The effects of trophic interactions on brood habitat selection & survival in a declining shorebird, the Mountain Plover

2021 Lois Webster Fund - Final Report

Casey Weissburg
M.S. Graduate Student
Department of Biology
Colorado State University Pueblo

Questions can be directed to:
Casey.weissburg@pack.csupueblo.edu
(925) 360-1142

Figure 1. *A male Mountain Plover pauses between song bouts to look over his territory at Chico Basin Ranch, with a snow-capped Pike's Peak in the background. April 2021, Pueblo co. Colorado. © Casey Weissburg*

INTRODUCTION

North American prairies are a crucial resource for the biodiversity of the region,[1,2] promoting numerous ecosystem services that are critical for the continuation of society as we know it, including methane consumption, carbon sequestration, pest suppression, and pollination,[3,4] as well as soil, nutrient and water retention.[4] These services arise not only from the diversity of species but from the functional roles of those species, which are influenced by species interactions.[5] With over 70% of our native prairies already lost and numerous grassland species in decline,[1,2] understanding the interactions that impact the diversity and function of this ecosystem is more pressing than ever.

However, interactions among species in a community are complex, especially among different trophic levels, carrying both direct and indirect effects. **Predation** is one such interaction and one of the primary drivers of community structure and function, with *direct* costs of mortality, as well as the *indirect* effects of **predation *risk*** on behaviors, such as changes in habitat use.[5,6,7] The spatial and temporal variation in predation risk are characterized as a **landscape of fear,** which creates tradeoffs for prey between meeting energy needs and avoiding predation,[3,8] tradeoffs that in turn influence population fitness.

Investigation into these predator-prey interactions is critical to fill knowledge gaps about our declining prairie communities. The perspective of the **Mountain plover** is especially useful to this end. As a Species of Concern in the state of Colorado, with population losses of over 60%,[9] this upland shorebird occurs in diverse grassland habitats ranging from shortgrass prairie to high plains to mixed-grass prairie, along with varying suites of predator species.[10] The diversity of interactions across this species' range provides an opportunity to examine spatial context of those interactions in different communities. The goal of this research is to fill major knowledge gaps about how Mountain Plovers respond to interactions with predator and prey species of this endangered community. Through the plover's interactions with multiple predators, its prey, and its habitat, we can better understand the species responses at the population level and gain insights into the interactions that shape the community as a whole.

In order to examine the impacts of these trophic interactions at the population level, this research focuses on the brood-rearing phase of the Mountain Plover. **Chick survival** is the vital rate that affects Mountain plover population growth the most after adult survival during migration.[11] Thus, we can use the brood responses as a lens for population responses during the breeding season. This research will quantify two brood responses, a behavioral response, **brood habitat selection**, and a fitness response, **chick survival rates**, to evaluate two hypotheses: **(H1)** Mountain plover brood habitat selection patterns depend on variation in predation risk levels, mediated by forage availability and vegetation structure; **(H2)** Mountain plover chick survival depends on variation in predation risk levels, mediated by forage availability and vegetation structure. In this paper, we report the progress and preliminary findings of this project after the first of two field seasons.

METHODS

Study Areas

Research was conducted at two study sites representing two distinct breeding populations with varying habitat and predator suites. In Pueblo County, Colorado, research was conducted at Chico Basin Ranch (hereafter, CHBR), where the landscape is characterized as shortgrass prairie, with Black-tailed prairie-dog colonies providing a mosaic of bare ground, short-trimmed grass, sparse shrub cover, and widespread cacti. In Park County, CO, research was conducted at James Mark Jones State Wildlife Area (hereafter, South Park or SP), at an elevation above 9,000 feet where the landscape is characterized as high plains, with less bare ground, denser shrub cover, no cactus, and taller grass relative to CHBR. The two sites also differ in the size of the study area, with CHBR encompassing 15 square kilometers and SP encompassing 24.

In addition to habitat differences, the wildlife community varies between the two sites. SP lacks prairie-dogs, while the two sites share the Coyote as the most common mammalian predator, CHBR has Swift fox, while SP has American badger and the occasional Black bear. The predatory bird community is fairly similar between the two, represented primarily but not exclusively by Ferruginous and Swainson's hawks, Common ravens, and Prairie falcons, but CHBR has the addition of the Burrowing owl, a species that eats insects, rodents, and also birds and has the unique breeding strategy of utilizing prairie-dog burrows for nesting.

Figure 2. *Photographs illustrating to varying habitats of the two study areas, with CHBR (top) having more grass, bare ground and cacti, while SP (bottom) has a more even distribution of short grass and shrubs, with reduced bare ground and no cactus.*

Brood Responses
Due to phenological differences between the two study areas, research was conducted at CHBR from April 1 until July 23, and at SP from June 23 until September 1, although nest searching efforts began at SP in mid-May in coordination with Allison Pierce of the CU Denver Wunder Lab. Breeding surveys were conducted following the guidelines of Knopf (2002),[12] and breeding pairs were observed extensively from a distance or in a blind until nests were located. Hatch dates were estimated by egg flotation[13] and nests were checked every 3-5 days until hatching. Adults were trapped on the nest using a bow-net to color-band for easy identification of brood parents. Whenever possible, chicks were banded on the day of hatching, while still in the nest cup to minimize disturbance. Broods that were discovered at later dates were also opportunistically captured and banded. One chick from each captured brood was randomly selected for deployment of VHF radio-transmitting tags (Lotek Ag379 PicoPip), affixed by epoxy to a small patch on the back clipped free of down. Tagged broods were then tracked by radio telemetry and daily locations obtained, until fledging or death were confirmed.

Environmental Covariates
Three main environmental **covariates** are evaluated in this research: predation risk, forage availability, and vegetation structure. All three covariates were sampled across a standardized landscape-wide grid to assess **spatial variation**, with locations spaced 600 meters apart. Due to differences in the size of the

study areas, CHBR had 38 sampling locations and SP had 70. Each covariate was evaluated by multiple measurements.

Predation risk was evaluated by quantifying **encounter rates** of **both mammalian and avian predators. Mammalian predator encounter rates** were quantified as detections from trail cameras, adjusted by the number of active camera nights. **Avian predator encounter rates** were generated from standardized 10-minute point counts surveys, with raw counts adjusted by the number of surveys and to an hourly rate for three groups, based on anecdotal relevance to plover broods: all raptor species together, Burrowing owls, and Common ravens. Raptor counts were conducted once per week, while cameras were active continuously for 3-4 weeks, beginning when the first nests hatched for the duration of the brood-rearing phase.

Forage availability was evaluated by two measures as well: dry biomass of arthropods, sampled using pitfall traps set for 72 hours, and dry biomass of grasshoppers, sampled by net-sweeping. Sampling was conducted once, during the period of peak brood activity for each study area (June 17-22 at CHBR, July 19-August 7 at SP). Insect samples were frozen on the day of collection and later thawed and sorted to exclude individuals with body lengths larger than 20 millimeters, as similar-sized shorebird species have been shown to select for prey under this size.[14] Sorted samples were then dried in a drying oven at 32 degrees Celsius for 68-72 hours.[15] Dry biomasses were adjusted by sampling effort.

Vegetation structure was evaluated using three measures of vegetation density: percent bare ground, average groundcover height, and shrub density. 0.25 square-meter quadrants were used to assess percent bare ground and the heights of groundcover including grasses and forbs at five meters from the central point in the four cardinal directions, to be averaged for each sampling location.

Statistical Analysis

Brood home ranges will be estimated using Minimum Convex Polygons (MCP) and used to parameterize Resource Selection Functions in order to assess preferential use of a location compared to estimated spatial variation of *forage availability*, *predation risk* and *vegetation structure*. Chick survival will be estimated from daily survival rates.[5,16] **Covariates** will be rasterized and interpolated to a finer resolution in QGIS. The two brood responses, **habitat selection** and **chick survival,** will then each be modeled independently as functions of **predation risk**, **forage availability**, and **vegetation structure**, in a series of *a prior* models to be compared for best fit using AIC model selection.

RESULTS

Plover Monitoring

We located 14 nests at CHBR and 38 at SP. At CHBR, 4 nests successfully hatched, and 20 hatched at SP, along with at least 12 unknown nests whose broods were later encountered. Altogether, we tagged and tracked chicks from 25 broods (3 in CHBR, and 22 in SP) daily from hatch date or discovery until chicks fledged or were lost to predators or unknown causes.

Of the 25 broods, 8 were successful at fledging at least one chick (1 in CHBR and 7 in SP). 12 broods were confirmed lost to predators (2 in CHBR and 12 in SP) while 6 other broods were lost for ambiguous reasons, such as tags dropping or signal loss, where depredation was suspected but could not be confirmed.

Brood Home Ranges

Of the 25 tagged broods, only 20 provided enough location data to use for analyses. From daily locations, MCPs were generated for each brood, mapped on the landscape in Figure 3 (CHBR) and 4 (SP). Home range sizes at CHBR ranged from 4.86 to 60.77 hectares, while at SP they ranged from 8.75 to 347.44 hectares, with broods at SP in general ranging farther throughout their pre-fledge phase.

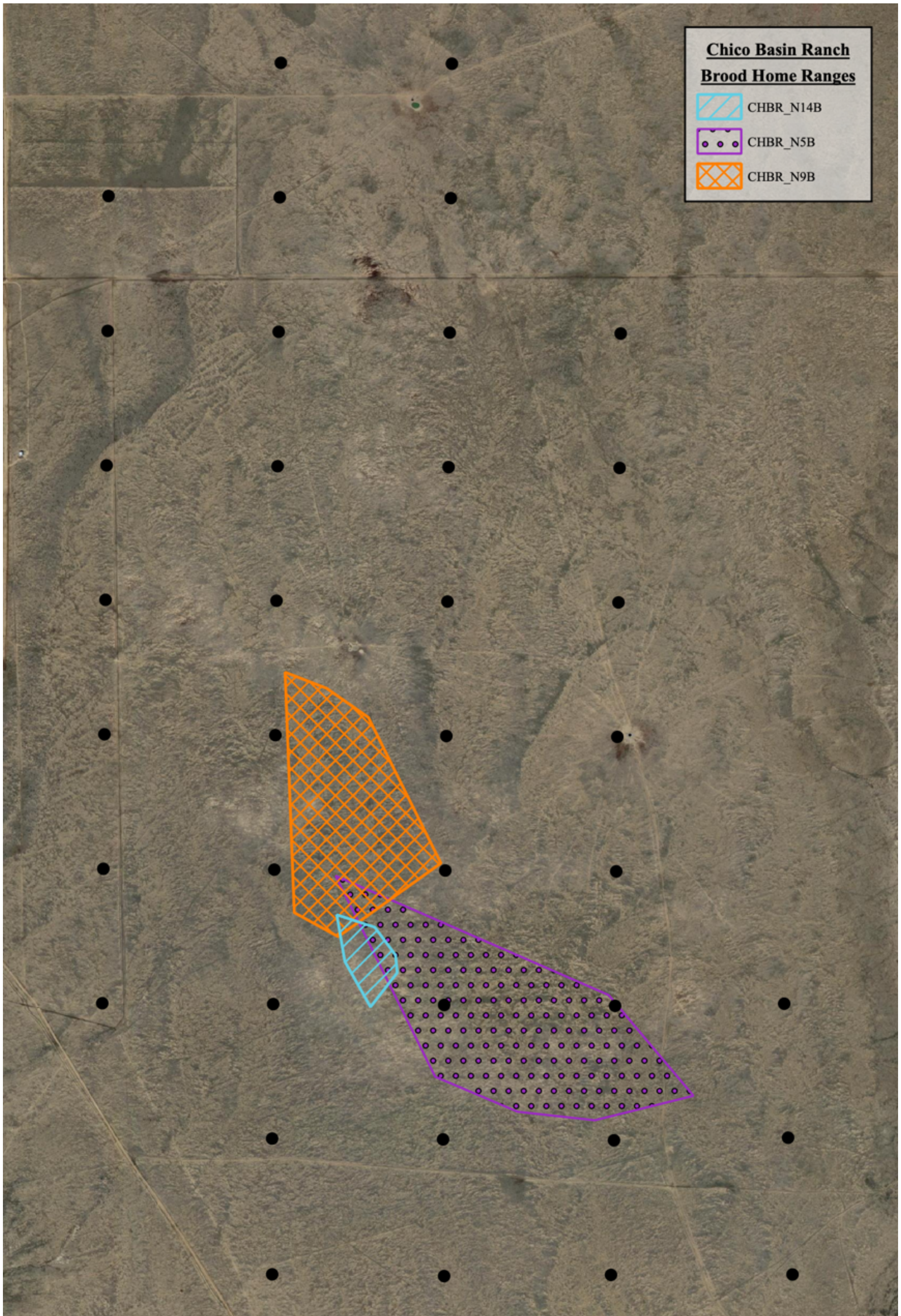

Figure 3. *Minimum Convex Polygon home ranges for the three tagged broods from Chico Basin Ranch, Pueblo co. Colorado.*

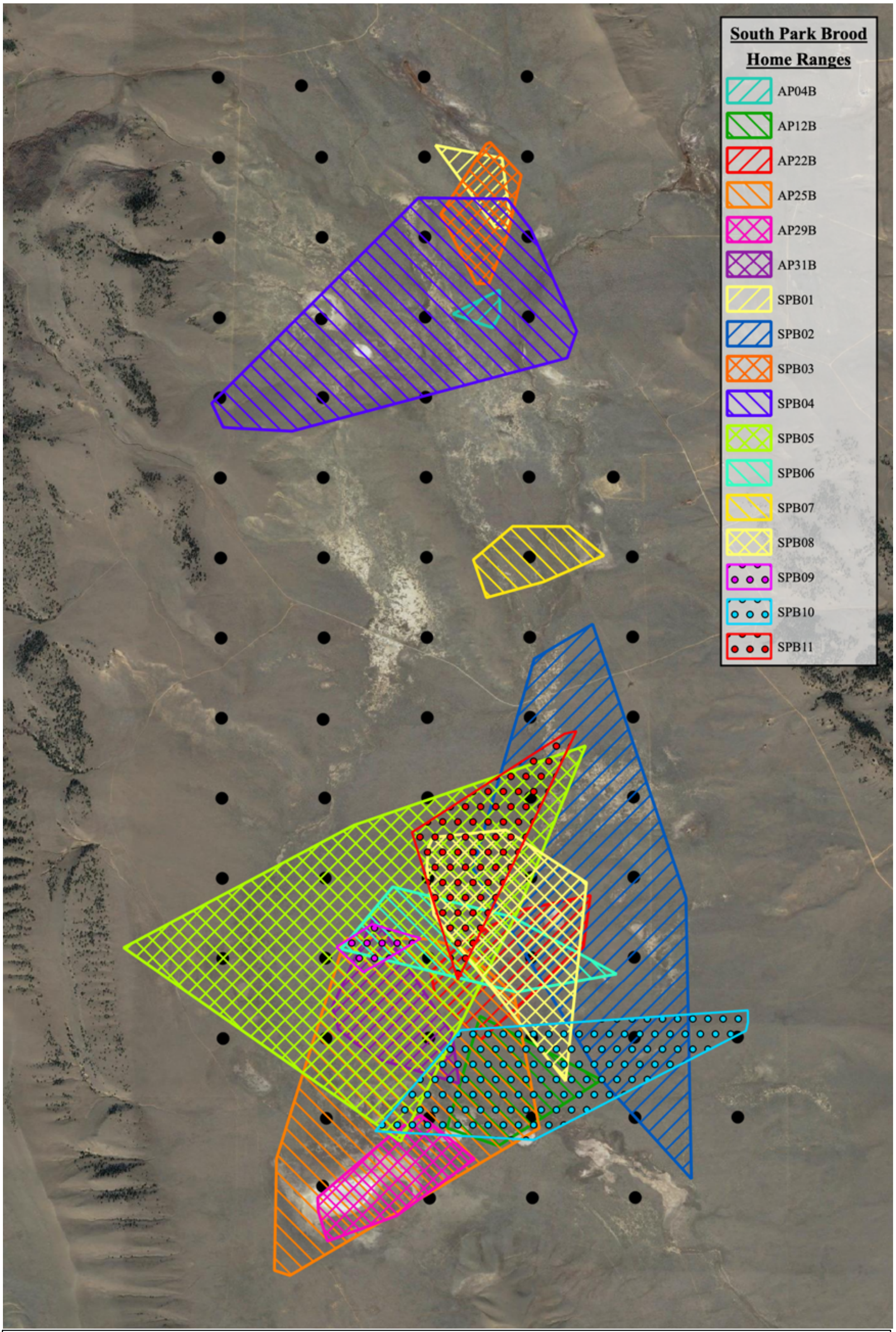

Figure 4. *Minimum Convex Polygon home ranges for the three tagged broods from South Park, Park co. Colorado.*

Environmental Covariates

We collected an extensive amount of data that will take some time to process and analyze. As of the end of October, we have processed data on all covariates at CHBR, with data processing for SP still in progress. Preliminary correlation tests of covariates at CHBR were performed using the Spearman's rank correlation method for nonparametric data and resulting correlations can be seen in Table 1 along with the mean and standard deviations of all covariates.

Covariate	Mean	St.Dev.	Corr
Average Encounters per hour of All Avian Predators	10.53	3.88	A
Average Encounters per hour of Burrowing Owl	2.86	3.22	B, C, I
Average Encounters per hour of Common Raven	1.10	1.64	B
Average Encounters per day of Mammalian Predators	0.03	0.05	C
Average Bareground per square meter	54.80	13.09	D
Average Groundcover Height per square meter	13.61	4.59	E, H
Average Shrub Heights (cm)	20.87	19.48	F
Shrub Density per square meter	0.04	0.06	F
Dry Biomass of Insects (grams)	0.30	0.16	G
Dry Biomass of Grasshoppers (grams)	0.12	0.17	H, I

Table 1: *Means, standard deviations, and correlations of all environmental covariates. Correlations between covariates are indicated by same letters, with covariates of the same letter having a significant correlation (p-value < 0.05).*

Statistical Analyses

Statistical analyses of the influences of covariates on brood habitat selection and chick survival will be performed this winter after data processing is completed.

DISCUSSION

Initial impressions from our observations in the field suggest many interesting interactions between Mountain plover broods and their predator, prey and vegetation communities. For example, there is a fascinating and potentially significant interaction between Mountain Plovers and Burrowing Owls at Chico Basin Ranch. Our anecdotal observations in the field suggest that although a plover nests within a prairie-dog colony where it shares habitat with the owls, as soon as the precocial chicks hatch and leave the cup, the plover brood quickly moves to areas where we detected fewer owls. Even though plovers potentially benefit from listening in on alarm calls from prairie-dogs to avoid predation, the danger from owls still exists as owls were responsible for two of our three confirmed predations of tagged plover chicks at CHBR. The statistical significance of this interaction remains to be confirmed, but this is just one of several interactions that we look forward to modeling.

We anticipate that plover broods at CHBR will select for habitat with lower Burrowing owl encounter rates and moderate-density vegetation structure, regardless of forage availability. We anticipate that these selection patterns will differ at SP, where there are no predictable predators like the Burrowing owl, and thus broods at SP will select for forage availability regardless of predator encounter rates and vegetation structure. We further anticipate that these responses will be associated with differential chick survival rates.[17,18]

In conclusion, this season was long and challenging, but a very successful first season of my Master's thesis research. Funds allowing, we intend to collect another season of data next year. In the meantime, we will conduct preliminary data analyses and look forward to presenting some insights during the annual LWF program as well as the CFO conference in May.

ACKNOWLEDGEMENTS

We want to acknowledge the many people and organizations who made it possible for me to build and actualize this new and complex project from scratch. This research would not have been possible without the research grants provided by the **Lois Webster Fund of Denver Audubon** and **Colorado Field Ornithologists**, nor without the trail cameras graciously loaned by **Colorado Parks and Wildlife**. I also want to acknowledge the invaluable advice and administrative support of my graduate advisor, **Dr. Claire Ramos of CSU Pueblo**. Furthermore, the fieldwork of this labor-intensive project could not have been completed without the assistance of the undergraduates of CSU Pueblo's **Communities to Build Active STEM Engagement program:** Chrissy Gatian, Shawn Overby, and Elissa Velasquez, nor without the aide of Zoe Erkenbeck of CU Denver and the collaborative exchange of knowledge, data and friendship that I shared with the **Wunder Lab of CU Denver**. Additional thanks go to my colleagues, Edward Lande, Ellen Norton, Samantha Bundick and Hunter Westacott, whose field and emotional support got me through some of the most trying periods of a five-month, 1,000-mile field season. We are so grateful for all of the support and effort that went into this project.

Figure 5. *Freshly hatched chicks rest in the nest cup after being banded and tagged, while their parent hovers anxiously nearby. July 2021, CHBR, Pueblo co. Colorado.*

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