DISSERTATION

ECOLOGICAL AND SOCIAL CONSEQUENCES OF COLLABORATIVE BISON REINTRODUCTION IN THE WESTERN U.S.

Submitted by

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ABSTRACT

ECOLOGICAL AND SOCIAL CONSEQUENCES OF COLLABORATIVE BISON REINTRODUCTION IN THE WESTERN U.S.

Collaborative conservation has been underway for centuries in diverse communities across the globe. More recently, collaborative groups of private and public land managers have coalesced around common natural resource objectives in the United States. This dissertation advances the science and practice of collaborative conservation through a literature review and two highly collaborative projects on bison reintroduction in the western United States. My specific objectives are: 1) To evaluate the status and impact of collaborative conservation groups in the United States; 2) To assess the ecological consequences of bison reintroduction for birds, mammals, and plants in Colorado's shortgrass prairie; 3) To understand how bison reintroduction affects human connections to grassland landscapes; and 4) To compare the effects of bison and cattle grazing on birds and plants in Colorado and New Mexico.

To evaluate the status of U.S.-based collaborative conservation groups, I conducted a literature review to identify what factors motivate group formation, and to quantify biophysical, social, and economic goals, actions to achieve those goals and outcomes, and how outcomes were assessed. I also characterized the geographic distribution, participants and funding sources of U.S.-based collaborative conservation groups. To accomplish these objectives, I searched for peer-reviewed journal articles, book chapters, and reports in online databases, resulting in 174 papers that described 257 collaborative conservation groups in all 50 states. Overall, information on outcomes and how groups assessed outcomes was sparse. For those groups with published outcomes, most outcomes had positive results for biophysical, social, and economic goals.

To assess the ecological consequences of species reintroduction and how reintroductions may catalyze public engagement in grassland conservation, I assessed both the ecological and social effects of bison reintroduction to northern Colorado. Specifically, I explored the effect of bison reintroduction on: 1) bird density and habitat use, 2) mammal habitat use, 3) vegetation composition and structure, and 4) human connections (place attachment) to a shortgrass prairie. To measure ecological responses, I surveyed birds, mammals, and plants before and after bison reintroduction. To understand how bison shape visitor connections to grasslands, I gave structured surveys to people who visited the site before and after bison reintroduction. I found few short-term effects of bison on grassland birds, mammals, and plants. However, I measured a significant increase in place attachment to the grassland site post reintroduction. These results suggest that bison reintroduction does not have strong, short-term ecological effects, but does have immediate, positive benefits for connecting people to ecosystems. I recommend that future projects prioritize monitoring ecological and social outcomes to advance the science and practice of bison reintroduction.

To understand whether non-native species can serve as proxies for extinct or rare native species, I evaluated the role of bison and cattle grazing in shaping habitat for grassland birds and plants. To compare ecological responses, I surveyed birds and plants between bison, cattle, and reference sites in Colorado and New Mexico. While I found few differences in plant height and cover among bison, cattle, and reference sites, I did find significant differences in bird densities among the sites. In both Colorado and New Mexico, some grassland obligate birds preferred bison sites, while others preferred cattle sites. Bison and cattle may serve as reciprocal ecological surrogates in cases where they have similar densities on the landscape, where cattle graze on a rotational system.

Overall, my dissertation demonstrates that collaborative conservation often achieves success, but these outcomes are not always assessed or reported. I also show that a highly collaborative bison reintroduction effort in Colorado had few ecological effects in the short-term, but did help connect people to a grassland landscape. In addition, my study found that collaboratively managed bison and cattle herds in Colorado and New Mexico create viable habitat for obligate grassland birds.

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PREFACE

Each individual chapter in this dissertation is intended for publication as an article in a peer-reviewed journal. Therefore, formatting, language and tense may differ between chapters. All articles have at least one co-author, thus I use the plural pronoun “we” throughout. The titles and full authorship for each chapter/manuscript are listed below.

Chapter 1: Goals, activities, and outcomes of collaborative conservation groups in the United States

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Chapter 3: Ecological replacements? Effects of bison and cattle grazing on bird and plant communities in shortgrass prairie

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CHAPTER ONE: GOALS, ACTIVITIES, AND OUTCOMES OF COLLABORATIVE CONSERVATION GROUPS IN THE UNITED STATES

INTRODUCTION

Collaborative conservation is as an important tool for reducing conflict and for helping groups achieve common environmental, social, and economic goals (Conley & Moote 2003). Often synonymous with other terms, such as community-based or collaborative natural resource management, we define collaborative conservation based on the work of Margerum (2008) as a process that unites diverse stakeholders to collectively manage natural resources with the goal of enabling people and places to thrive now and in the future. When diverse public and private stakeholders collaborate on environmental issues, the solutions that emerge can be more effective, innovative, and longer-lasting (McKinney & Harmon 2004). In contrast, environmental problems addressed only through centralized, government-led efforts are more difficult to resolve, and can foster mistrust for government institutions charged with managing natural resources (Koontz & Thomas 2006).

While many scientists enumerate the benefits of collaborative conservation, others have raised concern about the amount of time and money invested in these collaborations (Kenney 2000) and the lack of evidence that they lead to better outcomes (Conley & Moote 2003). Success stories include the local recovery of African elephants due to community-based natural resource management practices (Getz et al. 1999). In addition, collaborative groups in the western United States have been successful in partnering with a variety of stakeholders to create management plans for declining Sage Grouse populations (Belton & Jackson-Smith 2010). The success of these working groups has been attributed to the presence of an unbiased mediator for leading meetings, the equal distribution of responsibilities among all involved stakeholders, and achieving success early-on in the collaborative process (Belton & Jackson-Smith 2010). In contrast, when there is an imbalance of power among stakeholders and group goals are not clearly defined, collaborations can fail, such as the attempt to manage pronghorn on natural gas fields in Wyoming (Kretser et al. 2018). In addition, collaborative groups may not incorporate the full range of perspectives needed to address an environmental issue, such as the lack of women involved with community forest groups (Agarwal 2000). Without these diverse perspectives, ideas about group success may be misguided and could hinder the long-term viability of collaborative groups (Agarwal 2000).

Most previous work on collaborative conservation groups has focused on groups and projects in developing countries (Getz et al. 1999; Turner 1999; Agarwal 2000). The only comprehensive literature review of collaborative conservation in the United States provides an overview of theoretical papers on the topic (Conley et al. 2001). Other literature assessing U.S.-based collaborative conservation groups focuses on a single species (e.g. Sage Grouse conservation, Belton & Jackson-Smith 2010), region (e.g. collaborative groups in the west, Brick et al. 2001) or process (e.g. comparing governance structures, Gerlak & Heikkila 2006). Several groups (e.g. Malpai Borderlands, Sage Grouse Initiative) have received much attention (Weber 2000; Brogden & Greenberg 2003; Belton & Jackson-Smith 2010; Meretsky et al. 2012), yet a comprehensive review of the goals, activities and outcomes of collaborative groups across the United States is lacking. As such, little is known about the number and distribution of groups, group membership, nor whether collaboration natural resource management is achieving conservation success (Conley & Moote 2003; Koontz & Thomas 2006).

To address this gap, we conducted a systematic literature review of collaborative conservation groups throughout the U.S. The objectives of this review were to: 1) quantify motivations for group formation, goals, actions to achieve those goals, outcomes, and how outcomes were assessed; 2) identify whether these goals, actions, and outcomes were more likely to be biophysical, social, and/or economic; and, 3) characterize the geographic distribution, types of participants, and funding sources of U.S. collaborative conservation groups. By synthesizing existing knowledge on the characteristics and practices of U.S.-based collaborative conservation groups, we provide an important resource to current and emerging collaborative groups, and we identify priorities for future inquiry and recommendations for practice.

METHODS

We conducted a systematic literature review following the approach outlined in Pickering et al. (2014). We first defined our topic and research questions, and then we developed our list of search terms (keywords) by drawing on the collective expertise of the authors. Our final list included 36 terms related to collaborative conservation and 55 terms for geographic location (Appendix 1). Collaborative conservation terms included phrases such as "community led collaboration" and "collaborative ecosystem management", while geographic terms included all 50 states and variations for abbreviations of United States of America. We then formulated a relevant list of search engines (Academic Search Premier, Aquatic Sciences and Fisheries Abstracts, CAB Abstracts, Google Scholar, Web of Science, EBSCO's Wildlife and Ecology Studies Worldwide, WorldCat, and ProQuest's Environmental Science and Pollution Management Index, PAIS Index, and Zoological Records Plus) and Boolean search strings (Boland et al. 2014), which used combinations of our terms for collaborative conservation and geographic location (Appendix 1). Four reviewers then searched for peer-reviewed journal articles, book chapters, and reports (non-profit or government) in the search engines (split among the group) using all Boolean search strings. For Google Scholar, which often returned thousands of results, we imported the first 200 sources sorted by relevance (Haddaway et al. 2015).

We compiled all documents (n=10,158) obtained from this initial search and uploaded them to EndNote Web. We used the automatic duplicate deletion feature in EndNote Web, which resulted in 7,644 documents. We then manually screened titles (Boland et al., 2014) and deleted papers with titles that: 1) indicated the document was a thesis, dissertation, school project report, flyer, conference proceeding or abstract, forum proceeding, hearing, news article, press release, website, grant application, meeting note, or an entire book; 2) clearly stated that the study occurred outside the United States (we did not delete documents if the title contained the United States and another country's name in the title); 3) indicated that the paper focused on medicine, health care, housing, or business not related to the environment; or 4) were statistical, spatial modelling or methods-focused papers (unless they referenced any collaborative term in the title).

We then conducted an abstract screening on the remaining 4,800 documents. To screen abstracts, we again applied the above criteria and added the following two criteria in the event that an abstract mentioned a potential collaborative group: 1) stakeholder diversity and 2) duration. For stakeholder diversity, groups needed to contain three or more participants (Margerum 2008) and for duration, a group needed to exist for more than two years (Plummer & Fitzgibbon 2004). If this information was vague or not available in the abstract, then we erred on the side of caution and accepted the abstract. Before dividing the 4,800 documents among the four reviewers for the abstract screening, we performed an interrater reliability analysis using the Kappa statistic (Hallgren, 2012). All reviewers performed a group abstract screening on the same 30 papers until we reached substantial agreement (0.61-0.80; Hallgren 2012). Our Kappa statistic of 0.80 (p= 0.462) indicated that our scores were not significantly different from one another, so we proceeded to divide the documents among the reviewers to screen abstracts individually.

We then began our search for information on collaborative conservation groups among the remaining 1,051 documents. For a group to be considered collaborative, we established the following inclusion criteria: 1) U.S.-based (excluded U.S. groups that collaborate across international borders), 2) Stakeholder diversity (three or more stakeholders), 3) Involvement of at least one non-governmental entity, 5) Duration (have existed for 3 years or more), 5) Purpose (must be focused on conservation, policy, or management related to the environment), and 6) the group itself is not a public entity (e.g. state or local government, department, agency, or special purpose district; Appendix 1). If the document did not provide enough information on group characteristics, we would verify that the group met our criteria by reading the "About Us" (or equivalent) section of the group's website. If we could not verify that a group met our criteria either in the document or online, then the group was excluded.

We distributed the 1,051 documents among four reviewers after we reached substantial agreement (K= 0.78; p= 0.98) using the same interrater reliability analysis described previously. During this phase, reviewers applied the inclusion criteria and, for groups that met these criteria, collected information on group characteristics, including: geographic location, types of participants (e.g., federal government, non-governmental organization/non-profit, and individual/citizen; Appendix 1), and which type of participant initiated the group. After this screening, we retained 174 papers. A single reviewer (K. Wilkins) then extracted information on primary funding sources for groups, motivations that drove group formation, as well as goals, actions, outcomes, and how outcomes were evaluated, and identified whether each of these goals, actions and outcomes were biophysical, economic and/or social.

We present summary statistics on the numbers of groups in each state, the top five participant types responsible for group formation, and the primary funders for these groups. Groups often had multiple members from a particular participant type. For example, the U.S. Fish and Wildlife Service and the National Park Service are associated with the same participant type (e.g., "federal government") and individuals from both agencies might serve in the same group. Thus, we tallied the frequency with which group participant types appeared across all groups. We also report the percent of collaborative groups that have a biophysical, social, and/or economic focus for their motivations, goals, actions, and outcomes, and report the proportion of groups reporting positive, negative or neutral outcomes relative to their stated goals. To identify gaps in the literature, we report the number and percent of groups that report geographic location, types of participants, who initiated the group, funding sources, motivations, goals, actions, and outcomes, and evaluations of success.

RESULTS

We identified 174 papers describing 257 collaborative conservation groups that met our criteria for inclusion (Appendix 1). The collaborative groups or initiatives reported on most frequently (these groups collectively were discussed in 13% of the papers) included the Chesapeake Bay Program (Massachusetts), the Public Lands Partnership (Colorado), and the Quincy Library Group (California). Most papers (79%) reported the geographic location for at least one group. We found collaborative groups in all 50 states and the District of Columbia (Figure 1.1). The highest concentrations of groups were located in the western United States, but groups were also prevalent in Massachusetts, Pennsylvania, and Florida.

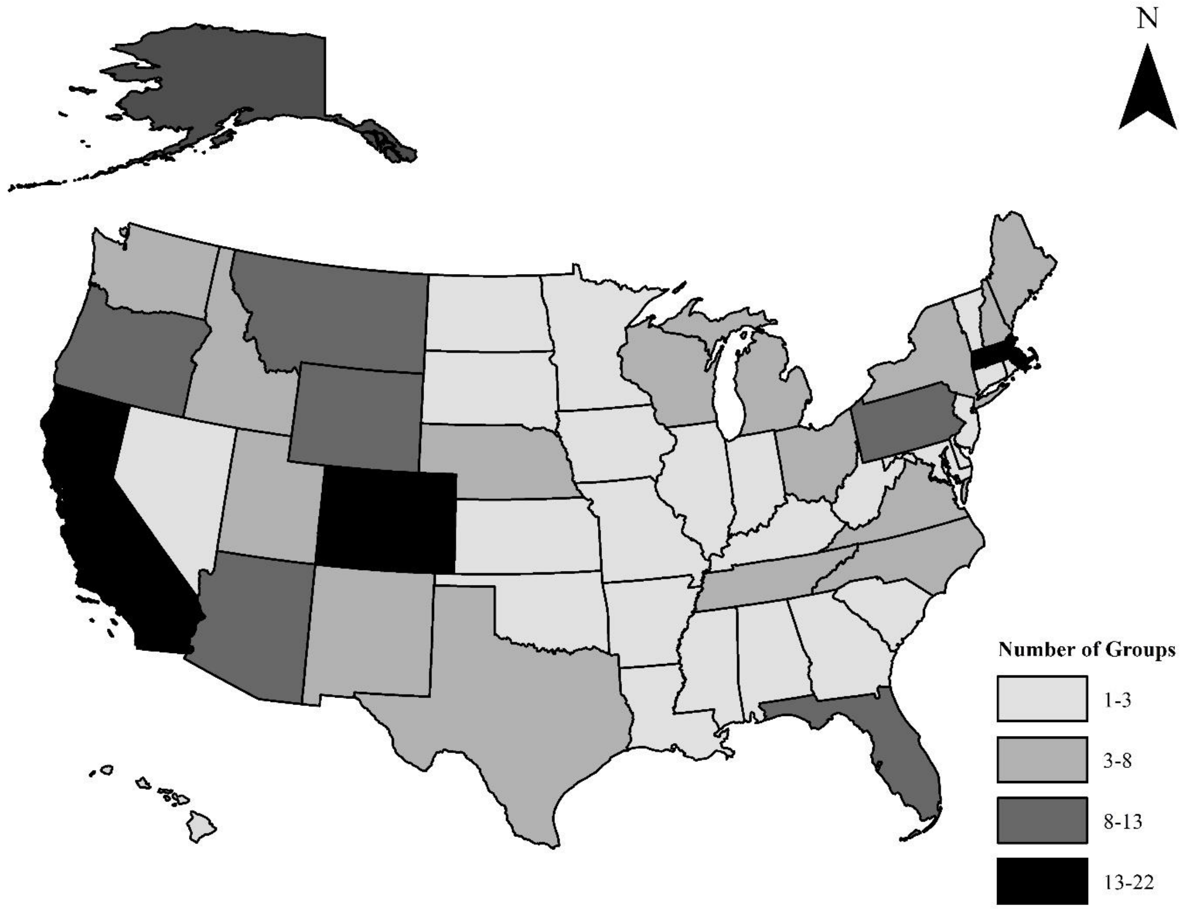

Figure 1.1. Geographic distribution of collaborative conservation groups in the United States.

Initiators, participants, and funders- The individuals or organizations responsible for initiating collaborative groups were reported for 48 groups (19%). Of these 48 groups, the top five initiators included the federal government (56%), state governments (25%), individuals or communities (19%), industry (10%), and county government (8%). The literature described participants for 107 groups (42%). The top six participant types (Figure 1.2) based on the number of groups (n=107) with information on participants, included state government (55%), federal government (51%), higher education (29%), local government and non-profits (both 23%), and individuals (21%). The top five federal agencies included the U.S. Fish and Wildlife Service, National Oceanic and Atmospheric Administration, U.S. Forest

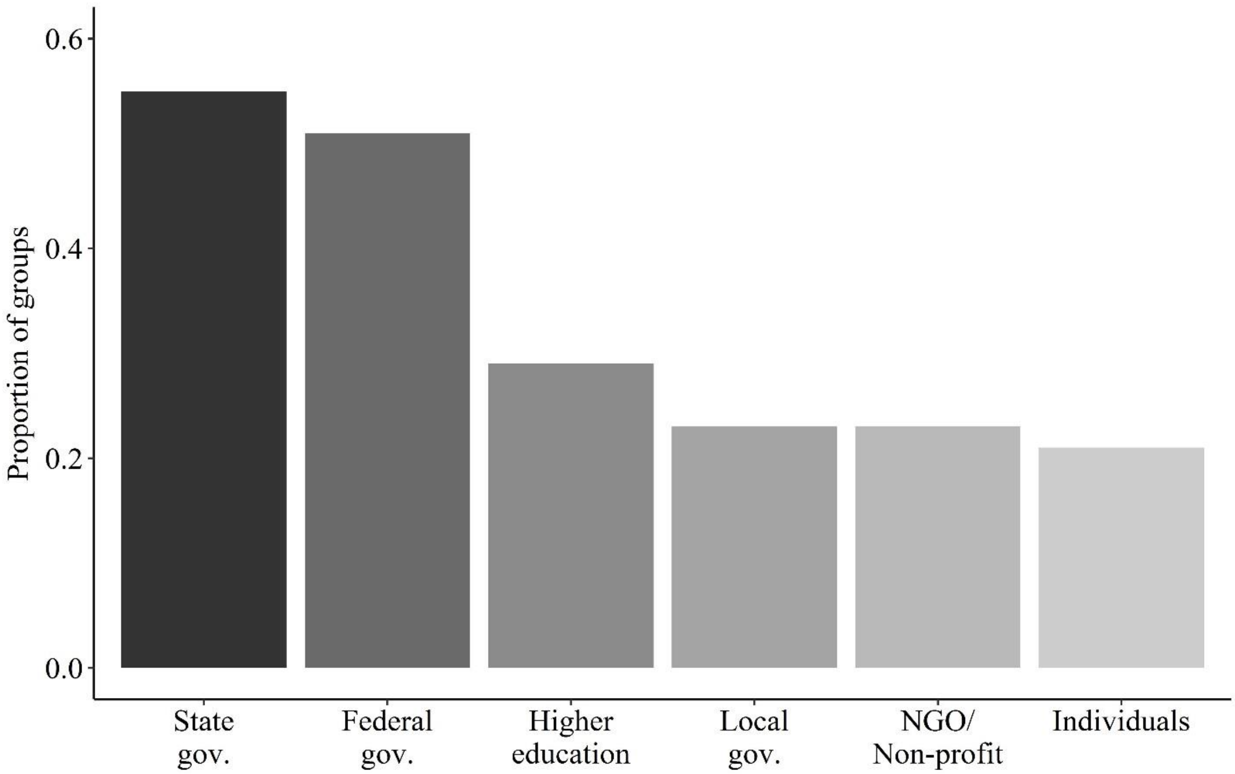

Figure 1.2. Percent of collaborative conservation groups (n = 107) containing at least one member of various participant types.

Service, Natural Resource Conservation Service, and the U.S. Geological Survey. The main non-profit or non-governmental organization included the Nature Conservancy. Sources of funding were reported for 18 groups and included the federal government (50%), state governments (28%) and non-profit organizations (28%).

Motivations – The literature described motivations for group formation for 45 groups (18%). The top motivations for those 45 groups included concerns for endangered, threatened, or declining flora or fauna species (18%), watershed health or water quality concerns (13%), natural or human-caused disasters (13%), ecosystem degradation or loss (11%), and concerns over landscape/habitat management.

Goals – Group goals were described for 38% (n=102) of the collaborative groups, with 10% of groups stating more than one goal. Biophysical goals were identified most frequently (n=69 groups), 21 groups had both biophysical and social goals, and 12 groups had biophysical, social, and economic goals. The most common biophysical goal included management or preservation of habitats, species, or ecosystems. Common social goals involved building or maintaining the trust, support, or engagement of stakeholders, and economic goals included improving or protecting livelihoods (Table 1.1).

Actions- Actions taken to achieve goals were reported for 32% (n=82 groups) of groups. For groups with actions listed, the most common biophysical actions included monitoring biophysical metrics (34%) and developing a project plan or proposal (30%). The most prevalent social actions included education and outreach (22%), convening meetings or workshops (9%), and empowering stakeholders to make management decisions (5%). Only 3% of groups were described as implementing economic actions, with the main action involving facilitating outdoor recreation and tourism (2%).

Assessment- Formal processes to evaluate whether actions were successful in achieving goals were published for 23 groups (9%). Of the groups that listed goals (n=102), 19% had information on assessments. For groups with assessments reported, success of biophysical goals were measured through stakeholder interviews or surveys (48%), ecological monitoring (35%), and document analyses (30%). Progress towards social goals was assessed through interviews and surveys (30%) and no group quantitatively assessed economic outcomes. The authors of the papers most often performed the biophysical assessments (74%), with fewer assessments performed by authors working with collaborative group members (9%). Social assessments were performed by the authors of the paper (30%) and authors working with collaborative group members (17%).

Table 1.1. Biophysical, social and economic goals, actions, and outcomes most frequently reported for collaborative conservation groups (number of groups in parentheses) in the United States.

Goal (n=102 groups)	Action (n=82 groups)	Outcomes (n=29 groups)
	Biophysical	
Manage landscapes or species, and/or natural resources (23)	Monitored biophysical metrics (28)	Facilitated management (10)
Restore habitat, species, watersheds, and/or ecosystems (16)	Developed a plan or proposal (25)	Improved outlook for endangered/threatened/declining species (9)
Monitor and/or assess environmental metrics (14)	Convened a meeting or workshop to advance biophysical goals (10)	Protected landscapes or marine areas (8)
Advise and/or support a group or project (7)	Informed/advised a group or project (8)	Restored habitat (7)
Improve water quality (7)	Engaged stakeholders in conservation actions (3)	Improved water quality (5)
	Social	
Build or maintain stakeholder trust/engagement/support (10)	Education and outreach (18)	Increased stakeholder trust/engagement/support (17)
Increase collaboration (9)	Convened a meeting or workshop to advance social goals (7)	Failed to increase stakeholder trust/engagement/support (2)
Monitor and/or assess socioeconomic metrics (4)	Empowered stakeholders to make decisions (4)	Decreased human-wildlife conflicts (2)
Improve quality of life (3)	Wrote grants (2)	Increased public access to open space (1)
Increase awareness (3)	Increased collaboration (2)	
	Economic	
Improve or protect livelihoods (11)	Facilitated outdoor recreation and tourism (2)	Improved the local economy/industry (5)
Monitor and/or assess socioeconomic metrics (4)	Education and outreach (1)	Decline in local economy/industry (3)
Advise and/or support a group or project (2)	Supported livelihoods (1)	
Promote sustainable development and/or ecotourism (2)	Wrote grants (1)	

Outcomes- Whether groups were successful in achieving their goals was reported for 29 groups (11%). For groups with information on outcomes, 90% reported biophysical outcomes, 52% reported social outcomes, and 21% reported economic outcomes. Approximately half of these groups (n=13) reported more than one outcome, resulting in a total of 61 biophysical, 21 social, and 8 economic outcomes. The literature reported mostly positive results (Figure 1.3) for these outcomes, which included facilitating management of landscapes or species (biophysical), increasing stakeholder trust and engagement (social), and improving local economies (economic; Table 1.1).

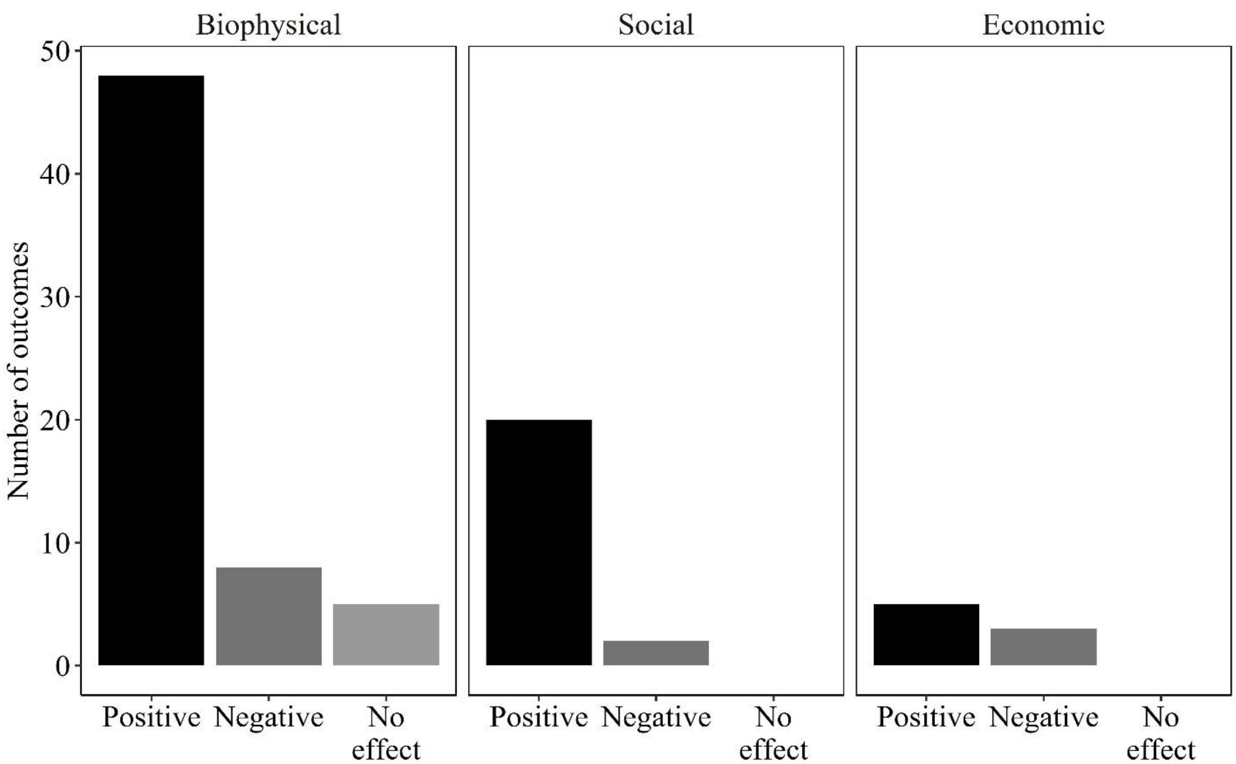

Figure 1.3. The number of biophysical (n=61), social (n=21), and economic (n=8) outcomes that the literature cited as positive (black), negative (dark gray), or no effect (light gray).

DISCUSSION

This review is the first nation-wide synthesis of published information on the status, motivations, activities and outcomes of collaborative conservation groups in the United States. We find that these groups are widespread, occurring in all fifty states, but are disproportionally clustered in the western U.S. The federal government frequently initiated the formation of these groups and provided the main source of funding, yet group participants are diverse and often include representatives from state and local government, and non-profit organizations. Most groups formed to address concerns over endangered, threatened, or declining flora and fauna species. Groups often focused on biophysical goals, actions, and outcomes, with fewer groups specifying social and economic goals and activities. To assess whether goals were achieved, the majority of groups used surveys or interviews of collaborative group members rather than biophysical metrics, and group members were usually not active participants in these assessments. Knowledge gaps that emerged from this review include motivations for group formation, social and economic dimensions of collaborative conservation, and outcomes assessments.

The concentration of collaborative groups in the western U.S. could be associated with the strong role of government agencies in facilitating and funding these groups (Koontz & Johnson 2004). In the western U.S., an average of 46% of the land is owned by the federal government, compared to 5% in the eastern U.S. (Vincent et al. 2017). Landscapes with a mosaic of ownership types may be more likely to benefit from cross-boundary public-private partnerships focused on natural resource issues. We found that most groups were motivated to form due to concerns about endangered, threatened, or declining flora or fauna species. Government agencies may be more likely to initiate and fund groups in places where private rural lands provide critical habitat and thus are subject to the federal Endangered Species Act (Koontz & Johnson 2004).

We found sparse information on outcomes assessment for most collaborative groups. This finding is consistent with a 10-year-old review (Koontz & Thomas 2006), suggesting that little progress has been made over the past decade, despite widespread and increasing interest in this approach to conservation (Margerum 2008). Information on social and economic assessments and outcomes was particularly meager, perhaps due to the challenges of measuring socioeconomic outcomes in relation to conservation efforts (Conley & Moote 2003). Furthermore, most collaborative groups evaluated success through structured surveys or interviews with stakeholders (Selin & Schuett 2000; Conley & Moote 2003). These shortcomings, sparse outcome assessments and lack of direct biophysical measures of success, could be attributed to the time and resources it takes to collect these data and for environmental or socioeconomic effects to manifest (Selin & Schuett 2000). To refine goals and actions in an adaptive management framework, collaborative groups may use interviews and surveys as a relatively rapid and low-cost mechanism to assess success (Selin & Schuett 2000).

For the subset of groups for which there is published information on outcomes, most report success, and there was little difference in the likelihood of a positive outcome among biophysical, social and economic goals and activities. Common characteristics among groups with positive outcomes included government funding and at least 5 group participants, including community members or individuals, non-profit or non-governmental organizations, and government entities (federal, state and/or local government). These groups also focused on either management (landscapes, species, and/or natural resources) or restoration (habitat, species, watersheds, and/or ecosystems). This combination of participants was particularly effective at solving problems with management and restoration (Weber et al. 2007; Kretser et al. 2018). Alternatively, the high ratio of positive to negative or no effect outcomes from collaborative group activities could be attributed to publication bias. For example, findings of “no effect” are often perceived as less compelling and can be difficult to publish (Fanelli 2012).

Our review of the status and outcomes of collaborative conservation groups in the United States was limited to information available in peer-reviewed articles and book chapters and non-profit or government reports. While we recognize that more information on these groups may appear in the gray literature or online (Conley et al. 2001), our review was intended to synthesize evidence on collaborative conservation groups from peer-reviewed studies. In the future, a comprehensive review could include information from all venues. However, in addition to the time and resources needed for such an exhaustive search, this approach is complicated by the variation in validity associated with information that comes from sources that are not peer-reviewed. Our review was also constrained by our definition of what constitutes a collaborative conservation. Future syntheses may wish to broaden our definition to groups that consist of only participants associated with either public or private organizations, groups that form for a short time (<3 years) to accomplish a specific goal, or those that cross international borders.

Collaborative conservation is a promising tool for resolving conflict and achieving benefits for conservation and human well-being. We find that collaborative conservation groups are widespread across the United States, and those measuring success, report positive outcomes. However, major gaps in published studies include an understanding of why groups form, how they are funded, and what actions they have adopted to achieve goals. In addition, there is little evidence that success is measured or reported for most groups. This review has demonstrated an important opportunity for scientists to play a stronger role in engaging with collaborative groups to describe and evaluate biophysical, social, and economic goals, actions, and outcomes. We expect such partnerships will improve practitioners' ability to make evidence-based decisions in an adaptive-management framework (McKinney & Harmon 2004). Although our findings suggest that collaborative conservation has been a successful tool for cross-boundary environmental problem solving, advancing the science and practice of collaborative conservation will benefit from more systematic analysis and reporting of group goals, actions and outcomes.

CHAPTER TWO: ECOLOGICAL AND SOCIAL CONSEQUENCES OF BISON REINTRODUCTION IN COLORADO

INTRODUCTION

The local decline or extinction of animals, also known as defaunation, has important consequences for natural communities and human well-being (Dirzo et al. 2014). Donlan et al. (2014) suggests that the loss of "mega-herbivores" has threatened ecological and evolutionary interactions across the globe. Today, the large herbivores that are still functionally extant serve as ecological engineers by shaping trophic guilds (Fritz et al. 2002), and contributing to species diversity and abundance (Olff & Ritchie 1998; Ogada et al. 2008). Refaunation, the reestablishment of locally extinct animal species, has the potential to restore these ecological functions (Oliveira-Santos & Fernandez 2010). Refaunation is rapidly emerging as an important subfield of conservation biology (Oliveira-Santos & Fernandez 2010), and further research is warranted to better understand its conservation potential, and its socio-cultural implications.

Plains bison (Bison bison), along with natural fire regimes, were instrumental in shaping North America's Great Plains (Samson et al. 2004). The prairies that form the Great Plains store carbon (DeLuca & Zabinski 2011), support biodiversity (Schulte et al. 2017), and help reduce run off from agricultural pollutants (Schulte et al. 2017). These services have been lost over time due to industrial agriculture and the large-scale loss of native grazing animals (DeLuca & Zabinski 2011). As a keystone species that directly and indirectly affects grassland ecosystems, bison could help restore these services. Bison alter plant community composition (Knapp et al. 1999; Towne et al. 2005), change soil nutrient cycling (Frank & Evans 1997), and cause shifts in bird species richness (Griebel et al. 1998), bird abundance (Powell 2006), and small mammal abundance (Matlack et al. 2001). Despite their critical contributions to land and wildlife health, bison have been nearly extirpated from North America. The plains bison currently occupy 1% of their historic range (Hedrick 2009), with very few populations persisting outside of Yellowstone National Park. Some researchers suggest that the range contraction of bison has rendered them ecologically extinct (Freese et al. 2007), meaning they no longer serve the same foundational role in grassland ecosystems. However, popular and political interest in restoring this iconic species is rapidly gaining momentum across the United States (Isenberg 2000).

As charismatic, native mega-herbivores of the American west, bison are an ideal species for advancing cross-disciplinary understanding of refaunation. These grazers are popular with the public, and could serve as a flagship species or focal species for grasslands conservation (Walpole & Leader-Williams 2002). While flagships can serve as an important conservation tool, these species also tend to be associated with greater conflict with human populations (Woodroffe et al. 2005). Conflicts include crop-raiding (e.g. elephants in Africa), livestock depredation (e.g. wolves in North America or lions in Africa), or extirpation of certain species by human populations for agricultural production (Woodroffe et al. 2005), such prairie dogs in North America (Reading et al. 2005). Thus, understanding how flagship species are perceived by local communities and other stakeholders is critical to mitigating potential human-wildlife conflicts that could emerge as result of reintroduction (Douglas & Veríssimo 2013).

To date, there are still relatively few studies that examine the effects of species reintroductions on visitors to reintroduction sites, and that document the realities of co-existence with reintroduced charismatic species for local communities (Seddon et al. 2007). Social factors, such as human attitudes and perceptions of reintroductions, only account for 4% of the 454 papers in the reintroduction literature reviewed from 1990 to 2005 (Seddon et al. 2007). Thus, expanding both the ecological and human dimensions of refaunation will be critical to achieving successful species reintroductions and recovery of ecosystem processes.

A recent bison reintroduction to shortgrass prairie in northern Colorado has the potential to restore grassland function and habitat quality for birds and other animals, while also catalyzing the public to engage in grassland conservation efforts. Previous studies assessing the effects of bison reintroduction on plants and animals generally occurred at sites where bison have been present for 4-10+ years and with higher bison densities (1.2-1.7 animal units/hectare; Griebel et al. 1998; Matlack et al. 2001; Towne et al. 2005) than our study site, for which densities progressed over time from 0.03 animal units/hectare in 2015 to 0.07 animal units/hectare in 2017. Thus, our research also offers an opportunity to understand if social and ecological effects are evident at the early stages of bison reintroduction. Our specific research questions evaluate the short-term effects of bison reintroduction on: 1) bird habitat use and density, 2) habitat use by mammals, and 3) visitor connections to shortgrass prairie.

METHODS

Study area-We studied the ecological effects of reintroducing a single bison herd to Soapstone Prairie Natural Area and Red Mountain Open Space, hereafter, Soapstone and Red Mountain (Figure 2.1), located approximately 48 km north of Fort Collins, Colorado (U.S.A.). Our assessment of the effects of bison reintroduction on human visitors was restricted to Soapstone because the bison are not visible to the public from Red Mountain trails. Elevation in the study area ranges from 1219-2200 m and 70 percent of the area is classified as shortgrass

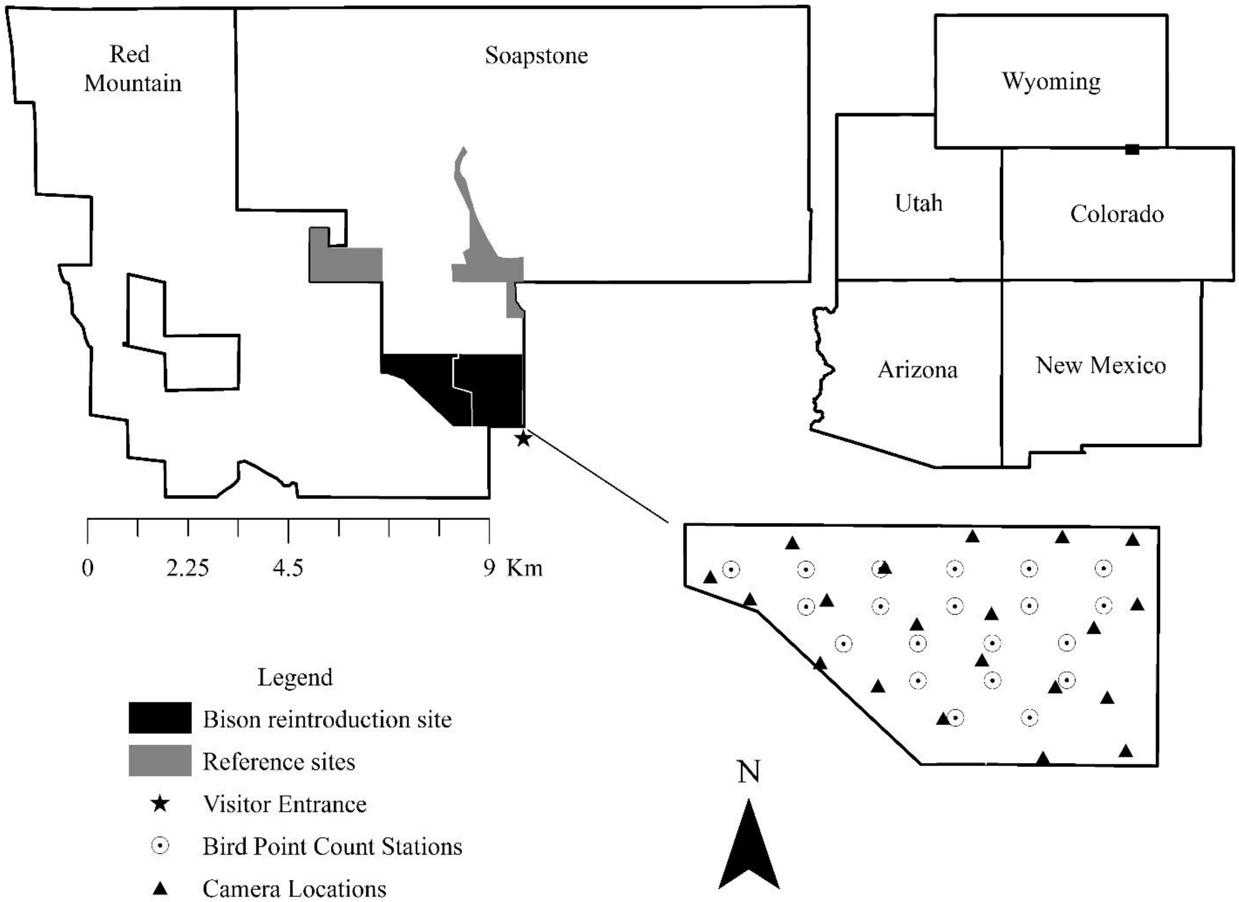

Figure 2.1. Location of bison reintroduction and reference (ungrazed) sites in northern Colorado. Inset illustrates the locations of bird point count stations and wildlife cameras within the bison reintroduction site.

prairie/grassland ecosystem with dominant vegetation including blue grama (*Bouteloua gracilis*) and buffalo grasses (*Bouteloua dactyloides*) (City of Fort Collins Natural Areas Program 2007). This ecosystem also hosts a diverse animal community, including 130 bird species and more than 30 mammal species. These include species of conservation concern, such as the Lark bunting (*Calamospiza melanocorys*), burrowing owl (*Athene cunicularia*), black-tailed prairie dog (*Cynomys ludovicianus*), swift fox (*Vulpes velox*), and black-footed ferret (*Mustela nigripes*) (City of Fort Collins Natural Areas Program 2007).

The shortgrass prairie at Soapstone and Red Mountain was grazed by large herds of bison up until approximately 100 years ago (Isenberg 2000). Homesteaders arrived in the late 1860's and began to graze sheep and cattle (Martin et al. 2009). These lands were purchased by the City of Fort Collins (Soapstone) in 2009 and Larimer County (Red Mountain) in 2001. After this change in ownership, the majority of this land continued to be grazed by cattle through leases with local ranchers. In November 2015, eleven bison were reintroduced to a fenced 393-hectare pasture that extends across Soapstone Prairie and Red Mountain (hereafter "bison site"; Figure 2.1). The bison site was not grazed by cattle for five years prior to the reintroduction (J. Frederickson, personal communication). The herd has since tripled, with 54 bison grazing the site as of July 2018. Several areas (308 hectares) near to the bison pasture on Soapstone have only infrequently been grazed by cattle for approximately 10 years (hereafter "reference sites"). Mule deer (*Odocoileus hemionus*), American elk (*Cervus canadensis*), and pronghorn (*Antilocapra americana*) can cross fences and graze both the bison and reference sites.

To assess changes in habitat use and density in response to the presence of bison on the landscape, we surveyed vegetation, birds, and mammals at the bison and reference sites at Soapstone and Red Mountain from May-November 2015 (pre-bison reintroduction) and May-November 2016 and 2017 (post-bison reintroduction). To understand how the bison reintroduction to northern Colorado shaped visitor connections to the reintroduction site (Soapstone and Red Mountain), we gave structured surveys to people who visited Soapstone between June-October before the bison reintroduction (2015) and after the bison reintroduction (2016).

Bird surveys-To estimate habitat use and density of birds before and after bison reintroduction, we randomly selected point count locations within the bison-grazed (n=20) and reference (n=14) sites. The point count locations (Figure 2.1) were buffered 200 m from fences (Fuhlendorf et al. 2006), and spaced 200-250 m from one another to minimize the likelihood of double-counting individuals (Hanni et al. 2014). We also buffered points at least 200 m from stands of trees to ensure sampling within the same vegetation type across bison and reference sites. This resulted in 6 point counts stations in one reference site and 8 point count stations in the other reference site. Birds were surveyed at all point count locations between 5:30 am and 10 am from May-June in 2015, 2016, and 2017. Each survey consisted of identifying all bird species in 5-minute intervals by both visual and aural indicators (Fuhlendorf et al. 2006; Hani et al. 2014). Using a rangefinder, we measured the distance (m) between the observer and each bird. Each bird point count location was surveyed five times per field season at the bison site (n=100 surveys) and the reference sites (n=70 surveys) to account for imperfect detection. We estimated wind speed, rainfall, and cloud cover during each survey using standard bird monitoring protocols (Hanni et al. 2014).

Mammal surveys- We used remotely-triggered wildlife cameras (Cuddeback Long Range IR Trail Camera, Cuddeback Capture, Bushnell Primos Truth Cam 35, and Cuddeback Attack IR 1156), to estimate habitat use by mid-to-large sized mammals before and after the bison reintroduction. We evenly distributed different camera models among the three different sites (Figure 2.1). To select locations for remotely-triggered wildlife cameras, we used ArcGIS software to divide bison and reference sites into 200 x 200 m grids. We then randomly selected 20 grids at each site, and identified areas within each grid that had signs of wildlife (e.g. trails and scat). We placed cameras at least 200 m apart in these areas to maximize species detection (O’Connell & Bailey 2011), but did not buffer cameras from fences that divided different sites. If we placed a camera near a fence dividing different sites, we made sure to face the camera into the site of interest. We placed cameras 60-80 cm above the ground on posts hammered into the ground at each site. Wildlife cameras at bison-grazed (n=19) and reference sites (n=20) operated from May-November 2015, 2016, and 2017. We replaced batteries and SD cards every 2-4 weeks based on the camera type and weather. We downloaded photographs from each camera monthly and uploaded photos to the CPW Photo Warehouse program (Newkirk 2016). To ensure accuracy in identifying species, at least two observers viewed each photo and identified all mammals to species. Discrepancies in species identification were resolved by the lead author (KW).

Vegetation surveys-We measured vegetation from June-July (2015-2017) to observe changes in habitat among sites and years that might influence birds and mammals. To measure plant composition and structure, we established one 50 m vegetation transect at each wildlife camera and point count location in bison-grazed (n=40) and reference sites (n=38). We used a Daubenmire frame (Daubenmire 1959) and modified Robel pole (Vinton et al. 1993) to estimate percent canopy cover and height, respectively, every 10 m along each transect. We placed the Daubenmire frame to the right of the transect tape and alternated sides of the tape every 10 m. Within each frame, we recorded the percent canopy cover of bare ground, litter, rock, grasses, forbs and shrubs with non-overlapping percentages (Fletcher & Koford 2002). We identified all grasses, forbs, and shrubs to species. To measure vegetation structure, we placed the modified Robel pole (3.4 cm PVC pipe, 1 meter tall, 1 cm increments marked by alternating black and white bands) in the center of each Daubenmire frame. To estimate vegetation height, we observed the pole from each cardinal direction (N, S, E, W) at a distance of 4 meters and a height of 1 m (Robel et al. 1970). We also conducted a shrub count along the 50 m transect, for which we counted and identified to species all shrubs and sub-shrubs that occurred within 1 m of each side of the transect line.

Visitor Intercept Surveys-To better understand how bison reintroduction affected people's connection to Soapstone, we implemented a mixed-methods approach of a survey followed by open-ended questions (Borrie et al. 2002). We implemented structured visitor surveys to compare visitor demographics, place attachment, and motivations for visiting this prairie ecosystem before and after bison reintroduction (Freimund & Dalenberg 2010). We piloted the surveys in June 2015 and determined that weekday visitation rates were too low for sampling (1-2 people intercepted per day). Thus, we intercepted visitors at the only public entrance gate to Soapstone on Saturdays and Sundays during peak visitation months (June-October; (Freimund & Dalenberg 2010; Skibins et al. 2012; Folmer et al. 2013) before (2015) and after bison reintroduction (2016). Due to low visitation rates on weekends (average of 12 visitors per day), we intercepted every vehicle at the entrance gate (Bernard 2011).

We used two separate structured surveys: the first survey (Appendix 2) took place before bison reintroduction (2015) and the second survey (Appendix 2) took place after bison reintroduction (2016). The first questionnaire (before reintroduction) included a place attachment survey to gauge people's connections to Soapstone, questions about if and why people thought Soapstone was important, and questions regarding people's past visitation to Soapstone, their planned activities for the visit, and demographic information. The second questionnaire included the same content; however, if visitors mentioned visiting the site to see bison, we asked follow-up questions about the bison herd to better understand visitor motivations. These questions asked about other places visitors viewed bison, how visitors heard about the Soapstone bison herd, and why they wanted to see the Soapstone bison herd. In both years, we also logged all visitors who refused to take the survey, made a note of their group size, and asked them a single question, "Is Soapstone important to you?". We used this information to calculate non-response bias of visitors who refused to take the survey.

Place attachment surveys- The place attachment survey (Appendix 2) is based on scales created by Folmer et al. (2013). This survey asked participants how much they agreed or disagreed with a series of four statements, such as "I feel very attached to Soapstone Prairie Natural Area" and "I want to spend more time in grasslands like Soapstone Prairie Natural Area". The average score of these four statements provided an overall measure of place attachment, or the level of connection people feel for a certain space. Folmer et al. (2013) tested the ability of the scale to measure these connections using the Cronbach's alpha test. Cronbach's alpha describes the extent to which each statement in the survey measures the same concept—place attachment in this instance (Tavakol & Dennick 2011). Folmer et al.'s (2013) scale produced a Cronbach alpha of .88, which demonstrates that the statements in the scale accurately measure place attachment (Folmer et al. 2013).

Open-ended questions - We followed the place attachment survey with two questions, "Is Soapstone important to you" and, "If yes, why". These follow-up questions were intended to provide more context for understanding people's connections to bison and the ability of bison to make people more aware of grasslands and grassland conservation efforts. These questions were designed to help elucidate to what extent charismatic species serve as a flagships in conservation awareness (Walpole & Leader-Williams 2002; Smith & Sutton 2008).

Data Analysis

Bird Density- To estimate bird detection probabilities and determine whether the density of each species differed before and after bison reintroduction, we employed a two-stage approach

(Buckland et al. 2015a), in which we used program Distance (Thomas et al. 2010) and the Rdistance package (McDonald et al. 2015) in R version 3.4.3. For the first stage of the density analysis, we used program Distance to model variation in detection probability, which the program used to calculate an effective detection radius (EDR) at each site type (bison or reference) and year (2015-2017). Independent variables used to model detection probability included categorical (observer, wind, rain) and continuous variables (cloud cover, vegetation height, distance to bird; Diefenbach et al. 2003). We report the EDR and detection probability estimates for obligate grassland birds (Appendix 2) with models containing p-values ≥ 0.20 for Kolmogorov–Smirnov $\chi 2$ goodness-of-fit tests (K-S goodness-of-fit) or $\chi 2$ goodness-of-fit tests (Buckland et al. 2015). For bird species with detection probability models that did not converge or meet our criteria for the goodness-of-fit test, we estimated occupancy (habitat use). Three obligate grassland bird species met our criteria for calculating density estimates: Horned Larks (*Eremophila alpestris*), Vesper Sparrows (*Pooecetes gramineus*), and Western Meadowlarks (*Sturnella neglecta*). Before running the analyses, we truncated 10% of observations recorded at the largest distances for each species (Buckland et al. 2001). We modelled the data using exact distances and the half-normal cosine function for Horned Larks and Vesper Sparrows. To improve the fit of the detection function for Western Meadowlarks, we placed data into 5-bins, and used a hazard rate cosine function (Buckland et al. 2015).

For the second stage of the analysis, we constructed generalized linear mixed effects models (GLMMs) using the glmer function in the lme4 package in R version 3.4.3 (Bates et al. 2015). We used the effective detection radius (EDR, expressed as meters) estimated in program Distance to calculate an effective area in hectares ($\prod$*EDR2*0.0001); the log of the effective area served as an offset in the GLMMs to account for detectability in the model (Buckland et al.

2015). The fixed effects in the GLMMs included site type (bison or reference) and year (2015, 2016, or 2017). We set individual point count stations, located within the bison and reference sites, as a random effect in the model to account for potential correlation in repeat visits to each point count station (Oedekoven et al. 2013). We used Akaike's information criterion (AIC) to rank models of bird detection probability and density produced in program Distance and R-Studio, respectively. We report information on competing models with a ΔAIC<2.0, and AIC weights (Burnham & Anderson 2002).

Bird Habitat Use- To determine whether habitat use by birds differed before and after bison reintroduction, we built dynamic occupancy models (Kéry & Chandler 2016) using the colext function in R's unmarked package (Fiske & Chandler 2011). We compared models using the AIC model selection process described above. Since our data did not meet all assumptions required to estimate occupancy (O'Connell & Bailey 2011), we refer to results from these analyses as "habitat use".

We included all obligate and facultative grassland bird species (Appendix 2) with models containing p-values ≥ 0.20 $\chi 2$ goodness-of-fit tests (Buckland et al. 2015), and we truncated all data to 100 m (half the distance between point count stations) to maximize independence between sites (O'Connell & Bailey 2011). Bird species that met this criteria included Brewer's Blackbirds (*Euphagus cyanocephalus*), Grasshopper Sparrows (*Ammodramus savannarum*), and Lark Sparrows (*Chondestes grammacus*). Site-level covariates used to model variation in habitat use included site (bison or reference) and vegetation cover types that did not vary by site or year (cool and warm season grasses, and forbs) at the bird point count stations. Covariates used to model colonization and extinction probabilities included site (bison or reference) and year (2015-2017). Observation-level covariates used to model detection probability included categorical covariates (observer, wind, and year) and scaled continuous covariates (cloud cover and vegetation height). Rain was highly correlated with year, and thus was not included as a covariate.

The dynamic occupancy model provides estimates of occupancy for the first year, in addition to colonization and extinction estimates in the first time step (from 2015 to 2016) and the second time step (from 2016-2017) (MacKenzie et al. 2002). To estimate habitat use for each bird species by site in 2016 and 2017, we used a recursive function in R-studio (Appendix 2) using the first year habitat use estimate (MacKenzie et al. 2002). We then ran the function through parametric bootstrapping (10,000 simulations) to calculate 95% confidence intervals for occupancy estimates in each year. We used the outputs of this procedure to calculate $\chi 2$ p-values to assess model fit.

Mammal habitat use – To determine the effect of bison reintroduction on habitat use by mammals, we selected photos collected in the summer (June-September 2015-2017) to ensure that all mammals were resident in the system during the survey period (O'Connell & Bailey 2011). We defined a sampling occasion in our analysis as 7 days, with each set of 7 days separated by a 24-hour rest period to maintain independence between occasions (Shannon et al. 2014). We constructed a dynamic occupancy model (Kéry & Chandler 2016) using the unmarked package (Fiske & Chandler 2011). Site-level covariates used to model variation in habitat use included site (bison or reference). Covariates used to model colonization and extinction probabilities included site and year (2015-2017). Observation-level covariates used to model detection probability included categorical covariates (year and camera model) and scaled continuous covariates (vegetation height). We compared models using the same AIC model selection process, as well as the parametric bootstrapping function, described for bird analyses above to derive estimates of mammal habitat use and $\chi 2$ p-values to assess model fit.

Plant community characteristics- To determine which vegetation data to use as covariates in bird density and bird and mammal habitat use models, we used the results from linear mixed effects model for vegetation cover and height at bird point count stations separately from vegetation at camera locations. To assess vegetation cover, we grouped species into four categories that served as the response variables: Cool season grasses, warm season grasses, forbs, shrubs, and bare ground. If the top linear mixed effects models (ΔAIC<2.0) contained site, year, or a site by year interaction for a vegetation cover category, then we considered the vegetation cover category to be correlated with site or year and we excluded these cover categories as covariates in bird and mammal models to avoid issues associated with multicollinearity (Graham 2003).

To assess the effect of bison reintroduction on the plant community, we averaged vegetation cover and height data from point count stations and wildlife cameras at the bison and reference sites. We then built linear mixed effects models using the individual location (camera or point count station) as a random effect in the model. For cover and height analyses, we divided species into cool season grasses, warm season grasses, forbs, and shrubs. We also included bare ground as a category for vegetation cover analyses. Response variables included vegetation type, and covariates included site (bison or reference) and year (2015, 2016, or 2017). We used Akaike's information criterion (AIC) to rank models and report information on competing models with a ΔAIC<2.0, and AIC weights (Burnham and Anderson 2002). We used Simpson's diversity index (vegan package) to compare plant diversity before and after bison reintroduction (Oksanen et al. 2018). We considered indices to be significantly different if their confidence intervals did not overlap.

Place attachment surveys and open-ended questions- To assess the effects of bison reintroduction on visitors, we calculated mean and standard deviation for answers to each of the place attachment scale items on the place attachment survey administered before and after bison reintroduction. We performed a Welch's two-sample, unpaired, one-sided t-test using R version 3.4.3 to test the hypothesis that mean place attachment scores would be higher after bison reintroduction (Bernard 2011). We coded responses to the open-ended question, "Why is Soapstone important to you?" into themes using NVivo (Bernard 2011). Themes emerged from the data based on visitor responses to this question. Two authors (KW and RG) discussed the coded statements within each theme and theme definitions to verify the coding structure (Saldaña 2016). To quantify themes, we calculated the percent of visitors that mentioned each theme (Bernard 2011). We also measured non-response bias in 2015 and 2016 using Pearson's Chi-square test to see if non-respondents and respondents differed in group sizes and response to the question, "Is Soapstone important to you?" (Barclay et al. 2002).

RESULTS

Effect of Bison Reintroduction on Bird Density and Habitat Use- Across all sites and years, we observed 50 species of birds (Appendix 2). For bird species with sufficient detections for analysis, we report densities (Horned Lark, Western Meadowlark, Vesper Sparrow) and habitat use (Grasshopper Sparrow, Lark Sparrow, Brewer's Blackbirds; Figure 2.2). We also report estimates of detection probability and the variables that appeared in the top model for all modeled species (Appendix 2).

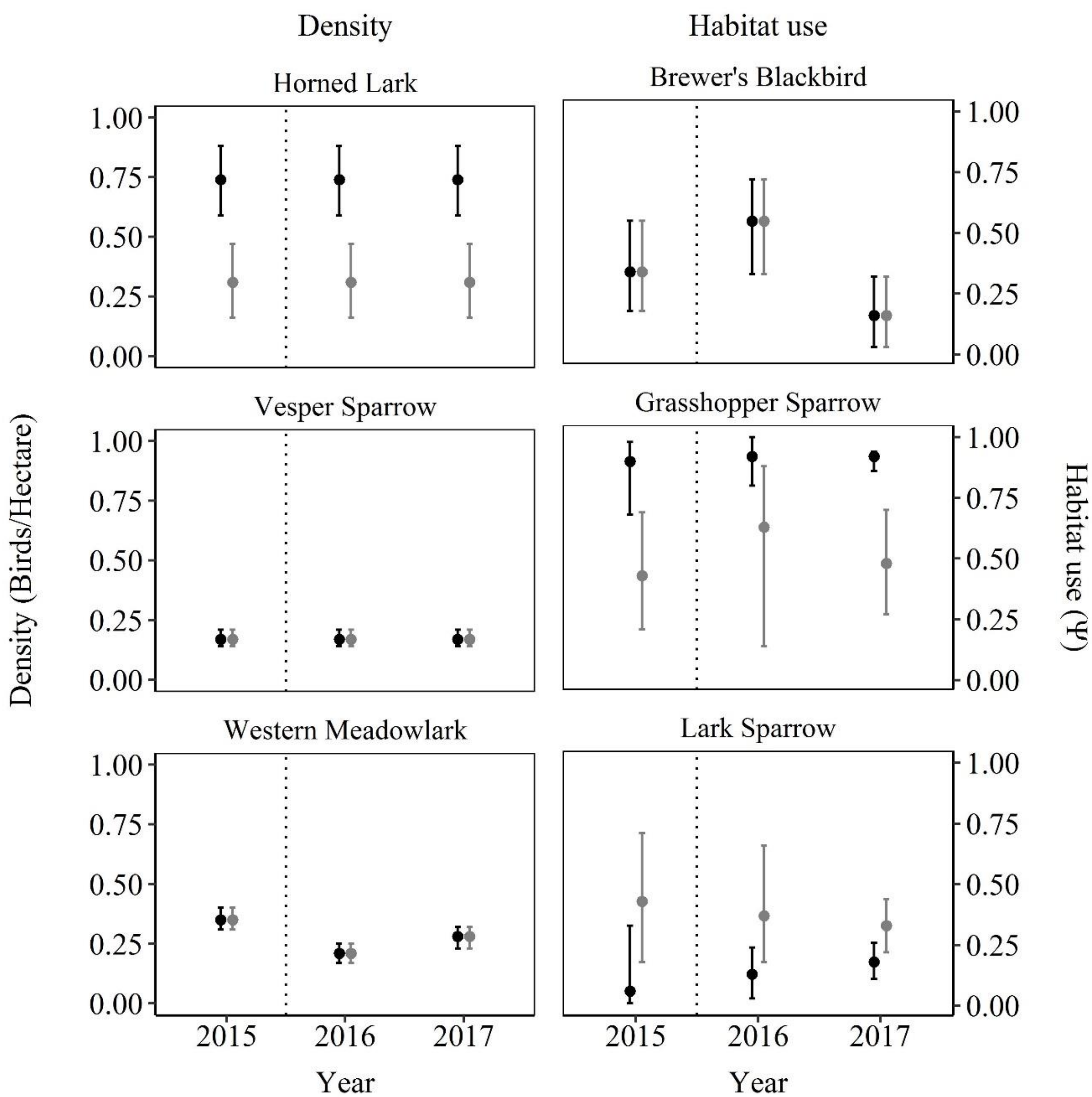

Figure 2.2. Density (left axis) and habitat use (right axis) of grassland birds at bison (black), and reference sites (gray) before (2015) and after (2016-2017) bison reintroduction.

There was no strong or consistent effect of bison reintroduction on bird density or habitat use (Figure 2.2). None of the top models for density or habitat use included a site by year interaction (Appendix 2). Horned Lark and Vesper Sparrow densities remained constant over time at both the bison and reference sites (Figure 2.2). In addition, Western Meadowlark densities and habitat use for Lark Sparrows and Brewer's Blackbirds did not change at bison site relative to the reference site over the study period (Figure 2.2). Grasshopper Sparrow habitat use increased slightly in the bison site over time, but the top model for this species did not include a site by year interaction (Appendix 2).

Effects of Bison Reintroduction on Mammal Habitat Use- Across all sites and years, we observed 14 species of mammals (Appendix 2). The species or taxa with a sufficient number of detections for occupancy analyses included mule deer, pronghorn, coyote (*Canis latrans*), and lagomorphs: black-tailed jackrabbits (*Lepus californicus*), white-tailed jackrabbits (*Lepus townsendii*), and desert cottontails (*Sylvilagus audubonii*).

Bison reintroduction did not affect habitat use of coyote or pronghorn, and models with site by year interactions for colonization and extinction probabilities did not converge for any species. We observed a decreasing trend in habitat use for lagomorphs and mule deer at the bison site compared to the reference site (Figure 2.3), and mule deer extinction probabilities were higher at the reference site compared to the bison site (Appendix 2).

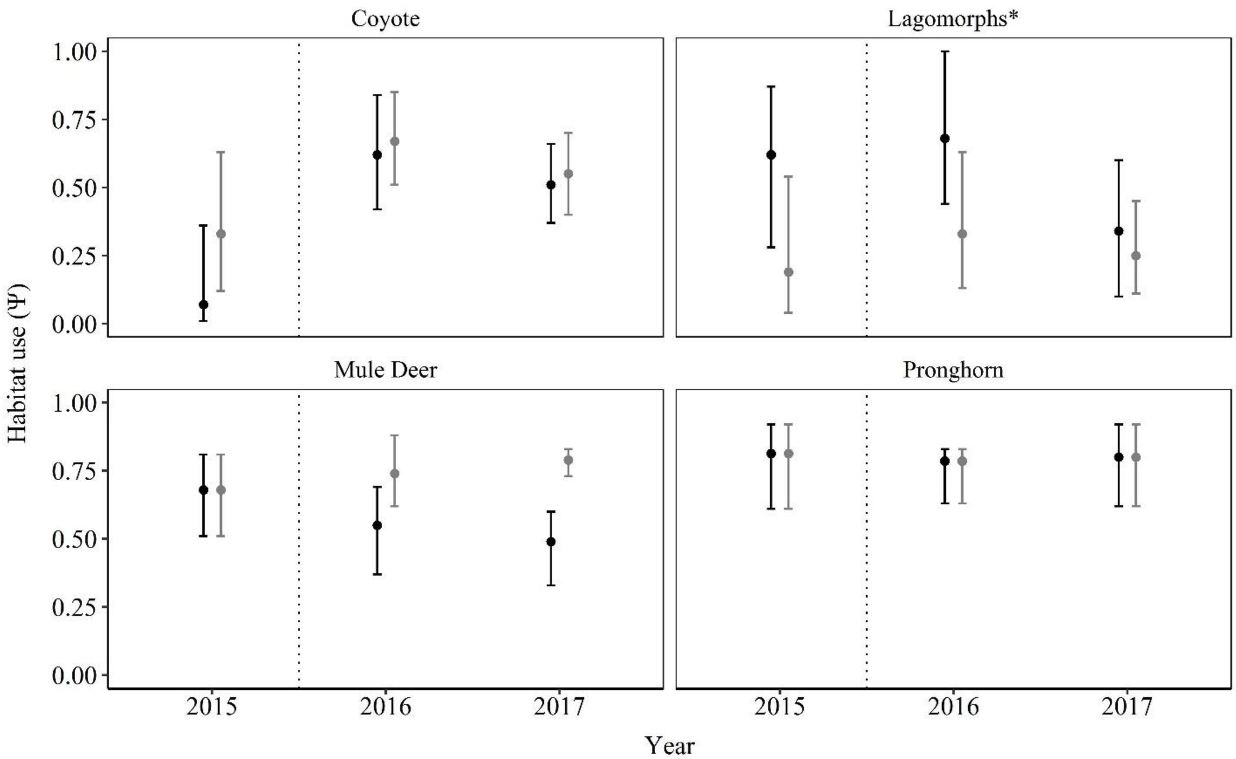

Figure 2.3. Habitat use for coyote, lagomorphs, mule deer, and pronghorn at bison (black) and reference (gray) sites before (2015) and after (2016-2017) bison reintroduction. *Lagomorphs include Black-tailed Jackrabbits, White-tailed Jackrabbits, and Cottontail rabbits.

Plant community characteristics- We documented 19 grass species, 40 species of forbs, and 14 shrub species at bison and reference sites. Top models for height and cover of forbs and cover for bare ground included an interaction between site and year (Table 2.1). Cover for bare ground was significantly higher in the bison site compared to the reference site and declined over time in both sites. The cover and height of forbs, warm and cool season grasses, and shrubs did not differ significantly in the bison site after bison reintroduction (Appendix 2).

Table 2.1. Top linear mixed models (ΔAIC ≤ 2) for how fixed effects—bison (Bis) or reference (Ref) sites and year (2015, 2016, 2017)—influenced cover and height of cool season grasses (Cool), warm season grasses (Warm), forbs, and shrubs, and bare ground (Bare) percent cover. We list the model, parameters (k), AIC, ΔAIC, and model weight (w). We list the direction of the fixed effects for the top model (model with the most weight). We present the cover and height estimates and their direction, cited as (+) = positive, (-) = negative, or no change (.) in reference to the bison site before reintroduction (2015). Dotted line separates years before (2015) and after (2016 and 2017) bison reintroduction.

						β					
	Model	K	AIC	ΔAIC	w	Bis 2015	Bis 2016	Bis 2017	Ref 2015	Ref 2016	Ref 2017
COVER											
Cool	Null	3	1680.13	0.00	0.42	19.08	19.08(.)	19.08(.)	19.08(.)	19.08(.)	19.08(.)
	Site	4	1681.58	1.45	0.20						
	Site x Year	8	1681.62	1.49	0.20						
	Year	5	1681.92	1.78	0.17						
Warm	Null	3	1736.59	0.00	0.54	19.06	19.06(.)	19.06(.)	19.06(.)	19.06(.)	19.06(.)
	Site	4	1737.71	1.12	0.31						
Forbs	Site x Year	8	1200.64	0.00	0.86	5.10	6.85(+)	4.55(-)	4.38(-)	2.51(-)	2.43(-)
Shrubs	Site	4	1450.38	0.00	0.85	4.69	4.69(.)	4.69(.)	8.15(+)	8.15(+)	8.15(+)
Bare	Site x Year	8	1584.48	0.00	0.84	28.43	16.99(-)	15.02(-)	17.29(-)	32.97(+)	32.13(+)
HEIGHT											
Cool	Site x Year	8	1323.76	0.00	0.86	11.16	9.18(-)	5.15(-)	15.10(+)	9.18(-)	8.96(-)
Warm	Year	5	719.33	0.00	0.62	5.55	5.99(+)	3.42(-)	5.55(.)	5.99(+)	3.42(-)
	Site x Year	8	720.30	0.96	0.38						
Forbs	Site x Year	8	1030.46	0.00	0.97	9.46	9.55(+)	4.35(-)	17.60(+)	4.24(-)	3.82(-)
Shrubs	Site x Year	8	1245.68	0.00	0.99	12.66	11.81(-)	8.04(-)	26.95(+)	10.44(-)	5.29(-)

Effects of Bison Reintroduction on Visitor Place Attachment- We intercepted 243 people before bison reintroduction (2015) and 525 people after bison reintroduction (2016). Our response rate was 75% (n=184) in 2015 and a 56% (n=302) in 2016. We surveyed approximately the same ratio of women to men in 2015 (74%) and 2016 (76%), and most were in the age range of 36-55 in both years (49% in 2015 and 45% in 2016). Most respondents (81% in 2015 and 85% in 2016) were local to the area. In both years, the majority of visitors identified as Caucasian (94%) and had either bachelors or graduate degrees (40%; Appendix 2). We did not detect a non-response bias based on responses of participants and non-respondents in both years to the question, "Is Soapstone Prairie important to you?" (2015: $\chi2= 1.52$, df = 1, p = 0.21 and 2016: $\chi2 = 3.10$, df = 1, p = 0.08). Further, we did not find a significant difference in group size between participants and non-respondents (2015: $\chi2 = 4.02$, df = 7, p = 0.78 and 2016: $\chi2 = 9.75$, df = 5, p = 0.08).

Of the people who responded "yes" to taking the survey, all completed the place attachment in 2015 and 2016. The statements ranked by visitors had high internal consistency (Cronbach alpha>.8; Folmer et al. 2013) for measuring place attachment in both years (Appendix 2). Visitors had significantly higher place attachment scores after the bison reintroduction (Figure 2.4). In addition, a higher percent of people agreed that they felt at home in Soapstone and wanted to spend more time in grasslands like Soapstone after the bison reintroduction (Appendix 2).

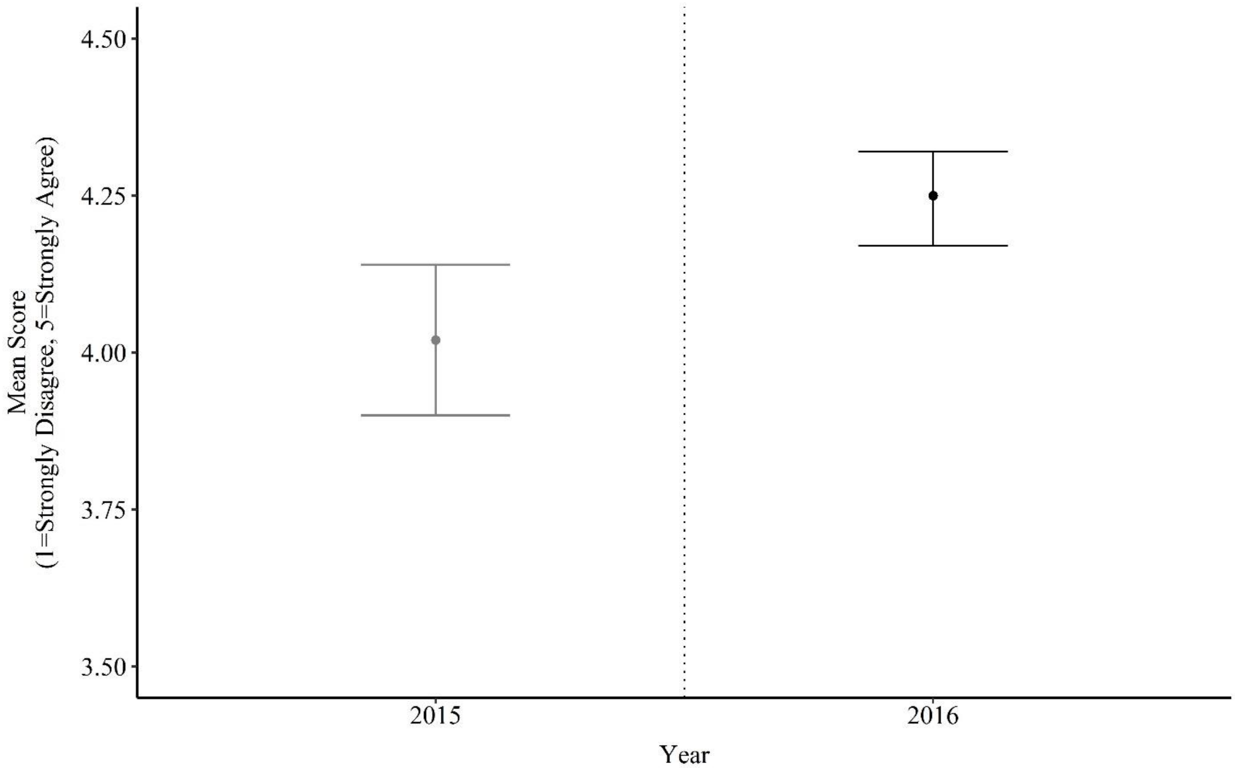

Figure 2.4. Mean score with confidence intervals for “place attachment” of visitors to Soapstone Prairie Natural Area on a scale of 1-5 (1 =“Strongly Agree” and 5 = “Strongly Disagree”) before (2015) and after (2016) bison reintroduction. This index was calculated from a series of questions on a survey administered to visitors to Soapstone Prairie Natural Area.

For the open-ended question, “Why is Soapstone important to you?”, around 95% of visitors in 2015 (n=174) and in 2016 (n=286) said Soapstone was important to them and explained why. The top ten themes (Figure 2.5) that emerged from responses were similar between years, but several themes shifted, including “Historical Significance” emerging as a main theme in 2016, and more people citing the “Importance of Protecting Open Space” in 2016 compared to 2015 (Appendix 2).

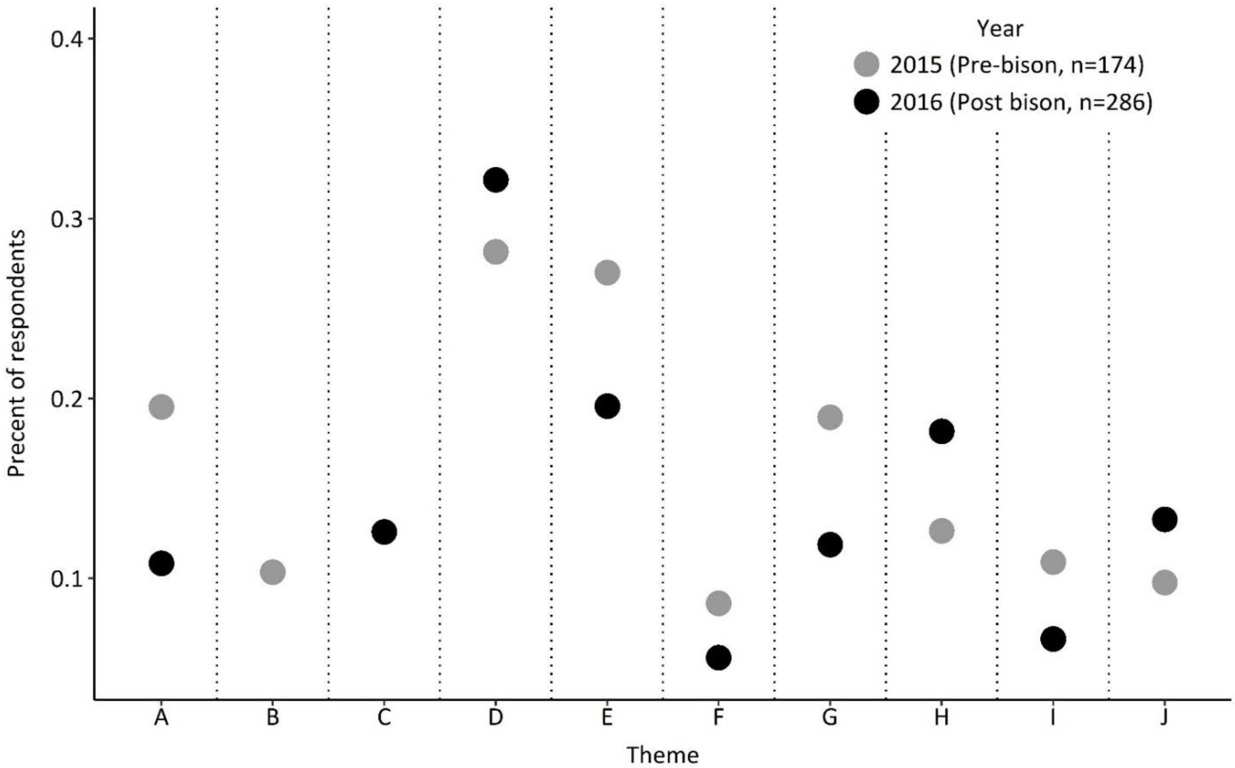

Figure 2.5. Percent respondents (number of respondents within each theme/total number of respondents) of themes before (2015) and after (2016) the bison reintroduction at SPNA in response to the open-ended question, “Why is Soapstone Prairie important to you?” (A. An uncrowded place to get away, B. Close and convenient, C. Historical significance, D. Important to protect open space, E. Nature preservation or conservation, F. Place to enjoy nature or the outdoors, G. Recreation asset, H. Undisturbed or undeveloped, I. Unique place, J. Wildlife)

DISCUSSION

Our results highlight the importance of assessing both ecological and social dimensions of reintroduction efforts. Most previous research on the ecological effects of bison focused on their keystone role in ecosystem processes (Frank & Evans 1997; Knapp et al. 1999; Coppedge et al. 1999; Fuhlendorf & Engle 2004; Towne et al. 2005). In contrast, no previous study has quantified the ecological effects of bison reintroduction in tandem with social outcomes such as place attachment. We helped fill this knowledge gap by assessing changes in bird density, bird and mammal habitat use, vegetation characteristics, and human connections in response to the reintroduction of this charismatic, native herbivore. We detected few changes to bird and mammal communities within two years of bison reintroduction, but we did observe reduced plant cover and height for some vegetation types. Furthermore, we found immediate and significant differences in people's attachment to the site following reintroduction.

Our bird density and habitat use results are somewhat inconsistent with other studies that demonstrated increases in bird abundance in tall and mixed grass prairie. However, these studies occurred at sites that were grazed by bison over longer time periods (up to 23 years), at higher densities (1.2 animal unites/hectare/year), and were burned as well as grazed (Griebel et al. 1998; Powell et al. 2006). In contrast to these studies, we found that Western Meadowlark, Horned Lark, and Vesper Sparrow densities and Grasshopper Sparrow habitat use did not change in response to bison reintroduction. Lark Sparrows, which increased slightly, but not significantly following bison reintroduction, prefer to forage or nest in moderately grazed areas with mixed to tall grasses (Dechant et al. 2001). We observed decreases in plant cover and height following bison reintroduction, which could indicate that bison have begun to create conditions that provide high quality habitat for obligate and facultative grassland birds (Towne et al. 2005).

It is possible that we detected little to no bird response to bison reintroduction because climate can be more important than grazing as a driver of bird abundance in arid grasslands, particularly where grazing intensity is low-moderate (Niemuth et al. 2008; Lipsey & Naugle 2017). For example, the decrease in density and habitat use by Western Meadowlark across both bison and reference sites can probably be attributed to fluctuations in precipitation during our study period (Niemuth et al. 2008). During 2015, the year prior to bison reintroduction, rainfall averages peaked at 196 mm from May-June, which was three times higher than historic averages (58 mm) for northern Colorado ("Historical Weather" 2018). Rainfall during this year was also higher than in May-June 2016 (43 mm) and 2017 (95 mm) ("Historical Weather" 2018). Other studies have demonstrated the effects of climate on nest survival for shortgrass prairie bird species (Skagen & Adams 2012; Conrey et al. 2016). Conrey et al. (2016) describe decreases in nest survival for shortgrass prairie birds during periods of drought or increased temperatures. For example, Lark Buntings were only abundant at our site during 2015, which is consistent with previous studies that demonstrated positive correlations between Lark Bunting productivity in areas with higher precipitation (Skagen et al. 2012).

Few studies have measured the effects of bison reintroduction on mid-to-large sized mammals. We did not observe significant changes in habitat use by mammals in response to bison reintroduction, but we did observe several trends (Figure 3). Pronghorn habitat use remained constant and coyote habitat use increased in the bison site after the reintroduction, while lagomorph and mule deer habitat use decreased. Coyote have been known to prey upon bison calves in Yellowstone (Sheldon et al. 2009), which could explain increased habitat use following bison reintroduction. We observed decreases in lagomorph habitat use following the bison reintroduction that contrasts with previous studies on small mammals that have found an increase in abundance following bison introduction (1.2 animal units/hectare), particularly when grazing was paired with burning (Matlack et al. 2001). The decrease in lagomorphs could be in response to the increased habitat use by their main predator, coyotes (Gosselin et al. 2017).

We observed no change in plant species diversity or percent cover of cool and warm season grasses, but the percent cover of forbs and bare ground decreased following the bison reintroduction. These vegetative responses to bison grazing were inconsistent with previous findings. Towne et al. (2005) examined shifts in vegetation on bison-grazed, cattle-grazed, and ungrazed sites over ten years in tallgrass prairie with stocking densities of 1.7 animal units/hectare, and found that warm season grass cover decreased and cool season grass cover increased on bison-grazed pastures. Others have documented higher forb biomass (Fahnestock & Knapp 1994) and cover (Towne et al. 2005) in annually or seasonally burned bison-grazed pastures. In contrast to vegetation cover, we documented a decline in the average height of cool and warm season grasses, forbs, and shrubs after the bison reintroduction. This is consistent with past studies showing that bison in other shortgrass prairie systems graze on cool and warm season grasses, forbs and sub-shrubs, such as *Artemisia frigida* and *Gutierrezia sarothrae* (Peden et al. 1974), which are the two most common sub-shrubs in our study site. Yet, while our models provided some indication that plant cover and height were altered by bison grazing, we urge caution in interpreting these results as the confidence intervals for cover and height estimates before and after bison reintroduction were often overlapping (Appendix 2).

Bison serve as a "flagship" species (Leader-Williams & Dublin 2000), which can serve as an icon for protecting a particular ecosystem. Although we detected few ecological effects in the two years following bison reintroduction, we measured a significant increase in people's connections to Soapstone. Our research supports the idea that people connect with landscapes in which they can view wildlife (Tremblay 2008), and more specifically, bison. We found that visitors cited the importance of protecting open spaces more frequently after the bison reintroduction, suggesting that the presence of bison forged stronger connections between visitors and grassland ecosystems. Historical significance emerged as a top ten theme for 2016 compared to 2015, which may be attributed to the reintroduction of the iconic bison that once roamed the Great Plains. On the contrary, people cited the importance of Soapstone as an uncrowded place less often after the bison reintroduction compared to before. This shift could suggest that the bison reintroduction attracted more visitors and people who visited Soapstone in 2016 did not perceive the area as uncrowded. Understanding people's connections to open space can aid parks and protected area managers in developing programs or making management decisions informed by public perception. In doing so, managers can potentially reduce future conflicts, while enhancing the visitor experience and conservation goals (Williams & Vaske 2003).

Although we found marked differences in social responses and some ecological responses to bison reintroduction, our study was limited both spatially and temporally and should be interpreted accordingly. We expect that the direction and magnitude of our ecological and social results may reverse over time. We may observe stronger ecological responses to the bison as the herd grows, grazing intensity increases, and bison spend more time on the landscape. Conversely, place attachment scores in the coming years following the bison reintroduction may decrease or stabilize as the initial public excitement surrounding the reintroduction ebbs.

To fully understand how bison reintroduction influences grassland birds, mammals, plants, and people, future research should employ a before-after-control-impact (BACI) design, with consistent long-term monitoring, across a network of reintroduction sites (Griebel et al.1998; Towne et al. 2005). Because fire was historically also an important part of disturbance regimes in western grasslands, evaluating the effects of coupling bison grazing with controlled burns should also be a priority. Pyric herbivory in grasslands has been cited as an important tool for creating heterogeneous habitat that is critical for sustaining obligate grassland birds, mammals, and insects (Fuhlendorf et al. 2009). Most studies in tall and mixed grass prairie have observed changes to flora and fauna in response to bison grazing coupled with annual burns (Fahnestock & Knapp 1994; Griebel et al.1998; Matlack et al. 2001; Towne et al. 2005; Powell et al. 2006), yet the potential interactive effects of bison and fire in shortgrass prairie is virtually unknown.

In addition to measuring ecological responses, bison reintroduction research should consider the social factors surrounding the reintroduction. Social science remains poorly represented in species reintroduction efforts (Seddon et al. 2007), yet the success of these reintroductions requires understanding a broad range of people's perspectives. Our study was limited to evaluating visitor responses to bison reintroduction. Future studies should also consider the perspectives of adjacent landowners, cattle and bison ranchers, tribal groups, and other relevant stakeholder groups (Reading et al. 2002). Collaboration across disciplines, space, and time will be critical to gaining a better understanding of bison's current and future role as a keystone and flagship species in grassland landscapes.

CONCLUSION

In the two years following the reintroduction of bison to shortgrass prairie, we found that obligate and facultative grassland bird densities and habitat use did not change. Bison reintroduction also did not strongly affect habitat use by coyote, lagomorphs, mule deer, or pronghorn. We did find some support for a decrease in the percent cover and height of cool season grasses, forbs, and bare ground, and a slight increase in the percent cover of warm season grasses as a result of bison reintroduction. Although we observed few ecological effects, we documented significant increases in human visitor attachment to the grassland after reintroduction, with people more frequently emphasizing the importance of protecting open spaces with bison on the landscape. These findings could be an indication of the largely untapped potential for bison refaunation to catalyze the conservation of grasslands, which remains one of the world's most threatened biomes.

CHAPTER THREE: ECOLOGICAL REPLACEMENTS? EFFECTS OF BISON AND CATTLE GRAZING ON BIRD AND PLANT COMMUNITIES IN SHORTGRASS PRAIRIE

INTRODUCTION

Defaunation (the local decline or extinction of animals) can rapidly shift evolutionary patterns (Palumbi 2001) and disrupt ecosystem functions (Ascunce et al. 2011). An often controversial approach to counter global defaunation involves introducing non-native species to replace the ecological role of functionally extinct species (Seddon et al. 2014). Opponents to non-native species reintroductions cite the well-documented ecological and economic threats that invasive species pose to the environment and society (Simberloff 2005, Lodge et al. 2006), which may take years to manifest (Crooks & Soulé 1999). In cases where non-native species become invasive, they impact global biodiversity (Sax & Gaines 2008), cost billions of dollars to eradicate (Pimentel et al. 2005), and threaten human well-being by altering the flow of ecosystem services (Pejchar & Mooney 2009). However, there is a growing body of work that suggests that non-native species can help advance conservation goals (Marris 2011, Schlaepfer et al. 2011). For example, non-native species can serve as ecosystem engineers and restore ecosystem services where native species are extinct (Griffiths et al. 2010, Schlaepfer et al. 2011).

Whether non-native species can serve as proxies for extinct or rare native species without causing negative ecological effects (Caro & Sherman 2009, Ricciardi & Simberloff 2009) is a particularly relevant question in North American grasslands. Cattle have largely replaced bison as large grazing animals in these ecosystems (Knapp et al. 1999; Towne et al. 2005; Fuhlendorf et al. 2010; Kohl et al. 2013). Previous research has demonstrated that cattle and bison can interact differently with grassland ecosystems. Bison tend to graze across larger areas than cattle

(Kohl et al. 2013) and prefer grasses (Plumb & Dodd 1993; Knapp et al. 1999), while cattle graze both grasses and shrubs and spend more time at sites with woody vegetation (Allred 2011). Yet despite potential differences in grazing between the two species, it is feasible that cattle can be managed to achieve similar conservation outcomes as bison (Fuhlendorf et al. 2010). This idea is supported by a meta-analysis that found grazing intensity and evolutionary history of grazing serve as primary drivers affecting plant species composition and above ground net primary production (Milchunas & Lauenroth 1993).

Past studies comparing the effects of bison and cattle grazing on plant and animal communities report mixed results. Towne et al. (2005) found that both bison and cattle promoted diversity of tallgrass prairie plants at a site with 1.7 animal units/ha after 10 years of grazing. In contrast, sites that were burned and grazed by bison at an intensity of 1.2 animal units/ha supported higher bird species richness compared to cattle-grazed sites (Griebel et al. 1998). Yet, effects on bird abundance were inconsistent among species; Horned Larks (*Eremophila alpestris*) and Lark Sparrows (*Chondestes grammacus*) were more abundant in burned sites with bison, while Western Meadowlark (*Sturnella neglecta*) densities were higher in cattle grazed sites (Griebel et al. 1998). Some researchers suggest one mechanism that could explain similar ecological effects is bison wallowing and cattle pawing at the ground, which may act as analogous forms of disturbance that generate heterogeneity in grasslands (Milchunas et al. 1998). In addition, both bison and cattle use riparian areas ten times more frequently at high temperatures (36-39°C), an important factor to consider as the climate warms in some regions. Whether or not cattle can serve as an ecological proxy for bison may depend on abiotic and biotic characteristics of the site, as well as historic and ongoing management practices (Fuhlendorf 2010).

Most research comparing the ecological effects of bison and cattle grazing has focused on tallgrass, mixed grass, and shrub steppe grasslands, but the relative ecological roles of bison and cattle in shortgrass prairie are not well understood. Of all prairie ecosystems in North America, the largest percent (52%) of shortgrass prairie persists, with the potential to support a wide diversity of prairie flora and fauna compared to the more fragmented and less abundant tall and mixed grass prairies (Samson et al. 2004). Shortgrass prairie may respond differently to grazing compared to tall or mixed grass prairies because shortgrass prairies fall within semiarid landscapes (Lauenroth & Sala 1992), with mean annual precipitation (MAP) ranging from 246-375 mm (Knapp et al. 2015). In contrast, tall and mixed grass prairies have higher mean annual precipitation at 400-584 mm and 892 mm, respectively (Knapp et al. 2015). These precipitation regimes affect nutrient cycling and net primary production, and act as one of the primary factors that affect the plant species that can survive in these environments (Knapp et al. 2008). Thus, it is important to understand the comparative effects of bison and cattle grazing in semiarid shortgrass prairies where climate may interact with grazing to shape plant and bird communities.

Recent bison reintroductions to shortgrass prairie in Colorado and New Mexico offer the opportunity to explore whether bison and cattle have similar potential to maintain or restore habitat quality for grassland plants and birds. Ten bison were reintroduced to a shortgrass prairie site in northern Colorado in 2015 and this herd grew to 54 animals by 2018. Sixty bison were reintroduced to Rio Mora National Wildlife Refuge in New Mexico in 2009 and have grazed continuously to the present. Bison were reintroduced to northern Colorado as part of an effort to restore historic, native animal communities on Soapstone Prairie Natural Area and Red Mountain Open Space (City of Fort Collins Natural Areas Program 2007). In addition, these bison are part of a larger effort to mitigate disease (e.g., brucellosis) while preserving the unique genetic lineage of the Yellowstone bison herd. In northern New Mexico, bison were reintroduced to Rio Mora National Wildlife Refuge to help restore grassland habitat and as cultural resource for local Native American tribes, who help to manage the herd (U.S. Fish and Wildlife Service 2012a). Prior to bison reintroduction, cattle grazed both sites for more than 100 years (Martin 2009; (U.S. Fish and Wildlife Service 2012b), and cattle continue to graze most of the pasture surrounding the bison-grazed areas in both states.

The objectives of this study were to evaluate whether bison and cattle have similar effects on shortgrass prairie bird and plant communities, and to evaluate whether the effect size differs between a recent reintroduction site (Colorado) compared to a site where bison have been established for almost 10 years (New Mexico). Our specific research questions were: 1) how do bison and cattle grazing differentially affect bird habitat use, bird density, plant cover, and plant height relative to ungrazed sites?, and 2) does the direction and magnitude of these effects differ in shortgrass prairie where bison are well-established compared to a recent bison reintroduction?

METHODS

Study areas- To compare the effects of bison and cattle grazing on bird and plant communities, we selected bison, cattle, and ungrazed reference sites in shortgrass prairies of northern Colorado and northeastern New Mexico (Figure 3.1). Cattle have grazed these areas in both Colorado and New Mexico for more than 100 years, while bison have grazed the Colorado site since 2015 and the New Mexico site since 2009. Our Colorado study sites were located at Soapstone Prairie Natural Area and Red Mountain Open Space, hereafter, Soapstone and Red Mountain (Figure 3.1), located about 48 km north of Fort Collins, Colorado (U.S.A.). The elevation ranges from 1219-2200 m and 70 percent of the area is classified as shortgrass prairie/grassland ecosystem with dominant vegetation including grama (*Bouteloua gracilis*) and buffalo grasses (*Bouteloua dactyloides*) (City of Fort Collins Natural Areas Program 2007). This ecosystem also hosts a diverse animal community, including 130 bird species and more than 30 mammal species. These include species of conservation concern, such as the Lark bunting

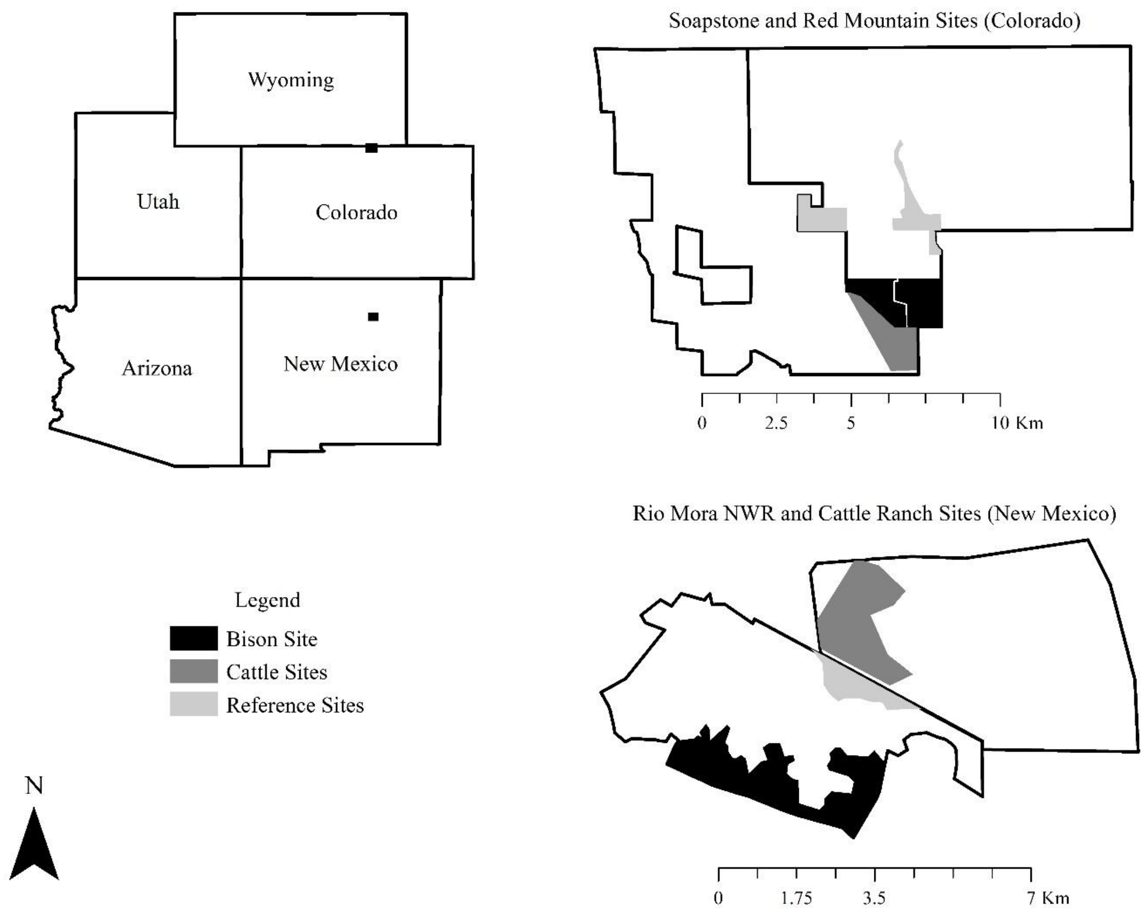

Figure 3.1 Study areas in Colorado and New Mexico

(*Calamospiza melanocorys*) and burrowing owl (*Athene cunicularia*) (City of Fort Collins Natural Areas Program 2007). Until approximately 100 years ago, Colorado's shortgrass prairies were grazed by large herds of bison (Isenberg 2000). Homesteaders arrived in the late 1860's and began to graze sheep and cattle at Soapstone and Red Mountain (Martin et al. 2009). These lands were purchased by the City of Fort Collins (Soapstone) in 2009 and Larimer County (Red Mountain) in 2001. After this change in ownership, the majority of this land continued to be grazed by cattle through leases with local ranchers. In November 2015, eleven bison were reintroduced to a fenced 393-hectare pasture split between Soapstone Prairie and Red Mountain (Figure 3.1). The bison site was not grazed by cattle for five years prior to the reintroduction (J. Fredrickson, personal communication). The herd has since grown, with 54 bison grazing the site as of June 2018.

Our New Mexico study sites were located in and adjacent to the Rio Mora National Wildlife Refuge (hereafter, Rio Mora). Rio Mora's elevation ranges between 1219-2100 m, and the primary vegetation communities include shortgrass steppe and piñon juniper woodlands (U.S. Fish and Wildlife Service 2012b). Rio Mora also hosts more than 150 avian species (U.S. Fish and Wildlife Service 2012c), including grassland bird species of conservation concern such as the burrowing owl (*Athene cunicularia*), loggerheaded shrike (*Lanius ludovicianus*), and long-billed curlew (*Numenius americanus*) ((U.S. Fish and Wildlife Service 2012b). The Rio Mora National Wildlife Refuge was established in Northeastern New Mexico in September 2012, after the former Wind River Ranch donated approximately 1862 hectares of land to create the refuge (U.S. Fish and Wildlife Service 2012b). The Wind River Ranch ceased cattle ranching activities in the 1980's to set their property aside for conservation purposes, and donated the land to the National Wildlife Refuge system in 2012 ("One Year of Rio Mora" 2013; U.S. Fish and Wildlife Service 2012b). The refuge is a unique system in that it is the only National Wildlife Refuge not managed solely by the federal government. Rio Mora works with the Denver Zoo to manage the land and wildlife, while the Pueblo of Pojoaque people own and manage the bison herd (U.S. Fish and Wildlife Service 2012c; McKinney 2014). Bison were reintroduced to the Wind River Ranch in 2009 and include between 58-61 individuals.

Study Design- We established a bison, cattle and ungrazed reference site at each study location. In Colorado, the fenced bison site located within Soapstone Prairie Natural Area (Figure 3.1) is about 393 hectares and had around .07 animal units/ha in 2016 and 2017. The reference site consists of several areas (309 acres in total) near the bison site that were infrequently grazed by cattle for the previous 10 years. The adjacent 266 ha cattle site is on Red Mountain Open Space and is grazed yearly by .10 animal units/ha for 4-6 weeks from March 1st – November 30th. The cattle are then rotated to other pastures on Red Mountain (T. Rollins, personal communication).

The fenced bison site (370 ha) and reference site (83 ha) in New Mexico are both within Rio Mora National Wildlife Refuge (Figure 3.1). The bison site has .04 animal units/ha and the reference site is theoretically available to bison but is difficult to access and bison graze at this location only 1-2 times per year (L. Ramirez, personal communication). The cattle site (266 ha) is located on an adjacent, privately-owned ranch. This pasture is grazed yearly, with occasional rest periods, by an average of .10 animal units/ha (Fort Union Ranch 2017). Mule deer, elk and pronghorn can cross fences and graze bison, cattle and reference sites at both locations.

Bird surveys- To estimate density and habitat use of birds at bison, cattle, and reference sites in Colorado and New Mexico, we randomly selected point count locations within the bison-grazed, cattle-grazed, and reference sites. The point count locations (Figure 1) were buffered 200 m from fences (Fuhlendorf et al. 2006), and spaced 200-250 m from one another to minimize the likelihood of double-counting individuals (Hanni et al. 2014). In addition, we also buffered points at least 200 meters from tree stands to ensure sampling within the same vegetation type at all sites. This resulted in 20 point count locations in bison and cattle sites in Colorado and New Mexico, 14 point count stations across two reference site sites in Colorado and 6 point count locations in the New Mexico reference site. Birds were surveyed at all sampling points between 5:30 am and 10 am between May-July in 2016 and 2017. Each survey consisted of identifying all bird species visually or aurally in 5-minute intervals (Fuhlendorf et al. 2006; Hani et al. 2014). Using a rangefinder, we measured the distance (m) between the observer and individual birds. Each bird point count location was surveyed five times per field season at the bison (n=100 surveys), cattle (n=100 surveys), and reference sites (n=70 surveys) in Colorado to account for imperfect detection. In New Mexico, each bird point count station was surveyed four times per field season at the bison (n=72 surveys), cattle (n=80 surveys), and reference sites (n=24 surveys). During each survey, we estimated wind speed, rainfall, and cloud cover using standard protocols and codes from the Bird Conservancy of the Rockies bird monitoring program (Hanni et al. 2014).

Plant surveys-We surveyed plant communities between June and August (2016) in both Colorado and New Mexico to quantify potential differences in plant composition and structure, and to measure habitat characteristics that might influence bird density and use. To measure plant composition and structure, we established one 50 m vegetation transect at each point count location in bison-grazed, cattle-grazed, and reference sites. We used a Daubenmire frame (Daubenmire 1959) and modified Robel pole (Vinton et al. 1993) to estimate percent canopy cover and height, respectively, every 10 m along each transect. We placed the Daubenmire frame to the right of the transect tape and alternated sides of the tape every 10 m. Within each frame, we recorded the percent canopy cover of bare ground, litter, rock, grasses, forbs and shrubs with non-overlapping percentages (Fletcher & Koford 2002). We identified all grasses, forbs, and shrubs to species. To measure plant structure, we placed the modified Robel pole (3.4 cm PVC pipe, 1 meter tall, 1 cm increments marked by alternating black and white bands) in the center of each Daubenmire frame. To estimate plant height, we observed the pole from each cardinal direction (N, S, E, W) at a distance of 4 meters and a height of 1 m (Robel et al. 1970). We also conducted a shrub count along the 50 m transect, for which we counted and identified to species all shrubs and sub-shrubs that occurred within 1 m of each side of the transect line.

Data Analysis

Bird Density- To determine if bird density differed between bison, cattle, and reference sites, we estimate densities of a subset of bird species using a two stage approach (Buckland et al. 2015b).First, we used program Distance to model variation in detection probability and estimate an effective detection radius. We modeled detection probability for birds with models that converged in program Distance and truncated 10% of observations collected at the largest distances for each species (Buckland et al. 2001). To estimate detection probability between bison, cattle, and reference sites, we analyzed each geographic location (Colorado or New Mexico), site type (bison, cattle, or reference) and year (2016 and 2017) separately. Independent variables used to model detection probability included categorical variables, such as observer, wind, and rain, while continuous variables included cloud cover, plant height, and distance from the observer to the bird. Three obligate grassland birds in Colorado and New Mexico met our criteria for density analyses. The species included Horned Lark, Vesper Sparrow (*Pooecetes gramineus*), and Western Meadowlark. We used either a half normal cosine function or a hazard rate cosine function, sometimes with data placed into 5 intervals or bins, to improve the fit of the detection function (Appendix 3).

For the second stage of the analysis, we constructed generalized linear mixed effects models (LMMs) using the glmer function in the lme4 package in R-studio (Bates et al. 2015). We used the effective detection radius (EDR, expressed as meters) estimated in program

Distance to calculate an effective area in hectares ($\prod$*EDR2*0.0001); the log of the effective area served as an offset in the GLMMs. The fixed effects in the GLMMs included site type (bison, cattle, or reference) and year (2016 or 2017). We set individual point count stations, located within the bison, cattle, and reference sites, as a random effect in the model. For bird species with models that did not converge in program Distance or meet our criteria for the goodness-of-fit tests in program Distance, we estimated occupancy (habitat use). To rank models produced in program Distance and R-Studio, we used Akaike's information criterion (AIC). We report information on competing models with a ΔAIC between 0.0-2.0, which indicates that these models have empirical support, and we report the AIC weight (Burnham et al. 2002). We only included models with rounded p-values$\geq$0.20 for Kolmogorov–Smirnov $\chi 2$ goodness-of-fit tests (K-S goodness-of-fit) or $\chi 2$ goodness-of-fit (Buckland et al. 2015).

Bird Habitat Use (Colorado only)- To determine if habitat use by birds varied among bison, cattle, and reference sites, we built dynamic occupancy models (Kéry & Chandler 2016) in RStudio's unmarked package (Fiske & Chandler 2011). We compared models using the AIC model selection process described above. We will refer to results from occupancy analyses as "habitat use", since we did not meet all assumptions for independence of sites and detections for occupancy (O'Connell & Bailey 2011). Since we included bird species with a minimum of 2-12 observations for each site and year, we were only able to conduct habitat use analyses on birds in Colorado. To maximize independence between sites we truncated all data to 100 m (half the distance between point count stations) to maximize independence between sites (O'Connell & Bailey 2011). Site-level covariates used to model variation in habitat use included site (bison, cattle, or reference). Yearly covariates for modelling colonization and extinction probabilities included site and year (2016 and 2017). Observation-level covariates used to model detection probability included rain, observer, wind, cloud cover, and vegetation height.

The dynamic occupancy model provides estimates of occupancy for the first year (2016), in addition to colonization and extinction estimates from 2016 to 2017. To calculate an estimate of habitat use in 2017, we constructed a recursive equation (MacKenzie 2003) in RStudio (Appendix 2) using the 2016 habitat use estimate derived from the top model and ran the function through parametric bootstrapping (10,000 simulations) to obtain 95% confidence intervals. To assess model fit, in addition to AIC values, we used parametric bootstrapping (10,000 simulations) to calculate $\chi 2$ p-values.

Plant Cover and Height- To assess the effect of bison reintroduction on plant communities, we grouped species into four categories that served as the response variables: Cool season grasses, warm season grasses, forbs, shrubs, and bare ground. We then built linear mixed effects models, using the individual location (point count station) as a random effect in the model. Response variables included plant category, and covariates included site (bison, cattle, or reference). We used Akaike's information criterion (AIC) to rank models (Burnham and Anderson 2002). If the top model for plant cover or height category included site as the covariate, then we considered the plant category to be correlated with site and we excluded these cover categories as covariates in the bird density and habitat use models described above to avoid issues associated with multicollinearity (Graham 2003). To compare plant species diversity among bison, cattle, and reference sites, we calculated Simpson's diversity index using the vegan package (Oksanen et al. 2018) and considered diversity to differ among sites if confidence intervals did not overlap.

RESULTS

Bird density and habitat use- We found that grassland bird responses to bison and cattle grazing were not uniform across species or study areas (Appendix 3). In both Colorado and New Mexico, bison and cattle grazed sites supported higher densities of Horned Larks compared to reference sites (Figure 3.2).

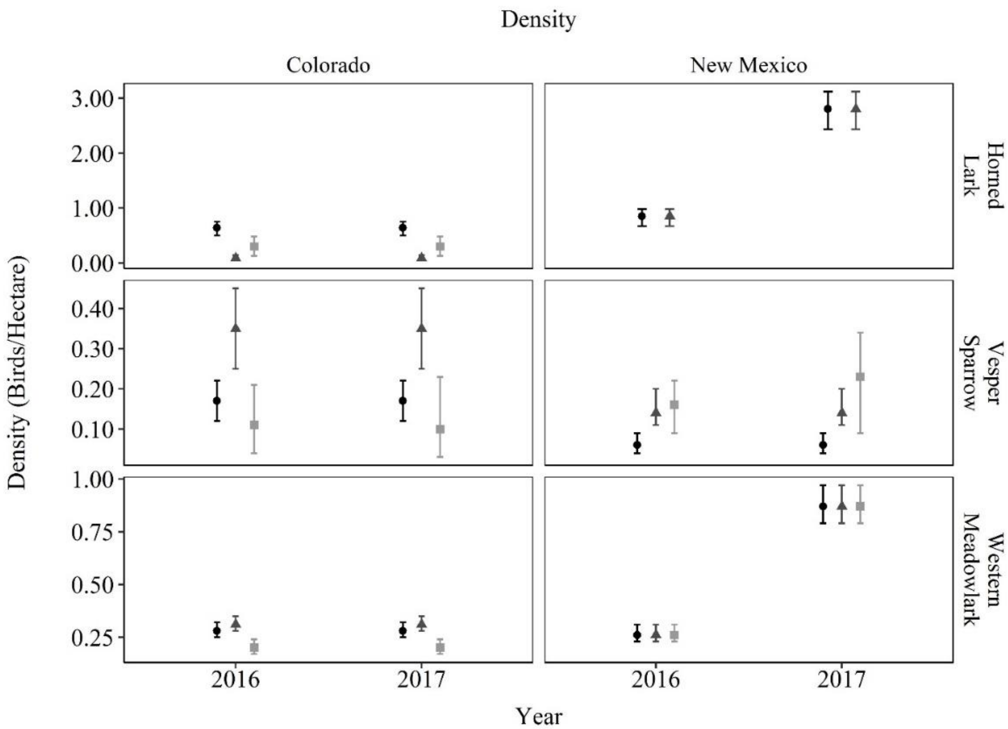

Figure 3.2 Density estimates for grassland birds in Colorado and New Mexico at sites grazed by bison (black circle), cattle (dark gray triangle), and ungrazed reference sites (light gray square). There were insufficient observations to estimate density at the reference site for Horned Larks in New Mexico.

However, bison-grazed sites in Colorado supported higher densities of Horned Larks compared to cattle and reference sites, while in New Mexico, bison and cattle sites supported equal densities of Horned Larks, with too few individuals to estimate density on the reference site. Furthermore, cattle grazed sites in Colorado and New Mexico supported higher densities of Vesper Sparrows compared to bison sites. In Colorado, Vesper Sparrow density at the cattle-grazed site was significantly different from both the bison and reference sites, while in New Mexico, Vesper Sparrow density in the cattle site differed significantly from the bison site. Western Meadowlark densities in Colorado were higher at the bison and cattle sites compared to the reference site, yet equal among all sites in New Mexico.

Based on overlapping confidence intervals, we report no significant differences in habitat use for Lark Sparrows or Grasshopper Sparrows at the Colorado study area (Figure 3.3).

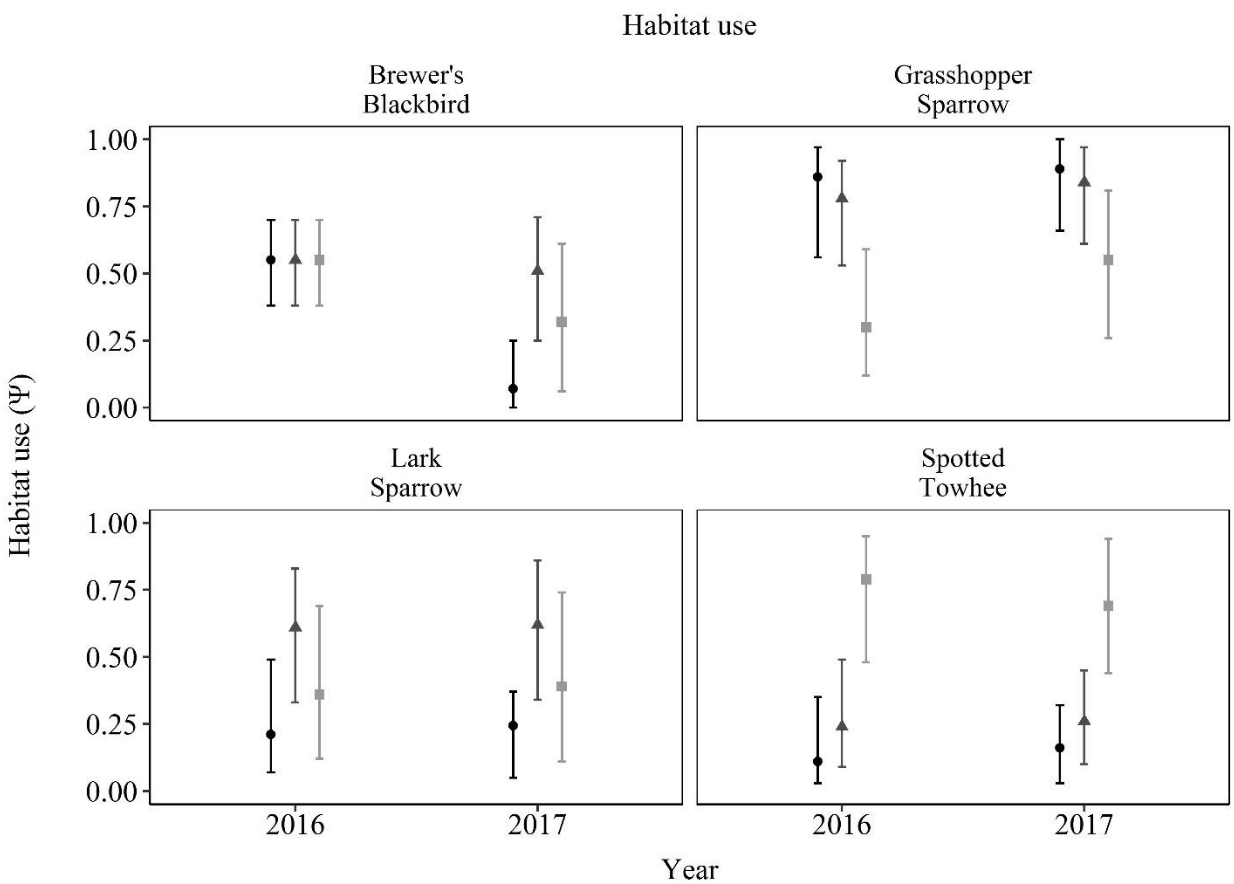

Figure 3.3 Density and habitat use estimates for obligate and facultative grassland birds in Colorado at sites grazed by bison (black circle), cattle (dark gray triangle), and ungrazed reference sites (light gray square).

Habitat use by Brewer's Blackbirds also did not vary among site types in 2016, but in 2017 Brewer's Blackbird habitat use was significantly higher in the cattle site compared to the bison site, but not compared to the reference site. We noted a trend of higher habitat use for Grasshopper Sparrows in the bison and cattle grazed sites compared to the reference site. In addition, we saw a trend of higher habitat use by Lark Sparrows in the cattle site compare to the bison and reference sites. The reference site supported significantly higher densities of Spotted Towhees compared to either the bison or cattle sites.

Plant cover and height- Based on overlapping confidence intervals, we measured no significant differences in the percent cover or height of plants among bison, cattle, and reference sites in Colorado or New Mexico (Table 3.1; Figure S14). However, we observed several interesting trends. In Colorado, the cattle site had higher percent cover of forbs compared to the bison or reference sites, and the percent cover of shrubs was higher at the reference site compared to the bison or cattle sites (Table 3.1). In both Colorado and New Mexico, bison and cattle sites had higher bare ground cover compared to reference sites. In New Mexico, the cattle site contained a higher percent cover of warm season grasses, while the bison site had higher percent cover of both shrubs and bare ground compared to the cattle and reference sites (Table 3.1). We observed no significant differences in plant diversity among bison, cattle, and reference sites based on overlapping confidence intervals (Appendix 3).

Table 3.1 COLORADO: Top generalized linear mixed models (ΔAIC ≤ 2) for how fixed effects—bison (Bis), cattle (Cat), or reference (Ref) sites—influenced cover and height of cool season grasses (Cool), warm season grasses (Warm), forbs, and shrubs, and bare ground (Bare) percent cover. We list the model, parameters (k), AIC, ΔAIC, and model weight (w). We list the direction of the fixed effects for the top model (model with the most weight). We present the cover and height estimates and their direction, cited as positive (+), negative (-), and no difference (.) in reference to the bison site.

COLORADO								
							β2016	
	Model	K	AIC	ΔAIC	w	Bis	Cat	Ref
COVER								
Cool	Null	3	442.48	0.00	0.81	17.83	17.83 (.)	17.83 (.)
Warm	Null	3	480.52	0.00	0.75	23.71	23.71 (.)	23.71 (.)
Forbs	Site	5	295.35	0.00	0.80	4.22	6.49 (+)	0.00 (-)
Shrubs	Site	4	362.83	0.00	0.95	5.24	4.88 (-)	11.54 (+)
Bare	Site	4	431.11	0.00	0.83	13.11	17.1 (+)	4.46 (-)
HEIGHT								
Cool	Null	3	223.38	0.00	0.77	9.96	9.96 (.)	9.96 (.)
Warm	Null	3	268.44	0.00	0.87	6.35	6.35 (.)	6.35 (.)
Forbs	Null	3	336.72	0.00	0.83	11.02	11.02 (.)	11.02 (.)
Shrubs	Null	3	389.53	0.00	0.61	14.52	14.52(.)	14.52(.)
	Site	5	390.53	0.89	0.39			

NEW MEXICO								
COVER								
Warm	Site	5	390.67	0.00	0.61	25.14	37.91 (+)	33.85 (+)
	Null	3	391.55	0.88	0.39			
Forbs	Null	3	275.51	0.00	0.78	2.02	2.02 (.)	2.02 (.)
Shrubs	Site	5	340.25	0.00	0.93	13.88	3.11 (-)	8.6 (-)
Bare	Site	5	336.82	0.00	0.68	27.72	20.19 (-)	20.98 (-)
	Null	2	338.32	1.50	0.32			
HEIGHT								
Warm	Null	3	190.52	0.00	1.00	5.07	5.07 (.)	5.07 (.)
Forbs	Null	3	211.14	0.00	1.00	1.44	1.44 (.)	1.44 (.)
Shrubs	Null	3	232.10	0.00	1.00	6.42	6.42 (.)	6.42 (.)

DISCUSSION

Bird densities and habitat use varied among sites grazed by bison, cattle, and ungrazed reference sites in Colorado and New Mexico, but the direction and magnitude of these differences was species-dependent. In Colorado, where bison were reintroduced shortly before our study, one grassland bird species occurred more frequently at the bison grazed site, three species were more prevalent at the cattle grazed site, and habitat use for another species was similar in bison and cattle sites, but less prevalent in ungrazed grasslands. At the New Mexico site, where bison have been established for nearly a decade, the density of one obligate grassland bird was higher in the cattle grazed site, and another species occurred in higher densities in both bison and cattle grazed sites compared to reference sites. These differences in bird density and habitat use are only partially explained by plant height and cover; we found few differences in grass and forb cover and only marginal differences in shrub cover and height among sites. Our findings suggest that low intensity grazing by either cattle and bison improve habitat quality for most common bird species in our shortgrass prairie study areas. These results are consistent with previous studies from tallgrass prairie that show similar plant responses at bison and cattle grazed sites relative to ungrazed areas (Towne et al. 2005).

We find that cattle are partial, but not complete ecological replacements for bison in prairie ecosystems (Griebel et al. 1998). Differences in bird density between bison and cattle sites were species-dependent. For example, Vesper Sparrow densities were higher in the cattle site in both Colorado and New Mexico, perhaps due to a higher percent cover of forbs at cattle sites, which could provide preferred nesting habitat for this species (Harrison et al. 2011). In contrast to Vesper Sparrows, Horned Larks had higher densities at the bison grazed site relative to reference sites, and densities were also high in the cattle grazed site in New Mexico. This result is consistent with past research that suggests Horned Larks prefer to nest in grazed areas and forage in bare patches (Lomolino & Smith 2004). Although not significantly different, the bison site and cattle sites generally had higher percent cover of bare ground than the reference sites. This finding also corresponds with past research in a mixed grass prairie that found higher densities of Horned Larks in bison sites compared to reference sites (Griebel et al. 1998). Grasshopper Sparrows, which prefer to nest in sites with light to intermediate grazing (Powell 2006), had higher habitat use in areas grazed by bison and cattle compared to reference sites. Rotational grazing practices on the cattle-grazed site could result in light to moderate herbivory, maintaining habitat quality for this bird species. In contrast to these three species, Spotted Towhee habitat use was significantly higher in reference sites, which is likely due to higher shrub cover at these sites, which is the preferred habitat for this species (Small et al. 2007). Western Meadowlark densities were significantly higher in bison and cattle sites compared to reference sites in Colorado. However, their densities remained constant among bison, cattle, and reference sites in New Mexico. Western Meadowlarks prefer moderately grazed pastures, which could explain their higher densities at bison and cattle sites compared to reference sites Colorado (Knopf 1996). In New Mexico, Western Meadowlark densities may have remained constant across sites because we did not observe any differences in plant cover or height at bison, cattle, and reference sites in this study area.

We observed the trend of higher habitat use by Lark Sparrows at the cattle-grazed site compared to bison or reference sites in Colorado, possibly due to the higher percent cover of forbs at this site. Past studies have demonstrated positive correlations between Lark Sparrow densities and forb cover (Wiens & Rotenberry 1981). This contrasts with previous work in mixed grass prairie that has demonstrated higher densities of Lark Sparrows at bison relative to cattle grazed sites (Griebel et al. 1998), which could be due to the difference in the landscapes, including more mixed grass heights in Colorado and more shrubs in New Mexico.

We found similar responses for several bird species at a recent (2-year-old) bison reintroduction site and a site where bison have been on the landscape for almost ten years. Furthermore, cattle-grazed sites in both Colorado and New Mexico supported higher densities of Vesper Sparrows compared to the bison-grazed site. Yet, there were also notable differences between study areas. The bison reintroduction site in Colorado supported higher densities of Horned Larks, another obligate grassland bird, while in New Mexico, this same species was found in equal densities at bison and cattle grazed sites. If the Colorado bison site follows the same trajectory as the well-established bison grazed site in New Mexico, then we might predict Horned Lark densities as bison and cattle grazed sites in Colorado to become more even with time.

The similarities in plant community cover, height, and diversity between bison and cattle sites that we observed is consistent with previous studies in other grassland ecosystems (Towne et al. 2005). These similarities could be attributed to relatively low density grazing by both species in our study areas, including rotational grazing of cattle. At higher grazing intensities, it is possible that bison and cattle could have different effects on plant communities because of documented differences in foraging preferences (Allred et al. 2011, 2013; Kohl et al. 2013). In addition, our bison sites were grazed by cattle for approximately 100 years before bison reintroduction. This legacy could have shaped grassland plant communities (Milchunas & Lauenroth 1993) such that any effects of bison grazing might not be detected for decades (Towne et al. 2005; Powell 2006). Finally, in arid and semiarid ecosystems with low to moderate grazing intensity, climate may play a strong role in influencing bird and plant communities, and could mask any comparatively minor effects of bison and cattle grazing (Niemuth et al. 2008, Lipsey & Naugle 2017).

This study provides important insight into the effects of cattle and bison grazing on shortgrass prairie biota, but is limited in its spatial and temporal scale. Our study occurred over two-years in two study areas that each support single herds of bison and cattle. Because bison herds are uncommon and occur in relatively small and completely isolated fenced areas, we were unable to replicate our study across multiple bison sites in each study area or across the full range of shortgrass prairie in western North America. As a result, we could not experimentally evaluate the potential effects of animal grazing intensity, time since bison reintroduction, precipitation, or potential interactive effects of grazing or burning, on birds and plants (Fuhlendorf et al. 2010). To better predict the conditions under which bison and cattle play similar or disparate ecological roles, we recommend establishing a research network to standardize data collection across the many new and emerging plains bison reintroduction efforts in North America. Many of these bison projects are embedded in landscapes dominated by cattle ranching, offering excellent opportunities to advance interdisciplinary science around bison reintroduction and conservation-compatible grazing practices.

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APPENDIX 1:

SUPPORTING INFORMATION FOR CHAPTER ONE

FULL LIST OF SEARCH TERMS RELATED TO COLLABORATIVE CONSERVATION

“adaptive co management”
“adaptive governance”
“adaptive management”
“collaborative conservation”
“co-management”
“community based forestry”
“community based collaboration*”
“community led collaboration*”
“community based natural resource management”
“collaborative adaptive management”
“collaborative environmental management”
“collaborative environmental governance regime*”
“collaborative ecosystem management”
“collaborative fest management”
“collaborative forum*”
“collaborative natural resource management”
“collaborative roundtable*”
“collaborative watershed management”
“Conservation cooperative”
“conservation partnership*”
“cross sect collaboration*”
“environmental conflict resolution”
“fest association*”
“fest coalition*”
“grass roots ecosystem management”
“integrated natural resource management”
“landowner association*”
“landowner coalition*”
“landscape conservation*”
“multiparty collaboration*”
“multistakeholder collaboration*”
“participatory natural resource management”
“Place based collaboration*”
“Results oriented conservation*”
“watershed association*”
“watershed coalition*”
Geographic Location Terms
“U.S.A.”
“USA”

"U.S."
"United States"
"United States of America"
"Alabama"
"Alaska"
"Arizona"
"Arkansas"
"California"
"Colorado"
"Connecticut"
"Delaware"
"Florida"
"Georgia"
"Hawaii"
"Idaho"
"Illinois"
"Indiana"
"Iowa"
"Kansas"
"Kentucky"
"Louisiana"
"Maine"
"Maryland"
"Massachusetts"
"Michigan"
"Minnesota"
"Mississippi"
"Missouri"
"Montana"
"Nebraska"
"Nevada"
"New Hampshire"
"New Jersey"
"New Mexico"
"New York"
"North Carolina"
"North Dakota"
"Ohio"
"Oklahoma"
"Oregon"
"Pennsylvania"

“Rhode Island”
“South Carolina”
“South Dakota”
“Tennessee”
“Texas”
“Utah”
“Vermont”
“Virginia”
“Washington”
“West Virginia”
“Wisconsin”
“Wyoming”

Table A1.1. Boolean search terms, search engines and date searched

Date	Database	Search Term String
1/6/17 and 1/7/17	Web of Science's Advanced Search	TS=(“adaptive co management” OR “adaptive governance” OR “adaptive management” OR “collaborative conservation” OR “co management” OR “community based forestry” OR “community based collaboration*” OR “community led collaboration*” OR “community based natural resource management” OR “collaborative adaptive management” OR “collaborative environmental management” OR “collaborative environmental governance regime*” OR “collaborative ecosystem management” OR “collaborative forest management” OR “collaborative forum*” OR “collaborative natural resource management” OR “collaborative roundtable*” OR “collaborative watershed management” OR “Conservation cooperative” OR “conservation partnership*” OR “cross sector collaboration*” OR “environmental conflict resolution” OR “forest association*” OR “forest coalition*” OR “grass roots ecosystem management” OR “integrated natural resource management” OR “landowner association*” OR “landowner coalition*” OR “landscape conservation*” OR “multiparty collaboration*” OR “multistakeholder collaboration*” OR “participatory natural resource management” OR “Place based collaboration*” OR “Results oriented conservation*” OR “watershed association*” OR “watershed coalition*”) AND TS=(“U.S.A.” OR “USA” OR “U.S.” OR “United States” OR “United States of America” OR “Alabama” OR “Alaska” OR

Date	Database	Search Term String
		“Arizona” OR “Arkansas” OR “California” OR “Colorado” OR “Connecticut” OR “Delaware” OR “Florida” OR “Georgia” OR “Hawaii” OR “Idaho” OR “Illinois” OR “Indiana” OR “Iowa” OR “Kansas” OR “Kentucky” OR “Louisiana” OR “Maine” OR “Maryland” OR “Massachusetts” OR “Michigan” OR “Minnesota” OR “Mississippi” OR “Missouri” OR “Montana” OR “Nebraska” OR “Nevada” OR “New Hampshire” OR “New Jersey” OR “New Mexico” OR “New York” OR “North Carolina” OR “North Dakota” OR “Ohio” OR “Oklahoma” OR “Oregon” OR “Pennsylvania” OR “Rhode Island” OR “South Carolina” OR “South Dakota” OR “Tennessee” OR “Texas” OR “Utah” OR “Vermont” OR “Virginia” OR “Washington” OR “West Virginia” OR “Wisconsin” OR "Wyoming")
1/24/17	WorldCat	(kw: adaptive and kw: co and kw: management) OR (kw: adaptive and kw: governance) OR (kw: adaptive and kw: management) OR (kw: collaborative and kw: conservation) OR (kw: co and kw: management) OR ((kw: community and kw: based and kw: forestry) OR ((kw: community and kw: based and kw: collaboration*) OR ((kw: community and kw: led and kw: collaboration*) OR ((kw: community and kw: based and kw: natural and kw: resource and kw: management) OR ((kw: collaborative and kw: adaptive and kw: management) OR ((kw: collaborative and kw: environmental and kw: management) OR ((kw: collaborative and kw: environmental and kw: governance and kw: regime*) OR ((kw: collaborative and kw: ecosystem and kw: management) OR ((kw:

Date	Database	Search Term String
		collaborative and kw: forest and kw: management) OR (kw: collaborative and kw: forum*) OR ((kw: collaborative and kw: natural and kw: resource and kw: management) OR (kw: collaborative and kw: roundtable*) OR ((kw: collaborative and kw: watershed and kw: management) OR (kw: Conservation and kw: cooperative) OR (kw: conservation and kw: partnership*) OR ((kw: cross and kw: sector and kw: collaboration*) OR ((kw: environmental and kw: conflict and kw: resolution) OR (kw: forest and kw: association*) OR (kw: forest and kw: coalition*) OR ((kw: grass and kw: roots and kw: ecosystem and kw: management) OR ((kw: integrated and kw: natural and kw: resource and kw: management) OR (kw: landowner and kw: association*) OR (kw: landowner and kw: coalition*) OR (kw: landscape and kw: conservation*) OR (kw: multiparty and kw: collaboration*) OR (kw: multistakeholder and kw: collaboration*) OR ((kw: participatory and kw: natural and kw: resource and kw: management) OR ((kw: Place and kw: based and kw: collaboration*) OR ((kw: Results and kw: oriented and kw: conservation*) OR (kw: watershed and kw: association*) OR (kw: watershed and kw: coalition*)))))))))))))))))))) not mt: fic and la= "eng" and (dt= "bks" or dt= "ser" or dt= "com" or dt= "mix" or dt= "art" or dt= "url" or dt= "int")) and ((kw: U.S.A.OR and kw: USA) OR kw: U.S. OR (kw: United and kw: States) OR ((kw: United and kw: States and kw: America) OR kw: Alabama) OR kw: Alaska OR kw: Arizona OR kw: Arkansas OR kw:

Date	Database	Search Term String
		California OR kw: Colorado OR kw: Connecticut OR kw: Delaware OR kw: Florida OR kw: Georgia OR kw: Hawaii OR kw: Idaho OR kw: Illinois OR kw: Indiana OR kw: Iowa OR kw: Kansas OR kw: Kentucky OR kw: Louisiana OR kw: Maine OR kw: Maryland OR kw: Massachusetts OR kw: Michigan OR kw: Minnesota OR kw: Mississippi OR kw: Missouri OR kw: Montana OR kw: Nebraska OR kw: Nevada OR (kw: New and kw: Hampshire) OR (kw: New and kw: Jersey) OR (kw: New and kw: Mexico) OR (kw: New and kw: York) OR (kw: North and kw: Carolina) OR (kw: North and kw: Dakota) OR kw: Ohio OR kw: Oklahoma OR kw: Oregon OR kw: Pennsylvania OR (kw: Rhode and kw: Island) OR (kw: South and kw: Carolina) OR (kw: South and kw: Dakota) OR kw: Tennessee OR kw: Texas OR kw: Utah OR kw: Vermont OR kw: Virginia OR kw: Washington OR (kw: West and kw: Virginia) OR kw: Wisconsin OR kw: Wyoming)
1/17/17	PAIS	(“adaptive co management” OR “adaptive governance” OR “adaptive management” OR “collaborative conservation” OR “co management” OR “community based forestry” OR “community based collaboration*” OR “community led collaboration*” OR “community based natural resource management” OR “collaborative adaptive management” OR “collaborative environmental management” OR “collaborative environmental governance regime*” OR “collaborative ecosystem management” OR “collaborative forest management” OR “collaborative forum*” OR “collaborative natural resource

Date	Database	Search Term String
		management” OR “collaborative roundtable*” OR “collaborative watershed management” OR “Conservation cooperative” OR “conservation partnership*” OR “cross sector collaboration*” OR “environmental conflict resolution” OR “forest association*” OR “forest coalition*” OR “grass roots ecosystem management” OR “integrated natural resource management” OR “landowner association*” OR “landowner coalition*” OR “landscape conservation*” OR “multiparty collaboration*” OR “multistakeholder collaboration*” OR “participatory natural resource management” OR “Place based collaboration*” OR “Results oriented conservation*” OR “watershed association*” OR “watershed coalition*”) AND (“U.S.A.” OR “USA” OR “U.S.” OR “United States” OR “United States of America” OR “Alabama” OR “Alaska” OR “Arizona” OR “Arkansas” OR “California” OR “Colorado” OR “Connecticut” OR “Delaware” OR “Florida” OR “Georgia” OR “Hawaii” OR “Idaho” OR “Illinois” OR “Indiana” OR “Iowa” OR “Kansas” OR “Kentucky” OR “Louisiana” OR “Maine” OR “Maryland” OR “Massachusetts” OR “Michigan” OR “Minnesota” OR “Mississippi” OR “Missouri” OR “Montana” OR “Nebraska” OR “Nevada” OR “New Hampshire” OR “New Jersey” OR “New Mexico” OR “New York” OR “North Carolina” OR “North Dakota” OR “Ohio” OR “Oklahoma” OR “Oregon” OR “Pennsylvania” OR “Rhode Island” OR “South Carolina” OR “South Dakota” OR “Tennessee” OR “Texas” OR “Utah” OR

Date	Database	Search Term String
		“Vermont” OR “Virginia” OR “Washington” OR “West Virginia” OR “Wisconsin” OR "Wyoming")
1/17/17 and 1/24/17	Environmental Science and Pollution Management	(“adaptive co management” OR “adaptive governance” OR “adaptive management” OR “collaborative conservation” OR “co management” OR “community based forestry” OR “community based collaboration*” OR “community led collaboration*” OR “community based natural resource management” OR “collaborative adaptive management” OR “collaborative environmental management” OR “collaborative environmental governance regime*” OR “collaborative ecosystem management” OR “collaborative forest management” OR “collaborative forum*” OR “collaborative natural resource management” OR “collaborative roundtable*” OR “collaborative watershed management” OR “Conservation cooperative” OR “conservation partnership*” OR “cross sector collaboration*” OR “environmental conflict resolution” OR “forest association*” OR “forest coalition*” OR “grass roots ecosystem management” OR “integrated natural resource management” OR “landowner association*” OR “landowner coalition*” OR “landscape conservation*” OR

Date	Database	Search Term String
		“multiparty collaboration*” OR “multistakeholder collaboration*” OR “participatory natural resource management” OR “Place based collaboration*” OR “Results oriented conservation*” OR “watershed association*” OR “watershed coalition*”) AND (“U.S.A.” OR “USA” OR “U.S.” OR “United States” OR “United States of America” OR “Alabama” OR “Alaska” OR “Arizona” OR “Arkansas” OR “California” OR “Colorado” OR “Connecticut” OR “Delaware” OR “Florida” OR “Georgia” OR “Hawaii” OR “Idaho” OR “Illinois” OR “Indiana” OR “Iowa” OR “Kansas” OR “Kentucky” OR “Louisiana” OR “Maine” OR “Maryland” OR “Massachusetts” OR “Michigan” OR “Minnesota” OR “Mississippi” OR “Missouri” OR “Montana” OR “Nebraska” OR “Nevada” OR “New Hampshire” OR “New Jersey” OR “New Mexico” OR “New York” OR “North Carolina” OR “North Dakota” OR “Ohio” OR “Oklahoma” OR “Oregon” OR “Pennsylvania” OR “Rhode Island” OR “South Carolina” OR “South Dakota” OR “Tennessee” OR “Texas” OR “Utah” OR “Vermont” OR “Virginia” OR “Washington” OR “West Virginia” OR “Wisconsin” OR "Wyoming")
1/20/17	Wildlife and Ecology Studies Worldwide	TX (“adaptive co management” OR “adaptive governance” OR “adaptive management” OR “collaborative conservation” OR “co management” OR “community based forestry” OR “community based collaboration*” OR “community led collaboration*” OR “community based natural resource management” OR “collaborative adaptive management” OR “collaborative environmental

Date	Database	Search Term String
		management" OR "collaborative environmental governance regime*" OR "collaborative ecosystem management" OR "collaborative forest management" OR "collaborative forum*" OR "collaborative natural resource management" OR "collaborative roundtable*" OR "collaborative watershed management" OR "Conservation cooperative" OR "conservation partnership*" OR "cross sector collaboration*" OR "environmental conflict resolution" OR "forest association*" OR "forest coalition*" OR "grass roots ecosystem management" OR "integrated natural resource management" OR "landowner association*" OR "landowner coalition*" OR "landscape conservation*" OR "multiparty collaboration*" OR "multistakeholder collaboration*" OR "participatory natural resource management" OR "Place based collaboration*" OR "Results oriented conservation*" OR "watershed association*" OR "watershed coalition*") AND TX ("U.S.A." OR "USA" OR "U.S." OR "United States" OR "United States of America" OR "Alabama" OR "Alaska" OR "Arizona" OR "Arkansas" OR "California" OR "Colorado" OR "Connecticut" OR "Delaware" OR "Florida" OR "Georgia" OR "Hawaii" OR "Idaho" OR "Illinois" OR "Indiana" OR "Iowa" OR "Kansas" OR "Kentucky" OR "Louisiana" OR "Maine" OR "Maryland" OR "Massachusetts" OR "Michigan" OR "Minnesota" OR "Mississippi" OR "Missouri" OR "Montana" OR "Nebraska" OR "Nevada" OR "New Hampshire" OR "New Jersey" OR

Date	Database	Search Term String
		“New Mexico” OR “New York” OR “North Carolina” OR “North Dakota” OR “Ohio” OR “Oklahoma” OR “Oregon” OR “Pennsylvania” OR “Rhode Island” OR “South Carolina” OR “South Dakota” OR “Tennessee” OR “Texas” OR “Utah” OR “Vermont” OR “Virginia” OR “Washington” OR “West Virginia” OR “Wisconsin” OR "Wyoming")
1/18/17	Aquatic Science and Fisheries Abstracts	TS=(“adaptive co management” OR “adaptive governance” OR “adaptive management” OR “collaborative conservation” OR “co management” OR “community based forestry” OR “community based collaboration*” OR “community led collaboration*” OR “community based natural resource management” OR “collaborative adaptive management” OR “collaborative environmental management” OR “collaborative environmental governance regime*” OR “collaborative ecosystem management” OR “collaborative forest management” OR “collaborative forum*” OR “collaborative natural resource management” OR “collaborative roundtable*” OR “collaborative watershed management” OR “Conservation cooperative” OR “conservation partnership*” OR “cross sector collaboration*” OR “environmental conflict resolution” OR “forest association*” OR “forest coalition*” OR “grass roots ecosystem management” OR “integrated natural resource management” OR “landowner association*” OR “landowner coalition*” OR “landscape conservation*” OR “multiparty collaboration*” OR “multistakeholder collaboration*” OR “participatory natural resource

Date	Database	Search Term String
		management” OR “Place based collaboration*” OR “Results oriented conservation*” OR “watershed association*” OR “watershed coalition*”) AND TS=(“U.S.A.” OR “USA” OR “U.S.” OR “United States” OR “United States of America” OR “Alabama” OR “Alaska” OR “Arizona” OR “Arkansas” OR “California” OR “Colorado” OR “Connecticut” OR “Delaware” OR “Florida” OR “Georgia” OR “Hawaii” OR “Idaho” OR “Illinois” OR “Indiana” OR “Iowa” OR “Kansas” OR “Kentucky” OR “Louisiana” OR “Maine” OR “Maryland” OR “Massachusetts” OR “Michigan” OR “Minnesota” OR “Mississippi” OR “Missouri” OR “Montana” OR “Nebraska” OR “Nevada” OR “New Hampshire” OR “New Jersey” OR “New Mexico” OR “New York” OR “North Carolina” OR “North Dakota” OR “Ohio” OR “Oklahoma” OR “Oregon” OR “Pennsylvania” OR “Rhode Island” OR “South Carolina” OR “South Dakota” OR “Tennessee” OR “Texas” OR “Utah” OR “Vermont” OR “Virginia” OR “Washington” OR “West Virginia” OR “Wisconsin” OR "Wyoming")
1/17/17	CAB Abstracts (1975-Present)	TS=(“adaptive co management” OR “adaptive governance” OR “adaptive management” OR “collaborative conservation” OR “co management” OR “community based forestry” OR “community based collaboration*” OR “community led collaboration*” OR “community based natural resource management” OR “collaborative adaptive management” OR “collaborative environmental management” OR “collaborative environmental governance regime*” OR “collaborative ecosystem

Date	Database	Search Term String
		management” OR “collaborative forest management” OR “collaborative forum*” OR “collaborative natural resource management” OR “collaborative roundtable*” OR “collaborative watershed management” OR “Conservation cooperative” OR “conservation partnership*” OR “cross sector collaboration*” OR “environmental conflict resolution” OR “forest association*” OR “forest coalition*” OR “grass roots ecosystem management” OR “integrated natural resource management” OR “landowner association*” OR “landowner coalition*” OR “landscape conservation*” OR “multiparty collaboration*” OR “multistakeholder collaboration*” OR “participatory natural resource management” OR “Place based collaboration*” OR “Results oriented conservation*” OR “watershed association*” OR “watershed coalition*”) AND TS=(“U.S.A.” OR “USA” OR “U.S.” OR “United States” OR “United States of America” OR “Alabama” OR “Alaska” OR “Arizona” OR “Arkansas” OR “California” OR “Colorado” OR “Connecticut” OR “Delaware” OR “Florida” OR “Georgia” OR “Hawaii” OR “Idaho” OR “Illinois” OR “Indiana” OR “Iowa” OR “Kansas” OR “Kentucky” OR “Louisiana” OR “Maine” OR “Maryland” OR “Massachusetts” OR “Michigan” OR “Minnesota” OR “Mississippi” OR “Missouri” OR “Montana” OR “Nebraska” OR “Nevada” OR “New Hampshire” OR “New Jersey” OR “New Mexico” OR “New York” OR “North Carolina” OR “North Dakota” OR “Ohio” OR “Oklahoma” OR

Date	Database	Search Term String
		“Oregon” OR “Pennsylvania” OR “Rhode Island” OR “South Carolina” OR “South Dakota” OR “Tennessee” OR “Texas” OR “Utah” OR “Vermont” OR “Virginia” OR “Washington” OR “West Virginia” OR “Wisconsin” OR "Wyoming")
1/20/17	Zoological Records Plus	TS=(“adaptive co management” OR “adaptive governance” OR “adaptive management” OR “collaborative conservation” OR “co management” OR “community based forestry” OR “community based collaboration*” OR “community led collaboration*” OR “community based natural resource management” OR “collaborative adaptive management” OR “collaborative environmental management” OR “collaborative environmental governance regime*” OR “collaborative ecosystem management” OR “collaborative forest management” OR “collaborative forum*” OR “collaborative natural resource management” OR “collaborative roundtable*” OR “collaborative watershed management” OR “Conservation cooperative” OR “conservation partnership*” OR “cross sector collaboration*” OR “environmental conflict resolution” OR “forest association*” OR “forest coalition*” OR “grass roots ecosystem management” OR “integrated natural resource management” OR “landowner association*” OR “landowner coalition*” OR “landscape conservation*” OR “multiparty collaboration*” OR “multistakeholder collaboration*” OR “participatory natural resource management” OR “Place based collaboration*” OR “Results oriented

Date	Database	Search Term String
		conservation*" OR "watershed association*" OR "watershed coalition*") AND TS=("U.S.A." OR "USA" OR "U.S." OR "United States" OR "United States of America" OR "Alabama" OR "Alaska" OR "Arizona" OR "Arkansas" OR "California" OR "Colorado" OR "Connecticut" OR "Delaware" OR "Florida" OR "Georgia" OR "Hawaii" OR "Idaho" OR "Illinois" OR "Indiana" OR "Iowa" OR "Kansas" OR "Kentucky" OR "Louisiana" OR "Maine" OR "Maryland" OR "Massachusetts" OR "Michigan" OR "Minnesota" OR "Mississippi" OR "Missouri" OR "Montana" OR "Nebraska" OR "Nevada" OR "New Hampshire" OR "New Jersey" OR "New Mexico" OR "New York" OR "North Carolina" OR "North Dakota" OR "Ohio" OR "Oklahoma" OR "Oregon" OR "Pennsylvania" OR "Rhode Island" OR "South Carolina" OR "South Dakota" OR "Tennessee" OR "Texas" OR "Utah" OR "Vermont" OR "Virginia" OR "Washington" OR "West Virginia" OR "Wisconsin" OR "Wyoming")
1/24/17	Academic Search Premier	TX ("adaptive co management" OR "adaptive governance" OR "adaptive management" OR "collaborative conservation" OR "co management" OR "community based forestry" OR "community based collaboration*" OR "community led collaboration*" OR "community based natural resource management" OR "collaborative adaptive management" OR "collaborative environmental management" OR "collaborative environmental governance regime*" OR "collaborative ecosystem management" OR "collaborative forest management" OR

Date	Database	Search Term String
		“collaborative forum*” OR “collaborative natural resource management” OR “collaborative roundtable*” OR “collaborative watershed management” OR “Conservation cooperative” OR “conservation partnership*” OR “cross sector collaboration*” OR “environmental conflict resolution” OR “forest association*” OR “forest coalition*” OR “grass roots ecosystem management” OR “integrated natural resource management” OR “landowner association*” OR “landowner coalition*” OR “landscape conservation*” OR “multiparty collaboration*” OR “multistakeholder collaboration*” OR “participatory natural resource management” OR “Place based collaboration*” OR “Results oriented conservation*” OR “watershed association*” OR “watershed coalition*”) AND TX (“U.S.A.” OR “USA” OR “U.S.” OR “United States” OR “United States of America” OR “Alabama” OR “Alaska” OR “Arizona” OR “Arkansas” OR “California” OR “Colorado” OR “Connecticut” OR “Delaware” OR “Florida” OR “Georgia” OR “Hawaii” OR “Idaho” OR “Illinois” OR “Indiana” OR “Iowa” OR “Kansas” OR “Kentucky” OR “Louisiana” OR “Maine” OR “Maryland” OR “Massachusetts” OR “Michigan” OR “Minnesota” OR “Mississippi” OR “Missouri” OR “Montana” OR “Nebraska” OR “Nevada” OR “New Hampshire” OR “New Jersey” OR “New Mexico” OR “New York” OR “North Carolina” OR “North Dakota” OR “Ohio” OR “Oklahoma” OR “Oregon” OR “Pennsylvania” OR “Rhode Island” OR “South Carolina”

Date	Database	Search Term String
		OR “South Dakota” OR “Tennessee” OR “Texas” OR “Utah” OR “Vermont” OR “Virginia” OR “Washington” OR “West Virginia” OR “Wisconsin” OR "Wyoming")
1/26/17	Google Scholar String A	(“adaptive co management” OR “adaptive governance” OR “adaptive management” OR “collaborative conservation” OR “co management”) AND (“U.S.A.” OR “USA” OR “U.S.” OR “United States” OR “United States of America”)
1/27/17	Google Scholar String B	(“community based forestry” OR “community based collaboration*” OR “community led collaboration*”) AND (“U.S.A.” OR “USA” OR “U.S.” OR “United States” OR “United States of America”)
1/29/17	Google Scholar String C	(“collaborative environmental management” OR “collaborative environmental governance regime*” OR “collaborative ecosystem management”) AND (“U.S.A.” OR “USA” OR “U.S.” OR “United States” OR “United States of America”)
1/29/17	Google Scholar String D	(“collaborative roundtable*” OR “collaborative watershed management” OR “Conservation cooperative” OR “grass roots ecosystem management”) AND (“U.S.A.” OR “USA” OR “U.S.” OR “United States” OR “United States of America”)
1/28/17	Google Scholar String E	(“environmental conflict resolution” OR “forest association*” OR “forest coalition*” OR “landowner association*”) AND (“U.S.A.” OR

Date	Database	Search Term String
		"USA" OR "U.S." OR "United States" OR "United States of America")
1/27/17	Google Scholar String F	("landowner coalition*" OR "landscape conservation*" OR "multiparty collaboration*" OR "Place based collaboration*") AND ("U.S.A." OR "USA" OR "U.S." OR "United States" OR "United States of America")
1/28/17	Google Scholar String G	("collaborative adaptive management" OR "Results oriented conservation*" OR "watershed association*" OR "watershed coalition*") AND ("U.S.A." OR "USA" OR "U.S." OR "United States" OR "United States of America")
1/28/17	Google Scholar String H	("community based natural resource management" OR "collaborative forum*" OR "collaborative natural resource management") AND ("U.S.A." OR "USA" OR "U.S." OR "United States" OR "United States of America")
1/29/17	Google Scholar String I	("conservation partnership*" OR "cross sector collaboration*" OR "integrated natural resource management") AND ("U.S.A." OR "USA" OR "U.S." OR "United States" OR "United States of America")
1/29/17	Google Scholar String J	("multistakeholder collaboration*" OR "participatory natural resource management" OR "collaborative forest management") AND ("U.S.A." OR "USA" OR "U.S." OR "United States" OR "United States of America")
1/27/17	Google Scholar String K	("Place based collaboration*" OR "Results oriented conservation*" OR "watershed association*" OR "watershed coalition") AND ("U.S.A." OR "USA" OR "U.S." OR "United States" OR "United States of America")

Table A1.2. Inclusion criteria applied to groups found in the literature developed by experts in the field.

Priority Criteria	Description	Relevant citation (if applicable)
U.S.-based collaborative	Must be a U.S.-based group focusing on projects in the U.S., cannot be a U.S. group partnering with a group in a different country.	
Stakeholder diversity	Include a range (3+) of participant types representing the diverse perspectives of organizations, agencies, businesses, interest groups, and/or individuals with a stake in the outcome. Considers both number and type of perspectives present in the decision making.	(Coughlin et al. 1999; Margerum 2008)
Non-government entity involvement	An NGO, industry group, coalition of landowners or community members, or an individual citizen. (Note: tribal representatives are government-entities).	(Coughlin et al. 1999; Margerum 2008)
Duration and or Sustained Process	Must be a group that has existed for more than 2 years	(Plummer & Fitzgibbon 2004; Margerum 2008)
Purpose/Focus	Group formed to achieve one or more goals related to environmental conservation, policy, or management	
Collaborative group itself is not a public entity	"A public entity is defined as follows: (A) any State or local government; (B) any department, agency, special purpose district, or other instrumentality of a State or States or local government; and. (C) the National Railroad Passenger Corporation, and any commuter authority." (legal dictionary)	

LIST OF CLASSIFICATIONS FOR PARTICIPANT TYPES

Federal government

State government

Tribal government

County government

Local/municipal government

Non-governmental organization (NGO)/nonprofit organization

Water conservation/conservancy/irrigation district

Soil conservation district

Ditch/reservoir Company

Utility/special district

Power utility

Environmental organization

University/higher education

Scientists

Consultants

Community-based organization

Private industry

Local business/contractor

Individual/citizen

Collaborative initiative

Trade/advocacy organization

Farmers/ranchers

Hunters

Landowners/homeowners

Community members

Loggers

Homeowner Association

Other

FULL LIST OF LITERATURE ANALYZED FOR CHAPTER ONE

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COLLABORATIVE CONSERVATION GROUPS FOUND IN THE LITERATURE THAT MET THE INCLUSION CRITERIA

ACE Basin Task Force

Adirondack Research Consortium

Alaska Beluga Whale Committee

Alaska Migratory Bird Co-management Council

Aleutian and Bering Sea Islands Landscape Conservation Cooperative

Aleutian Islands Cultural Resources Working Group

Algonquin to Adirondacks

Alliance for Aquatic Resource Monitoring (ALLARM)

Alliance for Chesapeake Bay

Altar Valley Conservation Alliance

America’s Longleaf Restoration Initiative

Animas River Stakeholders Group

Appalachian LCC

Appalachian Trail Landscape Conservation Initiative

Applegate Partnership (now the Applegate Partnership and Watershed Council)

Arctic Landscape Conservation Cooperative

Arizona Common Ground Roundtable

Atlantic States Marine Fisheries Commission's Horseshoe Crab and Shorebird Technical committee

Barrens Topminnow Working Group

Bellevue Deer Task Force

Black Bear Conservation Committee

Black Hills National Forest Advisory Board

Blackfoot Challenge

Blackstone Headwaters Coalition

CALFED Public Advisory Committee

California Bay-Delta Authority

California Collaborative Fisheries Research Program

California LCC

California Natural Communities Conservation Program

California Wetland Monitoring Workgroup

Center for Watershed Protection

Central Oregon Partnerships for Wildfire Risk Reduction

Channel Islands Sanctuary Advisory Council

Chesapeake Bay Program

Chesapeake Conservation Partnership

Chicago Wilderness Alliance

Citizen Task Force

Clark Fork Coalition

Clark Fork Superfund complex Milltown site restoration project

Clearwater Basin Collaborative

Collaborative Adaptive Management Network

Colorado Front Range Landscape Restoration Initiative

Colorado Front Range Roundtable

Colorado Watershed Assembly

Columbia Sharp Tail Grouse Working Group

Community Agriculture Alliance

Communities Committee of the Seventh American Forest Congress

Community Water Dialogue

Community-Based Collaboratives Research Consortium

Conemaugh Valley Conservancy

Conservation of the Wild Rivers Legacy Forest

Cook Inlet Sound Regional Citizens' Advisory Councils

Critical Area Advisory Committee

Dane County Lakes and Watershed Commission

Darby Partnership

Delaware County Action Plan

Delta Stewardship Council

Delta Vision's Blue Ribbon Task Force

Demonstration project to grow fish in the open ocean

Deschutes Collaborative Forest Project

Desert LCC

Dinkey Landscape Restoration Project

Dolores River Restoration Partnership

DRRP Core Team

DRRP Implementation subcommittee

DRRP Science and Monitoring subcommittee

Dry Forest Working Group

Dungeness Crab Task Force

Dungeness River Management Team

East Kootenay Conservation Program

Eastern Brook Trout Joint Venture

Eastern Tallgrass Prairie and Big Rivers LCC

Eastern Upper Peninsula Partners in Ecosystem Management

Flathead Basin Commission

Four Forest Restoration Initiative

Friends of Arcola Creek

Friends of the Inyo

Friends of Winter Pond

Glen Canyon Dam Adaptive Management Work Group

"Governor’s Commission for a Sustainable

South Florida"

Grand River Partnership

Great Basin LCC

Great Bay Resource Protection Partnership

Great Northern LCC

Great Plains Landscape Conservation Cooperative

Greater Flagstaff Forest Partnership

Greater Lansing Regional Committee for Stormwater Management

Groton Lakes Association

Groundwork Lawrence

Gulf Coast Prairie LCC

Gulf Coastal Plains and Ozarks LCC

Heart of the Rockies

Henry's Fork watershed Council

Herring Ponds Watershed Association

Horseshoe Crab Advisory Panel

Horseshoe Crab and Shorebird Technical Committee

Housatonic River Initiative

Hudson River Sustainable Shorelines Project

IAS Conservation Committee

Ichetucknee Springs Basin Working Group

IMW Working Group for Middle Fork John Day River

Independent Scientific Advisory Board

Independent Scientific Review Panel

Ipswich River Watershed Association

Jackson Blue Springs Basin Working Group

Karuk-UC Berkeley Collaborative

Kirtland’s Warbler Recovery Team

Klamath Forest Alliance

Klamath Settlement Group: Klamath Basin Restoration Agreement (KBRA)

Klamath Water Users Association

Lake County Community Sustainability Initiative

Lake Onota Preservation Association

Las Vegas Wash Coordination Committee (LVWCC)

Laurel Highlands Marcellus Shale Monitoring Project

Little Miami River Partnership

Lolo Restoration Committee

Long Tom Watershed Council

Longleaf Alliance

Lower Boise Watershed Council

Lower Colorado River Multispecies Conservation Program

Lower Mississippi Valley Joint Venture

Loyalhanna Watershed Association

Maine Congress of Lake Associations (now the Maine Lakes Society)

Maine’s Volunteer Lake Monitoring Program

Makai Watch

Malpai Borderlands Group

Marin Agricultural Land Trust

Massachusetts Bay Program

Massachusetts Watershed Coalition

Metropolitan Affairs Coalition

Mid-Atlantic Fisheries Management Council

Middle Rio Grande Endangered Species Collaborative Program

Middle Spring Watershed Association

Mineral County Challenge Steering Committee

Missouri Resource Assessment Partnership

MLPA Initiative

Monterey Bay National Marine Sanctuary Sanctuary Advisory Council

Monterey Bay National Marine Sanctuary Sanctuary Advisory Council Research Advisory Panel

Monterey Bay National Marine Sanctuary Sanctuary Advisory Council Sanctuary Education Panel

National Alliance for Community Trees

National Bobwhite Technical Committee

National Network of Forest Practitioners

Neponset River Watershed Association

Network of Oregon Watershed Councils

New England Fisheries Management Council

Newtok Planning Group

Nisqually River Council

North & South Rivers Watershed Association

North American Wetlands Conservation Council

North Atlantic LCC

North Pacific Research Board

Northwest Boreal Landscape Conservation Cooperative

Northwest Colorado Sage Grouse Working Group

Northwest Colorado Stewardship

Northwestern Interior Forest

NSF Collaborative Stewardship Team

Orange County Marine Protected Area Council

Oregon Watershed Enhancement Board

Organization for the Assabet River

Oyster Recovery Partnership

Pacific Islands

Pacific Northwest Aquatic Monitoring Partnership

Parker River Clean Water Association

Peninsular Florida LCC

Piscataqua Region Estuaries Partnership (PREP)

Plains and Prairie Pothole LCC

Platte River Recovery and Implementation Program

Platte River Recovery Implementation Plan

Platte River Recovery Implementation Plan Governance Committee

Platte River Recovery Implementation Program Governance Committee

Pollock Conservation Cooperative

Ponderosa Pine Forest Partnership

Poplar Creek Watershed Coalition

Prince William Sound Regional Citizens' Advisory Councils

Private Forest Management Team

Prospect Park Alliance

Public Lands Partnership

Quincy Library Group

Rainbow Springs Basin Working Group

Randolph Community Forest

Redesign Initiative

Regional Conservation Partnership Network

Restudy Team

Rock River Coalition

Rural Voices for Conservation Coalition

Sacramento River Riparian Conservation Area Advisory Committee

Sacramento Valley Open Space Conservancy

Sage-Grouse Initiative

Salem Sound Coastwatch

Salt Ponds Coalition

Santa Fe Blue Springs Basin Working Group

Santa Fe County Water Policy Advisory Committee

Scallop Advisory Council

Scientific and Statistical Committee

Seafood Management Assistance Resource Recovery Team

Sierra Nevada Adaptive Management Project

Silver Springs Basin Working Group

Sonoita Valley Planning Partnership

South Atlantic LCC

South Mountain Partnership

South River Science Team

Southeast Fox Partnership

Southern Appalachian Forest Coalition

Southern Group of State Foresters

Southern Rockies LCC

Southern Utah Forest Products Association

Southwest Jemez Mountains

Southwestern Crown of the Continent Collaborative

Stakeholder Coordination Group

SuAsCo Watershed Coalition

SuAsCo Watershed Community Council

Sugar Creek Partners

"Sustainable Harvesting and

Resource Program"

Sustainable Sandhills Partnership

Sustainable Santa Fe Commission Energy Committee

Suwanee River Partnership

Swan Ecosystem Center

Tapash Sustainable Forest Collaborative

Taunton River Watershed Alliance

Tennessee River Lake Sturgeon Working Group

Tern and Plover Conservation Partnership

Texas Quail Conservation Initiative

The Diablo Trust

The Grand River Grasslands Partnership

The Kinzua Quality Deer Cooperative

The Kinzua Quality Deer Cooperative Leadership Team

The Last Green Valley (formerly the Quinebaug-Shetucket Heritage Corridor, Inc.)

TMDL (total maximum daily load) Executive Committee

Umpqua Basin Watershed Council

Uncompahgre Partnership (now Western Colorado Landscape Collaborative)

Uncompahgre Plateau Collaborative Restoration Project

Union River Watershed Coalition

Upper Colorado River Endangered Fish Recovery Program

Upper Middle Fork Working Group

Upper Midwest and Great Lakes LCC

USA National Phenology Network

Vernal Pool Streamlining Working Group

Vernal Pool Team

Virginia Seaside Heritage Program

Wakulla Springs Basin Working Group

Washington County Watershed Alliance

Water Resources Advisory Council in Florida

Watershed Agricultural Council

Weir River Watershed Association

West Creek Preservation Committee

West Tiger Mountain NRCA Advisory Committee

Western Alaska Landscape Conservation Cooperative

Western Colorado Landscape Collaborative

Western Forestry Leadership Coalition

Western Pennsylvania Conservancy

White Oak River Watershed Advisory Board

Wildlands and Woodlands Initiative

Wisconsin Initiative on Climate Change Impacts

WLCI Local Project Development Teams

Yakima River Watershed Council

Yampa River System Legacy Project

APPENDIX 2:

SUPPORTING INFORMATION FOR CHAPTER TWO

SURVEY FOR VISITORS TO SOAPSTONE IN 2015 (PRE-BISON REINTRODUCTION)

DENVER ZOO

The Human Dimensions of Bison Reintroduction

Laramie Foothills Interview Guide

Colorado State University

Date: ___________ (Please circle one: Saturday/Sunday)

#

INTERVIEW GUIDE

[Interviewer greets the potential respondent]: Hello. My name is _____________, and I am a researcher with Denver Zoo and CSU. Would you be willing to answer a few brief questions today to help us better understand the Soapstone Prairie visitor experience? It will take no more than ten minutes of your time.

[Interviewer: If they meet the criteria for an interview, then state: "Ok, Great. Before we begin, I want to make sure you fully understand our project, and the purpose of this interview." CONDUCT INFORMED CONSENT by telling them about the study, handing them the informational sheet, and obtaining their consent.

If they decline the interview or refuse study participation, then say: "Ok, I understand. Before you go, would you mind answering one or two brief questions?" [Record respondent characteristics and any reasons given for refusal on REFUSAL SHEET].]

Interview Questions

1. Is this your first visit to Soapstone Prairie Natural Area?
    a. *If the visitor responds "Yes", ask the following:*
        i. How many times have you visited Soapstone Prairie in the past 12 months?
2. Have you visited Red Mountain Open Space in the past 12 months?
    a. *If the visitor responds "Yes", ask the following:*
        i. How many times have you visited Red Mountain Open Space in the past 12 months?
3. Are you a current member of a nature conservation organization that protects animals or habitats? (Membership is defined as anyone who donates to or pays dues to an organization on a yearly basis as an expression of their support.)
    a. *If the visitor responds "Yes", ask the following:*
        i. Which organizations?
4. Are you a current member of Denver Zoo?
5. Do you consider Denver Zoo a nature conservation organization?
    a. *Probe:*
        i. Why or why not?

1

#

6. Why are you visiting Soapstone Prairie today?
    a. *If the visitor states that they came to see wildlife, THEN PROBE:*
        i. What kinds of wildlife did you come to see today?
    b. *If the visitor specifically mentions bison in their response, then probe:*
        i. Why do you want to see the Laramie Foothills bison herd?
        ii. How did you hear about this bison herd?
        iii. What do you know about these bison?
        iv. How do you feel about bringing bison back to Northern Colorado?
        v. Do you anticipate returning to see the Laramie Foothills bison herd again in the next 12 months?
        vi. What will it be/is it like to see bison in nature at Soapstone?
        vii. When you think about bison in general, what comes to mind?
        viii. Have you traveled to another site to view a bison herd in the past 12 months?
            1. *If the visitor responds "Yes", ask the following:*
                a. If yes, where?
    c. *If the visitor does not specifically mention bison, then continue with Question #7.*
7. How did you hear about Soapstone Prairie?

8. What is the main recreational activity you will participate in today?

   (Interviewer: Please check one. List them for visitor, if additional prompting is necessary)

   #

   - ☐ Day Hiking
   - ☐ Taking a Scenic Drive
   - ☐ Horseback Riding
   - ☐ Trail Running
   - ☐ Bird Watching
   - ☐ Viewing Wildlife
   - ☐ Nature Photography
   - ☐ Mountain Biking
   - ☐ Cultural Tourism
   - ☐ Other

9. What locations will you visit in Soapstone Prairie today?
10. About how many hours will you spend at Soapstone Prairie today?
11. [2016 ONLY] Do you plan on viewing/have you viewed the bison?
    a. *If the visitor responds "Yes", ask the following:*
       i. Why do you want to see the Laramie Foothills bison herd?
       ii. How did you hear about this bison herd?
       iii. What do you know about these bison?
       iv. How do you feel about bringing bison back to Northern Colorado?
       v. Do you anticipate returning to see the Laramie Foothills bison herd again in the next 12 months?
       vi. What will it be/is it like to see bison in nature at Soapstone?
       vii. When you think about bison in general, what comes to mind?
       viii. Have you traveled to another site to view a bison herd in the past 12 months?
          1. *If the visitor responds "Yes", ask the following:*
             a. If yes, where?

12. What words would you use to describe the Soapstone Prairie Natural Area?
13. Why is Soapstone Prairie important to you?
    a. *If the visitor responds "Yes", ask the following:*
        i. Why is it important to you?
14. Soapstone is classified by scientists as a grassland. When you think about grasslands in general, what comes to mind?
15. [2016 ONLY] Do you feel generally positive or generally negative towards grasslands in general?
16. Is there anything else you would like to add about this topic?

Could you please answer a few questions about yourself? *(Hand them clipboard/iPad with place attachment scale and demographic questions. BE SURE IT HAS AN INTERVIEW NUMBER WRITTEN ON IT.)*

The Human Dimensions of Bison Reintroduction

Place Attachment and Demographics

Tell us a little about you...

[This part of the questionnaire is self-administered]

#

1. Please indicate how much you agree or disagree with the following statements. Please circle one number for each statement.

	Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
I feel very attached to Soapstone Prairie Natural Area	1	2	3	4	5
Soapstone Prairie Natural Area means a lot to me	1	2	3	4	5
I feel at home in Soapstone Prairie Natural Area	1	2	3	4	5
I would like to spend more time in grasslands like Soapstone Prairie	1	2	3	4	5
[2016] Bison are an important part of the visitor experience at Soapstone Prairie Natural Area	1	2	3	4	5
[2016] Bison make me feel more attached to Soapstone Prairie Natural Area	1	2	3	4	5

2. Are you a resident of the United States?
3. Please enter your U.S. zip code (5 digits):
4. If you live outside of the United States, what is your country of residence?

#

5. What category best describes your gender identity? (please select one):
   - ☐ Female
   - ☐ Female to Male Transgender
   - ☐ Male
   - ☐ Male to Female Transgender
   - ☐ Not Sure
   - ☐ Other

6. What is your age?
   - ☐ 18-25
   - ☐ 26-35
   - ☐ 36-45
   - ☐ 46-55
   - ☐ 56-65
   - ☐ 66-75
   - ☐ 76+

7. What is your ethnic background or heritage? Please check all that apply.
   - ☐ African, African American or Black
   - ☐ American Indian, Native American or Alaskan Native
   - ☐ Asian or Asian American American
   - ☐ Latino, Hispanic, Chicano or Latin American
   - ☐ Middle Eastern, Arab or Arab American
   - ☐ Native Hawaiian, Filipino, Maori or Pacific Islander
   - ☐ White, Caucasian or European
   - ☐ Other

8. What is the highest level of education you have completed?
   - ☐ Some high school
   - ☐ High school diploma / GED
   - ☐ Some college or technical education
   - ☐ Bachelor's or technical degree
   - ☐ Graduate degree

9. How many times have you visited Denver Zoo in Denver, Colorado in the past 12 months?
   - ☐ Never
   - ☐ 1-2 times
   - ☐ 2-4 times
   - ☐ 5+ times

10. Do you plan to visit Soapstone Prairie again in the next 12 months?
    - ☐ Yes
    - ☐ No

11. [2015 ONLY] May we contact you for a follow-up interview for this project in 2016?
    - ☐ Yes
    - ☐ No

    a. *If visitor responds "Yes", ask the following:*
       i. Please enter your name (first and last).
       ii. Please enter your ten digit phone number.
       iii. Please enter your email address.

The Human Dimensions of Bison Reintroduction

GPS Units

Would you be willing to carry a GPS unit with you on your visit today to help us understand visitor use patterns?

☐ Yes ☐ No

#

7

The Human Dimensions of Bison Reintroduction

All Visitors

Interviewer, PLEASE RECORD the following information for all visitor groups:

#

[If the visitor responded "Yes" to Question 12]: GPS Unit Number: __________

Visitor Group Size: __________Number of Children (under 18) in Visitor Group: ____________

Visitor Group Description (Write anything notable here about the observable characteristics of the visitor group you spoke with. This is also a good place to add in additional comments made by the visitor that may be important to record):

The Human Dimensions of Bison Reintroduction

Refusal Sheet

#

If a visitor refuses to conduct an interview, please note:

1. Responses to the following two questions:
    a. Why are you visiting Soapstone Prairie today?
    b. Is Soapstone Prairie important to you?
        i. *If the visitor responds "Yes", ask the following:*
            1. If yes, why is Soapstone important to you?

2. Any reasons offered by the visitor for his/her refusal:

SURVEY FOR VISITORS TO SOAPSTONE IN 2016 (POST-BISON REINTRODUCTION)

The Human Dimensions of Bison Reintroduction

Laramie Foothills Interview Guide

Date: __________ **(Please circle one: Saturday/Sunday)**

#

INTERVIEW GUIDE

[Interviewer greets the potential respondent]: Hello. My name is ____________, and I am a researcher with Denver Zoo and CSU. Would you be willing to answer a few brief questions today to help us better understand the Soapstone Prairie visitor experience? It will take no more than ten minutes of your time.

[Interviewer: If they meet the criteria for an interview, then state: "Ok, Great. Before we begin, I want to make sure you fully understand our project, and the purpose of this interview." CONDUCT INFORMED CONSENT by telling them about the study, handing them the informational sheet, and obtaining their consent.

If they decline the interview or refuse study participation, then say: "Ok, I understand. Before you go, would you mind answering one or two brief questions?" [Record respondent characteristics and any reasons given for refusal on REFUSAL SHEET].]

Interview Questions

1. Is this your first visit to Soapstone Prairie Natural Area?
   a. *If the visitor responds "Yes", ask the following:*
      i. How many times have you visited Soapstone Prairie in the past 12 months?
2. Have you visited Red Mountain Open Space in the past 12 months?
   a. *If the visitor responds "Yes", ask the following:*
      i. How many times have you visited Red Mountain Open Space in the past 12 months?
3. Are you a current member of a nature conservation organization that protects animals or habitats? (Membership is defined as anyone who donates to or pays dues to an organization on a yearly basis as an expression of their support.)
   a. *If the visitor responds "Yes", ask the following:*
      i. Which organizations?
4. Are you a current member of Denver Zoo?
5. Do you consider Denver Zoo a nature conservation organization?
   a. *Probe:*
      i. Why or why not?
6. Why are you visiting Soapstone Prairie today?
   a. *If the visitor states that they came to see wildlife, THEN PROBE:*

#

i. What kinds of wildlife did you come to see today?

b. *If the visitor specifically mentions bison in their response, then probe:*

i. Why do you want to see the Laramie Foothills bison herd?

ii. How did you hear about this bison herd?

iii. What do you know about these bison?

iv. How do you feel about bringing bison back to Northern Colorado?

v. Do you anticipate returning to see the Laramie Foothills bison herd again in the next 12 months?

vi. What will it be/is it like to see bison in nature at Soapstone?

vii. When you think about bison in general, what comes to mind?

viii. Have you traveled to another site to view a bison herd in the past 12 months?

1. *If the visitor responds "Yes", ask the following:*

a. If yes, where?

c. *If the visitor does not specifically mention bison, then continue with Question #7.*

7. Do you live in Larimer County?

a. *If the visitor responds "No", ask the following:*

i. If no, what is the primary reason for your visit to Northern Colorado?

8. How did you hear about Soapstone Prairie?

\#

9. What is the main recreational activity you will participate in today? (Interviewer: Please check one. List them for visitor, if additional prompting is necessary)

- [ ] Day Hiking
- [ ] Taking a Scenic Drive
- [ ] Horseback Riding
- [ ] Trail Running
- [ ] Bird Watching
- [ ] Viewing Wildlife
- [ ] Nature Photography
- [ ] Mountain Biking
- [ ] Cultural Tourism
- [ ] Other

10. What locations will you visit in Soapstone Prairie today?
11. About how many hours will you spend at Soapstone Prairie today?
12. What words would you use to describe the Soapstone Prairie Natural Area?
13. Why is Soapstone Prairie important to you?
    a. *If the visitor responds "Yes", ask the following:*
        i. Why is it important to you?
14. Soapstone is classified by scientists as a grassland. When you think about grasslands in general, what comes to mind?
15. Is there anything else you would like to add about this topic?

Could you please answer a few questions about yourself? *(Hand them clipboard/iPad with place attachment scale and demographic questions. BE SURE IT HAS AN INTERVIEW NUMBER WRITTEN ON IT.)*

The Human Dimensions of Bison Reintroduction

Place Attachment and Demographics

Tell us a little about you…

[This part of the questionnaire is self-administered]

#

1. Please indicate how much you agree or disagree with the following statements. Please circle one number for each statement.

	Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
I feel very attached to Soapstone Prairie Natural Area	1	2	3	4	5
Soapstone Prairie Natural Area means a lot to me	1	2	3	4	5
I feel at home in Soapstone Prairie Natural Area	1	2	3	4	5
I would like to spend more time in grasslands like Soapstone Prairie	1	2	3	4	5

2. Are you a resident of the United States?
3. Please enter your U.S. zip code (5 digits):
4. If you live outside of the United States, what is your country of residence?
5. What category best describes your gender identity? (please select one):
   - ▯ Female
   - ▯ Female to Male Transgender
   - ▯ Male
   - ▯ Male to Female Transgender
   - ▯ Not Sure
   - ▯ Other

6. What is your age?
   - ▯ 18-25
   - ▯ 26-35
   - ▯ 36-45
   - ▯ 46-55
   - ▯ 56-65
   - ▯ 66-75
   - ▯ 76+

#

7. What is your ethnic background or heritage? Please check all that apply.
   - [ ] African, African American or Black
   - [ ] American Indian, Native American or Alaskan Native
   - [ ] Asian or Asian American
   - [ ] Latino, Hispanic, Chicano or Latin American
   - [ ] Middle Eastern, Arab or Arab American
   - [ ] Native Hawaiian, Filipino, Maori or Pacific Islander
   - [ ] White, Caucasian or European American
   - [ ] Other

8. What is the highest level of education you have completed?
   - [ ] Some high school
   - [ ] High school diploma / GED
   - [ ] Some college or technical education
   - [ ] Bachelor's or technical degree
   - [ ] Graduate degree

9. How many times have you visited Denver Zoo in Denver, Colorado in the past 12 months?
   - [ ] Never
   - [ ] 1-2 times
   - [ ] 2-4 times
   - [ ] 5+ times

10. Do you plan to visit Soapstone Prairie again in the next 12 months?
   - [ ] Yes
   - [ ] No

11. May we contact you for a follow-up interview for this project in 2016?
   - [ ] Yes
   - [ ] No

   a. *If visitor responds "Yes", ask the following:*
      i. Please enter your name (first and last).
      ii. Please enter your ten digit phone number.
      iii. Please enter your email address.

12. Would you be willing to carry a GPS unit with you on your visit today to help us understand visitor use patterns?
   - [ ] Yes
   - [ ] No

The Human Dimensions of Bison Reintroduction

All Visitors

#

Interviewer, PLEASE RECORD the following information for all visitor groups:

[If the visitor responded "Yes" to Question 12]: **GPS Unit Number:** _________

Visitor Group Size: _________**Number of Children in Visitor Group:** ___________

Visitor Group Description (Write anything notable here about the observable characteristics of the visitor group you spoke with. This is also a good place to add in additional comments made by the visitor that may be important to record):

The Human Dimensions of Bison Reintroduction

Refusal Sheet

\#

If a visitor refuses to conduct an interview, please note:

1. Responses to the following two questions:
    a. Why are you visiting Soapstone Prairie today?
    b. Is Soapstone Prairie important to you?
        i. If the visitor responds "Yes", ask the following:
            1. If yes, why is Soapstone important to you?

2. Any reasons offered by the visitor for his/her refusal:

8

PLACE ATTACHMENT SURVEY ADMINISTERED TO VISITORS AT SOAPSTONE IN 2015 (PRE-BISON REINTRODUCTION) AND 2016 (POST-BISON REINTRODUCTION)

Please rate the extent to which you agree or disagree with the following statements:
1. I feel very attached to Soapstone Prairie Natural Area.
Strongly Disagree
Disagree
No Opinion
Agree
Strongly Agree

2. Soapstone Prairie Natural Area means a lot to me.
Strongly Disagree
Disagree
No Opinion
Agree
Strongly Agree

3. I feel at home in Soapstone Prairie Natural Area
Strongly Disagree
Disagree
No Opinion
Agree
Strongly Agree

4. I would like to spend more time in grasslands like Soapstone Prairie Natural Area
Strongly Disagree
Disagree
No Opinion
Agree
Strongly Agree

R CODE FOR RECURSIVE EQUATION USED WITH RESULTS FROM PROGRAM UNMARKED TO CALCULATE OCCUPANCY AND CONFIDENCE INTERVALS FOR BIRD SPECIES AT EACH SITE IN 2016 AND 2017

```
#Calculating occupancy in the second year (2016) for bison (bis) and reference (ref) sites
Y2Bis<- function(Top model) {
  psi1.hat <-predict(Top model, type="psi")[row, column] #select correct row and column
  gamma.hat <- predict(Top model, type="col")[row, column]
  eps.hat <- predict(Top model, type="ext")[row, column]
  psi2.hat <- psi1.hat*(1-eps.hat) + (1-psi1.hat)*gamma.hat
  return(psi2.hat)}

pbY2Bis <- parboot(Top model, statistic=Y2Bis, nsim=10000)
pbY2Bis

Y2Ref<- function(Top model) {
  psi1.hat <-predict(Top model, type="psi")[row, column]
  gamma.hat <- predict(Top model, type="col")[row, column]
  eps.hat <- predict(Top model, type="ext")[row, column]
  psi2.hat <- psi1.hat*(1-eps.hat) + (1-psi1.hat)*gamma.hat
  return(psi2.hat)}

LpbY2Ref <- parboot(Top model, statistic=Y2Ref, nsim=10000)
LpbY2Ref

#Calculating occupancy in the third year (2017) for bison (bis) and reference (ref) sites
Y3Bis<- function{
  Psi3.hat <-psi2.hat #Result for psi (occupancy) in year 2 (2016) from above
  gamma.hat <- predict(Top model, type="col")[row, column]
  eps.hat <- predict(Top model, type="ext")[row,column]
  psi3.hat <- psi2.hat*(1-eps.hat) + (1-psi2.hat)*gamma.hat
  return(psi3.hat)}

pbY3Bis <- parboot(Top model, statistic=Y3Bis, nsim=10000)
pbY3Bis

Y3Ref<- function(Top model) {
  Psi3.hat <-psi2.hat #Result for psi (occupancy) in year 2 (2016) from above
  gamma.hat <- predict(Top model, type="col")[row, column]
  eps.hat <- predict(Top model, type="ext")[row, column]
  psi3.hat <- psi2.hat*(1-eps.hat) + (1-psi2.hat)*gamma.hat
  return(psi3.hat)}

LpbY2Ref <- parboot(Top model, statistic=Y3Ref, nsim=10000)
LpbY2Ref
```

Table A2.2. List of 57 bird species at the bison and reference sites at Soapstone Prairie Natural Area and Red Mountain Open Space in Colorado. *Indicates obligate grassland birds as listed in Vickery et al. 1999, pg 8. ** Indicates facultative grassland birds as listed in Vickery et al. 1999, pg 10.

Common name	Scientific name	Banding codes
American Goldfinch	*Spinus tristis*	AMGO
American Kestrel **	*Falco sparverius*	AMKE
American White Pelican	*Pelecanus erythrorhynchos*	AWPE
Baird's Sparrow*	*Ammodramus bairdii*	BAIS
Bank Swallow	*Riparia riparia*	BANS
Barn Swallow	*Hirundo rustica*	BARS
Black-capped Chickadee	*Poecile atricapillus*	BCCH
Blue-gray Gnatcatcher	*Polioptila caerulea*	BGGN
Brown-headed Cowbird **	*Molothrus ater*	BHCO
Brewer's Blackbird **	*Euphagus cyanocephalus*	BRBL
Brewer's Sparrow	*Spizella breweri*	BRSP
Brown Thrasher	*Toxostoma rufum*	BRTH
Broad-tailed Hummingbird	*Selasphorus platycercus*	BTLH
Bullock's Oriole	*Icterus bullockii*	BUOR
Clay-colored Sparrow **	*Spizella pallida*	CCSP
Chipping Sparrow	*Spizella passerina*	CHSP
Cliff Swallow	*Petrochelidon pyrrhonota*	CLSW
Common Grackle	*Quiscalus quiscula*	COGR
Cooper's	*Accipiter*	COHA

Common name	Scientific name	Banding codes
Hawk	*cooperii*	
Common Nighthawk **	*Chordeiles minor*	CONI
Common Raven	*Corvus corax*	CORA
Double-crested Cormorant	*Phalacrocorax auritus*	DCCO
Eastern Kingbird **	*Tyrannus tyrannus*	EAKI
European Starling	*Sturnus vulgaris*	EUST
Great Blue Heron	*Ardea herodias*	GBHE
Grasshopper Sparrow*	*Ammodramus savannarum*	GRSP
Green-tailed Towhee	*Pipilo chlorurus*	GTTO
Horned Lark*	*Eremophila alpestris*	HOLA
Lark Bunting*	*Calamospiza melanocorys*	LARB
Lark Sparrow **	*Chondestes grammacus*	LASP
Loggerhead Shrike **	*Lanius ludovicianus*	LOSH
Mourning Dove **	*Zenaida macroura*	MODO
Northern Mockingbird	*Mimus polyglottos*	NOMO
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	NRWS
Ring-billed Gull	*Larus delawarensis*	RBGU
Rock Wren	*Salpinctes obsoletus*	ROWR
Red-tailed hawk	*Buteo jamaicensis*	RTHA

Common name	Scientific name	Banding codes
Red-winged Blackbird **	*Agelaius phoeniceus*	RWBL
Say's Phoebe **	*Sayornis saya*	SAPH
Savannah Sparrow*	*Passerculus sandwichensis*	SAVS
Spotted Towhee	*Pipilo maculatus*	SPTO
Tree Swallow	*Tachycineta bicolor*	TRES
Vesper Sparrow*	*Pooecetes gramineus*	VESP
Violet-green Swallow	*Tachycineta thalassina*	VGSW
Western Kingbird **	*Tyrannus verticalis*	WEKI
Western Meadowlark*	*Sturnella neglecta*	WEME
Western Scrub-Jay	*Aphelocoma californica*	WESJ
Western Tanager	*Piranga ludoviciana*	WETA
Wilson's Snipe	*Gallinago delicata*	WISN OR WSNP
Yellow-rumped Warbler	*Setophaga coronata*	YRWA

Table A2.3. Top models (ΔAIC ≤ 2 and goodness-of-fit~.20) based on AIC value for Horned Lark (HOLA) density detection probability (p) for bison or reference (Ref) sites and year. We list the site, year, model, parameters (k), AIC, ΔAIC, model weight (w), and p-value for the K-S goodness-of-fit test (K-S). We report the effective detection radius (EDR), detection probability, and associated standard errors (SE) for models with the most weight.

Site	Year	Models for p	k	AIC	ΔAIC	w	K-S	EDR	p (SE)
Bison	2015	Observer	2	1256.14	0.00	0.40	0.19	68.92	0.34 (0.025)
		Null	1	1256.55	0.41	0.33	0.22		
	2016	Rain	3	933.70	0.00	0.47	0.27	71.68	0.36 (0.49)
		Null	1	935.49	1.80	0.19	0.28		
	2017	Null	1	980.22	0.00	0.44	0.19	77.58	0.36 (0.05)
		Observer	2	981.84	1.62	0.20	0.30		
Ref	2015	Null	1	310.39	0.00	0.37	0.79	63.70	0.57 (0.14)
		Vegetation height	2	311.24	0.85	0.24	0.89		
		Obs	2	311.81	1.42	0.18	0.83		
		Cloud	2	312.34	1.95	0.14	0.86		
	2016	Cloud	2	235.03	0.00	0.43	0.65	63.70	0.37 (0.06)
		Vegetation height	2	236.22	1.20	0.24	0.29		
		Observer	2	236.77	1.74	0.18	0.56		
	2017	Null	1	202.22	0.00	1.00	0.59	67.53	0.38 (0.10)

Table A2.4. Top models (ΔAIC ≤ 2 and goodness-of-fit~.20) based on AIC value for Vesper Sparrows (VESP) detection probability (p) for bison or reference (Ref) sites and year. We list the site, year, model, parameters (k), AIC, ΔAIC, model weight (w), and p-value for the K-S goodness-of-fit test (K-S). We report the effective detection radius (EDR), detection probability, and associated standard errors (SE) for models with the most weight
.

Site	Year	Models for p	k	AIC	ΔAIC	w	K-S	EDR	p (SE)
Bison	2015	Observer	2	663.27	0.00	0.69	0.41	112.00	0.52 (0.06)
	2016	Observer	2	533.69	0.00	0.94	0.41	79.48	
	2017	Null	1	524.81	0.00	0.41	0.28	124.00	0.61 (0.14)
		Observer	2	525.85	1.04	0.24	0.23		
		Cloud	2	526.31	1.50	0.19	0.30		
		Vegetation height	2	526.80	1.99	0.15	0.28		
Ref	2015	Vegetation height	2	271.06	0.00	1.00	0.24	70.69	0.29 (0.05)
	2016	Null	2	125.18	0.00	1.00	0.71	78.95	0.43 (0.13)
	2017	Vegetation height	2	290.63	0.00	0.98	0.43	80.46	0.29 (0.06)

Table A2.5. Top models (ΔAIC ≤ 2 and goodness-of-fit~.20) based on AIC value for Western Meadowlark (WEME) detection probability (p) for each site and year. We list the site, year, model, parameters (k), AIC, ΔAIC, model weight (w), and p-value for the χ2 goodness-of-fit test (χ2-p). We report the effective detection radius (EDR), detection probability, and associated standard errors (SE) for models with the most weight. The area surveyed for bison and reference (Ref) sites was 393 and 308 hectares respectively.

Site	Year	Models for p	k	AIC	ΔAIC	w	χ2-p	EDR	p (SE)
Bison	2015	Observer	3	408.60	0.00	0.69	0.41	132.54	0.52 (0.06)
	2016	Null	2	305.80	0.00	0.47	0.48	132.21	0.68 (0.09)
	2017	Vegetation height	3	388.71	0.00	0.76	0.32	135.22	0.69 (0.05)
Ref	2015	Observer	3	264.31	0.00	0.43	0.16	118.41	0.54 (0.04)
		Null	2	265.03	0.72	0.30	0.37		
	2016	Null	2	188.93	0.00	0.46	0.63	134.22	0.70 (0.07)
		Cloud	3	190.59	1.66	0.20	0.32		
	2017	Null	2	258.49	0.00	0.49	0.99	149.52	0.87 (0.05)
		Observer	3	259.85	1.36	0.25	0.51		
		Vegetation height	3	260.44	1.96	0.19	0.59		

Table A2.6. Direction of the beta (β) estimates for top model (model with the most weight) of detection probability for Horned Larks, Vesper Sparrows, and Western Meadowlarks at the bison and reference sites in 2015, 2016, and 2017. Beta estimates (β) are cited as + = positive and -- = negative and indicate the effect of covariates on detection probability.

				Observer		Rain*			Cloud (0-100%)	Vegetation Height (cm)
Site	Species	Year	Model	1	2	0	1	2		
		2015	Observer	+	--					
	HOLA	2016	Rain			+	+	--		
		2017	Null							
		2015	Observer	+	--					
Bison	VESP	2016	Observer	+	--					
		2017	Null							
		2015	Observer	+	--					
	WEME	2016	Null							
		2017	Vegetation							--
		2015	Null							
	HOLA	2016	Cloud						+	
		2017	Null							
		2015	Vegetation							+
Reference	VESP	2016	Null							
		2017	Vegetation							--
		2015	Observer	+	--					
	WEME	2016	Null							
		2017	Null							

*Rain was a categorical variable in which observers used a scale to estimate rainfall, where 0=No rain, 1= Mist or Fog, 2= Light drizzle. Observers ceased point counts if rain category rose above level 2.

Table A2.7. Top generalized linear mixed models (ΔAIC ≤ 2) for how fixed effects—site (bison or reference), year (2015, 2016, 2017), and vegetation cover (warm season grasses, cool season grasses, or forbs)—influenced density of Horned Larks (HOLA), Vesper Sparrows (VESP), and Western Meadowlarks (WEME). We list the model, parameters (k), AIC, ΔAIC, and model weight (w). We only list the direction of the fixed effects on density for the top model (model with the most weight). The direction of the beta estimates (β) are cited as + = positive and -- = negative. Dotted line separates years before (2015) and after (2016 and 2017) bison reintroduction.

						β Site		β Year		
Species	Model for density	k	AIC	ΔAIC	w	Bison	Reference	2015	2016	2017
HOLA	Site	3	232.24	0.00	0.65	+	--			
VESP	Null	2	176.09	0.00	0.25					
	Forb	3	176.23	0.14	0.23					
	Trt*Year	7	177.50	1.40	0.12					
	Cool	3	177.62	1.52	0.12					
	Warm	3	177.74	1.65	0.11					
	Trt	3	177.85	1.76	0.10					
WEME	Year	4	275.12	0.00	0.50			+	--	--

Table A2.8. Top models (ΔAIC ≤ 2 and goodness-of-fit~.20) based on AIC value for Brewer' Blackbirds, Grasshopper Sparrows, and Lark Sparrows. Site-level covariates affecting habitat use included sites (Trt), which were either bison or reference (Ref). Observation-level covariates included year (2015, 2016, or 2017), observer (Obs), wind, cloud (C), or vegetation height (Ht). Rainfall was highly correlated with year, and thus was not included in the models.

Species and Models	k	AIC	Δ AIC	w
Brewer's Blackbird				
Ψ(1) ϒ(Yr) ε(Yr) p(Ht)	7	285.30	0.00	0.52
Ψ(Trt) ϒ(Yr) ε(Yr) p(Ht)	6	287.25	1.96	0.20
Grasshopper Sparrow				
Ψ(Trt) ϒ(1) ε(Trt) p(Year)	8	536.30	0.00	0.43
Ψ(Trt) ϒ(Trt) ε(Trt) p(Yr)	9	536.58	0.28	0.37
Lark Sparrow				
Ψ(Trt) ϒ(1) ε (1) p(Obs)	6	210.92	0.00	0.06
Ψ(Trt) ϒ(1) ε (1) p(Ht)	6	211.15	0.23	0.06
Ψ(Trt) ϒ(Yr) ε(1) p(Obs)	7	211.16	0.24	0.06
Ψ(Trt) ϒ(Yr) ε(1) p(Ht)	7	211.25	0.33	0.05
Ψ(Trt) ϒ(1) ε(1) p(1)	5	211.42	0.50	0.04
Ψ(Trt) ϒ(Yr) ε(1) p(1)	6	211.89	0.97	0.04
Ψ(Trt) ϒ(1) ε(Yr) p(Ht)	7	212.12	1.20	0.03
Ψ(Trt) ϒ(1) ε(Trt) p(Obs)	7	212.20	1.28	0.03
Ψ(Trt) ϒ(Yr) ε(Yr) p(Ht)	8	212.24	1.32	0.03
Ψ(Trt) ϒ(1) ε(Yr) p(Obs)	7	212.30	1.38	0.03
Ψ(Trt) ϒ(Yr) ε(Yr) p(Obs)	8	212.69	1.77	0.03
Ψ(Trt) ϒ(1) ε(Yr) p(1)	6	212.74	1.82	0.03
Ψ(1) ϒ(1) ε(1) p(Ht)	5	212.80	1.88	0.03
Ψ(Trt) ϒ(Trt) ε(1) p(Obs)	7	212.92	2.00	0.02

Table A2.9.Results from top model (Δ AIC = 0.00) for Brewer' Blackbirds (BRBL), Grasshopper Sparrows (GRSP), and Lark Sparrows (LASP). We list the species, habitat use (Ψ), colonization (ϒ), extinction (ε) and detection probabilities (p), and associated confidence intervals (CI). Colonization estimates for year 1 (Yr 1) indicate the proportion of unoccupied site in 2015 that became occupied in 2016, while the extinction estimate for year 1 (Yr 1) indicate the proportion of occupied sites in 2015 that became unoccupied in 2016. Year 2 (Yr 2) estimates for colonization and extinction indicate the same probabilities between 2016 and 2017. Site-level covariates affecting habitat use included sites (Trt), either bison (B) or reference (R), and warm season grasses, cool season grasses, or forbs. Observation-level covariates included year (2015, 2016, or 2017), observer (Obs), wind, or cloud (C), or vegetation height (Ht).

Species	Ψ2015 (SE)		Υ_{YEAR} (CI)		ε_{YEAR} (CI)		ε_{TRT} (CI)		p (CI)			
	B	R	Yr1	Yr2	Yr1	Yr2	B	R	2015	2016	2017	Ht
BRBL	0.34 (0.18-0.55)	0.34 (0.18-0.55)	0.32 (0.13-0.60)	0.00 (0.00-1.00)	0.00 (0.00-1.00)	0.72 (0.43-0.90)						0.28 (0.20-0.37)
GRSP	0.90 (0.68-0.98)	0.43 (0.21-0.69)	0.19 (0.07-0.43)	0.19 (0.07-0.43)			0.00 (0.00-1.00)	0.34 (0.10-0.70)	0.65 (0.56-0.73)	0.46 (0.37-0.56)	0.30 (0.22-0.39)	
LASP	0.06 (0.01-0.33)	0.43 (0.18-0.71)	0.10 (0.04-0.25)	0.10 (0.04-0.25)	0.27 (0.07-0.66)	0.27 (0.07-0.66)						0.23 (0.14-0.36)

Table A2.10. List of mammal species at the bison and reference sites at Soapstone Prairie Natural Area and Red Mountain Open Space in Colorado.

Common name	Scientific name
American Badger	*Taxidea taxus*
American Black Bear	*Ursus americanus*
American Elk	*Cervus canadensis*
Black-tailed Jackrabbit	*Lepus californicus*
Bobcat	*Lynx rufus*
Desert Cottontail	*Sylvilagus audubonii*
Coyote	*Canis latrans*
Mountain Lion	*Puma concolor*
Mouse	*Unknown species*
Mule deer	*Odocoileus hemionus*
Pronghorn	*Antilocapra americana*
Thirteen-lined Ground Squirrel	*Ictidomys tridecemlineatus*
White-tailed deer	*Odocoileus virginianus*
White-tailed Jackrabbit	*Lepus townsendii*

Table A 2.11. Top models (ΔAIC ≤ 2 and goodness-of-fit~.20) based on AIC value for coyote, lagomorphs, mule deer, and pronghorn. Site-level covariates affecting habitat use included sites (Trt) and either bison or reference (Ref). Observation-level covariates included year (2015, 2016, or 2017), vegetation height (Ht), or camera model (Cam).

Species and Models	k	AIC	Δ AIC	w
Coyote				
Ψ(Trt) ϒ(Year) ε(1) p(Cam)	10	520.80	0.00	0.26
Ψ(1) ϒ(Year) ε(1) p(Cam)	9	521.69	0.90	0.17
Ψ(Trt) ϒ(Year) ε(Year) p(Cam)	11	522.41	1.61	0.12
Lagomorphs				
Ψ(Trt) ϒ(1) ε(1) p(Cam)	9	425.41	0.00	0.17
Ψ(Trt) ϒ(Trt) ε(1) p(Cam)	10	425.84	0.43	0.14
Ψ(Grass) ϒ(Trt) ε(1) p(Cam)	10	426.25	0.84	0.11
Ψ(Trt) ϒ(1) ε(1) p(Cam+Ht)	10	427.17	1.76	0.07
Ψ(Trt) ϒ(Yr) ε(1) p(Cam)	10	427.40	2.00	0.06
Mule deer				
Ψ(1) ϒ(1) ε (Trt) p(Cam)	10	1075.28	0.00	0.12
Ψ(Trt) ϒ(1) ε(1) p(Cam)	9	1075.75	0.47	0.10
Ψ(1) ϒ(1) ε(1) p(Cam)	9	1076.23	0.96	0.08
Ψ(Trt) ϒ(1) ε(Yr) p(Cam+Ht)	11	1076.49	1.21	0.06
Ψ(1) ϒ(1) ε(1) p(Cam)	8	1076.85	1.57	0.05
Ψ(Trt) ϒ(1) ε(Yr) p(Cam)	10	1077.00	1.72	0.05
Ψ(Trt) ϒ(Yr) ε(1) p(Cam+Ht)	11	1077.16	1.88	0.05
Ψ(Trt) ϒ(Trt) ε(1) p(Cam+Ht)	11	1077.28	2.00	0.04
Pronghorn				
Ψ(1) ϒ(Yr) ε(1) p(Cam+Ht)	11	1131.51	0.00	0.10
Ψ(1) ϒ(1) ε(1) p(Cam+Ht)	9	1131.79	0.28	0.08
Ψ(Trt) ϒ(Trt) ε(1) p(Cam+Ht)	10	1131.80	1.11	0.12
Ψ(1) ϒ(Trt) ε(Trt) p(Cam+Ht)	11	1132.40	1.72	0.09
Ψ(1) ϒ(1) ε(Yr) p(Cam+Ht)	10	1132.60	1.92	0.08

Table A2.12. Results from top model (Δ AIC = 0.00) for coyote, lagomorphs (Lago), mule deer (Mule), and pronghorn (Prong). We list the species, habitat use (Ψ), colonization (ϒ), extinction (ε) and detection probabilities (p), and associated confidence intervals (CI). Colonization estimates for year 1 (Yr 1) indicate the proportion of unoccupied site in 2015 that became occupied in 2016, while the extinction estimate for year 1 (Yr 1) indicate the proportion of occupied sites in 2015 that became unoccupied in 2016. Year 2 (Yr 2) estimates for colonization and extinction indicate the same probabilities between 2016 and 2017. Site-level covariates affecting habitat use included sites, either bison or reference (Ref). Observation-level covariates included year (2015, 2016, or 2017), vegetation height (Ht), or camera model (a, b, c, d, e)*.

Species	Ψ2015 (SE)		ϒ (CI)		ε (CI)				p(CI)				
	Bison	Ref	Yr1	Yr2	Yr1	Yr2	Bis	Ref	a	b	c	d	e
Coyote	0.07 (0.01-0.36)	0.33 (0.12-0.63)	0.61 (0.37-0.81)	0.02 (0.00-1.0)	0.19 (0.05-0.50)	0.19 (0.05-0.50)			0.09 (0.05-0.16)	0.38 (0.29-0.48)	0.18 (0.06-0.41)	0.17 (0.11-0.24)	0.02 (2e-3-0.15)
Lago	0.62 (0.28-0.87)	0.19 (0.04-0.54)	0.17 (0.05-0.44)	0.17 (0.05-0.44)	0.00 (0.00-1.00)	0.58 (0.24-0.85)			0.08 (0.05-0.15)	0.34 (0.25-0.43)	0.35 (0.21-0.53)	0.06 (0.01-0.20)	0.03 (0.00-0.26)
Mule**	0.46 (0.20-0.73)	0.46 (0.20-0.73)	0.20 (0.05-0.52)	0.20 (0.08-0.45)			0.06 (0.00-1.00)	0.29 (0.08-0.64)	0.08 (0.04-0.15)	0.29 (0.19-0.41)	0.38 (0.22-0.57)	0.03 (0.01-0.13)	0.02 (0.00-0.15)
Prong**	0.81 (0.61-0.92)	0.81 (0.61-0.92)	0.30 (0.04-0.78)	0.87 (0.21-0.99)	0.15 (0.07-0.30)	0.15 (0.07-0.30)			0.22 (0.18-0.28)	0.23 (0.16-0.30)	0.17 (0.10-0.26)	0.22 (0.16-0.29)	0.42 (0.30-0.54)

*Camera models: a= Long Range IR Trail Camera, b=Cuddeback Attack, c=Bushnell Primo, d=Cuddeback Capture, e=Wild Game Innovations

**Mule deer and pronghorn detection probabilities for camera model also include average vegetation height

Table A2.13. Grasses, forbs, and shrubs identified to species at Soapstone Prairie Natural Area

Scientific name
Cool Season Grasses
Achnatherum hymenoides
Achnatherum nelsonii
Achnatherum robustum
Bromus tectorum
Eleocharis palustris
Elymus elymoides
Elymus lanceolatus
Elymus trachycaulus
Hesperostipa comate
Koelaria macrantha
Pascopyrum smithii
Vulpia octiflora
Warm Season Grasses
Aristida purpurea
Bouteloua dactyloides
Muhlenbergia filiculmis
Muhlenbergia filiformis
Muhlenbergia torreyii
Bouteloua curtipendula
Schedonnardus paniculatus
Forbs
Allium textile
Astragalus bisulcatus
Astragalus drummondii
Astragalus flexuosus
Astragalus laxmanii
Astragalus shortianus
Brassica sp.
Chamaesyce glyptosperma
Chamaesyce missurica
Cirsium sp.
Comandra umbellate
Dalea candida
Delphinium L.
Equisetum laevigatum
Erigeron sp.
Grindelia subalpine
Helianthus annus
Iva axillaris
Leucocrinum sp.
Linaria dalmatica
Melilotus oficianales

Scientific name
Musineon divaricatum
Oenothera suffrutescens
Oxytropis sericea
Paronychia jamesii
Phlox muscoides
Physaria montana
Physaria ludoviciana
Picradeniopsis oppositifolia
Plantago patagonica
Medivago sativa
Sophora nutalliana
Sphaeralcea coccinea
Symphyotrichum ericoides
Taraxacum officinale
Thermopsis rhombifolia
Towsendia grandiflora
Tragopogon dubius
Vicia Americana
Viola nuttallii
Shrubs/Sub-shrubs
Artemisia dracunculus
Artemisia frigida
Artemisia ludoviciana
Atriplex canescens
Cercocarpus montanus
Eriogonum effusum
Ericameria nauseosa
Gutierrezia sarothrae
Krascheninnikovia lanata
Machaeranthera pinnatifida
Opuntia polyacantha
Prunus virginiana
Rhus trilobata
Rosa sp.

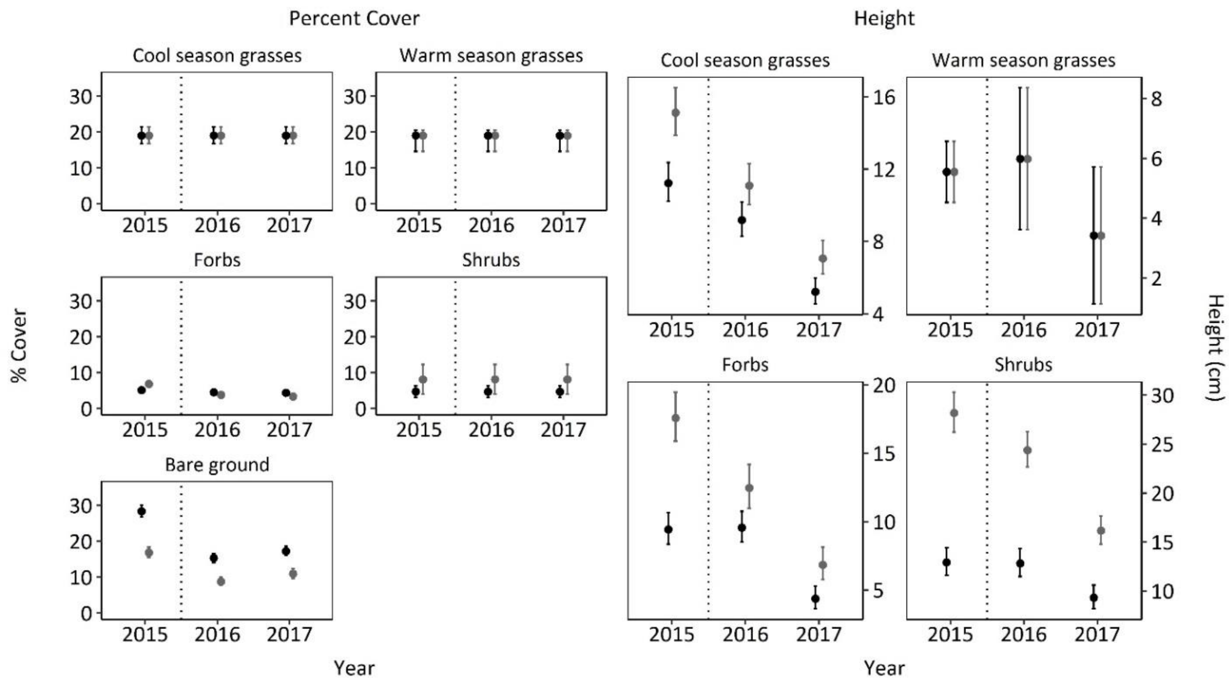

Figure A2.1. Percent cover and height by year and vegetation type at bison-grazed (black) and reference (gray) sites. The vertical dotted line separates the years before (2015) and after (2016-2017) bison reintroduction.

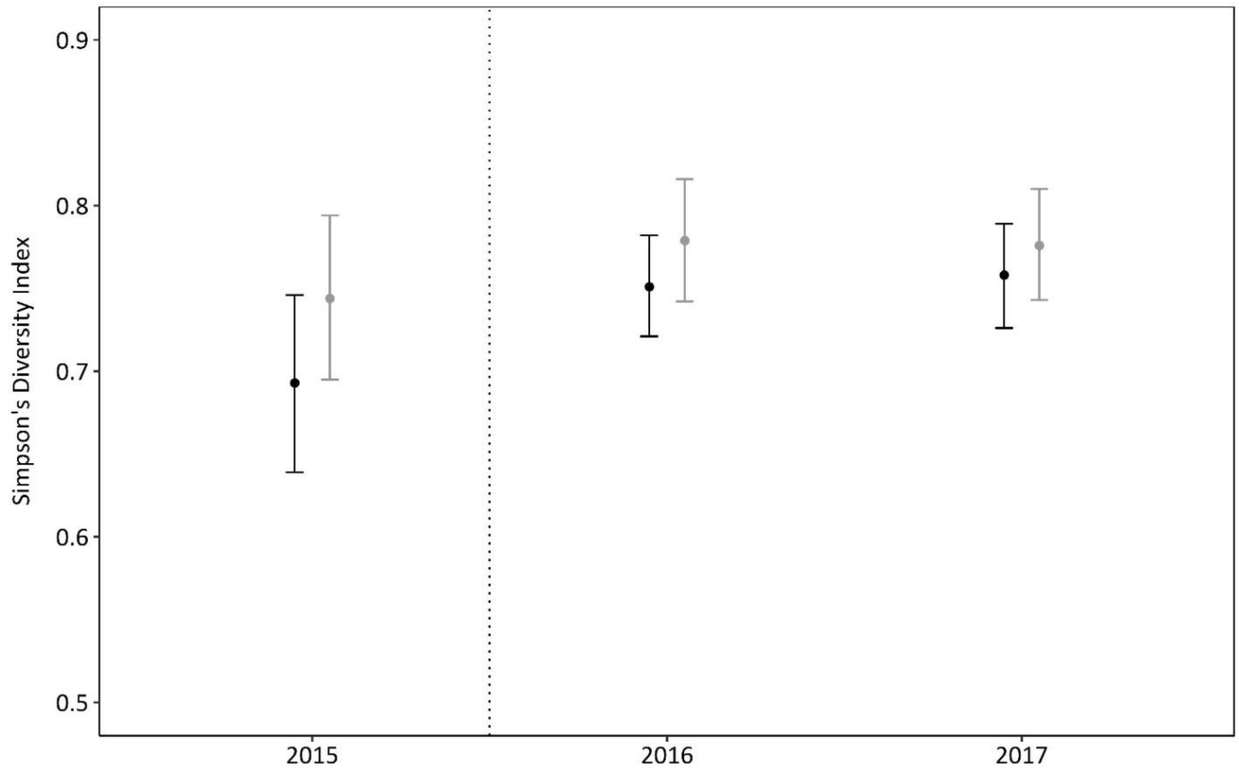

Figure A2.2. Simpson’s diversity index by bison (black) and reference (gray) sites. The vertical dotted line separates the years before (2015) and after (2016-2017) bison reintroduction.

Table A2.14. Demographics for respondents to the visitor survey at Soapstone Prairie Natural Area in 2015 and 2016

Demographics	2015 (n=184)	2016 (n=302)
GENDER		
Male	104	166
Female	80	128
Prefer not to Respond	0	7
Not Sure	0	1
AGE		
18-25	9	19
26-35	34	44
36-45	30	68
46-55	60	68
56-65	37	56
66-75	13	30
76+	0	16
No response	1	1
ETHNICITY (Multiple options possible)		
White, Caucasian or European American	171	283
Latino, Hispanic, Chicano or Latin American	6	13
Asian or Asian American	1	2
African, African American or Black	1	1
American Indian, Native American or Alaskan Native	1	3
Middle Eastern, Arab or Arab American	0	1
Native Hawaiian, Filipino, Maori or Pacific Islander	0	1
Multiple ethnicities	4	10
EDUCATION		
Graduate Degree	66	121
Bachelor's or Technical Degree	71	120
Some College or Technical Education	41	48
High School Diploma/GED	6	12
No Response	0	1

Table A2.15. Cronbach's Alpha test estimates, mean place attachment scores, and place attachment scores for each statement in 2015 and 2016. We include confidence intervals for the mean place attachment score and Cronbach's Alpha.

Statement	Mean 2015 (n=184)	Mean 2016 (n=302)	t-value	d.f.	p-value
Cronbach's Alpha	0.92 (0.90-0.94)	0.89 (0.87-0.91)			
Overall place attachment scores	4.02 (3.90-4.14)	4.25 (4.17-4.32)	3.19	318.88	7.7e-04
I feel very attached to SPNA	3.82	4.12			
SPNA means a lot to me	4.01	4.25			
I feel at home in SPNA	3.97	4.17			
I would like to spend more time in grasslands like SPNA	4.28	4.44			

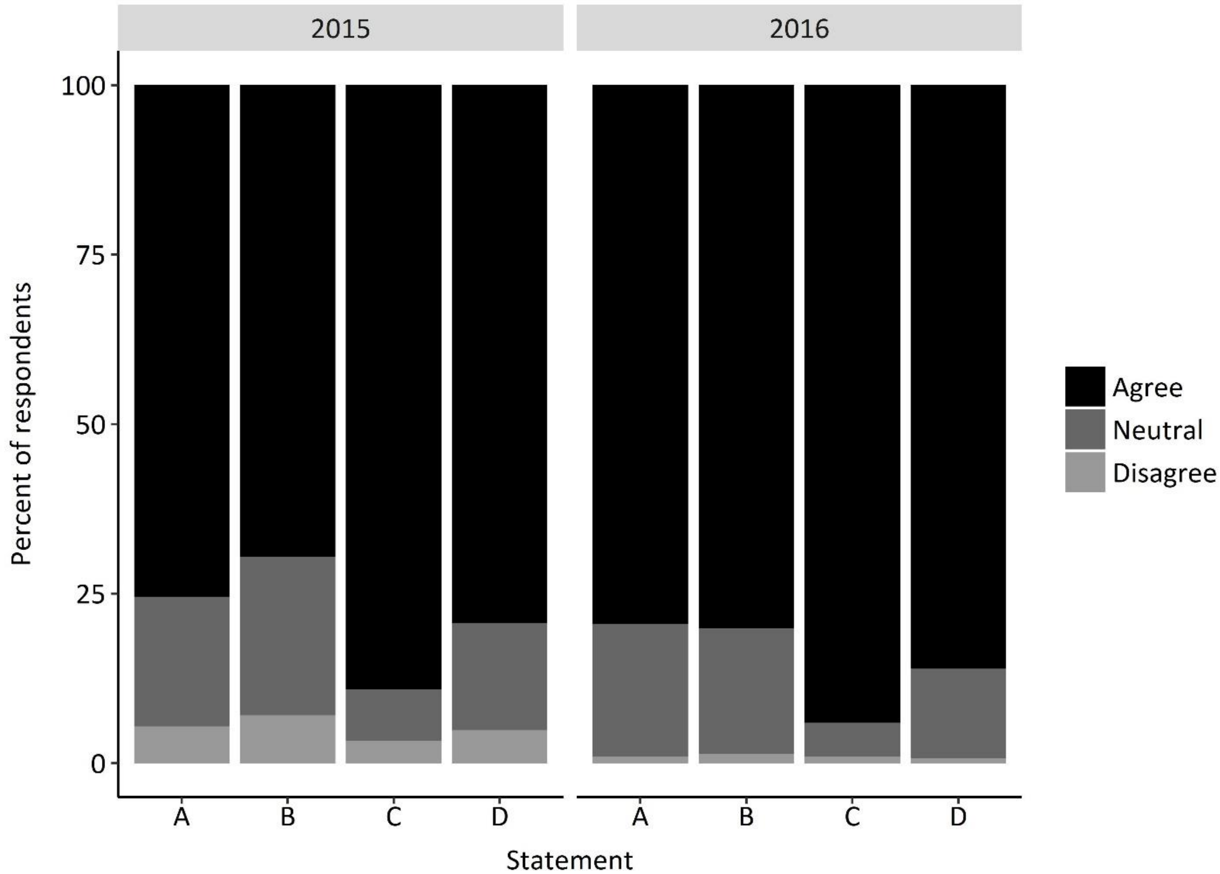

Figure A2.3. Percent of respondents who agreed (agree or strongly agree), felt neutral, and disagreed (disagree or strongly disagreed) with the place attachment statements in 2015 and 2016 (A. I feel very attached to Soapstone Prairie Natural Area, B. Soapstone Prairie Natural Area means a lot to me, C. I feel at home in Soapstone Prairie Natural Area, D. I would like to spend more time in grasslands like Soapstone Prairie Natural Area).

Table A2.16. Top ten themes and illustrative quotes from 2015 (pre-bison reintroduction) and 2016 (post bison reintroduction) in response to the question, “Why is Soapstone important to you?”

2015	2016
In general, it’s important to protect open space: “All protected areas are important to me, we don’t have enough of them.”	In general, it’s important to protect open space: “We need to maintain open space so we have nature to explore.”
Nature preservation or conservation: “It plays a role in long term land stewardship for public land access with the city and county.”	Nature preservation or conservation: “Because there doesn’t seem to be a lot of open prairie these days.”
An uncrowded place to get away: “Good to get out of the Front Range hustle and bustle where there’s no people.”	Undisturbed or undeveloped: “Gives you a place to go to see and feel what the prairie was like before we were here.”
Recreation Asset: “It’s a great resource for equestrians, hikers, mountain bikers, and historically speaking.”	Wildlife (includes mention of bison): “Maintaining the lands for bringing buffalo back…is important.”
Undisturbed or undeveloped: “Good to keep some areas as pristine as possible short of closing it completely.”	*Historical significance: “History and natural aspects are important for future generations…there are more stories out here than at the public library.”
Unique Place: “Because it is so different from other available options”	Recreation asset: “Great place to recreate outdoors.”
*Close and Convenient: “I think it’s a great opportunity to have such a great natural area so close to our house to visit.”	An uncrowded place to get away: “Important to go out and explore areas without hundreds of cars and houses.”
Wildlife (includes mention of bison): “Seeing so much wildlife is a transcendent experience.”	Unique place: “The landscape is interesting and different than other areas in the Front Range.”
Place to enjoy nature or the outdoors: “Because it’s a beautiful natural space where we can enjoy ourselves.”	Place to enjoy nature or the outdoors: “Opportunity to connect with the outdoors.”

*Denotes themes that differed between years.

APPENDIX 3:

SUPPORTING INFORMATION FOR CHAPTER THREE

Table A3.1. Functions used to calculate species' detection probability by bison cattle, or reference (Ref) sites and year (2016 or 2017). GRSP= Grasshopper Sparrow, HOLA=Horned Lark, VESP= Vesper Sparrow, WEME= Western Meadowlark

<table>
<tr><th>Species</th><th>Bison 2016</th><th>Bison 2017</th><th>Cattle 2016</th><th>Cattle 2017</th><th>Ref 2016</th><th>Ref 2017</th></tr>
<tr><td>Colorado</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>HOLA</td><td colspan="2">Half normal cosine</td><td colspan="2">Half normal cosine</td><td colspan="2">Half normal cosine</td></tr>
<tr><td>VESP</td><td colspan="2">Half normal cosine</td><td colspan="2">Half normal cosine</td><td colspan="2">Half normal cosine</td></tr>
<tr><td>WEME</td><td colspan="2">Hazard rate cosine, 5 bins</td><td colspan="2">Half normal cosine</td><td colspan="2">Hazard rate cosine, 5 bins</td></tr>
<tr><td>New Mexico</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>HOLA</td><td colspan="2">Half normal cosine, 5 bins</td><td colspan="2">Hazard rate cosine, 5 bins</td><td colspan="2">Half normal cosine</td></tr>
<tr><td>VESP</td><td colspan="2">Half normal cosine</td><td>Half normal cosine</td><td>Hazard rate cosine, 5 bins</td><td colspan="2">Half normal cosine</td></tr>
<tr><td>WEME</td><td colspan="2">Hazard rate cosine, 5 bins</td><td colspan="2">Half normal cosine</td><td colspan="2">Hazard rate cosine, 5 bins</td></tr>
</table>

Table A3.2. COLORADO: Top models (ΔAIC ≤ 2 and goodness-of-fit~.20) based on AIC value for Horned Lark (HOLA) density detection probability (p) for each site and year for Colorado. We list the site, year, model, parameters (k), AIC, ΔAIC, model weight (w), and p-value for the K-S goodness-of-fit test (K-S). We report the effective detection radius (EDR), detection probability, and associated confidence intervals (CI) for models with the most weight.

Site	Year	p Models	k	AIC	ΔAIC	w	K-S	EDR (CI)	p (CI)
Bison	2016	Rain	3	933.70	0.00	0.54	0.28	71.68 (62.62-82.04)	0.36 (0.28-0.47)
		Null	1	935.49	1.80	0.22	0.28		
	2017	Null	1	980.22	0.00	0.52	0.19	78.71 (68.22-89.56)	0.36 (0.28-0.47)
		Vegetation Height	2	981.68	1.45	0.25	0.18		
		Observer	2	981.84	1.62	0.23	0.30		
Cattle	2016	Cloud	2	280.58	0.00	0.32	0.96	75.56 (54.54-104.59)	0.36 (0.19-0.68)
		Null	1	280.71	0.13	0.30	0.84		
		Vegetation Height	2	281.51	0.57	0.24	0.89		
		Observer	2	282.27	1.69	0.14	0.81		
	2017	Null	1	224.87	0.00	1.00	0.30	97.00 (69.06-136.24)	1.00 (0.51-1.00)
Ref	2016	Cloud	2	235.03	0.00	0.43	0.65	63.69 (53.14-76.34)	0.37 (0.26-0.53)
		Vegetation Height	2	236.21	1.18	0.24	0.37		
		Observer	2	236.77	1.74	0.18	0.56		
		Null	1	237.02	2.00	0.16	0.32		
	2017	Vegetation Height	2	197.13	0.00	0.83	0.57	54.03 (31.39-93.01)	0.24 (0.09-0.68)

Table A3.3. COLORADO: Top models (ΔAIC ≤ 2 and goodness-of-fit~.20) based on AIC value for Western Meadowlark (WEME) density detection probability (p) for each site and year in Colorado. We list the site, year, model, parameters (k), AIC, ΔAIC, model weight (w), and p-value for the K-S or Chi-square goodness-of-fit test (GOF). We report the effective detection radius (EDR), detection probability, and associated confidence intervals (CI) for models with the most weight.

Site	Year	p Models	k	AIC	ΔAIC	W	GOF	EDR (CI)	p (CI)
Bison	2016	Null	2	305.80	0.00	0.47	0.48	132.21 (116.75-149.72)	0.68 (0.53-0.88)
		Observer	3	307.68	1.87	0.18	0.11		
	2017	Vegetation Height	3	384.63	0.00	0.96	0.31	130.12 (113.23-149.54)	0.66 (0.50-0.87)
Cattle	2016	Vegetation Height	2	118.30	0.00	0.36	0.50	110.59 (102.31-119.54)	0.50 (0.42-0.58)
	2017	Null	2	1351.23	0.00	0.54	0.22	130.84 (117.65-145.51)	0.76 (0.62-0.94)
		Vegetation Height	3	1352.68	1.46	0.26	0.19		
		Cloud	3	1353.16	1.93	0.20	0.20		
Ref	2016	Null	2	188.93	0.00	0.44	0.63	134.22 (122.45-147.12)	0.70 (0.59-0.85)
		Cloud	3	190.59	1.66	0.21	0.32		
	2017	Null	2	258.49	0.00	0.53	0.99	149.52 (140.55-159.06)	0.87 (0.77-0.99)
		Observer	3	259.85	1.36	0.27	0.51		
		Vegetation Height	3	260.44	1.95	0.20	0.57		

Table A3.4. COLORADO: Top models (ΔAIC ≤ 2 and goodness-of-fit~.20) based on AIC value for Vesper Sparrow (VESP) density detection probability (p) for each site and year in Colorado. We list the site, year, model, parameters (k), AIC, ΔAIC, model weight (w), and p-value for the K-S goodness-of-fit test (K-S). We report the effective detection radius (EDR), detection probability, and associated confidence intervals (CI) for models with the most weight.

Site	Year	p Models	k	AIC	ΔAIC	w	K-S	EDR (CI)	p (CI)
Bison	2016	Observer	2	533.69	0.00	0.94	0.41	79.48 (69.39-91.04)	0.40 (0.30-0.52)
	2017	Null	1	524.81	0.00	0.41	0.28	124.19 (98.81-156.09)	0.61 (0.39-0.96)
		Observer	2	525.85	1.04	0.24	0.23		
		Cloud	2	526.31	1.50	0.19	0.30		
		Vegetation Height	2	526.78	1.97	0.14	0.27		
Cattle	2016	Observer	2	830.94	0.00	0.36	0.88	72.49 (66.15-79.44)	0.34 (0.28-0.41)
		Cloud	2	831.31	0.37	0.30	0.68		
		Null	1	831.17	1.23	0.20	0.65		
	2017	Cloud	2	282.27	1.69	1.00	0.96		
Ref	2016	Null	1	119.28	0.00	1.00	0.30	78.95 (57.39-108.61)	0.43 (0.23-0.81)
	2017	Observer	2	285.85	0.00	0.63	0.79	80.85 (64.16-100.89)	0.29 (0.18-0.41)

Table A3.5. COLORADO: Direction of the beta (β) estimates for top model (model with the most weight) of detection probability for Horned Larks, Vesper Sparrows, and Western Meadowlarks in Colorado at the bison, cattle and reference (Ref) sites in 2016 and 2017. Beta estimates (β) are cited as + = positive and -- = negative and indicate the effect of covariates on detection probability.

				Observer		Rain*			Cloud (0-100%)	Vegetation Height (cm)
Species	Site	Year	Model	1	2	0	1	2		
HOLA	Bison	2016	Rain			+	+	--		
		2017	Null							
	Cattle	2016	Cloud						--	
		2017	Null							
	Reference	2016	Cloud						+	
		2017	Vegetation							--
VESP	Bison	2016	Observer	--	+				+	
		2017	Null							
	Cattle	2016	Observer	+	--					
		2017	Cloud						--	--
	Reference	2016	Null							
		2017	Observer	--	+					
WEME	Bison	2016	Null							
		2017	Vegetation							--
	Cattle	2016	Vegetation							--
		2017	Null							
	Reference	2016	Null							
		2017	Null							

*Rain was a categorical variable in which observers used a scale to estimate rainfall, where 0=No rain, 1= Mist or Fog, 2= Light drizzle. Observers ceased point counts if rain category rose above level 2.

Table A3.6. COLORADO: Top generalized linear mixed models (ΔAIC ≤ 2) for how fixed effects—bison, cattle, or reference (ref) site, year (2016, 2017), and average warm and cool season grass cover—influenced density of Horned Larks (HOLA), Vesper Sparrows (VESP), and Western Meadowlarks (WEME) in Colorado. We list the model, parameters (k), AIC, ΔAIC, and model weight (w). We only list the direction of the fixed effects on density for the top model (model with the most weight). The direction of the beta estimates (β) are cited as + = positive and -- = negative.

						β Site		
Species	Model for density	k	AIC	ΔAIC	w	Bison	Cattle	Ref
HOLA	Site	4	195.98	0.00	1	+	--	--
VESP	Site	4	206.29	0.00	0.50	--	+	--
	Year	3	206.42	0.12	0.47			
WEME	Site	4	282.18	0.00	0.34	--	+	--
	Null	2	282.40	0.21	0.31			
	Year	3	283.84	1.65	0.15			

Table A3.7. COLORADO: Top models (ΔAIC ≤ 2 and goodness-of-fit~.20) based on AIC value for Brewer's Blackbirds, Grasshopper Sparrows, Lark Sparrows, and Spotted Towhees. Site-level covariates affecting habitat use included sites (Trt), either bison, cattle, or reference, and average cool season or warm season grass cover. Observation-level covariates included year (2016 or 2017), observer (Obs), wind (W), cloud (C), or vegetation height (Ht). Rainfall was highly correlated with year, and thus was not included in the models.

Species and Models	k	AIC	Δ AIC	w
Brewer's Blakbird				
Ψ(1) ϒ(1) ε(Trt) p(Ht+Obs+C)	9	313.04	0.00	0.20
Ψ(1) ϒ(1) ε(Trt) p(Ht)	7	314.45	1.41	0.10
Ψ(Warm) ϒ(1) ε(Trt) p(Ht)	8	314.54	1.50	0.09
Grasshopper Sparrow				
Ψ(Trt) ϒ(1) ε(1) p(Year)	7	556.59	0.00	0.48
Lark Sparrow				
Ψ(Trt) ϒ(.) ε(.) p(Ht)	7	288.84	0.00	0.22
Ψ(1) ϒ(1) ε(1) p(Ht)	5	290.13	1.29	0.12
Ψ(Warm) ϒ(1) ε(1) p(Ht)	6	290.20	1.35	0.11
Spotted Towhee				
Ψ(Trt) ϒ(1) ε(Trt) p(1)	6	312.38	0.00	0.25
Ψ(Trt) ϒ(1) ε(1) p(Obs)	7	313.69	1.31	0.13
Ψ(Trt) ϒ(1) ε(1) p(Yr)	7	314.03	1.66	0.11
Ψ(Trt) ϒ(1) ε(1) p(Ht)	7	314.08	1.70	0.11
Ψ(Trt) ϒ(1) ε(1) p(C)	7	314.37	2.00	0.09

Table A3.8.COLORADO: Results from top model (Δ AIC = 0.00) for Brewer' Blackbirds (BRBL), Grasshopper Sparrows (GRSP), Lark Sparrows (LASP), and Spotted Towhees (SPTO). We list the species (Sp), habitat use (Ψ), colonization (ϒ), extinction (ε) and detection probabilities (p), and associated confidence intervals (CI). Colonization estimates for year (null) indicates the proportion of unoccupied site in 2016 that became occupied in 2017, while the extinction estimate for year (null) indicate the proportion of occupied sites in 2016 that became unoccupied in 2017. Site-level covariates affecting habitat use included sites (Trt), either bison (Bis), cattle (Cat) or reference (Ref), and warm season grasses, cool season grasses, or forbs. Observation-level covariates included year (2016 or 2017), observer (Obs), wind, or cloud (C), or vegetation height (Ht).

	Ψ2016 (SE)			ϒ (CI)	ε (CI)	εTRT (CI)			p (CI)					
Sp	Bis	Cat	Ref	Null	Null	Bis	Cat	Ref	Null	2016	2017	Ht	Obs 1	Obs 2
BRBL *	0.55 (0.38-0.70)	0.55 (0.38-0.70)	0.55 (0.38-0.70)	1.4e-4 (0.00-1.00)		0.88 (0.44-0.98)	0.07 (6.1e-5-0.99)	0.41 (0.07-0.87)					0.18 (0.11-0.27)	0.26 (0.17-0.38)
GRSP	0.86 (0.57-0.97)	0.78 (0.53-0.92)	0.30 (0.12-0.59)	0.36 (0.12-0.70)	0.02 (1.65e-7-1.00)					0.44 (0.36-0.52)	0.23 (0.16-0.33)			
LASP	0.21 (0.07-0.49)	0.61 (0.33-0.83)	0.36 (0.12-0.69)	0.05 (7.0e-4-0.78)	4.5e-4 (0.00-1.00)							0.22 (0.16-0.30)		
SPTO	0.11 (0.03-0.35)	0.24 (0.09-0.49)	0.80 (0.48-0.95)	0.08 (0.02-0.28)	0.15 (0.03-0.55)				0.27 (0.27-0.43)					

*For Brewer's Blackbird detection probability, the observer covariate includes observer + cloud + vegetation height.

Table A3.9. NEW MEXICO Top models (ΔAIC ≤ 2 and goodness-of-fit~.20) based on AIC value for Horned Lark (HOLA) density detection probability (p) for each site and year in Colorado. We list the site, year, model, parameters (k), AIC, ΔAIC, model weight (w), and p-value for the K-S goodness-of-fit test (K-S). We report the effective detection radius (EDR), detection probability, and associated confidence intervals (CI) for models with the most weight.

Site	Year	p Models	k	AIC	ΔAIC	w	K-S	EDR (CI)	p (CI)
Bison	2016	Null	1	459.64	0.00	0.38		93.67 (85.22-102.85)	0.35 (0.29-0.42)
		Vegetation Height	2	459.66	0.02				
		Cloud	2	460.92	1.28				
	2017	Null	1	524.20	0.00	0.93		59.79 (53.73-64.31)	0.35 (0.29-0.41)
		Vegetation Height	2	526.19	1.99				
Cattle	2016	Null	2	365.30	0.00	1.00		94.30 (85.63-103.85)	0.79 (0.34-1.00)
	2017	Null	2	684.23	0.00	0.72		61.09 (56.48-66.07)	0.40 (0.34-0.46)
Ref	2016	N/A							
	2017	Null	1	137.02	0.00	1.00		150.49 (105.04-215.16)	0.57 (0.28-1.00)

Table A3.10. NEW MEXICO Top models (ΔAIC ≤ 2 and goodness-of-fit~.20) based on AIC value for Vesper Sparrow (VESP) density detection probability (p) for each site and year in Colorado. We list the site, year, model, parameters (k), AIC, ΔAIC, model weight (w), and p-value for the K-S goodness-of-fit test (K-S). We report the effective detection radius (EDR), detection probability, and associated confidence intervals (CI) for models with the most weight.

Site	Year	p Models	k	AIC	ΔAIC	w	K-S	EDR (CI)	p (CI)
Bison	2016	Null	1	317.01	0.00	0.58		138.56 (99.57-192.81)	0.91 (0.48-1.00)
		Vegetation Height	2	317.64	0.64				
	2017	Null	1	214.88	0.00			169.47 (116.51-246.49)	0.78 (0.37-1.00)
Cattle	2016	Null	1	534.90	0.00	0.53		174.69 (141.70-215.36)	0.93 (0.61-1.00)
		Vegetation Height	2	536.26	1.36				
		Cloud	2	536.75	1.86				
	2017	Null	2	230.56	0.00	1.00		104.41 (90.51-120.45)	0.42 (0.31-0.55)
Ref	2016	Null	1	283.33	0.00	0.49		188.00 (134.50-262.79)	1.00 (0.52-1.00)
		Vegetation Height	2	284.20	0.97				
		Cloud	2	285.01	1.78				
	2017	Null	2	225.92	0.00	1.00		103.91 (64.67-166.95)	0.27 (0.11-0.67)

Table A3.11. NEW MEXICO Top models (ΔAIC ≤ 2 and goodness-of-fit~.20) based on AIC value for Western Meadowlark (WEME) density detection probability (p) for each site and year in Colorado. We list the site, year, model, parameters (k), AIC, ΔAIC, model weight (w), and p-value for the K-S goodness-of-fit test (K-S). We report the effective detection radius (EDR), detection probability, and associated confidence intervals (CI) for models with the most weight.

Site	Year	p Models	k	AIC	ΔAIC	w	K-S	EDR (CI)	p (CI)
Bison	2016	Null	1	325.65	0.00	1.00		180 (151.91-213.28)	1.00 (0.71-1.00)
	2017	Observer	2	378.55	0.00	0.38		98.43 (92.16-105.13)	0.38 (0.33-0.43)
		Cloud	2	378.91	0.36				
		Null	1	379.09	0.54				
		Vegetation Height	2	380.14	1.59				
Cattle	2016	Null	2	644.30	0.00	1.00		175.48 (155.77-197.69)	0.91 (0.72-1.00)
	2017	Null	2	695.76	0.00	0.72		113.22 (100.85-127.12)	0.44 (0.35-0.56)
		Vegetation Height	1	697.63	1.87				
		Vegetation Height	2	284.20	0.97				
Ref	2016	Null	1	400.29	0.00	1.00		150.00 (114.50-196.51)	1.00 (0.59-1.00)
	2017	Null	2	820.29	0.00	1.00		115.02 (102.19-129.47)	0.46 (0.36-0.58)

Table A3.12. NEW MEXICO: Top generalized linear mixed models (ΔAIC ≤ 2) for how fixed effects—bison, cattle, or reference (ref) site, year (2016, 2017), and average forb cover—influenced density of Horned Larks (HOLA), Vesper Sparrows (VESP), and Western Meadowlarks (WEME) in New Mexico. We list the model, parameters (k), AIC, ΔAIC, and model weight (w). We only list the direction of the fixed effects on density for the top model (model with the most weight). The direction of the beta estimates (β) are cited as + = positive and -- = negative.

							β Site		β Year	
Species	Model for density	k	AIC	ΔAIC	w	Bison	Cattle	Ref	2016	2017
HOLA	Year	3	276.37	0.00	0.85				--	+
VESP	Site	4	218.96	0.00	0.96	--	+	+		
WEME	Year	3	310.65	0.00	1.00				--	+

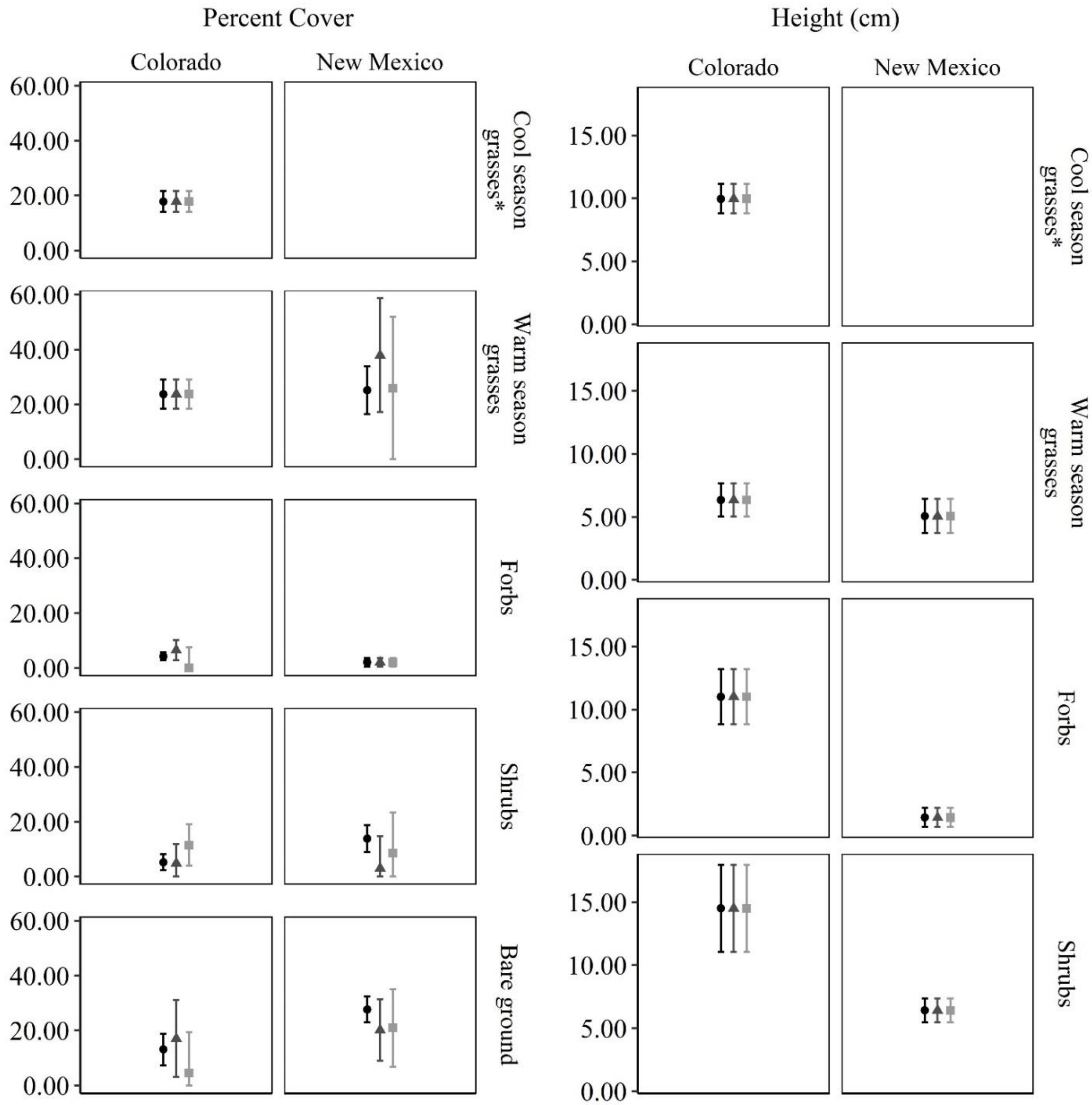

Figure A3.1. Vegetation cover and height estimates in 2016 at bison (black dot), cattle (dark gray triangle), and reference (light gray square) sites in Colorado and New Mexico. *Cool season grasses were not present at the sites in New Mexico.

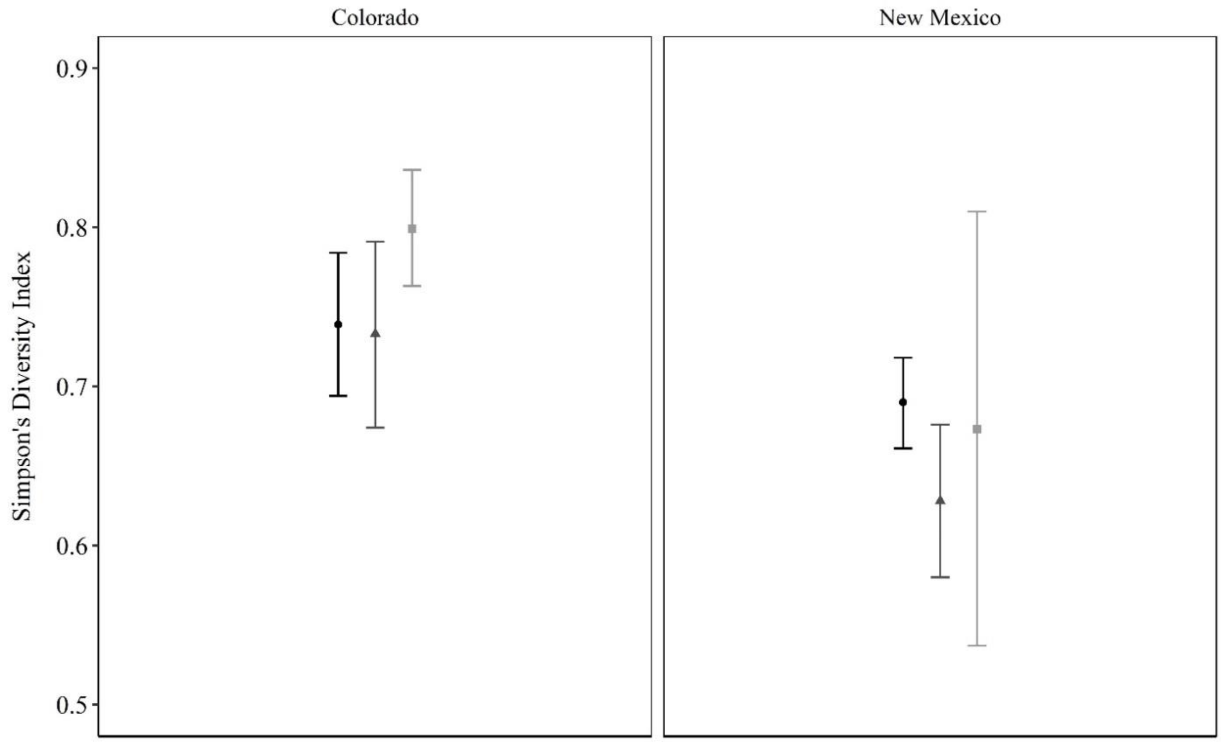

Figure A3.2. Simpson diversity index in 2016 at bison (black dot), cattle (dark gray triangle), and reference (light gray square) sites in Colorado and New Mexico.