservation efforts. The usefulness of focal species to provide protection for other taxa is controversial (Carignan & Villard, 2002; Fleishman et al., 2001; Lindenmayer et al., 2002; Nicholson et al., 2013; Roberge & Angelstam, 2004); a multi-species strategy may, therefore, be necessary to provide representation of a variety of habitats or communities (Roberge & Angelstam, 2004). We provide a formal, structured approach to identify a suite of priority species that optimize the trade-offs among biological, social, and logistical objectives, while ensuring representation of a variety of species and habitats.

The top species assemblage identified by our SDM process represents a suite of grassland species that utilize a wide range of grassland types, from species found in short-grass vegetation (McCown's Longspur) to those that utilize taller vegetation (Baird's Sparrow) and shrubs (Lark Bunting). Baird's Sparrow had the second highest score in high herbaceous cover behind Grasshopper Sparrow, and scored higher in other heavily weighted criteria, such as the importance of the NGP to the species, and global population size. These non-habitat criteria outweighed the gain in habitat diversity, so Baird's Sparrow, rather than Grasshopper Sparrow, came out in the top 20 species groups. The

Table 3
Overall scores for the best 10 groups of five grassland bird species representing the ability of the group to balance the criteria identified by the working group. "Species combination" columns identify the species in each group and their respective scores, not including habitat criteria, are shown in the "Species overall score" columns. The "Group habitat score" quantifies the ability of each group to represent a diversity of grassland habitats. The "Group overall scores" combines all species overall scores and the group habitat score. Habitat use scores were equally weighted (i.e., use category 0 = score 0, 1 = 0.33, 2 = 0.67, 3 = 1). Species include: Baird's Sparrow, BAIS; Bobolink, BOBO; Burrowing Owl, BUOW; Chestnut-collared Longspur, CCLO; Ferruginous Hawk, FEHA; Grasshopper Sparrow, GRSP; Lark Bunting, LARB; Long-billed Curlew, LBCU; McCown's Longspur, MCLO; Mountain Plover, MOPL; Sprague's Pipit, SPPI; Sharp-tailed Grouse, STGR; Upland Sandpiper, UPSA; Western Meadowlark, WEME.

	Species combination					Species overall score						
Group	1	2	3	4	5	1	2	3	4	5	Group habitat score	Group overall score
1	BAIS	CCLO	LARB	MCLO	SPPI	0.684	0.651	0.567	0.535	0.566	3.20	4.176
2	BAIS	BOBO	CCLO	LARB	MCLO	0.684	0.544	0.651	0.567	0.535	3.20	4.154
3	BAIS	CCLO	LARB	LBCU	MCLO	0.684	0.651	0.567	0.538	0.535	3.20	4.149
4	BAIS	CCLO	LARB	MCLO	STGR	0.684	0.651	0.567	0.535	0.505	3.20	4.115
5	BAIS	BUOW	CCLO	LARB	MCLO	0.684	0.482	0.651	0.567	0.535	3.20	4.093
6	BAIS	CCLO	GRSP	LARB	MCLO	0.684	0.651	0.420	0.567	0.535	3.35	4.085
7	BAIS	CCLO	LARB	MCLO	UPSA	0.684	0.651	0.567	0.535	0.464	3.20	4.074
8	BAIS	CCLO	LARB	MCLO	MOPL	0.684	0.651	0.567	0.535	0.463	3.20	4.073
9	BAIS	CCLO	FEHA	LARB	MCLO	0.684	0.651	0.439	0.567	0.535	3.20	4.050
10	BAIS	CCLO	LARB	MCLO	WEME	0.684	0.651	0.567	0.535	0.437	3.20	4.047

high group habitat score for Baird's Sparrow, Chestnut-collared Longspur, Lark Bunting, and McCown's Longspur drove their inclusion in the top 10 species groups, with the fifth species varying based on their overall species scores (Table 3). This priority species group was robust to changes in the relative value of habitat use, with the top grouping for all scenarios including the same four species. This is intuitive because the each species was an indicator species for their respective habitats, and despite changing the values of habitat use, all four species remained the highest ranked species for their respective habitat (Table B2).

Other iconic species of the focal region, such as Long-billed Curlew, Mountain Plover, Ferruginous Hawk, and Burrowing Owl were not included in the top species group. These species did not perform as competitively because a smaller percentage of their populations are found in the region and their populations are fairly stable (Table 2). These species are also not well-monitored using the IMBCR point count survey protocols, which contributes to their lower species scores. Fortunately, Long-billed Curlew, Ferruginous Hawk, and Burrowing Owl utilize habitat very similar to Black-footed Ferrets (*Mustela nigripes*), a species prioritized in a different section the NGP business plan. These bird species will likely benefit from conservation actions directed towards this mammal species. Additionally, we did not consider Greater Prairie-Chicken in our analysis because very little of its range is contained within the NGP boundaries defined by NFWF and NFWF has addressed the specific needs of this species within the business plan.

Our SDM approach addresses many of the mistakes commonly made when setting conservation priorities (Game et al., 2013). The SDM process addresses a well-defined problem because objectives (i.e., criteria) are explicit and measurable and actions (i.e., funding allocation, selection of management actions) are well-defined. We attempted to remove the arbitrary nature of previous attempts at objectively identifying priority species (Beazley & Cardinal, 2004; Coppolillo et al., 2004) by including a comprehensive set of criteria thought to be important from all members of the working group using direct, measurable metrics of these criteria for each species. We also quantified the values of the working group explicitly by including the relative weights of each criterion in the priority species selection. While not all of these quantitative measures are exempt from subjectivity (i.e. expert opinion depends on the experts in question), the methods we present use the best available information to make decisions instead of allowing a lack of data to prohibit decisions from being made.

As with any decision process, our methods are one of many ways to achieve consensus with repeatable methods. Because all members of our working group shared the ultimate objective of bird conservation in the Northern Great Plains, the use of SDM methods to help clarify and identify sub-objectives and priority species based on those objectives was appropriate due to the relative similarity of viewpoints across participants. Conflict resolution or other, more general decision-making methods should be used when working group participants have contradicting, potentially inflammatory differences in the ultimate objective of the working group. Similarly, the quantitative selection methods described here work well in the context of a well-studied ecosystem in a westernized country with comparatively abundant resources available for supporting working group meetings and for resulting conservation effort on the ground. In situations where 1) relatively little is known about an ecosystem, and/or 2) there are relatively few resources available for conservation effort, an expert-opinion-based approach may be more appropriate, with later iterations of the process incorporating new information about conservation concern, resources, and ecological processes learned as a result of these initial efforts. The methods described in this paper can be used as a way to record and repeat the priority species selection process within our described context, and can be adapted and updated as additional quantifiable metrics are identified and prioritized within the working group to prioritize conservation actions for the species (e.g. McCarthy et al., 2010; Wilson, Carwardine, & Possingham, 2009).

Finally, while our methods outline a transparent, repeatable method for identification of a focal species assemblage in a relatively well-studied ecosystem, we recognize that both the selection of criteria and weighting of these criteria are based on human opinion and are, therefore, ultimately subjective. While this subjectivity is inherent in any SDM process, validation of our methods through observation of implemented conservation effort and the resulting effect on the selected species assemblage is a clear next step in evaluating this species selection process. Validation of our species selection was not possible in this case due to the extended timeline of implementing and measuring noticeable change on the ground after the focal assemblage was chosen; however, future research should attempt to better quantify the criteria used to select priority species, given adequate resources to do so. Given the need of NFWF to prioritize how they allocate financial resources, the SDM approach outlined here provides an objective framework for the prioritization process using available information, and this framework can be extended to optimize management actions so as to benefit these priority species. Study of the efficacy of these prioritization efforts through actual change on the ground is a necessary next step in the full assessment of the decision-making processes described in this paper.

5. Conclusions

The prioritization methods we developed and implemented here identified a species assemblage that serves as a single unit for prioritization (e.g., the grassland bird community) while concurrently identifying individual species available to monitor and track over time. This method avoids some of the major pitfalls inherent with the selection and use of the focal species concept but maintains the practical utility of monitoring a few discrete species instead of entire ecosystems. The SDM methods presented here provide a roadmap not only for prioritization of grassland bird species but also offer an objective, transparent, and repeatable method of selection for focal species in other ecosystems.

Competing interests

The authors declare that they have no competing interests.

Acknowledgement

This work was partially funded through a grant to Bird Conservancy of the Rockies from the National Fish and Wildlife Foundation (NFWF, Project # 0103.14.044195/44195) to support the development of a business plan for grassland birds in the Northern Great Plains.

Appendix A. Description of working group members' organizations and missions

The National Fish and Wildlife Foundation's is dedicated to achieving maximum conservation impact by developing and applying best practices and innovative methods for measurable outcomes to sustain, restore, and enhance the nation's fish, wildlife plants and habitats through leadership conservation investments with public and private partners, the foundation. Staff include Ian Davidson (director, Bird Biology and Conservation), Seth Gallagher (manager, Rocky Mountain Regional Programs), Chris West (director, Rocky Mountain Regional Office), and Annamarie Lopata (senior evaluation officer).

Bird Conservancy of the Rockies' mission is to conserve birds and their habitats through science, education and land stewardship. Staff include Adam Green (biometrician), Maureen Correll (landscape ecologist), Luke George (science director), David Pavlacky (biometrician), Laura Quattrini (stewardship program manager), Allison Shaw (GIS and data manager), Erin Strasser (avian ecologist), Tammy VerCauteren (executive director), and Arvind Panjabi (avian conservation scientist).

Northern Great Plains Joint Venture's mission is to seek out new opportunities and foster new partnerships while strengthening existing alliances for the protection, enhancement and restoration of prairie, riverine and forest ecosystems important to priority birds of the NGPJV. Staff include Daniel Casey (coordinator).

World Wildlife Fund's mission is to conserve nature and reduce the most pressing threats to the diversity of life on Earth. Staff include Kevin Ellison (grasslands ecologist).

Appendix B. Rescaled criteria scores and sensitivity analysis results

Table B1
Rescaled scores for measurable attributes used to identify focal species for the Northern Great Plains ecosystem of the US. A score of 0 represents the lowest value of that criterion for identifying a focal species, and a score of 1 represents the highest value.

Common name	Breeding range (km^2)	Global population	BBS trend	Breeding threats	Prop. Pop. In NGP	Density CV	Number of SOC lists	Correlated species	Ability to impact	Landowner recognition	Low herb	Mod herb	High herb	Shrub
American Kestrel	0.62	0.98	0.35	0.50	0.06	0.61	0.10	0.00	0.67	0.67	–	–	–	–
Baird's Sparrow	1.00	0.99	0.53	1.00	1.00	0.73	0.80	0.75	0.89	0.03	0.00	0.40	0.60	0.33
Bobolink	0.95	0.96	0.41	0.50	0.43	0.73	0.40	0.50	1.00	0.48	0.00	0.50	0.50	0.00
Burrowing Owl	0.78	0.99	0.27	1.00	0.02	0.10	0.90	0.00	1.00	0.85	0.50	0.25	0.25	0.00
Chestnut-collared Longspur	1.00	0.98	0.74	0.50	0.97	0.74	1.00	0.88	0.44	0.09	0.20	0.60	0.20	0.00
Common Nighthawk	0.80	0.91	0.41	0.50	0.07	0.65	0.20	0.00	0.22	0.45	–	–	–	–
Dickcissel	0.95	0.89	0.20	0.50	0.09	0.25	0.40	0.00	0.89	0.27	0.00	0.50	0.50	0.00
Ferruginous Hawk	0.97	1.00	0.01	1.00	0.48	0.00	0.90	0.00	0.44	0.55	0.33	0.33	0.33	0.33
Golden Eagle	0.63	1.00	0.13	0.50	0.05	0.11	0.40	0.00	0.00	0.73	–	–	–	–
Grasshopper Sparrow	0.93	0.83	0.52	0.50	0.33	0.00	0.40	1.00	0.89	0.00	0.00	0.25	0.75	0.33
Greater Sage-Grouse	0.99	1.00	0.59	1.00	0.26	0.00	0.90	0.00	1.00	1.00	0.25	0.38	0.38	1.00
Horned Lark	0.67	0.33	0.46	0.00	0.18	0.90	0.00	1.00	0.22	0.33	0.75	0.25	0.00	0.33
Lark Bunting	0.98	0.95	0.70	0.50	0.59	0.86	0.20	0.50	0.56	0.64	0.60	0.20	0.20	1.00
Loggerhead Shrike	0.87	0.97	0.57	0.50	0.10	0.55	0.70	0.00	0.33	0.42	0.67	0.33	0.00	0.67
Long-billed Curlew	0.98	1.00	0.07	1.00	0.33	0.61	0.90	0.13	0.44	0.94	0.40	0.40	0.20	0.00
McCown's Longspur	1.00	1.00	1.00	0.50	0.60	0.51	0.80	0.00	0.56	0.09	1.00	0.00	0.00	0.00
Mountain Plover	1.00	1.00	0.56	1.00	0.08	0.07	0.90	0.00	0.89	0.30	0.75	0.25	0.00	0.33
Northern Harrier	0.61	0.99	0.29	0.50	0.20	0.65	0.20	0.25	0.33	0.39	0.25	0.25	0.50	0.00
Prairie Falcon	0.95	1.00	0.00	0.50	0.12	0.00	0.20	0.00	0.33	0.42	0.33	0.33	0.33	0.33
Savannah Sparrow	0.79	0.00	0.30	0.00	0.17	0.79	0.10	0.63	0.33	0.00	–	–	–	–
Sharp-tailed Grouse	0.96	1.00	0.09	0.50	0.76	0.00	0.30	0.13	1.00	1.00	0.33	0.33	0.33	0.33
Short-eared Owl	0.00	0.98	0.58	0.50	0.03	0.00	0.70	0.00	0.56	0.48	0.00	0.67	0.33	0.33
Sprague's Pipit	0.99	1.00	0.62	1.00	0.96	0.23	0.90	0.13	0.56	0.00	0.50	0.50	0.00	0.00
Swainson's Hawk	0.93	1.00	0.03	0.50	0.34	0.42	0.20	0.13	0.67	0.52	0.33	0.33	0.33	0.33
Upland Sandpiper	0.96	1.00	0.04	0.00	0.84	0.75	0.30	0.38	0.33	0.58	0.33	0.33	0.33	0.33
Vesper Sparrow	0.91	0.85	0.24	0.50	0.50	0.95	0.00	0.00	0.22	0.03	0.40	0.40	0.20	0.67
Western Meadowlark	0.90	0.53	0.30	0.50	0.38	1.00	0.00	0.50	0.22	0.70	0.00	0.60	0.40	0.33

Table B2
Overall scores for the best 10 groups of five grassland bird species representing the ability of the group to balance the criteria identified by the working group under different scales for the value of habitat use. The "Group habitat score" quantifies the ability of each group to represent a diversity of grassland habitats. The "Group overall scores" combines all species overall scores and the group habitat score. Species abbreviations are show in Table 2.

Habitat use values					Species						
No use	Used	Required	Indicator/required	Group	1	2	3	4	5	Group habitat score	Group overall score
0.00	0.10	0.20	1.00	1	BAIS	CCLO	GRSP	LARB	MCLO	5.74	26.35
				2	CCLO	GRSP	LARB	MCLO	SPPI	5.74	26.24
				3	BOBO	CCLO	GRSP	LARB	MCLO	5.74	26.21
				4	CCLO	GRSP	LARB	LBCU	MCLO	5.74	26.21
				5	BAIS	CCLO	LARB	MCLO	SPPI	5.67	26.19
				6	CCLO	GRSP	LARB	MCLO	STGR	5.74	26.17
				7	BAIS	BOBO	CCLO	LARB	MCLO	5.67	26.17
				8	BAIS	CCLO	LARB	LBCU	MCLO	5.67	26.16
				9	BUOW	CCLO	GRSP	LARB	MCLO	5.74	26.15
				10	BAIS	GRSP	LARB	MCLO	WEME	5.74	26.14
0.00	0.10	0.90	1.00	1	BAIS	CCLO	GRSP	LARB	MCLO	5.74	26.35
				2	BAIS	GRSP	LARB	MCLO	SEOW	5.81	26.30
				3	CCLO	GRSP	LARB	MCLO	SEOW	5.81	26.27
				4	CCLO	GRSP	LARB	MCLO	SPPI	5.74	26.24
				5	BOBO	CCLO	GRSP	LARB	MCLO	5.74	26.21
				6	CCLO	GRSP	LARB	LBCU	MCLO	5.74	26.21
				7	GRSP	LARB	MCLO	SEOW	SPPI	5.81	26.19
				8	CCLO	GRSP	LARB	MCLO	STGR	5.74	26.17
				9	BOBO	GRSP	LARB	MCLO	SEOW	5.81	26.16
				10	GRSP	LARB	LBCU	MCLO	SEOW	5.81	26.16
0.00	0.45	0.55	1.00	1	BAIS	CCLO	LARB	MCLO	WEME	5.29	24.52
				2	BAIS	GRSP	LARB	MCLO	WEME	5.34	24.47
				3	CCLO	GRSP	LARB	MCLO	WEME	5.34	24.44
				4	BAIS	LARB	MCLO	SPPI	WEME	5.29	24.44
				5	BAIS	BOBO	LARB	MCLO	WEME	5.29	24.41
				6	BAIS	LARB	LBCU	MCLO	WEME	5.29	24.41
				7	BAIS	LARB	MCLO	STGR	WEME	5.29	24.37
				8	GRSP	LARB	MCLO	SPPI	WEME	5.34	24.35
				9	BAIS	BUOW	LARB	MCLO	WEME	5.29	24.35
				10	BAIS	LARB	MCLO	UPSA	WEME	5.29	24.33
0.00	0.80	0.90	1.00	1	BAIS	CCLO	LARB	MCLO	SPPI	5.03	23.57
				2	BAIS	CCLO	LARB	MCLO	WEME	5.05	23.55
				3	BAIS	BOBO	CCLO	LARB	MCLO	5.03	23.55
				4	BAIS	LARB	MCLO	SPPI	WEME	5.05	23.46
				5	BAIS	BOBO	LARB	MCLO	SPPI	5.03	23.46
				6	BAIS	GRSP	LARB	MCLO	SPPI	5.06	23.46
				7	BAIS	LARB	LBCU	MCLO	SPPI	5.03	23.46
				8	BAIS	CCLO	LARB	MCLO	SEOW	5.06	23.45
				9	BAIS	BOBO	LARB	MCLO	WEME	5.05	23.44
				10	BAIS	GRSP	LARB	MCLO	WEME	5.08	23.44

References

Andres, B. A., & Stone, K. L. (2009). *Conservation plan for the Mountain Plover (Charadrius montanus), version 1.0.* Massachusetts, USA: Manomet Center for Conservation Sciences.

Andres, B. A., Smith, P. A., Morrison, R. I. G., Gratto-Trevor, C. L., Brown, S. C., & Friis, C. A. (2012). Population estimates of North American shorebirds, 2012. *Wader Study Group Bulletin, 119*, 178–194.

Andres, B., Brown, S., Clay, R., Davidson, I., Donaldson, G., Golder, W., et al. (2015). *Atlantic flyway shorebird initiative: A business plan.* Washington, D.C., USA: National Fish and Wildlife Foundation.

Arponen, A., Moilanen, A., & Ferrier, S. (2008). A successful community-level strategy for conservation prioritization. *Journal of Applied Ecology, 45*, 1436–1445.

Axelrod, D. I. (1985). Rise of the grassland biome: Central North America. *Botanical Review, 51*, 163–201.

Beazley, K., & Cardinal, N. (2004). A systematic approach for selecting focal species for conservation in the forests of Nova Scotia and Maine. *Environmental Conservation, 31*, 91–101.

Bird Life International (2016). *Bird life international data zone.* Available from . (Accessed 7 June 2016) http://datazone.birdlife.org.

Bragg, T., & Hulbert, L. (1976). Woody plant invasion of unburned Kansas bluestem prairie. *Journal of Range Management, 29*, 19–24.

Briggs, J. M., Knapp, A. K., Blair, J. M., Heisler, J. L., Hoch, G. A., Lett, M. S., et al. (2005). An ecosystem in transition: Causes and consequences of the conversion of Mesic Grassland to Shrubland. *Bioscience, 55*, 243–254.

Brooks, T. M., Mittermeier, R. A., da Fonseca, G. A. B., Gerlach, J., Hoffman, M., Lamoreux, J. F., et al. (2006). Global biodiversity conservation priorities. *Science, 313*, 58–61.

Brookshire, E. N. G., & Weaver, T. (2015). Long-term decline in grassland productivity driven by increasing dryness. *Nature Communications, 6*, 7148.

Brown, S., Hickey, C., Harrington, B., & Gill, R. (2001). *The U.S. Shorebird Conservation Plan.* Massachusetts, USA: Manomet Center for Conservation Sciences.

Butchart, S. H. M., Walpole, M., Collen, B., van Strien, A., Scharlemann, J. P. W., Almond, R. E. A., et al. (2010). Global biodiversity: Indicators of recent declines. *Science, 328*, 1164–1168.

Canada Center for Remote Sensing (2013). *Land Cover of North America at 250 meters 1.0.* Ottawa, CA: Canada Center for Remote Sensing. (Accessed 11 November 2016) https://catalog.data.gov/dataset/2010-land-cover-of-north-america-at-250-meters.

Carignan, V., & Villard, M.-A. (2002). Selecting indicator species to monitor ecological integrity: A review. *Environmental Monitoring and Assessment, 78*, 45–61.

Conroy, M. J., & Peterson, J. T. (2013). *Decision making in natural resource management: A structured, adaptive approach.* Oxford, UK: John Wiley & Sons.

Coppolillo, P., Gomez, H., Maisels, F., & Wallace, R. (2004). Selection criteria for suites of landscape species as a basis for site-based conservation. *Biological Conservation, 115*, 419–430.

Diamond, J. M., Ashmole, N. P., & Purves, P. E. (1989). The present, past and future of human-caused extinctions and discussion. *Philosophical Transactions of the Royal Society B, 325*, 469–477.

Donaldson, G. M., Hyslop, C., Morrison, R. I. G., Dickson, H. L., & Davidson, I. (2000). *Canadian shorebird conservation plan.* Ottawa, ON, Canada: Canadian Wildlife Service Special Publication, Environment Canada.

Elliot, L., & Johnson, D. (2018). The Grasshopper Sparrow as an indicator species in tallgrass prairies. *Journal of Wildlife Management, 82*(5), 1074–1081.

Fleishman, E., Blair, R. B., & Murphy, D. D. (2001). Empirical validation of a method for umbrella species selection. *Ecological Applications, 11*, 1489–1501.
Gage, A. M., Olimb, S. K., & Nelson, J. (2016). Plowprint: Tracking cumulative cropland expansion to target grassland conservation. *Great Plains Research, 26*, 107–116.
Game, E. T., Kareiva, P., & Possingham, H. P. (2013). Six common mistakes in conservation priority setting. *Conservation Biology, 27*, 480–485.
Gorzo, J. M., Pidgeon, A. M., Thogmartin, W. E., Allstadt, A. J., Radeloff, V. C., Heglund, P. J., et al. (2016). Using the North American Breeding Bird Survey to assess broad-scale response of the continent's most imperiled avian community, grassland birds, to weather variability. *Condor, 118*, 502–512.
Hoekstra, J. M., Boucher, T. M., Ricketts, T. H., & Roberts, C. (2005). Confronting a biome crisis: Global disparities of habitat loss and protection. *Ecology Letters, 8*, 23–29.
International Union for Conservation of Nature (2016). *The IUCN red list of threatened species. Version 2016-3.* (Accessed 11 November 2016) http://www.iucnredlist.org.
Kukkala, A. S., & Moilanen, A. (2013). Core concepts of spatial prioritisation in systematic conservation planning. *Biological Reviews of the Cambridge Philosophical Society, 88*, 443–464.
Lambeck, R. J. (1997). Focal species: A multi-species umbrella for nature conservation. *Conservation Biology, 11*, 849–856.
Lindenmayer, D. B., Manning, A. D., Smith, P. L., Possingham, H. P., Fischer, J., Oliver, I., et al. (2002). The focal-species approach and landscape restoration: A critique. *Conservation Biology, 16*, 338–345.
Lindenmayer, D. B., Pierson, J., Barton, P., Beger, M., Branquinho, C., Calhoun, A., et al. (2015). A new framework for selecting environmental surrogates. *Science of the Total Environment, 538*, 1029–1038.
Lyons, J. E., Runge, M. C., Laskowski, H. P., & Kendall, W. L. (2008). Monitoring in the context of structured decision-making and adaptive management. *Journal of Wildlife Management, 72*, 1683–1692.
McCarthy, M. A., Thompson, C. J., Hauser, C., Burgman, M. A., Possingham, H. P., Moir, M. L., et al. (2010). Resource allocation for efficient environmental management. *Ecology Letters, 13*, 1280–1289.
Nichols, J. D., & Williams, B. K. (2006). Monitoring for conservation. *Trends in Ecology and Evolution, 21*, 668–673.
Nicholson, E., & Possingham, H. P. (2006). Objectives for multiple-species conservation planning. *Conservation Biology, 20*, 871–881.
Nicholson, E., Lindenmayer, D. B., Frank, K., & Possingham, H. P. (2013). Testing the focal species approach to making conservation decisions for species persistence. *Diversity & Distributions, 19*, 530–540.
Panjabi, A. O., Blancher, P. J., Dettmers, R., & Rosenberg, K. V. (2012). *Partners in flight technical series No. 3.* Brighton, Colorado: Rocky Mountain Bird Observatory.
Partners in Flight Science Committee (2012). *Species assessment database, version 2012.* Available from . (Accessed 20 July 2016) http://rmbo.org/pifassessment.
Pavlacky, D. C., Lukacs, P. M., Blakesley, J. A., Skorkowsky, C., Klute, D. S., Hahn, B. A., et al. (2017). A statistically rigorous sampling design to integrate avian monitoring and management within Bird Conservation Regions. *PLoS One, 12*, 1–22.
Pool, D. B., Panjabi, A. O., Macias-Duarte, A., & Solhjem, D. M. (2014). Rapid expansion of croplands in Chihuahua, Mexico threatens declining North American grassland bird species. *Biological Conservation, 170*, 274–281.
Regan, H. M., Hierl, L. A., Franklin, J., Deutschman, D. H., Schmalbach, H. L., Winchell, C. S., et al. (2008). Species prioritization for monitoring and management in regional multiple species conservation plans. *Diversity & Distributions, 14*, 462–471.
Roberge, J.-M., & Angelstam, P. (2004). Usefulness of the umbrella species concept as a conservation tool. *Conservation Biology, 18*, 76–85.
Sauer, J. R., Niven, D. K., Hines, J. E., Ziolkowski, D. J., Jr, Pardieck, K. L., Fallon, J. E., et al. (2017). *The North American Breeding Bird Survey, results and analysis 1966–2015. Version 02.07.2017.* Laurel, Maryland: USGS Patuxent Wildlife Research Center.
VerCauteren, T., & Gillihan, S. W. (2004). *Integrating bird conservation into range management.* Brighton, Colorado: Rocky Mountain Bird Observatory.
Williams, B. K., Nichols, J. D., & Conroy, M. J. (2002). *Analysis and management of animal populations.* San Diego, California: Academic Press.
Wilson, K. A., Carwardine, J., & Possingham, H. P. (2009). Setting conservation priorities. *Annals of the New York Academy of Sciences, 1162*, 237–264.
World Wildlife Fund (2017). *The plowprint report*Bozeman, Montana: World Wildlife Fund, Northern Great Plains Program.