Density and Reproductive Success of Breeding Birds in the Mountains to Plains Project Area in Northern Colorado

FINAL REPORT

2010

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Technical Report: I-NEOTROP-MTP-09-01

ROCKY MOUNTAIN BIRD OBSERVATORY

***Mission**: To conserve birds and their habitats*

***Vision**: Native bird populations are sustained in healthy ecosystems*

***Core Values**: (Our goals for achieving our mission)*

1. ***Science** provides the foundation for effective bird conservation.*
2. ***Education** is critical to the success of bird conservation.*
3. ***Stewardship** of birds and their habitats is a shared responsibility.*

RMBO accomplishes its mission by:

***Monitoring** long-term bird population trends to provide a scientific foundation for conservation action.*

***Researching** bird ecology and population response to anthropogenic and natural processes to evaluate and adjust management and conservation strategies using the best available science.*

***Educating** people of all ages through active, experiential programs that create an awareness and appreciation for birds.*

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***Partnering** with state and federal natural resource agencies, private citizens, schools, universities, and other non-governmental organizations to build synergy and consensus for bird conservation.*

***Sharing** the latest information on bird populations, land management and conservation practices to create informed publics.*

***Delivering** bird conservation at biologically relevant scales by working across political and jurisdictional boundaries in western North America.*

Suggested Citation:

Youngberg E.N., Macias, A., and Panjabi, A.O. 2010, *Density and Reproductive Success of breeding birds in the Mountains To Plains project area in Northern Colorado: Final Report. RMBO technical report I-NEOTROP-MTP-09-01.* Rocky Mountain Bird Observatory, Brighton, CO, 24pp.

***Cover Photo**:* Horned Lark (*Eremophila alpestris)* nestlings on Soapstone Prairie Natural Area, photo by Erin Youngberg

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EXECUTIVE SUMMARY

Grassland bird populations have declined more than any other guild of North American birds and are among the highest of conservation priorities for state, federal and non-governmental natural resource conservation organizations. In effort to aid conservation and management of grasslands in Colorado, the Rocky Mountain Bird Observatory has partnered with the City of Fort Collins to inventory and monitor grassland birds on city-owned properties in Larimer and Weld counties. This project began in 2006 and 2007 on Soapstone Prairie Natural Area, expanded significantly in 2008-2009 with the incorporation of Meadow Springs Ranch and Round Butte Ranch, and again in 2010 with the addition of the Bernard Ranch.

We conducted avian point count surveys at 408 stations across roughly 4,937 acres in the four city-owned properties. We surveyed all of Bernard Ranch and concentrated on prairie dog colonies in Soapstone Prairie Natural Area, Meadow Springs Ranch, and Round Butte Ranch during the 2010 nesting season. We also surveyed vegetation at each station and recorded observations of other wildlife. During 22 survey days in 2010, we observed 4,137 individual birds of 60 species. We estimated densities of all common breeding bird species across the study area, and post-stratified estimates by year, prairie dog colony habitat, and in some cases active vs. inactive prairie dog colony habitat.

A nest productivity study was conducted on Soapstone Prairie Natural Area in two pastures containing over 7,000 acres of shortgrass prairie. We monitored four 56.25 ha plots (750m x 750m) in each pasture (8 total) for reproductive success between May 17 and August 11, 2010. Nests were discovered using rope-dragging and when found, their locations were documented using GPS, and nest contents (eggs and/or young) were recorded along with other important information such as parent behavior, presence of cattle, weather events, etc. Nests were revisited every 2 days to determine their status and fate. We found 169 nests in 2010; the most common were those of Horned Lark followed by McCown's Longspur, Vesper Sparrow, Western Meadowlark, Red-winged Blackbird, Lark Bunting, Grasshopper Sparrow, Common Nighthawk, Lark Sparrow, Say's Phoebe, and Mallard. Apparent nest success (the percentage of nests found producing at least one fledging) was 39.5% across all species. Daily survival rates were compared between pastures and among species to determine possible causes of nest success or failure.

The most common birds within the entire study area were Horned Lark, Western Meadowlark, McCown's Longspur, and Vesper Sparrow, which together accounted for 78% of all individual birds observed, and 83% of nests found. We also observed active nests of Ferruginous Hawk, Prairie Falcon, and Brewer's Sparrow as well as a recently fledged Great Horned Owl.

The acres of these properties include some of the most significant grasslands in northern Colorado, and present an excellent opportunity to conserve vulnerable wildlife while deriving many other valuable ecosystem services. These properties support nearly all of the breeding and migratory grassland bird species expected for this region, including 20 high-priority grassland-dependent species, in addition to other prairie wildlife. Of special note, in 2008 & 2009 these properties supported a breeding population of approximately 56 Mountain Plovers, a species of high conservation concern. That number had declined to only 5 individuals in 2010. In order to sustain populations of this and other shortgrass prairie species, including Ferruginous Hawk, Burrowing Owl, and Long-billed Curlew, management should strive to conserve and augment prairie dog populations, protect and restore wetlands, and maintain a low-level of human presence.

ACKNOWLEDGEMENTS

This project was funded by the City of Fort Collins Utilities Department and the Neotropical Migratory Bird Conservation Act (NMBCA #4138). The City of Fort Collins Natural Resources Department also provided valuable in-kind assistance and matching support for this project. We thank Loni Beyer for crew leadership and guidance on this project, as well as our field assistants Erin Youngberg, Matt Webb, Stacy Taeuber, and Bill Tiedje. Thanks go to our field volunteers Nat Warning and Joe Ehrenberger with the City of Fort Collins. We also thank Alberto Macias, Greg Levandoski, Rob Sparks, and Jennifer Blakesley for technical guidance on this report.

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INTRODUCTION

North American short grass prairies are the most endangered and anthropogenically altered ecosystems on the continent (Samson et al. 2004; Brennan et al. 2005). The primary threat to existing prairies is conversion to crop agriculture and development (Samson et al. 2004). Birds are the most abundant vertebrates in grasslands (Kennedy et al. 2008), and grassland birds have shown more significant declines in the last three decades than any other guild of birds (Smith and Lomolino 2004). Breeding grassland birds act as environmental indicators, as individual bird species are associated with specific habitat components within the larger grassland ecosystem (Browder et al. 2002). Monitoring avian populations in remaining North American prairies is important to understanding the overall health of grassland ecosystems and directly contributes to the conservation management of these habitats and the species that depend on them.

The goal of this project is to help managers conserve bird species and their habitats on City of Fort Collins properties in northern Colorado by helping them better understand the abundance, distribution and habitat requirements of breeding birds on the properties. The objectives are to: 1.) document migratory and breeding bird use of the project area, 2.) provide locations of sensitive bird species, and 3.) monitor reproductive health of breeding grassland birds in relation to different management practices. These properties support breeding populations of more than 20 high-priority bird species, primarily grassland species, recognized by the Colorado Division of Wildlife, the U.S. Fish and Wildlife Service, Partners in Flight, the U.S. Shorebird Conservation Plan, The Nature Conservancy, and other conservation groups. These properties comprise the southern end of the largest remaining contiguous prairie in North America, stretching from here to Alberta and Saskatchewan and east into Nebraska and the Dakotas, and thus present an incredible opportunity for grassland conservation. This is the final report for the 2010 monitoring activities.

METHODS

Study Area

We conducted this study on four City of Fort Collins (CFC) properties in Larimer and Weld counties of northern Colorado that comprise roughly 47,000 acres of short grass prairie and rolling foothills: Soapstone Prairie Natural Area (SPNA), Meadow Springs Ranch (MSR), Bernard Ranch (BE), and Round Butte Ranch (RBR). We used spatial data provided by CFC Natural Resources Department of active prairie dog colony habitat in 2007 (hereafter referred to as 2007-PDCH) to delineate areas of PDCH.

For our point counts we surveyed all of BE, and on the MSR, RBR, and SPNA properties we limited our surveys to areas of PDCH (Figure 1).

For nest monitoring we surveyed eight 750m x 750m plots within two pastures (Jack Springs and Brannigan) on the eastern half of Soapstone Prairie Natural Area where the majority of the shortgrass habitat exists.

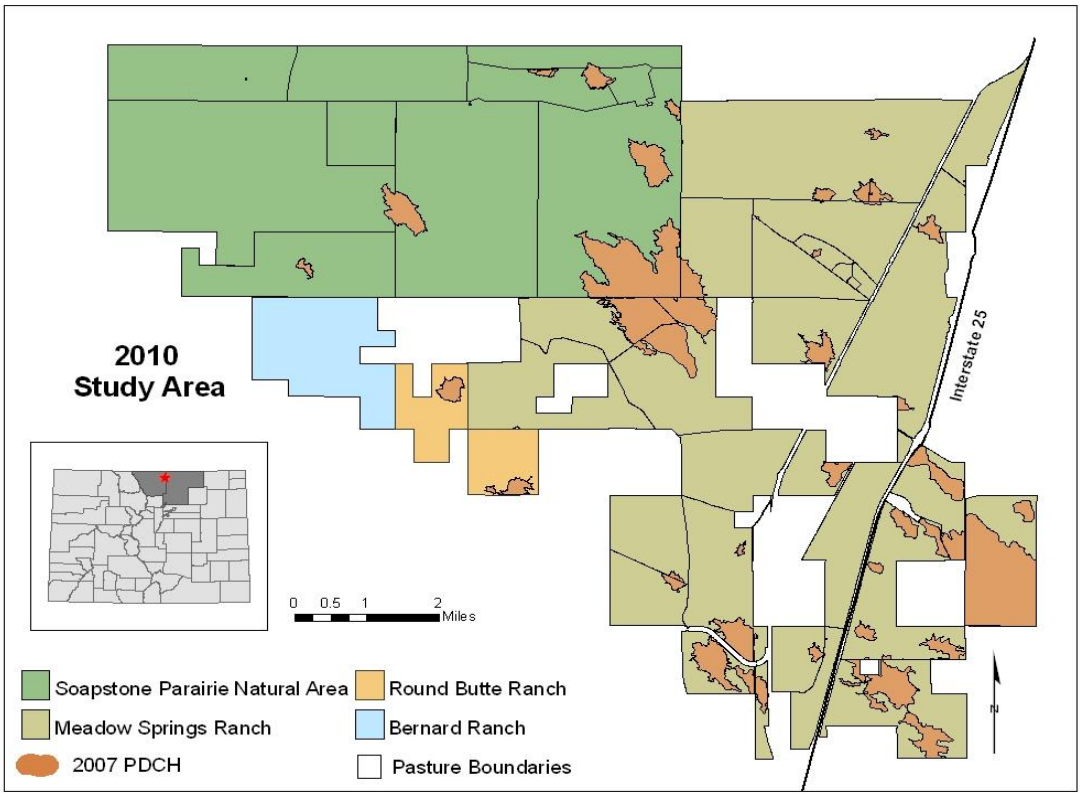


Figure 1: Study area in 2010 on Meadow Springs Ranch, Round Butte Ranch, Soapstone Prairie Natural Area, and Bernard Ranch (added in 2010) in Larimer and Weld counties, Colorado.

Although sylvatic plague appeared to wipe out 70% or more of the prairie dogs in SPNA and MSR between 2007 and 2008, we documented four small, but active prairie dog colonies outside of 2007-PDCH on MSR. In 2010, prairie dogs were still absent from 65% of the total PDCH.

Avian Surveys

We utilized a grid of point count stations used to survey SPNA, MSR, and other properties since 2006 and used Arc Map 9.1 to lay out 408 systematic point count stations in 2010, each separated by 250 meters (Fig. 2). The point count stations in SPNA, MSR and RBR were located in PDCH. All of BE was surveyed because it had not been surveyed previously (Table 1). There were no areas of PDCH in Bernard Ranch.

Table 1: Number of point count stations surveyed in PDCH in 2008, 2009 & 2010:

Point Count Stations	2008 (May 19 – July 3)	2009 (April 20 – June 17)	2010* (April 19 – June 25)	Total
Stations on Soapstone Natural Area	64	68	67	199
Stations on Meadow Springs Ranch	62	224	221	507
Stations on Round Butte Ranch	4	8	8	20
Stations on Bernard Ranch°			112	112
TOTAL	**130**	**300**	**408**	**838**

*A subset of stations surveyed in 2008 and 2009 were re-surveyed in 2010

°Bernard Ranch (BE) was surveyed for the first time in 2010

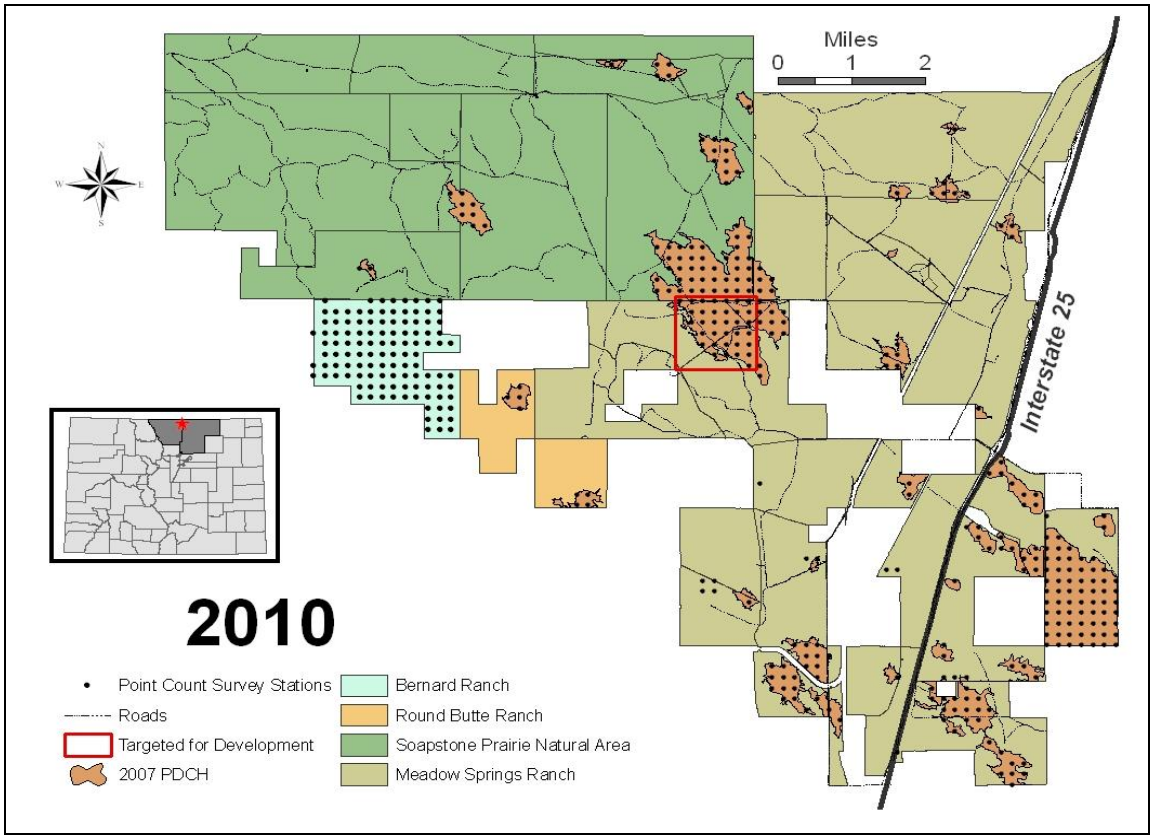


Figure 2: Point count survey stations in 2010 (Meadow Springs Ranch, Soapstone Prairie Natural Area, Round Butte Ranch and Bernard Ranch).

All point count surveys started no earlier than one half-hour before sunrise and ended no later than 11 a.m., often earlier. We navigated on foot to each point count station using a handheld GPS unit. We recorded atmospheric data (temperature, cloud cover, precipitation, and wind speed) and time of day at the start and end of each day's point counts. We logged all GPS data in Universal Transverse Mercator (UTM) North American Datum 1927. At each station, we conducted a 5-minute point count survey consisting of five consecutive 1-minute intervals. This protocol, which is described more fully by Hanni et al. (2009), uses Distance sampling (Buckland et al. 2001) with removal (Farnsworth et al. 2002). For each bird detected, observers recorded species, sex, how it was detected (call, song, visual, wing beat, other), distance from observer, and the 1-minute interval in which it was detected. Whenever possible, we measured distances using laser rangefinders. When it was not possible to directly measure the distance to a bird, we measured distance to a nearby object and then gauged our estimate to the bird.

Between point count surveys, we recorded the presence of high-priority and other rare or unusual bird species, but we did not use these observations in our analyses. We also noted other wildlife present including mammals and reptiles.

Nest Monitoring

A nest productivity study was conducted on Soapstone Prairie Natural Area on Brannigan and Jack Springs pastures. Seventy-four percent of the habitat on SPNA is shortgrass prairie with most of it occurring in these two pastures (Figure 3).

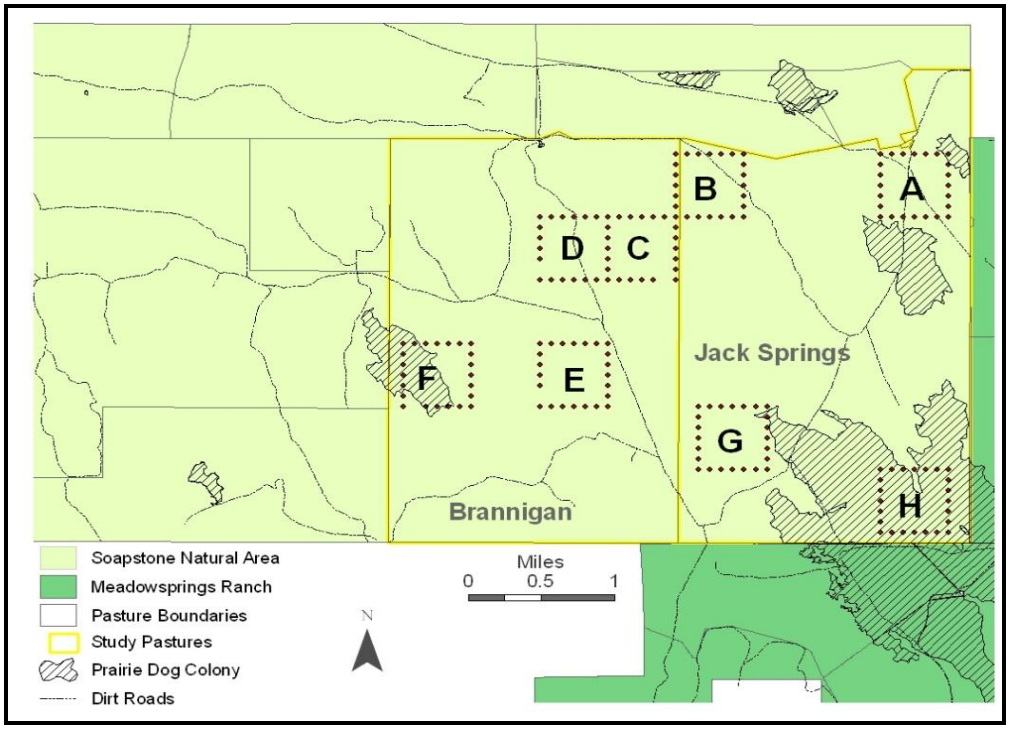


Figure 3: Eight 750mx750m nest monitoring plots (A-H) on Soapstone Prairie Natural Area (SPNA).

Field biologists monitored the reproductive success of grassland birds on eight 56.25 ha plots (750m x 750m) between May 17 and August 11, 2010. The primary method for finding nests was dragging a 30m rope between two people along transects in each plot to flush birds from their nests. We were able to drag all eight plots twice to account for both early and late nesting birds. When nests were found we recorded the species, date and time, plot name and location (using GPS), substrate/ cover on which the nest was located, number of eggs/ chicks present, developmental stage of eggs/ chicks, and behavior of parents, if known. Then a wooden stake was placed in the ground 10-20m away from the nest and a compass bearing from the nest to the stake was recorded (as well as the GPS location of the stake) to help locate the nest for future nest checks while minimizing disturbance around the nest.

The development of eggs was determined using an egg floating technique developed by Westerskov (1950). Eggs were floated in a clear plastic container filled with tepid water. Gloves were worn when touching the nest or eggs as an extra precaution to reduce human scent that may attract nest predators. Eggs were submerged in the water and their float status was recorded using an egg floating chart (Figure 4). Values on the chart were used to estimate the time of hatching, for example, an egg with a 12 day incubation period that reads ¾ means it is approximately 9 days into incubation and has approximately 3 days before hatching. We floated several eggs per nest to determine an approximate nest age.

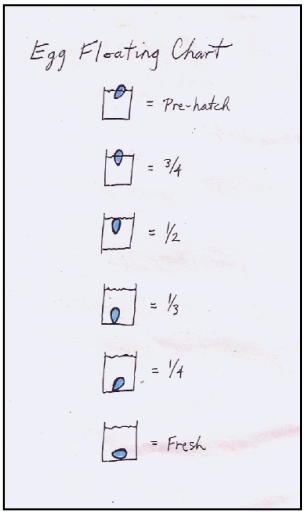


Figure 4: Egg floating chart used to determine incubation stage (A. Adams, 2009).

Incubation periods vary by species and were referenced using The Birds of North America (A. Poole, Ed.).

Nests were checked every 2-3 days to monitor their status and determine their fate. During each visit we recorded the number of chicks or eggs present and their developmental stage, as well as any other information of interest such as parental behaviors, disturbance factors, or weather events. When nests became inactive, observers searched for any evidence of success (i.e. feces in and/or around rim of the nest, fledglings in the area, etc) or failure (i.e. eggshell fragments, nest damage, remains, etc) around the nest site. Unless there was evidence to suggest a nest had failed, nests that were found empty on or after their predicted fledge date and that had been checked (and were active) during the previous 2-3 days were assumed successful.

Habitat Surveys

After completing each point count survey we performed a rapid habitat survey at each point by estimating several vegetation parameters. Within 25 m of each point we visually estimated percent cover of grasses, forbs, bare ground, exotic plants, and 'other cover' to the nearest 1%. 'Other cover' included cactus, low woody plants, rock, and other minor ground cover types. Also within this radius we estimated average grass height by assigning it to one of five categories: (1) ≤ shoe sole height, (2) ankle height, (3) mid-calf height, (4) knee height, and (5) mid-thigh height. Within 100 m of each station we documented shrub and overstory tree species and estimated percent cover (to nearest 1%) and average height of each. We recorded whether prairie dog colonies at point survey stations were 'active' or 'inactive' based on the detection of at least one prairie dog within 100 m.

Analyses

Avian Densities

We estimated bird species density using Program Distance 6.0 release 2 (Thomas et al. in press). We used Half-normal cosine, Hazard-rate cosine, Uniform cosine, Uniform Simple-Polynomial and Hazard-rate Simple Polynomial detection function models to determine the best fit model for each species. We then used Goodness-of-fit tests to determine truncation points in each species dataset to eliminate outliers (generally the furthest 5-15% of observations) and improve model performance, as recommended by Buckland et al. (2001). We used Akaike's Information Criterion (AICc) to select among competing models of detectability of each species (across all strata), and post-stratified estimates by year and/or PDCH. In this report, (n) denotes the total number of detections observed in the field and (n_t) represents the truncated number of detections used to estimate density.

We estimated densities for all bird species with at least 20 independent detections, on either Bernard Ranch or within PDCH. For bird densities in PDCH we pooled all point count data from PDCH since 2008 to generate species specific detection functions, and post-stratified estimates by year. Although species' density estimates calculated with less than 75 observations may be unreliable representations of true populations (Buckland et al. 2001), we present estimates for all species with n≥ 20, and for high-priority species with fewer observations. Many species with relatively few observations are low-density species of high conservation interest, and having even rough estimates of density in a comparable format to other species, along with associated measures of error, can aid in the conservation and management of these species. Nonetheless, we urge that caution be used in interpreting estimates derived from relatively few observations, and that special attention be paid to %CV and confidence limits.

Burrowing Owl, Mountain Plover, McCown's Longspur and Horned Lark are strongly associated with prairie dog colonies (Smith and Lomolino 2004; Tipton et al. 2008). For each species we calculated a global PDCH density estimate and post-stratified estimates by year, active PDCH and inactive PDCH.

Nest Survival

We used a logistic-exposure model (Shaffer 2004a) to estimate the effects of potential explanatory variables on daily nest survival rates. Explanatory variables included in the analysis were *date* (Julian date); *PLOT*, with levels A, B, … , H (Fig. 3); *PASTURE* with levels Jack Springs and Brannigan; and *SPECIES* with nine levels, although Horned Larks and McCown's Lonsgpurs account for 68% of our dataset. Variable *PLOT* was introduced in the models as a nested variable within *PASTURE*. We tested all main effects models possible with these variables. In addition, we also fit and tested a model that includes interaction *date*×*PASTURE*, since pastures differed in management during the breeding season. We used the Akaike's Information Criterion (Burnham and Anderson 2002) to select the model with superior performance in explaining nest survival variation. We used package *stats* of program R version 2.10.1 for Mac® (R Development Core Team 2009) and used a modification of the script provided by Shaffer (2004b) to conduct our logistic-exposure analysis.

RESULTS

Avian Point Count Surveys

We detected 4,137 birds during point count surveys, and observed 58 species within the study area in 2010 (Appendix A). We confirmed or strongly suspected breeding for 29 bird species, including 12 high-priority species. Several other species, such as Chestnut-collared Longspurs, were mainly using the study area during migration. We detected 16 species within the study area outside of our formal survey efforts, including Wilson's Phalarope, Great-horned Owl, and Long-Billed Curlew. In Butte pasture on MSR (area targeted for potential oil and gas development) we detected 16 species, including 7 priority species (Appendix B).

Bird Density in Prairie Dog Colonies

We detected 63 bird species over the three survey years (2008, 2009, 2010) in prairie dog colony habitat (PDCH), but only nine in sufficient numbers to estimate density. The three properties containing PDCH were SPNA, RBR, and MSR. Bernard Ranch was analyzed separately. Of the nine species analyzed, Horned Lark and McCown's Longspur were most abundant. The densities of Mountain Plover and Burrowing Owl are the lowest of the species found in PDCH, and both species showed declines from 2009 to 2010 (Table 2).

Table 2: Average and annual densities (birds/km^2) of nine bird species inside prairie dog colony habitat on SPNA, RBR, and MSR in 2008, 2009, 2010. (n_t = number of detections used to obtain density estimates, %CV = percent coefficient of variation, LCL & UCL = 95% lower and upper confidence limits of the density estimate).

Species	Year	Density	%CV	LCL	UCL
Horned Lark (n_t = 2261)	2008	192.98	6.73	169.16	220.16
	2009	352.45	6.69	309.19	401.75
	2010	237.74	6.67	208.60	270.95
	All yrs.	**261.06**	**6.57**	**229.55**	**296.89**
McCown's Longspur (n_t = 1291)	2008	156.28	8.36	132.68	184.09
	2009	197.47	8.54	167.06	233.42
	2010	147.04	8.62	124.20	174.08
	All yrs.	**169.98**	**8.37**	**143.43**	**199.08**
Western Meadowlark (n_t = 810)	2008	2.36	6.71	2.07	2.69
	2009	12.61	5.16	11.39	13.95
	2010	21.22	5.11	19.19	23.46
	All yrs.	**12.067**	**5.08**	**10.92**	**13.31**
Lark Bunting (n_t = 143)	2008	9.70	196.57	.043	2162.8
	2009	4.11	6.04	3.64	4.62
	2010	3.01	15.70	2.19	4.11
	All yrs.	**4.89**	**84.33**	**.215**	**110.77**
Mountain Plover (n_t = 74)	2008	1.75	16.63	1.26	2.43
	2009	1.35	16.00	.984	1.85
	2010	.413	15.54	.303	.562
	All yrs.	**1.17**	**15.88**	**.856**	**1.60**
Vesper Sparrow (n_t = 60)	2008	1.22	14.45	.915	1.63
	2009	16.13	15.32	11.91	21.86
	2010	13.94	16.10	10.14	19.16
	All yrs.	**12.06**	**15.04**	**8.95**	**16.26**
Burrowing Owl (n_t = 36)	2008	.961	15.99	.696	1.33
	2009	1.07	16.57	.769	1.49
	2010	.561	18.58	.387	.815
	All yrs.	**.865**	**16.20**	**.624**	**1.19**
Chestnut-collared Longspur (n_t = 36)	2008	0	0	0	0
	2009	1.56	41.08	.430	5.67
	2010	23.95	21.37	15.69	36.53
	All yrs.	**8.50**	**21.00**	**5.61**	**12.88**
Brewer's Sparrow (n_t = 35)	2008	0	0	0	0
	2009	15.53	32.16	8.17	29.51
	2010	17.24	25.31	10.44	28.45
	All yrs.	**12.853**	**24.22**	**7.97**	**20.72**

Of special interest, there were 13 observations of Mountain Plover in 2010 compared to 34 in 2009 (Figure 5). All Mountain Plover observations were within PDCH, both active and inactive. None were observed in SPNA.

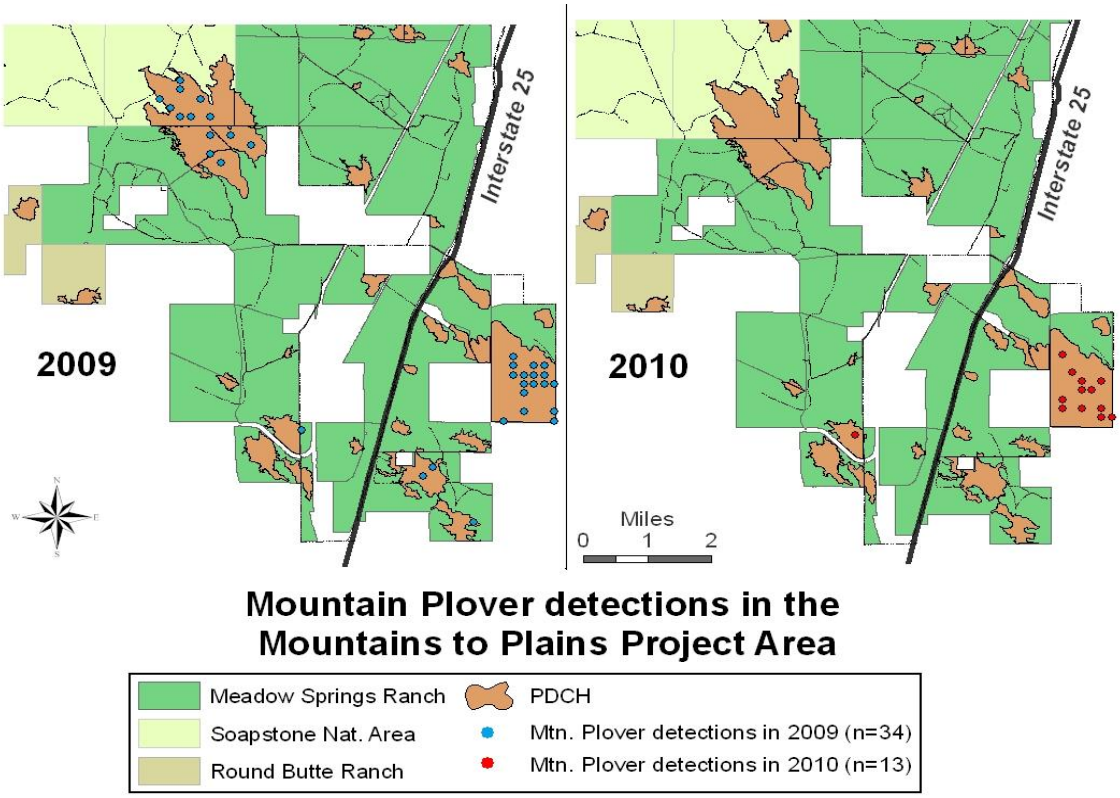


Figure 5: Detections of Mountain Plover at point count stations in 2009 & 2010 on Meadow Springs Ranch, Larimer County, Colorado.

Burrowing Owls had significantly lower densities in inactive prairie dog colonies (D = .45, %CV = 17.38, LCL = .317, UCL = .637) than in active ones (D = 1.65, %CV = 16.31, LCL = 1.19, UCL = 2.29) in 2010 (Fig 6, left graph). This may be due to the need for recently excavated burrows for nesting. Mountain Plovers did not show a significant difference in abundance between active (D = 1.15, %CV = 16.23, LCL = .835, UCL = 1.58) and inactive (D = .856, %CV = 15.88, LCL = .625, UCL = 1.17) prairie dog colonies in 2010 (Figure 6, right graph).

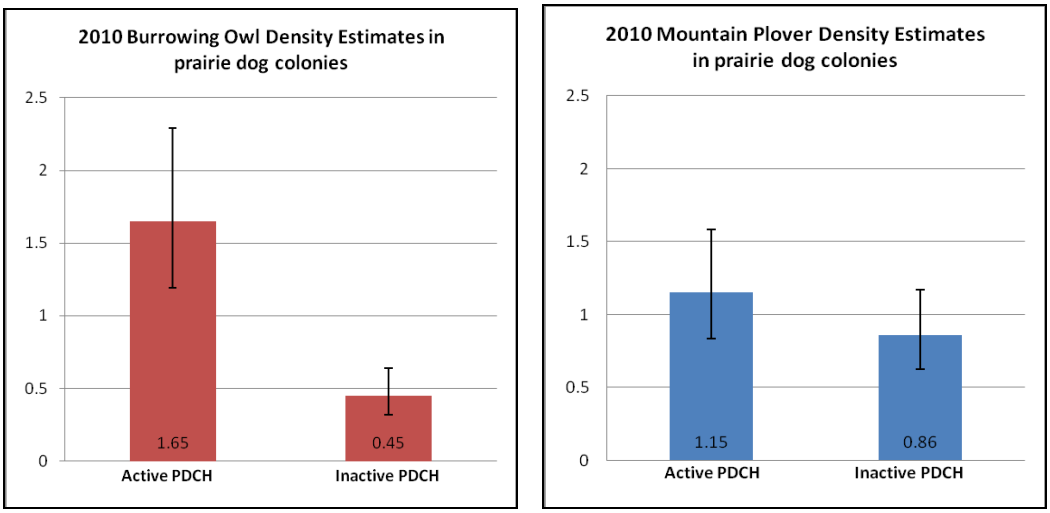


Figure 6: Left - Burrowing Owl density estimates in PDCH for 2010.
Right - Mountain Plover density estimates in PDCH for 2010.

Bird Density on Bernard Ranch

We detected thirty-one bird species on BE in 2010, including seven species of special concern (Appendix A). We estimated densities of the six most common breeding bird species found on BE (Table 3). Horned Lark were the most abundant, although less dense than within PDCH. There were no observations of Mountain Plover, Burrowing Owl, McCown's or Chestnut collared Longspurs in BE.

Table 3: Density estimates (birds/ km^2) of six species outside prairie dog colonies on BE in 2010. (n_t = number of detections used to obtain density estimates, %CV = percent coefficient of variation, LCL & UCL = 95% lower and upper confidence limits of Density.)

Species	Year	Density	%CV	LCL	UCL
Horned Lark (n_t = 331)	2010	160.78	4.11	148.30	174.30
Western Meadowlark (n_t = 150)	2010	9.78	1.88	9.42	10.15
Lark Bunting (n_t = 88)	2010	13.06	14.12	9.88	17.26
Brewer's Sparrow (n_t = 53)	2010	29.02	16.32	20.98	40.15
Vesper Sparrow (n_t = 46)	2010	15.85	22.29	10.17	24.69
Grasshopper Sparrow (n_t = 40)	2010	10.81	14.87	8.01	14.58

Horned Lark and Western Meadowlark had higher densities in areas with PDCH. Vesper and Brewer's Sparrows did not have significant differences in density between areas with PDCH and areas without PDCH.

Vegetation

Grass was the dominant ground cover type in the 2010 point count study area (total cover inside PDCH = 87%, on BE = 77%) followed by bare ground (total cover inside PDCH = 7%, on BE = 14%). Other cover was 6% inside PDCH, 0% on BE; total shrub cover = .31% inside, 7% on BE; and exotic vegetation cover = .4% inside, 2% on BE (Figure 9).

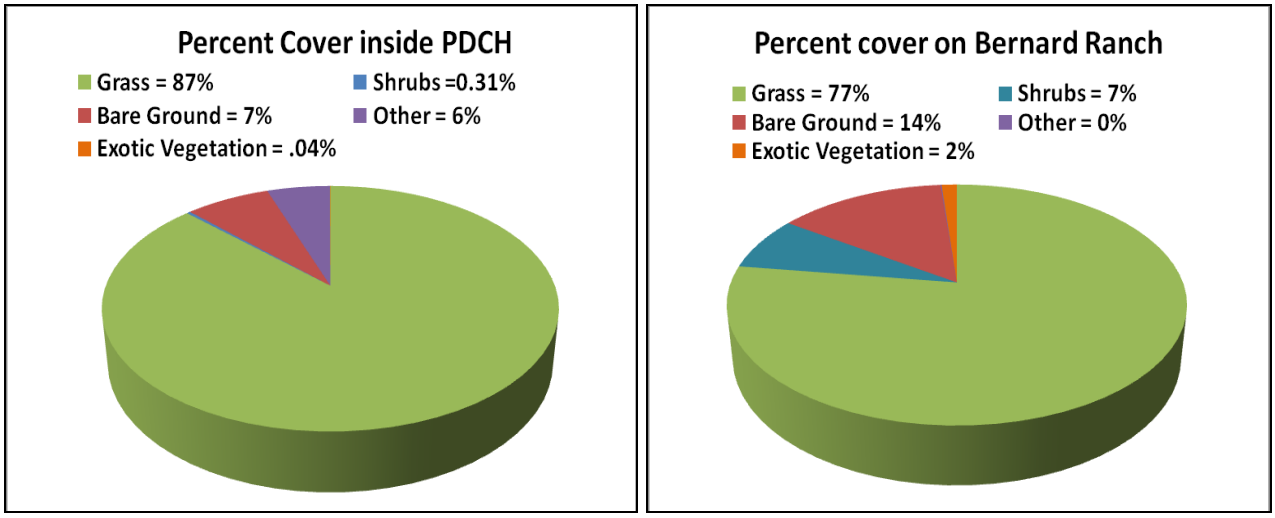


Figure 9: Average percent ground cover sampled at point count survey stations inside prairie dog colony habitats (PDCH) and the Bernard Ranch in 2010.

Total cover of overstory trees was .05% inside PDCH and 1.19% on BE. Average shrub height inside PDCH was .064m and an average of .558m on BE. Average grass height was category 1 (shoe sole height) inside PDCH, and category 3 (mid-calf height) on BE, with a minimum of 1 and a maximum of 5. Figure 10 shows the breakdown of percentage of point count stations had which grass height category.

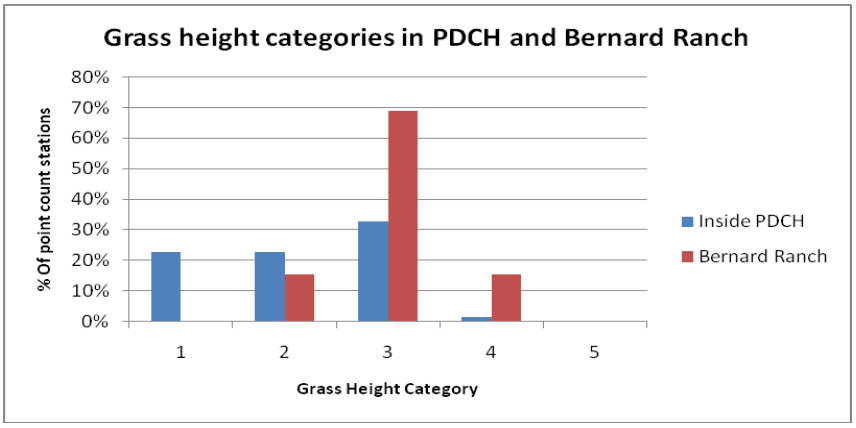


Figure 10: Grass height category percentage at point count stations in PDCH and BE.

Nest Monitoring

We found 169 nests on Soapstone Prairie Natural Area in 2010 (167 of which were active), and monitored them until they fledged or failed. Two nests were found empty and their fate was unknown. Seventy-eight nests were found on Jack Springs pasture and 91 were found on Brannigan pasture. The most common nests found were those of Horned Lark (n=64) followed by those of McCown's Longspur (n=58). Other species for which we found nests were: Vesper Sparrow (n=11), Western Meadowlark (n=8), Red-winged Blackbird (n=8), Lark Bunting (n=5), Grasshopper Sparrow (n=4), Common Nighthawk (n=4), Lark Sparrow (n=2), Say's Phoebe (n=1), and Mallard (n=1).

The average number of eggs for the Horned Lark was 2.7 per nest. Apparent nest success, the percentage of nests found producing at least one fledging, was 48% for this species. The average

number of eggs for McCown's Longspur was 3.3 per nest. The apparent nest success was 36% for this species.

The overall nest density estimate (D) in Brannigan pasture was 40.63 nests/ km^2, whereas the density in Jack Springs pasture was 34.82 nests/ km^2. The most common nests found in Brannigan were Horned Lark nests (17.86/km^2) followed by McCown's (10.27/km^2). The most common nests found in Jack Springs were McCown's Longspur (15.63/km^2) followed by Horned Lark (10.71/ km^2).

Date is also an important predictor for nest survival in SPNA, and nest survival differs between the two pastures. Variables *date* and *PASTURE* were included in the best three models (ΔAIC<4). Nesting survival rates did not differ among species and plots since these variables were not included in the best three models (Table 4). In this regard, models including species and plot had inferior performance compared to the intercept-only model. Model probabilities (Akaike weights) for the two best models were similar (w=0.43 and w=0.38) and considerably higher than the rest of the models. Therefore, these two models can be considered equally likely to explain the variation in nest survival in SPNA. The best model with additive effects of date and pasture predicts a steady increase in daily nest survival probability and higher survival at Brannigan pasture during the entire breeding season (Figure 11, upper plot). The second model, that adds an interaction term between date and pasture, predicts equal nest survival at the onset of the breeding season, with divergent increasing trends between pastures as the breeding season progresses (Figure 11, lower plot).

Table 4. Information-theoretical evaluation of logistic-exposure models that estimate daily nest survival in Soapstone Prairie Natural Area, Colorado. Models include explanatory variables date (Julian date), pasture (Jack Springs and Brannigan), plots (A, B, … H), and bird species (nine species, see text). AIC denotes Akaike's Information Criterion and *w* are the Akaike weights. *PASTURE|PLOT* denotes that the levels of plots are nested within the levels of pasture.

Model	AIC	ΔAIC	*w*
date + PASTURE	558.01	0.00	0.4302
date + PASTURE + date×PASTURE	558.25	0.24	0.3815
date	561.85	3.84	0.0631
date + PASTURE + PASTURE|PLOT	562.09	4.08	0.0559
PASTURE	562.18	4.17	0.0535
Intercept only (null model)	565.82	7.81	0.0087
PASTURE + PASTURE|PLOT	567.55	9.54	0.0036
date + PASTURE + SPECIES	568.68	10.67	0.0021
date + SPECIES	570.06	12.05	0.0010
SPECIES	573.22	15.21	0.0002
date + PASTURE + PASTURE|PLOT + SPECIES	573.58	15.57	0.0002
PASTURE + PASTURE|PLOT + SPECIES	576.89	18.88	>0.0001

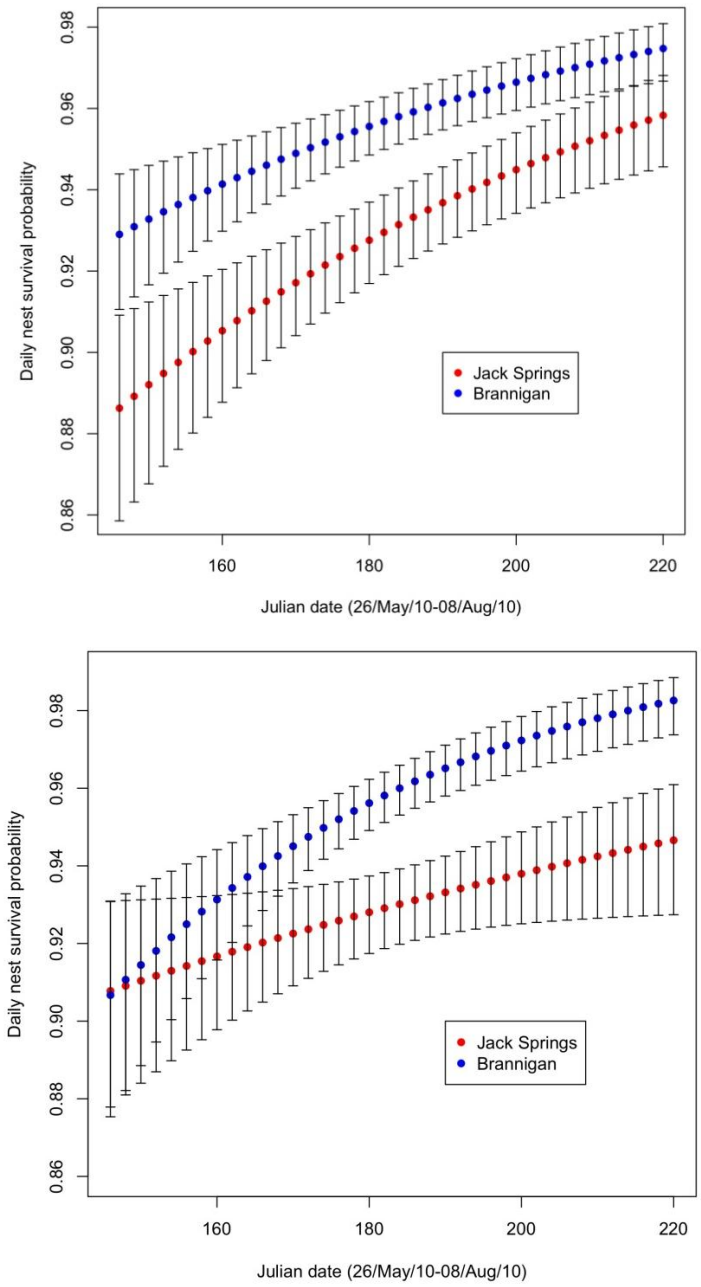


Figure 11: Seasonal variation in daily nest survival at Jack Springs and Brannigan pastures in Soapstone Prairie Natural Area in the breeding season of 2010, as predicted by the best two logistic-exposure models examined (Table 4). Error bars denote standard errors.

Excluding failure by cattle, we found no evidence that the frequency of causes of failure differed between Jack Springs and Brannigan pastures (Chi-square test for homogeneity of proportions, $\chi^2 = 0.0534$, d.f. = 3, $P = 0.99$). Therefore, we present below summaries of nest failures lumping data from these two pastures (Fig 12 & 13).

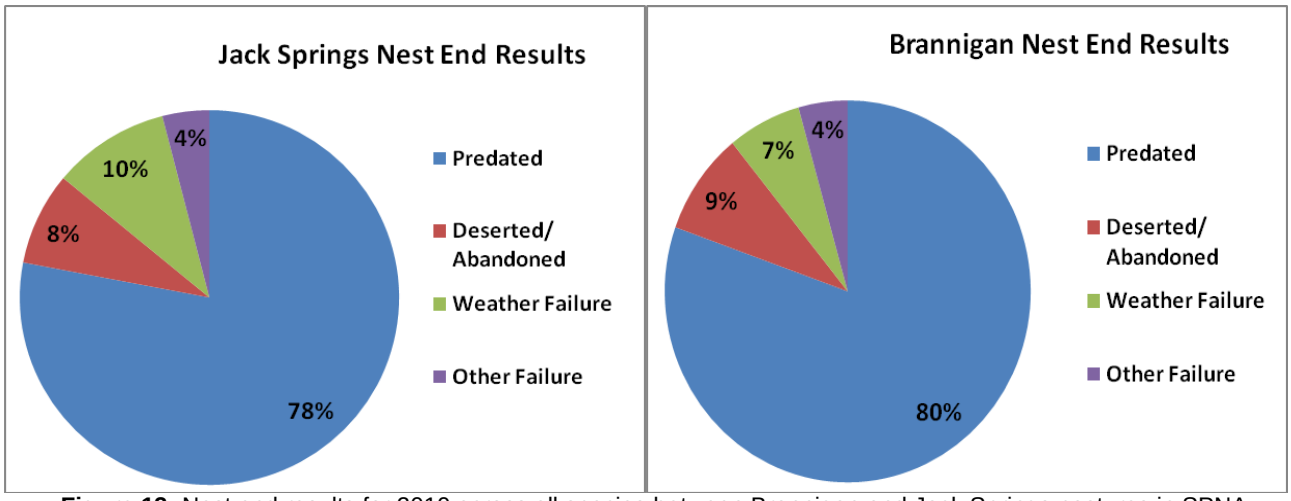
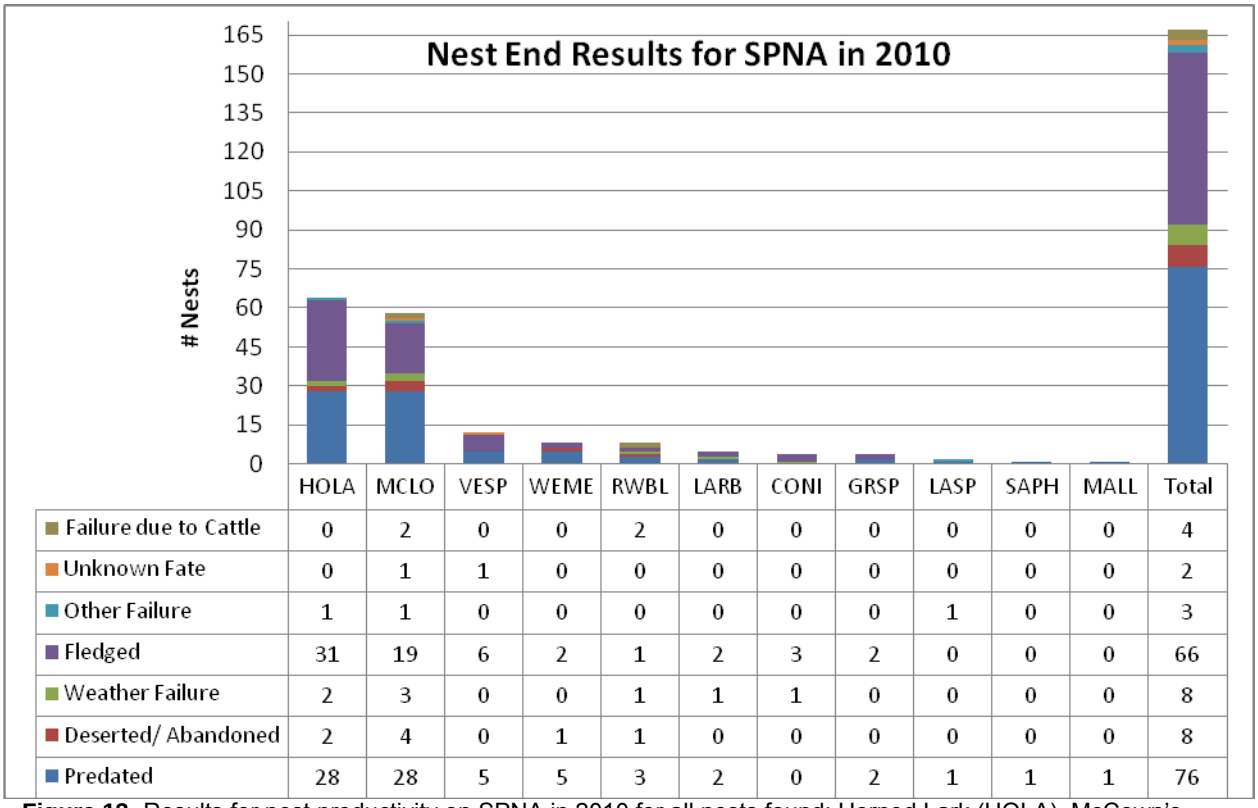


Figure 12: Nest end results for 2010 across all species between Brannigan and Jack Springs pastures in SPNA.



	HOLA	MCLO	VESP	WEME	RWBL	LARB	CONI	GRSP	LASP	SAPH	MALL	Total
Failure due to Cattle	0	2	0	0	2	0	0	0	0	0	0	4
Unknown Fate	0	1	1	0	0	0	0	0	0	0	0	2
Other Failure	1	1	0	0	0	0	0	0	1	0	0	3
Fledged	31	19	6	2	1	2	3	2	0	0	0	66
Weather Failure	2	3	0	0	1	1	1	0	0	0	0	8
Deserted/ Abandoned	2	4	0	1	1	0	0	0	0	0	0	8
Predated	28	28	5	5	3	2	0	2	1	1	1	76

Figure 13: Results for nest productivity on SPNA in 2010 for all nests found: Horned Lark (HOLA), McCown's Longspur (MCLO), Vesper Sparrow (VESP), Western Meadowlark (WEME), Red-winged Blackbird (RWBL), Lark Bunting (LARB), Common Nighthawk (CONI), Grasshopper Sparrow (GRSP), Lark Sparrow (LASP), Says Phoebe (SAPH), and Mallard (MALL)

Overall apparent nest success was 39.5% meaning 66 out of 167 nests found produced at least one fledgling. Forty-seven percent of nests failed as a result of predator activity, followed by 4.8% abandoned/ deserted and 4.8% failed due to weather related events (Figures 12 & 13). There were four nest failures due to cattle on the Jack Springs pasture. Two nests were lost directly to cattle trampling, and two nests to possible cow predation (Nack & Ribic, 2005). Evidence of this was observed in a visit to a nest directly after cattle were seen walking around and over the nest location.

Two of the three nestlings were found outside of the nest and had suffered death by trampling, and the third could not be accounted for, leading us to believe the cow had possibly eaten the nestling as it was documented to be too young to fly. Another case was the disappearance of a red-winged blackbird nest in a riparian area after the area had been heavily disturbed and grazed by a herd of cattle. The visit to the nest the next day revealed the entire nest and its contents of 4 eggs gone from the tall grass where it had been the day before. There were no signs of the nest anywhere nearby; leading us to again believe that it may have been eaten by the herd of cattle as it passed through. The possibility of cow predation is difficult to assess using information from nest visits alone, but nest failure due to cattle activity is evident.

DISCUSSION

Soapstone Prairie Natural Area, Meadow Springs Ranch, Bernard Ranch, and Round Butte Ranch support a rich and diverse shortgrass prairie avifauna, complete with many grassland bird species that are declining or extirpated in much of their range, including more than 20 bird species that have been identified as high concern for conservation. Due to the unique geographical location in the transition zone between the southern Rocky Mountains and the Western Great Plains, the properties surveyed provide not only high-quality breeding habitat for these species, but also migratory stopover habitat for these species and many more (Sparks et al 2007). Appropriate conservation and management of these areas can play an important role in sustaining regional populations of grassland birds and other wildlife.

Prairie dogs are a keystone species in prairie ecosystems, meaning their presence and activity is essential to sustaining other species. Prairie dogs are an important food source to predatory birds such as Ferruginous Hawk and Golden Eagle (Giovanni et al. 2007). Long-term prairie dog colony stability leads to significant changes in plant community composition with elevated levels of bare soil, forbs and reduced cover (Augustine, et al 2007), preferred conditions for nesting habitat for several shortgrass obligate species such as Burrowing Owl, Mountain Plover, McCown's Longspur and others (Tipton et al. 2008; Kennedy et al. 2008). The areas of non-PDCH had more overstory tree cover, more shrubs, and higher grass heights than areas within PDCH. Mulhern & Knowles (1995) recommend a goal of 5-10% of suitable grassland area to be occupied by prairie dogs to ensure long-term population persistence. Without active prairie dogs, habitat suitability for prairie dog associated bird species, including Mountain Plover (a federal and state species of conservation concern), will eventually decline. Our data show that Mountain Plover and Burrowing Owl numbers are down from previous years, especially the Mountain Plover population. Our calculations show that Plover numbers have declined from around 50 individuals in 2008 & 2009, to 5 birds in 2010. Even though there were 13 observations during the point counts (Fig.5), it is likely that the same bird could have been detected from different point count stations. This decline is most likely due to the episode of sylvatic plague in 2007-2008. A study by Augustine et al. (2008) found that Mountain Plover nesting activity in PDCH declines rapidly within 1-2 years after a plague episode and also suggests that nesting habitat for plovers may not recover as quickly as the prairie dogs after a plague event. Even with augmented prairie dog populations, we may not see a return in population numbers for several years. Therefore, regular monitoring of prairie dog dependent bird species within the study area would allow managers to identify and respond to conservation concerns and guide management actions in a time-sensitive manner that would increase the probability of success of conserving these species and their habitat (Panjabi A.O. et al. 2009).

The heterogeneity of habitats including the various wetlands, shrublands, different grassland types, and woodlands, supports a wide diversity of bird life found in the study area. Although prairie dog towns may be important for some of the most vulnerable and sensitive bird species in the region,

conservation and management in this area should also strive to incorporate and protect these other unique ecological elements.

Timing of nest monitoring is an important consideration in grassland surveys as some species start nesting earlier than others. Nest survival on SPNA showed an increasing seasonal trend, and may be because the 2010 nesting season was delayed due to snow and unseasonably cold weather in the first two weeks of May. Many early season first nesting attempts may have been started and failed as a result. Several nestlings in both pastures died during nights of cold rain and excessive wind. The weather became more favorable during second nesting attempts in June & July which increased egg and nestling survival.

Predation is also a major factor in nest survival (Pietz & Granfors, 2000). Possible nest predators in the short grass prairie include Thirteen-lined Ground Squirrels (Ribic. Et al 2009), Swift Fox, Coyotes, avian predators, (Pietz & Granfors, 2000.) and a variety of snakes like this Western Hog-Nosed Snake we encountered near a McCown's Longspur nest in plot C of the Brannigan pasture (note the wide spot in the snake where it is digesting the nest contents it just consumed) (Fig 14).

Figure 14: Western Hog-nosed snake (*Heterodon nasicus)* on Soapstone Prairie near McCown's Longspur nest on Brannigan pasture.

Brannigan had a higher nest success rate than Jack Springs pasture, with fewer nests lost to predation and weather events. We witnessed a higher occurrence of ground squirrels in the Jack Springs pasture, a known ground-nesting predator. Jack Springs also had a higher number of McCown's and Horned Lark nests, which are more conspicuous open-cup nest structures than other species such as Lark Buntings and Meadowlarks that have better concealed nest structures. Having a more conspicuous nest may lead to increased vulnerability to predation (Pietz and Ganfors, 2000), and exposure to weather, but more data would need to be collected to determine the effect of weather on nest success rate.

Interestingly, Lark Buntings were the most common nest found in 2008 & 2009 (n=60), but one of the least common found in 2010 (n = 5). The species is known for habitat use fluctuation, and populations can vary from one year to the next. Future monitoring of this species can give us more information on its habitat use and population size in the area.

Bernard Ranch is an area of significantly different habitat with mixed grassland and shrublands, a landscape which does not support prairie dogs. Because of the shrubs and taller grasses, Bernard Ranch had a higher frequency of shrub-loving species like Lark Buntings bird as well as species that were not detected in areas within PDCH such as Grasshopper and Brewer's Sparrows.

Management Recommendations

Grassland birds have varied habitat requirements and are sensitive to environmental conditions (Ribic et al. 2009). The shortgrass prairie habitats of Meadow Springs Ranch, Round Butte Ranch, Bernard Ranch, and Soapstone Prairie Natural Area were historically maintained by a combination of ungulate grazing (e.g. bison), small herbivore activity (e.g. prairie dogs), and fire, combined with climate. These ecological conditions resulted in a mosaic of vegetation structures, composition, and ecosystem dynamics (Winter et al 2002; Smith and Lomolino 2004). Such natural disturbances create heterogeneity in grassland habitats which in turn support avian species diversity (Fuhlendorf et al. 2006).

Moderate grazing contributes to creating ideal nesting habitat for the Mountain Plover (Augustine et al. 2008), however intense cattle grazing should be scheduled for late autumn and into the winter to minimize impact on summer ground nesting birds.

Management actions would be well-served to create conditions mimicking those created by natural disturbance regimes, and should allow for natural processes that maintain variation within native short grass prairies, especially prairie dogs, which serve a keystone role in this ecosystem by creating a unique habitat that sustains a suite of other animal species (Figure 15) (Smith and Lomolino 2004). Protection of this keystone species can aid in the transition of single-species management to managing the system as a whole (Miller et al 1994).

Figure 15: Pronghorn Antelope on a black-tailed prairie dog colony on Meadow Springs Ranch Larimer County, Colorado. Photo by Mike Forsberg.

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Appendix (A)

Number of Individuals of all species detected in prairie dog colony habitat during point counts on SPNA, RBR, and MSR in 2008, 2009, and 2010, and in non-prairie dog colony habitat on BE in 2010.

		Prairie Dog Colony Habitat				
Common Name	**Scientific Name**	**2008 (130 points)**	**2009 (300 points)**	**2010 (296 points)**	**Total PDCH**	**2010 BE (112 points)**
American White Pelican *	*Pelecanus erythrorhynchos*				0	9
Canada Goose	*Branta canadensis*			11	11	
Mallard	*Anas platyrhynchos*		3	3	6	
Double-crested Cormorant	*Phalacrocorax auritus*		7	6	13	
Great Blue Heron	*Ardea herodias*		19	4	23	
Turkey Vulture	*Cathartes aura*	2			2	
Northern Harrier *	*Circus cyaneus*	3	8	8	19	
Cooper's Hawk	*Accipiter cooperii*			2	2	
Swainson's Hawk *	*Buteo swainsoni*	1	7	9	17	
Red-tailed Hawk	*Buteo jamaicensis*		6		6	
Ferruginous Hawk *	*Buteo regalis*	1	3	1	5	
Golden Eagle *	*Aquila chrysaetos*		2	3	5	
American Kestrel	*Falco sparverius*	1	19	15	35	
Merlin	*Falco columbarius*		1		1	
Peregrine Falcon *	*Falco peregrinus*			1	1	
Prairie Falcon*	*Falco mexicanus*	3	4	10	17	
Sandhill Crane *	*Grus canadensis*			2	2	
Killdeer	*Charadrius vociferus*		18	14	32	1
Mountain Plover *	*Charadrius montanus*	30	41	14	85	
Greater Yellowlegs	*Tringa melanoleuca*		1		1	
Long-billed Curlew *	*Numenius americanus*	1	9	14	24	
Wilson's Snipe	*Gallinago delicata*		1		1	
Wilson's Phalarope *	*Phalaropus tricolor*			3	3	
Rock Pigeon	*Columba livia*			3	3	
Mourning Dove	*Zenaida macroura*	1	5	4	10	36
Great Horned Owl	*Bubo virginianus*				0	1
Burrowing Owl *	*Athene cunicularia*	9	19	10	38	
Common Nighthawk	*Chordeiles minor*				0	7
Broad-tailed Hummingbird *	*Selasphorus platycercus*			1	1	
Say's Phoebe	*Sayornis saya*	1	11	4	16	4
Western Kingbird	*Tyrannus verticalis*	1	1	3	5	1
Eastern Kingbird	*Tyrannus tyrannus*	1		1	2	
Loggerhead Shrike *	*Lanius ludovicianus*		6	3	9	2
Common Raven	*Corvus corax*		4	7	11	2
Horned Lark	*Eremophila alpestris*	479	1834	1176	3489	441
Tree Swallow	*Tachycineta bicolor*		3		3	
Violet-green Swallow	*Tachycineta thalassina*		4		4	
Unknown Swallow	*Tachycineta spp.*			2	2	
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*				0	6
Cliff Swallow	*Petrochelidon pyrrhonota*	6	2	10	18	86
Barn Swallow	*Hirundo rustica*	8	10	11	29	1
Rock Wren	*Salpinctes obsoletus*	2	7	8	17	10
Western Bluebird	*Sialia mexicana*		1		1	

Common Name	Scientific Name	2008 (130 points)	2009 (300 points)	2010 (296 points)	Total PDCH	2010 BE (112 points)
American Robin	*Turdus migratorius*			2	2	1
Northern Mockingbird	*Mimus polyglottos*		1		1	
European Starling	*Sturnus vulgaris*		2	11	13	
Green-tailed Towhee	*Pipilo chlorurus*				0	7
Spotted Towhee	*Pipilo maculatus*				0	4
Cassin's Sparrow *	*Aimophila cassinii*	1			1	19
Chipping Sparrow	*Spizella passerina*		8	5	13	
Clay-colored Sparrow	*Spizella pallida*		1	4	5	
Unknown Sparrow	*Spizella spp.*			8	8	4
Brewer's Sparrow *	*Spizella breweri*		40	47	87	66
Vesper Sparrow *	*Pooecetes gramineus*	2	46	35	83	95
Lark Sparrow *	*Chondestes grammacus*	1	2	5	8	9
Lark Bunting *	*Calamospiza melanocorys*	20	123	90	233	29
Savannah Sparrow	*Passerculus sandwichensis*		6	2	8	
Grasshopper Sparrow *	*Ammodramus savannarum*	1	4	7	12	42
McCown's Longspur *	*Calcarius mccownii*	411	913	735	2059	
Chestnut-collared Longspur *	*Calcarius ornatus*		6	78	84	
Bobolink *	*Dolichonyx oryzivorus*			2	2	
Red-winged Blackbird	*Agelaius phoeniceus*	1	30	19	50	10
Eastern Meadowlark	*Sturnella magna*			1	1	
Western Meadowlark	*Sturnella neglecta*	56	384	575	1015	182
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*		1		1	
Brewer's Blackbird	*Euphagus cyanocephalus*		28	16	44	14
Common Grackle	*Quiscalus quiscula*		10		10	
Brown-headed Cowbird	*Molothrus ater*	5	14	2	21	13
Bullock's Oriole	*Icterus bullockii*				0	2
House Finch	*Carpodacus mexicanus*		1		1	
Lesser Goldfinch	*Carduelis psaltria*				0	1
American Goldfinch	*Carduelis tristis*			1	1	1
House Sparrow	*Passer domesticus*		2		2	
Total Individuals		**1048**	**3678**	**2998**	**7734**	**1106**

Bold face type indicates high conservation priority status in Canada and the U.S. as determined by Partners In Flight.
* indicates species of special state concern/ threatened determined by the Colorado Division of Wildlife.

Appendix (B)

List of species detected in Butte Pasture (area targeted for oil and gas development) on Meadow Springs ranch Ranch in 2010. (N = number of individual detections).

Common Name	Scientific Name	N
Canada Goose	*Branta canadensis*	1
Double-crested Cormorant	*Phalacrocorax auritus*	1
Northern Harrier	*Circus cyaneus*	1
Swainson's Hawk	*Buteo swainsoni*	1
American Kestrel	*Falco sparverius*	1
Prairie Falcon	*Falco mexicanus*	4
Loggerhead Shrike	*Lanius ludovicianus*	1
Common Raven	*Corvus corax*	1
Horned Lark	*Eremophila alpestris*	84
Cliff Swallow	*Petrochelidon pyrrhonota*	1
Brewer's Sparrow	*Spizella breweri*	1
Vesper Sparrow	*Pooecetes gramineus*	1
McCown's Longspur	*Calcarius mccownii*	41
Red-winged Blackbird	*Agelaius phoeniceus*	1
Western Meadowlark	*Sturnella neglecta*	61
Brewer's Blackbird	*Euphagus cyanocephalus*	6

Bold face type indicates high conservation priority status in Canada and the U.S. as determined by Partners In Flight and is a species of special state concern/ threatened determined by the Colorado Division of Wildlife.