An Assessment of Grassland Bird Communities, Shrub Use, and Reproduction In the Context of Shrub Encroachment

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Authorization to Submit Thesis

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Abstract

Grassland communities are declining and are considered an endangered ecosystem in North America. The decline in grassland community's extent and availability directly influences the grassland bird community. One cause of the decline in grassland communities is the increasing encroachment of shrubs into grasslands. This thesis explores grassland bird in a wet meadow system experiencing shrub encroachment, mainly by black hawthorne (*Crataegus douglasii)*, in Weippe Idaho. In the first chapter, we report how artificial nest temperatures are influenced by distance from shrubs. Shrubs act as a temperature buffer from extreme temperature fluctuations. In the second chapter, we describe the avian community on the Weippe Prairie and report how birds are using the shrubs on site. Shrub use is evaluated by season, time of day, and species.

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Dedication

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

GENERAL INTRODUCTION

Grassland communities have declined by almost 80 percent and are considered among the most endangered ecosystems in North America (Samson and Knopf, 1994), and the decline of grassland communities' availability has changed the abundance and distribution of grassland bird species (Herkert, 1994). Studies have focused on several main factors driving changes in grassland composition, extent, and availability: climate change and increasing atmospheric CO2 levels (Parmesan, 1996); the conversion of prairie to agricultural fields (Askins et al., 2007); livestock grazing (Askins et al., 2007; Bachelet et al, 2000); fire suppression (Smit et al., 2010; Trollope, 1984); invasive and non-native plant species (Skorka et al., 2010; Lloyd and Martin 2005); and shrub encroachment (Coppendge et al., 2001; Sirami et al., 2009; Sirami and Monadjem, 2012). The decline in grassland communities is due to all of these factors individually and synergistically, and grassland bird declines are generally declining as grasslands decline in quantity and quality; since 1970, declines are 70% in species that winter in Mexico and 33% in other temperate species (State of the Birds, 2016).

Shrub encroachment is among the factors in grasslands that have been shown to influence grassland bird species and communities; mechanisms that influence shrub encroachment include climate change, the presence of windbreaks, and grazing. For instance, climate change is a significant factor in the distribution and abundance of northward geographical range shifts in shrubs causing habitat alterations (Parmesan, 1996; Parmesan and Yohe, 2003; Pimm et al., 1995; Strum et al, 2001). The warming temperatures, increased rainfall at higher elevations and increased atmospheric CO_2 levels facilitates these range shifts (Parmesan and Yohe, 2003). For example, Strum et al. (2001) examined four plant species in the arctic: dwarf birch (*Betula nana*), willow (*Salix* sp.) and green alder (*Alnus crispa*), and for changes in treeline, white spruce (*Picea glauca*). Between the 1950's and 2000, dramatic increases in shrub diameter and height as well as significant in-filling were found in over half of their study area (400km by 150km). Strum et al. (2001) asserted that these changes in plant range shifts were a result of climate change because of the minimal anthropogenic and natural disturbance in the area.

Windbreaks usually consist of non-native woody shrubs that were previously not present on the landscape, and the presence of windbreaks can influence grassland bird diversity and abundance (Ellison et al., 2013). Windbreaks typically surround grasslands that have been converted into agricultural fields. This conversion has created a homogenous or monodominant ecosystem, and while these agricultural fields can serve as habitat for some bird species, they can also act as ecological traps (Askins et al., 2007). In addition, the installation of windbreaks can increase predation of grassland bird nests along these linear features (Ellison et al., 2013), while also changing the breeding bird community to include more shrub nesting species.

Livestock grazing and fire might also influence shrub encroachment. Grazing reduces herbaceous biomass above and below ground, which may increase shrub cover via reduced competition for resources (Askins et al., 2007). Livestock can also reduce shrub biomass, but typically, herbaceous resources are preferred (Martin and Possingham, 2005). Because fire frequencies and intensities are influenced by the vegetation that is present, changes in grass biomass and shrub densities will alter fire intensity and the ability of fire to move across the landscape. In some areas, a decrease in fire frequency has resulted in an increase of shrubs because established shrubs are not suppressed to the extent they once were naturally (Briggs et al., 2002). The encroachment of woody plants into grasslands has increased (Archer, 1994; Gibbens et al., 2005; Van Auken 2000, 2009) and Asia, Africa, Australia, Europe and North and South America are actively studying this phenomenon (Coppedge et al., 2001; Eldridge et al., 2012; Maher et al., 2010; Sirami et al., 2009). Encroachment is occurring in open woodlands, savannahs, rangelands and grasslands and converting these systems to shrublands or closed woodlands across the globe. During these transformations, grass biomass declines as woody biomass increases as well as woody cover and density. For example, Briggs et al. (2005) evaluated over 20 years of research on woody cover expansion. This shift (from grassland to shrubland) alters plant productivity, species diversity, and once shrubs have established in an area, they are very difficult to eradicate.

Patterns of shrub encroachment are dependent on the ecosystem in which they are occurring. For example, deserts, savannahs, mesic grasslands, and arctic systems are all experiencing shrub encroachment in a unique way (Naito and Cairns 2001). Each of these communities are complex but shrub encroachment generally follows the same process: 1) shrub in-filling occurs in existing shrub patches, 2) shrub size increases and, 3) shrubs expand into new areas (Goslee et al., 2003; Tape et al., 2006). Mesic grasslands and savannahs are unique in that facilitation of shrub encroachment is by high-intensity grazing, fire exclusion and woody species adaptive techniques to nutrient poor sites (Miller et al., 2008; O’Connor, 1995). One of the adaptive traits that shrubs have are their deep roots; these roots often allow them to access deep moisture stores not accessible to shallow-rooted grasses.

The goal of this thesis was to evaluate the effects of shrub encroachment in a grassland community on avian reproduction, avian community composition, and shrub use. It is important to understand how shrub encroachment is influencing grassland bird communities with the continuing decline of grassland birds. In order to preserve the existing grassland communities, providing baseline data can be useful for planning management actions for conservation activities. Shrub encroachment can have multiple simultaneous positive and negative effects on birds and other wildlife. The specific objectives for this research were 1) to evaluate factors influencing nest microclimates in a shrub encroached grassland, 2) examine bird community composition across a shrub density gradient and bird use and behaviors as a function of shrub height and density.

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CHAPTER 1

Factors influencing nest microclimate for grassland birds in shrub-encroached wet prairie systems

Introduction

Shrub encroachment is a widespread process that influences grassland communities (Sirami et al. 2009, Sirami and Monadjem 2012, Sherer et al. 2016). Not only does shrub encroachment change the vegetation composition and structure of grasslands, it is also one of several factors driving changes to grassland extent and availability (Sirami et al. 2009, Sirami and Monadjem 2012,). In North America, rates of encroachment vary among rangeland types (increases between 0.1–2.3 % cover per year; Barger et al. 2011) while grasslands in the west have been reported to be experiencing encroachment rates of 22-30% between 1985 and 2005 (Sankey and Germino 2005). Reported rates of change in shrub encroachment in Africa, Australia, and South America are comparable to those observed in North America (0.1–1.1 % cover year; Stevens et al. 2016).

Grassland habitat management involves the manipulation of vegetation structure and composition, and managers are often faced with making decisions to accommodate multiple management objectives. Shrub encroachment can have multiple simultaneous positive and negative effects on birds and other wildlife. For example, as shrub encroachment increases, birds that specialize in grasslands may be replaced by birds of shrubby or woodland habitats (e.g. State of the Bird Report, 2010). Bird communities also experience a higher likelihood of shrub nesting species in an area where shrubs are present compared to a site without shrubs (Ingold and Dooley 2013). In addition to the presence of shrubs, increases in the availability of perch points for avian predators heightens predation risk for songbirds (Burger 1988, Duguay and Wood 1997, Renfrew and Ribic 2003), and Ellison et al. (2013) found that the presence of woody vegetation attracts woodland associated predators including snakes and mammalian species.

As shrub encroachment into grasslands increases, it is additionally important to understand patterns of microclimate variation across these landscapes because there are likely multiple resources and processes sensitive to these changes in temperature (Elmore et al. 2017; Figure 1.1). Elmore et al. (2017) suggest thermal environments should be understood for managers to adequately address the full extent of habitat management and restoration for species of concern. For instance, the magnitude of the effect of shrubs on microclimate (represented here by temperature) might be a function of the distance from the shrub, clumping of shrubs, and shrub canopy cover and height (Figure 1.1). The thermal environments that can affect plant and animal communities might include aspects such as daily and/or seasonal variability in temperature range, maximum temperatures, and minimum temperatures (Figure 1.1). For instance, changes in shrub cover can influence nocturnal temperatures (He et al. 2011). He et al. (2011) simulated nighttime temperature differences between a shrubland and grassland located 5km apart using a coupled land-atmosphere model. They found shrublands became warmer than grasslands during nighttime by ~ 1.8°C. Herbaceous cover has been found to decrease in the presence of shrubs compared to open grassland areas (Good et al. 2013) which can increase the amount of bare soil near shrubs. The presence of shrubs was proposed to influence nighttime temperatures because of increased radiation from bare soils surrounding shrubs as compared to the lower radiation from the grasslands during nighttime (He et al. 2011).

Changes in microclimates associated with shrubs can influence the biogeochemical processes of the area, which can then influence vegetation decomposition and nutrient availability in the grassland community, demonstrated across multiple biomes (e.g. Arctic tundra, prairie; Mclaughlin et al. 2014, Predick et al. 2018). For example, Predick et al. (2018) examined UV-B radiation on decomposition in a Sonoran Desert grassland experiencing increases in shrub cover. UV radiation is considered an important driver of biogeochemistry in grasslands and the presence of shrubs can alter both abiotic and biotic drivers of biogeochemistry (such as slowing decomposition rates and lowering solar radiation; Predick et al. 2018). They found leaf litter decomposition was slower under shrubs, where daily ground temperatures and total solar radiation was lower than locations away from shrubs. Their findings differ from He et al. (2011) regarding different ground temperature patterns as a function of distance from shrubs; this is likely because Predick et al. (2018) examined day time temperatures whereas He et al. (2011) was focused only on night time temperatures. These studies demonstrate that temperatures associated with shrubs are cooler during the day and warmer at nighttime compared to open grassland areas. This difference would influence the microclimate of a nest and the temperatures of the developing embryo. In addition, Predick et al. (2018) suggest that landscape-scale decomposition could decline with increases in woody plant canopy cover owing to shrub-driven changes in microclimate, and these differences might influence the herbaceous groundcover found within these grasslands. Good et al. (2013) found herbaceous groundcover in grassland dominated patches was significantly greater than in shrub encroached patches (~65% compared to ~ 16%), and this might be associated with nutrient availability in addition to competition for resources (e.g., light and water). Vegetation characteristics have been found to mediate nest microclimates (Carroll et al. 2015b) and changes in the vegetation may influence the amount of temperature mediation that can occur through the vegetation at a nest time. Further, carbon balance in the arctic tundra can be impacted by temperature and through leaf respiration rates (McLaughlin et al. 2014). McLaughlin et al. (2014) assessed the inhibition of respiratory response between grasses and shrubs to long-term temperature warming. They found grasses were able to respond and acclimate to long-term temperature warming but woody shrubs were unable to acclimate. With changes in species dominance as shrubs encroach into grasslands and warming continues, respiratory response and carbon balance may be impacted as well as the process of nest site selection.

The thermal environments of a landscape can affect animal physiology, behavior, survival, and reproduction (Feder 1987, Angilletta 2009, Cossins 2012, Deeming and Reynolds 2015). Thermal refuge for species trying to escape temperatures beyond critical thresholds plays an important role because much of the landscape can exceed the temperature tolerance for organisms to the point that survival is affected (Gilchrist 1995, Suggitt et al. 2011, Tanner et al. 2017), which may lead to population declines (Lenarz et al. 2009, Sinervo et al. 2010). For example, Carroll et al. (2015) found maximum temperatures of microclimates at northern bobwhite nest sites in western Oklahoma, USA, were at least 10°C cooler than paired random sites. This temperature difference was explained by vegetation characteristics such as vegetation height at the nest and angle of obstruction of the nest from solar radiation (Carroll et al. 2015a) and this demonstrates the important aspect of vegetative cover and how it relates to thermal refuges (Hovick et al. 2014, Bestion et al. 2015, Carroll et al. 2015b, Payne and Smith 2017).

Thermal environments are only recently being explicitly considered in management actions for wildlife (e.g. Carroll et al. 2015a, Elmore et al. 2017). It is important to understand how thermal characteristics of landscapes vary across space and time in addition to species-specific thermal tolerances (Cunnington et al. 2008). For birds, temperature patterns are likely to influence nesting activities, particularity during incubation and hatchling phases. Temperatures above 40 °C are generally lethal to avian embryos, and optimal embryonic development occurs between 34 °C and 40 °C, depending on the species (Webb 1987; DuRant et al. 2013; Mainwaring 2015). When temperatures are less than 24–26°C (Webb 1987; DuRant et al. 2013; Mainwaring 2015) avian embryonic development is suspended, but adult birds can generally mediate egg temperature through incubation activities (e.g. see review by Deeming 2008).

There is a large body of literature that addresses thermal environments regarding avian nesting in tree cavities (e.g., Vierling et al. 2018, Wiebe 2001, Haftorn and Reinertsen 1985). To date, however, there are few studies that explicitly describe the temperature influences of shrubs on adjacent patches of grassland. He et al. (2011), McLaughlin et al. (2014), and Predick et al. (2018) focused on how shrub encroachment affected vegetation and biogeochemical cycles under shrubs and away from shrubs; however, no studies have examined how temperature regimes are affected by structural changes that result from shrub encroachment (in this case, distance from shrub). The objective of this study is to evaluate the effects of shrub characteristics on summer microclimates (e.g., temperatures) in a grassland ecosystem experiencing shrub encroachment using artificial bird nests. Specifically, our objectives were to: 1) describe how temperatures varied within summer months and across years in a temperate wet meadow grassland experiencing shrub encroachment, and 2) to model the influence of local vegetative characteristics (including herbaceous plant height and shrub cover) on thermal regime of artificial nests placed on the ground to mimic grassland bird nests. In this shrub encroached grassland, we hypothesized that shrub characteristics (distance from focal shrub and height of the nearest focal shrub) are the most important factors determining changes the thermal regime in artificial nests. This study provides a temperature baseline for comparison in grassland and shrubland environments. Additionally, it is the first study which examines the magnitude of temperature effects as distance from a shrub increases. Finally, it provides specific temperature data which can be used to assess management and restoration plans for sensitive wildlife species.

Study Site

The study area is located on the Weippe Prairie (hereafter WP), a National Historic Landmark managed by the Nez Perce National Historical Park (NEPE). WP is a characteristic north Idaho wet meadow and is located approximately 2.4 km south of Weippe, Idaho (46°21’16.04” N, 115°55’17.66” W) in Clearwater County (Becker 2016). The site is 111 ha in size and is composed of large open grassland sections, native black hawthorn (*Crataegus douglasii*), small ponds, manufactured canals, and a stretch of approximately 1.6 km of the perennial Jim Ford Creek (flowing southeast to the northwest). The site is extremely flat, with < 1 m difference in altitude between its highest and lowest point (Rodhouse et al. 2011). The average annual precipitation ranges from 71cm to 139cm of rainfall and 289cm to 612cm of snowfall (WRCC 2015). Average high temperatures in nearby Pierce, Idaho (~16km from WP) are approximately 27˚C in summer and 2˚C in winter (WRCC 2015).

The Weippe Prairie is a grassland community within the Northern Rockies ecoregion (Mcgrath et al., 2002). It was primarily used for hay and cattle grazing after European settlement, but cattle grazing activities ceased in 2008 after the acquisition of the property by the United States National Park Service (Becker et al., 2016). The extent of historical haying on WP is unclear but there is documentation of approximately 27% of the site being used for hay up until 2003 (H. Tamm, personal communication). Native forbs and grasses are dominant on the site and include small camas (*Camassia quamash)*, plantainleaf buttercup (*Ranunculus alismifolius*), tufted hairgrass (*Deschampsia cespitosa*), and California oatgrass (*Danthonia californica*) and are intermixed with non-native creeping bentgrass (*Agrostis stolonifera*), timothy (*Phleum pretense*), meadow foxtail (*Alopecurus pratensis*) and smooth brome (*Bromus inermis*; Becker et al. 2016).

The current management focus is restoring small camas populations because it is an important cultural resource for the site and for the Nez Perce tribe. At our study site, small camas is a focal species for management, and those seeds require 42-100 days of temperatures (34-40° C) under moist stratification for maximum germination (90-100%) (Emery 1988, Deno 1993, Guerrant and Raven 1995). Currently, canals are being infilled, and weed management is occurring for specific plants, including but not limited to orange hawkweed (*Pilosella aurantiaca*), common tansy (*Tanacetum vulgare*), and reed canary grass (*Phalaris arundinacea*). Black hawthorn shrubs are present throughout the WP at various heights and densities, and due in part to the lack of grazing and fire, shrub densities have increased since the mid-2000s (J. Lyon, personal communication; Figure 1.3). Black hawthorn represent 99% of the shrubs on site and the other 1% are snowberry *(Symphoricarpos albus*. It is important to note for the purposes of this study that the black hawthorn on WP is referred to as a shrub because of its multiple non-dominant stems regardless of its height. Birds that breed at this site include western meadowlarks (*Sturnella neglecta*), red-winged blackbirds (*Agelaius phoeniceus*), savannah sparrows (*Passerculus sandwichensis),* eastern kingbirds *(Tyrannus tyrannus)* and bobolinks *(Dolichonyx oryzivorus).* The three species documented on site were on the USGS Species of Greatest Conservation Need in Idaho (bobolinks; sandhill cranes, *Grus canadensis*; and Wilson's Phalarope, *Phalaropus tricolor;* Ehlen, unpublished data).

Methods

We sampled nest temperatures between mid-June and mid-July of 2017 and 2018. Although many bird species nest earlier in the summer, several species (western meadowlarks, savannah sparrows, and eastern kingbirds) are still noted to have eggs in the nest into early July (Wheelwright and Rising 2008, Vickery 1996). To evaluate shrub effects on temperatures, we used artificial grass nests composed of a mixture of grass and coconut fibers that were weaved together (purchased from a craft store) and placed iButton dataloggers (DS1921G Thermochron iButtons; accuracy ± 1.0° C, resolution 0.5° C; Embedded Data Systems, Inc.) in the nest cup. In addition to the iButton, we placed a quail egg and a waxed wooden egg in the nest cup to assess depredation patterns for a different study (results not reported here).

In 2017, we placed a total of 78 nests with iButtons around 9 large focal shrubs. Focal shrubs were large groupings of shrub stems in close proximity to each other (stems ≤ 1m from each other). These focal shrubs are prominent features of these grasslands (generally > 4m in height), and we chose focal shrubs that had no other shrubs > 1m in height within a 30-m radius because we wanted to minimize the potential effects other shrubs might have on the nests themselves. At each focal shrub, we established a transect in each cardinal direction. We placed three nests along each transect; one nest was placed at the edge of the focal shrub (distance 0) and the other nests were placed 10 and 20m from the focal shrub edge. Nests were placed within 1m of the exact distance measured from the focal shrub within any form of vegetation to avoid any nests placed on bare ground. Temperature data were gathered hourly over the course of a 5-day sampling period. A sample period lasted 4 nights and there were two sample periods: sample period one lasted from June 15 to June 23 and sample period two from June 30 to July 8. Two sampling periods were carried out to span the entirety of the breeding season.

In 2018, 78 nests were placed around the same nine focal shrubs and an additional 9 shrubs were added to the study design as there were no other large shrubs to include within the study area. Adding shrubs of varying heights allowed us to assess shrub effects on temperature for a wider variety of shrub heights. Because there were no statistical differences in mean temperature between transects around individual shrubs during 2017 ($p = >0.20$), we reduced the number of transects around each shrub the following year. We placed 3 nests along a single transect radiating from each shrub center and placed nests at distances 0, 10, and 20m from the shrub. In 2018, we also added external iButtons to nests located at 0 and 20m from each shrub to record ambient temperatures by placing them immediately outside of the nest and covered them with a solar shield to protect them from solar heat exposure (Hubbart et al. 2005). Temperature data were gathered at 4-hour intervals over the 5-day sampling period. The duration of each sampling period was the same as in 2017, and occurred at roughly the same time during the summer. Sampling period one extended from June 5 to June 13 and sampling period two extended from July 2 to July 9.

Vegetation was measured at each artificial nest site after sampling ceased and artificial nests were retrieved. The nest site and surrounding 5m was measured for nest concealment, herbaceous cover (dead and live), and vegetation height following Martin and Geupel (1993). Nest concealment was measured by placing a 6.5cm-diameter ball marked with a grid of 61 dots into the nest and recording the number of dots visible from a distance of 1m directly above the nest (Nelson and Martin 1999). We measured herbaceous cover surrounding the nest sites by estimating percentages of grass, forbs, and bare-ground using ocular estimation within 1m of the nest (Martin and Geupel 1993). Vegetation height was taken at the nest and 0.25m, 0.5m, 1m, and 3m from the nest using a pole marked in 10cm increments. Shrub locations recorded using a Trimble using National Agriculture Imaging Program (NAIP) imagery from 2018 at 1m resolution (USDA-FSA-APFO) and on-site visits between September and November 2016, and shrub height measurements were collected using a laser range finder.

Analysis

Daily average temperatures were calculated for maximum temperature (hereafter T_{max}), minimum temperature (T_{min}), and temperature range (T_{range}) for each nest, and only temperature readings between days 2-4 of each of the two sampling periods were used in the calculation of the average T_{max}, T_{min}, and T_{range}. T_{max}, and T_{min} were defined by a 24-hour daily period (0:00-24:00) and T_{range} was calculated by taking the average T_{max} minus the average T_{min} of all sampling periods combined for each nest to demonstrate the temporal variation each nest experienced between day and night. Sampling periods were combined for T_{range} because there was no statistical difference between sampling periods. We calculated the proportion of nests that exceeded 40°C because multiple studies have found temperatures above 40 °C are generally lethal to developing avian embryos (e. g., Vierling et al. 2018). To identify the factors affecting nest temperatures (T_{max} and T_{min}), we used mixed-effects linear regression modeling, applying standard model-selection procedures based on Akaike Information Criterion AIC values (Burnham and Anderson 2002). To avoid pseudoreplication due to multiple sampling periods, we treated unique nests as a random effect. Fixed effects included local vegetative canopy cover over the nest (continuous, numerical), proximity to nearest shrub (categorical), height of focal shrub (continuous, numerical), an interaction between proximity to focal shrub and its height, sampling period and year. In addition to the individual fixed effects variables listed, an interaction term between height of focal shrub and distance from focal shrub was included.

We followed the 10-step protocol for fitting a mixed-effect model (Zuur et al. 2009) and all of the assumptions were met (Appendix 1). We ran several model combinations as well as a null and global model (n=15; Table 1.1). To test for best model fit, we used AIC selection and models within a ΔAIC ≤2 were considered to have similar explanatory power (Burnham and Anderson 2002). A second-order corrected AIC (AIC_c) was used because sample sizes were small (*n/k* < 40; Burnham and Anderson, 1998).

Results

A total of 7,277 hours of temperature data were collected for all nests (n=156) and an average of 63 ± 25.4 temperature readings were taken per nest. We found that nest microclimates experienced extreme temperature ranges (-2°C to 63.5°C) compared to ambient temperature (0°C to 43.5°C) throughout 24-hour periods (Table 1.4). The two top models (ΔAIC <2) explained mean T_{max} and T_{min} but the final top model for T_{min} was different than for T_{max} (Table 1.2). For mean T_{max}, the top model included all predictor variables and no interaction between distance from focal shrub and focal shrub height (Table 1.3). Significant predictors for mean T_{max} included distance from focal shrub, herbaceous plant height at the nest, and year (Table 1.3). Distance from focal shrub had a positive relationship with mean T_{max} while herbaceous plant height at the nest was negatively associated with mean T_{max} (Table 1.3). The top model for mean T_{min} included all the predictor variables but also included an interaction term between distance from focal shrub and focal shrub height (Table 1.3). The two significant predictor variables in this model were year and the interaction term (distance from focal shrub interacting with focal shrub height). Both the interaction term and year had a strong negative relationship with mean T_{min} (Table 1.3), so as distance from focal shrub and focal shrub height increased, T_{min} decreased or became cooler.

Shrubs acted as buffers against thermal conditions occurring on the surrounding landscape for nests at 0m by remaining cooler during the day (on average 13.75°C) and warmer at night (on average 1.38°C) than nests away from shrubs. Furthermore, artificial nest at 10 and 20m from the shrub experienced higher absolute T_{max} (the average between 2017 and 2018 as 57.75°C) compared to the absolute ambient maximum temperature (43.5°C) demonstrating a different of 14.25°C compared to nests under the shrub. Site specific differences in artificial nest microclimates were driven by distance from shrub (T_{max} and T_{min}) and herbaceous vegetation cover (T_{max}; Table 1.4). Vegetation measurements relating to focal shrubs and nest sites were highly variable. Focal shrub heights ranged from 1.21m to over 5m in height with the majority of the focal shrubs >4m (Table 1.4). Herbaceous plant height at the nest site was highly variable (5.5-240 cm) and herbaceous canopy cover at the nest site ranged from 5% to 100% (Table 1.4).

Temperatures were highly variable between years and as a function of distance from shrub (Table 1.5). The predicted T_{max} at 10m and 20m from the shrub was higher (effect size= 12.1 and 14.38, respectively) than immediately under the shrub and this was consistent among years (F-statistic= 21.35, df= 124; Table 1.5), and this pattern was similar to absolute T_{range} (Table 1.5). Conversely, the absolute T_{min} of artificial nests was higher immediately under the shrub compared to sites further away from the shrub, but not all distances were statistically significant (0m p= 0.007, 10m p=0.473, 20m p=0.032; Table 1.5). Absolute T_{min} varied diurnally; at night absolute T_{min} was warmer immediately under the shrub compared to sites further from the shrub, but during the day absolute T_{min} was cooler under the shrub than further away from the shrub (Table 1.5). In 2018, ambient temperatures were recorded and ambient absolute T_{max} and T_{min} followed the same patterns as absolute T_{min} at artificial nest sites (warmer at night and cooler during the day; Table 1.5). Only 7% of nests under the shrub reached 40°C compared to nests away from the shrub (10m and 20m nests) where more than 50% of the nests were at or above 40°C for at least an hour (Figure 1.2).

Discussion

This study is the first to our knowledge to examine how distance from shrubs might alter thermal environments in temperate grasslands. Our findings describe the magnitude of temperature differences as well as the effect of distance from shrubs on thermal characteristics. In previous work, research focused on using cover to mitigate convective heat loss at nests (Sherfy and Pekins 1995), decomposition rate of vegetative litter changes in the presence of shrubs (Predick et al. 2018), differences between shrubland and grassland nighttime air temperatures (He et al. 2010), carbon balance and respiratory response of plants in a shrub encroaching system (Mclaughlin et al. 2014), and heterogeneity in thermal environments in nest site selection for ground dwelling species (Carroll et al. 2015a; Hovick et al. 2015). This work adds additional knowledge to the body of literature by evaluating how temperatures vary as a function of environmental characteristics during critical developmental stages for birds.

Distance to focal shrub was found to be a major predictor for nest temperature. During the day, maximum temperatures were higher away from shrubs, supporting the findings by Predick et al. (2018). Conversely, at night, minimum temperature was higher under the shrub than in distant areas, and this pattern is generally consistent with findings from He et al. (2010). Vegetative cover at the site of interest (e.g., nests) can influence the amount of solar radiation absorbed into the soil during the day (e.g., He et al. 2010), and areas under and directly next to shrubs typically have less herbaceous vegetation with more bare ground exposed to solar radiation (Guido et al. 2017). Therefore, nighttime temperatures under and near shrubs are likely higher than those in grasslands due to increased absorbed radiation from the ground and the ability of the shrubs to trap some of this radiation, providing a form of insulation, (He et al. 2010).

We found that nest temperatures exceeded the lethal thresholds for embryonic development in most (>50%) of the nests that occurred at least 10m from the focal shrubs. Other studies of temperature as related to avian reproduction in grasslands are limited. For instance, Carroll et al. (2015a) assessed thermal environments available for nest site selection by ground nesting bird species. They found nest sites compared to random sites differed in temperature by more than 10°C (Carroll et al. 2015a) and multiple studies have found that successful nests remained on average 4-6°C cooler than unsuccessful nests (Carroll et al. 2015a; Carroll et al. 2015b; Hovick et al. 2015). Beyke (2017) evaluated behaviors of adults and nest site selection decisions on two ground nesting species and found incubating adults selected nest sites (nest substrates) that substantially mediated the thermal environment during the heat of the day. Raynor et al. (2018) found Sharp-tailed grouse (*Tympanuchus phasianellus*) selected nesting sites that moderated temperatures on average up to 2.7°C more than available landscape sites. We acknowledge that we used artificial nests for this study which may not represent the the decisions birds make to mitigate the thermal regime of their nest during nest site selection processes. We attempted to mitigate this limitation by placing nests within a wide range of plant heights and canopy cover (Table 1). In addition, birds may make decisions during nest construction and incubation that may mitigate temperature in ways we were unable to evaluate. Our artificial nests were composed of a mixture of dry grass and coconut fibers, which is natural material but coconut fiber is not typical in grassland environments and therefore might influence nest temperatures compared to a more natural nest composed of only dry grasses. our findings are defendable.

There is likely a trade-off between being under a shrub for thermal advantages and the potential that these shrubs might support nest predators. An increase in the availability of perch points for avian predators heightens predation risk for songbirds (Toland 1987, Burger 1988, Duguay and Wood 1997, Renfrew and Ribic 2003) and the presence of woody vegetation attracts snakes and mammalian predators (Ellison et al. 2013). This introduction of woodland predators can drive changes in bird behavior and therein changes in bird communities associated with shrub encroachment (Ellison et al. 2013, Macias-Duarte et al. 2017). In addition, rates of predation by snakes and birds were found to increase as daily maximum temperatures increased (Cox et al. 2013). Predation risk is just one of many factors that influence nest site selection (e.g., Chalfoun and Marin 2010, Martin et al. 1993) but explicitly incorporating thermal environments into studies addressing nest survival are likely to enhance our understanding of nest site selection (Carroll et al. 2015b, Elmore et al. 2017).

An additional challenge for birds nesting within wet meadows is the interaction between hydrology, climate, and nesting phenology. Ground nesting species select nesting sites where certain micro-topographical characteristics prevail or where surface water does not accumulate during the breeding season (Boelman et al. 2016, Rodrigues 1994; Norment 1993; Oakeson 1954). At our study site, a characteristic northern Idaho wet meadow, early spring floods inundate the entire site and the avian community using the site are comprised almost entirely of waterfowl until May (Ehlen, unpublished data). This results in the native ground nesting species beginning nesting typically in late May-June when adequate drying occurs. Shifts in this spring hydrology as a function of climate change will influence the timing of breeding for ground nesting species because bare ground could be a limiting factor for nesting sites (Boelman et al. 2016). If projected increases in spring precipitation (Abatzoglou et al. 2014) are realized, the timing of the ground drying out and nest construction may shift later into the summer (e.g., mid-late June). Coupled with projected increases in summer temperatures (Mote and Salathe 2010, Abatzoglou et al. 2014), ground nesting species in this area may be exposed to even higher temperatures than we have reported. Understanding these thermal changes within grassland communities, particularly during developmental stages in summer, is important to understand for successful management of both plants and animals (Deno 1988, Emery 1993, Dawson et al, 2005, Cunningham et al. 2013). The data presented here provides a baseline for future studies at this site but also adds to our understanding of how shrub encroachment might affect thermal environments which are critical for a variety of plant and animal species.

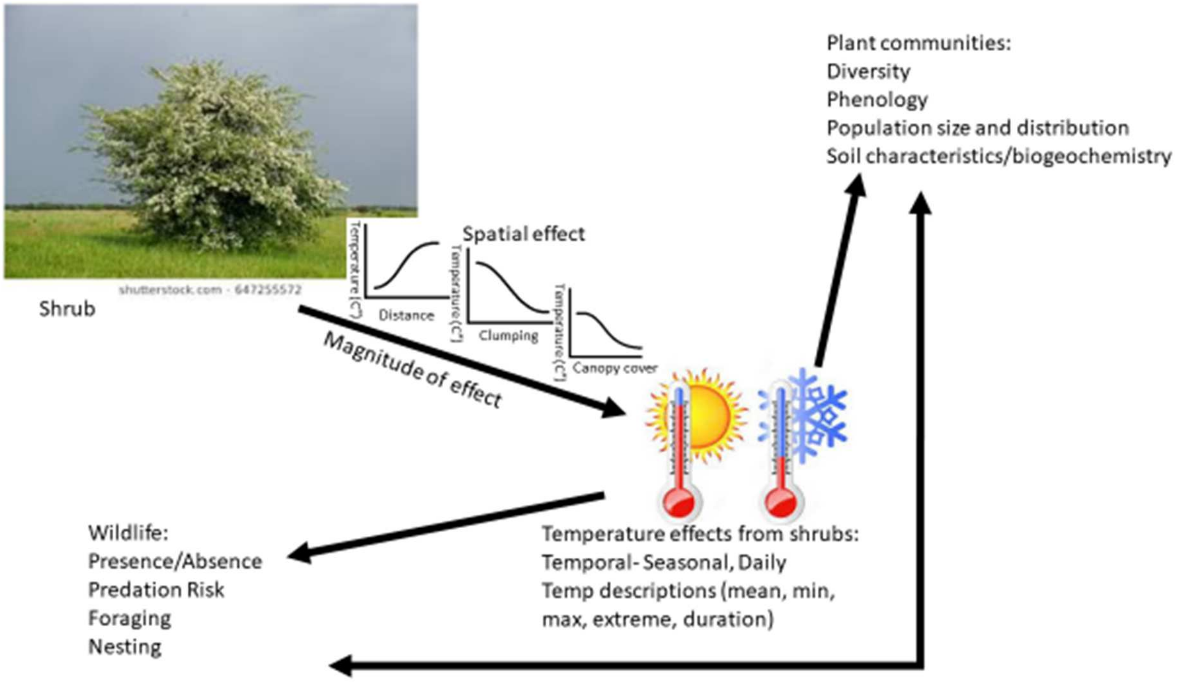

Figure 1.1. Conceptual diagram of the thermal effects from shrubs in a grassland community. Variability in the microclimates (temperatures) in shrub-encroached grasslands may be influenced by the distance from the shrub, the clumping of shrubs, and the canopy cover of shrubs. Those spatial effects could result in daily and seasonal variability in thermal environments, and can have multiple effects on soil, plant and animal communities.

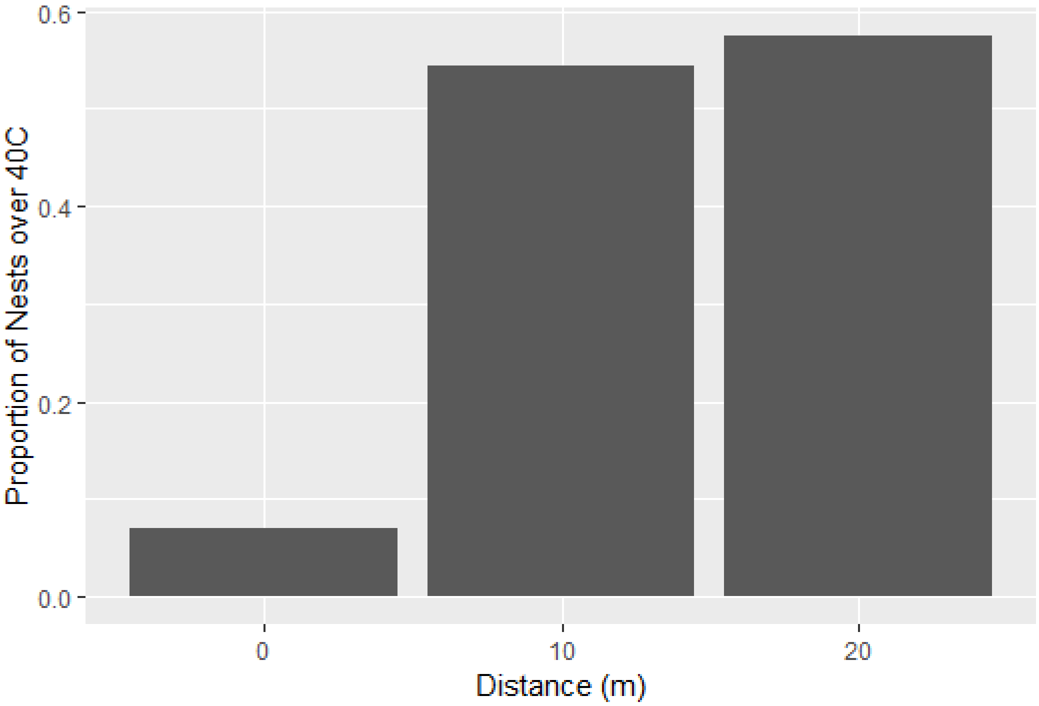

Figure 1.2. Proportion of nests that reached 40°C or higher for each distance from the shrub. Nest temperatures were measured using an iButton that was placed inside the nest and measured hourly in 2017 (n=78 nests) and every 4 hours in 2018 (n=78 nests).

Figure 1.3. Black hawthorn shrubs across the Weippe Prairie in Idaho. Black hawthorn vary in height across the site from 0.88m to over 5m tall.

Table 1.1. All models ran (n=15) following the 10-step protocol for fitting a mixed-effect model (Zuur et al. 2009). Models included all predictor variables: distance to focal shrub (m), focal shrub height (m), % canopy cover, herbaceous plant height (cm), sampling period, year, and an interaction between distance to focal shrub and focal shrub height.

Model name	Distance to focal shrub (m)	Focal shrub height (m)	% Canopy cover	Plant height (cm)	Sampling period	Year	Interaction
Null							
Global w/interaction	x	x	x	x	x	x	x
Distance	12x						
Shrub Height		x					
Canopy Cover			x				
Plant height				x			
Sampling pd.					x		
Year						x	
Global w/o interaction	x	x	x	x	x	x	
Dis + s.ht	x	x					
Dis + s.ht + cc	x	x	x				
Dis + s.ht + cc p.ht	x	x	x	x			
Dis + s.ht + cc p.ht + s.pd	x	x	x	x	x		
Dis + s.ht + cc + p.ht + yr	x	x	x	x		x	
Dis + s.ht + p.ht + yr	x	x		x		x	

Table 1.2. Akaike's information criterion (AIC_c, second-order corrected AIC for small sample sizes) for the two best competing linear mixed effects models (out of a larger set of candidate models ran) to explain variation in mean T_{max} and T_{min} of artificial nest temperatures as a function of shrub height, distance from shrub (0, 10, and 20m), plant height at nest, % canopy cover at nest, sampling period, and year (2017 and 2018). Nest temperatures were measured using iButtons in 2017 (n=78) and 2018 (n=78). All other models had a ΔAIC_c of at least 40.

	Model	K (+1)	AIC_c value	ΔAIC_c	w_i
T_{max}	Model 1: Distance Shrub height (m) %Canopy cover Plant height (cm) Sampling period Year	9	959.21	0.0	0.64
	Model 2: Distance Shrub height (m) % Canopy Cover Plant height (cm) Sampling period Year *Distance interaction with Shrub height (m)	11	961.19	1.0	0.36
T_{min}	Model 2: Distance Shrub height (m) % Canopy Cover Plant height (cm) Sampling period	12	693.31	0.0	0.63

Year				
*Distance interaction with Shrub height (m)				
Model 1:	10	694.37	1.1	0.37
Distance				
Shrub height (m)				
%Canopy cover				
Plant height (cm)				
Sampling period				
Year				

Table 1.3. Parameter estimates of the best fit linear mixed-effects model based on AIC values to examine the factors affecting mean T_{max} and mean T_{min} in grasslands with shrubs. Means, standard errors and p-values are presented for each predictor variable. Herbaceous plant height and % canopy cover are measurements taken at the artificial nest location. Variables in bold are statistically significant at p<0.005. An interaction was included in the top model for T_{min} between distance from focal shrub and focal shrub height and is denoted by Distance x shrub ht.

	Predictor variables	Estimates	Standard error	p-value
Tmax	Intercept	18.05	6.49	0.0068
	Distance 10m	13.01	2.10	<0.001
	Distance 20m	14.50	2.09	<0.001
	Shrub height (m)	-0.09	0.75	0.508
	% Canopy Cover	-0.03	0.03	0.424
	Herbaceous plant height (cm)	-0.01	0.02	0.003
	Sampling period	2.54	1.69	0.199
	Year2018	8.30	2.44	0.001
Tmin	Intercept	7.27	2.63	0.007
	Distance 10m	0.85	2.59	0.744
	Distance 20m	5.24	2.73	0.059
	Shrub height	0.20	0.41	0.5625
	% Canopy Cover	-0.01	0.01	0.667
	Herbaceous plant height	-0.00	0.01	0.785
	Sampling period	0.53	0.60	0.386
	Year2018	-6.22	0.88	<0.001
	Distance 10 x Shrub ht	-0.42	0.58	0.473
	Distance 20 x Shrub ht	-1.30	0.60	0.033

Table 1.4. Summary statistics of vegetation metrics used to evaluate the effect of shrubs on temperature characteristics within artificial nests in the Weippe Prairie, Idaho. These measurements were taken at nests in 2017 (n=78) and 2018 (n=78). Focal shrub height (m) is the height of the shrub from which the artificial nests were placed at increasing distances. Plant height (cm) and % herbaceous canopy cover were measured at the nest.

Predictor Variables	Mean ± 1STD	Maximum	Minimum
Focal shrub height (m)	4.4 ± 1.2	5.6	1.2
Plant height (cm)	99.4 ± 51.8	240.0	5.5
Canopy cover (%)	52.4 ± 25.0	100.0	5.0

Table 1.5. Summary statistics of 2017 and 2018 nest temperatures (°C) used in evaluating the effects of shrubs on temperature characteristics within artificial nests in the Weippe Prairie, Idaho. These temperature measurements were taken at each nest placed near a focal shrub at distances (0m, 10m, and 20m). Nest temperatures were measured using an iButton placed inside the nest and measured every hour in 2017 (n=78 nests) and every 4 hours in 2018 (n=78 nests). Ambient temperatures were measured using an iButton placed adjacent to the nest and protected from direct solar radiation. Temperatures are the absolute minimum, maximum, and the range of the absolute temperatures for each distance from the focal shrub.

		0m	10m	20m
2017 nests (n=78)	T_{min} mean ±1STD	8.72 ± 2.05	7.53 ± 1.59	8.24 ± 1.97
	T_{max} mean ±1STD	23.84 ± 5.50	36.03 ± 8.25	34.47 ± 8.72
	T_{min} absolute	4.50	3.50	3.00
	T_{max} absolute	34.50	51.50	57.00
	T_{range} absolute	30.00	48.00	54.00
2018 nests (n=78)	T_{min} mean ±1STD	2.90 ± 2.05	1.94 ± 1.78	2.46 ± 6.98
	T_{max} mean ±1STD	30.23 ± 9.00	42.92 ± 13.46	47.29 ± 6.74
	T_{min} absolute	0.00	-1.00	-2.00
	T_{max} absolute	53.50	62.50	60.00
	T_{range} absolute	53.50	63.50	62.00
Ambient (2018 only, n= 55)	T_{min} mean ±1STD	4.20 ± 11.82	NA	4.08 ± 2.12
	T_{max} mean ±1STD	25.85 ± 8.96	NA	33.30 ± 7.58
	T_{min} absolute	0.55	NA	0.00
	T_{max} absolute	56.50	NA	43.50
	T_{range} absolute	55.95	NA	43.50

CHAPTER 2

Avian Behaviors and Use of Shrubs Across a Shrub Density Gradient

Introduction

As the process of shrub encroachment increases in many grassland systems (e.g. Barger et al. 2011), it is important to understand how bird communities respond to shrub density and spatial arrangement (Grant et al. 2004; Fletcher et al. 2007; Sirami et al. 2009; Sirami and Monadjem 2012; Sherer et al. 2016). Multiple studies have recorded changes in bird community composition and increases in bird diversity (Sadoti et al. 2018; Sherer et al. 2016; Sirami et al. 2009). Bird diversity is generally highest at intermediate levels of shrub encroachment (Lindsay et al. 2013; Sirami et al., 2009). As shrub encroachment increases, birds that specialize in grasslands may be replaced by birds of shrubby or woodland habitats (e.g. State of the Bird Report, 2010), and grassland species have different thresholds of tolerance for shrub encroachment. For example, Loggerhead Shrike (*Lanius ludovicianus*) and Northern Bobwhite (*Colinus virginianus*) do best in mixed areas of grasses and shrubs, but disappear when the grass becomes rare while others, like Chestnut-collared Longspur (*Calcarius ornatus*), are intolerant of even a low percentage of shrub cover (State of the Bird Report, 2010; Sadoti et al. 2018). Bird communities also include a higher likelihood of shrub nesting species in an area where shrubs are present compared to a site without shrubs (Ingold and Dooley, 2013).

In addition to community-level effects, the presence or absence of shrubs, as well as the density of shrubs, in an area might influence bird behaviors being performed in that particular area (Ellison et al., 2013; Kim et al., 2003; Sprau et al. 2012). Sprau et al. (2012) compared nightingales (*Luscinia megarhyncho*) responses to singing at different perch heights. Male residents increased song output and overlapped song playbacks when rivals (playbacks) were singing at similar perch heights as the individual compared to when playbacks were singing at higher perches. In addition to the presence of shrubs, increases in the availability of perch points for avian predators heightens predation risk for songbirds (Burger 1988; Duguay and Wood 1997; Winter et al., 2000; Renfrew and Ribic 2003). Ellison et al. (2013) found that the presence of woody vegetation attracts woodland associated nest predators (white-tailed deer, *Odocoileus virginianus;* raccoons, *Procyonidae*; and snake species, *Serpentes*). This increased use by predators can influence grassland birds' productivity and nesting behavior as well as productivity at patch and landscape levels. Most grassland birds avoid nesting within 50m of shrubs because of the increased predator diversity and abundance (Ellison et al. 2013). Such behavior can effectively reduce the number of suitable patches for grassland birds (e.g. Winter et al. 2000). Whether the mechanism for this avoidance reflects a behavioral response to woody vegetation or predators directly is unknown. Indeed, changes in bird behavior is one of the primary mechanisms that governs the changes in bird communities associated with shrub encroachment. Unfortunately, however, much remains unknown concerning the behavioral mechanisms of shrub-induced impacts.

Although multiple studies have evaluated the influence of shrubs on bird community composition (Sadoti et al. 2018; Sherer et al. 2016; Sirami et al. 2009) and nest site selection for ground nesting species (e.g. With and Webb, 1993, Klug et al. 2010; Ruth and Skagen, 2017) much remains unknown concerning the seasonal use of shrubs by grassland birds. Shrub use might change for avian species from season to season. For example, Wheelright and Rising (1993) found in the early stages of breeding season, ground nesting birds use shrubs as perches to attract a mate (Wheelwright and Rising, 1993) but when ground nesting birds are establishing a nest site they tend to avoid shrubs (Elliott, 2016). In wintering grounds for migratory species, Macias-Duarte et al. (2017) demonstrated that the presence of shrubs can lower winter survival, and suggest that shrub encroachment in wintering grounds of sparrows may be an important driver of their population declines.

Previous work on shrub encroachment in grassland ecosystems focused on perch points for raptors and their community dynamics (Wong et al. 2018; Becker et al. 2009; Kim et al. 2009) and the role of habitat structure (presence of shrubs) on survival of grassland-obligate bird species (Wong et al. 2018; Macias-Duarte et al. 2017). The objective of our study was to evaluate shrub use by bird species in a wet meadow ecosystem experiencing shrub encroachment. Specifically, we sought 1) to characterize the diurnal and seasonal avian community in a wet meadow system experiencing shrub encroachment, and 2) to describe patterns of shrub use and associated bird behaviors. This is the first study to our knowledge to examine shrub use and associated bird behaviors across seasons and time of day in a grassland system experiencing shrub encroachment.

Study Site

The study area is located on the Weippe Prairie (hereafter WP), a National Historic Landmark managed by the Nez Perce National Historical Park (NEPE). The Weippe Prairie is approximately 2.4 kilometers south of Weippe, Idaho (46°21’16.04” N, 115°55’17.66” W) in Clearwater County. The site is 111 ha in size and is composed of large open grassland sections, the native black hawthorn

(*Crataegus douglasii*), small ponds, manufactured canals, and a stretch of approximately 1.6 kilometers of the perennial Jim Ford Creek (flowing southeast to the northwest). The average annual precipitation ranges from 71 cm to 139cm of rainfall and 289cm to 612cm of snowfall (WRCC 2015). Average high temperatures in the summer in nearby Pierce, Idaho (~16 km from WP) are approximately 27˚C and in the winter are approximately 2˚C (WRCC 2015).

WP is a grassland community within the Northern Rockies ecoregion (Mcgrath et al. 2002). This site was primarily used for hay and cattle prior after European settlement, but cattle grazing activities ceased in 2008 after the acquisition of the property by the United States National Park Service (Becker et al. 2016). The extent of historical haying on WP is unclear but there is documentation of approximately 27% of the site being used for hay up until 2003 (H. Tamm, personal communication). The native forbs and grasses present on the site are small camas (*Camassia quamash)*, plantainleaf buttercup (*Ranunculus alismifolius*), tufted hairgrass (*Deschampsia cespitosa*), and California oatgrass (*Danthonia californica*) with intermixed non-native creeping bentgrass (*Agrostis stolonifera*), timothy (*Phleum pretense*), meadow foxtail (*Alopecurus pratensis*) and smooth brome (*Bromus inermis*; Becker et al. 2016).

The current management focus is restoring small camas populations because it is an important cultural resource for the site and for the Nez Perce tribe. At our study site, small camas is a focal species for management, and those seeds require 42-100 days of temperatures (34-40° C) under moist stratification for maximum germination (90-100%) (Emery 1988, Deno 1993, Guerrant and Raven 1995). Currently, canals are being infilled, and weed management is occurring for specific plants, including but not limited to orange hawkweed (*Pilosella aurantiaca*), common tansy (*Tanacetum vulgare*), and reed canary grass (*Phalaris arundinacea*). Black hawthorn shrubs are present throughout the WP at various heights and densities, and due in part to the lack of grazing and fire, shrub densities have increased since the mid-2000s (J. Lyon, personal communication). Black hawthorn represent 99% of the shrubs on site and the other 1% are snowberry *(Symphoricarpos occidentalis*). For the purposes of this study the black hawthorn on WP is referred to as a shrub because of its multiple non-dominant stems regardless of its height.

Methods

Using the 2011 NAIP imagery, we digitized shrubs to determine shrub densities across the site, and established 53 individual shrub density plots of 200m by 200m across the study site. 200m by 200m plots were chosen based on the Breeding Biology Research and Monitoring Database

(Martin et al. 1997). These plots (hereafter referred to as shrub density plots) were categorized into three groups of varying shrub densities: low, medium, and high to stratify the site into rough shrub density groupings so we could include a range of shrub density values. These shrub density groupings were initially based on examining a histogram of shrub densities across all 53 shrub density plots and dividing the histogram evenly into three distribution classes (Figure 2.1). Within each shrub density plot, four 11.3m radius ground truthing plots were sampled for shrubs. Shrub ground truthing plots were located directly in the center of the plot as well as 30m from the center plot in directions 0°, 120°, and 240° (Martin et al. 1997). In each shrub ground truthing plot, every shrub location was recorded using a Trimble GPS with a resolution of <50cm, and height was measured with a ruler and/or a laser range finder for all shrub sizes ranging from the smallest (0.18m) to over 5m. Both the digitized and field-based information were used together to examine the initial shrub density plots. Shrub densities were classified as low (0-2 shrubs,) medium (8-22 shrubs), and high (25+ shrubs). These density classifications were established as strata for the sampling design, and shrub densities of shrubs >0.5m ranged from 0 - 214 within these plots.

Objective 1: Characterizing the avian community diurnally and seasonally in the wet meadow system

Within all 53 shrub density plots, avian communities on the WP were monitored by using 50m fixed radius point count procedures generally following the standard BBIRD protocols (Martin et al. 1997). Three surveys were conducted during each of three seasons: the breeding season (mid-May until mid-July), spring (March/April), and fall (September/October). Each sampling point originated at the center of each shrub density plot (200m by 200m) and sampling was limited to 50m radius to eliminate the possibility of double counting individuals. We sampled the avian community in the spring, summer and fall of 2017 and again in the spring and summer of 2018. In 2018, fall surveys were not conducted due to the small number of individuals using the site in the previous year. Point count surveys occurred three times during each breeding season (mid-May until mid-July), in the spring (March/April), and in the fall (September/October). Point counts consisted of a 5-minute waiting period, followed by a 5-minute survey where all birds heard or seen (except those flying over) were counted within a 50m radius of the plot center. All point counts and replicates were conducted in consecutive days until finished (Johnson et al. 2011). Surveys were performed in the morning (sunrise to 4 hours after sunrise) as well as at dusk (3 hours before dusk to dusk) (Sullivan and Vierling 2009).

To capture the entirety of the avian community, owl surveys were also performed following the same framework as the point counts. For owl surveys, we used callbacks and started with the smaller species (western screech-owl, *Megascops kennicottii*) and ended with larger species (short eared-owl, *Asio flammeus*; Bailey et al., 2009). Each survey lasted up to 15 minutes if there was no response but no longer to avoid calling in owls outside of the sampling area (Rodrguez-Estrella and Careaga, 2003; Weins et al. 2011). These surveys were performed no earlier than 40 minutes before dusk.

We evaluated the community using the Shannon-Wiener diversity index and Jaccard's similarity index. The Shannon-Wiener diversity index and Jaccard's similarity index were calculated within the shrub density classes (low, medium, and high) and by season (spring, summer, and fall). Within the Jaccard's similarity index, a value of 1 means that the two communities being compared are exactly the same compared to a value closer to 0 meaning communities are completely dissimilar (Jaccard 1908).

Objective 2: Describing patterns of shrub use and behaviors

Shrub use surveys were conducted in the spring, summer and fall of 2017 and 2018. Shrub use surveys were performed for 3 minutes following each point count following a modified protocol from Kim et al. (2003). In the shrub use surveys, the point count plot was divided into 3 subplot sections (0-120°, 120-240°, and 240-360°) and I surveyed each of the three subplot sections for one minute. Within each subplot section, avian species, sex, and behavior (singing or perched and not singing; Kim et al. 2003) were recorded when a bird was seen on a shrub. A compass bearing and distance to the shrub location was taken during the behavior survey. No birds were individually marked, and although the methodology would generally ensure that there was no "double counting" individuals within a single shrub use survey session, it is possible the same individuals were recorded between shrub use survey sessions.

After the shrub use surveys were completed, we measured the height of the used (hereafter focal) shrub and the number of shrubs within 5m of the focal shrub. To determine the vegetation shrub availability, we paired the focal shrub vegetation measurements with measurements from the ground-truthed shrub plots and from shrub plots selected via a random distance and bearing within 15m of the focal shrub. Focal shrubs and random shrubs were sampled for height, and we counted all shrubs > 0.5m tall within 5m of the focal shrub to estimate shrub density. A random shrub within a 5m subplot from the nearest shrub ground-truthed plot was used as the center of the random shrub plot, and the same shrub measurements of height and shrub density were taken within 5m of that random plot. No birds were ever recorded using shrubs within these subplots during the surveys. When shrub ground-truthed plots did not contain shrubs, we used a random compass bearing (generated from a randomized list) and distance within 15m from the focal used shrub. We rotated in a clockwise movement until a shrub of at least 0.5m was located and used that as the center of the random shrub vegetation plot. Summary statistics were conducted on used and random shrubs. T-tests with 95% confidence intervals were ran on to compare characteristics of used shrubs to random shrubs with shrub characteristics included: shrub height and shrub density. We also modeled the probability of Savannah sparrows using a shrub with shrub height, shrub density within 5m, and shrub density across 200m plots as predictor variables using logistic regression modeling. During our shrub and bird surveys, we also searched for nests in shrubs within the plots.

Results

Fifty-three 200m x 200m plots were surveyed three times in spring and summer of 2017 and 2018 as well as three times in the fall of 2017. A total of 2,862 surveys were conducted. During the surveys, 612 birds of 49 avian species (Appendix 2) were recorded across all point count plots. There were more species noted in the spring (n=48) compared to the summer (n=39) for both 2017 and 2018. In the spring, there were several species of water birds that only used the Weippe prairie during the migratory period (e.g. Cinnamon teal, *Anas cyanoptera*; Common mergansers, *Mergus merganser*; Gadwalls, *Anas strepera*; and Hooded mergansers*, Lophodytes cucullatus*). Common species in the breeding season included Eastern kingbirds (*Tyrannus tyrannus*), Savannah sparrows, Red-winged blackbirds (*Agelaius phoeniceus*), and Western meadowlarks (*Sturnella neglecta*). All of the species that were recorded in the fall had been recorded to use the site in the spring or summer (Appendix 1).

Bird species richness varied across plots with different shrub densities but not across the time of day. Species richness was highest in the high shrub density plots (n=38) as compared to the medium shrub density plots (n=30) or low shrub density plots (n=30). Bird species recorded in the morning surveys (n=40) were very similar to evening surveys (n=41) but more individuals of each species were detected during morning surveys (n=1032) compared to evenings surveys (n=665). Owl surveys were also conducted and only one species (long-eared owls) was observed throughout the seasonal surveys.

The Shannon-Wiener index was highest within the high shrub density plots compared to the medium and low shrub density plots (Table 2.1). Spring had the highest diversity index compared to summer (Table 2.1) across all shrub density plots. Fall diversity index metrics were not calculated because there were only two species recorded during the fall surveys (Brewer's blackbirds, *Euphagus cyanocephalus*; and Savannah sparrows). The Jaccard similarity index was calculated for shrub density plots for spring and summer seasons (Tables 2.2 and 2.3). Bird communities were most dissimilar between high and low shrub density plots for both spring and summer. More than 50% of the bird communities between medium and high shrub density plots were similar (Table 2.2).

We recorded a small number of species using shrubs in different ways over the course of the study (Tables 2.4-2.6). We detected 12 bird species using shrubs within the 50m radius point counts (n=2,862) during our surveys. Of the 12 species total, two were ground nesting species, one was a cavity nester, and nine were shrub nesting species. Despite the presence of multiple shrub nesting species, shrubs within our study site were rarely used as nesting substrates. With the exception of a small number of nests (n= 7) in shrubs > 5m in height (primarily of Black-billed magpies, *Pica hudsonia*, and Eastern kingbirds, *Tyrannus tyrannus*), no nests were found in shrubs that were located within the 111-ha meadow matrix.

We rarely saw raptors using shrubs in the study site, although several raptor species were recorded on our point counts as flyovers and additional raptor species (i.e. American kestrels, *Falco sparverius*) were recorded on powerlines adjacent to our study site. The only owl species seen to perch on shrubs was a long-eared owl (*Asio otus*). The most frequently observed species using shrubs were Savannah sparrows and Eastern kingbirds (Tables 2.4-2.6).

Shrub use varied by species and time of day. There were more species using shrubs during the summer (n= 11; Table 2.6) compared to the spring (n=6; Table 2.5). Shrub use surveys conducted during the morning surveys saw more use than the evening surveys (Table 2.5 and 2.6). Shrub heights of used shrubs were on average 0.88m or higher (Table 4) and, in general, the heights of used shrubs increased from spring to summer (Table 2.5 & 2.6).

Shrubs that were used (n=99) were 2.27±1.61m taller than random shrub heights (Table 2.7). Observations of birds using shrubs were higher in shrub heights over 1m tall (Table 2.7). Savannah sparrows were responsible for 56% of all shrub use. The probability of shrubs being used by Savannah sparrows increased as shrub height increased by a magnitude of 1.55 and increases in shrub density within 5m and 200m decreased the probability of Savannah sparrows using shrubs by a magnitude of -0.36 and -0.11, respectively (Table 2.8). Savannah sparrows shrub use during morning surveys (n=58) was significantly higher than for evening surveys (n=17). Used shrub heights for Savannah sparrows (n=49) differed between spring (n=23) and summer seasons (n=49; Table 2.9). Morning use of shrubs by Savannah sparrows had taller shrub heights than evening use (Table 2.9) and shrub density within 5m of the used shrub was similar between seasons and time of day surveys (Table 2.9).

Discussion

Our objective was to evaluate characteristics of shrubs that are being used by bird species in a grassland ecosystem experiencing shrub encroachment. In previous work, research was focused on 1) predation/survival rates in the presence of shrubs (Ellison et al., 2013; Macius Duarte et al., 2017) and, 2) raptor community's use of shrubs as perch points (Burger 1988; Duguay and Wood 1997; Winter et al., 2000; Renfrew and Ribic 2003; Kim et al., 2009) and 3) feeding behaviors in relation to shrub cover (Ya-Fu et al., 2005). Here we attempted to fill a knowledge gap by looking at specific shrub characteristics (including shrub height, and shrub density within 5m of focal shrub) that influenced shrub use by avian species relative to random shrubs and what behaviors were performed when using a shrub. We found that used shrubs were taller than random shrubs and shrub density was lower around used shrubs compared to random shrubs. Shrub use was primarily associated with singing behaviors across seasons and species. It is important to note that high density shrub plots might have had lower detected use than actual use; these plots often contained dense, large shrub clusters and visibility was sometimes poor.

The avian community at WP was diverse and changed across seasons but shrub use was similar across seasons and species. The Weippe Prairie is a wet meadow that experiences spring flooding which leaves little dry ground for grassland species to inhabit, therefore lots of water fowl use the site while it is inundated with water as a stopover area. As the site dries out water fowl species leave and more grassland species inhabit the area and this process varies by year due to differences in precipitation. This change in the community is not uncommon as Riffell et al. (2001) found the same shift in species using dry areas within a wet meadow system in Michigan. Riffell et al. (2001) found as wet meadows experienced dry conditions, species who needed water were absent or in low densities compared to those species who nested in drier, grassier areas. This results in the native ground nesting species beginning nesting typically in late May-June when adequate drying occurs. In addition, Boelman et al. (2016) evaluated how shifting seasonality in environmental conditions affects the timing of arrival on breeding grounds. They found environmental conditions influenced arrival times as well as breeding-cycle phenology during years of late snow cover. Shifts in this spring hydrology as a function of climate change will influence the timing of breeding for ground nesting species because bare ground could be a limiting factor for nesting sites (Boelman et al. 2016).

Seasonal shrub use (spring/summer) did not vary drastically for shrub height, taller shrubs were used more than shorter shrubs regardless of bird species. This finding is similar to Lee et al. (2005) where he found wintering birds did not change their preferred feeding heights at established feeding perches in open grasslands as the winter season progressed. Lee et al. (2005) did not test changes in feeding heights at feeder perches across multiple seasons but found birds selected feeders at higher perches and attributed it to lower predation risk. Bird community composition could influence which shrubs are being used and by which species. For example, Kim et al. (2003) evaluated artificial perches and interspecific interactions on patch use by three wintering raptor species in a prairie in south Texas. They found that the raptor community influenced which perches each species used during the winter. Loggerhead shrikes (*Lanius ludovicianus*) patch and perch use was limited by Northern Harriers (*Cirucs cyaneus*) predating on them as well as competition for resources with American Kestrels (*Falco sparverius*; Kim et al, 2003). We were unable to separate out our shrub use by species due to the low observations but further work evaluating use by species could provide some insight on the community dynamics on the site.

Behaviors observed by birds using shrubs varied by species. Eastern kingbirds and Savannah sparrows were the main two species using shrubs and these species have different foraging techniques which might explain why their behaviors differed when using shrubs. Eastern kingbirds are a species that typically hunts for food from perches, sallying out to catch insects from perches (Fitzpatrick, 1980; Murphy 1987) which is congruent with our findings of seeing them perched and not singing more often than perched and singing. Murphy (1987) found that Eastern kingbirds change their hunting tactics depended on the weather because of how it affects the activity of insect prey. We were unable to break down observations by weather due to our small sample size of Eastern kingbird observations. Savannah sparrows were most seen singing from perches and their foraging strategy is stalking through grassy areas or along water edges (Wheelright and Rising, 2008). Ginter and Desmond (2005) found savannah sparrows foraged in open areas which likely provide easier access to available resources. These birds also foraged in areas with higher seed abundance than randomly selected locations, suggesting that they may cue in on resource abundance. Grzy bowski (1982, 1983) also found individual and loose aggregations of Savannah Sparrows foraging in areas with low vegetation height and density. Therefore, the difference in behaviors between species could be due to differences in life histories and survival tactics.

Shrub height was found to be the major predictor for shrub use. Birds used shrubs that were taller when a range of shrub heights were available, supported the findings by Lee et al. (2009). Sprau et al. (2012) evaluated songbird responses to playbacks from varying perch heights throughout the breeding season (spring into summer months) and found unpaired singing males only responded to playbacks are similar heights the birds sang from compared to playbacks at taller perch heights. Songbird species might select a range of perch heights and therefore shrub heights of used shrubs might be species dependent. While some species utilize the shrubs, regardless of size, others such as Sprague's pipit (Robbins and Dale 1999, Grant et al. 2004) and horned lark (Beason 1995) avoid them. Interestingly, Lee et al (2005) found no avian predators using perch sites and attributed it to the low profile (poor visibility) of the infrastructure at their sites. We found no use by avian predators regardless of shrub height which can be explained by the small size of the study site and therefore could be only a small portion of a few large avian predator’s territory in the area.

As shrub encroachment continues to occur, studies like this will be helpful to managers. Understanding the bird community composition can be key in determining which species may be of conservation concern and how to manage for the desired bird community. Not all species use shrubs and those that do may not use them for the same functions, so understanding how species are using them and quantifying the characteristics of used shrubs may inform managers on what heights and densities of shrubs bird populations are willing to tolerate.

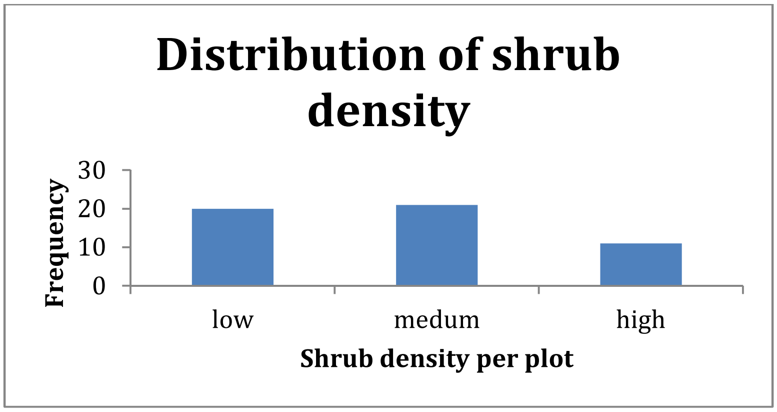

Figure 2.1. The distribution of shrub densities across all 53 50m fixed radius plots. Shrub density was determined using NAIP and ground-truthed plots. Four ground-truthed plots were sampled in each 50m radius plots in 2017.

Table 2.1. The Shannon-Weiner index for bird diversity across shrub density classifications (low, medium, and high) for all seasons (spring, summer and fall). These calculations are based on point count surveys performed three times each season in both 2017 and 2018. Point count surveys lasted 5 minutes and all species seen within a fixed 50m radius were recorded.

Shrub density classification	Spring	Summer	Total
Low (0 shrubs)	2.17	1.65	3.82
Medium (1-29 shrubs)	1.97	1.26	3.23
High (30+ shrubs)	2.43	1.82	4.25
Total	6.57	4.73	11.3

Table 2.2. Jaccard's similarity index for the spring season. Bird community data was collected during three point count surveys conducted within a fixed 50m radius plot across spring and summer for years 2017 and 2018.

Shrub density classification	Low	Medium	High
Low (0 shrubs)	1.0	0.59	0.36
Medium (1-29 shrubs)	0.59	1.0	0.52
High (30+ shrubs)	0.36	0.52	1.0

Table 2.3. Jaccard's similarity index for summer season. Bird community data was collected during three point count surveys conducted within a fixed 50m radius plot across spring and summer for years 2017 and 2018.

Shrub density classification	Low	Medium	High
Low (0 shrubs)	1.0	0.50	0.47
Medium (1-29 shrubs)	0.50	1.0	0.48
High (30+ shrubs)	0.47	0.48	1.0

Table 2.4. Individual species seen using shrubs during the spring season, the mean shrub height (m) used (with sample sizes) ± 1 standard deviation, the mean shrub density (m) used ± 1 standard deviation, and the percent of uses detected in the AM compared to the PM surveys. Black-billed magpies were not captured using shrubs during our surveys because they were outside of our sampling area and therefore are under-represented.

Species	# of individuals seen using shrubs	Mean shrub height (m) ± 1 s.d.	Mean shrub density (shrubs/5m) ± 1 s.d.	% AM (compared to PM)
Black-billed Magpie	0	NA	NA	NA
Brewers blackbird	3	>5.00 ± 0.00 (n=2)	4.00 ± 0.00	50.00
Cedar waxwing	0	NA	NA	NA
Chipping sparrow	0	NA	NA	NA
Common yellowthroat	1	>5.00 ± 0.00 (n=1)	6.00 ± 0.00	100.00
Eastern kingbird	1	>5.00 ± 0.00 (n=1)	2.00 ± 0.00	0.00
Northern flicker	0	NA	NA	NA
Red-winged blackbird	3	3.77 ± 0.00 (n=3)	3.00 ± 2.65	66.67
Savannah sparrow	30	1.31 ± 0.88 (n=22)	2.26 ± 2.51	82.61
Song sparrow	0	NA	NA	NA
Western meadowlark	2	1.04 ± 0.37 (n=2)	1.00 ± 0.00	0.00
Willow flycatcher	0	NA	NA	NA

Table 2.5. Individual species seen using shrubs during the summer season, the mean shrub height (m) used (with sample sizes) ± 1 standard deviation, the mean shrub density (m) used ± 1 standard deviation, and the percent of uses detected in the AM compared to the PM surveys.

Species	# of individuals seen using shrubs	Mean shrub height (m) ± 1 s.d.	Mean shrub density (shrubs/5m) ± 1 s.d.	% AM (compared to PM)
Black-billed Magpie	3	0.88 ± 0.51 (n=2)	2.00 ± 1.41	50.00
Brewers blackbird	3	1.51 ± 0.58(n=3)	2.33 ± 0.58	66.67
Cedar waxwing	6	>5.00 ± 0.00 (n=1)	2.00 ± 0.00	100.00
Chipping sparrow	1	>5.00 ± 0.00 (n=1)	1.00 ± 0.00	100.00
Common yellowthroat	1	>5.00 ± 0.00 (n=1)	7.00 ± 0.00	100.00
Eastern kingbird	23	3.77 ± 0.50 (n=14)	3.58 ± 2.23	46.67
Northern flicker	0	NA	NA	NA
Red-winged blackbird	9	2.22 ± 0.37 (n=5)	2.00 ± 2.58	60.00
Savannah sparrow	59	1.55 ± 0.92 (n=45)	2.65 ± 0.00	73.47
Song sparrow	2	>5.00 ± 0.00 (n=2)	1.00 ± 0.00	50.00
Western meadowlark	4	>5.00 ± 0.00(n=1)	1.00 ± 0.00	50.00
Willow flycatcher	7	2.23 ± 0.35 (n=6)	4.50 ± 4.36	83.33

Table 2.6. Shrub use summary by species for all seasons including the number of individuals of each species seen using shrubs during the breeding season, the mean shrub height (m) used (with sample sizes) ± 1 standard deviation, the mean shrub density (m) used ± 1 standard deviation, and the percent of uses detected in the AM compared to the PM surveys. Shrub use surveys were conducted three times during the spring, summer and fall seasons in years 2017 and 2018. Each survey lasted three minutes and any birds seen using a shrub were recorded. Used shrubs were measured for height and location.

Species	# of individuals seen using shrubs	Mean shrub height (m) ± 1 s.d.	Mean shrub density (shrubs/5m) ± 1 s.d.	% AM (compared to PM)
Black-billed Magpie	6	0.88 (n=2)	2.00 ± 1.41	66.67%
Brewers blackbird	6	1.51 (n=5)	2.75 ±0.96	60.00%
Cedar waxwing	6	>5.00 (n=1)	2.00 ± 0.00	100.00%
Chipping sparrow	1	>5.00 (n=1)	1.00 ± 0.00	100.00%
Common yellowthroat	2	>5.00 (n=2)	6.50 ± 0.71	100.00%
Eastern kingbird	24	3.77 (n=15)	3.46 ± 2.18	43.75%
Northern flicker	1	>5.00 (n=1)	6.00 ± 0.00	100.00%
Red-winged blackbird	12	2.73 (n=8)	2.60 ± 0.00	62.50%
Savannah sparrow	92	1.45 (n=69)	2.47 ± 4.36	77.33%
Song sparrow	2	>5.00 (n=2)	1.00 ±	50.00%
Western meadowlark	6	1.04 (n=3)	1.00 ±	33.33%
Willow flycatcher	7	2.23 (n=6)	4.50 ±	33.33%

Table 2.7. Summary statistics of vegetation metrics used in evaluating shrub characteristics on bird shrub use in the Weippe Prairie, Idaho. These measurements were taken in 2017 and 2018. Used shrubs were used by birds and the random shrubs were available to birds but we did not see birds using them during the time of our shrub use surveys. Shrub height (m) is the height of the shrub being used by bird species and shrub density within 5m is the number of shrubs within 5m of the used shrub.

	Used			Random		
	Mean ± 1STD	Maximum	Minimum	Mean ± 1STD	Maximum	Minimum
Shrub height (m)**	3.57 ± 1.74	>5.00	0.79	1.43 ± 1.48	>5.00	0.33
Shrub density within 5m*	2.39 ± 1.99	10 shrubs	1 shrub	3.90 ± 2.70	15 shrubs	1 shrub

*p<0.10

**P<0.05

Table 2.8 Parameter estimates of a generalized linear model examining the factors affecting shrub use by Savannah sparrows in a grasslands with shrubs. Estimates, standard errors and p-values are presented for each predictor variable. 200m shrub density was determined using 2016 NAIP imagery and ground-truthed verification plots to determine shrub density in all 53 200m plots. Shrub height was measured at each shrub location and 5m plot shrub density was taken by measuring each shrub within 5m of a used shrub. Variables in bold are statistically significant at p<0.05.

Predictor Variable	Estimate	Std. Error	p-value
Intercept	1.619	0.956	0.090
200m plot shrub density	-0.109	0.051	0.032
Shrub height (m)	1.546	0.509	0.002
5m plot shrub density	-0.367	0.118	0.002

Table 2.9. Savannah sparrow shrub use. Day use surveys were conducted in between sunrise until 4 hours past sunrise and night surveys were between 4 hours before sunset until sunset.

	Shrub height (m)	Shrub density (shrubs/5m)
	Mean (s.d.)	Mean (s.d.)
Day	1.53 ± 0.93	2.69 ± 3.57
Night	1.03 ± 0.40	1.69 ± 1.03
Spring	1.31 ± 0.88	2.26 ± 2.51
Summer	1.55 ± 0.92	2.47 ± 3.58
Fall	1.25 ± 0.18	1 ± 0.00

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GENERAL CONCLUSION

Shrub encroachment in grassland systems can influence bird populations in a variety of ways. Previous research suggests the presence of shrubs can change the thermal environments in grassland community (Predick et al. 2018, He et al. 2011), bird community composition changes (Sirami and Monadjem, 2011; Zakkak et al. 2014), and perch availability influences on species occupancy (Wong et al. 2018; Becker et al. 2009; Kim et al. 2003). Our work builds off of these concepts and creates a new baseline of data for future work to be conducted.

Chapter 1: Our objective was to evaluate factors influencing nest microclimates in a grassland system experiencing shrub encroachment. We set out artificial nests at varying distances from shrubs with a wide range of vegetative cover and monitored temperatures throughout the breeding season. We found nest temperature was influenced by distance from shrub and 50% of nests away from shrubs experienced temperatures beyond the critical threshold for embryonic development (Webb 1987; DuRant et al. 2013; Mainwaring 2015). The temperatures experienced on our study site were similar to those found by Carroll et al. (2015a) with average daily maximum temperatures of nests exceeding 60°C in some cases. This is important for managers to consider when making strategic plans for grassland bird conservation activities as climate change warms breeding season temperatures (Elmore et al. 2017).

Chapter 2: Our objective was to describe the bird community on Weippe Prairie and evaluate shrub use and behaviors. We performed point count surveys and shrub use surveys through spring, summer and fall seasons following a modified protocol of Martin et al. (1997). There were 49 species found during point counts on Weippe Prairie but only 12 species were found using shrubs. Used shrubs were found to be taller than random shrubs and Savannah sparrows were the prominent species using shrubs. No raptors were found to use shrubs during surveys and there were minimal species using shrubs for nesting purposes.

The results of this thesis create a baseline of data for future work to be conducted on the impacts of shrub encroachment in grassland communities. This baseline data will provide opportunities to expand upon our understanding of functional links between the animal and its environment as well as help inform managers so they can create effective plans for managing for specific species.

Appendix 1: 10-step protocol for fitting a mixed-effect model.

10 Step protocol for fitting mixed- effect model	Results
Distribution of variables and scatterplot of raw data	No data transformations needed
Addressing violations of homogeneity	NA, no violations
Linear regression with all explanatory variables and interactions residual vs. fitted plot	Normalized distribution without heterogeneity of variance
Correlation matrix	No collinearity issues
Fit new model with selected variance structure	
Compare new model to earlier results using AIC	Most suitable model found based on AIC
Plot residuals vs. fitted	Normalized distribution without heterogeneity of variance
Finding optimal fixed component	Most suitable model found based on F-statistic
Find all significant explanatory variables	
Refit new model with REML estimation and apply graphical model validations	Assumptions are met
Present results in a table	

Appendix 2: List of bird species found on the Weippe Prairie.

Species	**Latin**	**Spring**	**Summer**	**Fall**
American Crow	*Corvus brachyrhynchos*	X	X	
American Goldfinch	*Spinus tristis*			
American Robin	*Turdus migratorius*	X	X	
Bald Eagle	*Haliaeetus leucocephalus*	X	X	
Barn Swallow	*Hirundo rustica*	X	X	
Black-billed Magpie	*Pica hudsonia*	X	X	
Blue winged Teal	*Anas discors*	X	X	
Bobolink	*Dolichonyx oryzivorus*		X	
Brewer’s Blackbird	*Euphagus cyanocephalus*	X	X	X
Brown Headed Cowbird	*Molothrus ater*	X	X	
Bufflehead	*Bucephala albeola*	X		
Canada Goose	*Branta canadensis*	X	X	
Cedar Waxwing	*Bombycilla cedrorum*		X	
Chipping Sparrow	*Spizella passerina*		X	
Cinnamon Teal	*Anas cyanoptera*	X	X	
Cliff Swallow	*Petrochelidon pyrrhonota*	X		
Common Merganser	*Mergus merganser*	X		
Common Yellowthroat	*Geothlypis trichas*	X	X	
Cooper’s Hawk	*Accipiter cooperii*		X	
Eastern Kingbird	*Tyrannus tyrannus*		X	

European Starling	*Sturnus vulgaris*		X	
Gadwall	*Anas strepera*	X		
Great Blue Heron	*Ardea herodias*		X	
Greater Yellowlegs	*Tringa melanoleuca*	X	X	
Green-winged Teal	*Anas carolinensis*	X	X	
Hooded Merganser	*Lophodytes cucullatus*	X		
Killdeer	*Charadrius vociferus*	X	X	
Long-eared Owl	*Asio otus*	X	X	
Mallard	*Anas platyrhynchos*	X	X	
Northern Flicker	*Colaptes auratus*	X	X	
Northern Harrier	*Circus cyaneus*		X	
Northern Shrike	*Lanius excubitor*	X		
Osprey	*Pandion haliaetus*		X	
Plover spp.	*Charadriinae spp.*	X		
Red-winged Blackbird	*Agelaius phoeniceus*	X	X	
Ring-necked Pheasant	*Phasianus colchicus*	X	X	
Sandhill Crane	*Grus canadensis*	X	X	
Savannah Sparrow	*Passerculus sandwichensis*	X	X	X
Song Sparrow	*Melospiza melodia*	X	X	
Tree Swallow	*Tachycineta bicolor*	X	X	
Turkey Vulture	*Cathartes aura*	X		
Violet Green Swallow	*Tachycineta thalassina*	X	X	

White-crowned Sparrow	*Zonotrichia leucophrys*	X		
Western Meadowlark	*Sturnella neglecta*	X	X	
Willow Flycatcher	*Empidonax traillii*		X	
Wilson's Phalarope	*Phalaropus tricolor*	X	X	
Wilson's Snipe	*Gallinago delicata*	X	X	
Yellow Warbler	*Setophaga petechia*	X	X	
Yellow headed Blackbird	*Xanthocephalus xanthocephalus*	X	X	