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Vocalizations influence roost-site selection in overwintering cavity-nesting birds in Eastern Washington

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VOCALIZATIONS INFLUENCE ROOST-SITE SELECTION IN OVERWINTERING

CAVITY-NESTING BIRDS IN EASTERN WASHINGTON

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for the Degree

Master of Science in Biology

By

Shelby M. Hunter

Spring 2018

THESIS OF SHELBY M. HUNTER APPROVED BY

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ABSTRACT

Primary cavity-nesting birds are keystone species because the annual tree cavities they excavate become critical habitat for other species. In eastern Washington, most primary cavity-nesting birds are year-round residents. They increase overwinter survival by night roosting in cavities and forming flocks. The timing of roost site selection can impact the quality of a roost site, thus selecting a roost site too late reduces the odds of selecting the most favorable microclimate available. Birds in flocks use alarm calls to warn of threats and contact calls to promote group cohesion. My study asks if timing of roost site selection and vocalizations influence the frequency and flock size of cavity-nesting birds inspecting roosting sites and if flock size varies with temperature. The study was conducted during the winters of 2016-17 and 2017-18 on Turnbull National Wildlife Refuge. Roost boxes were located at 36 stations divided between 3 forest units. At each station, I conducted an 8-minute point count prior to sunset. Following the initial point count, I conducted a second point count with 1 of 3 broadcast treatments: 1) no call 2) alarm call and 3) contact call. I compared the number of cavity-nesting birds observed and mean temperature to time before sunset using a Chi-squared test and t-test, respectively. I compared the mean differences in the number of birds observed between initial and treatment point counts and the frequency of point counts in which species' were present between treatments with an ANOVA and a Fisher's exact test, respectively. I examined the effect of temperature on flock size using Poisson regression. During the 2016-17 winter, I recorded 516 observations of 8 species and during the 2017-18 winter 730 observations of 9 species. In 2016-17 there was an increase in birds present during the 105 - 0 minutes before sunset time period and in 2017-18 more birds were observed

during the 210 – 105 minutes before sunset time period. Mean temperatures were significantly colder during both time periods in 2016-17. The number and presence of pygmy nuthatches increased following contact call treatment for both winters. The presence of chickadees increased following alarm and contact call treatments in 2016-17 and alarm call treatment in 2017-18. The number of black-capped and mountain chickadees increased following the alarm call treatment, and red-breasted nuthatches increased following the alarm and contact call treatments in 2017-18. As temperature decreased flock size increased in 2017-18. Timing of roost site selection varied with abiotic conditions. Vocalizations influence roost selection for some cavity-nesting birds.

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I. INTRODUCTION

Cavity-nesting birds nest and roost in tree cavities during the breeding and non-breeding season (Mazgajski 2002). Primary cavity-nesting birds excavate cavities annually and the previous year's cavities provide critical habitat for secondary cavity-nesting birds as well as other vertebrates (Fokidis and Risch 2005; Martin et al. 2004). Because they provide critical habitat for a variety of species, primary cavity-nesting birds are considered keystone species in forest habitats (Martin et al. 2004). In eastern Washington, most primary cavity-nesting birds such as woodpeckers (Picidae), nuthatches (Sittidae), and chickadees (Paridae) are year-round residents; thus, overwinter survival of these keystone species is critical (Haveri and Carey 2000; Martin et al. 2004). Winter survival influences the size of breeding populations and therefore directly impacts probability of a species' persistence (Haveri and Carey 2000). Mortality of cavity-nesters is greatest during the winter because overwintering birds face high thermoregulatory costs due to low temperatures, reduced food availability, and increased predation because snow and lack of leaves on the trees increases visibility (Haveri and Carey 2000; Maziarz and Wesołowski 2013; Tyller et al. 2012). Wintering birds use two main behavioral strategies to deal with these challenges: flock formation and use of cavity roosts (Tyller et al. 2012).

To increase overwinter survival cavity-nesters form flocks (Ekman 1989; MacKay 2001; Waite 1987; Ward and Zahavi 1973). Forming flocks increases foraging efficiency because of information transfer and more time to forage given more individuals being vigilant for predators (Beauchamp 1999; Carrascal and Alonso 2006; Ekman 1989; MacKay 2001; Waite 1987). In addition to increased vigilance, flocks reduce predation

through confusing and mobbing potential predators (Beauchamp 1999; Ekman 1989; MacKay 2001). Many species of overwintering birds roost individually, but some species roost communally (Stanback 1998; Sydeman and Guntert 1983). For example, 100 pygmy nuthatches (*Sitta pygmaea*) have been observed roosting in one cavity to reduce thermal stress (Stanback 1998; Sydeman and Guntert 1983). The size of overwintering flocks is correlated with ambient temperatures (Ekman 1989; Ward and Zahavi 1973). With lower temperatures, flocks are larger because the benefits of being in a group (e.g., foraging efficiency, reduced predation, thermoregulation benefits) outweigh the costs (e.g., competition between individuals for food and space; Caraco 1979).

Flocks can be either a single-species flock or a mixed-species flock (Dolby and Grubb 1999; Haftorn 2000; Klein 1988; Ward and Zahavi 1973). Members of mixed-species flocks are categorized as either a nuclear species that are the leaders or as a satellite species that are the followers (Nolen and Lucas 2009). Chickadees are considered a nuclear species because they have a highly sophisticated and complex call system (Templeton and Greene 2007). Nuthatches and woodpeckers are known as a satellite species because their vocalizations are not as developed as the chickadees (Nolen and Lucas 2009). Flock members recognize and respond to different call types of other species (Templeton and Greene 2007).

Birds in flocks use alarm calls to reduce predation risk and contact calls to promote flock cohesion (Barber et al. 2010; Krams et al. 2006; MacKay 2001). The structure of alarm calls can be either a high-and modulated-frequency or high- and continuous-frequency depending on the predator threat (Bartmess-LeVasseur et al. 2010). High- and continuous-frequency alarm calls make it difficult for predators to locate the origin of the

call (Bartmess-LeVasseur et al. 2010). Alarm calls by nuclear species relay pertinent information (e.g., threat, size, aerial or terrestrial) about the predator (Haftorn 2000; MacKay 2001; Sirot 2006). For example, the number of dee notes in a black-capped chickadee's (*Poecile atricapillus*) alarm call (chick-a-dee) will increase if the predator poses a greater threat (Bartmess-LeVasseur et al. 2010; MacKay 2001). Small high-risk avian predators generate more dee notes because these predators maneuver quicker and are harder to detect than large low-risk predators (Bartmess-LeVasseur et al. 2010; MacKay 2001). In eastern Washington owls (Strigidae and Tytonidae) are the primary avian predators of cavity-nesters during both the winter and summer seasons (Rodríguez et al. 2001). The small northern pygmy owls (*Glaucidium gnoma*) are high-risk predators and chickadee alarm calls incorporate the dee note four to seven times depending on predator proximity (Bartmess-LeVasseur et al. 2010). Conversely, the larger great horned owls (*Bubo virginianus*) are low-risk predators and chickadee alarm calls only incorporate one to two dee notes (Bartmess-LeVasseur et al. 2010). Wintering home-range sizes differ between species (Templeton and Greene 2007). Nuthatches wintering home-range is smaller compared to chickadee's home-ranges (Templeton and Greene 2007). Similar to the chickadees, nuthatches respond differently to different degrees of predator threats (Templeton and Greene 2007). With high energetic demands and low availability of food during the winter, it is beneficial for birds to be selective about which predator they will expend energy mobbing (Templeton and Greene 2007).

Nuclear and satellite species use contact calls to promote flock cohesion by "sounding off" their location when visibility is limited, so the flock does not get separated (Krams 2001; MacKay 2001). Contact vocalizations are organized into either

low frequency and long-range or high frequency and short-range contact calls (Krams 2001). During winter, highly coherent flocks use high- and continuous-frequency calls that are short range and less detectable by most predators (Krams 2001). Depending on the cohesiveness of a flock their winter home-range size can differ (Hadley and Desrochers 2008). A study in Quebec, Canada in a boreal forest found that the wintering home-range size for a chickadee ranges between 9.5 – 14.6 ha (Hadley and Desrochers 2008). Flocks have to be selective of locations within large home-ranges while flocks that have small home-ranges can allocate their activities more evenly (Hadley and Desrochers 2008).

Roosting in cavities helps decrease nighttime costs of thermoregulation and provides protection from the elements and predators (Paclík and Weidinger 2007; Stuber et al. 2014). Overwintering birds expend 40-60% of their total daily energy on basal and thermoregulatory costs (Cooper 1999; Walsberg 1986). The metabolic heat that the bird generates increases the temperature of the cavity (Paclík and Weidinger 2007). Cavity-nesting birds conserve body heat by altering their roosting and foraging behavior in thermally stressful conditions (Carr and Lima 2011). Nightly torpor is another strategy overwintering bird's use where they lower their body temperature and metabolic rate providing substantial energy savings (Nord et al. 2014).

The abundance of primary cavity-nesting birds is positively correlated to snag density and the number of available natural cavities in coniferous forests (Ohmann et al. 1994). Low snag densities can cause fragmentation of cavity-nesting populations (Martin and Eadie 1999; Fokidis and Risch 2005; Lombardo et al. 1989; McComb and Noble 1981; Miller 2010; Nilsson 1984). To mitigate for low snag densities, managers provide

artificial cavities in managed forests (Mainwaring 2011; Martin and Eadie 1999; Miller 2010). The success of artificial cavities (nest boxes) in managed forests during the breeding season is well documented, but the use during the non-breeding is not as clear (Fokidis and Risch 2005; Paclík and Weidinger 2007). Studies in Europe and North America indicate that cavity-nesting birds also utilize artificial cavities (roost and nest boxes) as their overnight roosting cavity during the winter seasons and saved 10-38% of the thermal energy used during the night (Mainwaring 2011; McComb and Noble 1981; Paclík and Weidinger 2007; Ekner and Tryjanowski 2008; Newton 1994; Veľký et al. 2010).

Given the importance of tree cavities, cavity-nesters invest time and energy searching for roost-sites. Overwintering birds spend about 3 hours (210 minutes) before sunset, known as the selection period, to reconnoiter for potential cavities (Amo et al. 2011; Veľký et al. 2010; Zahavi 1971). Cavity-nesters change roost sites often to select cavities that have a favorable microclimate to maximize thermoregulatory benefits (Veľký et al. 2010), are near foraging sites, and have a minimal predator presence because predators become familiar with locations of active roosts (Amo et al. 2011; Fokidis and Risch 2005; Paclík and Weidinger 2007; Thiel et al. 2007; Zahavi 1971).

Amo et al. (2011) used odors of mammals (e.g., urine, fur) and artificial raptors to examine how predator presence affects the selection of roost sites. They did not detect any response and concluded that these simulations of predator presence did not significantly portray a predator presence. They suggested that auditory cues would be a more accurate representation of a predator presence (Amo et al. 2011). Timing of roost selection has impacts on the quality of roosts selected (Veľký et al. 2010). Aviary captive

studies have manipulated roost microclimates and have demonstrated that birds increase roost selection activity and they select the roosts that provide the best microclimate (Veľký et al. 2010). Under natural conditions, cavity-nesters can experience a trade-off between time for roost selection and foraging time (Nord et al. 2014). For example, beginning roost selection too early would reduce time for foraging whereas beginning roost selection later could reduce the likelihood of identifying the best roost for that night's conditions and increase exposure to predators as well as having a non-favorable microclimate (Nord et al. 2014).

Survivorship of overwintering cavity-nesting birds relies on the formation of flocks to increase foraging efficiency and reduce predation risk and tree cavities to decrease thermoregulatory costs. Despite the importance of roost-site selection and flock formation for overwinter survival, relatively few studies have examined the interaction of these strategies in selection of night-time roosts in overwintering cavity-nesters (Amo et al. 2011). Timing of roost selection has been shown to play a role in the quality of the roost selected, which depends on whether the bird selects a roost earlier or later in the selection period, but it is unclear what is driving this selection behavior (Veľký et al. 2010). Vocalizations can be used to portray a predator presence, but how a bird is affected by this presence during the selection period is variable (Amo et al. 2011). Having a predator presence during the selection period could trigger a mobbing response from the birds or they can retreat if the risk is too great (Bartmess-LeVasseur et al. 2010; MacKay 2001). It is unclear the role that timing of roost selection and vocalizations play on cavity-nesters during the selection period during the winter seasons. The purpose of this study is to examine how timing of roost selection, vocalizations, and temperature

influence roost-site selection in overwintering cavity-nesting birds by addressing four major questions.

   1) Does the number of birds observed vary with respect to time before sunset? If so, how does temperature during the selection period vary between the two years?

   2) Does the number of birds observed during the selection period vary with respect to vocalization type?

   3) Because only pygmy nuthatches roost communally, the number of birds observed might not be expected to vary in response to vocalization type. Therefore, I asked: how does the presence of individual species vary in response to vocalization type?

   4) How does the number of birds observed vary with changing temperatures?

II. METHODS

II.1.   Study Area

The study was conducted on Turnbull National Wildlife Refuge (TNWR), 8 km south of Cheney, WA (Fig. 1). TNWR is located in the Channeled Scablands of eastern Washington, a landscape formed by Pleistocene flooding events (Rancourt et al. 2007). The refuge encompasses 6,500 ha of wetlands, ponderosa pine forests (*Pinus ponderosa*), aspen stands (*Populus tremuloides*), and open steppe habitats (Rancourt et al. 2007; Rule et al. 1999; USFW 2012). TNWR's diverse habitat supports over 200 avian species; 124 of these, including all cavity-nesting birds, breed on the refuge (USFW 2012).

II.2.   Study Design

The study began mid-November and ended early March over two winters. The study was conducted in 3 forest units Kepple Butte (GP), Lower Pine (LP), and Turnbull Laboratory for Ecological Studies (TLES) (Fig. 1). The GP forest unit is 153,266m^2, LP forest unit is 172,054m^2, and the TLES forest unit is 172,924m^2. The forest units are in ponderosa pine woodlands with an understory of snowberry (*Symphoricarpos albus*), which have not received timber management (Rancourt et al. 2007; Rule et al. 1999; USFW 2012). The forest units were divided into 12 point count stations that were ≥ 100m apart (Fig. 1). The stations were circular grids with a radius of 50m and were flagged at 25m and 50m in all cardinal directions to assist in estimating distances (Fig. 2; Bateman and O'Connell 2006). In the center of the stations, a cedar roost box was mounted on a tree a week before the sampling began and was removed once the sampling ended. The orientation of the roost boxes faced south allowing for ample sun exposure (Cooper 1999; Kristín et al. 2001; Strubbe and Matthysen 2009). The roost boxes were placed 1.5m off the ground, which was determined by chickadee and nuthatch cavity preferences illustrated by the Washington Department of Fish and Wildlife data (Fig. 2; WDFW 2018).

II.3.   Point Count Sampling Protocol

Point counts are a survey method used to monitor avian populations (Bibby 2000). During point counts, a single observer stands in a designated location for a fixed period of time, recording all birds that are seen and heard in a designated radius (Bibby 2000). Point counts cannot be conducted during high wind and rain events due to the difficulty seeing and hearing birds (Schieck 1997).

For my study, I conducted two point counts at each station during each sample session. The initial point count started upon arrival at a station and lasted 8-minutes. Following the initial point count at the same station a second 8-minute point count was conducted using one of three treatments: 1) no broadcast call 2) alarm broadcast call and 3) contact broadcast call. The calls were broadcasted for 4-minutes leaving the remaining 4-minutes for recording birds. The broadcasted alarm calls were recordings of black-capped chickadee alarm calls, having a high level of dee notes. The broadcasted contact calls were recordings of pygmy nuthatch contact calls. Both call recordings were provided by The Cornell Lab of Ornithology and were broadcasted from a Lohman Predator Master with a 15W speaker 10m away from the roost box. The volume had a decibel reading of 75 dB, which has been determined to have a detection distance of 50m for both birds and humans (Schieck 1997).

Given that sampling was constricted to 210 minutes before sunset, I sampled 3 stations per day (Fig. 3). I reversed the order of sampling on each transect to account for differences in response calls during the beginning of the 210 minute period compared to just before sunset.

II.4.   Data Analysis

These methods yielded the following data: 1) number of observations by species per point count and 2) temperature. I recorded the temperature daily using my phone and corroborated the measurements with TNWR and NWS temperature data records during both winter seasons.

To examine relative abundance of the different species observed, I calculated species composition. This was calculated as a percentage for the three families (nuthatches,

chickadees, and woodpeckers) and the individual species observed during both winters. It was then calculated further for the individual species observed during the different treatment types for both winters (Bateman and O'Connell 2006).

To address my first question, I compared the frequency of all cavity-nesting birds observed between 210 - 105 and 105 - 0 minutes before sunset for both winters separately using a Chi-squared test. Since the selection period is 210 minutes total, I separated it into two time periods (105 minutes each). I used a t-test to compare how the mean temperature varied between the two years. To compare how the mean temperature per time period varied between years I used a t-test. Addressing my second question, I calculated the difference between the number of birds observed during the initial point count and after each treatment type. I then compared these differences using an ANOVA and Tukey's comparison in R (R 2016). To address my third question, whether species presence varied in response to treatment, I calculated the number of point counts in which species 1) were observed during the initial point count (control) but not during the treatment point count or 2) were not observed during the initial point count and were in the treatment point count. I then compared these frequencies using a Fisher's exact test in R (R 2016). Addressing my fourth question, I calculated the mean number of birds observed per point count on each day. I then used a Generalized Linear Model (GLM) to examine how this mean number of observations varied with ambient temperature and year in R (R 2016).

The R statistical software was used to analyze the data and all tests were considered significant at the $P < 0.05$ level (R 2016).

III. RESULTS

I conducted 216 point counts per year, but rainfall in November 2017 precluded initiation of sampling until December. The temperatures between the two seasons were colder in 2016-17 (Fig. 4; t = -4.9, df = 1, P < 0.0001). The mean temperature during 2016-17 was 29 °F and in 2017-18 the mean temperature was 34 °F. When examining the difference of snow and rainfall between the two winters there was a greater amount of snowfall December through March in 2016-17. In 2017-18 rainfall was greater November through January and in 2016-17 rainfall was greater from February to March (Fig. 5). There were a total of 516 cavity-nesting birds of 8 species and 730 cavity-nesting birds of 9 species observed during 2016-2017 and 2017-2018, respectively. Auditory observations of chickadee species were recorded to genus only because they do not use their species-specific calls during the winter, making it difficult to identify individuals to species (Bateman and O'Connell 2006). During both winters, nuthatches were the most common group observed and pygmy nuthatches were the most common species (Fig. 6). Pygmy nuthatches and combined chickadees were the most observed species responding to the alarm and contact call treatments during 2016-17. In 2017-18 pygmy nuthatches were observed most during the contact call and both pygmy nuthatches and chickadees were observed the most during the alarm call (Fig 7).

My first question asked if the number of birds observed varied between the beginning of the selection period vs. just before sunset. There was a difference between the two years. During 2016-17, I observed more birds during time period closer to sunset (X^2 = 5.16, df = 1, P = < 0.0001) whereas during 2017-18 I observed fewer birds during this same time period and more during the 210 – 105 minutes before sunset time period

($X^2 = 78.446$, df = 1, P = < 0.0001; Fig. 8). In the 2016-17 winter mean temperatures were significantly colder during both the 105 - 0 minutes before sunset time period (t = -2.35, df = 1, P = 0.01) and the 210 – 105 minutes before sunset time period (Fig. 9; t = -1.63, df = 1, P = 0.05).

My second question asked if the number of birds observed varied between vocalization types during the selection period. There were differences in the number of birds responding to call treatments. The mean difference in the number of all cavity-nesting birds observed in the 2016-18 winters combined was greater between the alarm call and no call (F = 12.46, df = 2, P = 0.0000376) treatments and between contact call and no call (F = 12.46, df = 2, P = 0.0001373) treatments, but did not differ between the alarm call and contact call treatments (Fig. 10C; F = 12.46, df = 2, P = 0.9475194). The mean difference in the number of all cavity-nesting birds observed in the 2016-17 winter was greater between the alarm call and no call (F = 4.11, df = 2, P = 0.02) treatments, but did not differ between the contact call and no call treatments (F = 4.11, df = 2, P = 0.08) and between the alarm call and contact call treatments (Fig. 10A; F = 4.11, df = 2, P = 0.86). The mean difference in the number of all cavity-nesting birds observed in the 2017-18 winter was greater between the alarm call and no call (F = 11.87, df = 2, P = 0.00014) treatments and between contact call and no call (F = 11.87, df = 2, P = 0.00016) treatments but did not differ between the alarm call and contact call treatments (Fig. 10B; F = 11.87, df = 2, P = 0.99).

The mean difference in the number of pygmy nuthatches observed was significantly greater between the contact call and no call treatments (F = 4.155, df = 2, P = 0.02) during the 2016-17 winter, and was greater between the contact call and no call (F = 8.15,

df = 2, P = 0.0003) and between alarm call and no call treatments (F = 8.15, df = 2, P = 0.048) during the 2017-18 winter (Fig. 11). The mean difference in the number of red-breasted nuthatches observed was greater between the contact call and no call (F = 7.17, df = 2, P = 0.006) and between alarm call and no call (F = 7.17, df = 2, P = 0.0026) treatments during the 2017-18 winter (Fig. 12). The response of red-breasted nuthatches was not analyzed during the 2016-17 winter due to lack of observations. For the 2016-17 winter, most of the chickadee observations were auditory and because of the difficulty of distinguishing call types during the non-breeding season, observations of all chickadees were combined. In the 2017-18 winter, chickadee species identification was primarily visual, allowing the difference in the number of chickadee species to be separated (Fig. 13). The mean difference in the number of black-capped chickadees (F = 6.689, df = 2, P = 0.0019) was greater between the alarm call and no call and between the alarm call and contact call treatments during the 2017-18 winter. The mean difference in the number of mountain chickadees (F = 5.055, df = 2, P = 0.008) was greater between the alarm call and no call treatments during the 2017-18 winter (Fig. 13).

My third question asked if the presence of individual species varied in response to vocalization type. Due to low sample size for most species, I only analyzed pygmy nuthatches and chickadees combined. The frequency of point counts in which pygmy nuthatches was present during the treatment point count but not during the control point count was greater following the alarm call (2016-17: P = 0.0001526; 2017-18: P = 0.0152), contact call (2016-17: P = 7.489e-05; 2017-18: P = 0.00923), and no call (2016-17: P = 0.0003365; 2017-18: P = 0.035) treatment point counts during both winters (Fig. 14). The frequency of point counts in which all combined chickadee species were present

during the control point count but not during the treatment point count was greater

following the contact call treatment (P = 0.01618) point count during the 2016-17 winter

and decreased following the contact call treatment point count in 2017-18. The combined

chickadee species present during the treatment point count but not during the control

point count were greater following the alarm call (2016-17: P = 0.001354; 2017-18: P =

0.02646) and no call (2016-17: P = 0.014; 2017-18: P = 0.02) treatments during both

winters (Fig. 15).

My fourth question addressed temperature and group size. There was a significant

relationship between temperature and group size (R^2 = 0.035, P = 0.00024). In the 2016-

17 winter, temperature did not affect the number of birds observed (R^2 = 0.035, P =

0.42885). However, during the 2017-18 winter when temperatures decreased the number

of birds observed significantly increased (Fig. 16; R^2 = 0.035, P = 7.13e-08).

IV. DISCUSSION

Roost cavities provide a critical resource for overwintering cavity-nesting birds,

and their survival depends on the selection of roost sites (Curtis et al. 1998). Roosts

provide a microclimate that buffer birds from abiotic conditions and protection from

predators (Amo et al. 2011). Given that abiotic conditions change and predators learn

locations of active roosts, birds change roosts frequently (Amo et al. 2011). Aviary

captive studies manipulated roost microclimates and demonstrated that birds increase

roost selection activity and select roosts that provide the best microclimate (Veľký et al.

in 2010). The results of my study suggest that roost site selection involves potential

tradeoffs in when birds enter roosts and that vocalizations influence the selection of

roosting cavities.

Timing can have an effect on when cavity-nesters select their roost sites (Veľký et al. in 2010). The number of birds observed during the beginning of the selection period vs. right before sunset differed between years. In 2016-17 more birds were observed right before sunset and in 2017-18 more birds were observed during the beginning of the selection period. These differences might relate to temperature differences between the two years. Temperatures were colder during the 2016-17 winter and were specifically colder during the selection period. Birds may have extended their foraging time to ensure they had adequate energy stores for overnight survival (Mayor et al. 1982). Additionally, when birds remain active longer, their elevated body temperature helps increase temperatures inside the roost and contributes to energy savings (Mayor et al. 1982). The greater number of birds observed in the beginning of the selection period in 2017-18 could be related to the warmer temperatures. Given the warmer temperatures, it might have been more beneficial for the birds to roost earlier because they did not need to expend as much energy foraging to aid in their overnight survival when thermal stressors were not as strong. By entering roosts earlier, they also reduced exposure to predators. Another reason could be due to the differences in sample size between years. There were more birds observed during the 2017-18 winter, thus the benefits of having larger flock's increases energy savings by decreasing time spent foraging. This is because more individuals are searching for food, allowing the birds to spend more time selecting the most favorable roost site for a given nights condition.

Vocalizations are another factor that can influence the selection of roost sites (Amo et al. 2011). Birds can either have a mobbing response to alarm calls or they can retreat (MacKay 2001). During both winters there was an increase in response following

the alarm calls suggesting that having a predator presence during the selection period might not influence the selection of a roost site. For example, even with the risks of mobbing a predator away from roost sites the benefits of defending a roost site might outweigh the costs of looking for a new one due to a limited number of cavities available. The greater differences in birds observed in response to the alarm call treatment were mostly driven by the response of the pygmy nuthatch and combined chickadee species, which might suggest that whenever there is a predator present, pygmy nuthatches and chickadees will exert the mobbing behavior no matter the time of day. The number of birds observed increased following the contact call in the 2017-18 winter and both winters combined. The increases in the contact call treatment were driven by the responses of the pygmy nuthatch, which is likely due to pygmy nuthatches roosting communally. The increases in the contact call treatment were also driven by chickadee presence, which could be that they were relying information of rich roost site locations to other flock members.

The formation of larger flocks during the winter is advantageous because, the benefits of being in a group (e.g., foraging efficiency, reduced predation, thermoregulation benefits) outweigh the costs (e.g., competition between individuals for food and space (Caraco 1979). This is especially true for mixed species flocks because of reduced competition due to diet and foraging differences (Dolby and Grubb 1999; Haftorn 2000; Klein 1988; Ward and Zahavi 1973). In the 2017-18 winter there was a significant increase in the number of birds observed as temperature decreased, but not in the 2016-17 winter. The 2016-17 results could be due to low sample sizes, since I observed fewer birds in 2016-17 than 2017-18. An additional reason for these results in

2016-17 could be due to weather conditions such as temperatures being too cold and increased amounts of snowfall and rainfall (NWS 2018).

Given the reliance of cavity-nesting birds on cavities for overwinter survival and the frequent switching of roost cavities, it is critical to understand the effects of low snag abundance on these keystone species. One management practice is the use of artificial boxes to mitigate for low snag density (Ohmann et al. 1994). My study suggests that cavity-nesting birds will vary the timing of roost site selection in response to abiotic conditions and the choice of sites in response to vocalizations. Understanding factors influencing roost site selection can provide insight into the optimal number and placement of snags or artificial roosts to help ensure overwinter survival.

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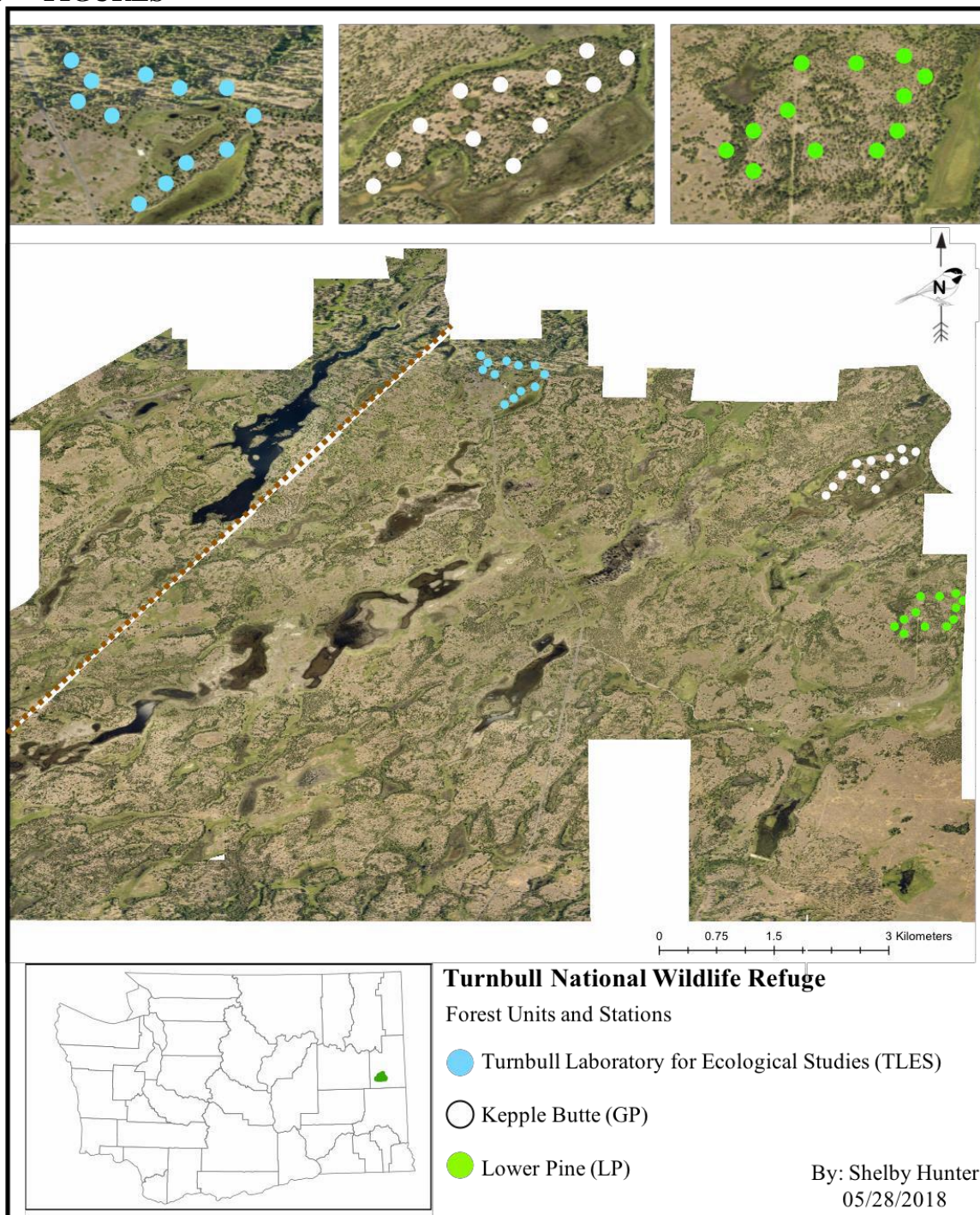   113:106-109.

VI. FIGURES

Figure 1: Location of the study site and 3 forest units (TLES, GP, and LP) on the Turnbull National Wildlife Refuge. The 36 point-count stations were divided between the 3 forest units (12 stations per unit). Stations were greater than 100m apart from another station and each contained 1 roost box.
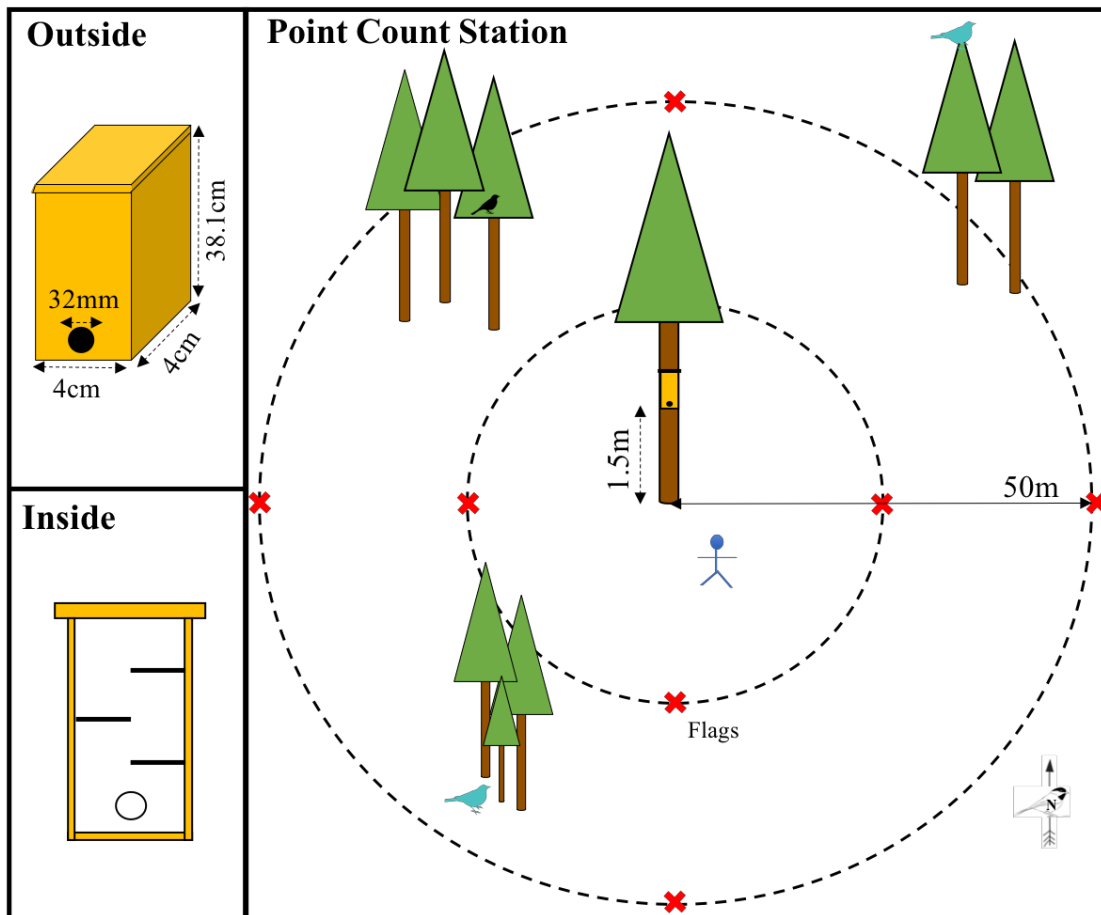
Figure 2: Schematic of a circular 50m radius point-count station encompassing a roost box in the center. The outside and inside roost box design is shown to left. Inside the roost boxes contains 3 dowels for roosting.
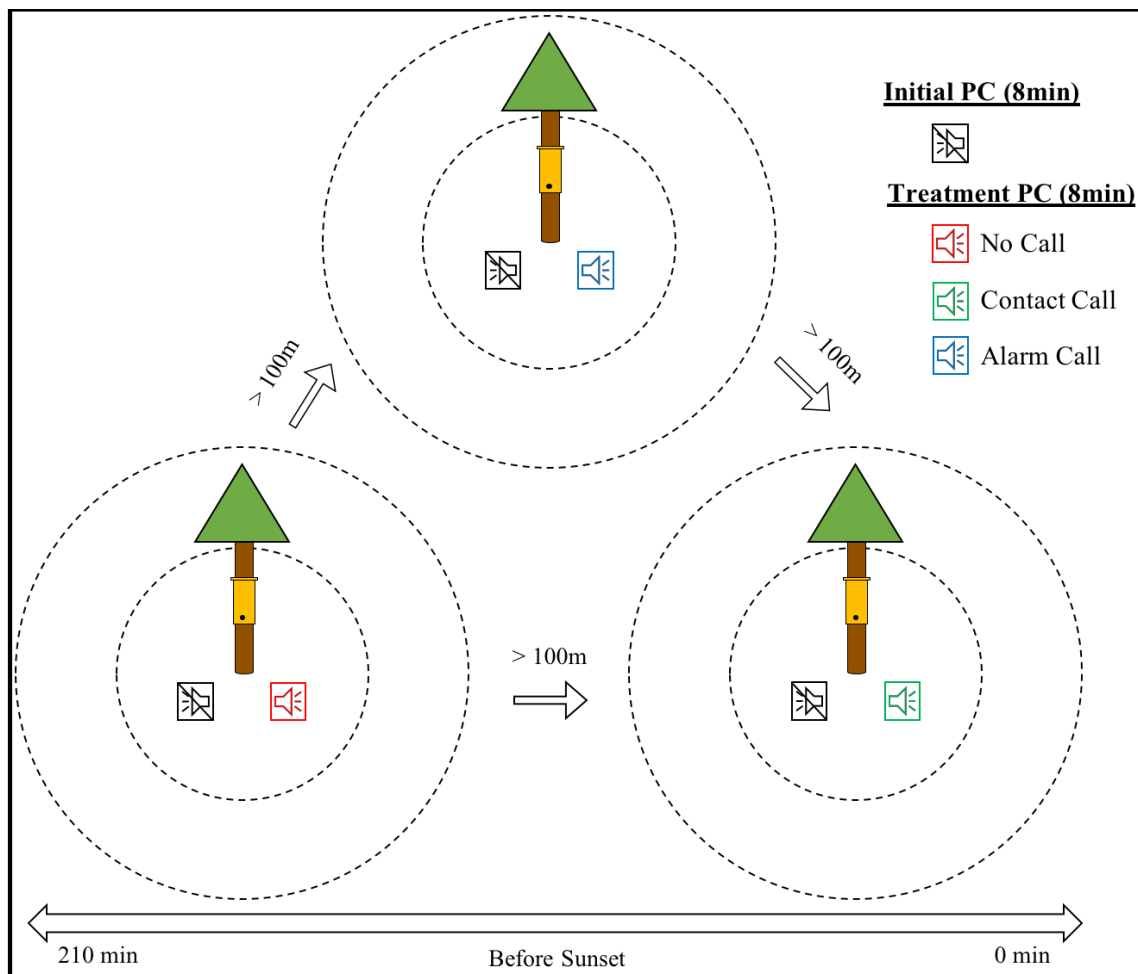
Figure 3: Schematic of sampling design. All stations received an 8 minute initial point count (black) followed by an 8 minute treatment type point count (no call, alarm call, contact call). Three stations were sampled a day and conducted during the selection period (210 min before sunset).
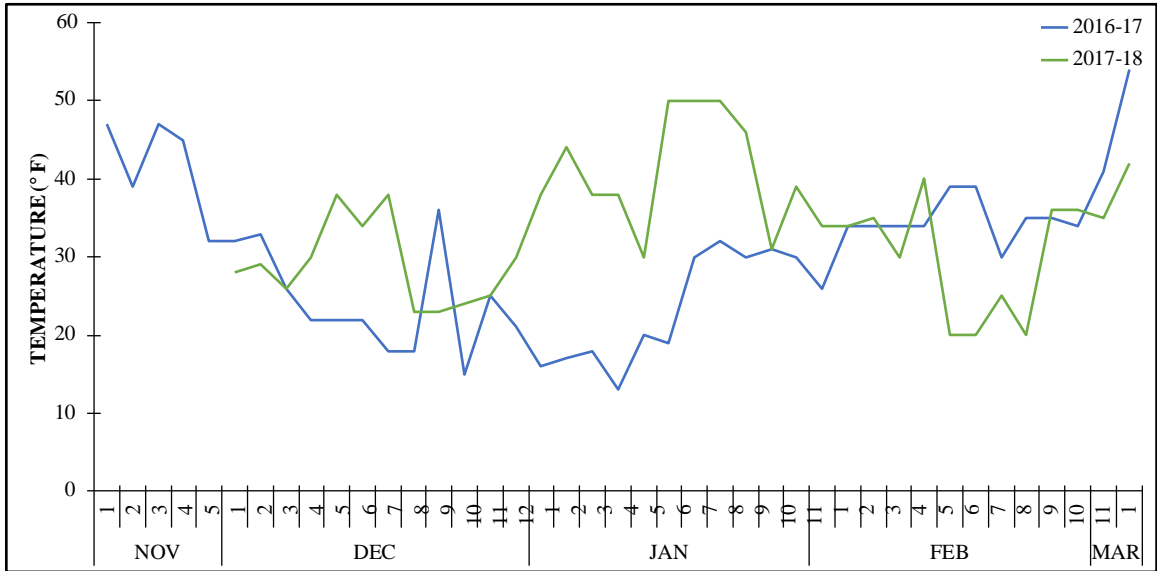
Figure 4: Total monthly and daily temperature amounts for both winters.
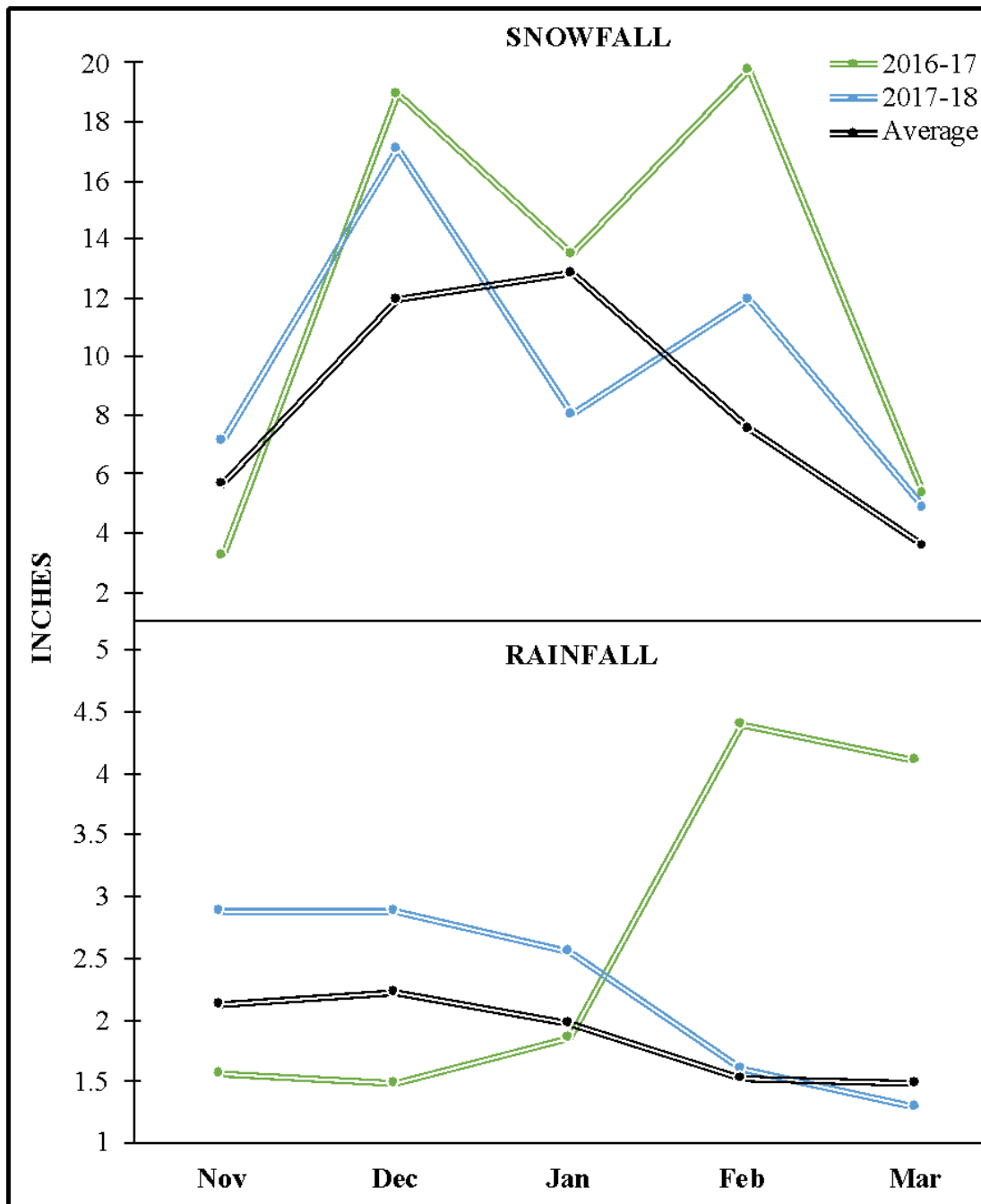
Figure 5: Climograph of the total monthly snowfall and rainfall amounts. The snowfall and rainfall average lines (black) both ranged from 1882-2018 (NWS 2018).
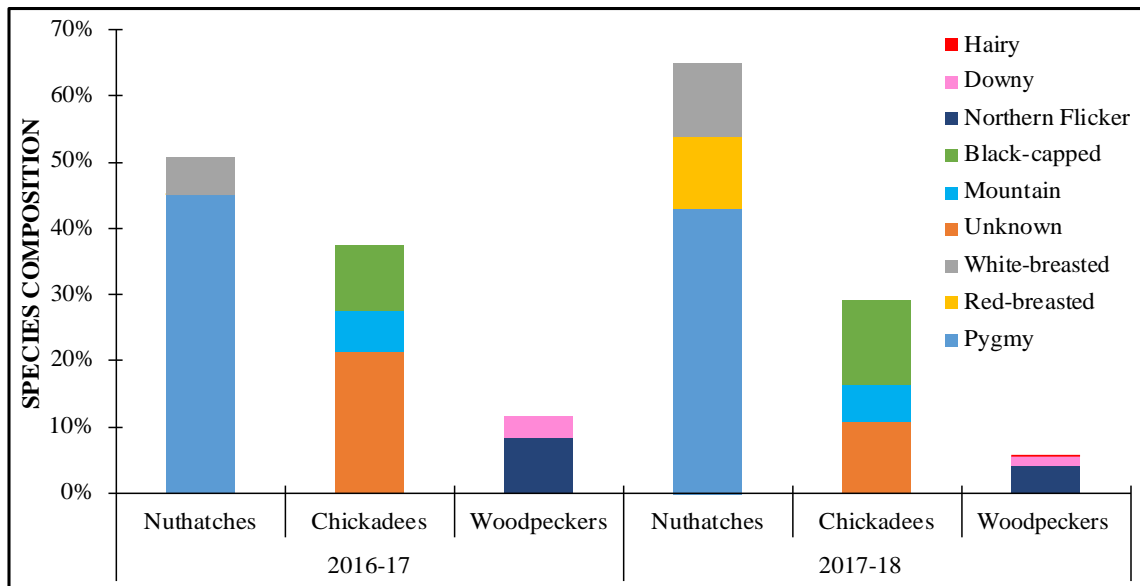
Figure 6: Percent species composition of the three (nuthatches; chickadees; woodpeckers) families and individual species during both winter seasons. Due to the difficulty in identifying the difference in call types between chickadee species they were recorded as unknown.
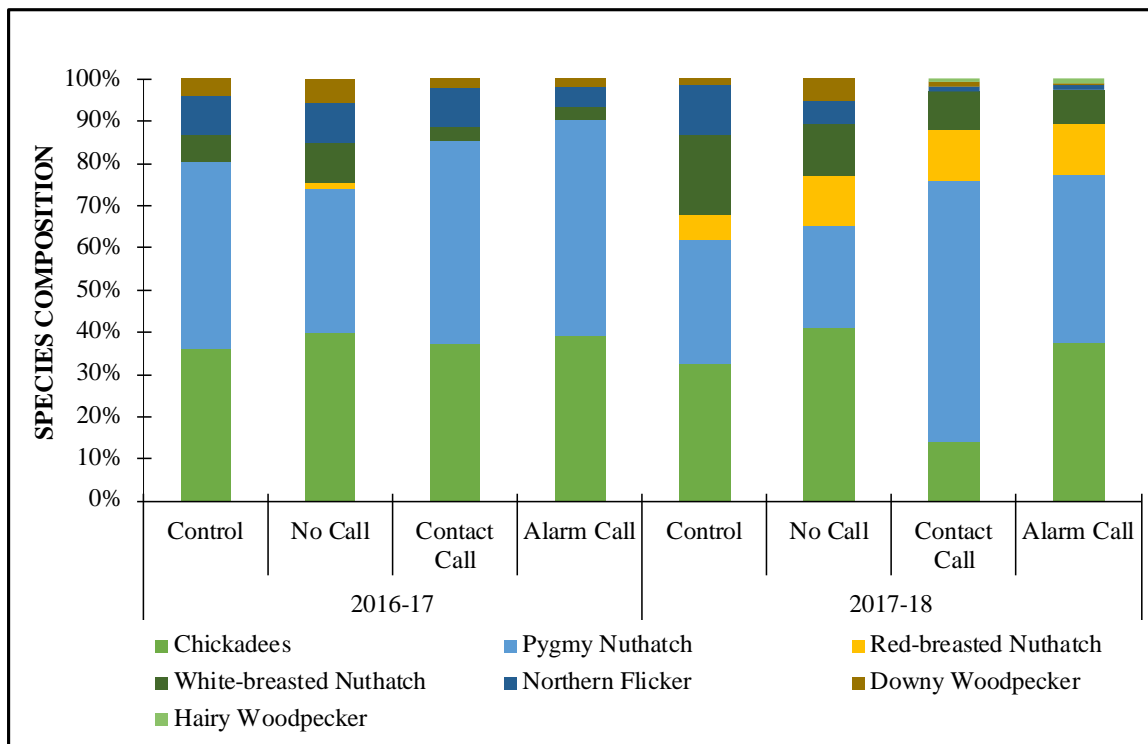
Figure 7: Percent species composition of the individual species observed during the different treatment point counts for both winter seasons.
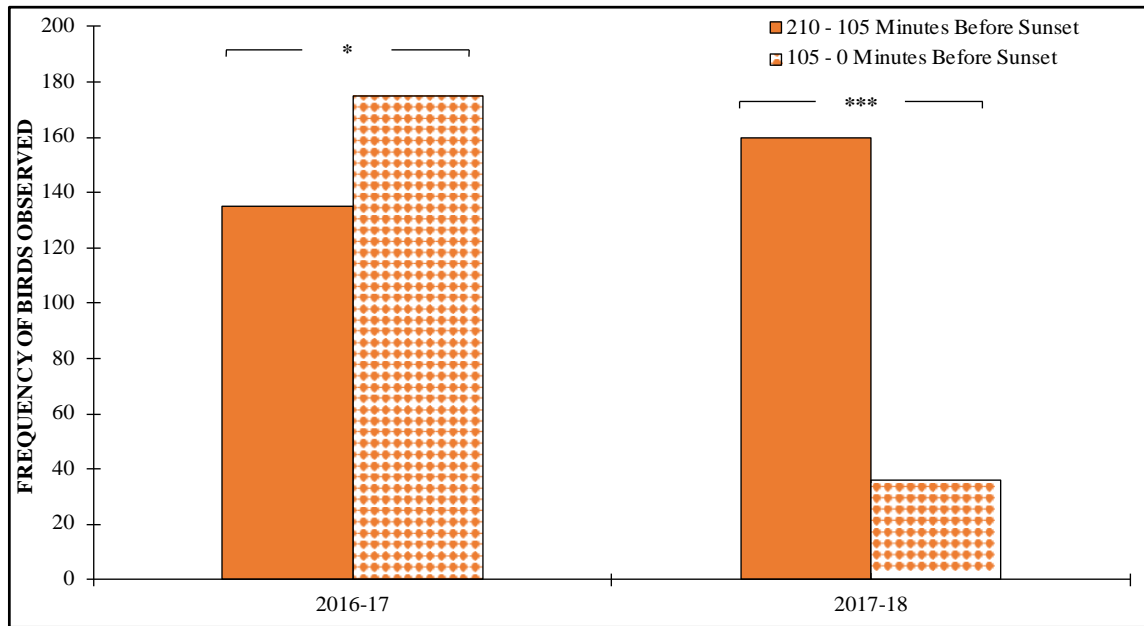
Figure 8: Comparison of number of birds observed during the 210 - 105 minutes and 105 − 0 minutes before sunset time periods for both winters ('*' = P < 0.05; '***' = P < 0.0001).
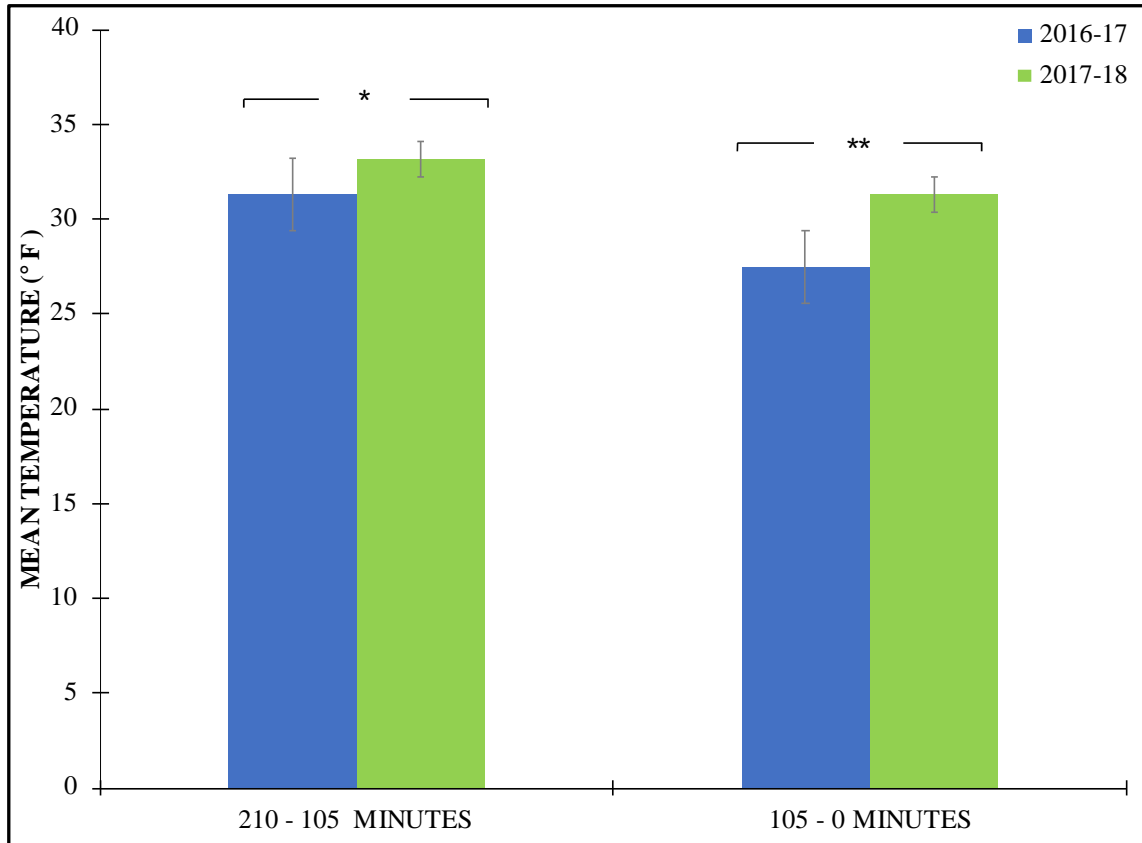
Figure 9: Comparison of mean temperatures during the 210 - 105 minutes and 105 – 0 minutes before sunset time periods for both winters.
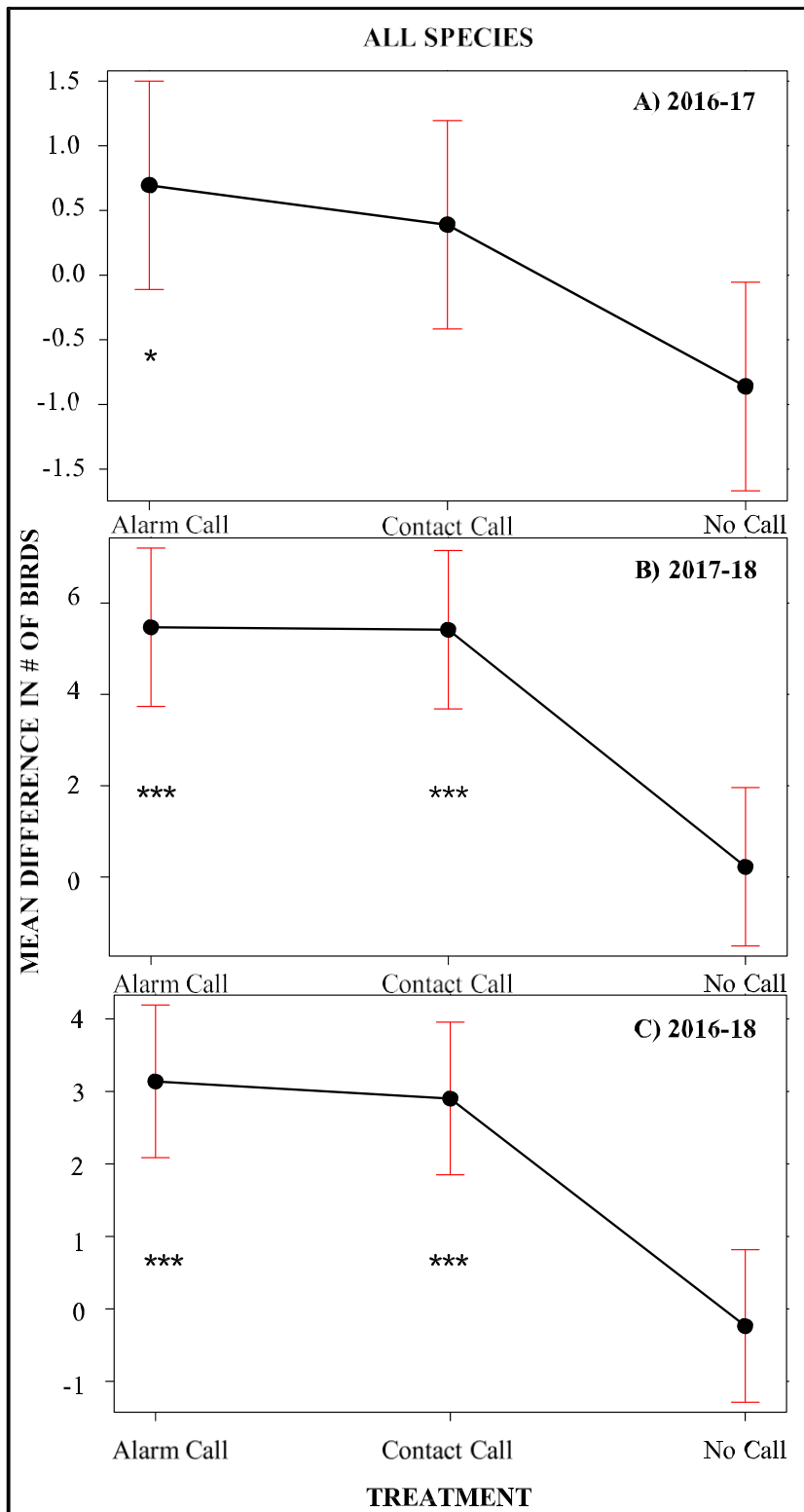
Figure 10: Comparison of the mean differences in the number of all cavity-nesting birds observed between the initial point count and the 3 treatment point counts for both winters separately (A and B) and combined (C) ('*' = P < 0.05; '***' = P < 0.0001).
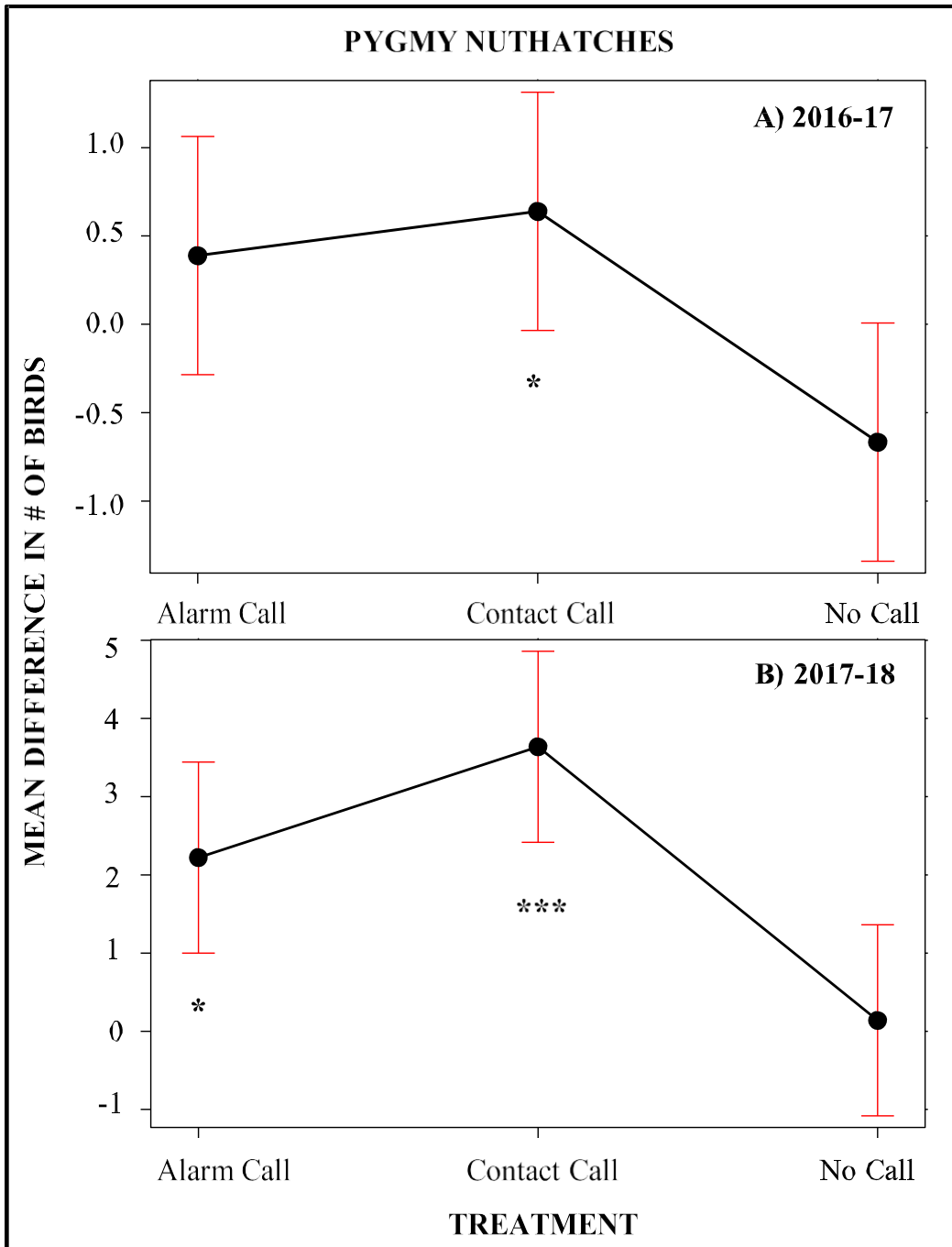
Figure 11: Comparison of the mean differences in the number of pygmy nuthatches observed between the initial point count and the 3 treatment point counts for both winters separately (A and B) ('*' = P < 0.05; '***' = P < 0.0001).
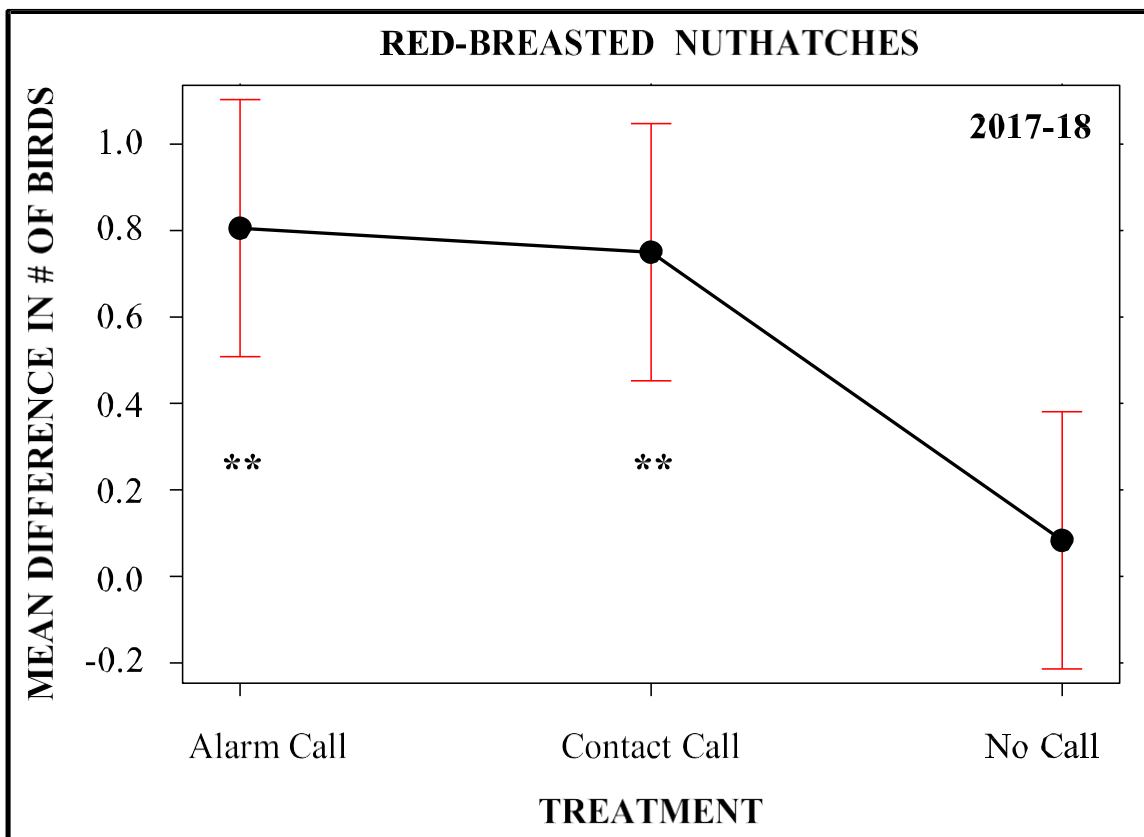
Figure 12: Comparison of the mean differences in the number of red-breasted nuthatches observed between the initial point count and the 3 treatment point counts for the 2017-18 winter ('**' = P < 0.01).
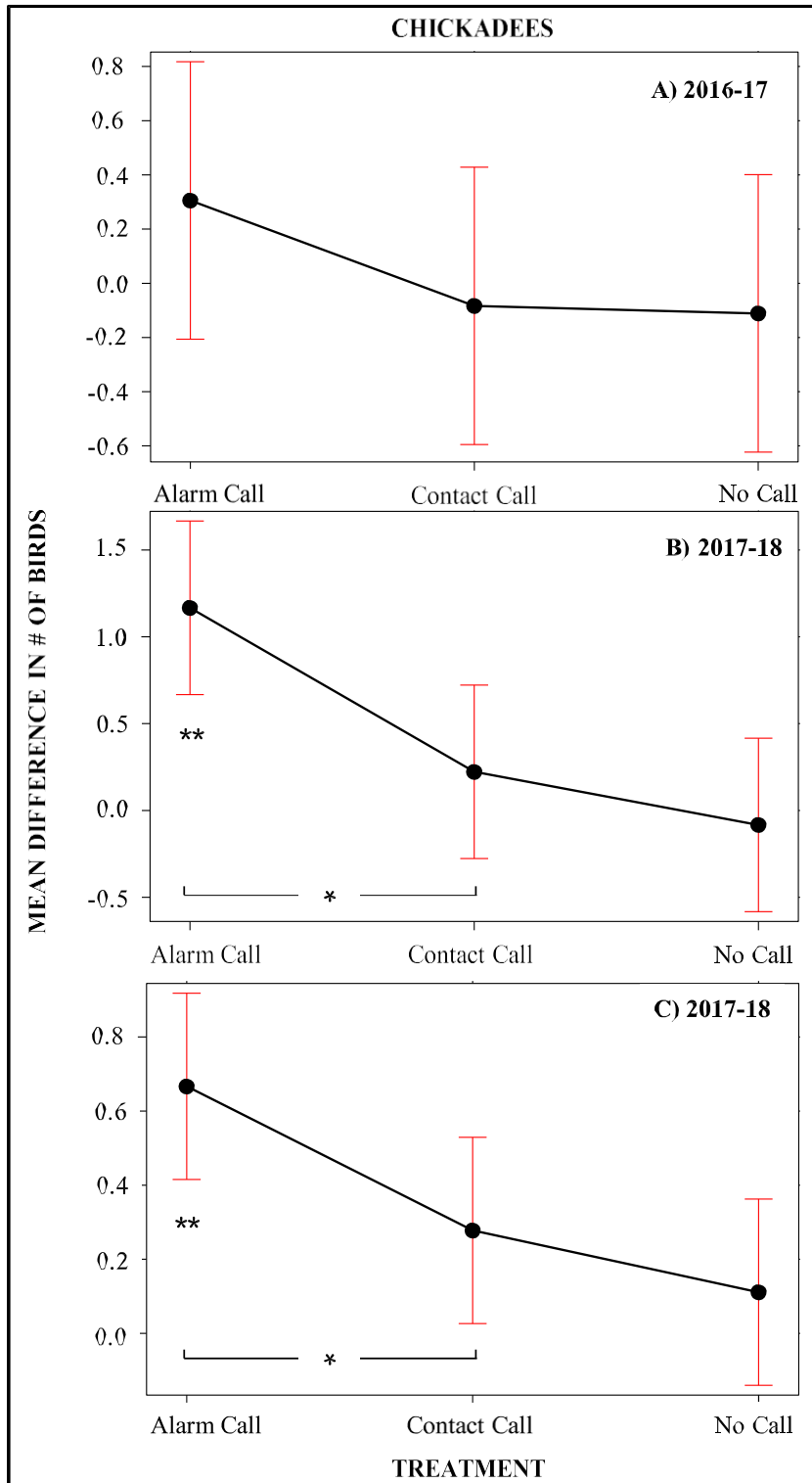
Figure 13: Comparison of the mean differences in the number of combined (A) chickadee species observed in 2016-17 and black-capped (B) and mountain (C) chickadee species in 2017-18 observed between the initial point count and the 3 treatment point counts ('*'= P< 0.05; '**'= P < 0.01).
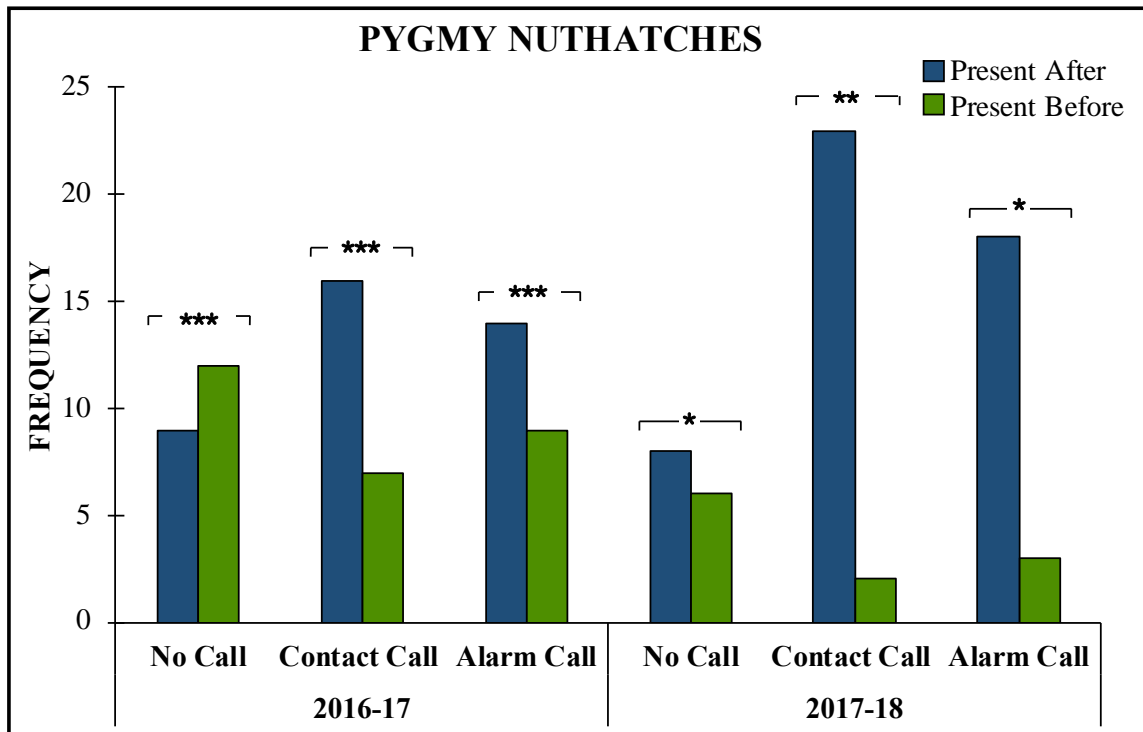
Figure 14: Comparison by treatment of the frequency of point counts in which the pygmy nuthatch was present during control point count but not after the treatment (green) to the number of point counts in which the pygmy nuthatch was present after the treatment but not during the control point count (blue) ('*'= p< 0.05; '**'= p<0.01; '***'=p<0.0001).

Figure 15: Comparison by treatment of the frequency of point counts in which the chickadee was present during control point count but not after the treatment (green) to the number of point counts in which the pygmy nuthatch was present after the treatment but not during the control point count (blue) ('*'= p< 0.05; '**'= p<0.01; '***'=p<0.0001).
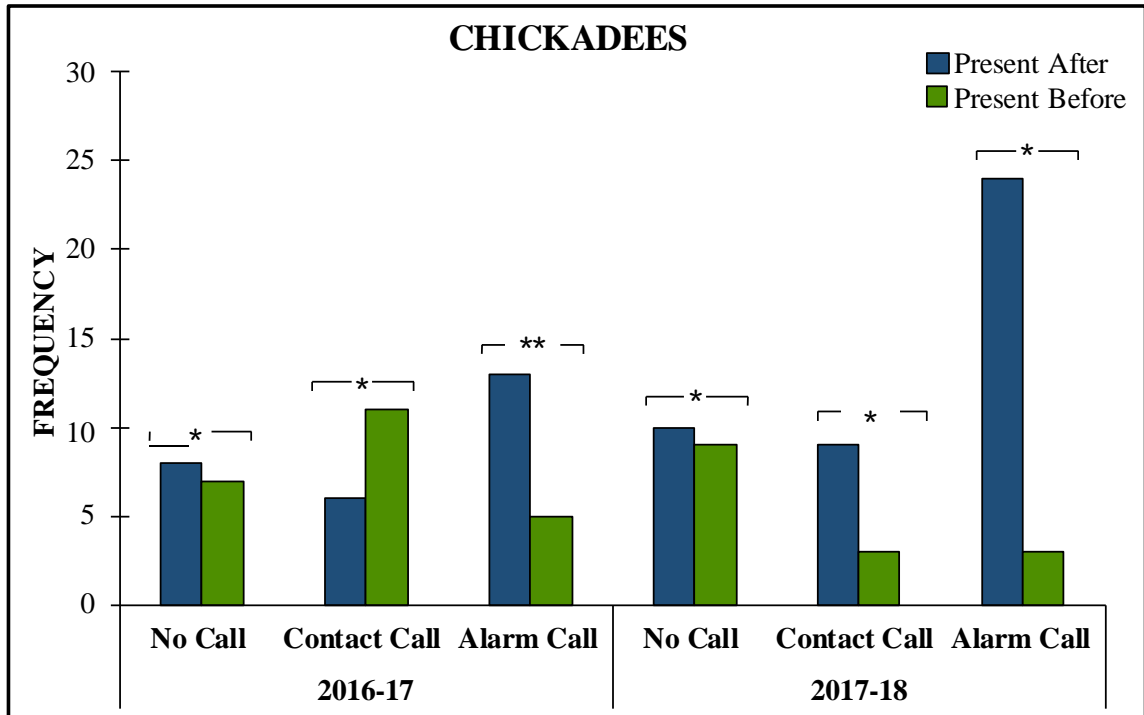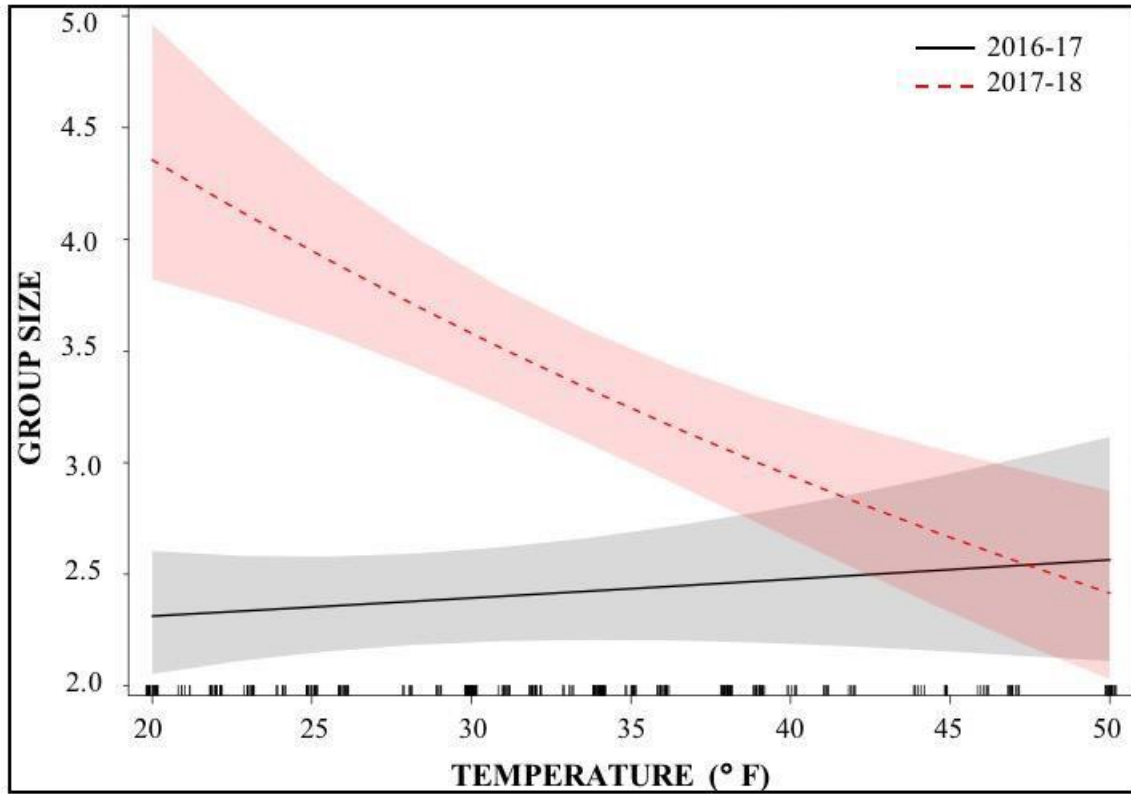
Figure 16: Relationship between ambient temperature and the mean number of individuals in a group.

VII.   VITA

Author: Shelby M. Hunter

Place of Birth: Spokane, Washington

Undergraduate Schools Attended: Eastern Washington University

Degrees Awarded: Bachelor of Science, 2016, Eastern Washington University

Honors and Awards: Student Travel Grant, Biology Department, Eastern Washington University, for presentation at Northwest Scientific Association Annual Meeting, Olympia, WA, 2018

J. Herman, Jean Swartz & Nate Narrance Scholarship, Biology Department, Eastern Washington University, 2017

Graduate Assistantship, Biology Department, Eastern Washington University, 2017 – 2018

Student Research Grant, Biology Department, Eastern Washington University, 2016

Teaching Experience: Ornithology, Vertebrate Zoology, Biology 171 and 172, Environmental Science

Professional Experience: Field Crew Lead Volunteer, Inland Northwest Land Conservancy and Washington Dept. of Fish and Wildlife, Deep Creek Preserve Biological Assessment, small mammal trapping, Reardan, Washington, 2017

Invasive Plant Management Intern, Student Conservation Association, Cheney, Washington, 2016

Field Crew Member Volunteer, Inland Northwest Land Conservancy and Washington Dept. of Fish and Wildlife, Deep Creek Preserve Biological Assessment, small mammal trapping, Reardan, Washington, 2016

Academic Research Experience: Thesis project on "Vocalizations influence roost-site selection in overwintering cavity-nesting birds in Eastern Washington", Eastern Washington University, Master of Science in Biology, 2016-2018

Field Student Research Assistant, "An observational study of ticks on the 30 acre lake trail at Turnbull National Wildlife Refuge", small mammal trapping and tick ecology, Cheney, WA, 2016

Field Student Research Assistant, Population studies of small mammals, Turnbull National Wildlife Refuge, Cheney, WA, 2016

Field Student Research Assistant, "Examining how noncommercial thinning affects the owl biodiversity on the Turnbull National Wildlife Refuge", Cheney, WA, 2015-2016

Field Student Research Assistant, Early waterfowl breeding pair surveys and distribution of marsh birds on the Turnbull National Wildlife Refuge, Cheney, WA, 2015

Field Student Research Assistant, Monitored river discharge, riparian vegetation, river topography, and river conditions, Yakima, WA and Spokane, WA, 2014

Field Student Research Assistant, Soil surveys on different burn histories and the effect they have on nematodes and nitrate levels, Cheney, WA, 2014

Field Student Research Assistant, How snails mobility is effected by different amounts volcanic ash, Cheney, WA, 2014

Field Student Research Assistant, Electro- backpack & boat electro-fishing surveys of fish populations, Cheney, WA, 2014

Lab Student Research Assistant, Cryopreservation of zebra fish sperm and their survival rates detected by sperm mobility, Cheney, WA, 2013

Presentations: S. M. Hunter. 2018. Vocalizations influence roost site selection in overwintering cavity-nesting birds in Eastern Washington. Eastern Washington University Research and Creative Works Symposium, Cheney, WA.

S. M. Hunter and M. A. O'Connell. 2018. Vocalizations influence roost site selection in overwintering cavity-nesting birds in Eastern Washington. Northwest Scientific Association Annual Meeting, Olympia, WA.

S. M. Hunter. 2017. Factors influencing roost site selection in overwintering cavity-nesting birds in Eastern Washington. Eastern Washington University Research and Creative Works Symposium, Cheney, WA.

S. M. Hunter and J. Colegrove. 2016. Early Waterfowl Breeding Pair Survey of Wetlands on Turnbull National Wildlife Refuge. Eastern Washington University Research and Creative Works Symposium, Cheney, WA.

Outreach:	Cub Scouts, taught a group of cub scouts how to conduct an avian vocalization point-count survey, Cheney, WA, 2017
	4-H Military Youth Program, Led a group of 15 4-H Military children teaching them how an avian point-count survey is conducted. I lectured about avian feathers, different feet types and different beak types. Guided an avian flight demonstration/activity, Washington State University – Spokane, WA, 2017
	Environmental Career Program, Lectured about my college experiences and presented my thesis research project, Washington Virtual Academy K-12, Tacoma, WA, 2017
	Floods, Flowers, and Feathers Festival, Volunteered at the Turnbull National Wildlife Refuge booth, Cheney, WA, 2016
Professional Organizations:	Ornithological Societies of North America, 2017 – Present
	Spokane Audubon Society, 2017 - Present