WINTER ECOLOGY OF NORTHERN SAW-WHET OWLS

(*AEGOLIUS ACADICUS*) IN THE SIERRA NEVADA FOOTHILLS

OF CALIFORNIA

A Thesis

Presented

to the Faculty of

California State University, Chico

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

in

Biological Sciences

---

by

Julie Shaw

Summer 2014

WINTER ECOLOGY OF NORTHERN SAW-WHET OWLS (*AEGOLIUS ACADICUS*) IN THE SIERRA NEVADA FOOTHILLS OF CALIFORNIA

A Thesis

by

Julie Shaw

Summer 2014

APPROVED BY THE DEAN OF GRADUATE STUDIES

AND VICE PROVOST FOR RESEARCH:

____

E. K. Park, Ph.D.

APPROVED BY THE GRADUATE ADVISORY COMMITTEE:

____

Colleen Hatfield, Ph.D., Chair

____

Tag Engstrom, Ph.D.

____

Raymond J. Bogiatto, M.S.

ACKNOWLEDGEMENTS

I would have not been able to complete this thesis without the help and support of many people. First and foremost, Dr. Colleen Hatfield has been instrumental in keeping me on track with making progress. She especially helped keep me sane when I was feeling overwhelmed, and has provided guidance on both research and personal matters.

I also would like to thank Dawn Garcia who has put forth hours of additional help for this project. She was an amazing ally in planning and executing much of the field logistics of my research, and this project would have never gotten off the ground without her.

I would also like to thank the remainder of my thesis committee-Jay Bogiatto, MS and Dr. Tag Engstrom, for accepting the extra work of taking on another graduate student. Dr. Kathy Gray has also been extremely helpful with the "statistical challenges" of my thesis.

Thank you to Scott Weidendsaul for your expertise on eastern saw-whets, your knowledge and experience was truly appreciated in the early stages of my research.

The BCCER staff-Jeff Mott, Scott Huber, and Dr. Paul Maslin were all extremely helpful, and I would like to thank them for allowing me access to the reserve in search of my owls. I would like to extend a special thank you to the

BCCER funding committee for awarding me a grant to conduct this research for all three of my study years. Additionally, thanks to the Vesta Holt award committee for funding three of my transmitters.

I would also like to thank the remaining Owl Banding volunteers-Steve and Raina King, Mike Fisher, and Colleen Martin for their enthusiasm for my project. My undergraduate students, Noah Strong, Cheryl Hausle, Nikki Ramey, Jeff Lauder, Cody Akana, and Tyrone Asencio were great assets in the field.

Finally, I want to thank my friends Shannon Rich, Shannon McCamy and Will McCall, who were always willing to help, and my partner Glenn Woodruff, who continues to support me.

TABLE OF CONTENTS

CHAPTER PAGE

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

WINTER ECOLOGY OF NORTHERN
SAW-WHET OWLS
(*AEGOLIUS ACADICUS*) IN THE SIERRA
NEVADA FOOTHILLS OF CALIFORNIA

by

Julie Shaw

Master of Science in Biological Sciences

California State University, Chico

Summer 2014

Northern Saw-Whet Owls (NSWO, *Aegolius acadicus*), one of the smallest owls in North America, migrate in large numbers every fall from higher latitudes and elevation to overwinter at both lower latitude and elevation. While extensive efforts have been devoted to understanding their migration patterns in the eastern US, little is known regarding NSWO migration patterns or winter habitat preferences in the west. The goals of this study were to determine wintering destination of local migrant NSWO, winter habitat, and diet patterns for the first time in California using the Big Chico Creek Ecological Reserve (BCCER) as a study area. NSWO were captured at BCCER during fall migration and fitted with 2.5-gram radio-transmitters. During the fall/winter of 2010-2012, a total of 19 NSWO were

tagged and 112 different roost sites were described. Over 80% of diurnal roosts were between two species: toyon (*Heteromeles arbutifolia*) and canyon live oak (*Quercus chrysolepis*). Paired random sites were also sampled 50 meters from roost sites to determine roosting preferences. Shrub canopy cover was found to be significantly higher at owl roosts compared to random. A diet analysis of 77 pellets collected between ten owls showed NSWO took few prey species, primarily consuming western harvest mice (*Reithrodontomys megalotis*), comprising 48% of 103 prey items. Voles (*Microtus* spp.) and deermice (*Peromyscus* spp.) made up the remainder of the diet. Though NSWO are a common species, little is known about their general habits in the west; therefore results from this study contribute to our understanding of this species.

CHAPTER I

INTRODUCTION

Introduction

Environmental change over time due to human disturbance has caused significant changes to habitat compositions and ecosystem function (Chapin et al. 2000, Hinam and St. Clair 2008). Decades of fire-suppression, logging, grazing, and clearing habitat for residential and commercial uses have all played a role in the destruction of millions of acres of critical wildlife habitat without the consequences of such actions being fully understood. It has been suggested that disproportionate losses of species occur when total habitat cover decreases to 10-30% of the landscape (Radford et al. 2005). The increasing frequency of large, catastrophic fires, such as the Rim fire near Yosemite National Park in 2013 which burned 104,131 hectares, may have devastating effects in the long run for species that are displaced due to immediate habitat loss.

Habitats that are on the edge of urban communities are at greater risk for disturbance because of residential expansion into wild lands and proximity for recreational use. Natural communities existing in close proximity to areas of human disturbance are thus more likely to experience negative impacts, either directly or indirectly, and these disturbances may not be detected in natural communities for a long period of time. In a study examining habitat configuration and species richness in areas with high habitat loss due to pastoralism, cropping, mining, and forestry, Radford et al. (2005) found that tree cover (habitat loss) was the principal determinant of species richness and extinctions. Small habitat patches correspondingly had lower ecosystem function and species diversity (Radford et al. 2005). Simply reserving habitat patches for wildlife does not necessarily mean that populations will thrive; the success of species depends on the entire landscape configuration.

The foothills of the Sierra Nevada mountain range and the natural communities within are not resistant to ecosystem-level changes caused by anthropogenic disturbance. These communities include both seasonal and resident species that must face the challenges of adjusting their behaviors due to a variety of disturbances. Small species of owls, such as the northern saw-whet owl (*Aegolius acadicus*) are included with other raptors that may have their habits affected by environmental change, though effects of these disturbances on saw-whets' success are poorly understood (Groce and Morrison 2010). Several studies have demonstrated the negative effects of habitat disturbance. For example, Hinam and St. Clair (2008) found that male saw-whets had decreased reproductive success due to reduced foraging efficiency and increased physiological stress in heavily fragmented habitats in central Alberta, Canada, which may ultimately decrease population sizes. Because saw-whet owls are a fairly abundant raptor, preying primarily on small mammals, (Rasmussen et al. 2008) it is possible that their ecosystem impact is significant. Any notable decline in their population due to anthropogenic disturbances could potentially have negative consequences for the trophic system.

A study of habitat use by the northern saw-whet owl is warranted, as the species has a broad geographic distribution and as a result, experiences a range of disturbance factors. An extensive effort exists to study migration patterns for the northern saw-whet owl in the eastern US through Project Owlnet, an organization that first started in Maryland in 1995, after several studies began to report large numbers of migrant owls in the fall and winter (Mueller and Berger 1967, Duffy and Kerlinger 1992, Erdman and Brinker 1997, Weidensaul 2010). A network of over 100 banding stations has been created in an effort to determine the magnitude and timing of the migration. Through this effort, banding stations in the eastern US have frequent recaptures of migrant saw-whets and therefore have a relatively complete understanding of saw-whet migration demographics, including specific timing, routes, and magnitude. This understanding has allowed eastern saw-whet owl researchers to predict future fall owl migrations timing and magnitude, and determine if long-term changes over time exist, and if these changes are related to differences in resources, including habitat loss and prey availability.

In contrast to the knowledge base in the eastern US, little is known about population trends, specific habitat preferences, or movement patterns in the western US. Efforts to understand the ecology of the northern saw-whet owl in the west and particularly in the Pacific Northwest are quite limited compared to efforts east of the Rocky Mountains. However, the Pacific Northwest region of North America is inherently different than that of the eastern extent of the species range and there are likely different habitat pressures that are important to understand.

Very few studies in the Pacific Northwest have attempted to reduce the disparity between eastern and western regional efforts. In Washington state, Grove (1985) examined winter roosts and collected pellets. Saw-whet roosts were primarily found in the outer branches of Douglas fir (*Pseudotsuga menziesii*), and pellets collected at owl roosts contained mostly voles (*Microtus* spp., 54%), deermice (24%), and western harvest mice (*Reithrodontomys megalotis*, 15%). During the breeding season, Boula (1982) found roosts in Oregon to be in dense, moist forests of grand fir (*Abies grandis*) or western larch (*Larix occidentalis*) under old-growth canopies of ponderosa pine and grand fir. The North American deermouse (*Peromyscus maniculatus*) was the predominant prey species in 53 pellets, comprising 77% of all prey items (Boula 1982). However, these two studies did not focus specifically on criteria associated with habitat selection (such as specific roost attributes including percent canopy cover, slope, understory, or distance from trunk) and merely described broad roost-site selection.

Frye and Gerhardt (2003) were the first to document saw-whet migration in the Pacific Northwest; they found the magnitude and timing to be similar to that of eastern owls (Brinker et al. 1997), as well as similar patterns of fluctuation in the age ratio between banding years of captured birds, where ratios of hatch year to after hatch-year owls were markedly different between seasons. In addition, Frye and Gerhardt (2003) reported similar peak timing for saw-whet migration, capturing 73% of their owls during the month of October, while 90% of saw-whets at Cape May, NJ were captured between October 16 and November 19 (Duffy and Kerlinger 1992). However, Frye and Gerhardt did not keep the banding station open after their migration study was completed in 2000 after two years of operation, although they explicitly state "...a large-scale effort similar to that in the east is needed to provide comprehensive understanding of this phenomenon throughout the western US" (Frye and Gerhardt 2003).

In the first-ever northern saw-whet owl study in California, Groce and Morrison (2010) looked at breeding season habitat use in the sub-alpine zone in the Lake Tahoe Basin of the Sierra Nevada, and the importance of snags in occupied breeding territories. They found that elevation and dominant tree species influenced saw-whet owl occupancy; saw-whets were more likely to occupy areas containing red fir (*Abies magnifica)* in the upper-montane zone from 2,200-2,600 meters in elevation and less likely to inhabit areas with white fir (*A. concolor*), or the sub-alpnie zone, above 2,600 meters.

A multi-year banding study that began in 2005, focused on northern saw-whet owl migration patterns, showing that the Sierra Nevada Foothills of northern California are a potentially significant migration corridor (Figure 1, Garcia 2013). Nine years of saw-whet owl capture data at two locations; Big Chico Creek Ecological Reserve (BCCER) and Butte Creek Ecological Preserve (BCEP, Figure 2) reflect migration patterns similar to Frye and Gerhardt (2003) as well as banding stations in eastern North America (Weidensaul 2010, Beckett and Proudfoot 2011). One example includes peak migration timing during the last couple weeks of October and first week of November when the highest numbers of saw-whets were captured at the BCCER.

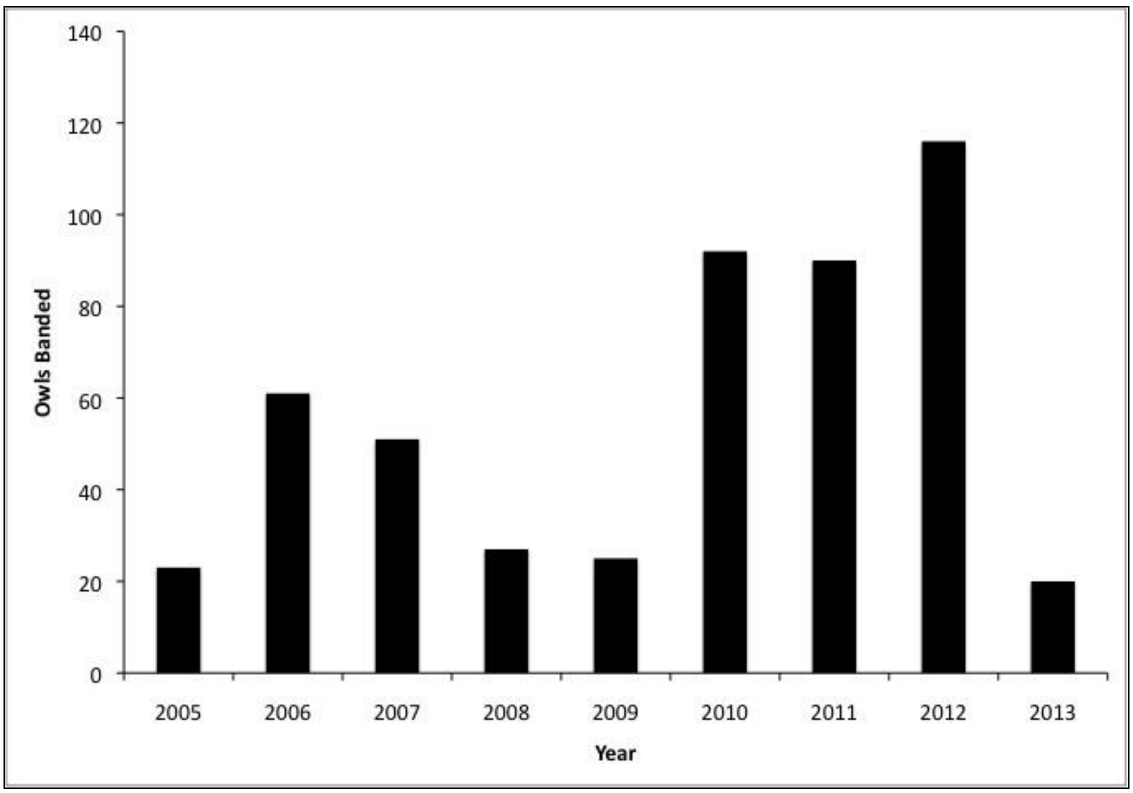

Figure 1. Number of migrant saw-whet owls at both the BCCER and BCEP banding stations, 2005-2013 (Garcia 2013).

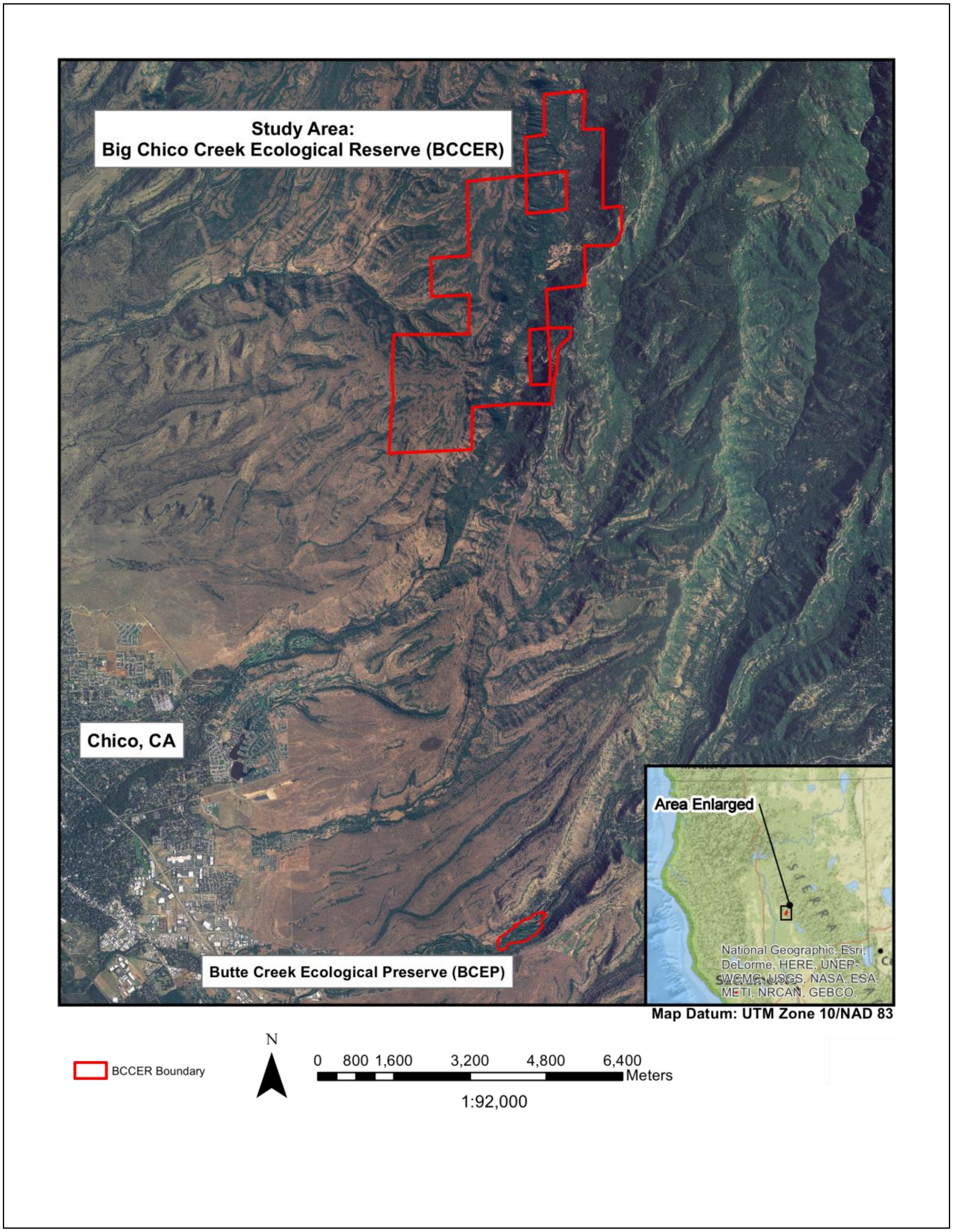

Figure 2. Study area map of both Big Chico Creek Ecological Reserve and Butte Creek Ecological Preserve, Butte County, CA.

Evidence provided by Garcia (2013) suggests that the Sierra Nevada Foothills are an active migration route for northern saw-whet owls, although information about their migration in the Pacific Northwest is lacking; indeed, the western saw-whet owl migration route(s) remains unknown (Johnson and Anderson 2003). It may be years before a migration corridor is described. The few migration studies in the west have only given us a glimpse of saw-whet owl habits relative to what is known about eastern saw-whets, where the concentrated banding effort through Project Owlnet has lead to the creation of many associated studies (Churchill 1998, Brittain 2008, DeRuyck 2009, Weidensaul 2010, and Speicher et al. 2011). The BCCER migration study has begun the effort to bridge the gap between the two regions; this is will be the first winter study associated with a migration project in California, and certainly one of very few in the west. Indeed, Frye and Gerhardt (2003) also mention the need for more western saw-whet owls studies for a more comprehensive understanding of this species.

In light of the changing northern California landscape due to disturbance associated with development, climate change, and in particular, urban development in the surrounding foothills, it is important that we better understand the habitat requirements of species utilizing the area. The goal of this project was to determine if the Sierra Nevada Foothills are a winter destination for saw-whet owls, and to characterize their winter habitat and diet. The objectives of this study were to: 1) use radio telemetry to monitor movements and winter habitat preferences of both resident and transient northern saw-whet owls; 2) conduct a diet analysis using owl pellet remains found at diurnal roosts; 3) determine if owl habitat use is random or selective; and 4) determine home range size for resident owls who spent a significant amount of time wintering at the BCCER.

Saw-whet owls have the potential to make a large impact on their habitat by consuming a significant portion of the prey base, especially during years when there is a migration irruption (when an unusually high number of first-year birds migrate to their winter grounds; Rasmussen et al. 2008). Additionally, saw-whets serve as a prey item for other predators, both mammalian and avian, so understanding their local winter ecology could aid in understanding how saw-whets choose habitat, as well as providing insight into which habitat types are ideal for land managers to support and maintain. In light of the rapidly changing landscape in northern California due to urbanization, logging, and farming, it is critical to understand the needs of the wildlife using the area to better protect them.

Species Description

The northern saw-whet owl is a small-bodied raptor, with a body mass ranging from 75-100 grams (Rasmussen et al. 2008). Males are smaller than females, weighing approximately 75 grams and measure 18-20 centimeters in length; female mass ranges from 85-100 grams and range from 20-21.5 centimeters in length. With the exception of size, males and females are sexually monomorphic. As adults, they have brown bodies spotted with white, with white breasts streaked with dark brown. Their facial disks are white surrounded by brown, they have large yellow eyes, and they lack ear tufts (Rasmussen et al. 2008).

Northern saw-whet owls are the most commonly banded bird species in North America (Erdman et al. 1997, Frye and Gerhardt 2003). They inhabit a broad variety of habitats throughout the year, including rural areas, although the highest concentrations are found in coniferous forests (Grove 1985, Swengel and Swengel 1992, Milling et al. 1997, Churchill et al. 2000, Marks and Doremus 2000, Johnson and Anderson 2003, Brittain 2008, Rasmussen et al. 2008, Groce and Morrison 2010). The species' geographic range is widespread, and stretches from southern Alaska, across Canada in the Boreal zone, and southward into Mexico (Rasmussen et al. 2008). Their breeding range is extensive, and includes mountainous zones in North America north of Mexico, riparian areas, poplar plantations, and coniferous swamps (Rasmussen et al. 2008, Dunn and Alderfer 2011). The highest concentrations of breeding saw-whet owls occur in the coniferous forests of North America, especially along riparian corridors: although a wide variety of woodland and forest habitats may be used if suitable nesting territory and nest cavities are available (Marks and Doremus 2000, Johnson and Anderson 2003, Rasmussen et al. 2008). Saw-whet owls are strictly secondary cavity nesters, preferring the excavated holes of northern flickers (*Colaptes auratus*, Johnson and Anderson 2003). Broods have also been reported in nest boxes (Marks and Doremus 2000).

Breeding site fidelity is extremely low and it has been suggested that saw-whets are nomadic, migrating to different areas in search of plentiful prey (Marks and Doremus 2000, Bowman et al., 2010, Beckett and Proudfoot 2011). In a thirteen-year study, Marks and Doremus (2000) banded 191 adult and juvenile saw-whet owls, with only one bird returning to breed to their study area in a subsequent year. In addition, the body of a banded male that had bred on the study area in 1990 was recovered 920 kilometers north three years later: only these two records were found out of the 191 banded owls, which emphasizes this species' enigmatic behavior (Marks and Doremus 2000). Additional evidence to support the notion that saw-whets are nomadic stem from Bowmen et al.'s (2009) study in central Ontario, Canada, which examined the relationship between northern saw-whet owls and red-backed vole (*Myodes gapperi*) densities. Results from this study found no time lag between the magnitude of the fall migration and the numbers of rodents caught during trapping surveys; when high numbers of red-backed voles were captured, the highest densities of saw-whets were recorded during fall migration, while the lowest vole densities led to low numbers of migrating owls (Bowmen et al. 2009). This evidence supports the idea that saw-whets, among several other owl species, can quickly assess food availability in an area and determine if there is an adequate supply to maintain a territory (Korpimaki 1994, Cote et al. 2007, Bowmen et al. 2009).

Every autumn, saw-whet owls migrate in large numbers from their breeding range to lower elevations and latitudes, possibly to escape the harsh winters on the breeding grounds (Brinker et al. 1997), or to find more abundant prey resources. There are three known migration routes for saw-whets in eastern North America; 1) from central Ontario through Ohio and on to Kentucky, 2) on the Atlantic coast from Nova Scotia to North Carolina, and 3) across and around the

Great Lakes, with dispersion occurring both south and east (Holroyd and Woods, 1975, Rasmussen et al. 2008). Even though there is a large effort in eastern North America to capture migrant saw-whets on these known migration paths, few owls are recovered between years or between owl banding stations despite the large concentration of banding sites. In particular, the western migration route is virtually unknown, but captures from several western stations reveal numbers as high as some eastern sites (Frye and Gerhart 2003, Johnson and Anderson 2003, Rasmussen et al. 2008).

Saw-whet owl habitat may be seasonally variable, as they may use habitats in the fall and winter that are unsuitable for breeding while supporting an abundant prey base and dense vegetation for roosting (Hayward and Garton 1984, Grove 1985, Swengel and Swengel 1992, Churchill et al. 2000, Churchill et al. 2002, Brittain 2008). Many studies examining saw-whet owl diurnal winter roosts found them almost exclusively using conifers, though other habitats were available (Mumford and Zusi 1958, Grove 1985, Swengel and Swengel 1992, Churchill et al. 2000, and Weidensaul 2010). Churchill et al. (2000) found radio-tagged saw-whet owls more often in pine forest habitat than expected; 52% of the roosts were in pine forest though this habitat type comprised only 6.9% of the area on Assateague Island, MD. Weidensaul (2010) found winter roosts for saw-whets in Michaux State Forest, Pennsylvania primarily in conifers, with over 85% of the roosts in conifers compared to 12% in deciduous species, including mountain laurel. In the only published study of saw-whet owl winter habitat in the Pacific Northwest, Grove

(1985) found birds roosting exclusively in douglas fir when those trees were present, though these roost sites were usually either adjacent to shrub-steppe or orchard habitats. Other roost sites were in an orchard and in a willow thicket (Grove 1985).

The diet of northern saw-whet owls has been examined in several studies, and although the studies were in different regions, most agree on which prey species were most important. North American deermice, and voles (*Microtus* and *Myodes* spp.) were important dietary items in all northern saw-whet owl prey studies (Boula 1982, Grove 1985, Hayward and Garton 1988, Marks and Doremus 1988, Swengel and Swengel 1992, Holt and Leroux 1996, and Rains 1997), although remains of house mice (*Mus musculus*), western harvest mice (*Reithrodontomys megalotis*), shrews (*Sorex* sp.), birds, and insects were also noted in nest box caches and pellet remains. The two Pacific Northwest region studies examining prey (Boula 1982, Grove 1985) also found deermice to be an important prey item, along with voles.

II.

METHODS

Study Area

Fieldwork for this project was conducted during the fall owl migration season, from early November through early February, for three seasons spanning 2010-2013. Sampling was primarily concentrated at the 1600-hectare Big Chico Creek Ecological Reserve (BCCER) south of Forest Ranch and 16 kilometers northeast of Chico in Butte County, California (Figure 3). BCCER, which is part of the CSU, Chico reserve system, begins in the foothills of the Sierra Nevada, 7.2 kilometers northeast of Chico and spans 7.2 kilometers of Big Chico Creek Canyon, ranging in elevation from 223 to 623 meters. Since BCCER is mostly contained within a canyon, much of the habitat is interspersed with rocky outcrops and steep slopes.

BCCER is a relatively "pristine" ecosystem compared to surrounding areas due to an emphasis on land management and removal of non-native species (BCCER 2014). Natural habitat types are found throughout BCCER, including: grassland, wet meadow, mixed woodland/forest, riparian, chaparral, blue-oak woodland, valley oak woodland, and chaparral. A majority of the west side of the property is dominated by chaparral/savannah (54%) and chaparral (23%), where bands of chaparral are interspersed with bands of savannah or grassland.

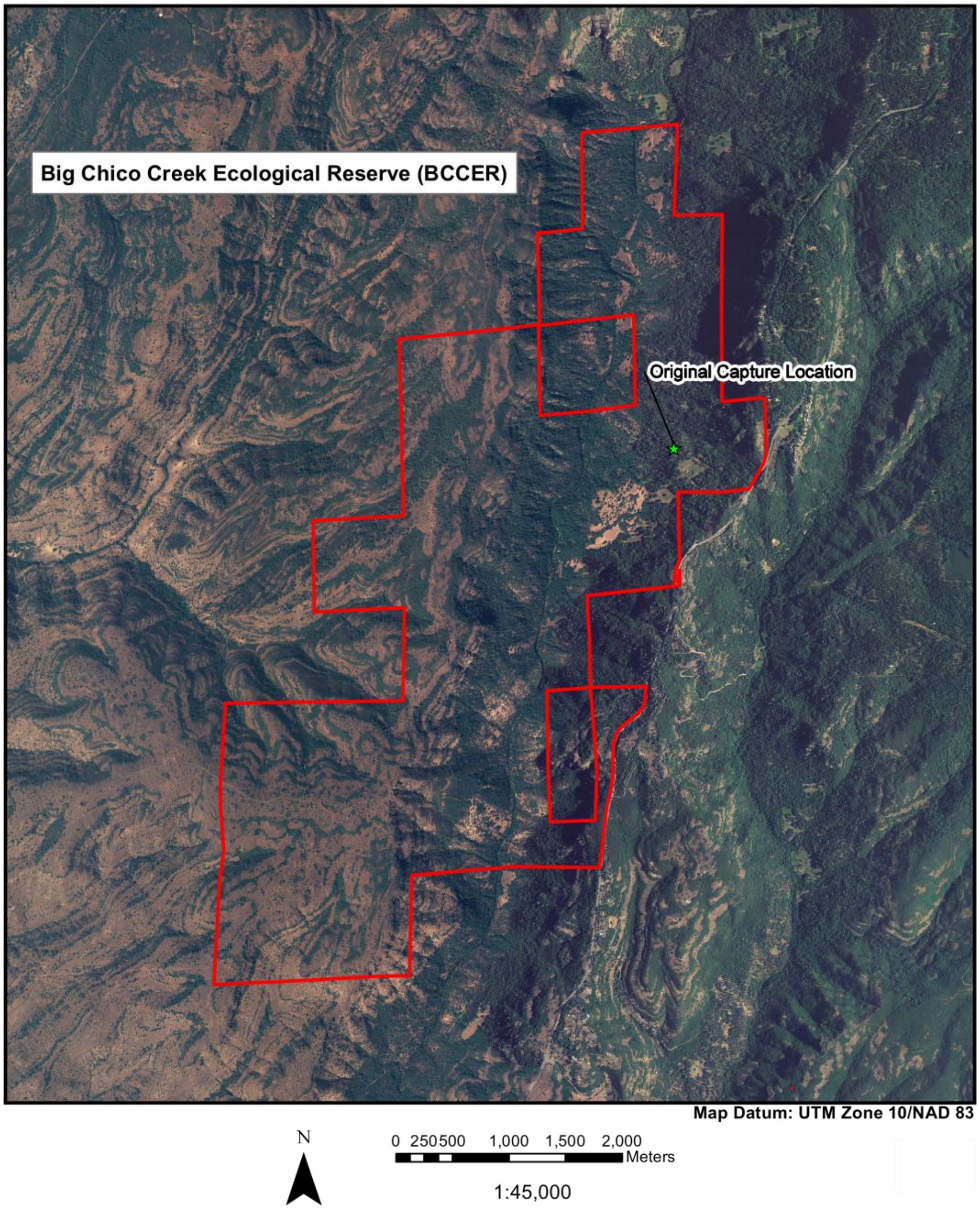

Figure 3. Map of Big Chico Creek Ecological Reserve study area. The green star on the map shows where northern saw-whet owls were originally captured in mist-nets on the BCCER property.

Chaparral species include buckbrush (*Ceanothus cuneatus*), scrub-oak (*Quercus berberidifolia*), birch-leaf mountain mahogany (*Cercocarpus betuloides*), California bay (*Umbellularia californica*), manzanita (*Arctostaphylos* spp.), toyon (*Heteromeles arbutifolia*), and foothill pines (*Pinus sabiniana*) in more open areas. Grassland species include an abundance of both native and exotic annual grasses, yellow star-thistle (*Centaurea solstitialis*), spring-blooming native forbs, and typically does not include woody vegetation.

Dominant tree species found in blue-oak woodland habitat (approximately 10% of the Reserve) include: blue oak (*Quercus douglasii*) and some scattered foothill pines with both non-native and native grasses and forbs (BCCER 2014). Valley oak woodland (*Q. lobata*) is a small percent of the Reserve (0.2%) and typically has a brushier understory than the blue-oak woodland, which includes poison oak (*Toxicodendron diversilobum*) and hoary coffeeberry (*Rhamnus tomentella*). The mixed woodland/forest habitat (11.5%) is the most diverse and contains a mixture of conifers and hardwoods as dominant species, including interior live oak (*Q. wislizenii*), canyon live oak (*Q. chrysolepis*), black oak (*Q. kelloggii*), foothill pine, ponderosa pine (*P. ponderosa*), incense cedar (*Calocedrus decurrens*), douglas fir, and bigleaf maple (*Acer macrophyllum*). Understory species include small canyon live oaks, incense cedars, and maples, or previously listed chaparral species, along with native forbs and grasses (BCCER 2014).

Riparian habitat, which occurs along the margins of Big Chico Creek and perennial water sources, contains a large diversity of both woody and herbaceous species. Dominant tree species include western sycamore (*Platanus racemosa*), willows (*Salix* spp.) and white alder (*Alnus rhombifolia*). Other common woody riparian species include California wild grape (*Vitis californica*) and spicebush (*Calycanthus occidentalis*). Many species of sedges, rushes, and forbs, along with several non-native woody species are common (BCCER 2014).

North of BCCER as elevation increases, the habitat is typical mixed-coniferous forest dominated by ponderosa pine, incense cedar, black oak, and douglas fir, which other western studies have characterized as saw-whet owl habitat (Boula 1982, Grove 1985). A large percentage of this land is owned by private timber companies and has a matrix of clear cuts throughout.

The BCCER is representative of habitat types throughout the Sierra Nevada foothills, near Chico. However, much more of the foothill region is more disturbed as a result of land development for residential and commercial uses, including land clearing for logging or grazing. The BCCER is a heavily managed property unlike much of the surrounding foothills, with management focused on the removal of invasive plants and providing fuel breaks to decrease the intensity of potential fires (BCCER 2014). Thus, the BCCER provides an ideal location for this study as it potentially provides suitable habitat for multiple species utilizing the Sierra Nevada Foothills because of the minimal human interference and emphasis on protecting natural resources.

Telemetry Installation

This study was an offshoot of a multi-year northern saw-whet owl banding project (Garcia 2013) and occurred in coordination with banding efforts during each year of the study. Radio-transmitter installation began in early November all three years of the study. Protocols for the capture of migrant northern saw-whet owls in order to attach radio-transmitters were consistent with the recommended methods from Project Owlnet (Brinker et al. 2014), where mist-nets were set up and an audio-lure was used to attract migrant saw-whet owls beginning 30 minutes after sunset.

The harness for the radio transmitter was made of thin, elastic nylon string provided by Wildlife Materials to allow for some stretch. The string was tied together using white cotton thread. Overall, the harness and transmitter weighed no more than 2.5 grams, or equivalent to less than 5% of an 85-gram owl's body weight. This design allowed the harness to move with the owl without constricting the animal, and the cotton thread tie to eventually be picked apart by the bird or decay so the owls did not have to wear the transmitter indefinitely (Figure 4). Transmitter frequencies were in the 218.000 MHz range, and were selected in coordination with CA Department of Fish and Wildlife telemetry studies occurring concurrently in northern California. Transmitter battery life was between 90 and 95 days, which was consistent with the duration of the predicted life of the harness attachment. Owl banding and telemetry installation activities were conducted under licensed Master Bander Dawn Garcia, permit number 23591, and under California Department of Fish and Wildlife Scientific Collecting Permit number SC-11362.

Figure 4. Backpack harness to be fitted on a saw-whet owl. Photo by Scott Weidensaul.

Winter Roost Site Characterization

To find northern saw-whet owl transmitter signals, I used a TRX-48S receiver (Wildlife Materials, Murphysboro, Illinois) in combination with an omni-directional car-mounted whip-antennae or a 3-element folding yagi antennae, also from Wildlife Materials. Radio-tracking occurred 4-6 times a week, weather permitting, to gather the maximum number of roost site records possible before owls removed their harnesses or left the area. When an owl signal was detected, their transmitter was followed using the receiver and antennae combination until each owl was located at its roost location, or its location was evident based on the presence of fresh urea, whitewash, and/or pellets (in combination with a transmitter signal). I attempted to get a visual on every radio-tagged bird once I located specific roost trees or shrubs. A GPS point in latitude/longitude coordinates was recorded for new every owl roost. Coordinates were later converted into Universal Transverse Mercator (UTM) coordinates and entered into a Geographic Information System (GIS) 10.1 (Esri 2011) for further analysis.

I also took multiple habitat measurements once I located an owl including: roost species, understory species, canopy species, roost height, owl distance from bole (trunk of tree, for tree roosts), diameter at breast height (DBH) for tree roosts, canopy cover (measured with a densiometer directly under the roost site), slope (measured with a clinometer or a compass), height of roost tree/shrub, size of understory or roost shrub, aspect of slope, and weather conditions. I also collected pellets at roost sites, if present, or I returned to roost sites after the owl had left to minimize disturbance to roosting owls. If present, prey cached at roost sites was also documented. Beginning in the second field season, I also measured mid-canopy gap, or the distance between the understory layer and the canopy, if there were multiple vegetation layers associated with the owl roost. These additional measurements were only collected during the second season of owl tracking and during all random vegetation surveys.

<u>Random roost site characterization</u>

In order to determine whether saw-whet owl roosts were the result of habitat selection, I randomly selected trees and shrubs to sample habitat saw-whet owls were not using. To compare roost sites to a non-roost (random) site, for each roost site a random bearing was generated. I then walked 50 meters in that direction and sampled the nearest shrub if the owl was using a shrub or tree if the owl was using a roost tree. The 50-meter distance was chosen, as it would be far enough from the original roost that it would not overlap with the original roost area yet close enough so that it was within the same habitat type. Measurements taken at random shrub sites were similar to those taken at the shrub roost sites and included: slope, aspect, canopy cover, height, width, and length of shrub, mid-canopy gap, which is the distance between the bottom of the canopy of the trees (overstory) and the shrub layer, and shrub species. These same measurements were taken at random tree sites, with the addition of DBH.

Only one random vegetation survey point was done for roosts used multiple times by the same owl. I tried to minimize within-season random roost spatial dependence between owls roosts by making sure random roost sites were at least 50 meters from the nearest neighbor of the same year, or nearest roost point from a different owl. All of the random tree and shrub measurements were taken during the winter season of 2012-2013 for all three tracking season roost sites.

Several of the paired random points were dropped from the analysis because an incomplete data set was collected.

Pellet Dissection and Analysis

Northern saw-whet owl pellets were collected at roost sites during the first two tracking seasons only. They were either collected directly beneath tracked owls while they were still present, or were collected on a subsequent day at the flagged roosts after the owl had left. On several occasions, pellets were observed being regurgitated from the radio-tagged saw-whet owls, and many pellets were still moist when the owl was still present, so I am confident that collected pellets were from my study owls at roost sites and not other owls or other small owl species. Prior to analysis, each individual pellet was frozen until further analysis.

Pellet analysis began by measuring length and width of each pellet, in millimeters, using digital calipers. Then, I separated fur and other detritus from the skeletal elements within each pellet, and further separated the bones into cranial and post-cranial categories. Using the CSU Chico Vertebrate Museum rodent crania for reference, I was able to identify the majority of the prey items to species as well as the minimum number of individuals (MNI) in the owl pellets (White 1953). Each pellet was double-checked to make sure the initial identification was accurate. When cranial elements were missing, I compared my known post-cranial elements found in pellets to the unknown based on size and shape to get positive identification for each prey item. In several instances, invertebrate remains were found in pellets, and I used the CSU, Chico entomology collection to classify insect remains to Order/Family/Genus.

<u>Statistics</u>

All statistics were performed using the software package R (R Development Core Team, 2011) or SPSS version 22 (SPSS Institute Inc. 2013). In order to compare random vegetation measurements with owl roost vegetation measurements to determine if habitat use was due to habitat selection by the owls or random selection, a matched-pairs logistic regression with a random effect was performed (Hosmer and Lemeshow 2000). The model used was of the form:

$$l_k(\beta) = \frac{e^{\beta' x_{1\lambda}}}{e^{\beta' x_{1\lambda}} + e^{\beta' x_{0k}}}$$

where β = the estimated coefficient (the specific value from the data) resulting in an n-unit increase in the explanatory variable for an $e^{n\beta_i}$ increase in the odds ratio (Compton et al. 2002). The term χ_{1k}=1 or χ_{0k}=0 based on if the owl was in “toyon” (1) or “other shrubs” (0) or “canyon live oak” (1) or “other trees” (0), for the *k*th stratum or pair (Hosmer and Lemeshow 2000). For each measured variable, values from the owl roosts were subtracted from the paired random roosts (“control”), which were then fitted to standard logistic regression with a response vector of all 1’s and a matrix of predictor variables (Compton et al. 2002).

Only owl roosts that had a matched random plot were used, so several roosts were dropped from the analysis. Table 1 includes a full list of habitat variables and their use in the model. I performed F-tests to determine equality of variances for which variables should be included in the model with an α=0.15. This

α-value was used instead of the usual α=0.05 because values over α=0.15 may be masking significance from other variables. A variable with an α-value greater than .15 in the model, when removed, may change the values of variables towards a more significant α-value. Some variables were not included in the analysis, as they were not consistently measured among all roosting locations between years. These variables included: length, width, and height of understory shrubs, and mid-canopy gap. Canopy species was not used in the model because many of the shrub roosts did not have canopy in the vicinity of the shrub. I considered variables to be significant at a p-value of 0.05.

I used SPSS for non-parametric, independent Kruskal-Wallis tests to compare between roosts in toyon and all other shrubs and canyon live oak trees and all other trees. I compared differences between years for owl pellet length, width, and MNI using t-tests. A chi-squared analysis was completed to test differences among the prey distribution between the first two years of saw-whet owl tracking. Summary statistics were also performed to describe the saw-whet owl pellet distribution.

Table 1. Descriptions and codes for habitat variables used in the paired linear regression to compare saw-whet owl roosts and random roosts.

Variable	Definition, Units, and Code
Random shrub species RAN. SP	Random paired shrub to owl roost shrub 0=Other, 1=Toyon
Shrub roost species ROO.SP	Shrub roost used by saw-whet owl 0=Other, 1=Toyon
Shrub roost difference SHRUB.D	Difference between random and roost shrub species
Random shrub height RAN.SH.HT	Height of random shrub species (meters)
Roost shrub height ROO.SH.HT	Height of owl shrub roost (meters)
Shrub height difference ROOST.HT.D	Difference between random and roost shrub heights (meters)
Random canopy percent cover RAN.CAN.SH	Percent cover at random roost (percent)
Roost canopy percent cover ROO.CAN.SH	Percent cover at owl roost (percent)
Canopy cover difference CANOPY.SH.D	Difference between random and roost canopy covers
Random shrub slope RAN.SH.SL	Slope of ground at random roost site (percent)
Roost shrub slope ROO.SH.SL	Slope of ground at owl roost site (percent)
Shrub slope difference SH.SL.D	Difference between random slope and roost slope
Random canopy species RAN.CAN.SP	Canopy species present at random roost sites 0=Other, 1=Canyon live oak
Roost canopy ROO.CAN.SP species	Canopy species present at owl roost sites 0=Other, 1=Canyon live oak
Canopy species difference SH.CAN.SP.D	Difference between canopy species of random and roost sites.
Random tree species RAND.TR.SP	Random tree species paired with owl tree roost site
Tree roost species ROO.TR.SP	Tree species used by saw-whet owl

Tree roost difference TREE.SP.D	Difference between random and roost tree species 0=Other, 1=Canyon live oak
Random understory species RAND.UND	Understory species present at random tree roost sites 0=Other, 1=Toyon
Roost understory species ROO.UND	Understory species present at owl tree roost sites 0=Other, 1=Toyon
Random tree height RAND.TR.HT	Height of random tree roosts
Roost tree height ROO.TR.HT	Height of roost trees used by owls
Tree height difference TR.HT.D	Difference between random tree height and roost tree height
Random tree DBH RAND.DBH	DBH of random roost trees
Roost tree DBH ROO.DBH	DBH of owl roost trees
DBH difference DBH.D	Difference between random tree DBH and roost tree DBH
Random tree canopy RAN.TR.CAN	Percent canopy cover of random roost trees
Roost tree canopy ROO.TR.CAN	Percent canopy cover of owl roost trees
Canopy cover difference TREE.CAN. D	Difference in percent canopy cover between random and roost trees
Random tree slope RAN.TR.SL	Slope of ground at random tree roosts
Roost tree slope ROO.TR.SL	Slope of ground at owl roost trees
Tree slope difference TREE.SL.D	Difference between random roost and owl roost slope

GIS Analysis

To determine home range, I used ArcGIS 10.1 (Esri 2011) to calculate both the minimum convex polygon (MCP) and Kernel Density Estimate for owls that remained in the area for more than two months. MCP is the minimum area created by connecting the outermost points of an animal's range (White and Garrott 1990). MCP is used as an estimate of an animal's home range, though it may include areas not used or inaccessible to the animal (White and Garrott 1990). I calculated MCP to compare values with prior saw-whet owl home range studies. Kernel estimators are another approach for estimating home ranges and are preferred as they produce an unbiased density estimate directly from the data and are not influenced by grid size or placement (Seaman and Powell 1996, Boitani et al. 2000). Additionally, kernel estimators can give a probability ellipse based on point density, predicting where an individual animal is likely to spend the most time. Therefore, kernel estimators provide a better prediction of home range based on observations and not just data points, as in MCP.

To find the kernel density of owl roost points, I converted my roost data layer to a point data layer in ArcGIS, and then used the "kernel interpolation with barriers" tool. I used the default settings within the kernel density tool for population field and search radius inputs, and changed the output raster to square meters. I used both 50 percent and 95 percent kernel estimates of the results to determine home range size.

Finally, to compare habitats between saw-whet owl roosts and random points, I used vegetation data from the Northern Sierra Nevada Foothills Vegetation Project: Vegetation Mapping Report (Menke et al. 2011). I created a 25-meter radius buffer around each owl roost point as well as each random site point. I then overlaid the buffered points onto the vegetation layer and clipped the vegetation layer to pair the habitat types within each 25-meter radius buffer. The area of each vegetation type within the clipped layer was calculated for saw-whet roosts and for random sites and averages were calculated and compared for each vegetation type in owl roost habitat and random habitat.

III.

RESULTS

BCCER Winter Residency Summary

Of the 19 radio-tagged owls, only three (owl #2, 5 and 12) stayed 27 days or longer (Table 2). Two birds (owls 5 and 12) stayed for 75 and 91 days, respectively; both were second-year females who used similar habitats on the Reserve. Nine owls left the reserve after spending an average of 6.7 days on site. Five of these birds spent three or fewer days on the reserve (Table 2). After spending an average of 38.3 days on the reserve, three owls (#'s 2, 12, and 16) harnesses with the transmitter intact were found removed and on the ground before the battery ran out. Four transmitters were removed owls by hand (#'s 4, 5, 6, and 13), three owls' transmitters had come loose, so owls were captured to remove them, and one (owl #5) we removed the transmitter from because its battery was about to expire after being active for 91 days (Table 2). Finally, three owls (#7, 8 and 14) died during the study; two were predated, likely by other raptors, based on the condition of the remains. The third bird, a hatch-year owl, lost one-third of its body weight following transmitter installation, likely starving to death. However, it is unclear whether the harness was the responsible. Overall, the average stay on the reserve was 19.4(±5.4) days.

Table 2. Summary data for radio-tagged northern saw-whet owls. *Age: HY=Hatch year, SY=Second Year, AHY=After hatch year, ASY=After second year, ATY=After third year. **Mass (2) refers to the second recorded mass of owls whose harnesses were removed manually (owls 4, 5, and 6) or those who we recovered dead (owl 14).

Frequency	Owl	Age*	Mass (grams)	Radio ON	Last Detection	Days Active	Status	Mass (2)**	Pellet Number
218.552	1	ASY	95.4	11/1/10	11/23/10	23	Left reserve with radio		
218.581	2	HY	96	11/5/10	12/2/10	27	Owl took transmitter off		3
218.562	3	HY	92.8	11/5/10	11/5/10	1	Left reserve with radio		
218.502	4	HY	87.5	11/6/10	11/18/10	12	I removed harness	76.1	
218.523	5	SY	94.4	11/6/10	2/5/11	91	I removed harness	97.1	39
218.591	6	HY	89.9	11/12/10	12/1/10	18	I removed harness	78.1	2
218.512	7	SY	90.1	11/13/10	12/2/10	19	predated (found on 12/5/10)		3
218.540	8	HY	94.3	11/30/10	12/11/10	12	predated (found on 12/11/10)		1
218.570	9	ATY	93.5	12/27/10	12/29/10	2	Left reserve with radio		
218.591	10	SY	90.8	11/2/11	11/11/11	10	Left reserve with radio partially detached		
218.531	11	ASY	92.2	11/2/11	11/11/11	10	Left reserve with radio		1
218.365	12	SY	93.3	11/12/11	1/23/12	75	Owl took transmitter off		20
218.476	13	SY	93.9	11/13/11	12/2/11	20	I removed harness		1
218.501	14	HY	96.9	11/20/11	12/11/11	21	Found dead-Starved to death	64.6	
218.581	15	SY	91.6	12/11/11	12/21/11	10	Left reserve with radio		1
218.698	16	ATY	97.6	1/10/12	1/23/12	13	Owl took transmitter off		6
218.697	17	SY	93.8	11/2/12	11/4/12	3	Left reserve with radio		
218.777	18	SY	87.8	11/7/12	11/8/12	1	Left reserve with radio		
218.835	19	ASY	96.6	11/7/12	11/8/12	1	Left reserve with radio		

Northern Saw-Whet Owl Telemetry

During the first year of the telemetry study, nine northern saw-whet owls were fitted with radio transmitters, beginning on November 1, 2010. Fifty-two different diurnal roosts between 9 different owls were recorded from November 2, 2010 to February 5, 2011. Several of the owls used the same roost multiple times during the first season of the study for a total of 74 roost observations, though these multiple roost sites were only included once in the analysis. During the second year of the study, 57 different diurnal roosts were found between seven radio-tagged saw-whet owls from November 3rd, 2011 to January 21, 2012. For the 2012 season, efforts to radio tag saw-whets owls were suspended after three owls that had been tagged beginning on November 1, 2012 had left the area by November 8. Attempts to radio-tag more owls were suspended due to a heavy rain during the second half of November 2012. Only two roosts between three owls were described for the 2012 season. A full summary of data for each radio-tagged saw-whet owl can be found in Table 2, which includes age, sex, mass at capture, frequency of transmitter, days active, status, and mass on recapture.

Habitat Use

For all three seasons of saw-whet owl radio tracking, 112 different roosts were found (Figure 5). Of these, 79.4% of roosts were of two species: canyon live oak (48 roosts) and toyon (41 roosts). The next most abundant roost species was California bay, which was used nine times (8% of roosts). The remaining 13 roosts were distributed across a number of different species: foothill pine (3 observations),

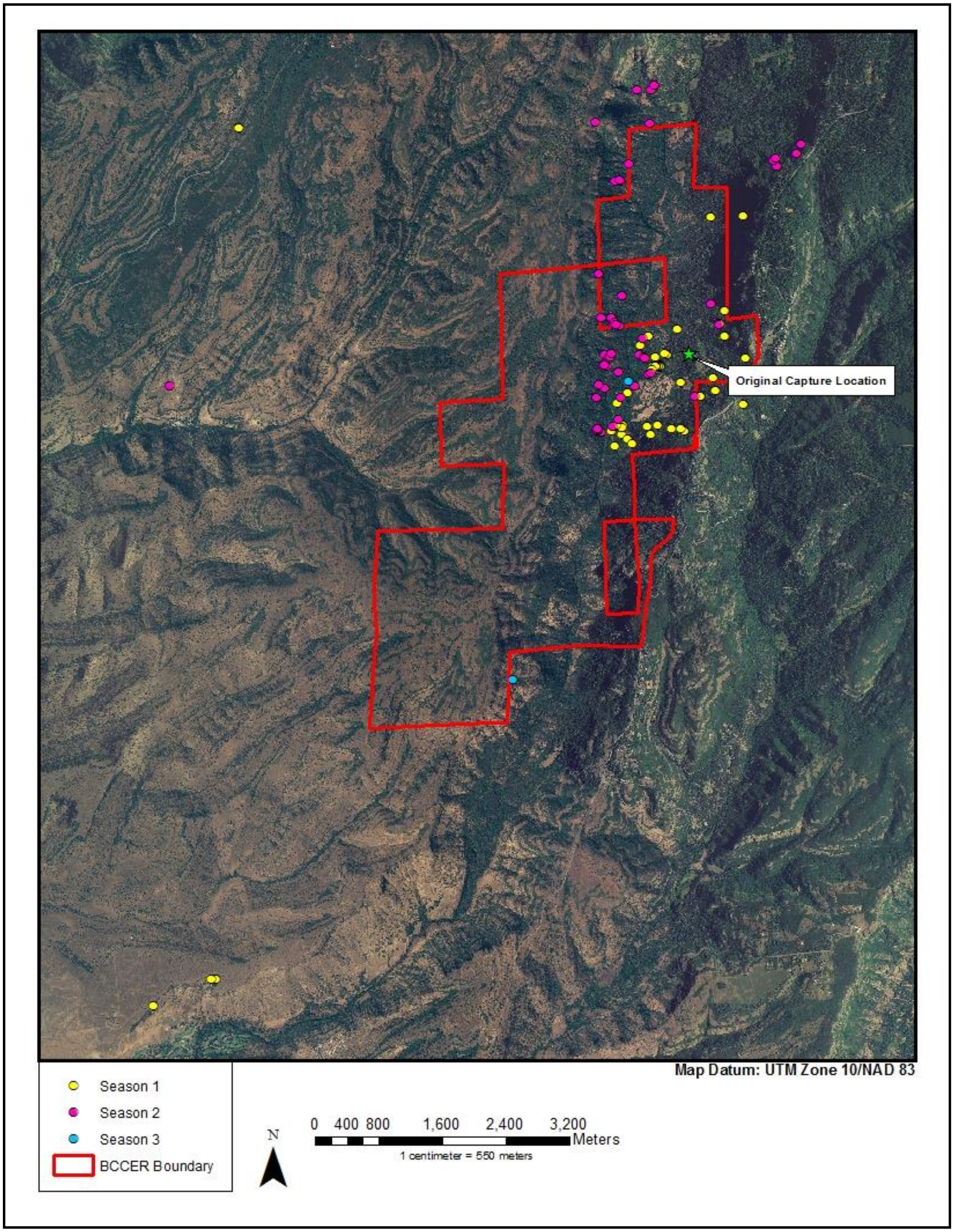

Figure 5. Map of all diurnal northern saw-whet owl roosts, 2010-2012. Each color represents different seasons of radio-tracking. The green star denotes where owls were originally captured during fall migration banding.

interior live oak (3), ponderosa pine (2), black oak (1) deerbrush (*Ceanothus integerrimus*) (1), incense cedar (1), scrub-oak (1), coffeeberry (1), and valley oak (1; Figure 6). Between years, roost preferences were reversed: in the first season of tracking, 32 of the 52 roosts were in canyon live oak, while only 11 were in toyon. In the second season, 29 roosts were in toyon while only 15 were in canyon live oak. The two roosts from the third season were in one each of toyon and canyon live oak. Interestingly, there was also a shift in roost sites within Big Chico Creek Canyon between years. During the 2010-2011 season, all of the saw-whet owls roosted on the east side of Big Chico Creek, while during the second year (2011-2012), all but one owl roosted on the opposite side for most of the time on the reserve. The third year, two of the three owls that were tagged were on the west side of Big Chico Creek, as well; one owl was not radio-tracked; her signal was strong the one day she spent at BCCER, but it was unsafe to cross the creek at that time (owl 18); the following day, her signal was lost.

<u>Differences in saw-whet owl roosts between years</u>

Not surprisingly due to the shift in location and in preferred roosting species between years, northern saw-whet owls perched significantly higher during the first season of the study (t-test; $t=3.0$, $df=104$, p-value=0.0026) when compared to the second season where the preference was for toyon (Figure 7). Canopy cover was denser on average in season two compared to season one, and was between 0.05 and 10.3 percent higher than season one (t-test: $t=-2.01$, df-83.4, p-value= 0.04). There were no changes in the DBH sizes of the roost trees between season one saw-whet owl roosts and season two (t-test: t-0.55, df=24, p-values=0.59). Season one trees averaged 1.15 meters DBH while season two trees averaged 1.02 meters DBH. However, there were many more trees used by owls in the first season so the sample sizes were unequal (38 trees in the first year versus 17 trees the second).

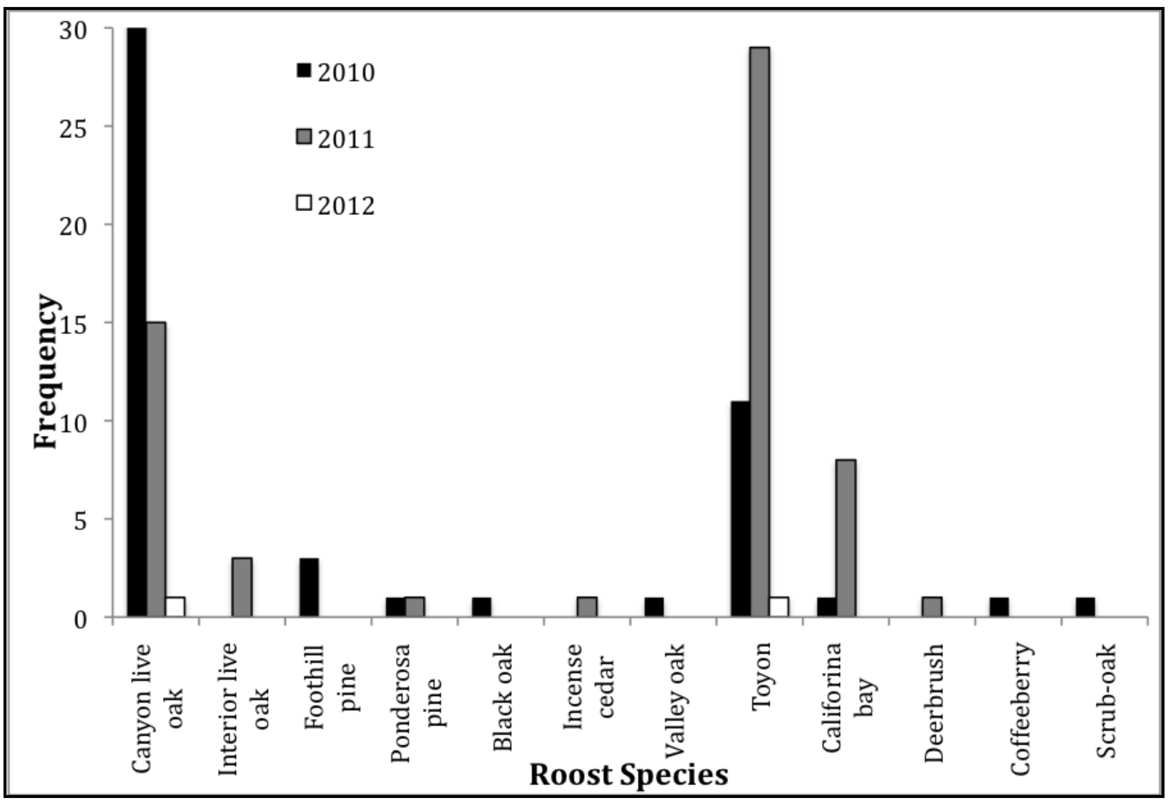

Figure 6. Frequency of diurnal roost species used by northern saw-whet owls, 2010-2012.

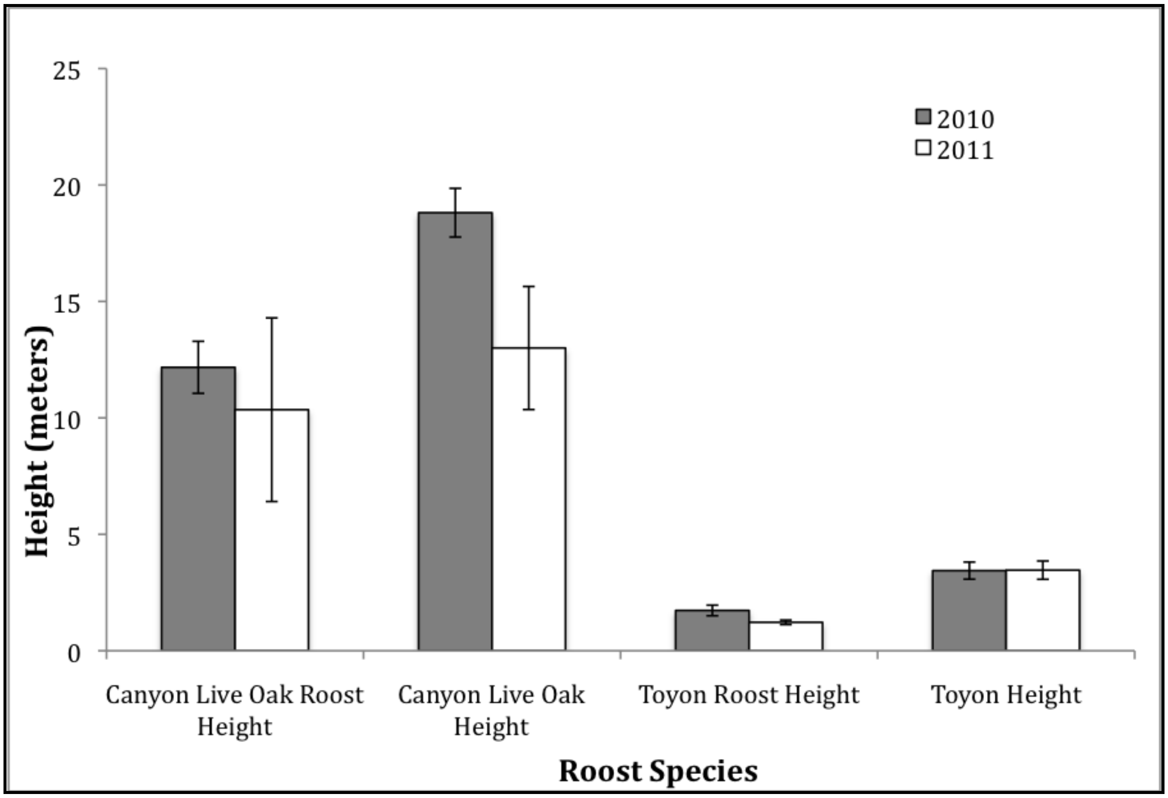

Figure 7. Comparison of average (±SE) height of roosting owl compared to overall height of the roost plant for the two principle roost species, canyon live oak and toyon.

Differences between predominant roost species and others

Because toyon and canyon live oak were the predominantly used roost species in my study, I compared roost height, roost plant height, canopy cover, and percent slope between toyon and other shrub species' roosts. Figure 8 shows the differences between toyon and other shrub's canopy cover and slope, while Figure 9 shows differences between the owl's roost height and the height of the shrub the owl was in, again for toyon and other shrub species.

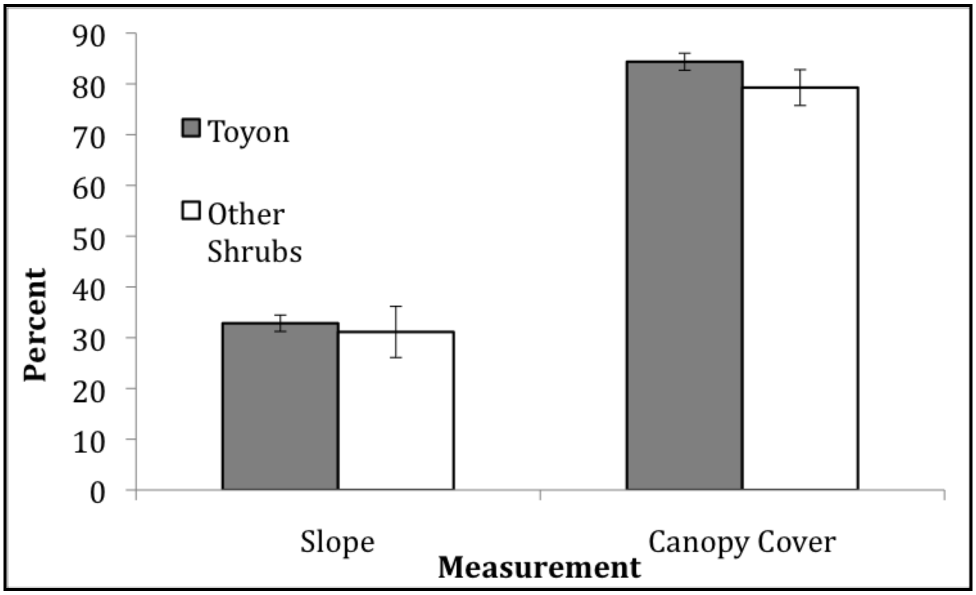

Figure 8. Comparison of mean values for percent slope and canopy cover between toyon roosts and other shrub roosts.

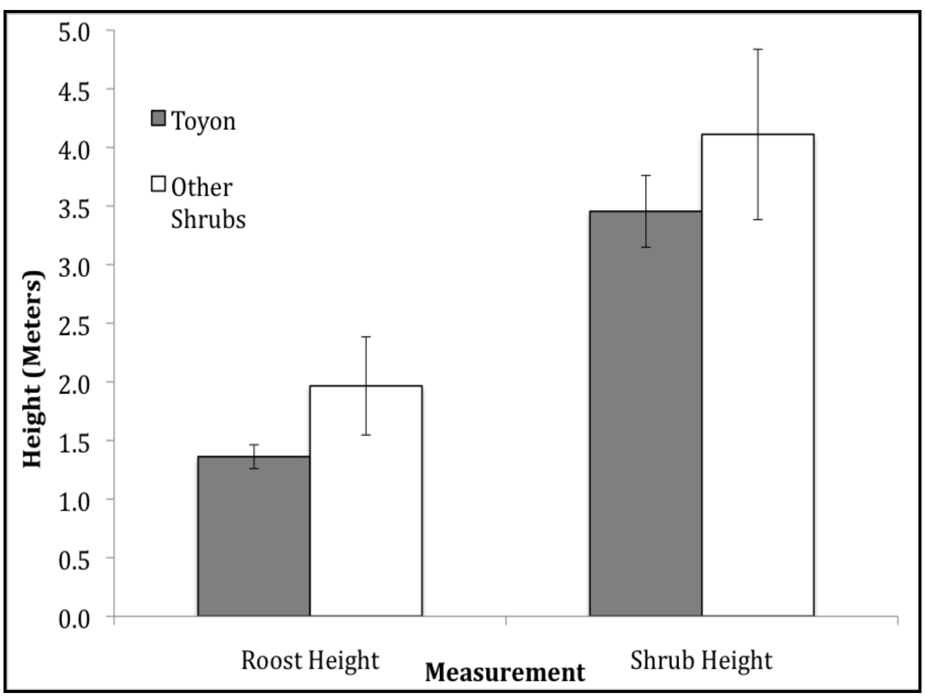

Figure 9. Comparison of mean values for roosting height and shrub height between toyon roosts and other shrub roosts.

Similarly, Figure 10 shows the differences between slope and canopy cover for both canyon live oak trees and other tree species, while Figure 11 illustrates differences between owl's roosting height, tree height, DBH, and roost distance from trunk.

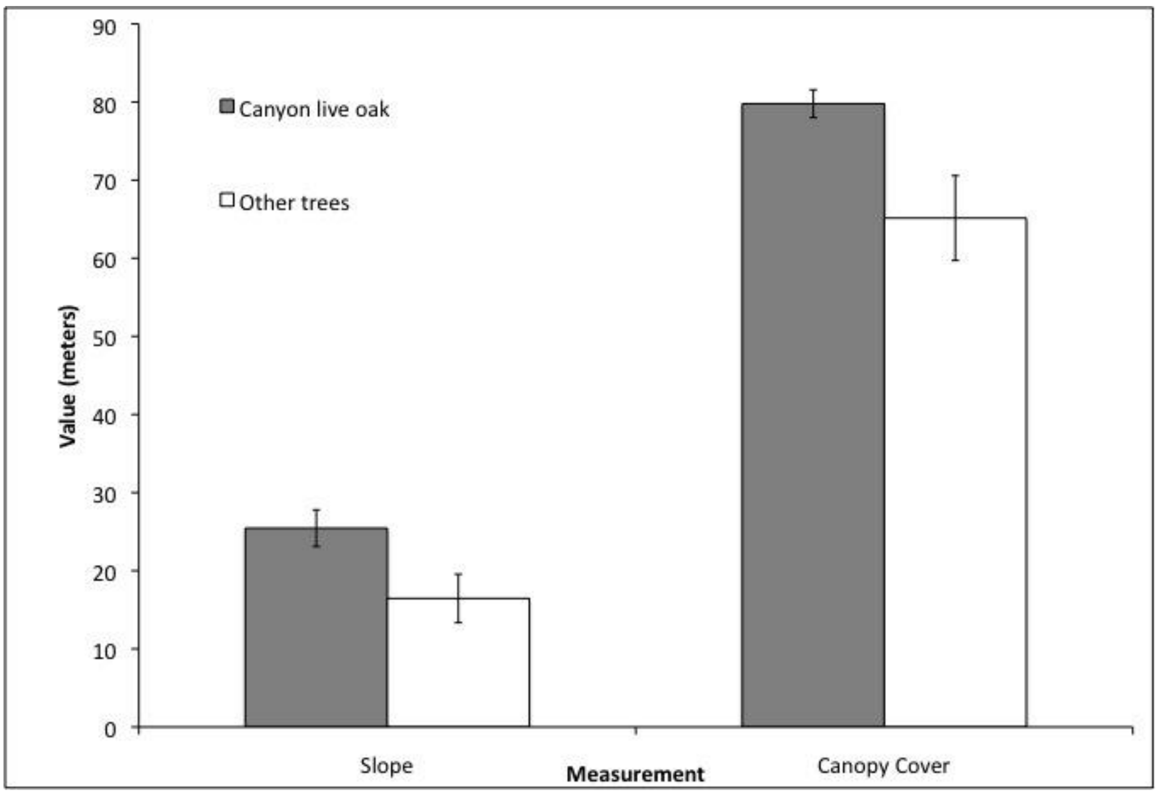

Figure 10. Comparisons of mean values for percent slope and canopy cover between canyon live oak roosts and other tree roosts.

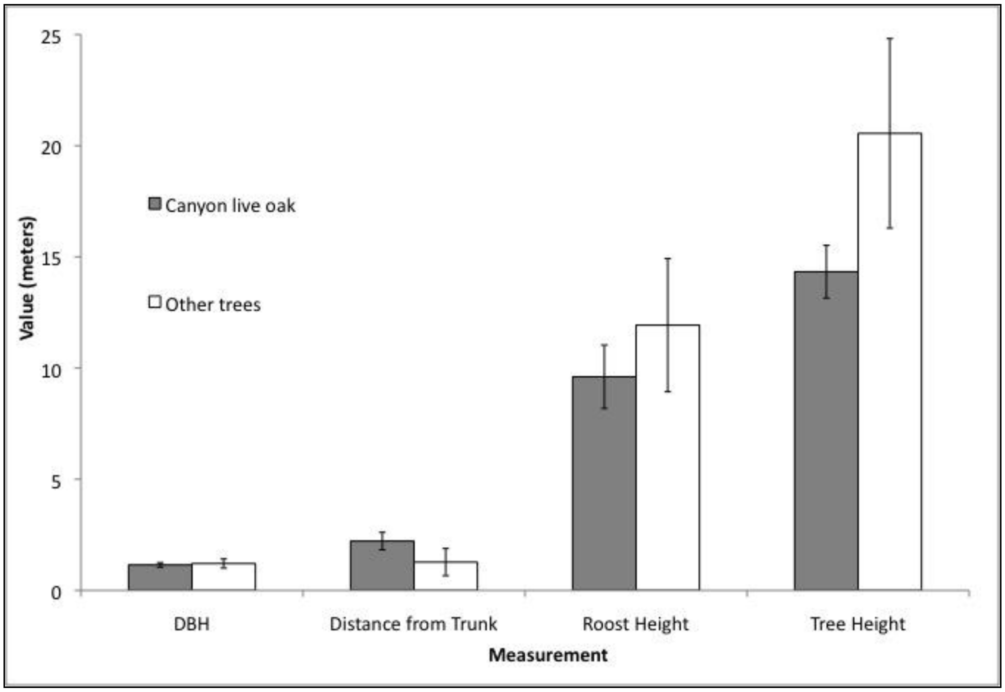

Figure 11. Comparison of mean values for canyon live oak and other trees.

Kruskal-Wallis tests indicated that there were no differences between toyon and other shrub roosts (Table 3). For canyon live oak versus other trees, the only significant difference was for canopy cover, which was higher when roosts were in canyon live oak trees than in other trees (Table 4, p=0.013).

Table 3. Results of Kruskal-Wallis Tests for differences between toyon measurements and other shrub measurements.

Measurement	Roost Height	Shrub Height	Canopy Cover	Slope
P-value	0.14	0.11	0.17	0.71

Table 4. Results of Kruskal-Wallis Tests for differences between canyon live oak measurements and other tree measurements. An asterisk (*) denotes significance at α=.05.

Measurement	Roost Height	Tree Height	Distance from Trunk	DBH	Canopy Cover	Slope
P-Value	0.42	0.18	0.19	0.66	0.013*	.092

Random Roost Site Selection

In the 107 random sites sampled, canyon live oak and toyon were the most often-encountered tree and shrub species, with 23 and 21 random plots, respectively. Figure 12 shows the count of every species encountered during random vegetation surveys. Several other species, including two types of manzanita (*A. manzanita* and *A. viscida*), buckbrush, mountain mahogany, blue oak, and big-leaf maples, were encountered in the randomized plots that were not used by northern saw-whet owls as a diurnal roost site during radio tracking. Of the 107 randomly sampled plots, 103 were used in a matched logistic regression analysis to determine the probability of an owl selecting their roost site over a random site. Four random sites were eliminated, as paired owl use sites had insufficient measurements to do complete comparisons. A random effect was added to each model to account for the variable "owl," because individual owls may have had different preferences for habitat types.

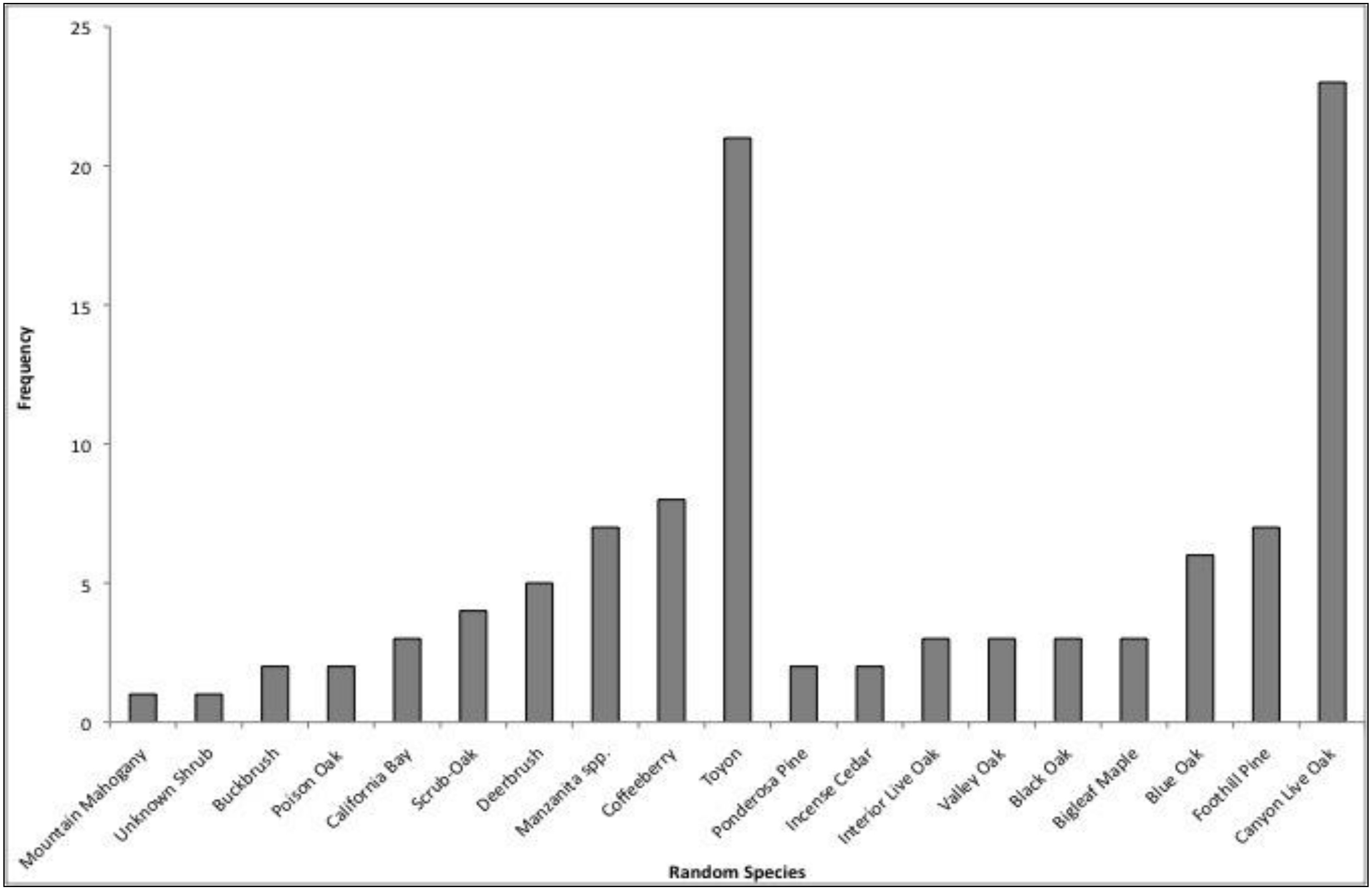

Figure 12.Comparison of species from randomly selected sites.

Two different models were created to determine the likelihood of roosting in either trees or shrubs. The full shrub model included five variables: shrub species, height of roost species, canopy cover, slope of ground at roost, and canopy species (Table 5). Two variables were dropped from the full model because their α-values were above 0.10: shrub species and slope, leaving three variables to be used in the simplified model.

Table 5. Full paired logistic regression model with owl variable for random effects describing northern saw-whet owl shrub selection (n=51).

Variable	Coefficient	Standard Error	Z-Value	P-Value
Shrub Species	-3.3	5.4	-0.6	0.54
Roost Height	-4.6	2.8	-1.6	0.099
Shrub Canopy	-0.87	0.51	-1.7	0.089
Shrub Slope	0.54	0.37	1.5	0.14
Shrub Canopy Species	7.4	4.5	1.7	0.099

Table 6 is the simplified shrub model, including only variables of α=0.10 or smaller: roost height, canopy cover, and canopy species. The only significant variable found in the simplified shrub model was canopy cover (p-value<0.01), predicting owls to choose their shrub roosts based on dense cover.

Table 6. Simplified logistic regression model with owl variable for random effects describing northern saw-whet owl shrub selection (n=51). An asterisk (*) denotes significance at α=.05.

Variable	Coefficient	Standard Error	Z-Value	P-Value
Roost Height	-0.38	0.35	-1.1	0.27
Shrub Canopy	-0.13	0.049	-2.7	0.0061*
Shrub Canopy Speies	-1.4	0.78	1.8	0.07

For comparing the tree roost sites with random sites, not all of the variables measured in the field at all roost sites were used in the analysis; some data were only taken in the second year, so these variables (understory size, length, and height, mid-canopy gap, aspect, and distance from trunk) were dropped from the analysis. In the full model for trees, tree canopy cover and slope were not significant at the α=0.10-level (Table 7) and were subsequently dropped. The simplified tree model included tree species, height of roost species, and DBH. All three of these variables were significant at the α=0.05, and two (tree species and tree height) had a p-value 0.01. Table 8 illustrates exact values for the simplified tree model. This model illustrates saw-whet owl selection for canyon live oak trees that have a larger DBH than random, but are shorter than random trees.

<u>Prey Analysis</u>

Northern saw-whet owl pellets were only collected during the first two seasons of radio tracking; too few roosts were tracked during the third season,

Table 7. Full paired logistic regression model with owl variable for random effects describing northern saw-whet owl tree selection (n=52).

Variable	Coefficient	Standard Error	Z-Value	P-Value
Tree Species	-10.3	6.74	-1.5	0.13
Tree Height	-0.61	0.32	-1.8	0.060
DBH	-2.4	1.38	1.7	0.085
Tree Canopy	0.036	0.084	0.43	0.66
Tree Slope	0.085	0.097	0.88	0.38

Table 8. Simplified paired logistic regression model with owl variable for random effects describing northern saw-whet owl tree selection (n=52). An asterisk (*) denotes significance at α=.05.

Variable	Coefficient	Standard Error	Z-Value	P-Value
Tree Species	-4.8	1.8	-2.7	0.0076*
Tree Height	-0.34	0.12	-2.9	0.0040*
DBH	2.9	1.2	2.5	0.014*

therefore no pellets were found. A total of 103 individual prey items from 77 pellets were found from 10 different owls. More pellets were collected the first year than the second; 48 pellets between five owls, while five owls in season two produced 29 pellets. Most of the pellets were collected from owl 5 (Table 2) in 2010/2011 because it stayed active at BCCER for the longest time (91 days). Owl 12, who was active for 75 days in 2011/2012, provided twenty pellets. Both owls were second-year females and 77% of the pellet data were from these two owls. However, there was a shift in the predominantly active areas on the BCCER between years where owls were roosting and these two owls used different parts of the Reserve (See Figure 5). On several instances, owls were "caching" prey items at their roost, and approximately half of them were identified by observation. These specimens were not included in the pellet analysis but are listed in the appendices (Table A1). As the majority of pellets were collected from just two owls, and as there were relatively small sample sizes for prey species and prey age, no statistical tests of significance could be run to determine the differences among the prey variation between seasons.

Characteristics of the pellets were, however, statistically compared. Mean length of pellets for both seasons was 28.4 mm (±4.2) and mean width was 15.7 mm (±0.56). Mean MNI (minimum number of individuals) was 1.36 individuals (±0.064) for both seasons. Differences in pellet length were observed between seasons ($t=-2.32$, $df=68$, $p=0.02$), with season two pellets, on average (31.95 mm ±1.03), being longer than season one (28.42 mm ±1.34). Pellet widths did not significantly vary between seasons (width: $t=0.561$, $df=68.46$, $p=0.58$). No differences were found with MNI between seasons, either: ($t=0.45$, $df=62$, $p=0.65$). And finally, no differences between prey numbers were observed between seasons ($\chi^2=4.01$, $df=3$, p-value = 0.26).

Only four species were represented in the 103 individual prey remains identified in the saw-whet owl pellet analysis (Figure 13). The most commonly taken prey item across both seasons was the western harvest mouse, comprising 48% of total individual prey items (49 mice; Figure 13). Specifically, juvenile harvest mice were the most abundant prey item, comprising 34 of 103 total pellet remains. The next most abundant prey species in the pellets was the California vole. Twice as many juvenile voles were taken than adults, and one-third of the total prey found in saw-whet pellets were voles, (30 total). Twenty deermice (*Peromyscus* spp.) were found in pellets, of which, 11 were juvenile. Finally, three of four identifiable invertebrate remains were those of rain beetles, Genus *Pleocoma*. Figure 14 illustrates the breakdown by age and season of the prey items found during the study.

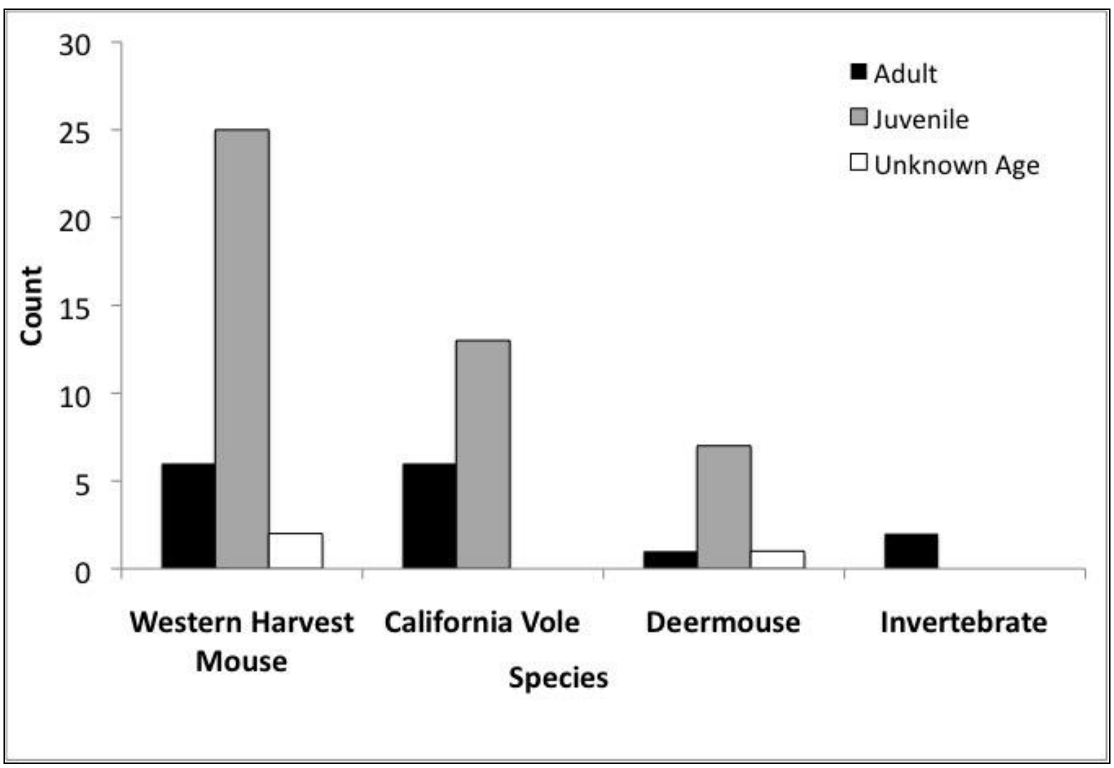

Figure 13. Northern saw-whet owl overall prey age distribution from pellets collected at winter diurnal roosts, 2010-2012.

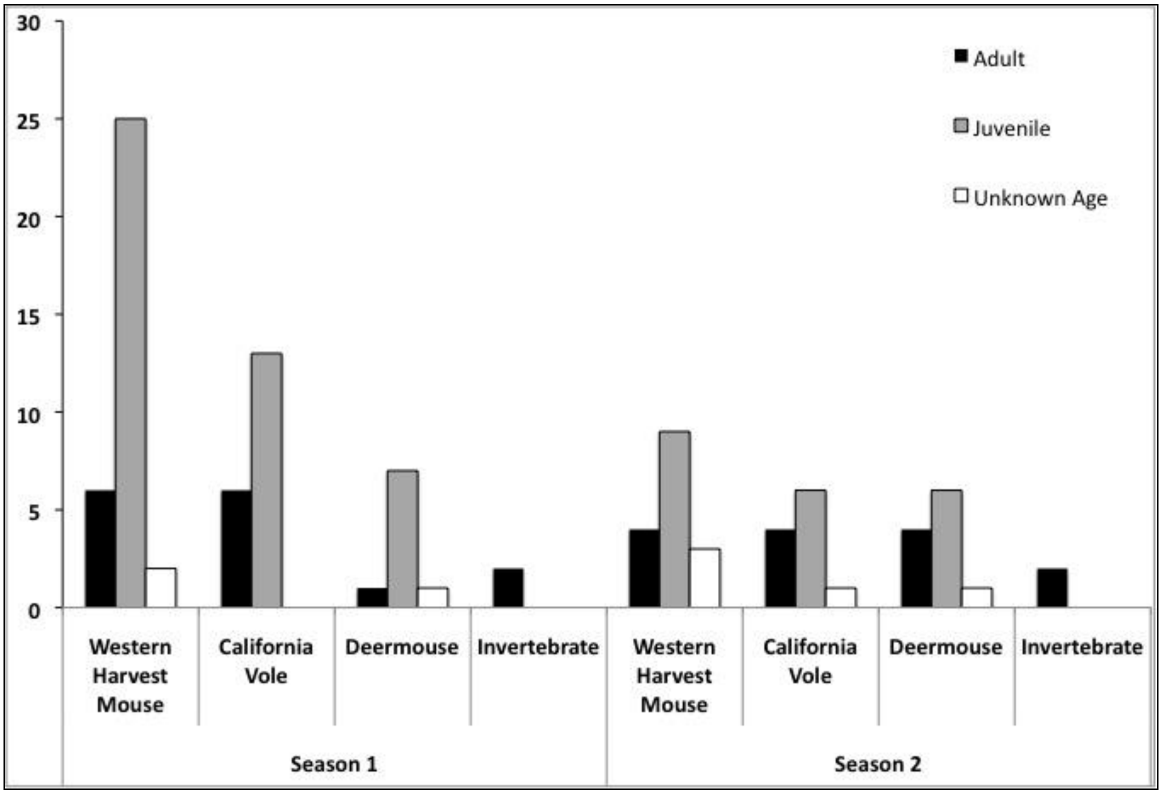

Figure 14. Prey distribution by age, for species found in northern saw-whet owl pellets, 2010-2012.

GIS Analysis

Wintering home range

The average minimum convex polygon (MCP) for both the owls spending the entire winter on the reserve was 118.2 (±2.9) hectares. The first owl (owl 5, Figure 15) spent 91 days radio-tagged at BCCER during the 2010-2011 season and had a MCP home range of 140.3 hectares. The second owl (owl 12, Figure 16) had a MCP of 96.05 hectares, and spent 75 days at BCCER.

The fixed kernel density analysis gives estimates of home range usage from the data at varying levels of use. A 95% contour would be the likelihood of finding an animal in part of their home range, or where the densest clusters of location points are located while a 25% contour would be the likelihood of finding that animal 25% of the time. I used 25, 50, 75, 95, and 100% contours for owl 12 and 36, 50, 75, 95, and 100% contours for owl 5. Different contours were calculated automatically in ArcGIS during KDE analysis based on the way the frequency and distribution of roost points. Owl 5's 95% KDE was 140 hectares (Figure 17) while owl 12's 95% KDE was calculated at 88.0 hectares (Figure 18). Table 9 gives percent contour results for each owl.

Table 9. Kernel Density contour values (in hectares) for owls 5 and 12.

Owl 5 Contour	Owl 5 area	Owl 12 Contour	Owl 12 area
36%	0	25%	0.45
50%	4.4	50%	31.0
75%	190.0	75%	148.0
95%	140.0	95%	88.0
100%	32.3	100%	21.2

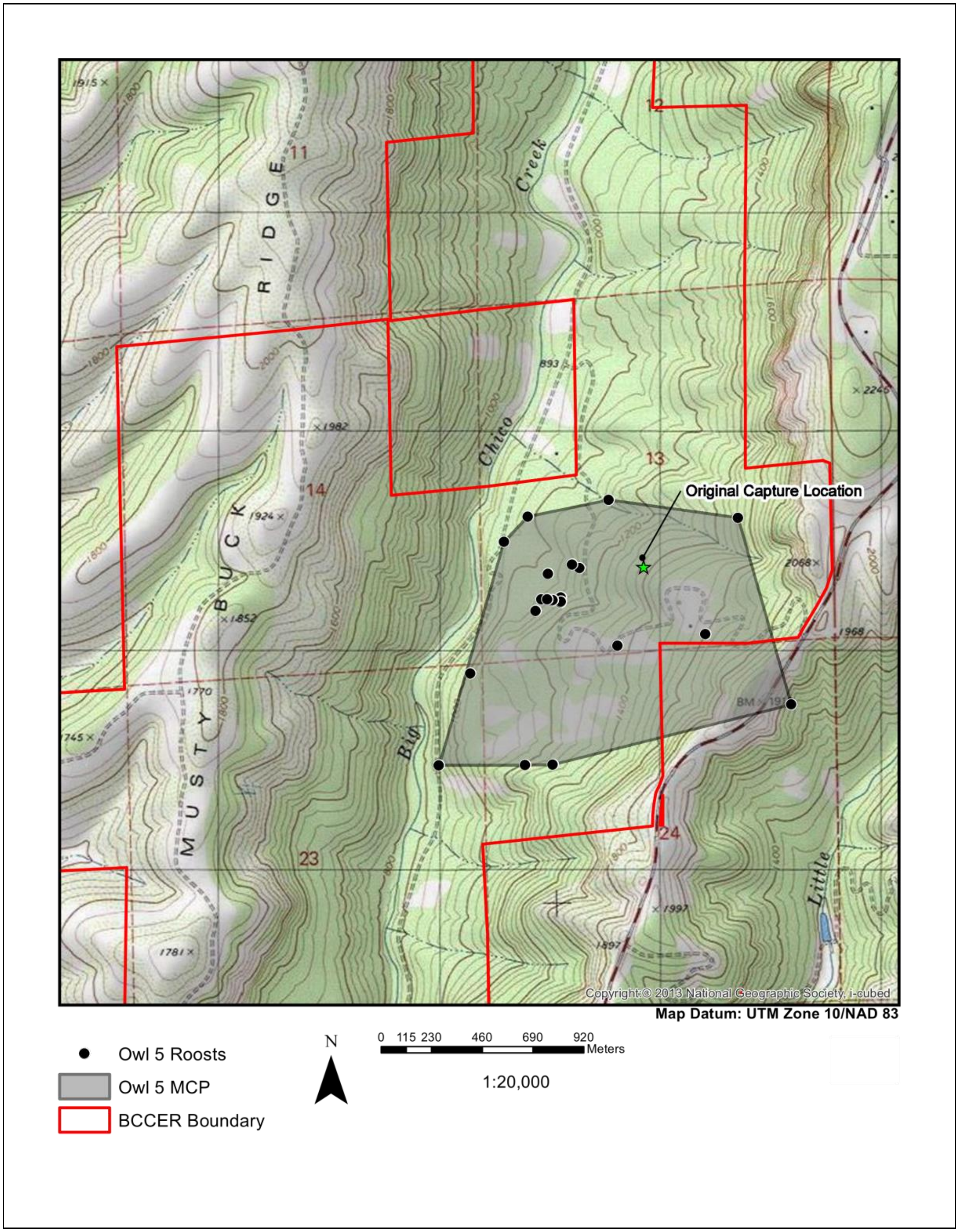

Figure 15. Owl 5 Minimum Convex Polygon, calculated to be 140.3 hectares.

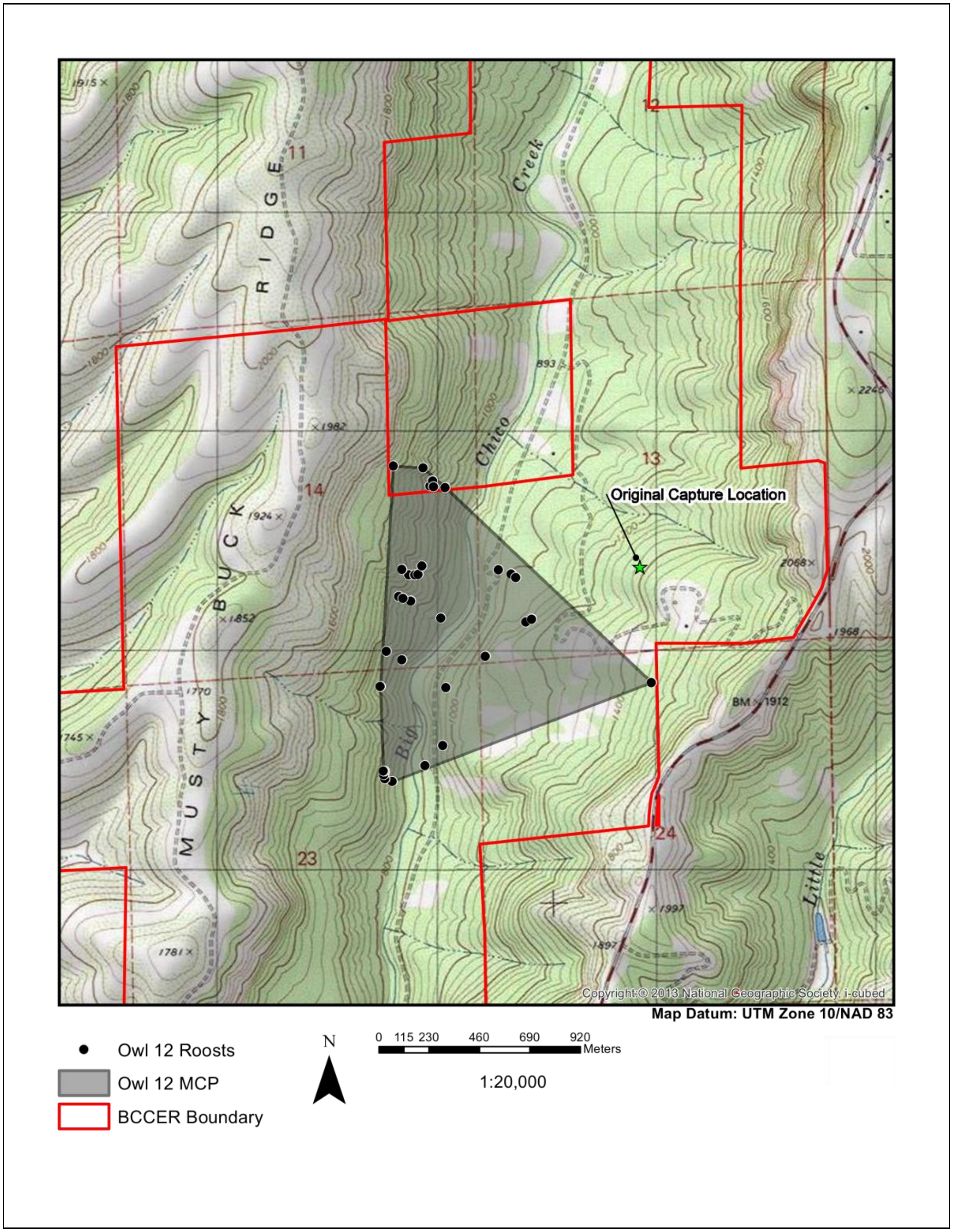

Figure 16. Owl 12 Minimum Convex Polygon was calculated at 96.05 hectares.

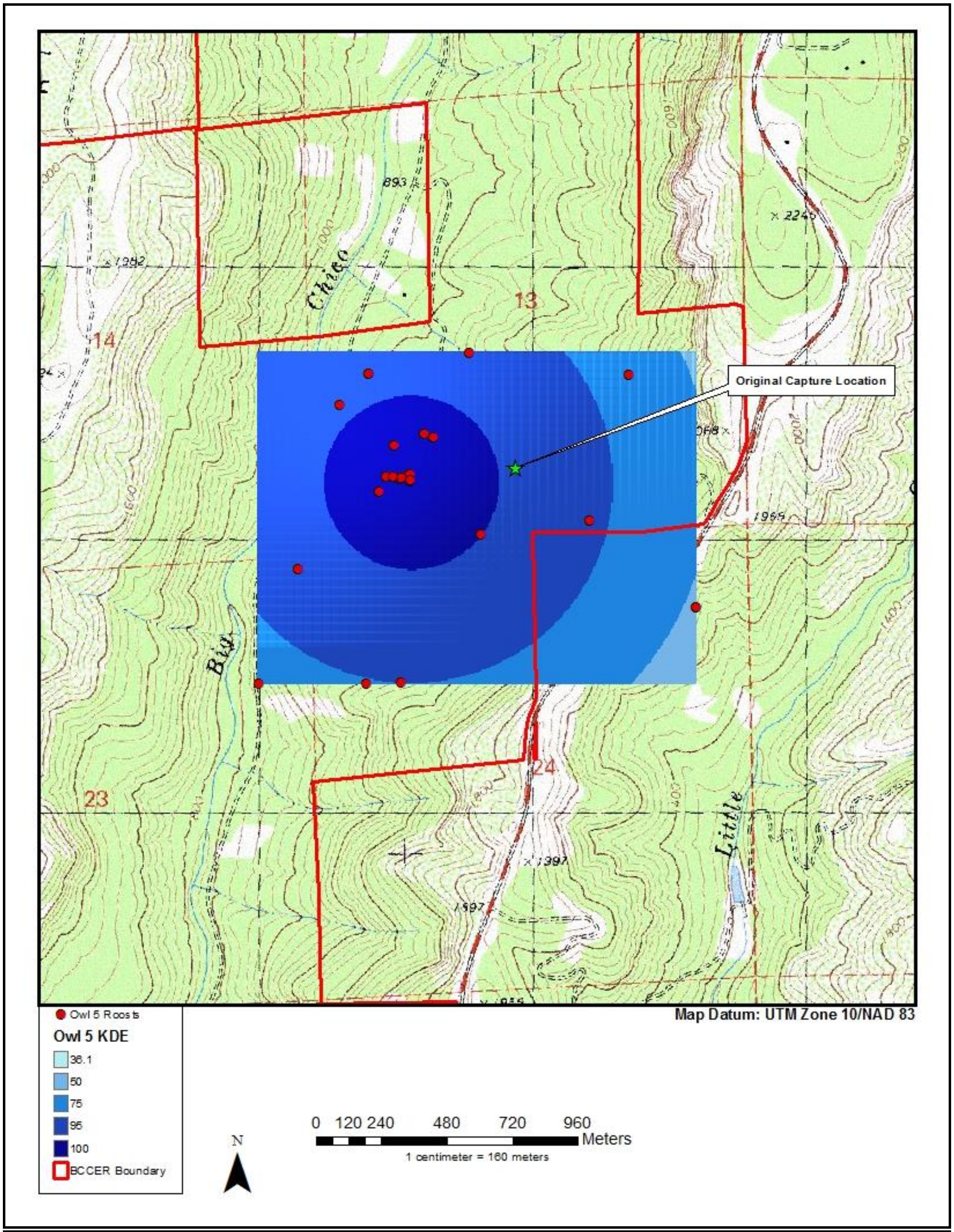

Figure 17. Owl 5 Kernel Density map showing calculated contours.

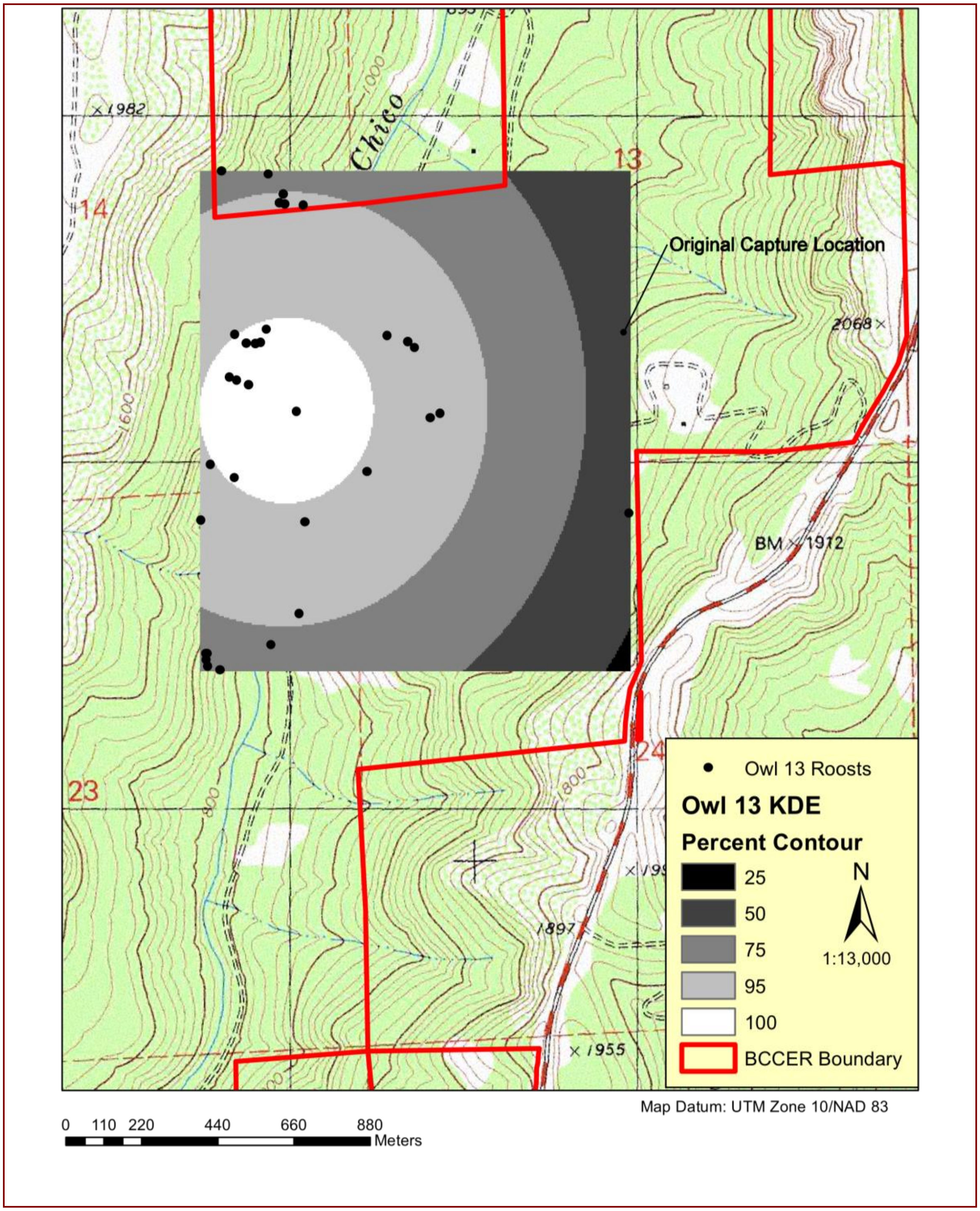

Figure 18. Owl 12 Kernel Density map showing calculated contours.

Habitat Use Analysis

The GIS analysis showed differences in the clipped vegetation layers between the owl roosts and random roosts. The most commonly used habitat type by roosting owls was canyon live oak, with 48% of the total roosting habitat. The next important habitat types for roosting owls were black oak, followed by interior live oak, at 18 and 13 percent, respectively (Table 10). Canyon live oak was also the most important habitat type for random roosts, comprising 39% of random habitat (Table 11). Blue oak and black oak (22% and 16%, respectively) were the next most important habitat types in random plots. The remainder was a mix of habitat types that were not seen in owl roosts, including incense cedar, built-up and urban disturbance, buckbrush, and scrub-oak (Figure 19). Owl roosts had several habitat types not seen in random roosts, as well: whiteleaf manzanita and California bay, though they were not largely used. Figure 19 shows all the habitat types encountered in both owl roosts and random roosts.

Table 10. Total area of clipped habitat types for northern saw-whet owl roosts and random roosts.

Habitat Type (Map Unit)	Sum of Clip Area-Roosts (m^2)	Count of Clip Area-Roosts	Average of Clip Area-Roosts (m^2, ±SE)	Sum of Clip Area-Random (m^2)	Count of Clip Area-Random	Average of Clip Area-Random (m^2, ±SE)
Built-up and Urban Disturbance				955.8	1	955.8 (±0)
Whiteleaf Manzanita	1360.1	2	680.1 (±610)			
California Annual and Perennial Grassland	3549.7	5	709.9 (±154)	3487.4	8	435.9 (±160)
Incense Cedar				1794.5	1	1794.5 (±0)
Buckbrush				813.4	1	813.4 (±0)
Cliffs and Rock Outcroppings				161.0	1	161.0 (±0)
Foothill Pine	423.6	1	423.6 (±0)	2683.8	1	2683.8 (±0)
Scrub-Oak				2398.7	1	2398.7 (±0)
Canyon Live Oak	80444.2	15	5362.9 (±1994)	72195.2	13	5553.5 (±2260)
Blue Oak	21828.2	17	1284.0 (±255)	41230.1	18	2290.6 (±393)
Black Oak	29568.8	4	7392.2 (±4881)	29181.2	3	9727.1 (±6602)
Valley Oak	5590.6	1	5590.6 (±0)	5285.3	2	2642.7 (±1074)
Interior Live Oak	22496.1	14	1606.9 (±415)	25112.5	13	1931.7 (±442)
California Bay	1953.5	1	1953.5 (±0)			
Vernal Pool Matrix	24.9	1	24.9 (±0)			

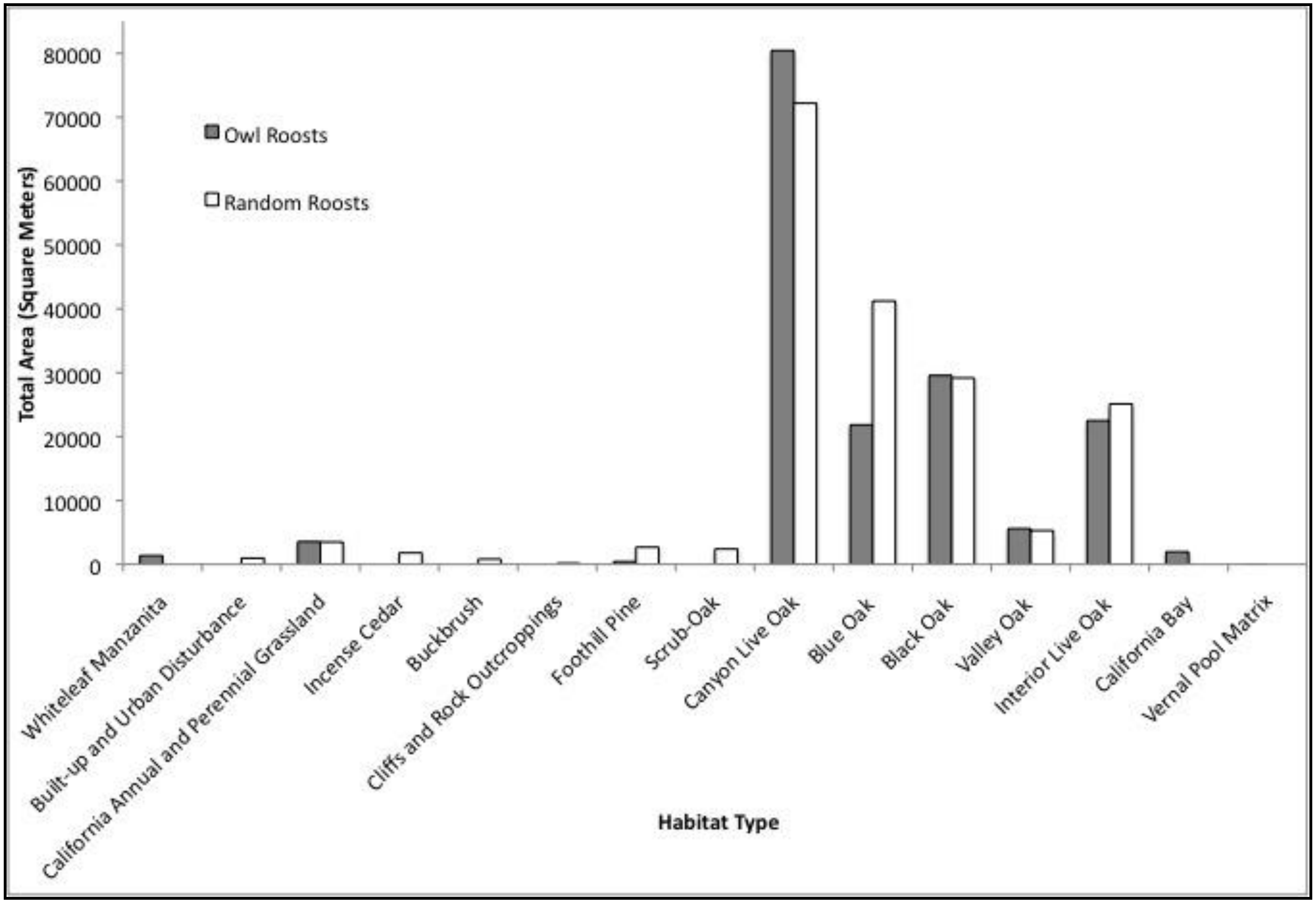

Figure 19. Area of habitat types within a 25-m buffer for saw-whet owl roosts (black) and random sites.

CHAPTER IV

DISCUSSION

This study is one of the first for California, and the west coast, to examine northern saw-whet owl winter habitat use and prey selection using radio-telemetry. This research is also the first to assess winter habitat use in the foothill region of the Sierra Nevada. The results from this study begin to provide insights into a common yet elusive raptor in a region where we know little about the species.

Telemetry

It is evident from the telemetry data that saw-whet owls use the Sierra Nevada foothills of northern California as both a temporary stopover site during fall migration and as a winter residence. Over half of the owls that received radio-transmitters left the Reserve and remained out of tracking range, although several attempts were made to pick up signals via plane. Through recaptures at fall banding stations, saw-whet owls are known to travel long distances in one night (distances documented are between 3.5km-88 km in one night, Brinker et al. 1997) so the missing owls could have migrated out of the area between tracking efforts. Five owls that left spent a maximum of three days on the Reserve, suggesting that they were migrating through the area, temporarily using the BCCER as a stopover site. Four other owls spent between ten and 23 days on the Reserve before moving out of the area.

The average length of stay for saw-whet owls between the first two seasons was nearly identical: season one length of stay was 22.8 days, while season two was 22.7 days. Season three's average length of stay was much shorter, 1.7 days, which was the main reason the season was cut short for radio-tracking.

Whalen and Watts (2002) suggested that saw-whets are nomadic and rapidly queue in on prey populations and competitor density at a potential wintering site, especially during irruption years. An irruption occurs when an abnormally high number of hatch-year owls migrate (Whalen and Watts 2002, Rasmussen et al. 2008). High population densities of wintering owls may result in shorter stopover periods (Whalen and Watts 2002,). During saw-whet owl irruptions, the average length of a stopover was five nights, as opposed to 10 nights in average migration years (Whalen and Watts 2002). Even though a record number of saw-whet owls for the monitoring project were banded at the Reserve during the third year of the study in 2012 (Figure 1), this would not be considered an irruption event because the proportion of hatch year and adult owls was near equal (55 hatch year, 61 after hatch year, one unknown age, Garcia, pers. comm.) This was also the year that the three radio-marked saw-whets left after an average of 1.7 days at the BCCER. Conversely, 2010 and 2011 saw almost identical numbers of saw-whets (92 and 90, respectively), and an almost-identical length of stay was observed during radio-tracking. However, the fall of 2010 was the closest the Reserve has had to an irruption, catching 64 hatch year saw-whets versus 28 adults, while the fall migration of 2011 saw 39 hatch year owls and 51 adults.

Three owls stayed on the Reserve for 27 days or longer before either they removed their transmitter or they were removed. I made the assumption that these owls spent the entire winter on the Reserve because of the length of stay, and based on the results of Whalen and Watts (2002) where owls tended to stay longer in non-irruption years. Two of these owls that stayed the longest were from season one and the third was from season two (see Table 2). Eight owls stayed longer than 10 days but fewer than 27 (Table 2, owls 1, 4, 6, 7, 8, from season one, and owls 13, 14, and 16 from season two). Three owls stayed 10 days (owls 10, 11, and 15, all from season two). Three saw-whet owls staying more than 10 days had removed their transmitters, and therefore we do not know if these owls overwintered at BCCER. Winter residency was suspected in at least one or two of these birds (Table 2, Owls 2 and 12, one each from seasons one and two) because of the duration of stay on the Reserve, lasting 27 and 75 days, respectively.

<u>Habitat Use</u>

The winter roosting habits of northern saw-whet owls in my study are consistent with data from previous studies assessing general winter habitat: saw-whets tend to use dense vegetation for perches and roosting (Mumford and Zusi 1958, Hayward and Garton 1984, Swengel and Swengel 1992, Johnson and Anderson, 2003, Rasmussen et al. 2008). My radio-marked owls were generally concealed in the outermost, densely leaved branches of canyon live oak trees, similar to the observations from other studies (Hayward and Garton 1984, Swengel and Swengel 1992), where owls used perches for maximum concealment and thermal benefits. Concealment from above has been shown to be a major factor in saw-whet roosts; (Mumford and Zusi 1958, Hayward and Garton 1984, Swengel and Swengel 1992, Brittain 2008) perches in dense shrubs or among thick canyon live oak branches would likely render an owl invisible to aerial predators (Figure 20). Many, if not most saw-whet owl roost sites in toyon bushes had an abundant canopy layer or other shrubs surrounding the roost plant. Rarely, if ever, was a saw-whet owl in a toyon shrub (or shrub in general) with any other associated woody structure nearby, illustratring northern saw-whet owl's preference for finding roosts in densely vegetated habitat. The several saw-whet roosts found in California bay were mostly in large, over five-meter tall shrubs. Most of the time when owls were in California bay, there was no canopy species associated, though California bay shrubs used as roosts were almost always larger than toyon roosts.

Saw-whet owls in this study were shown to use a high proportion of evergreen hardwoods (canyon live oak) and shrubs (toyon and California bay). In contrast, Weidensaul (2010), in Pennsylvania, found owls that used deciduous trees prior to leaf fall, but switched to mainly conifers thereafter. Similarly, wintering saw-whet owls were found to select habitats with dense deciduous understory cover and vertical structure (lots of canopy cover) in Indiana (Brittain 2008). Generally, winter habitat use is not well understood (Johnson and Anderson 2003, Rasmussen et al. 2008), and is likely substantially different among regions, but presence of dense vegetation for roosting and perches for foraging is critical and consistent across studies. Similarly, dense vegetation was important for saw-whet roosts in this study, as well: canopy cover found at saw-whet owl roost sites in

Figure 20. Northern saw-whet owl #13 camouflaged at her diurnal roost site in a canyon live oak tree.

toyon was significantly higher than random ($p = 0.006$), while canopy cover for owl roosts in canyon live oak was significantly denser than when owls were in other trees ($p = 0.01$). Average canopy cover for canyon live oak did not differ from random: ($p = 0.66$), although this could be attributed to the fact that canyon live oak was a major component of random vegetation surveys, constituting 45% of random trees sampled.

My findings are consistent with Boula (1982), Hayward and Garton (1984), Churchill et. al (2002), Johnson and Anderson (2003) Brittain (2008), Rasmussen et al. (2008), and Weidensaul (2010) in that non-breeding northern saw-whet owls prefer roosting in dense stands for maximum concealment. Although two of the owls in my study were found predated, the habitats they had been using were consistent with the rest of the radio-tagged owls, either roosting in low thickets of toyon or on the densely leaved outermost branches of canyon live oak. One owl roost in 2010 was on the ground; this tagged owl was located at the base of a foothill pine under a coffeeberry shrub, and was sitting on a large vole.

Many studies find that conifers are a key component for saw-whet winter habitat. Swengel and Swengel (1992) found that conifer stands were used almost exclusively in Wisconsin, though it only comprised 5% of the total forest area. Though there is not an abundance of continuous coniferous habitat, I would have expected owls to use this habitat type more frequently. At least one tree species present in the study area, douglas fir, was a primary component of winter and breeding-season saw-whet roost sites in two other studies on the west coast (Boula

1982, Grove 1985). This tree species was not used in this study, and was not sampled at random habitat sites. This habitat remained relatively unused by radio-tagged owls, comprising only 5% of all roosts. In addition, studies such as Churchill et. al (2000, 2002) found saw-whet owls using pine forest habitat more than would be expected on a coastal barrier island, but pine forests only accounted for 7% of the total study area and 52% of the roosts in this study.

In an example of saw-whet owls using roosts other than conifers, researchers found saw-whet owls using a poplar (*Populus* spp.) plantation during nighttime surveys in an Oregon study (Moser and Hilpp 2004). Owls were found using predominantly older plantings within the interior of the plantations, rather than the edges or open shrub-steppe habitat surrounding the plantation (Moser and Hilpp 2004). These habitats can be “ecological traps” that attract owls but provide sub-optimal habitat for foraging, roosting, and breeding (Moser and Hilpp 2004).

Although I did not find saw-whet owls roosting in coniferous forest habitat during my study, the few conifer roosts used were in mixed forest habitats, associated with oak trees. In a breeding season study in the central Sierra Nevada, the closest study area to my site, Groce and Morrison (2010) found that owls were more likely to be associated with stands of red fir (*Abies magnifica*) or lodgepole pine (*Pinus contorta*) than in stands of white fir (*Abies concolor*) at higher elevations near Lake Tahoe. Differences are likely due to differences in season and elevation. It is yet unclear if the BCCER is used as breeding habitat for saw-whet owls.

No other study examining saw-whet owl winter habitat has found them using an evergreen oak species and an evergreen shrub as their primary roosts. During nocturnal surveys, Brittain's study in Indiana (2008) found saw-whets using habitat that had a dense deciduous understory with a coniferous evergreen (red cedar, *Juniperus viginiana* or *Pinus* spp.) canopy (greater than 70%) as opposed to areas that had thin understory and evergreen stands (under 70% canopy cover). This is similar to my findings, in that percent canopy cover at saw-whet owl shrub roost sites was significantly higher than at non-roost sites.

Toyon and canyon live oak were also found in high proportion during the random vegetation sampling, although that could be attributed to the fact that random sampling occurred within 50 meters away from actual roosts and habitat was likely to be similar to what owls were actually using. Toyon occurred 40% of the time during random vegetation surveys, yet accounted for 80% of actual saw-whet shrub roosts. Similarly, canyon live oak was used in over 80% of tree roosts, but was sampled only 45% of the time during random roost surveys. Both of these examples demonstrate that although there are other species or possible roosts present, northern saw-whet owls perched selectively in toyon or canyon live oak.

Oak species dominated the habitat types used as diurnal habitat by saw-whet owls. The most frequently encountered habitat type from the GIS habitat analysis was canyon live oak, characterized by canyon live oak as the dominant overstory, and douglas fir as the co-dominant canopy species (Menke et al. 2011). Although douglas fir was a co-dominant species within the most utilized habitat type, it was not chosen as a roost despite its dominance in other studies (Boula 1982, Grove 1985). Black oak habitat, also characterized by douglas fir and ponderosa pine as co-dominant species, was the second most encountered habitat used by owls. Interior live oak habitat (third most used) is co-dominant with other oaks-such as canyon live oak, and can occur with scrub oak and other chaparral species (Mentz et al. 2011).

These habitat alliances were consistent were with the result of Boula (1982) who encountered saw-whet owls in dense, low thickets of sapling grand fir or western larch, and Weidensaul (2010) who found roosts in hardwood trees before they dropped their leaves, and then in conifers after leaf fall. However, there were also several habitat types in the random plots that were not encountered at owl roosts, which include: built up and urban disturbance, interior live oak, and scrub-oak. Scrub-oak habitat is typical of California chaparral, characterized by drought-tolerant species, including mountain mahogany, manzanita, and toyon (Mentz et al. 2011).This habitat type does not have a tree canopy association, which could be one of the reasons why it was not found at owl roosts. However, owls were found roosting in shrub swamp habitat on Assateague Island, MD, where the dominant shrub was wax myrtle *(Myrica cerifera;* Churchill et al. 2002). Though several owl roosts were found in shrubs (scrub oak and deerbrush) in this study, there was an associated tree canopy.

<u>Home Range Analysis</u>

The MCP home range analysis for both owls that stayed 75 days or longer was in agreement with the few previous wintering studies that used this method to determine home range for saw-whet owls (Forbes and Warner 1974, Churchill et. al 2002). Churchill et. al (2002) suggested that in years where saw-whet owl density is higher (i.e., irruption years) their home ranges are smaller (average female kernel home range of 61 hectares, range: 39-82 hectares, n=4) as opposed to low-density years and a larger home range (female owls' average kernel home range of 160 hectares, range: 96-249 ha, n=3). My MCP for owl 5 (140.3 ha) and owl 12 (96.05 ha) would suggest a low-density saw-whet owl year. However, caution is warranted, as it is difficult to compare the Assateague Island study with the mainland in a completely different system. Few data exist for saw-whet owl winter home range, so any additional information is important.

The kernel density method of home range estimated two owl's home ranges to be 195 ha and 180 ha, respectively, though the 95% kernel for owl 5 was significantly larger (140.0 ha) than for owl 12 (88 ha). The difference is largely due to Owl 5 who stayed in a small portion of its home range for a longer period of time towards the last 45 days of the transmitter's battery life. However, in the early portions of her stay on the reserve, she was travelling around the Reserve and constantly finding new roosts spread out from one another until she settled down to a smaller core range. In contrast, during the second season when there was a spatial shift in habitat use compared to the first season, the Owl 12 used a substantially larger home range, and core area. It is possible that prey were more difficult to find during the second season, as almost all of the radio-tagged owls moved to the north side of the canyon at various times, roosting on the south-facing slope compared to the first season when all of the owls were on the north-facing slope of the canyon. Churchill (1998) found an average of 103.5 ha for saw-whet owl home ranges on Assateague Island, MD using the kernel method, though his values varied from 38.5-248.6 ha. As with estimating the MCP home range, very little is known regarding the home range size or inter-annual variation in home range size of the saw whet owls during the winter.

Prey Selection

As the first study in California and one of few studies in the west to examine the winter diet of northern saw-whet owls, diet breadth was relatively narrow when compared with other studies (Boula 1982, Grove 1985, Marks and Doremus 1988, Swengel and Swengel 1992, Holt and Leroux 1996, Rains 1997). The most abundant prey species identified from pellets collected at diurnal roosts was the western harvest mouse, comprising 48% of all prey items. In a study from southwestern Idaho, Marks and Doremus (1988) also found western harvest mice as a primary diet component during the breeding season. This has been the only other study to identify primarily harvest mice from collected pellets. Interestingly, I did not recover any house mice (*Mus musculus*), shrews (*Sorex* spp.) or small birds in the pellet remains; these species have been present in almost every western saw-whet owl diet study (Boula 1982, Grove 1985, Marks and Doremus 1988, Swengel and Swengel 1992, Holt and Leroux 1996, Rains 1997) and are known to be present on the reserve.

Western harvest mice and voles were the most important diet components found in this study, with harvest mice comprising 48% of all prey and voles 30%. Deermice was the last mammalian prey item found in this study, comprising 18% of all prey remains found in pellets. Voles and deermice were the two taxa contributing the most to the biomass taken by saw-whet owls in other studies; in Montana, they accounted for 92% of the total prey species found in pellets (Holt and Leroux 1996), while in Idaho, they accounted for 46% of prey species (Rains 1997). Interestingly, based on personal observations, voles and deermice were the most commonly identified cached prey at saw-whet roosts in this study, probably because voles were too large to devour in one feeding. Based on the prey composition, saw-whet owls are likely using edge habitats and meadows to forage at BCCER. Blue-oak woodland habitats likely provide adequate “meadow-like” habitat to support meadow voles and harvest mice, as well; indeed, two of the owls transmitters that had been removed prematurely were found on low perches in the middle of blue oak woodland habitat (owls 2 and 12).

Prey species found in pellets did not change between the two most active years of the study, despite evidence that rodent populations experience dramatic fluctuations (Cheveau et al. 2004). Fewer pellets were collected during the second season, though the fact that the diet breadth was so low (only three rodent and two invertebrate taxa) might suggest a relatively low prey base. Additionally, two fewer owls were radio-tracked and the primary owl was tracked for a shorter amount of time in the second year. Owls have the ability to rapidly track prey populations during migration (Whalen and Watts 2002, Cheveau et al. 2004). On the other hand, saw-whet owl reproductive success, and therefore migration, has shown to be positively correlated with prey abundance (Cote et al. 2007).

Juvenile prey items constituted a significant portion of the diet found from saw-whet owl pellets in this study. Indeed, sub-adults of any species will be more prone to predation due to inexperience, and the results of my pellet analysis confirmed this: 64% of all prey items in pellets were juveniles. Specifically, juvenile western harvest mice were the most numerous prey items: 70% of all western harvest mice found in pellets in this study, or 34 of 49 harvest mice. To my knowledge, no other saw-whet owl study has compared ages of prey found in pellets. Sixty-one percent of California voles were juveniles, also; sub-adult voles would likely be easier to handle than their adult counterparts, which can weigh as much as a saw-whet owl. Finally, 68% of deermice were juveniles, as well, although deermice were not as taken in as high of numbers as harvest mice. The number of prey items found per pellet averaged an MNI of 1.36. This suggests that saw-whet owls hunt multiple times each night. Indeed, most of the remains of the study were from juvenile western harvest mice, constituting one-third of all prey taken.

This study, the first in California to look at migration stopover, winter habitat, and diet, has produced novel information important in understanding the habits of one of the most common yet mysterious owl species in North America.

Most of the questions we had concerning these owls after they had been captured during migration at the BCCER have been answered, although many more questions have arisen now that we have new information. Most notably, one question that still remains a mystery is where do northern saw-whet owls spend the winter after migrating through the Reserve? Now that we know some owls do, indeed, overwinter at BCCER or use it as a temporary stopover site, it would be vital to know where the dozens of banded owls continue during migration, or where owls that disappeared beyond radio-tracking range went. Additionally, we now know where the most likely places are to find saw-whet owls on the Reserve and possibly in similar habitats throughout northern California during winter; areas with complex structure and adequate open patches for foraging, especially using both evergreen oaks and shrubs for cover.

The data collected during this study can provide information to land managers about what types of habitat to create to foster overwintering species. Specifically, creating or maintaining environments with complex shrub cover-especially toyon or canyon live oak habitats-will continue to provide saw-whets with their habitat requirements. Additionally, providing and maintaining habitat that is suitable for prey to thrive is crucial in attracting and maintaining a predator population. Since open-meadow species such as voles and western harvest mice were an important dietary component for saw-whet owls, making sure adequate grassland and oak-savannah habitats are flourishing is essential, especially those patches of open area that are adjacent to dense drainages with complex vegetation components.

This study can provide a good comparison for other saw-whet owl research that has occurred recently; notably, on the east coast where other researchers have attempted to locate saw-whets during the day. Additionally, this study will hopefully spur some movement on the west coast in eliciting additional researchers to continue or start northern saw-whet owl fall migration studies. Ideally, understanding migration routes on the west coast in the same manner the east coast will become a higher priority. More studies throughout California would be critical in the next decade, in light of constant habitat conversion and loss, continued droughts and wildfires, and shrinking populations of wildlife everywhere. One of the only ways of preserving wildlife populations is to understand their basic habitat and dietary needs before they disappear from an area.

REFERENCES

REFERENCES

BCCER (2014) Big Chico Creek Ecological Reserve. CSU, Chico. Retrieved from http://www.csuchico.edu/bccer/index.shtml

Beckett, S. R., and G. A. Proudfoot. 2011. Large-scale movement and migration of northern saw-whet owls in eastern North America. The Wilson Journal of Ornithology 123:521-535.

Boula, K. M. 1982. Food habits and roost sites of northern saw-whet owls in northeastern Oregon. The Murrelet 63:92-93.

Boitani, L. and T.K. Fuller. 2000. Research Techniques in Animal Ecology: controversies and consequences. Columbia University Press.

Bowman, J., D. S. Badzinski, and R. J. Brooks. 2010. The numerical response of breeding northern saw-whet owls *Aegolius acadicus* suggests nomadism. Journal of Ornithology 151:499-505.

Brinker, D. F., K. E. Duffy, D. M. Whalen, B. D. Watts, and K. M. Dodge. 1997. Autumn migration of northern saw-whet owls (*Aegolius acadicus*) in the middle Atlantic and northeastern United States: what observations from 1995 suggest. Pages 74-89 in J. R. Duncan, D.H. Johnson, and T.H. Nicholls, editors. Biology and conservation of owls of the northern hemisphere: second international symposium. U.S. Department of Agriculture, Forest Service General Technical Report NC-190.

Brinker. D. F., S. Huy and S. Weidensaul. 2014. Project Owlnet website, accessed at projectowlnet.org.

Brittain, R. 2008. Characterizing northern saw-whet owl (*Aegolius acadicus*) winter habitats in south-central Indiana. Proceedings of the Indiana Academy of Science 117:71-80.

Chapin, F. S., E. S. Zavaleta, V. T. Eviner, R. L. Naylor, P. M. Vitousek, H. L. Reynolds, D. U. Hooper, S. Lavorel, O. E. Sala, S. E. Hobbie, M. C. Mack, and S. Diaz. 2000. Consequences of changing biodiversity. Nature 405:234-242.

Cheveau, M., P. Drapeau, L. Imbeau, and Y. Bergeron. 2004. Owl winter irruptions as an indicator of small mammal population cycles in the boreal forest of eastern North America. Oikos 107:190-198.

Churchill, J. B., P. B. Wood, D. F. Brinker, D. C. Dunning, and R. C. Whitmore. 1998. Winter movements and habitat use of northern saw-whet owls at Assateague Island, Maryland. Master's Thesis, West Virginia University, Morgantown, WV

Churchill, J. B., P. B. Wood, and D. F. Brinker. 2000. Diurnal roost site characteristics of northern saw-whet owls wintering at Assateague Island, Maryland. The Wilson Bulletin. 112:332-336.

Churchill, J. B., P. B. Wood, and D. F. Brinker. 2002. Winter home range and habitat use of female northern saw-whet owls on Assateague Island, Maryland. The Wilson Bulletin. 114:309-313.

Compton, B. W., J. M. Rhymer, and M. McCollough. 2002. Habitat selection by wood turtles (*Clemmys insculpta*): an application of paired logistic regression. Ecology 83:833-843.

Cote, M., J. Ibarzabal, M. H. St. Laurent, J. Ferron, and R. Gagnon. 2007. Age-dependent response of migrant and resident *Aegolius* owl species to small rodent population fluctuations in the eastern Canadian boreal forest. Journal of Raptor Research 41:16-25.

DeRuyck, C. 2009. Northern saw-whet owls: migration and population trends in Manitoba. MS Thesis, University of Manitoba, Winnipeg, Manitoba. pp:124.

Duffy, K., and P. Kerlinger. 1992. Autumn owl migration at Cape May Point, New Jersey. The Wilson Bulletin. 104:312-320.

Dunn, J.L. and J.K Alderfer. 2011. National Geographic field guide to the birds of North America. National Geographic books.

Erdman, T. C., T. O. Meyer, J. H. Smith, and D. M. Erdman. 1997. Autumn populations of migrant northern saw-whet owls (Aegolius acadicus) at Little Suamico, Wisconsin. Pages 167-172 in J.R. Duncan, D.H. Johnson, and T.H. Nicholls, editors. Biology and conservation of owls of the northern hemisphere: second international symposium. U.S. Department of Agriculture, Forest Service, General Technical Report NC-190.

Erdman, T. C., and D. F. Brinker. 1997. Increasing mist-net captures of migrant northern saw-whet owls (Aegolius acadicus) with an audiolure. Pages 533-544 in J.R. Duncan, D.H. Johnson, and T.H. Nicholls, editors. Biology and conservation of owls of the northern hemisphere: second international symposium. U.S. Department of Agriculture, Forest Service, General Technical Report NC-190.

ESRI. 2011. ArcView. Version 10.1. Environmental Systems Research Institute, Redlands, California, USA.

Forbes, J. E., and D. W. Warner. 1974. Behavior of a radio tagged saw-whet owl. The Auk. 91:783-795.

Frye, G. G., and R. P. Gerhardt. 2003. Northern saw-whet owl (*Aegolius acadicus*) migration in the pacific northwest. Western North American Naturalist. 63:353-357.

BCCER Owl Banding Log, Garcia 2013. BCCER Reports, Research Foundation, CSU Chico, Accessed 1 July 2014.

Groce, J. E., and M. L. Morrison. 2010. Habitat use by saw-whet owls in the Sierra Nevada. Journal of Wildlife Management 74:1523-1532.

Grove, R. A. 1985. Northern saw-whet owl winter food and roosting habits in north-central Washington. The Murrelet 66:21-24.

Hayward, G. D, and E. O. Garton. 1984. Roost habitat selection by three small forest owls. The Wilson Bulletin 96:690-692.

Hinam, H. L., and C. C. St. Clair. 2008. High levels of habitat loss and fragmentation limit reproductive success by reducing home range size and provisioning rates of northern saw-whet owls. Biological Conservation 141:524-535.

Holt, D. W., and L. A. Leroux. 1996. Diets of northern pygmy-owls and northern saw-whet owls in west-central Montana. The Wilson Bulletin 108:123-128.

Holroyd, G., and J. G. Woods. 1975. Migration of the saw-whet owl in eastern North America. Bird Banding 46:101-105.

Hosmer, D. W., and S. Lemeshow. 2000. Applied Logistic Regression. John Wiley and Sons, Inc. pages 223-259.

IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.

Johnson, A., and S. H. Anderson. 2003. Conservation assessment for the northern saw-whet owl in the Black Hills National Forest, South Dakota and Wyoming. U.S. Department of Agriculture, Forest Service, Black Hills National Forest, Custer, South Dakota. General Technical Report .

Korpimaki, E. 1994. Rapid or delayed tracking of multi-annual vole cycles by avian predators? Journal of Animal Ecology 63:619-628.

Marks, J. S., and J. H. Doremus. 2000. Are northern saw-whet owls nomadic? Journal of Raptor Research 34:299-304.

Menke, J., E. Reyes, D. Johnson, J. Evens, K. Sikes, T. Keeler-Wolf, and R. Yacoub. 2011. Northern Sierra Nevada foothills vegetation project: vegetation mapping report. California Native Plant Society website, 2011.

Milling, T. C., M. P. Rowe, B. L. Cockerel, T. A. Dellinger, J. B. Gailes, and C. E. Hill. 1997. Population densities of northern saw-whet owls (*Aegolius acadicus*) in degraded boreal forests of the southern Appalachians. Pages 272-285 in J.R. Duncan, D.H. Johnson, and T.H. Nicholls, editors. Biology and conservation of owls of the northern hemisphere: second international symposium. U.S. Department of Agriculture, Forest Service, General Technical Report NC-190.

Moser, B. W., and G. K. Hilpp. 2004. Wintering owl use of hybrid poplar plantations and surrounding cover types. Northwestern Naturalist 85:11-15.

Mueller, H. C., and D. D. Berger. 1967. Observations on migrating saw-whet owls. Bird Banding 38:120-125.

Mumford, R. E., and R. L. Zusi. 1958. Notes on movements, territory, and habitat of wintering saw-whet owls. The Wilson Bulletin 70:188-191.

R Development Core Team (2011). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.

Radford, J. Q., Bennett, A. F., and G. J. Cheers. 2005. Landscape-level thresholds of habitat cover for woodland-dependent birds. Biological Conservation 124:317-337.

Rains, C. 1997. Comparison of food habits of the northern saw-whet owl (*Aegolius acadicus*) and the western screech-owl (*Otus kennicottii*) in southwestern Idaho. Pages 339-346 in J.R. Duncan, D.H. Johnson, and T.H. Nicholls, editors. Biology and conservation of owls of the northern hemisphere: second international symposium. U.S. Department of Agriculture, Forest Service, General Technical Report NC-190.

Rasmussen, J. L., S. G. Sealy, and R. J. Cannings. 2008. Northern saw-whet owl (*Aegolius acadicus*), the Birds of North America Online. A. Poole, editor. Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/042.

Seaman, D. E., and R. A. Powell. 1996. An evaluation of the accuracy of kernel density estimators for home-range analysis. Ecology 77:2075-2085.

Speicher, J., Schreffler, L., and D. Speicher. 2011. Lunar influence on the fall migration of northern saw-whet owls. The Wilson Journal of Ornithology 123:158-160.

Swengel, S. R., and A. B. Swengel. 1992. Roosts of northern saw-whet owls in southern Wisconsin. The Condor 94:699-706.

Swengel, S. R. and A. B. Swengel. 1992. Diet of Northern Saw-Whet Owls in Southern Wisconsin. The Condor 94:707-711.

Weidensaul, S. 2010. Migration and winter ecology of northern saw-whet owls. Pennsylvania studies in avian ecology and conservation. Majumdar et al., editors, 10:137-147.

Whalen, D. M., and B. D. Watts. 2002. Annual migration density and stopover patterns of northern saw-whet owls *(Aegolius acadicus).* The Auk 119:1154-1161.

White, T.E. 1953. A method of calculating the dietary percentage of various food animals utilized by aboriginal peoples. American Antiquity 18:396-398.

White, G. C., & R.A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, San Diego, California, USA.

APPENDIX A

ADDITIONAL TABLES

Table 1A. Summary of prey observed at northern saw-whet owl roost sites, 2010-2012, and species recovered in pellets on subsequent days.

Owl #	Date of Roost	Cached prey species	Roost Date Pellet species	Next day pellet species
1	11/5/10	*Peromyscus*		
6	11/28/10	Unknown		
5	11/29/10	*Microtus*	*Microtus*	
7	11/29/10	*Microtus*		*Microtus, Reithrodontomys*
6	11/30/10	*Microtus*		*Microtus*
5	12/1/10	Unknown		
5	12/5/10	Unknown	*Microtus*	
8	12/8/10	Unknown	*Peromyscus, Pleocoma*	
5	12/15/10	Unknown		
5	12/19/10	Unknown	*Microtus*	*Reithrodontomys*
9	12/28/10	Unknown		
5	1/29/11	*Microtus*		
11	11/4/11	Unknown	*Microtus*	
12	11/23/11	Unknown		
13	11/28/11	*Peromyscus*		
12	12/2/11	*Peromyscus*	*Reithrodontomys*	
15	12/16/11	*Microtus*		
12	12/16/11	*Microtus*		
12	12/19/11	*Peromyscus*	*Reithrodontomys*	
12	12/21/11	*Peromyscus*	*Microtus*	
16	1/17/12	Unknown	*Microtus*	

Table 2A. Summary of prey items found during northern saw-whet owl pellet analysis, 2010-2012.

Species	Season 1 Adult	Season 1 Juvenile	Season 1 Unknown Age	Season 2 Adult	Season 2 Juvenile	Season 2 Unknown Age
Reithrodontomys	6	25	2	4	9	3
Microtus	6	7		4	6	1
Peromyscus	1	7	1	4	6	1
Pleocoma	1			2		
Unknown invertebrate	1					