State: Montana
Agencies: Fish, Wildlife & Parks and University of Montana

Grant: Migratory Songbird Grazing Study

Grant #: W-165-R-1

Time Period: 1 April 2020–31 December 2021

Final Report
Migratory Songbird–Grazing

Submitted by:
Victoria J Dreitz, Ph.D.
Associate Professor, Director of Avian Science Center
University of Montana

Kaitlyn Reintsma
Ph.D. Candidate, Wildlife Biology
Avian Science Center
University of Montana

Megan Delamont
Research Associate
Avian Science Center
University of Montana

Lorelle Berkeley, Ph.D.
Research Wildlife Biologist
Montana Fish, Wildlife, and Parks

December 1, 2021

Table of Contents

EXECUTIVE SUMMARY

Livestock grazing is the dominant land management practice in sagebrush steppe ecosystems in the western United States, but the direct effects of this land use on wildlife are poorly understood. It alters the structure, composition, and productivity of vegetation through increases in sagebrush size, cover, and density; decreases in forb cover and density; and decreases in grass cover and density. Recently, livestock grazing has been acknowledged as a management tool that can achieve desired vegetation conditions. Various conservation efforts have implemented grazing management as part of efforts to protect declining greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) populations. The most notable grazing conservation effort is within the Sage-Grouse Initiative (SGI) created by the Natural Resources Conservation Service (NRCS). In central and eastern Montana, SGI provided incentives for landowners to implement sage-grouse-friendly grazing systems that discourage the conversion of sagebrush steppe rangelands to farmlands or other development.

Sage-grouse may exhibit a "lag" effect in response to habitat management. Sagebrush steppe-associated migratory songbirds respond more quickly to habitat changes by shifting their distributions and adapting their reproductive performance. Thus, migratory songbirds can serve as a barometer for sagebrush steppe ecosystem integrity and measure the effects of grazing management designed to benefit avian communities positively. Numerous studies have documented community reassembly and effectiveness of conservation actions for migratory birds, which are among the few groups of species for which this has been done.

In 2012, we began a study to evaluate the relationships between grazing and avian community composition and demographic parameters related to SGI's rotational grazing regime. SGI's rotational grazing strategies allowed for periods of rest or deferment from grazing and varied the annual time of grazing in each pasture. We assessed the direct and indirect effects of SGI grazing systems by categorizing enrolled pastures into before, during, and after implementation of SGI grazing. Non-SGI grazing involved multiple types of grazing systems with less intensively managed and slower rotations, usually lacking annual changes in use.

This study had two objectives. Our first objective was to compare migratory songbird responses represented by species richness, species diversity, community composition, and species abundance and density on lands grazed using SGI and non-SGI strategies. To achieve this objective, we conducted avian count transect surveys using the dependent double-observer method. Our second objective was to evaluate the reproductive performance of three focal songbird species to understand the effects of SGI grazing on their populations more thoroughly. We identified three focal species, each associated with one of the three most common vegetation characteristics in sagebrush (*Artemisia* spp.) steppe. We conducted nest searches and monitored nesting activity of Brewer's sparrow (*Spizella breweri*; sagebrush nester), vesper sparrow (*Pooecetes gramineus*; generalist ground nester), and thick-billed longspur (*Rhynchophanes mccownii*; grassland ground nester; previously named McCown's longspur).

During 2013–2019, the total number of individuals we observed in the study area, regardless of grazing regime, ranged from 5,954–14,097, and the total number of species ranged from 72–88.

We observed low variation in avian community composition amongst years, suggesting a relatively stable species richness in our study area over time. The migratory songbird species observed most often since 2013 were: thick-billed longspur, vesper sparrow, Brewer's sparrow, horned lark (*Eremophila alpestris*), and western meadowlark (*Sturnella neglecta*). Estimates of abundance for the five most common species suggest species-specific responses to the two grazing systems. For instance, thick-billed longspurs were most abundant on lands using SGI grazing, while observations of western meadowlarks were higher on non-SGI plots during the early years of our study. For our three focal species, we located 40% of nests on lands using non-SGI grazing, compared to 60% of nests on lands using SGI grazing. Estimated nest density was higher on SGI grazing plots for thick-billed longspur, but nest success showed little difference between SGI and non-SGI.

Overall, our study suggests that SGI grazing regimes had minimal effects on the overall sagebrush steppe avian community and the highest species-specific response by a grassland specialist, thick-billed longspur. Livestock prefer grasses and forbs over shrubs for forage. Thus, the SGI grazing regimes are likely beneficial to grassland species, as we observed. We concur with previous studies that grazing management has varying impacts on different songbird species and that a mosaic of numerous grazing regimes will maintain the songbird community best. Future studies on sagebrush steppe songbirds should consider other grazing regimes or other grazing metrics (e.g., intensity, duration, frequency) along with other biotic and abiotic factors.

The involvement of private landowners in our study will continue to advance conservation efforts in sagebrush steppe. The foundation of the SGI grazing program allowed us to benefit from working with private landowners in our study area. We became involved members of the local community through communication with landowners and participation at local events. Thus, we contributed to furthering future partnerships of private landowners and local communities in collaborative conservation efforts.

BACKGROUND

Sagebrush steppe songbirds

Approximately 76% of sagebrush-associated bird species are declining nationally (Saab and Rich 1997, Paige and Ritter 1999, Dobkin et al. 2008). Sagebrush-nesting species make up the largest number of Species of Continental Importance within the Intermountain West (Rich et al. 2004). The greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) has shown significant declines over the last 30–40 years (Garton et al. 2011). Additional avian species that breed in Montana's sagebrush steppe are in decline and of conservation concern include Brewer's sparrow, sage thrasher (*Oreoscoptes montanus*), thick-billed longspur, chestnut-collared longspur (*Calcarius ornatus*), and lark bunting (*Calamospiza melanocorys*; Rich et al. 2004). Songbirds are often used as indicators for ecosystem health in sagebrush steppe because of their mobile and conspicuous nature (Bradford et al. 1998). Changes in songbird abundance are also of ecological importance because of their roles as predators, prey, pollinators, and seed dispersers (Murphy and Romanuk 2012). Songbirds exhibit a varying degree of reliance on grass vegetation, an important component of sagebrush steppe ecosystems (Rich et al. 2004). The songbirds range from grassland obligates such as thick-billed longspur and chestnut-collared longspur that use grass for most of their life history needs to facultative grassland species (e.g., vesper sparrow, *Pooecetes gramineus*) which use grass in addition to other vegetation to meet their life history needs; to sagebrush obligates such as Brewer's sparrow and sage thrasher that use sagebrush for most of their life history needs. Thus, sagebrush steppe-associated songbirds can serve as an initial barometer for system integrity and assist in evaluating the effectiveness of management actions.

Declines in sagebrush-associated avian species are congruent with significant losses of sagebrush steppe (Braun et al. 1976, Knick 1999). Significant stressors on sagebrush steppe ecosystems include the conversion of sagebrush lands to agriculture and fragmentation resulting from energy or subdivision development. Modifications such as prescribed fire, herbicides, and some grazing practices that lead to exotic, annual grass establishment can also act as stressors (Rich et al. 2004, MTSWAP 2015).

Livestock Grazing

Livestock grazing, hereafter referred to as grazing, is the most widespread land use across sagebrush steppe (Knick et al. 2010). It offers many benefits to a variety of stakeholders, ranging from conservation practitioners to private landowners. Depending on the timing and use rates of livestock, grazing can directly increase sagebrush size, cover, and density; decrease forb cover and density; and decrease grass cover and density (Beck and Mitchell 2000, Crawford et al. 2004). There is evidence that grazing can negatively affect sagebrush-associated bird habitat through rangeland degradation or reductions in invertebrate biomass (Jones 2000, Krausman et al. 2009), an important food source for many bird species. However, there is growing evidence that grazing can be used as a conservation tool to improve sagebrush steppe for bird species (Holechek et al. 1998, Coppedge et al. 2008, Lipsey and Naugle 2017).

Rotational grazing is currently the most common grazing strategy used to improve habitat for wildlife in sagebrush steppe ecosystems (Hormay 1970, Briske et al. 2008). Limited information suggests that rotational grazing may not have significant short-term effects on the density of songbirds (Lapointe et al. 2003). However, most studies that examine the effect of livestock grazing on wildlife compare areas with livestock grazing to areas without livestock grazing (e.g., Bock and Webb 1984, Harrison et al. 2010, Nelson et al. 2011). The majority of sagebrush steppe ecosystems and landscapes have livestock grazing (Knick et al. 2003). Thus, a clear need exists to evaluate and compare the benefits of different livestock grazing management strategies on sagebrush steppe-associated songbird populations.

Montana Fish, Wildlife and Parks (FWP) manages 200,000 acres (~81,000 ha) of rest-rotation grazed habitats on private land through conservation easements and Upland Game Bird Enhancement program projects and state-owned lands such as Wildlife Management Areas or state land leased from the Department of Natural Resources and Conservation. In addition, due to emphasis on conservation for sage-grouse, the Natural Resources Conservation Service (NRCS) has developed the Sage-Grouse Initiative (SGI). One program of this Initiative was rest-rotation grazing management that controlled the location and timing of grazing to benefit sage-grouse by maintaining or increasing grass cover for nesting grouse. NRCS enrolled land in private ownership into SGI with appropriate habitat, which they consider areas with ≥5% cover for sage-grouse.

Livestock producers enrolled in the SGI grazing program implemented an approximately 3-year grazing regime developed with collaboration from NRCS range management specialists. Range management specialists may have suggested 1) pasture rest, 2) pasture deferment, 3) a change in the number of animal units per month (AUMs), or 4) the installation of fences or water sources to adjust pasture size and livestock distribution. SGI grazing regimes were tailored to each ranch and pasture and varied based on producer needs or pasture condition while following the NRCS Conservation Practice Standard for Prescribed Grazing (NRCS 2017, Smith et al. 2018). Additionally, plans aligned with four minimum criteria intended to support sage-grouse habitat: 1) grazing utilization rates of ≤50% of the current year's key forage species growth, 2) ≥20-day shift annually in the timing of grazing, 3) an established plan to address unexpected circumstances like drought or fire, and 4) ≤45-day continuous grazing durations within any one pasture (Smith et al. 2018).

Of the 400,000 acres of pasture lands across Montana enrolled in SGI grazing program, 190,615 acres (~77,000 ha) were in Golden Valley and Musselshell counties. These efforts provided the infrastructural capacity to investigate the benefits of SGI rotational grazing on sage-grouse populations in that area. In contrast to sage-grouse, migratory songbirds can respond relatively quickly to alterations in their habitats by shifting distributions or varying reproductive performance accordingly (Caro 2010, Hart et al. 2012). Migratory songbirds are therefore among the few groups of organisms in which community reassembly (e.g., Lemoine et al. 2007, Zuckerberg et al. 2009) occurs quickly enough to use as a response to evaluate conservation actions shortly after implementation. Resource managers that incorporate monitoring of songbird populations into their wildlife monitoring efforts will be alerted to changes in habitat much more rapidly than changes in sage-grouse population demographics. Thus, the overarching goal of this study is to determine the response of breeding migratory songbird populations to SGI grazing.

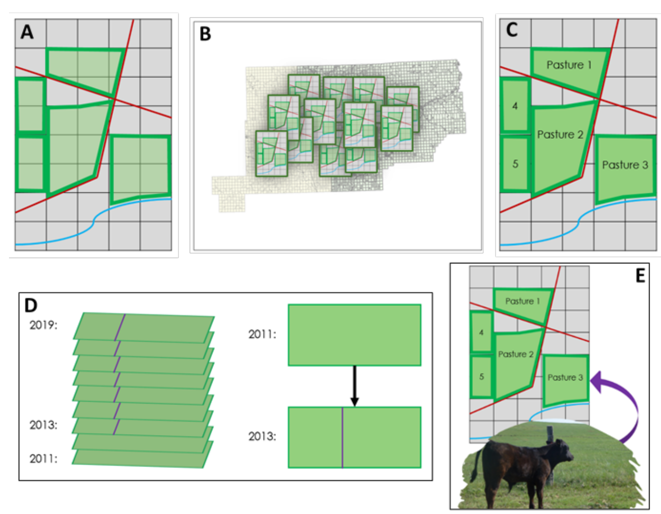

FIGURE 1. A. An example of a hand-drawn map created during a meeting with a livestock producer, where pasture boundaries are highlighted. **B.** Hand-drawn maps are georeferenced. **C.** Georeferenced pastures are digitized. **D.** Changes in pasture boundaries (e.g., a fence addition) over time are digitized. **E.** Grazing information (e.g., grazing timing and duration) is joined with the digitized pasture for each year.

SGI grazing

The grazing data compilation process required synthesis of several data streams into a cohesive spatially and temporally referenced layer. The first step of the process involved in-person conversations with livestock producers. FWP staff met with over 70 representatives from more than 40 ranches each year to collect pasture level information that included 1) changes in pasture boundaries over time, 2) timing of grazing, 3) grazing duration, 4) SGI enrollment status, and 5) other livestock-related variables (e.g., livestock species, age, sex). We obtained some grazing data from NRCS as well. During the study, the pasture boundaries, and any changes in the boundaries, were recorded on hand-drawn and NRCS-produced maps. Grazing data were obtained from landowners in the fall, following the completion of grazing for the year. Data obtained before grazing implementation would have been less accurate because weather, infrastructure issues, and other unforeseen disturbances could cause producers to change their grazing plans. Providing grazing information more detailed than SGI status was voluntary for producers.

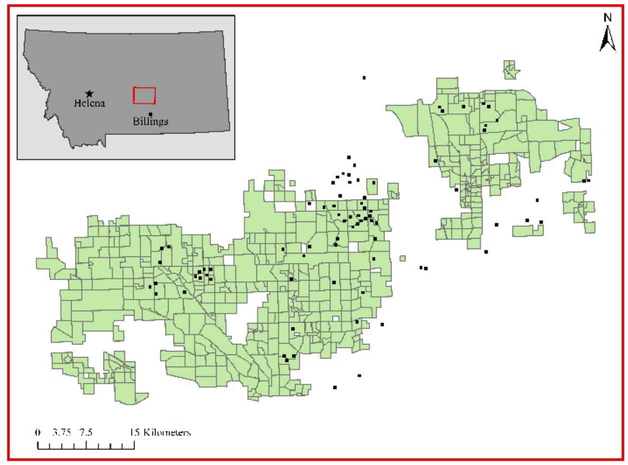

FIGURE 2. The final grazing digitization layer we created from georeferenced MTFWP maps and linked with grazing information (e.g., grazing timing and duration) is shown in green. The location of the layer relative to the state of Montana is shown on the top left locator map. There are approximately 523 pastures for one year, which are layered on top of the other approximately 4,711 pastures for the remaining years of the study. The 80 songbird plots used in our study from 2013–2018 are shown as black squares.

After collecting pasture-level grazing information, we compiled the information into a final grazing dataset in three steps: georeferencing, digitizing, and joining spatial layers with grazing information (Figure 1). First, we georeferenced approximately 97 hand-drawn (Figure 1A, 1B, 1C) and NRCS maps of the different sections of our study area. We then used these maps to digitize approximately 523 pastures for each of the nine years of the study (i.e., 5,234 pastures total, Figure 1C), which allowed us to account for any changes in pasture fence lines that occurred during the study. Finally, we linked the grazing information (e.g., timing and duration) for each pasture and year to the spatial data we created (Figure 1E). We did multiple quality control steps to finalize the grazing dataset. The complete spatial extent of the grazing layer is visible in Figure 2.

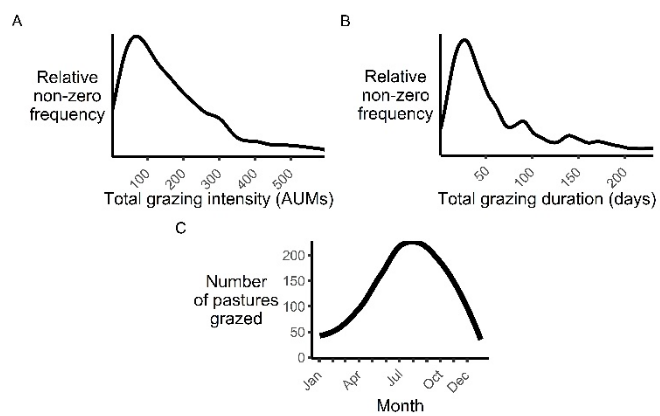

FIGURE 3. A. Average yearly grazing duration for all pastures area irrelevant of categorization without zeroes. **B.** The average yearly grazing intensity in animal units per month (aums) without zeroes. **C.** The number of pastures grazed during each month of the year.

The completed grazing dataset provides information on the SGI status, intensity (i.e., AUMs, Figure 3A), duration (i.e., total days grazed, Figure 3B), timing, and frequency (i.e., turn in and turn out dates, Figure 3C) of grazing. We obtained 1% (n= 522) of AUM data and 31% (n = 1,622) of turn-in and turn-out dates (i.e., dates used to determine duration, timing, and frequency) for pastures directly from NRCS or the producer. The remaining available AUM pasture data (n = 820) were calculated following NRCS guidelines as number of animal units appropriate for the livestock type (e.g., sheep, heifers, bulls) * number of livestock * number of days grazed / 30.4 days per month] = AUMs. To understand the programmatic effects of SGI grazing on sagebrush steppe songbirds we assessed the SGI grazing regime, the approximately three consecutive years during which pastures were actively enrolled in a rotational grazing program, as a whole. We quantified the programmatic aspect of SGI grazing in the following ways (Figure 4):

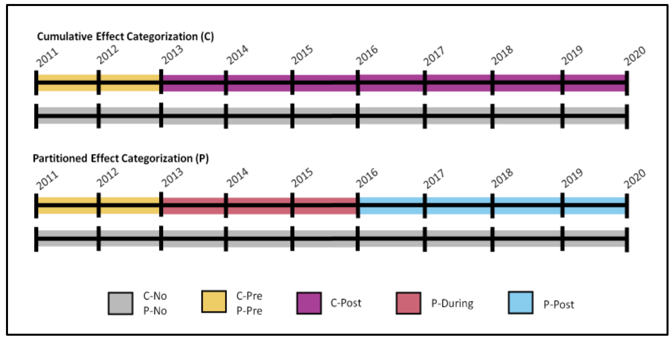

FIGURE 4. A visual description of the two grazing categorizations. In each pair of timelines, the top line represents the same hypothetical pasture that is implementing an SGI grazing regime from 2013 through the end of 2015, while the bottom timeline represents a different pasture that was never enrolled in an SGI grazing regime.

1. **Cumulative (C) Effect Categorization**: This categorization separates the pastures that were enrolled in SGI at one point into two subcategories based on the timing of the SGI grazing. Under this categorization we defined a pasture as C-Pre for years prior to active SGI grazing and C-Post the years during and after the pasture was enrolled in SGI. Pastures not participating in the SGI 3-year grazing regime were defined as C-No. This is a broad categorization that determines any general short- and long-term effects of SGI grazing using the maximum number of sample sizes.

2. **Partitioned (P) Effect Categorization**: This categorization separates the pastures that were enrolled in SGI at one point into three subcategories based on the timing of the SGI grazing. A pasture was considered P-Pre in the years before SGI grazing grazing implementation, P-During while SGI grazing actively occurred, and P-Post after active SGI grazing until the end of the study. This classification allows differentiation between the possible temporal effects of grazing (i.e. direct short-term effects vs indirect longer-term effects).

The subcategories used in analyses were constrained by the number of associated avian samples. The C-Pre and P-Pre subcategories had limited songbird data for both categorizations (i.e. only 6 plots and 5 nests, Table 1). Thus, the C-Pre and P-Pre subcategories and associated data were not included in analyses.

TABLE 1. The number of plots sampled over all years of the songbird study and the number of focal species nests found within those plots per grazing subcategory.

	C-Pre / P-Pre*	C-Post	P-During	P-Post	C-No / P-No*	Total
Number of plots	6	278	75	203	276	560
Number of nests	5	717	164	553	505	1,227

* The pre and no subcategories have the same sample sizes for plots and nests between categories. They represent the same area and nests, but are divided for easier comparison within categories.

Here, we describe our findings on the effects of SGI grazing management in terms of SGI categorization on the 1) sagebrush steppe songbird community (i.e., species richness, diversity, and composition); and 2) breeding performance of three focal songbird species that represent the different guilds of songbirds based on niches of vegetation characteristics in sagebrush steppe. We provide information from our long-term, 7-year study that began in 2013. This work takes place near Lavina and Roundup, Montana, in which we selected 80 plots (500 x 500 m or 25 ha each) to sample (Figure 2). The study area is in big sagebrush steppe, the most widely distributed sagebrush ecosystem in Montana. It is characterized by Wyoming big sagebrush (*Artemisia tridentate* ssp. *wyomingensis*) with perennial grasses and forbs dominating > 25% of vegetation cover. We provide a general summary of our field methods for each objective below.

OBJECTIVE: COMMUNITY RESPONSE TO SGI GRAZING

Methods

We examined species richness, composition, and diversity to investigate the effects of SGI grazing on the sagebrush steppe songbird community. Species richness is the number of species in an area. Composition is the species compromising species richness, which allows a more detailed insight into the community. Diversity is both species richness (i.e., the number of different species) and the evenness (i.e., the similarity of abundance between species) in the avian community.

We used count-based data collected by avian count transect surveys following the dependent double-observer method (DDO, Nichols et al. 2000; Figure 5). The DDO method increases the probability of detecting individual grassland songbirds (Tipton et al. 2008 and 2009) and multiple sagebrush steppe songbirds compared to point counts (Golding and Dreitz 2016). The method requires a two-person team (i.e., a primary observer and a secondary observer). The primary observer walks ahead of the secondary observer, maintaining ~10 m apart. The primary observer communicates visual observations of individual birds. The secondary observer records the primary observer's detections and any individuals detected that the primary observer missed. Primary and secondary observers alternated roles between consecutive surveys. We conducted three surveys within each sample plot between late April–August from 2013–2019 to account for differences in species-specific breeding phenology (Table 2). The third sampling occasion in 2015 did not occur due to an early nesting season, which made it difficult for observers to reliably distinguish between young of the year and adults. During the first and

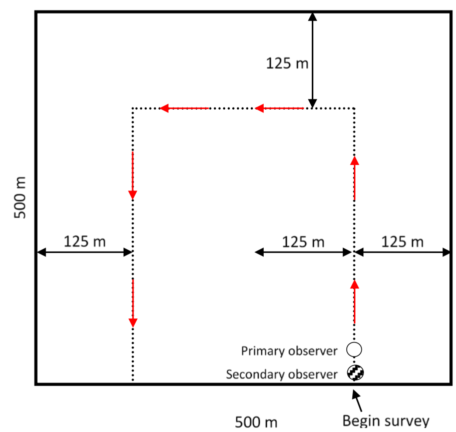

FIGURE 5. Schematic illustrating the dependent double-observer method used to estimate abundance of migratory songbirds in response to SGI grazing in Golden Valley and Musselshell counties, Montana. The primary (open circle) and secondary (dashed circle) observers walk single file along the transect (dotted line) within a 500m x 500m sampling plot. Observers survey up to 125m on either side of the transect (dotted line). All surveys start at the lower right corner of the sample plot. Red arrows indicate direction of travel.

third rounds, several transects were not completed in 2018 due to landowners' concerns (e.g., disturbance to young cattle in pastures). In 2019, we lost access to 14 plots due to land ownership change. No fieldwork was conducted in 2020 due to complications arising from the COVID-19 pandemic. Transect surveys occurred between sunrise (~0530 Mountain Daylight Time [MDT]) and 1100 MDT. Transect surveys did not take place during steady rains or wind speeds exceeding 15 mph.

We calculated the diversity and composition of sagebrush steppe songbirds using number of individuals, species richness (i.e., number of species), and Shannon's H diversity index (Shannon and Weaver 1949). We used the multispecies dependent double-observer abundance model (MDAM) to inform diversity as the abundance or density of multiple species (Golding et al. 2017).

Results

The total number of individuals observed ranged from 5,954–14,097 during 2013–2019 (Table 3, Appendix A). The lower observations of individuals in 2015 were likely due to the earlier breeding season resulting in only two avian count transect surveys that year. The migratory songbird species of which we observed the most individuals since 2013 were: thick-billed longspur, vesper sparrow, Brewer's sparrow, horned lark, and western meadowlark (Appendix A). Observations of avian community composition ranged from 72–88 species during 2013–2019 with low variation among years (Table 4, Appendix A), suggesting a relatively stable temporal species richness in our study area.

TABLE 2. The number of avian count transects surveyed and nest searches conducted on 500 m x 500 m sample plots during 2013–2019 in Golden Valley and Musselshell counties, Montana.

Year	Sampling Occasion	Date	Survey	Nest Search
2013	1	Apr 26–Jun 1	80	56
	2	Jun 4–Jul 31	80	30
	3	Jun 9–Aug 3	80	20
	Total		**240**	**106**
2014	1	May 22–Jul 12	80	30
	2	Jun 3–Jul 8	80	30
	3	Jul 8–Jul 23	80	20
	Total		**240**	**80**
2015	1	May 2–Jun 6	80	19
	2	Jun 6–Jun 29	80	47
	Total		**160**	**66**
2016	1	May 7–Jun 14	80	80
	2	May 22–Jul 1	80	66
	3	Jun 16–Jul 5	80	23
	4	Jun 23–Jul 8	-	19
	Total		**240**	**188**
2017	1	Apr 29–Jun 16	80	62
	2	May 11–Jul 5	80	43
	3	Jun 18–Jul 12	80	19
	4	Jun 24–Jul 12	-	6
	Total		**240**	**130**
2018	1	May 3–Jun 3	76	60
	2	May 24–Jun 21	80	44
	3	Jun 21–Jul 8	75	15
	4	1 Jul	-	1
	Total		**231**	**120**
2019	1	May 7–Jun 5	66	80
	2	Jun 10–Jul 24	66	80
	3	Jun 30–Jul 19	66	9
	Total		**198**	**169**
Study Total			**1549**	**859**

TABLE 3. Total number of individuals for all species detected on avian count transect surveys during 2013–2019 in Golden Valley and Musselshell Counties, Montana.

Year	C-Post	P-During	P-Post	C-No / P-No	Total
2013	7,093	6,894	199	7,004	14,097
2014	7,432	4,623	2,809	6,177	13,609
2015	3,291	322	2,963	2,663	5,954
2016	5,645	403	5,242	4,491	10,136
2017	5,124	89	5,035	5,437	10,561
2018	4,129	0	4,129	4,569	8,698
2019	4,138	0	4,138	4,527	8,665
All Years	36,852	12,331	24,521	34,868	71,720

The number of individuals and species richness varied between grazing subcategories (Tables 3 and 4). For C-No and P-No, we observed a total of 123 species and 34,868 individuals for non-SGI plots (Tables 3 and 4). C-Post had slightly lower species richness (100 species) but more individuals (36,852) than C-No (Tables 3 and 4). There was more contrast from P-No to P-During and P-Post with 95 species and 12,331 individuals in P-During and 68 species with 24,521 individuals in P-Post (Tables 3 and 4). However, the survey sample sizes for the during and post SGI subcategories were small relative to the other categories. Thus, observing fewer species and individuals was expected because the total area surveyed was smaller. The Shannon's H values, which factors in evenness (i.e., the number of species and their relative abundances) into a diversity index, showed very little difference between the grazing subcategories (Table 5).

We estimated abundance using MDAM for the five most common species using the Cumulative Effect Categorization. Sample sizes were not sufficient to use the Partitioned Effect Categorization. MDAM estimates suggest species-specific responses to C-No compared to C-Post (Figure 6, Appendix B). Thick-billed longspurs were estimated to be significantly more abundant on C-Post compared to C-No for all years of the study. Western meadowlarks were slightly more abundant on C-No in 2013 and 2014 but were more similar between C-No and C-Post for the remaining years of the study. There were no other apparent differences in abundance between the Cumulative Effect

TABLE 4. Species richness (the number of unique species) for all species detected on avian count transect surveys during 2013–2019 in Golden Valley and Musselshell Counties, Montana.

Year	C-Post	P-During	P-Post	C-No / P-No	Total
2013	61	60	9	77	87
2014	50	43	31	69	75
2015	50	15	48	60	72
2016	55	21	52	78	84
2017	55	12	55	79	83
2018	59	0	79	79	86
2019	65	0	65	79	88
All Years	100	68	95	123	133

TABLE 5. Shannon's Diversity Index for all species detected on avian count transect surveys during 2013–2019 in Golden Valley and Musselshell Counties, Montana.

Year	C-Post	P-During	P-Post	C-No / P-No	Total
2013	2.19	0.96	2.21	2.74	2.54
2014	2.06	1.34	2.20	2.56	2.34
2015	2.20	2.19	1.61	2.52	2.37
2016	2.20	2.15	1.59	2.75	2.48
2017	2.39	2.38	1.67	2.66	2.53
2018	2.57	2.57	0.00	2.89	2.65
2019	2.67	2.67	0.00	2.90	2.73
All Years	2.39	2.29	2.42	2.78	

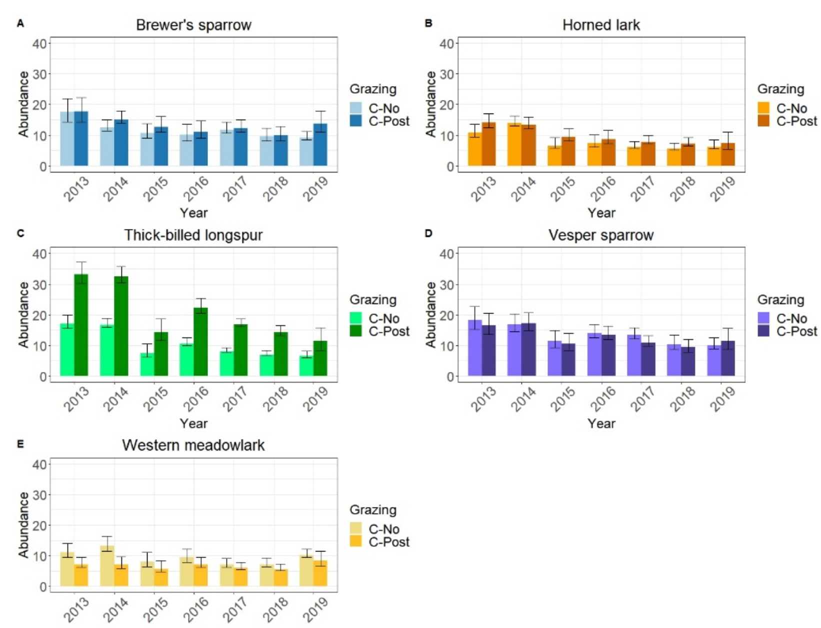

FIGURE 6. The estimated average abundance per 25 hectares for the top five songbird species observed during our study investigating the response of migratory songbird populations during the breeding season to the Cumulative Effect Categorization of grazing during 2013– 2019 in Golden Valley and Musselshell Counties, Montana.

Categorization subcategories for the other species.

Discussion

While we have not seen a clear response of every avian species within the community, our results suggest that SGI grazing may create vegetation conditions that are more favorable for thick-billed longspur and less so for Brewer's sparrow, horned lark, and vesper sparrow. For example, Brewer's sparrows are sagebrush obligates, and changes in grass structure and composition through changes in grazing regimes may not influence sagebrush in the short term.

OBJECTIVE: BREEDING PERFORMANCE OF THREE FOCAL SPECIES

Methods

Since 2013, we have monitored the nesting activity of songbird species. We focused on three species that represent guilds using specific vegetation characteristics in this sagebrush steppe ecosystem: Brewer's sparrow (i.e., a shrub nester and sagebrush obligate); vesper sparrow (i.e., a ground nester and a sagebrush and grassland facultative species); and thick-billed longspur (i.e., a ground nester and grassland obligate). We conducted nest searches in the same 80 sampling plots surveyed for the adult count-based transects. The exception was in 2019 when 14 plots changed in land ownership, and the new landowner did not grant access. Thus, we performed nest searches on the 14 replacement plots. We used one of three nest search methods depending on the dominant vegetation in the plot: 1) a systematic nest search using a rope or chain for grass-dominated plots; 2) a systematic tapping of the tops of shrubs with a dowel for shrub-dominated plots (Ruehmann et al. 2011), and 3) nests located opportunistically (e.g., during nest monitoring visits). When a nest was initially located, we recorded its location with a GPS unit and marked it from ~5 m away in each cardinal direction with flagging to facilitate nest monitoring. Nests were monitored at approximately three-day intervals, weather permitting. During each monitoring visit, we recorded the status of the nest (i.e., active or inactive), stage of the young (i.e., eggs, nestling, or fledgling), and the number of young at each stage. A nest was determined successful when at least one nestling was confirmed to have fledged, defined as at least one nestling leaving the nest. We assumed nestling fledged if we observed nestlings of the appropriate age on the prior visit and observed an intact nest with signs of fledging (e.g., whitewash at the edge of the nest). When a nest failed, we recorded whether the cause of failure was predation, weather, or unknown.

We determined the nest density and success for the three focal songbird species using apparent and time-to-event model estimates. Apparent nest success and density are common values reported in avian research, but they can be biased by imperfect detection or lack of nest availability during the surveys unlike the time-to-event estimates. Apparent nest density was determined by dividing the number of nests by the area of the plots. We calculated the apparent values of nest success by dividing the number of successful nests by the total number of nests found. We examined apparent nest density and nest success for both the Cumulative Effect Categorization and Partitioned Effect Categorization. We estimated daily survival rate (DSR), overall nest success, and nest density accounting for detection and availability using the time-to-event model by Péron et al. (2014). We allowed the nest success and density estimates to vary by year and grazing subcategories for Cumulative Effect Categorization. Sample sizes were too low to support examining the Partitioned Effect Categorization by year.

Results

A total of 859 nest searches were conducted over the 7 years of the study (Table 2). Every plot was nest searched 0-6 times each year. We were able to nest search the proportion of 80 plots as follows: 63 (79%) in 2013, 78 (98%) in 2014, 65 (81%) in 2015, 80 (100%) in 2016, 62 (78%) in 2017, 60 (75%) in 2018, and 80 (100%) in 2019. In 2015, a total of seven sample plots were surveyed up to six times as part of a specific project on Brewer's sparrows (Reintsma et al. 2019). In 2019, the 14 new plots were surveyed four times to increase the number of thick-billed longspur nests.

We located a total of 1,172 Brewer's sparrow, vesper sparrow, and thick-billed longspur nests in plots that were grazed using the subcategories we were interested in (Appendix C). We found 40% of the nests (n = 465) on C-No and P-No plots, compared to 60% of the nests (n = 707) on lands using SGI grazing (i.e., C-Post, P-During and P-Post plots, Appendix C). However, there are fewer P-During than any other category. Overall years, these patterns remain the same for all three focal species (Appendix C). We accounted for the area of the grazing subcategories by calculating apparent nest density. We found lower apparent nest densities for all three focal species in the C-No and P-No grazing subcategory plots (Appendix C). The P-Post subcategory had the highest apparent nest density for all focal species (Appendix C).

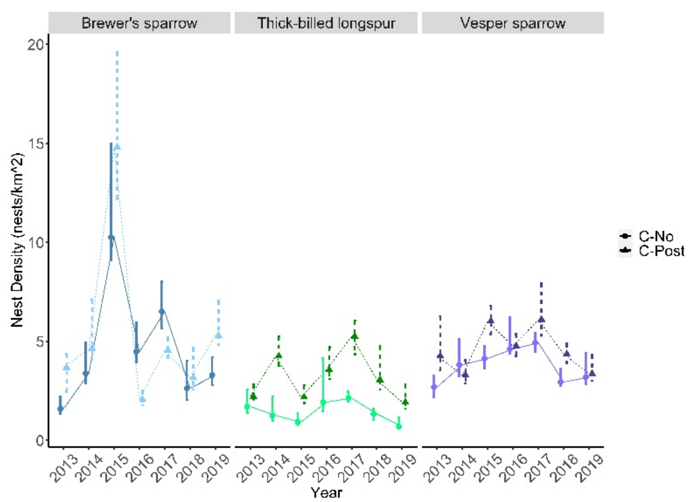

FIGURE 7. Estimated nest density, presented as number of nests per km², for Brewer's sparrow, thick-billed longspur, and Vesper sparrow across years using a time-to-event nest density estimator (TNDE) model for the Cumulative Effect Categorization of grazing in Golden Valley and Musselshell Counties, Montana.

Nest density and success estimates from the time-to-event estimator were generated for C-No compared to C-Post, which allowed yearly variation to estimate an overall nest density. Due to sample size limitations, time-to-event

TABLE 6. Estimated nest density, presented as number of nests per km², for Brewer's sparrow, thick-billed longspur, and Vesper sparrow across years using a time-to-event nest density estimator (TNDE) model for the Cumulative Effect Categorization of grazing in Golden Valley and Musselshell Counties, Montana.

Subcategory	Brewer's Sparrow	Thick-billed longspur	Vesper sparrow
C-no/P-no	3.752 (3.741–3.772)	1.201 (1.104–1.423)	3.316 (3.314–3.319)
C-post	3.154 (3.153–3.154)	2.874 (1.732–3.007)	3.128 (3.128–3.128)
P-during	4.99 (4.853–5.159)	10.126 (10.120–10.123)	4.604 (4.027–5.438)
P-post	5.422 (5.325–5.494)	0.765 (0.764–0.765)	4.694 (4.406–5.105)

estimations for nest density amongst the Partitioned Effect Categorization grazing subcategories did not allow for including yearly variation. Thus, we suggest caution when drawing conclusions based on the Partitioned Effect Categorization because the low sample sizes that vary over years could result in bias or spurious estimates. For example, only 34 thick-billed longspur nests were in P-During pastures and only in 2013–2014 (Appendix C). Thus, we cannot determine if grazing influenced nest density and nest success or if this is the natural yearly variation in these estimates for this species.

The time-to-event nest density estimations showed differences between grazing subcategorizations based on species (Table 6, Figure 7). For all years, Brewer's and vesper sparrows had higher nest densities in C-No compared to C-Post, while thick-billed longspur showed the opposite relationship (Table 6, Figure 7). The overall relationships were unclear once estimates were separated by year for the Cumulative Effect Categorization except for thick-billed longspur. Thick-billed longspurs showed a significant, but potentially biologically small (i.e., the largest effect was ~1 nest/km^2 in 2017), effect difference in C-No when compared to C-Post in most years. Conversely, the effect of C-No and C-Post on Brewer's sparrow and vesper sparrow appears to vary by year and not by grazing. All focal species had higher estimated nest density in P-During than P-No (Table 6).

Table 7. Estimated nest success and daily survival rate for Brewer's sparrow, thick-billed longspur, and Vesper sparrow across years using a time-to-event nest density estimator (TNDE) model for the Cumulative Effect Categorization of grazing during 2013–2019 in Golden Valley and Musselshell Counties, Montana.

	Overall Nest Success		**Daily Survival Rate**	
Brewer's Sparrow				
Year	C-No	C-Post	C-No	C-Post
2013	0.40 (0.25–0.48)	0.42 (0.35–0.54)	0.96 (0.94–0.97)	0.96 (0.95–0.97)
2014	0.41 (0.29–0.49)	0.42 (0.37–0.49)	0.96 (0.94–0.96)	0.96 (0.95–0.97)
2015	0.29 (0.21–0.36)	0.31 (0.22–0.39)	0.94 (0.93–0.95)	0.95 (0.93–0.96)
2016	0.45 (0.35–0.58)	0.47 (0.39–0.63)	0.96 (0.95–0.97)	0.97 (0.96–0.98)
2017	0.45 (0.36–0.58)	0.47 (0.40–0.59)	0.96 (0.95–0.97)	0.97 (0.96–0.98)
2018	0.47 (0.33–0.56)	0.49 (0.42–0.63)	0.97 (0.95–0.97)	0.97 (0.96–0.98)
2019	0.48 (0.33–0.58)	0.51 (0.37–0.61)	0.97 (0.95–0.97)	0.97 (0.96–0.98)
Thick-Billed Longspur				
Year	C-No	C-Post	C-No	C-Post
2013	0.57 (0.37–0.70)	0.59 (0.41–0.69)	0.98 (0.96–0.98)	0.98 (0.96–0.98)
2014	0.43 (0.26–0.50)	0.44 (0.35–0.55)	0.96 (0.94–0.97)	0.96 (0.95–0.97)
2015	0.60 (0.27–0.77)	0.61 (0.31–0.80)	0.98 (0.94–0.99)	0.98 (0.95–0.99)
2016	0.60 (0.42–0.67)	0.61 (0.49–0.67)	0.98 (0.96–0.98)	0.98 (0.97–0.98)
2017	0.40 (0.30–0.48)	0.42 (0.27–0.51)	0.96 (0.95–0.97)	0.96 (0.94–0.97)
2018	0.64 (0.52–0.77)	0.66 (0.59–0.78)	0.98 (0.97–0.99)	0.98 (0.98–0.99)
2019	0.69 (0.54–0.72)	0.69 (0.60–0.80)	0.98 (0.97–0.99)	0.98 (0.89–0.99)
Vesper Sparrow				
Year	C-No	C-Post	C-No	C-Post
2013	0.31 (0.20–0.41)	0.29 (0.19–0.38)	0.95 (0.94–0.97)	0.96 (0.94–0.97)
2014	0.33 (0.24–0.44)	0.31 (0.22–0.38)	0.96 (0.95–0.97)	0.96 (0.95–0.97)
2015	0.45 (0.41–0.52)	0.44 (0.37–0.51)	0.97 (0.97–0.98)	0.97 (0.97–0.98)
2016	0.51 (0.39–0.58)	0.48 (0.36–0.60)	0.97 (0.97–0.98)	0.97 (0.96–0.98)
2017	0.45 (0.36–0.52)	0.44 (0.34–0.54)	0.97 (0.96–0.98)	0.97 (0.96–0.98)
2018	0.51 (0.48–0.62)	0.49 (0.45–0.60)	0.98 (0.97–0.98)	0.98 (0.97–0.98)
2019	0.46 (0.34–0.57)	0.44 (0.32–0.54)	0.97 (0.96–0.98)	0.97 (0.96–0.98)

Apparent nest success (i.e., the number of nests successful divided by the total number of nests found) varied by species, year, and grazing subcategory ranging from 0.00–1.00 (Appendix C). The lowest and highest apparent nest successes have minimal sample sizes, which influenced the reported extreme nest success rates. For all years combined, apparent nest success for the three focal species was similar amongst the subcategories within the Cumulative Effect Categorization and Partitioned Effect Categorization and had overlapping confidence intervals for each grazing category (i.e., C-No and C-Post for Cumulative Effect Categorization; P-No, P-During, and P-Post for Partitioned Effect Categorization).

Table 8. Estimated nest success rate and daily survival rate for Brewer's sparrow, thick-billed longspur, and vesper sparrow s using a time-to-event nest density estimator (TNDE) model for the Partitioned Effect Categorization 2013–2019 in Golden Valley and Musselshell Counties, Montana.

Overall Nest Success		Daily Survival Rate	
Brewer's Sparrow			
P-No	0.44 (0.42–0.39)	P-No	0.96 (0.96–0.96)
P-During	0.35 (0.33–0.38)	P-During	0.95 (0.95–0.96)
P-Post	0.48 (0.46–0.49)	P-Post	0.97 (0.96–0.97)
Thick-Billed Longspur			
P-No	0.55 (0.55–0.55)	P-No	0.97 (0.97–0.97)
P-During	0.55 (0.55–0.55)	P-During	0.97 (0.97–0.97)
P-Post	0.54 (0.54–0.54)	P-Post	0.97 (0.97–0.97)
Vesper Sparrow			
P-No	0.46 (0.43–0.52)	P-No	0.97 (0.97–0.98)
P-During	0.34 (0.19–0.40)	P-During	0.96 (0.94–0.97)
P-Post	0.46 (0.44–0.49)	P-Post	0.97 (0.97–0.98)

Nest success estimates from the time-to-event model generally showed little evidence for a difference between grazing subcategories and years (Tables 7 and 8, Figure 8). There was no difference in DSR or overall nest success for any species and year between C-No and C-Post subcategories (Table 7, Figure 8). Brewer's sparrow showed slightly lower survival in the P-During subcategorization and higher in P-Post (Table 8). Vesper sparrow had lower DSR and overall nest success estimates for P-During than the other grazing subcategorizations (Table 8). Thick-billed longspur showed no differences in estimated nest success between any grazing subcategorization (Table 8).

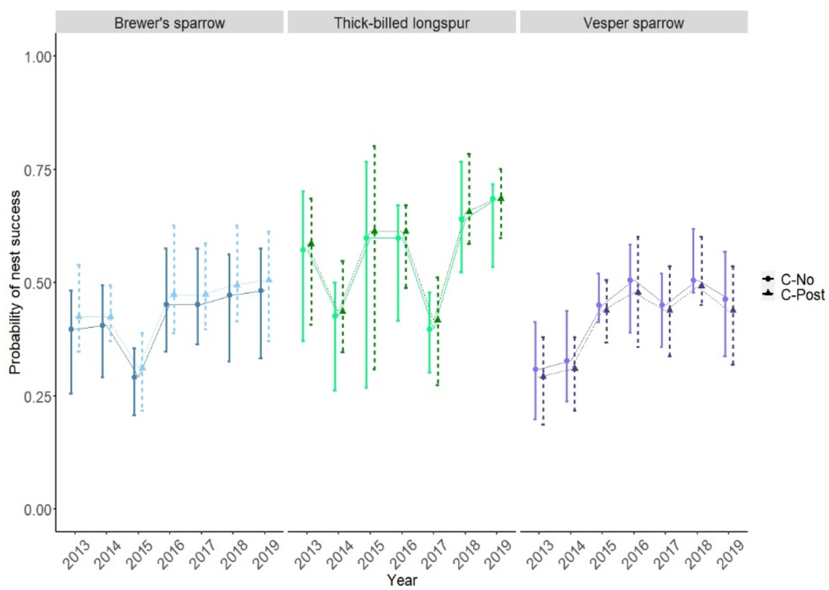

FIGURE 8. Estimated nest success for Brewer's sparrow, thick-billed longspur, and Vesper sparrow across years using a time-to-event nest density estimator (TNDE) model for the Cumulative Effect Categorization during 2013–2019 in Golden Valley and Musselshell Counties, Montana.

Discussion

The results for focal species estimated nest density and nest success show some evidence that SGI can positively influence thick-billed longspur reproduction and may affect the other species. Specifically, nest density shows some effect of SGI with increases for thick-billed longspur between C-No and C-Post and all three focal species in the P-During, P-Post, or both subcategories. DSR and nest success shows some differences in the P-During subcategory, but otherwise results vary. Year-to-year variation is an important factor of nest density (Figure 7) and nest success (Figure 8), supported by the lack of overlapping confidence intervals between many yearly estimates. Within our study area, most pastures enrolled in the SGI program at the beginning of the study, with few pastures enrolled in the later years of the study. Thus, our sample plots classified as P-During were early in the study, with very few sample plots in the later years. Therefore, it is important to consider that the strong effect of year and possibly habitat quality or sampling effort are conflated with some of the results from grazing subcategorization.

MANAGEMENT RECOMMENDATIONS

Our preliminary findings suggest that SGI grazing regimes had minimal effects on the overall sagebrush steppe avian community, including species richness, composition, diversity, and reproduction metrics. The SGI grazing regimes did not influence any community or reproduction metrics. The exception to this was the species-specific effects for thick-billed longspur, a grassland obligate species. Specifically, thick-billed longspur abundance and nest density appear to benefit from SGI grazing regimes compared to non-SGI grazing. Thus, we concur with previous studies that show grazing management has varying impacts on different songbird species (Pipher et al. 2016) and that a mosaic of numerous grazing regimes will maintain the songbird community best (Golding and Dreitz 2017, Ruth et al. in review).

We attribute the species-specific responses to SGI grazing to differences in preferred habitat and the variable influence of grazing on different vegetation types. Our study area is in the sagebrush steppe, so most of it contains some amount of sagebrush. Thus, most of the songbird species in our study area are sagebrush-associated or shrub-nester species (e.g., Brewer's sparrow, vesper sparrow) that would be expected to show responses primarily to changes in their sagebrush habitat. Grazing influences grass and forbs more strongly than shrubs in terms of plant structure and biomass in the short-term because the former are the preferred forage (Estell et al. 2012). Therefore, SGI grazing regimes may be more beneficial in areas with less shrub cover and more grasses.

Thus, it is logical that we would see the strongest response to SGI in a grassland obligate species such as the thick-billed longspur. The high density of shrubs in our study area are not typical characteristics of thick-billed longspur habitat (e.g., Greer and Anderson 1989, With 1994, Skagen et al. 2018). Despite that, our study area has a high density of thick-billed longspurs during the breeding season (Golding and Dreitz 2017) compared to other studies (e.g., Finzel 1964, Giezentanner and Ryder 1969, Wiens 1971, Porter and Ryder 1974, Martin and Forsyth 2003, Augustine and Derner 2015, Davis et al. 2020). Therefore, land managers interested in improving habitat for thick-billed longspurs or species with similar habitat requirements should consider the SGI grazing regimes.

This study is important in understanding the effects of grazing on sagebrush steppe songbirds, but it was observational and therefore is not conclusive. Our understanding of the SGI grazing regime changed throughout the course of the study as we gained more information. Thus, the definition of SGI is different from prior studies in our area (e.g., Golding and Dreitz 2017, Smith et al. 2018, Ruth et al. in review, Reintsma et al. in review), and our avian sample sizes, especially number of nests, are relatively small. This study used the finest scale of the SGI program available (i.e., pasture spatial scale and annual temporal scale), but that still may not be the scale at which songbirds respond to grazing during their annual breeding period. Alternatively, the vegetative response between SGI and non-SGI grazing regimes may be too insignificant to elicit a response from most songbird species. In addition, enrollment in the SGI grazing program decreased throughout the study, resulting in decreased sample sizes for the data when divided into subcategorizations, especially C-pre, C-During, P-pre, and P-During. The low sample sizes combined with yearly differences make it difficult to distinguish the effects of SGI from natural variation. Caveats to observational data like these are a normal aspect of studies that have the privilege of obtaining data on private lands while recognizing individual producer social and economic needs.

While our study did not find that SGI grazing affected sagebrush steppe songbirds, we believe that grazing can be used as a management tool. We explored only the overall influence of the SGI grazing program on avian data to look for a short-term cause and effect relationship. There are many other aspects of grazing with the potential to manipulate sagebrush steppe songbird habitat (e.g., timing, intensity, frequency). Further, grazing may take long periods of time to influence the landscape (Fuhlendorf and Smeins 1997). While our study was over 7 years, this may not be long enough for vegetation to response to SGI grazing regimes. Future studies should also investigate the relative influence of grazing compared to other biotic (e.g., vegetation structure and land classification) and abiotic (e.g., precipitation and temperature) factors known to influence wildlife habitat (Schieltz and Rubenstein 2016).

The participation of private landowners in conservation is one of the greatest successes of this project that will continue beyond this study. Lands in private ownership generally tend to be more productive than lands publicly managed (Scott et al. 2001), consequently, higher quality habitat for wildlife. Including private land in research is necessary for investigators to fully understand wildlife populations (Hilty and Merenlender 2003, Dreitz and Knopf 2007). Our study capitalized on what was already being done on the landscape including the infrastructure of SGI's grazing incentives, which initiative the collaborate with landowners for wildlife research and conservation. We became involved in the local community through dinners FWP organized with these landowners, opportunistically speaking with landowners in the field and participating in local community events, and through communicating our appreciation each year through thank you cards and a coffee table book at the end of data collection. The relationships we built with the private landowners provide a solid foundation for future research and conservation on private lands that will continue well into the future.

STATUS OF DELIVERABLES

Here we state the status of the deliverables to date as stated in the official proposal. Years 1–6 are defined as follows

- **Year 1: From the issuance of grant W-165-R-1 April 1, 2016–March 31, 2017.**
- **Year 2: April 1, 2017–March 31, 2018.**
- **Year 3: April 1, 2018–March 31, 2019.**
- **Year 4: April 1, 2019–March 31, 2020.**
- **Year 5: April 1, 2020–March 31, 2021.**
- **Year 6: April 1, 2021–December 1, 2021.**

1. Collect data on songbirds during the breeding season
    - **Year 1: Completed.**
    - **Year 2: Completed.**
    - **Year 3: Completed.**
    - **Year 4: Completed.**
    - **Year 5: Cancelled due to COVID-19 pandemic.**
    - **Year 6: No data collection planned.**

2. Provide annual progress report to FWP by March 1 each year
    - **Year 1: Completed.**
    - **Year 2: Completed.**
    - **Year 3: Completed.**
    - **Year 4: Completed.**
    - **Year 5: Completed by FWP.**
    - **Year 6: Completed with this report.**

3. Submit at least one manuscript to a peer-reviewed scientific journal for review and potential publication

    Completed- the following publications were sent to L. Berkeley:
    - **Reintsma, K.M., M.M. Delamont, L.I. Berkeley, and V.J. Dreitz. Thick-billed longspur reproduction shows minimal response to conservation program grazing regimes. Submitted to *Wilson Ornithological Society*, June 2021.**
    - **Ruth, K.A., L.I. Berkeley, K.M. Strickfaden, and V.J. Dreitz. Livestock grazing and density-dependent demographic relationships in sagebrush steppe songbirds. Submitted to *Conservation Science and Practice*, May 2021.**
    - **Golding, J.D., J.J. Nowak, and V.J. Dreitz. 2017. A multispecies dependent double-observer model: A new method for estimating multispecies abundance. *Ecology and Evolution* 7:3425–3435.**
    - **Golding, J.D. and V.J. Dreitz. 2017. Songbird response to rest-rotation and season-long cattle grazing in a grassland sagebrush ecosystem. *Journal of Environmental Management* 204: 605-612.**

4. Present research findings for the duration of the project (2013 to present) to at least one professional conference
    - **Year 1: Completed.**
        - **Presentation by MS student at Montana Chapter of the Wildlife Society meeting in Helena, Montana, March 8-10, 2017.**
    - **Year 2: Completed.**
        - **Presentation by MS student at Montana Chapter of the Wildlife Society meeting in Butte, Montana, February 21-23, 2018.**
    - **Year 3: Completed.**
        - **Presentation by MS and PhD student at Montana Chapter of the Wildlife Society meeting in Helena, Montana, February 27- March 1, 2019**.
    - **Year 4: Completed.**
        - **Presentation by PhD student at American Ornithological Society annual meeting in Anchorage, Alaska, June 24-June 28, 2019**.
        - **Presentation by Project PI Dreitz at American Ornithological Society annual meeting in Anchorage, Alaska, June 24-June 28, 2019**.
    - **Year 5:**
        - **Did not present due to COVID-19 pandemic complications.**
    - **Year 6: Completed.**
        - **Webinar presentation of preliminary songbird nesting results by PhD student to Sage-Grouse Oversight committee on April 16, 2021**.
        - **Webinar presentation about availability of grazing data by PhD student to Sage-Grouse Oversight committee on June 16, 2021.**

5. Meet with local FWP and NRCS regional managers and biologists to discuss research project
    - **Year 1**: **Completed during field season.**
    - **Year 2: Completed during field season and sent summary of the 2017 field season in August.**
    - **Year 3: Completed during field season and sent summary of the 2018 field season in August.**
    - **Year 4: Completed during field season.**
    - **Year 5: Met weekly to bi-weekly with FWP personnel to finalize grazing database and keep abreast of research progress.**
    - **Year 6: Completed during bi-weekly meetings with FWP personnel and webinars on April 16, 2021, and June 16, 2021.**

6. Participate in landowner outreach to provide information to landowners on our research objectives and results
    - **Year 1: Provided L Berkeley with information for landowner mailings on project status and participated at landowner dinner in Nov 2016.**
    - **Year 2: Provided thank you letters to private landowners allowing land access.**

Letters included specific information on their individual properties and summary of overall field season data. L. Berkeley received copies of individual landowner letters.
- **Year 3: Provided thank you letters to private landowners allowing land access.**
- **Year 4: Provided thank you letters to private landowners allowing land access.**
    - **Awarded small grant from MT TWS in February of 2020 to produce a coffee table book that will be completed in time to distribute to landowners at the end of the field season.**
- **Year 5: Developed and completed a 'coffee table' book to thank landowners and collaborators for their support of the project.**
- **Year 6: No activity planned.**

7. Conduct presentations of research results to private landowners, wildlife, and land management agencies as requested
    - **Year 1: Presented at Annual Oversight Meeting in February 2017. Talked briefly with landowners in the field opportunistically. Sent letters to individual landowners.**
    - **Year 2: MS student and PhD student presented at Annual Oversight Meeting in February 2018. Talked briefly with landowners in the field opportunistically. Sent letters to individual landowners.**
    - **Year 3: MS student and PhD student presented at Annual Oversight Meeting in January 2019. Talked briefly with landowners in the field opportunistically. Sent letters to individual landowners.**
    - **Year 4: Project PI: Dreitz and PhD student presented at Annual Oversight Meeting in February 2020. Talked briefly with landowners in the field opportunistically. Sent letters to individual landowners.**
    - **Year 5: Did not present due to COVID-19 pandemic complications. Sent a 'coffee table' book to thank landowners and collaborators for their support of the project.**
    - **Year 6: PhD student presented webinar to Sage-Grouse Oversight Committee on April 16, 2021.**

8. Provide a research opportunity for graduate students.
    - **Masters Student: Individual officially enrolled at the University of Montana in August 2016 (year 1). Student participated in 2016, 2017, and 2018 field seasons, year 1, 2, and 3 respectively. Student completed degree May 2019.**
    - **PhD Student: Selected PhD candidate in spring 2017 (year 2). Individual officially enrolled at the University of Montana in August 2017 and is on track to achieve their graduate degree in spring 2022.**

LITERATURE CITED

Augustine, D.J., and J.D. Derner. 2015. Patch-burn grazing management, vegetation heterogeneity, and avian responses in a semi-arid grassland. Journal of Wildlife Management 79(6):927–36.

Beck, J.L., and D.L. Mitchell. 2000. Influences of livestock grazing on sage grouse habitat. Wildlife Society Bulletin 28:993–1002.

Bock, C.E., and B. Webb. 1984. Birds as grazing indicator species in southeastern Arizona. Journal of Wildlife Management 48:1045–1049.

Bradford, D.F., S.E. Franson, A.C. Neale, D.T Heggem, G.R. Miller, and G.E. Canterbury. 1998. Bird species assemblages as indicators of biological integrity in Great Basin rangeland. Environmental Monitoring and Assessment 49:1–22.

Braun, C.E., M.F. Baker, R.L. Eng, J.S. Gashwiler, and M.H. Schroeder. 1976. Conservation committee report on effects of alteration of sagebrush communities on the associated avifauna. Wilson Bulletin 88:165–171.

Briske, D.D., J.D. Derner, J.R. Brown, S.D. Fulhendorg, W.R. Teague, R.L. Gillen, A.J. Ash, and W.D. Willms. 2008. Rotational grazing on rangelands: reconciliation of perception and experimental evidence. Rangeland Ecology & Management 61:3–17

Caro, T. 2010. Conservation by proxy, Island Press, Washington D.C. USA.

Coppedge, B.R., S.D. Fuhlendorf, W.C. Harrell, and D.M. Engle. 2008. Avian community response to vegetation and structural features in grasslands managed with fire and grazing. Biological Conservation 141(5):1196–1203.

Crawford, J.A., R.A. Olson, N.E. West, J.C. Mosley, M.A. Schroeder, T.D. Whitson, R.F. Miller, M.A. Gregg, and C.S. Boyd. 2004. Ecology and management of sage-grouse and sage-grouse habitat. Journal of Range Management 57:2–19.

Davis, K.P., D.J. Augustine, A.P. Monroe, J.D. Derner, and C.L. Aldridge. 2020. Adaptive rangeland management benefits grassland birds utilizing opposing vegetation structure in the shortgrass steppe. Ecological Applications 30(1).

Dobkin, D.S., A.C. Rich, and W.H. Pyle. 2008. Habitat and avifaunal recovery from livestock grazing in a riparian meadow system of the northwestern Great Basin. Conservation Biology 12(1):209–221. doi:10.1111/j.1523-1739.1998.96349.x.

Dreitz, V.J., and F.L. Knopf. 2007. Mountain plovers and the politics of research on private lands. BioScience 57(8):681–687. doi:10.1641/B570808.

Estell, R.E., K.M. Havstad, A.F. Cibils, E.L. Fredrickosn, D.M. Anderson, T.S. Schrader, and D.K. James. 2012. Increasing shrub use by livestock in a world with less grass. Rangeland Ecology & Management 65(6):553–562.

Finzel, J.E. 1964. Avian populations of four herbaceous communities in southeastern Wyoming.

The Condor 66(6):496–510.

Fuhlendorf S.D., and F.E. Smeins. 1997. Long-term vegetation dynamics mediated by herbivores, weather, and fire in a juniperus-quercus savanna. Journal of Vegetation Science. 8(6):819–28.

Garton, E.O., J. W. Connelly, J.S. Horne, C.A. Hagen, A. Moser, and M.A. Schroeder. 2011. Greater sage-grouse population dynamics and probability of persistence. Studies in Avian Biology 38:293–381.

Giezentanner, J.B., and R.A. Ryder. 1969. Avian distribution and population fluctuations at the Pawnee site. U.S. International Biological Program, Grassland Biome Technical Report 28.

Golding, J.D., and V.J. Dreitz. 2016. Comparison of removal-based methods for estimating abundance of five species of prairie songbirds. Journal of Field Ornithology 87:417–426.

Golding, J.D. and V.J. Dreitz. 2017. Songbird response to rest-rotation and season-long cattle grazing in a grassland sagebrush ecosystem. Journal of Environmental Management 204: 605–612.

Golding, J.D., J.J. Nowak, and V.J. Dreitz. 2017. A multispecies dependent double-observer model: A new method for estimating multispecies abundance. Ecology and Evolution 7:3425–3435. Doi 10: 10. 1002/ece32946.

Greer, R.D., and S.H. Anderson. 1989. Relationships between population demography of McCown's longspurs and habitat resources. The Condor 91(3):609.

Harrison, M.L., N.A. Mahony, P. Robinson, A. Newbury, and D.J. Green. 2010. Vesper sparrows and western meadowlarks show a mixed response to cattle grazing in the intermountain region of British Columbia. Avian Conservation and Ecology 5(1):1.

Hart, M., P. Bush, and C. Malouin. 2012. Indicator guilds representing forest composition and configuration in the Great Lakes – St. Lawrence Forest region – a nationally replicable selection method. Ecological Indicators 23:374–383.

Hilty, J. and A. Merenlender. 2003. Studying biodiversity on private lands. Conservation Biology 17:132–137.

Holechek, J.L., R.D. Pieper, and C.H. Herbel. 1998. Range management: principles and practices. 3rd ed. Prentice Hall, Upper Saddle River, New Jersey, USA.

Hormay, A.L. 1970. Principles of rest-rotation grazing and multiple-use land management. USDA, Forest Service Training Text. Vol. 4. No. 2200.

Jones, A. 2000. Effects of cattle grazing on North American arid ecosystems: a quantitative review. Western North American Naturalist 60(2):155–164.

Knick, S.T. 1999. Requiem for a sagebrush ecosystem? Norwest Science Forum 73:53–57.

Knick, S.T., D.S. Dobkin, J.T. Rotenberry, M.A. Schroeder, W.M. Vander Haegen, and C. Van Ripper III. 2003. Teetering on the edge or too late? Conservation and research issues for avifauna of sagebrush habitats. The Condor 105:611–634.

Knick, S.T., S.E. Hanser, R.F. Miller, D.A. Pyke, M.J. Wisdom, S.P. Finn, E.T. Rinkes, and C.J. Henny. 2010. Ecological influence and pathways of land use in sagebrush. Studies in Avian Biology 38:203–251.

Krausman, P.R., D.E. Naugle, M.R. Frisina, R. Northrup, V.C. Bleich, W.M. Block, M.C. Wallace, and J.D. Wright. 2009. Livestock grazing, wildlife habitat, and rangeland values. Rangelands 31(5):15–19.

Lapointe, S., L. Belanger, J.F. Giroux, and B. Filion. 2003. Effects of plant cover improvements for ducks on grassland songbirds. Canadian Field Naturalist 117:167–172.

Lemoine, N., H.G. Bauer, M. Peintinger, and K. Böhning-Gaese. 2007. Effects of climate and land-use change on species abundance in a central European bird community. Conservation Biology 21(2):495–503.

Lipsey, M.K., and D.E. Naugle. 2017. Precipitation and soil productivity explain effects of grazing on grassland songbirds. Rangeland Ecology and Management 70(3):331–340.

Martin, P.A., and D.J. Forsyth. 2003. Occurrence and productivity of songbirds in prairie farmland under conventional versus minimum tillage regimes. Ecosystems and Environment 96:107–17.

Montana's State Wildlife Action Plan [MTSWAP]. 2015. Montana Fish, Wildlife and Parks, Helena, MT.

Murphy, G.E., and T.N. Romanuk. 2012. A meta-analysis of community response predictability to anthropogenic disturbances. The American Naturalist 180(3):316–327.

Nelson, K.S., E.M. Gray, and J.R. Evans. 2011. Finding solutions for bird restoration and livestock management: comparing grazing exclusion levels. Ecological Applications 21:547–554.

Nichols, J.D., J.E. Hines, J.R. Sauer, F.W. Fallon, J.E. Fallon, and P.J. Heglund. 2000. A double-observer approach for estimating detection probability and abundance from point counts. Auk 117:393–408.

Paige, C., and S. A. Ritter. 1999. Birds in a sagebrush sea: managing sagebrush habitats for bird communities. Partners in Flight Western Working Group, Boise, ID.

Péron, G., J. Walker, J. Rotella, J.E. Hines, and J.D. Nichols. 2014. Estimating nest abundance while accounting for time-to-event processes and imperfect detection. Ecology 95(9):2548–57.

Pipher, E.N., C.M. Curry, and N. Koper. 2016. Cattle grazing intensity and duration have varied effects on songbird nest survival in mixed-grass prairies. Rangeland Ecology & Management 69(6):437–443.

Porter, D.K., and R.A. Ryder. 1974. Avian density and productivity studies and analysis on the Pawnee site in 1972. Fort Collins, CO.

Reintsma, K.M., A.H. Harrington, and V.J. Dreitz. 2019. Validation of a novel time-to-event nest density estimator on passerines: an example using Brewer's sparrows (*Spizella breweri*). PLoS ONE 14(12):1–7.

Reintsma, K.M., M.M. Delamont, L.I. Berkeley, and V.J. Dreitz. In review. Thick-billed longspur (Rhynchophanes mccownii) reproduction shows minimal short-term response to conservation-based program. Wilson Journal of Ornithology.

Rich, T.D, C.J. Beardmore, H. Berlanga, P.J. Blancher, M.S.W. Bradstreet, G.S. Butcher, D.W. Demarest, E.H. Dunn, W.C. Hunter, E.E. Inigo-Elias, J.A. Kennedy, A.M. Martell, A.O. Panjabi, D.N. Pashley, K.V. Rosenberg, C.M. Rustay, J.S. Wendt, and T.C. Will. 2004. Partners in Flight North American Landbird Conservation Plan. Cornell Lab of Ornithology. Ithaca, NY.

Ruehmann, M.B., M.J. Desmond, and W.R. Gould. 2011. Effects of smooth brome on Brewer's sparrow nest survival in sagebrush steppe. The Condor 113:419–428.

Ruth, K.A., L.I. Berkeley, K.M. Strickfaden, and V.J. Dreitz. In review. Livestock grazing and density-dependent demographic relationships in sagebrush steppe songbirds Conservation Science and Practice.

Saab, V.A., and T.D. Rich. 1997. Large-scale conservation assessment for neotropical migratory land birds in the interior Columbia River Basin. USDA Forest Service General Technical Report PNW-GTR-399. doi:10.2737/pnw-gtr-399.

Schieltz, J.M., and D.I. Rubenstein. 2016. Evidence based review: positive versus negative effects of livestock grazing on wildlife. What Do We Really Know? Environmental Research Letters 11(11).

Scott, J.M., F.W. Davis, R.G. McGhie, RG Wright, C. Groves, and J. Estes. 2001. Nature reserves: Do they capture the full range of America's biological diversity? Ecological Applications 11:999–1007.

Shannon, C., and W. Weaver. 1949. The mathematical theory of communication. Urbana: University of Illinois Press, 96.

Skagen, S.K., D.J. Augustine, J.D. Derner. 2018. Semi-arid grassland bird responses to patch-burn grazing and drought. Journal of Wildlife Management 82(2):445–56.

Smith, J.T., J.D. Tack, L.I. Berkeley, M. Szczypinski, and D.E. Naugle. 2018. Effects of rotational grazing management on nesting greater sage-grouse. The Journal of Wildlife Management 82:103–112.

Tipton, H.C., V.J. Dreitz, and P.F. Doherty Jr. 2008. Occupancy of mountain plover and burrowing owl in Colorado. The Journal of Wildlife Management 72: 1001–1006.

Tipton, H.C., P.F. Doherty Jr., and V.J. Dreitz. 2009. Abundance and density of mountain plover (*Charadruis montanu*s) and burrowing owl (*Athene cunicularia*) in eastern Colorado. The Auk 126:493–499.

Wiens, J.A. 1971. Avian ecology and distribution in the comprehensive network, 1970. Corvallis, OR: Grassland Biome, U.S. International Biological Program.

With, K.A. 1994. The hazards of nesting near shrubs for a grassland bird, the McCown's longspur. The Condor 96(4):1009–19.

Zuckerberg, B., A.M. Woods, and W.F. Porter. 2009. Poleward shifts in breeding bird distributions in New York State. Global Change Biology 15(8):1866–1883.

APPENDICES

Appendix A. Total number of individuals per songbird species for all species detected on avian count transect surveys during 2013–2019 in Golden Valley and Musselshell Counties, Montana.

Common Name	Scientific Name	2013	2014	2015	2016	2017	2018	2019
Totals		**15,715**	**13,710**	**6,013**	**10,230**	**10,689**	**8,832**	**8,665**
American avocet	Recurvirostra americana	28	31	5	1	29	44	61
American Bittern	Botaurus lentiginosus	0	0	0	0	0	1	0
American Coot	Fulica americana	0	13	0	0	0	39	9
American crow	Corvus brachyrhynchos	34	1	0	9	2	0	1
American goldfinch	Spinus tristis	2	3	0	0	1	0	5
American kestrel	Falco sparvarius	55	12	3	8	20	18	6
American pipit	Anthus rubescens	20	0	1	0	0	0	0
American robin	Turdus migratorius	20	26	9	18	23	14	44
American wigeon	Anas americana	20	9	6	0	7	19	24
American white pelican	Pelecanus erythrorhynchos	6	0	0	0	0	0	1
Bank Swallow	Riparia	0	0	1	9	8	41	6
Baltimore Oriole	Icterus galbula	0	0	0	0	1	0	0
barn swallow	Hirundo rustica	17	20	6	19	10	14	17
Baird's sparrow	Ammodramus bairdii	10	4	1	2	2	9	38
black-billed magpie	Pica hudsonia	32	20	2	14	14	8	9
black-capped chickadee	Poecile atricapillus	6	3	1	7	10	0	0
brown-headed cowbird	Molothrus ater	387	323	197	341	287	217	214
black-necked stilt	Himantopus mexicanus	1	0	0	0	0	0	0
Bobolink	Dolichonyx oryzivorus	0	0	0	0	2	2	0
Brewer's blackbird	Euphagus cyanocephalus	206	82	29	161	185	92	247
Brewer's sparrow	Spizella breweri	1,967	2,017	1,217	1,171	1,729	1,219	1,338
brown thrasher	Toxostoma rufum	0	1	0	0	0	0	0
bufflehead duck	Bucephala albeola	0	0	0	0	0	0	2
Bullock's Oriole	Icterus bullockii	0	1	0	0	0	4	1
burrowing owl	Athene cunicularia	0	1	0	5	0	1	0
blue-winged teal	Anas discors	18	3	13	6	5	38	23
Canada goose	Branta canadensis	169	46	121	137	8	2	4
California gull	Larus californicus	19	0	3	6	0	0	8

Common Name	Scientific Name	2013	2014	2015	2016	2017	2018	2019
Cassin's kingbird	Tyrannus vociferans	4	0	0	1	1	0	0
Canvasback	Aythya valisineria	0	0	0	0	2	4	3
chestnut-collared longspur	Calcarius ornatus	567	405	226	327	636	362	355
clay-colored sparrow	Spizella pallida	2	6	5	46	114	38	18
cedar waxwing	Bombycilla cedrorum	10	0	0	0	0	0	0
chipping sparrow	Spizella passerina	15	1	3	31	5	19	14
cinnamon teal	Anas cyanoptera	8	4	1	4	0	15	5
Clark's nutcracker	Nucifraga columbiana	3	0	0	0	0	0	0
cliff swallow	Petrochelidon pyrrhonota	493	222	2	566	107	132	226
common grackle	Quiscalus quiscula	1	0	1	1	0	3	0
common nighthawk	Chordeiles minor	5	19	2	5	10	12	4
common raven	Corvus corax	32	25	16	28	30	14	13
Common Yellowthroat	Geothlypis trichas	0	0	0	1	0	0	0
double-crested cormorant	Phalacrocorax auritus	4	24	5	0	4	2	5
Eared Grebe	Podiceps nigricollis	0	0	1	0	0	81	74
eastern kingbird	Tyrannus tyrannus	10	4	1	7	2	5	4
European starling	Sturnus vulgaris	63	1	10	42	22	61	27
ferruginous hawk	Buteo regalis	2	0	3	1	3	1	3
Field Sparrow	Spizella pusilla	0	0	0	2	0	31	1
Franklin's gull	Leucophaeus pipixcan	13	0	0	3	0	0	2
gadwall	Anas strepera	15	20	7	18	32	14	22
great blue heron	Ardea herodias	3	2	0	3	3	1	4
golden eagle	Aquila chrysaetos	3	0	2	2	5	2	6
gray partridge	Perdix perdix	2	15	0	0	0	0	0
Gray Catbird	Dumetella carolinensis	0	0	0	0	1	0	0
Greater Scaup	Aythya marila	0	0	0	0	0	0	7
greater sage-grouse	Centrocercus urophasianus	5	0	9	25	1	2	8
grasshopper sparrow	Ammodramus savannarum	92	71	58	18	83	61	176
green-winged teal	Anas Crecca	0	3	3	2	4	2	3

Common Name	Scientific Name	2013	2014	2015	2016	2017	2018	2019
herring gull	Larus argentatus	1	0	0	0	4	0	0
horned lark	Eremophila alpestris	1,919	1,936	811	965	1,048	885	694
Hooded Merganser	Lophodytes cucullatus	0	0	0	0	1	1	0
house wren	Troglodytes aedon	1	0	0	0	1	0	0
killdeer	Charadrius vociferus	38	57	28	46	61	55	47
Lazuli Bunting	Passerina amoena	0	0	0	1	0	26	0
lark bunting	Calamospiza melanocorys	475	586	64	267	606	474	565
lark sparrow	Chondestes grammacus	106	89	36	46	57	50	36
long-billed curlew	Numenius americanus	124	115	49	66	69	67	79
Least flycatcher	Empidonax minimus	0	0	0	0	1	0	0
Least Sandpiper	Calidris minutilla	0	0	0	2	0	0	0
loggerhead shrike	Lanius ludovicianus	29	20	13	7	20	13	18
marbled godwit	Limosa fedoa	12	7	2	4	8	11	3
mallard	Anas platyrhynchos	34	16	25	27	25	48	21
Thick-billed longspur	Rhynchophanes mccownii	3,990	3,545	1,075	2,391	2,064	1,615	915
merlin	Falco columbarius	0	2	1	0	2	1	0
mountain bluebird	Sialia currucoides	31	7	5	19	15	22	43
mourning dove	Zenaida macroura	206	279	95	169	170	151	143
mountain plover	Charadrius montanus	6	3	3	6	3	3	0
northern flicker	Colaptes auratus	39	11	4	6	19	5	3
northern harrier	Circus cyaneus	35	9	3	13	30	30	27
Northern Mockingbird	Mimus polyglottos	0	0	0	0	0	0	1
northern pintail	Anas acuta	4	0	2	11	12	34	16
Northern Shrike	Lanius excubitor	0	0	0	0	0	4	23
Northern Rough-winged Swallow	Stelgidopteryx serripennis	0	0	0	0	0	3	0
northern shoveler	Anas clypeata	4	4	5	1	10	63	21
Olive-side flycatcher	Contopus cooperi	0	0	0	1	0	0	0
Pied-billed Grebe	Podilymbus podiceps	0	0	0	0	0	0	4
peregrine falcon	Falco peregrinus	1	0	0	0	0	0	0

Common Name	Scientific Name	2013	2014	2015	2016	2017	2018	2019
pinyon jay	Gymnorhinus cyanocephalus	45	0	0	0	0	0	1
prairie falcon	Falco mexicanus	2	2	3	4	0	0	1
ring-billed gull	Larus delawarensis	3	8	1	0	0	0	8
Red-breasted Merganser	Mergus serrator	0	0	0	0	0	1	0
Redhead	Aythya americana	0	0	1	0	0	0	0
Red Crossbill	Loxia curvirostra	0	0	0	0	0	1	2
Redhead	Aythya americana	0	0	0	0	0	23	9
rough-legged hawk	Buteo lagopus	2	0	0	1	0	0	0
red-necked phalarope	Phalaropus lobatus	1	0	0	0	25	0	49
rock pigeon	Columba livia	10	3	0	7	12	2	0
rock wren	Salpinctes obsoletus	7	9	6	0	8	4	3
red-tailed hawk	Buteo jamaicensis	14	4	2	3	4	6	3
Ruddy Duck	Oxyura jamaicensis	0	0	0	0	1	0	0
red-winged blackbird	Agelaius phoeniceus	142	105	47	78	91	92	109
sandhill crane	Grus canadensis	0	4	0	0	0	0	2
Say's pheobe	Sayornis saya	30	10	5	7	10	6	9
sage thrasher	Oreoscoptes montanus	24	8	1	8	27	18	19
savannah sparrow	Passerculus sandwichensis	17	21	26	32	14	17	49
short-eared owl	Asio flammeus	0	2	2	0	0	5	43
semipalmated plover	Charadrius semipalmatus	22	0	0	0	0	0	0
Sora	Porzana carolina	0	0	1	0	0	0	0
solitary sandpiper	Tringa solitaria	1	0	0	0	5	1	0
Song Sparrow	Melospiza melodia	0	0	0	1	0	0	1
Sprauge's pipit	Anthus spragueii	6	8	4	1	12	7	6
Spotted Sandpiper	Actitis macularius	0	0	0	4	0	0	0
sharp-shinned hawk	Tringa solitaria	1	0	0	0	0	0	0
sharp-tailed grouse	Tympanuchus phasianellus	1	0	1	2	0	0	0
Swainson's hawk	Buteo swainsoni	2	0	0	1	1	0	2
Townsend's solitaire	Myadestes townsendi	1	0	0	0	1	0	0

Common Name	Scientific Name	2013	2014	2015	2016	2017	2018	2019
tree swallow	Tachycineta bicolor	17	18	4	4	5	0	2
tundra swan	Cygnus columbianus	2	0	0	0	0	0	0
turkey vulture	Cathartes aura	12	0	1	1	2	3	1
upland sandpiper	Bartramia longicauda	35	28	10	9	21	20	31
vesper sparrow	Pooecetes gramineus	2,329	2,072	1,037	1,907	1,826	1,298	1,247
violet green swallow	Tachycineta thalassina	5	2	0	2	6	1	0
white-crowned sparrow	Zonotrichia leucophrys	3	1	0	7	1	6	4
western kingbird	Tyrannus verticalis	2	3	1	3	0	3	2
western meadowlark	Sturnella neglecta	1,409	1,248	643	1,037	950	992	1,293
western wood-pewee	Contopus sordidulus	0	2	0	2	1	2	0
white-faced Ibis	Plegadis chihi	0	3	0	0	0	3	0
willet	Tringa semipalmata	21	6	3	3	16	15	6
Wilson's phalarope	Steganopus tricolor	119	14	23	7	11	87	60
Wilson's snipe	Gallinago delicata	0	3	0	0	0	9	5
Wilson's Warbler	Wilsonia pusilla	0	0	0	1	0	0	0
Yellow Warbler	Denroica petechia	0	0	0	1	0	0	0
yellow-headed blackbird	Xanthocephalus xanthocephalus	3	2	0	1	2	5	0
yellow-rumped warbler	Setophaga coronata	3	0	0	1	1	0	0

Appendix B. Estimates of abundance per 25 ha sample plot for the top five most abundant songbird species observed during avian count transect surveys during 2013–2019 in Golden Valley and Musselshell Counties, Montana for the Cumulative Effect Categorization. Estimates are derived from the multispecies dependent double-observer abundance model. Values in parentheses represent the 95% Bayesian credible intervals.

Year	Subcategory	Brewer's sparrow		Horned lark		Thick-billed longspur		Vesper sparrow		Western meadowlark	
2013	C-No	17.52	(14.34–21.91)	10.82	(9.45–13.54)	16.98	(15.54–19.86)	18.34	(15.32–22.68)	11.18	(9.54–13.95)
	C-Post	17.69	(14.19–22.28)	14.06	(12.41–17.00)	33.11	(30.33–37.17)	16.42	(13.55–20.44)	7.08	(6.25–9.41)
2014	C-No	12.55	(11.29–15.02)	13.98	(12.98–16.31)	16.75	(16.02–18.91)	16.86	(14.45–20.36)	13.34	(11.45–16.38)
	C-Post	15.06	(13.86–17.88)	13.31	(12.17–15.94)	32.50	(30.50–35.67)	17.17	(14.91–20.61)	7.14	(5.94–9.67)
2015	C-No	10.61	(8.93–13.70)	6.55	(5.68–9.11)	7.50	(6.11–10.50)	11.36	(9.32–14.84)	8.05	(6.36–11.07)
	C-Post	12.72	(11.08–16.06)	9.33	(8.03–12.03)	14.39	(11.61–18.75)	10.44	(8.33–14.00)	5.78	(4.83–8.36)
2016	C-No	10.10	(8.07–13.50)	7.39	(6.20–10.09)	10.50	(9.95–12.55)	14.00	(12.45–16.81)	9.45	(7.81–12.27)
	C-Post	11.08	(8.97–14.67)	8.67	(7.22–11.52)	22.22	(20.50–25.42)	13.47	(11.92–16.27)	7.14	(6.22–9.50)
2017	C-No	11.80	(10.73–14.20)	6.16	(5.75–7.93)	8.05	(7.79–9.34)	13.41	(12.14–15.86)	7.09	(6.23–9.16)
	C-Post	12.25	(10.99–14.97)	7.83	(7.22–9.83)	16.86	(16.36–18.69)	10.86	(9.78–13.25)	6.00	(5.23–7.81)
2018	C-No	9.53	(8.06–12.27)	5.57	(5.14–7.29)	6.91	(6.70–8.34)	10.39	(8.68–12.34)	7.20	(6.45–9.36)
	C-Post	9.86	(8.05–12.89)	7.19	(6.47–9.19)	14.31	(13.22–16.44)	9.36	(7.75–12.03)	5.50	(5.11–7.33)
2019	C-No	9.14	(8.50–11.23)	6.20	(5.55–8.41)	6.50	(6.06–8.16)	10.00	(8.91–12.50)	10.14	(9.55–12.20)
	C-Post	10.94	(10.94–17.86)	7.44	(5.36–11.00)	11.36	(8.31–15.86)	11.47	(8.69–15.64)	8.36	(6.67–11.56)

Appendix C. The number of nests found by year, species, and grazing subcategory during nest search efforts during 2013–2019 in Golden Valley and Musselshell Counties, Montana. The apparent nest success (number of successful nests / total number of nests) and associated 95% confidence intervals are also reported.

Year	Subcategory	Brewer's sparrow			Thick-billed longspur			Vesper sparrow		
		N	Success	Density	N	Success	Density	N	Success	Density
2013	C-No / P-No	12	0.67 (0.36–0.89)	1.26	10	0.20 (0.04–0.56)	1.05	18	0.72 (0.46–0.89)	1.89
	C-Post	16	0.63 (0.36–0.84)	1.73	21	0.48 (0.27–0.71)	2.27	29	0.48 (0.31–0.67)	1.75
	P-During	16	0.63 (0.36–0.84)	1.78	20	0.5 (0.30–0.70)	2.22	29	0.48 (0.30–0.67)	3.22
	P-Post	0	0.00	0.00	1	0 (0–0.95)	4.00	0	0.00	0.00
	Total	28	0.64 (0.44–0.80)	1.40	31	0.39 (0.23–0.58)	1.55	47	0.57 (0.42–0.71)	2.35
2014	C-No / P-No	22	0.59 (0.37–0.78)	3.32	11	0.55 (0.25–0.82)	1.16	27	0.63 (0.42–0.81)	1.84
	C-Post	32	0.72 (0.53–0.86)	3.12	37	0.59 (0.43–0.75)	3.61	24	0.63 (0.41–0.81)	2.34
	P-During	32	0.72 (0.53–0.86)	4.74	14	0.43 (0.19–0.70)	2.07	21	0.67 (0.43–0.85)	3.11
	P-Post	0	0.00	0.00	23	0.7 (0.47–0.86)	6.57	3	0.33 (0.02–0.87)	0.86
	Total	54	0.66 (0.52–0.78)	2.70	48	0.58 (0.43–0.72)	2.40	51	0.64 (0.49–0.77)	2.55
2015	C-No / P-No	57	0.54 (0.40–0.67)	6.00	6	0.50 (0.19–0.81)	0.63	27	0.52 (0.32–0.71)	2.84
	C-Post	85	0.67 (0.54–0.75)	8.09	17	0.29 (0.11–0.56)	1.61	53	0.45 (0.32–0.59)	5.05
	P-During	7	0.86 (0.42–0.99)	4.67	0	0.00	0.00	4	0.75 (0.22–0.99)	2.67
	P-Post	78	0.65 (0.53–0.75)	8.67	17	0.29 (0.11–0.55)	1.89	49	0.43 (0.29–0.58)	5.40
	Total	142	0.63 (0.54–0.71)	7.10	23	0.35 (0.17–0.57)	1.15	80	0.49 (0.38–0.60)	4.00
2016	C-No / P-No	25	0.48 (0.28–0.68)	2.63	12	0.50 (0.25–0.75)	1.26	30	0.46 (0.29–0.67)	3.15
	C-Post	23	0.57 (0.35–0.77)	2.19	29	0.35 (0.19–0.55)	2.76	41	0.42 (0.27–0.58)	4.32
	P-During	1	0 (0–0.95)	0.80	0	0.00	0.00	4	0 (0–0.60)	3.20
	P-Post	22	0.59 (0.37–0.78)	2.38	29	0.34 (0.18–0.54)	3.13	37	0.46 (0.30–0.63)	4.00
	Total	48	0.52 (0.37–0.66)	2.40	41	0.39 (0.25–0.55)	2.05	71	0.44 (0.32–0.56)	3.55
2017	C-No / P-No	37	0.62 (0.45–0.76)	3.52	17	0.41 (0.19–0.66)	1.61	45	0.40 (0.26–0.56)	4.28
	C-Post	42	0.36 (0.22–0.52)	4.42	37	0.67 (0.51–0.82)	3.89	42	0.57 (0.41–0.72)	4.42
	P-During	0	0.00	0.00	0	0.00	0.00	2	1.00 (0.19–1.00)	8.00
	P-Post	42	0.36 (0.22–0.52)	4.45	37	0.68 (0.51–0.82)	4.00	40	0.55 (0.39–0.70)	4.32
	Total	79	0.48 (0.37–0.59)	3.95	54	0.59 (0.45–0.72)	2.70	87	0.47 (0.37–0.59)	4.35

Year	Subcategory	Brewer's sparrow			Thick-billed longspur			Vesper sparrow		
		N	Success	Density	N	Success	Density	N	Success	Density
2018	C-No / P-No	18	0.44 (0.22–0.68)	1.71	11	0.26 (0.11–0.61)	1.05	26	0.35 (0.20–0.56)	2.47
	C-Post	24	0.46 (0.26–0.67)	2.52	24	0.25 (0.11–0.47)	2.52	37	0.49 (0.33–0.65)	3.89
	P-During	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
	P-Post	24	0.46 (0.26–0.67)	2.52	24	0.25 (0.11–0.47)	2.52	37	0.49 (0.33–0.65)	3.89
	Total	42	0.45 (0.31–0.62)	2.10	35	0.29 (0.16–0.47)	1.75	63	0.41 (0.29–0.54)	3.15
2019	C-No / P-No	23	0.52 (0.31–0.72)	2.30	7	0.57 (0.20–0.88)	0.70	24	0.67 (0.45–0.84)	2.40
	C-Post	45	0.49 (0.34–0.64)	4.50	15	0.33 (0.13–0.61)	1.50	34	0.44 (0.28–0.61)	3.40
	P-During	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
	P-Post	45	0.49 (0.34–0.64)	4.50	15	0.33 (0.13–0.61)	1.50	34	0.44 (0.26–0.62)	3.40
	Total	68	0.50 (0.38–0.62)	3.40	22	0.41 (0.22–0.63)	1.10	58	0.53 (0.39–0.66)	2.90
All years total	C-No / P-No	194	0.55 (0.48–0.62)	1.60	74	0.43 (0.32–0.55)	0.61	197	0.51 (0.44–0.58)	1.62
	C-Post	267	0.57 (0.51–0.63)	3.84	180	0.46 (0.39–0.54)	2.59	260	0.49 (0.43–0.55)	3.74
	P-During	56	0.70 (0.56–0.81)	2.99	34	0.47 (0.31–0.64)	1.81	60	0.55 (0.42–0.68)	3.20
	P-Post	211	0.53 (0.46–0.60)	5.16	146	0.46 (0.38–0.54)	2.88	200	0.47 (0.40–0.54)	3.94
	Total	461	0.56 (0.51–0.61)	3.29	254	0.45 (0.39–0.51)	1.81	457	0.50 (0.45–0.55)	3.26