AN ABSTRACT OF THE THESIS OF

Jason W. Schilling for the degree of Master of Science in Wildlife Science presented on June 18, 2009.

Title: Demography, Home Range, and Habitat Selection of Northern Spotted Owls in the Ashland Watershed

Abstract approved:

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Northern Spotted Owls (*Strix occidentalis caurina*) inhabit productive forests that historically supported frequent, large, variable-severity fires in the Klamath province of southwestern Oregon occur in complex. The potential for high-severity wildfire remains high throughout this region, so remaining spotted owl habitat is at risk. An adaptive management approach to fire management and owl recovery in these forests is being advocated under the Final Recovery Plan for the Northern Spotted Owl. However, it is currently unclear what short- or long-term effects these fuels reduction treatments will have on spotted owl populations. Proposed forest thinning treatments planned for the Ashland Watershed in southwestern Oregon provide an unprecedented opportunity to study the effects of thinning on spotted owl ecology. My objectives were to determine 1) monthly survival rates and 2) home range size of spotted owls in relation to habitat characteristics, and 3) owl habitat selection. Data were collected prior to forest manipulations and will serve as a baseline for comparison with post-thinning data. Survival, home range size and habitat selection for 15 Northern spotted owls were monitored using radio telemetry in

the Ashland Watershed and surrounding area from September 2006 to October 2008. A remote-sensed vegetation map of the study area was used to characterize habitat classes and configuration.

Estimates of monthly survival were generated in relation to habitat characteristics using program MARK. Monthly survival was positively correlated with the number of late forest patches within the individual home range and negatively correlated with the mean nearest neighbor of late forest patches.

Annual home range size varied from 189 to 894 ha. Annual home range size increased with increased amounts of edge and decreased with increased amounts of intermediate aged-forest. The mean breeding season home range size was 491 ha and was larger than mean non-breeding season home ranges. Home range size increased with the addition of hard edge, and amount of old and mature forest combined. The mean size for annual core areas was 77 ha. The best predictor of both non-breeding home range size and core area size was hard edge. While home range size was positively related to the amount of hard edge within non-breeding home range in a linear fashion, core area size increased with increasing amounts of hard edge, but only up to a threshold point, where further increases in edge did not increase core area size.

Logistic regression was used to model habitat selection of owls in relation to forest characteristics. Individual owls exhibited different preferences in selecting habitat for foraging and roosting. Overall, owls selected for habitat that was closer to streams and further away from edge. Old forest did not significantly influence selection, but mature forest was positively associated with annual and winter habitat

selection for several individual owls. Intermediate forests and non-habitat were only

weakly associated with spotted owl habitat selection.

Demography, Home Range, and Habitat Selection of Northern Spotted Owls in the
Ashland Watershed

by

Jason W. Schilling

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CONTRIBUTION OF AUTHORS

Dr. Katie Dugger assisted with the analysis, design, and editing of each chapter of this thesis. Dr. Robert Anthony was involved in the editing of chapters 1 - 4.

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This thesis is dedicated to my parents Dale and Linda Schilling, who have always enabled me to succeed.

"No one has explained what the leopard was seeking at that altitude."
-Ernest Hemingway, *The Snows of Kilimanjaro*

DEMOGRAPHY, HOME RANGE, AND HABITAT SELECTION OF NORTHERN
SPOTTED OWLS IN THE ASHLAND WATERSHED

CHAPTER 1

INTRODUCTION

Jason W. Schilling

The highest concentrations of remaining old-growth forests in the northwestern United States are in southwestern Oregon and Northern California (Bolsinger and Waddell 1993). Historically, these forests were influenced by high-frequency fires that maintained a mosaic of forest types and created canopy gaps, structural complexity, and species diversity (Agee 1993, Skinner et al. 2006, Sensinig 2002). During the last century, however, active fire suppression within this region is believed to have resulted in an overall decline in the occurrence of wildfire (Agee 1993, Sensenig 2002). A decrease in incidence and scale of wildfire has resulted in higher stand densities and increased fuel loads, and when fires do occur, fire severity is often high (Sensenig 2002). Large areas of southwestern Oregon, including the Ashland Watershed, are at risk to high-severity wildfire (Agee and Edmonds 1992). For example, major fires burned large portions of southwestern Oregon in 1992, 1994, 2001, and 2002.

To reduce the vulnerability of forests to wildfire, managers are proposing to alter forest structure so that the treated areas are more resilient to fires. The Healthy Forest Restoration Act (U. S. House of Representative 2003) was developed to restore more fire resilient forests on federally managed lands. It is a wide scale effort to perpetuate healthy and resilient forests in fire-adapted ecosystems where fire plays a vital role in maintaining diversity. Site-specific prescriptions for implementing fuels reduction treatments in the Ashland Watershed have been proposed within the Ashland Forest Resiliency (AFR) project (U. S. Forest Service 2008). The AFR project is supported by both forest managers and the local community, because the Ashland Watershed is directly adjacent to the city of Ashland and is a valuable recreational and

municipal resource. Community interest and participation in the health of the

watershed is reflected by the U. S. Forest Service's inclusion of the community

alternative as the preferred action plan in the final environmental impact statement for

the AFR Project (U. S. Forest Service 2008).

Recently, researchers have investigated the effects of commercial thinning on

forest wildlife (Hayes et al. 2003, Suzuki and Hayes 2003) and spotted owl prey

(Gomez et al. 2005). However, little is known about the effects of these strategies on

northern spotted owls (*Strix occidentalis caurina*), the conservation of which has been a

focal point in forest management in the Pacific Northwest for over three decades.

Northern spotted owls were listed as a Threatened sub-species in 1990, and

information on site occupancy (Olson et al. 2005), the effects of habitat characteristics

on survival and reproduction (Franklin et al. 2000, Olson et al. 2004, Dugger et al.

2005) and demographic variation throughout the range of the species (Anthony et al.

2006) has been well documented. Spotted owls find many of their habitat requirements

in structurally complex forest stands characterized by a multi-species and multi-storied

canopy as well as large standing snags and downed wood (Forsman et al. 1984, LaHaye

and Gutiérrez 1999). The vertical complexity of these stands provides the components

utilized by spotted owls for nesting, roosting, and foraging (U. S. Department of

Agriculture and U. S. Department of Interior 1994).

Forest structure and configuration affects the overall fitness of northern spotted

owls (Franklin 2000, Olson et al. 2004, Dugger et al. 2005). Annual survival has been

positively correlated with the amount of late-seral forest and amount of edge between

old forests and other vegetation types within the territory (Franklin et al. 2000, Olson et al. 2004, Dugger et al. 2005). However, while these studies estimated annual survival rates, no studies have estimated monthly survival in relation to habitat characteristics.

Several studies have documented home range and habitat selection of spotted owls in the Pacific Northwest (Forsman et al. 1984, 2005, Carey et al. 1990, Glenn et al. 2004, Hamer et al. 2007), but information on habitat selection and home range of spotted owls in the fire-prone forests of southwestern Oregon is limited (Anthony and Wagner 1999, Clark 2007). Spotted owls nest, roost, and forage in predominately mature/old forest (>80 years old) (Carey et al. 1990, Forsman et al. 1984, Hamer et al. 2007). Habitat selection in southwestern Oregon also increased as the primary canopy became more structurally advanced and mature (Wagner and Anthony 1999).

Spotted owls have large home ranges (Forsman 2005, Clark 2007, Hamer et al. 2007), but home range estimates for owls in the Klamath province tend to be smaller than in other parts of the subspecies' range (Zabel et al. 1995, Clark 2007). These differences have been attributed to factors such as the high proportion of old forest within home ranges (Carey et al. 1990, Forsman et al. 2005), an increased amount of hard edge (Clark 2007), and increased prey abundance (Carey et al. 1992, Zabel et al. 1995). A recent post-fire telemetry study in southwestern Oregon revealed that home ranges of resident spotted owls expanded by an average of 246 ha after wildfire (Clark 2007).

In southwestern Oregon, spotted owls are associated with structurally diverse stands that are susceptible to high-severity wildfire because of the increased fuel loads

and ladder fuels associated with these forests (Agee 1993, Sensenig 2002). The forests

of the Klamath region have a unique fire-regime history that differs from northern

spotted owl habitat found within the dry-forest ecosystems of the Eastern Cascades,

mesic forests of the Western Cascades and coastal mountains (Agee 1993, Sensenig

2003, Skinner 2006). The Final Northern Spotted Owl Recovery Plan (U. S. Fish and

Wildlife Service 2008) recognized these differences and recommended an adaptive

management approach specific to the Klamath province that addresses the threat of fire

in areas important for the persistence of northern spotted owls.

Fuels-reduction projects that simplify stands (e. g., thinning and prescribed

burning) may lower habitat quality for spotted owls. Likewise, high-severity wildfires

may eliminate or degrade suitable habitat for spotted owls and negatively influence

survival and occupancy rates of owl territories immediately following a burn (Clark

2007). If the objective is to maintain viable populations of northern spotted owls,

managers need to balance the habitat needs of spotted owls and other species that occur

in old forests with efforts to reduce the risk of catastrophic wildfire.

The effects of selective timber harvest on home-range and habitat selection

patterns have only been studied for one male northern spotted owl in the northern

Oregon Coast Range (Meiman et al. 2003). The owl's home range was slightly larger

after selective harvest than before, and he did not use the thinned forest. Selective

harvest could reduce habitat quality for species that thrive in older forests by removing

structural complexity and legacy trees. This could cause an expansion in home range

and potentially reduce the fitness of the bird. However, it is possible that thinning

operations that are designed to maintain these structural qualities could have reduced effects on site occupancy and home range size of the owls. There is a need for larger scale studies as more fire-reduction treatments such as selective harvest are being implemented across the home range of the spotted owl.

Little is known about the ability of owls to meet their habitat requirements and reproduce in landscapes subjected to selective harvest. With an increasing frequency of fuels reduction projects being proposed across the range of the spotted owl, information on the effects of these treatments on the home range attributes, habitat selection and demographic parameters of spotted owls is needed. My objectives were to estimate survival, habitat selection and home range size from a sample of radio-marked spotted owls prior to a selective harvest project proposed for the Ashland Watershed (U. S. Forest Service 2008). This study will provide pre-treatment data that will ultimately be compared to a post-treatment data after harvest treatments are complete. Ultimately, the data gathered in this project will assist land managers in implementing fuels management strategies that are consistent with historic fire disturbance regimes and spotted owl habitat requirements.

CHAPTER 2

SURVIVAL, MORTALITY, OCCUPANCY, AND REPRODUCTION OF
NORTHERN SPOTTED OWLS IN THE SISKIYOU MOUNTAINS

Jason W. Schilling

INTRODUCTION

The demography of northern spotted owls (*Strix occidentalis caurina*) including survival has been well-studied (Franklin et al. 1999, Anthony et al. 2006). Population declines of this species have been linked to decreases in apparent survival in some portions of the spotted owl's range (Franklin et al. 1999, Anthony et al. 2006). Initial research concerning the life history parameters of spotted owls did not investigate the underlying causes for variation in survival or reproduction (Burnham et al. 1994;1996), however, more recent spotted owl research has focused on the factors and mechanisms that are likely responsible for variation in demographics of northern spotted owls (Franklin et al. 2000, Olson et al. 2004, Dugger et al. 2005).

Potential factors that affect the survival of raptors can be separated into individual, biotic, and abiotic factors. Sources of individual variation include sex, age, and inherited traits (Burnham et al. 1996, McDonald et al. 2005, Anthony et al. 2006). Biotic influences include prey abundance and availability (Southern 1970, Ward and Kennedy 1996), the presence of predators and competitors (Anthony et al. 2006), as well as the configuration and composition of the landscape within individual territories (Franklin et al. 2000, Olson et al. 2004). Abiotic factors such as climate also have the potential to affect survival (Wichmann et al. 2003, McDonald et al. 2004), and climate effects on survival have been reported for spotted owls in some portions of their range (Franklin et al. 2000, Olson et al. 2004).

Initial population declines of spotted owls were attributed to the loss of suitable habitat caused by timber extraction (Forsman et al. 1984b), and recent research

emphasis has been placed on understanding the effects of forest landscape characteristics on temporal and spatial variation in survival and reproduction of the subspecies (Franklin et al. 2000, Olson et al. 2004, Dugger et al. 2005). The implementation of the Northwest Forest Plan has decreased the harvest of old-growth habitats on public land in the last decade, but harvest still continues on private lands within the owl's range (Azuma et al. 2002, Pierce et al. 2005). In addition, the barred owl (*Strix varia*) apparently has had detrimental effects on occupancy (Olson et al. 2005, Dugger et al., in review), survival, and reproduction in some portions of the subspecies' range (Anthony et al. 2006).

Suitable or high-quality habitat can be defined as that which positively contributes to the fitness of an individual (Fretwell and Lucas 1970, Van Horne 1983). For the purpose of this study, I defined fitness in terms of annual survival and reproduction (number of young produced per pair per year), both of which are associated with the amount and configuration of habitat within a owl's territory (Franklin 2000, Olson et al. 2004, Dugger et al. 2005). Spotted owls are most fit when habitat features are available in sufficient quantity and quality within a home range to fulfill life history requirements (Franklin et al. 2000). Annual survival has been positively correlated with the amount of late-seral forest within territories (Olson 2004, Dugger et al. 2005, Franklin et al. 2000) and negatively associated with the amount of unsuitable habitat (Blakesley et al. 2005, Dugger et al. 2005)   Although pole and young forest types have not been significantly associated with survival (Dugger et al. 2005), northern spotted owls have been noted to choose these intermediate-aged forests

more than expected based on availability (Wagner and Anthony 1999). In addition, annual survival was positively correlated with the amount of edge between old forests and other vegetative types in some but not all parts of the subspecies range (Franklin 2000, Olson et al. 2004) but not others (Dugger et al. 2005). Franklin and Gutiérrez (2002) also suggested the linkage of a number of landscape metrics (e. g. number of late forest patches, mean patch size of late forest patches, and mean nearest neighbor of late forest patches) with survival, reproduction and juvenile dispersal.

An additional threat to spotted owl survival in dry-forest ecosystems is the loss of habitat due to high-severity wildfires. In southwestern Oregon, survival was negatively associated with high-severity wildfire, and spotted owl survival rates were lower in burned areas than in unburned areas (Clark 2007). In an attempt to reduce the risk of high-severity wildfire to northern spotted owl habitat, fuels reduction projects in portions of the range of the northern spotted owl were recommended in the Final Recovery Plan for the Northern Spotted Owl (U. S. Fish and Wildlife Service 2008). However, the effects of selective timber harvest on the survival rates of owls are unknown. Such projects will provide an opportunity to study northern spotted owl response to selective timber harvest as managers attempt to strike a balance between fuels reduction and retention of late-successional habitat (U. S. Fish and Wildlife Service 2008).

The Ashland Forest Resiliency Project (AFR), a project authorized under the Healthy Forest Initiative (HFI) and National Fire Plan Pilot Project proposes the use of mechanical selective timber harvest and prescribed burning in the Ashland Watershed

to create stand structures that are similar to those produced by historic fire regimes. The goal of these treatments is to reduce fire hazard in a manner that would promote canopy gaps, structural complexity, species diversity, and forest structures that resemble natural conditions (U. S. Forest Service 2005). The purpose of this study was to estimate the impacts of habitat characteristics on northern spotted owl survival before the implementation of selective timber harvest. I predicted that (1) monthly survival rates would be positively associated with the amount of intermediate and old forest within individual territories, (2) monthly survival rates would be negatively related to various habitat fragmentation metrics that represent increased fragmentation of older forest habitats (patch size, number of patches), but positively related to the amount of edge between suitable (i.e., forested) and unsuitable habitat, (3) monthly survival would differ by sex and through time (particularly between seasons), and (4) monthly survival of spotted owls would be negatively associated with the presence of barred owls near the center of activity. This study served as a baseline dataset for future research on the effects of selective harvest management on spotted owl survival in the Siskiyou Mountains of Oregon.

METHODS

Study Area

The AFR Project is centered on the City of Ashland Municipal Watershed, Jackson County, Oregon (Figure 2.1). The Ashland Creek sub-watershed is approximately 6,388 ha and is one of the primary tributaries to Bear Creek. It is bordered by Mount Ashland to the south, the city of Ashland to the North, and the Neil

Creek sub-watershed to the East. Beyond its western edge lies the Little Applegate watershed. It is located primarily on the Ashland Ranger District of the Rogue River-Siskiyou National Forest, with small blocks of private and City of Ashland ownership interspersed (U. S. Forest Service 2005)

The study area was within the Siskiyou Range of the Klamath Mountains and the Mixed-Conifer and Shasta Red Fir (*Abies magnifica* var *shastensis*) vegetation zones (Franklin and Dyrness 1973). Among North American ecoregions, the Klamath Mountains equal only the southern Appalachians in terms of floristic diversity and concentrations of 'narrowly endemic' species (Whittaker 1960) . The most common tree species were ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), incense cedar (*Calocedrus decurrens*), white fir (*Abies concolor*), Shasta red fir, Oregon white oak (*Quercus garryana*), California black oak (*Quercus kellogii*), and Pacific madrone (*Arbutus menziesii*).

Management practices within the Ashland watershed were limited to small-scale timber harvest and other forms of vegetation modifications that benefited the management of the municipal watershed (U. S. Forest Service 2005). Fires were the most common forms of disturbance in red fir forests, occurring at short intervals (Agee 1993), with lightning as the main source of ignition. Mixed-conifer forests occur in geographic areas characterized by hot, dry summers and mild, wet winters, and they also burn on short intervals (50 years) at low to moderate severity (Agee 1993). A pronounced rain shadow existed from the Oregon coast to the Ashland watershed and resulted in precipitation ranging from 25 - 89 cm annually, increasing with elevation (U.

S. Forest Service 2005). Elevations within the study area ranged from 760 – 1,830 m.
The topography was characterized by moderate to steep (20 - 70 percent) slopes that
were highly dissected and characterized by high rates of erosion (U. S. Forest Service
2005).

Figure 2.1. Location of the Ashland Watershed in southwestern Oregon.

The project area was located within the Mt. Ashland Late Successional Reserve
(LSR) and contained over 3,600 ha of mature and late-successional forest (U. S. Forest

Service 2005). Limited management within the watershed resulted in contiguous and less fragmented blocks of late-seral forests than other areas of the Mt. Ashland LSR (U. S. Forest Service 2005). My study focused on spotted owl territories within the boundaries of the Ashland Forest Resiliency Project, as well as the Little Applegate River, Neil Creek, and upper Wagner Creek sub-watersheds.

A spotted owl demography study was conducted from 1992-1997 by the Oregon Cooperative Fish and Wildlife Research Unit (unpublished data). This study encompassed 16 spotted owl territories and provided a valuable dataset for comparison with current demographic data.

Occupancy and Reproduction

Demographic information was gathered in the project area using a density study area (DSA) approach (Franklin et al. 1996). Historical owl sites were visited during the day, while the remaining area was systematically surveyed with a minimum of three replicated nighttime spot calling surveys to detect any additional owls. Once owls were detected at historical and new sites, reproduction was determined following protocols established by Lint et al. (1999). Nesting surveys were conducted from April 1 to May 31, with "mousing" (Franklin et al. 1996) as the primary technique used to determine nesting status. Status was confirmed as nesting, non-nesting, nest failure, or unknown. Fledgling counts were conducted after the young fledged and until 31 August. A minimum of two brood counts were recorded to ensure that all young were counted. For the purpose of this study, occupancy was defined as the percent of historical sites occupied and reproduction was defined as the mean number of young

fledged per owl pair per year. We summarized general occupancy results and calculated reproduction rates for comparison with occupancy and reproduction after selective timber harvest.

Radio telemetry monitoring and survival

Resident owls occupying historical sites within the study area were located using demographic surveys during the breeding seasons of 2006 and 2007. Individuals were captured with a noose pole, foot snare, or by hand and fitted with 5 g backpack mounted radio transmitters (Holohil Systems Ltd. Model RI-2C, Ontario, Canada) with an expected life span of 12 months. Birds were monitored from September 2006 - October 2008. All unbanded birds were marked with a USFWS identification band as well as color bands. Owls were located using a directional yagi antennae and a Telonics model TR-2 receiver (Telonics, Inc., Mesa, Arizona, USA) or Communication Specialists model R-1000 receiver (Communication Specialists, Inc., Orange, California, USA). The fate of each owl was determined approximately every other day. If a transmitter signal switched to mortality mode, I hiked into the owl's territory to locate the remains of the bird. When a live owl was not detected in the study area for several weeks, I used a fixed-wing aircraft to conduct an aerial search throughout the study area and adjacent lands to locate the missing bird. If a bird was not located through an aerial search or subsequent demographic surveys, I assumed transmitter failure or emigration from the study area and censored the owl from the data set. An owl must have been verified alive and present on the study area at the beginning or end

of a month; otherwise it was censored for that interval. If an owl's transmitter failed, it was re-located and fitted with a new transmitter and censored for that month.

Habitat Covariates

I generated habitat covariates using an ArcGIS (ESRI, Redlands, CA, USA) map layer created by Geographic Resource Solutions (GRS; (Hill 1996), which used LandSat data acquired on August 29, 1993 and described canopy closure (%), average tree size (DBH), and dominant vegetation type for each 25 m^2 pixel. The accuracy of this habitat map was estimated to be 86%, 92%, and 88% for canopy closure, average DBH, and cover type, respectively (Hill 1996).

I re-classified the GRS vegetation layer into three general habitat classes that previous research has suggested are important to spotted owl demography (Franklin et al. 2000, Olson et al. 2004, Dugger et al. 2005) including old forest, intermediate-aged forest, and non-habitat (Table 2.1). Fragmentation metrics identified as pertinent to the life history of spotted owls (Franklin and Gutiérrez 2002) were derived from this layer using FRAGSTATS (McGarigal and Marks 1995) and included total core area of late-seral forest, mean patch size of late-seral forest, number of late-seral patches, mean nearest neighbor of late-seral forest, and length of edge (Table 2.1). I defined edge as the interface between non-habitat and old and intermediate-aged forests. All habitat covariates were generated from the individual 95% fixed-kernel home range estimated by KernelHR (Seaman et al. 1998) using ArcGIS 9.2 (Appendix A). Fixed Kernel estimates are less biased than adaptive kernel estimates when least squares cross-validation is used to select the smoothing parameter (Seaman and Powell 1996).

Table 2.1 Acronyms and definitions for habitat covariates used to model monthly
survival for northern spotted owls in the Siskiyou mountains from October 2006 -
October 2008. All covariates are values found within the 95% fixed kernel home range.

Acronym	Definition
LATE	The percentage of late-seral forest characterized by canopy closure $\geq 40\%$ and DBH > 50.8 cm.
INTER	The percentage of intermediate aged forest characterized by canopy closure $\geq 40\%$ and DBH 12.7 - 50.7 cm.
NON	The percentage of non-habitat (DBH ≤ 12.6 cm).
SUIT	Suitable habitat is considered the combined percentage of LATE and INTER habitat classes.
NUMP_L	The number of patches of late-seral forest.
MPS_L	The mean patch size of late-seral forest (ha)
EDGE	The amount of edge (m) between suitable and non-habitat
MNN_L	The mean nearest neighbor distance, which is the average of the shortest distances (edge to edge in meters) between patches of late-seral forest.
PERIM_L	Perimeter Density, which is the length (m) of the perimeter of late-seral conifer forest patches divided by the amount (ha) of late conifer forest
TCA_L	Total Core Area is the total amount (ha) of late-seral forest core area with a 100 meter buffer to edge.

Model structures

Several recent studies of northern spotted owls (Franklin et al. 2000, Anthony et
al. 2006) reported relationships between survival and habitat variables that were not
strictly linear in nature. I therefore modeled survival using three functional
relationships for each variable: linear, pseudo-threshold (log), and mean-centered
quadratic (mcq).

Survival Analysis

I used my radio telemetry data and known fate models in program MARK to estimate monthly survival rates (S) and model the affects of covariates on survival(Kaplan and Meier 1958, Pollock et al. 1989). This method allows for censoring of owls that die or emigrate from the study area, and also allows for the staggered entry of individuals into the analysis. Owls were entered into the data set the first month their fate was known for the entire monthly interval (i.e., at both the beginning and end of the month). Owls were recorded as being either alive, dead, or censored for each monthly interval.

I analyzed monthly survival rates for the entire 25 months of the study (i.e., 25 time intervals). I generated a list of *a priori* models based on my hypotheses regarding the effects of sex, time trends, season, study area (i.e., Ashland watershed vs. outside Ashland watershed), barred owls and habitat covariates (Table 2.2) on monthly survival. Seasonal models were based on separation of monthly intervals into winter (November-April) and non-winter (May-October) categories. The barred owl variable for a particular month represented incidental detections of single or paired barred owls while surveying for spotted owls within the study area during the previous nesting season. For example, a barred owl indicator variable would be included in a winter month survival estimate if a barred owl was detected in the individual owl's territory during the previous breeding season.

Table 2.2. *A priori* models used for determining effects of various factors on monthly survival estimates (S) of northern spotted owls in the Siskiyou Mountains from October 2006 through October 2007.

Description of model	Model
1. Sex effect	S(sex)
2. Area effect	S(area)
3. Time effect	S(t)
4. Seasonal effect	S(Winter)
5. Year effect	S(year)
6. Additive effects of season and year	S(winter+ year)
7. Interaction between season and year	S(winter*year)
8. No effect	S(.)
9. Linear time effect	S(T)
10. Quadratic time effect	S(TT)
11. Interaction between area and time	S(area*t)
12. Interaction between sex and area	S(sex*area)
13. Interaction between sex and time	S(sex*t)
14. Additive effects of area and time	S(area +t)
15. Additive effects of sex and time	S(sex + t)
16. Additive effects of sex and area	S(sex + area)
17. Presence of barred owl(s)	S(BAOW)
18. Effects of habitat covariates	S(X$_i$)[a]
19. Additive effects of area, sex, and time	S(area + sex + time)
20. Global Model (area, sex, and time) plus interactions	S(area * sex * time)

[a] Includes all habitat covariates listed in table 2.1

I used an information theoretic approach to select the best models and most important effects on survival (Burnham and Anderson 2002). Models were ranked according to AIC$_c$ adjusted for small sample size. The model with the lowest AIC$_c$ and highest model weight was considered the "best" model (Burnham and Anderson 2002). All models having an AIC$_c$ value within 2 units of the top model were considered competitive, and 95% confidence intervals on regression coefficients were used to

determine the strength of specific effects. After ranking all the habitat models by AIC_c,

I reduced the total model list by only retaining the best functional form (linear,

pseudothreshold, or quadratic) for each variable in the final model list. I made specific

predictions (hypotheses) regarding the affects of different habitat covariates on survival

(Table 2.3), so the direction and strength of effects was also evaluated. Finally, it is not

possible to test for goodness of fit for known-fate data with individual covariates

(Cooch and White 1999), so I assumed minimal overdispersion in the dataset (ĉ=1).

Table 2.3. Model structure and predictions for habitat covariates used for survival
analysis (S) of northern spotted owls in the Siskiyou Mountains from September 2006
through October 2008.

Model	Linear	Pseudothreshold	Quadratic
S_{LATE}	$\beta_{(LATE)} > 0$	$\beta_{(lg\_LATE)} > 0$	$\beta_{(LATE)} > 0$, $\beta_{(LATE)}^2 < 0$
S_{INTER}	$\beta_{(INTER)} > 0$	$\beta_{(lg\_INTER)} > 0$	$\beta_{(INTER)} > 0$, $\beta_{(INTER)}^2 < 0$
S_{NON}	$\beta_{(NON)} < 0$	$\beta_{(lg\_NON)} < 0$	$\beta_{(NON)} > 0$, $\beta_{(NON)}^2 < 0$
S_{NUMP_L}	$\beta_{(NUMP\_L)} > 0$	$\beta_{lg(NUMP\_L)} > 0$	$\beta_{(NUMP\_L)} > 0$, $\beta_{(NUMP\_L)}^2 < 0$
S_{MPS_L}	$\beta_{(MPS\_L)} > 0$	$\beta_{lg(MPS\_L)} > 0$	$\beta_{(MPS\_L)} > 0$, $\beta_{(MPS\_L)}^2 < 0$
S_{EDGE}	$\beta_{(EDGE)} > 0$	$\beta_{lg(EDGE)} > 0$	$\beta_{(EDGE)} > 0$, $\beta_{(EDGE)}^2 < 0$
S_{MNN_L}	$\beta_{(MNN\_L)} < 0$	$\beta_{lg(MNN\_L)} < 0$	
S_{PERIM_L}	$\beta_{(Perim\_L)} < 0$	$\beta_{lg(PERIM\_L)} < 0$	
S_{TCA_L}	$\beta_{(TCA\_L)} > 0$	$\beta_{lg(TCA\_L)} > 0$	$B_{(TCA\_L)} > 0$, $\beta_{(TCA\_L)}^2 < 0$
$S_{LATE+EDGE}$	$\beta_{(LATE)} > 0$	$\beta_{(lg\_LATE)} > 0$	$\beta_{(LATE)} > 0$, $\beta_{(LATE)}^2 < 0$
	$\beta_{(EDGE)} > 0$	$\beta_{lg(EDGE)} > 0$	$\beta_{(EDGE)} > 0$, $\beta_{(EDGE)}^2 < 0$
$S_{INTER+EDGE}$	$\beta_{(INTER)} > 0$	$\beta_{(lg\_INTER)} > 0$	$\beta_{(INTER)} > 0$, $\beta_{(INTER)}^2 < 0$
	$\beta_{(EDGE)} > 0$	$\beta_{lg(EDGE)} > 0$	$\beta_{(EDGE)} > 0$, $\beta_{(EDGE)}^2 < 0$

RESULTS

Occupancy and Reproduction

The mean occupancy rate during 2005-2008 ($\bar{x}$ = 0.525, SE = 0.078) was lower than during 1993-1997 ($\bar{x}$ = 0.817, SE = 0.035) (Table 2.4, Figure 2.2), but there were no consistent differences in reproduction between the two time periods ($\bar{x}$ =0.46, SE = 0.17; vs. $\bar{x}$ =0.39, SE = 0.16) (Figure 2.3). Each time period did, however exhibit alternating years of high and low reproduction, although prior to 2005 high reproduction occurred in even years, while during my study the highest reproduction occurred in odd years (Table 2.4).

Owl Mortalities

Fifteen owls were radio-marked from September 2006 through June 2007. Six were in the Ashland Watershed, three in the Neil Creek Watershed and six in the Little Applegate Watershed. One owl disappeared from the study area in May 2007 and was never seen again, despite multiple demographic surveys and aerial telemetry searches. This owl was censored from the data set in addition to two other owls that briefly left the study area but returned. Five of the 15 radio marked owls (33%) died from October 2006 through September 2008, and the fate of one owl was never determined (Table 2.5). Three of these five deaths were likely caused by predation. Scattered feathers and a radio transmitter were all that remained of the owls. No carcasses were found, and therefore necropsies could not be performed. Two females, one from McDonald Creek and the other from East Fork died early in the winter of

Table 2.4. Occupancy and reproduction rates for northern spotted owls in the Ashland Watershed Density Study Area from 1993-1997, and 2005-2008.

Year	Sites[a]	Sites Occupied	Occ.[b]	Pairs	Fledg.[c]	Product.[d]	BAOW (%)[e]
1993	16	13	0.81	8	1	0.13	0 (0)
1994	16	14	0.88	14	14	1.00	0 (0)
1995	16	14	0.88	11	5	0.45	0 (0)
1996	14	12	0.86	11	8	0.73	0 (0)
1997	3	2	0.67	2	0	0.00	0 (0)
	Mean		0.82			0.46	
	SE		0.04			0.17	
	95% C. I.		0.74 - 0.90			0.13 - 0.79	
2005	14	9	0.64	5	4	0.80	2 (14)
2006	16	11	0.69	8	2	0.25	5 (31)
2007	17	11	0.65	9	7	0.78	6 (35)
2008	17	9	0.53	7	1	0.14	6 (35)
	Mean		0.53			0.39	
	SE		0.08			0.16	
	95% C. I.		0.37 - 0.69			0.08 - 0.70	

[a] Number of sites surveyed
[b] Percentage of surveyed sites that were occupied
[c] Number of Fledglings
[d] Reproduction (i.e., the number of fledglings per pair).
[e] Percentage of sites where barred owls were detected.

2007/2008, just a few days before heavy snow fell on the study area. While the mortality sensors provided us with information regarding the death of these birds, these owls were subsequently buried under multiple feet of snow and by the time the snow had melted in the spring their transmitters had failed, so we were unable to locate the transmitters or remains of these individuals.

Monthly Survival

The best model for monthly survival over the entire 25 months of the study included the log transformed number of late-seral forest patches (lg_NUMP_L) found within the 95 % fixed kernel home range (Table 2.6). Although the top model

accounted for only 11% of the model weight of all models, the direction of the effect of

the number of late-seral forest patches on survival was positive as predicted, and the
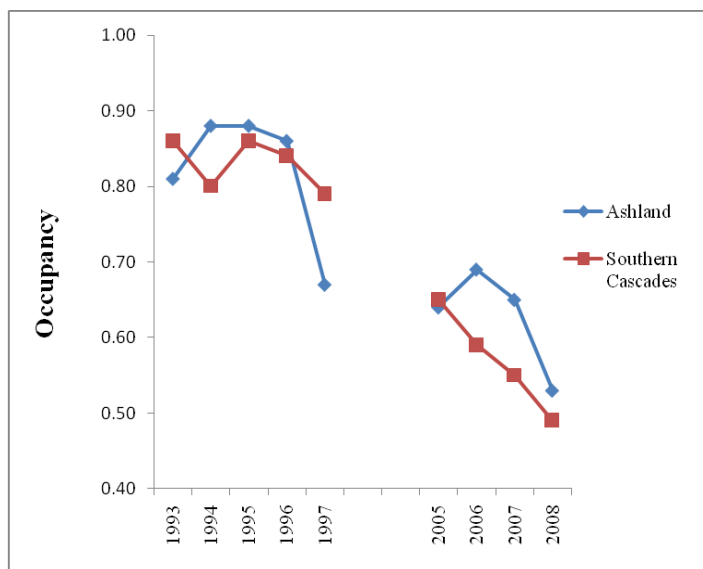
Figure 2.2 Proportion of surveyed sites where northern spotted owls were detected in the Ashland Density Area versus the Southern Cascades Demography Area during 1993-1997 and 2005-2008 in southern Oregon.
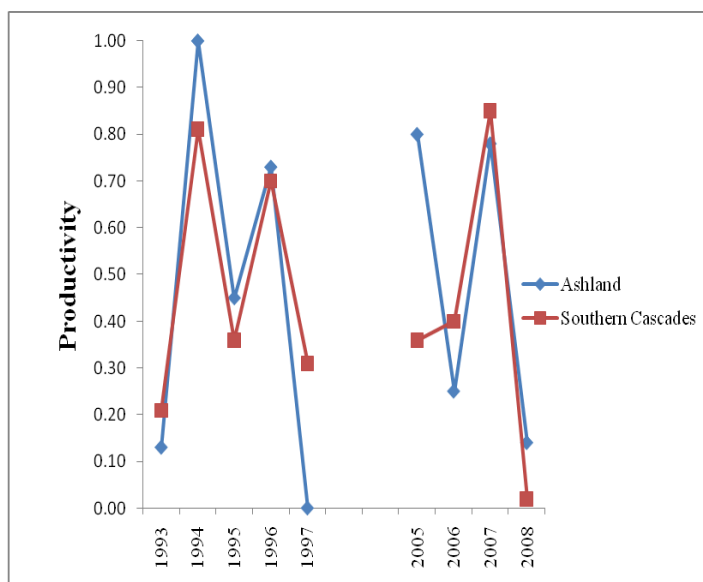
Figure 2.3 Mean number of young fledged per northern spotted owl pair for the Ashland Density Area versus the Southern Cascades Demography Area during 1993-1997 and 2005-2008 in southern Oregon.

95% CI on the β did not overlap zero (β = 2.51, SE = 1.22   95% C.I. = 0.12 - 4.90)

(Figure 2.4). There were a number of other highly competitive models, all including

habitat covariates (Table 2.6). However, the only other habitat covariate whose

confidence intervals did not overlap zero was the log of the mean nearest neighbor

distance between late-seral forest patches (lg_MNN_L). Survival decreased as the

mean nearest neighbor distance for late-seral forest patches increased (β = -4.35, SE =

2.10, 95% C.I. = -8.47 to -0.22), suggesting less forest fragmentation was beneficial for

spotted owl survival (Figure 2.5).

Table 2.5. Date and cause of death of 5 radio-tagged northern spotted owls monitored
during radio-telemetry research in the Ashland, Neil, and Little Applegate Watersheds
in southwestern Oregon from September 2006 – October 2008.

Owl	Mortality Date	Cause of Death
Greeley Creek Female	01/29/2006	Predation
Lightning Strike Male	06/01/2007	Predation
McDonald Creek Female	12/20/2007	Unknown
East East Fork Female	11/30/2007	Unknown
500 Road Male	05/01/2008	Predation

Survival was also associated with the amounts of late-seral, intermediate-aged,

and nonsuitable forest types (Table 2.6). However, these effects were relatively weak

as the 95% confidence interval on the coefficients overlapped zero for late-seral (β = -

17.28, SE = 9.70, 95% C.I. = -36.30 to 1.74), intermediate (β = 11.31, SE = 6.87 95%

CI: -2.15 to 24.78), and nonsuitable habitat (β = 28.99, SE = 20.89, 95% C.I. = -11.96 to

69.94).;; There was also weak support for a relationship between survival and the

habitat covariates edge (β = 2.39, SE = 1.27, C.I. = -0.09 to 4.88), mean late-seral patch

size (β = -2.54, SE = 1.67, C. I. = -5.82 to 0.73), and perimeter density of late-seral

patches (β = 0.01, SE = 0.01, C.I. = 0.00 - 0.02).

Table 2.6. Model selection results for 25-month- known fate models that estimated survival of northern spotted owls (n =15) in the Ashland, Neil, and Little Applegate Watersheds from October, 2006 – October 2008. Models including non-linear structures of covariates are designated as "lg" for pseudo-threshold and "mcq" for mean-centered quadratics.

Model	AICc	Δ AIC$_c$	AIC$_c$ WeightS	k	Deviance
S($_{lg\_NUMP\_L}$)	47.386	0.000	0.111	2	43.329
S($_{lg\_LATE}$)	47.400	0.015	0.110	2	43.344
S($_{lg\_EDGE}$)	47.861	0.475	0.088	2	43.805
S($_{lg\_MNN\_L}$)	48.240	0.855	0.073	2	44.184
S($_{NON}$)	48.260	0.874	0.072	2	44.203
S($_{INTER}$)	48.411	1.025	0.067	2	44.354
S($_{lg\_EDGE+lg\_LATE}$)	48.463	1.078	0.065	3	42.350
S($_{lg\_EDGE+lg\_INTER}$)	48.567	1.181	0.062	3	42.453
S($_{lg\_MPS\_L}$)	48.684	1.299	0.058	2	44.628
S($_{PERIM\_L}$)	49.340	1.955	0.042	2	45.284
S(.)	49.561	2.175	0.038	1	47.542
S($_{EDGE+LATE}$)	49.591	2.205	0.037	3	43.478
S($_{winter+year}$)	49.970	2.584	0.031	3	43.856
S($_{winter}$)	50.202	2.817	0.027	2	46.146
S($_{a*S}$))	50.571	3.185	0.023	4	42.381
S($_{a}$)	50.669	3.284	0.022	2	46.613
S(s)	51.100	3.714	0.017	2	47.044
S(T)	51.423	4.038	0.015	2	47.367
S($_{mcq\_TCA\_L}$)	51.442	4.056	0.015	2	47.385
S($_{BAOW}$)	51.596	4.210	0.014	2	47.540
S(a+s)	52.382	4.996	0.009	3	46.268
S(TT)	52.959	5.574	0.007	3	46.846
S(t)	88.991	41.606	0.000	25	32.149
S(a+t)	90.915	43.529	0.000	26	31.486
S(s+t)	91.026	43.640	0.000	26	31.597
S(a*s+t)	92.323	44.937	0.000	28	27.638
S(a+s+t)	93.022	45.636	0.000	27	30.979
S(a*t)	93.529	46.143	0.000	27	31.486
S(a*s*t)	393.70	346.316	0.000	100	18.049

Survival was not influenced by time, area, sex, season, or barred owls or any of the other habitat covariates since they were not within 2 AIC_c values of the best model (Table 2.6), and the 95% confidence interval on the coefficients for each covariate overlapped zero (Appendix B).
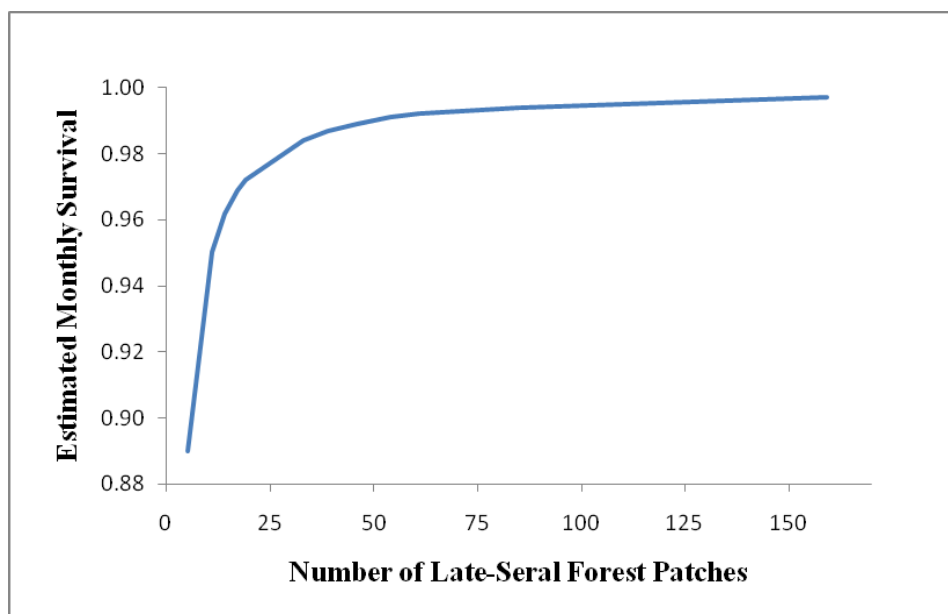
Figure 2.4. Predicted monthly survival estimates from the top model, $S_{(lg\_NUMP\_L)}$ plotted against the number of late-seral forest patches within individual northern spotted owl home ranges.

DISCUSSION

Occupancy and Reproduction

The general decline in occupancy rates I observed in the Ashland Watershed since 1993 were consistent with occupancy rates for the southern Oregon Cascades study area during the same time period, (Figure 2.2; Anthony et al. 2008). Reproductive rates for the Ashland area alternated yearly between high and low estimates and mirrored rates for the southern Cascades, except for 1997 and 2005, when

large disparities between the two study areas were observed (Figure 2.3). The number of sites surveyed in 1997 (n =3) was significantly less than the mean number surveyed for all other years ($\bar{x}$ = 16), and this reduction in sampling effort likely led to biased estimates of reproduction. The difference in reproduction between study areas in 2005 cannot be as easily explained and is in contrast to the cycle of higher reproduction in even years and lower reproduction in odd years (Figure 2.3). The Ashland Study area is smaller and therefore more likely affected by localized fluctuations in prey base and storm events. Weather (Wagner et al. 1996, Franklin et al. 2000, Olson et al. 2004) and average abundance of prey (Ward et al. 1998, Franklin et al. 1999, Rosenberg et al. 2003) were both influential factors in reproductive success of northern spotted owls in other studies. Both the southern Cascades and Siskiyou Mountains experienced a severe drought during the winter of 2004 - 2005 as accumulated precipitation reached record lows for both study areas. Summer precipitation amounts were also similar between study areas. Estimated prey abundances were not available for either study area, so I can only speculate that abundance of prey in the Ashland watershed and surrounding area may have led to a higher reproduction for that year. Mean reproduction estimates for this study ($\bar{x}$ = 0.394, SE = 0.16) were comparable with rates from the Tyee ($\bar{x}$ = 0.319, SE = 0.040) and south Cascades ($\bar{x}$ = 0.377, SE = 0.059; Anthony et al. 2006), and Timbered Rock ($\bar{x}$ = 0.420, SE = 0.155; Clark 2007) demography areas in southwestern Oregon.

Survival

Monthly survival rates ranged from 0.89 - 1, depending on the number of patches of late-seral forest within the owls' annual home range and these rates were comparable to those of northern spotted owls in unburned forest in the South Cascades (Clark 2007). Although monthly survival of spotted owls was not associated with the percentage or amount of late-seral forest within the home range of individuals, survival was positively correlated with the configuration or arrangement of late-seral forest habitat ($S_{lg\_NUMP\_L}$; Figure 2.4), which is consistent with my first hypothesis. Survival was lowest (0.89) when the number of late-seral forest patches was only 5 and sharply increased with the addition of late-seral patches, then leveled off around 33 patches (Figure 2.4). This top model suggested that home ranges that contained more patches of late-seral forest had the strongest effects on monthly survival and that a survival threshold was reached once late-seral forest patches increased to a certain minimum level.

It should be noted that while consistent with previous work (Clark 2007), monthly survival rates were quite low for owls with few older forest patches and these low monthly rates could result in very low annual survival. Our sample sizes were relatively small (although we followed birds for long periods of time), and 33% of my owls died during the study, so these individuals likely had a strong influence on overall monthly survival estimates. It is also possible that radios predisposed owls to predation or contributed to lower survival. The negative effects of radios on owls has not been reported previously (Foster et al. 1992), but this is an issue that should be researched.
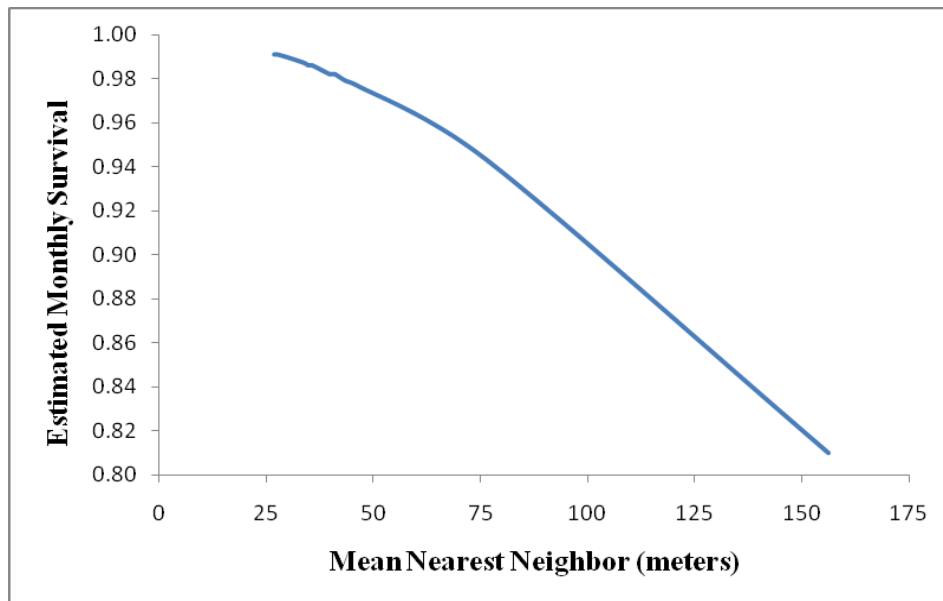
Figure 2.5. Predicted monthly survival estimates for the second best model, $S_{(lg\_MNN\_L)}$ plotted against mean nearest neighbor distances between late-seral forest patches within individual northern spotted owl home ranges.

The next competitive model included the log of the mean nearest neighbor distance between late-seral forest patches ($S_{lg\_MNN\_L}$). Both these two models indicate a relationship between monthly survival and late-seral forest fragmentation. Several non-telemetry studies have attempted to relate annual survival to fragmentation, but none have found any significant effects of these metrics (Olson et al. 2005, Dugger et al. 2005). Franklin and Guitierrez (2002) suggested a better understanding of the effects of forest fragmentation and heterogeneity on spotted owl life history traits was needed, and they emphasized that fragmentation and habitat loss can have different effects when considered separately. They also noted the potential to discover critical thresholds of habitat fragmentation in relation to demographic parameters including survival. While thresholds have been determined for quantity of late-seral forest as it

relates to spotted owl demographics (Lande 1988, Bart and Forsman 1992, Gutierrez 1994), they have not been related to forest configuration. The amount of late-seral forest near the core of spotted owl territories influenced the annual survival of spotted owls in southern Oregon (Olson et al. 2004, Dugger et al. 2005), but did not strongly influence monthly survival rates at the home range scale in my study. Sample size of this study was relatively small (n = 15), so I may have lacked the statistical power to find any existing associations between survival and the amount of late-seral forest. In addition, I did not look at habitat proportions at the core scale, and the mean percentage of late-seral forest within individual home ranges in my study was 71.68%, which is quite high, while the percent of non-habitat was only 8.02 (appendix A). Thus, the high percentage of late-seral forest at the larger scale of owl territory (i.e., generally small amount of variability) could explain the lack of relationship between late-seral forest and montly survival. Planned selective timber harvest projects might alter the age and structure composition and reduce the overall amounts of late-seral forest within the study area, thereby increasing the amount of intermediate forest and non-habitat (USDA 2008) and possibly fragment the existing older forest patches on the landscape. Therefore, I predict stronger relationships between survival and the quantity and configuration of late-seral forest at the home range scale after the proposed treatments.

There were weak effects of edge on survival in this study (β = 2.39, SE = 1.27, 95% C.I. = -0.09 to 4.88), which has not been reported previously for southwestern Oregon (Dugger et al. 2005, Clark 2007). However, a preference for the use of habitats closer to edge was noted in two other studies (Zabel 1995, Clark 2007). Survival of

raptors is often correlated with prey abundance (Southern 1970, Newton 1979, Steenhof et al. 1997). Although there is a lack of current information for my study area on both composition of prey remains in spotted owl pellets and abundances of small mammals, wood rats are believed to be abundant in the study area (Service 1996) and likely comprise a majority of owl diets (Zabel et al. 1995). Other studies of spotted owl diets in the interior southwest of Oregon have revealed the spotted owls' strong selection for wood rats (Forsman et al. 2004, Clark 2007), an edge associated species (Zabel et al. 1995). It has been hypothesized for foraging owls in the Siskiyou Mountains that the energetic benefit of denser wood rat populations along or near forest edges outweighs the negative aspects of foraging along these edges, such as increased exposure to predators (Zabel et al. 1995). My study suggests weak support for this hypothesis, consistent with Franklin et al. (2000) in the Klamath Mountains, but in contrast with Dugger et al. (2005) that found no relationship between annual apparent survival and the amount of edge.

While spotted owl detection rates (Olson et al. 2005), occupancy (Kelly et al. 2003, Olson et al. 2005) and reproductive success (Olson et al. 2004, Anthony et al. 2006) have all been negatively associated with the detection of barred owls adjacent to spotted owl territories, I found no influence of barred owls on spotted owl survival. It is difficult to link spotted owl detections during the breeding season to monthly survival rates throughout the year, so it's likely our barred owl covariate did not occur on a fine enough scale to model monthly survival.

CHAPTER 3

HOME RANGE AND HABITAT SELECTION OF NORTHERN SPOTTED
OWLS IN THE SISKIYOU MOUNTAINS

Jason W. Schilling

INTRODUCTION

The home range and habitat selection of spotted owls in the Pacific Northwest has been reasonably well documented, and considerable differences in home range size has been reported within and among regions (Carey et al. 1990, Glenn et al. 2004, Hamer et al. 2007). These differences have been attributed to factors such as amount of edge (Clark 2007), prey abundance and distribution (Carey et al. 1992, Zabel et al, 1995), and the amount of old forest available for foraging and roosting (Carey et al. 1990, Glenn et al. 2004). In most studies, northern spotted owls have consistently selected the oldest and most structurally diverse forest for foraging and nesting (Forsman et al. 1984a, Carey et al. 1990, Forsman et al. 2005, Hamer et al. 2007). However, home range size was inversely related to the number of old conifer stands in a given owl site in the northern Oregon coast range (Glenn et al. 2004), and owls were observed to select for hardwood forest more than any other forest cover type when old conifer stands were not readily available within their home ranges. (Glenn et al. 2004). Core areas for owls are usually centered on a nest tree or site center and have generally been reported to have higher amounts of old and mature forest than available sites (Hunter et al. 1995, LaHaye and Gutiérrez 1999, Franklin et al. 2000))

Information on habitat selection and home range size of spotted owls in the fire-prone forests of southwestern Oregon is more limited than other regions within the owls' range (Wagner and Anthony 1999, Clark 2007). A recent post-fire telemetry study revealed that owl home ranges of resident spotted owls expanded by an average of 246 ha after wildfire (Clark 2007). Canopy characteristics were important to habitat

selection, and owl use increased as the primary canopy became more structurally advanced and mature in southwest Oregon (Wagner and Anthony 1999).

The Ashland Forest Resiliency Project (AFR), a project authorized under the Healthy Forest Initiative (HFI) and National Fire Plan Pilot Project, proposes the use of selective timber harvest and prescribed burning in the Ashland Watershed to create stand structures that are similar to those produced by historic fire regimes. The goal of these efforts is to reduce fuel loadings and fire hazard in a manner that would promote canopy gaps, structural complexity, species diversity, and forest structures that resemble natural conditions (U. S. Forest Service 2005). Natural disturbance and prescribed fire are the expected tools for maintaining stand structures after the risk of large-scale, high-severity wildfire decreases.

Few studies have investigated the effects of selective timber harvest on home-range and habitat selection patterns of spotted owls, but a case study from the Northern Oregon Coast Range suggested that home range was slightly larger after management than before (Meiman et al. 2003), and there was little use of the forest after the selective harvest. Selective harvest management that changes habitat quality by removing structural complexity and legacy trees could increase the size of territories needed for owls to successfully survive and reproduce. However, it is also possible that selective harvest operations that are designed to maintain the structural qualities important for owls could have positive effects on site occupancy and home range size. The Final Spotted Owl Recovery Plan advocates strategic landscape-level treatments to reduce the risk of large-scale habitat loss to high-severity wildfire for the eastern Cascades and

Klamath Provinces of the owl's range (U. S. Fish and Wildlife Service 2008).

However, it is currently unclear what short- or long-term effects these treatments will

have on northern spotted owl populations. Thus, there is a need for larger scale studies

as more fire-reduction treatments such as selective timber harvest are being proposed

across the fire-prone regions of the northern spotted owls' range.

The AFR Project presents a unique opportunity to study the effects of fire

hazard and fuels reduction projects on spotted owls and the habitats they utilize. Little

is known about the ability of owls to meet their habitat and food requirements and

reproduce in managed landscapes, so understanding the effects of these treatments on

the home range size and habitat selection of spotted owls is badly needed.

I collected home range and habitat selection data on a sample of radio-marked

spotted owls on the Ashland Watershed in the Siskiyou Mountains of southwestern

Oregon. These data constitute "pre-treatment data" collected prior to a large-scale

selective timber harvest project (U. S. Forest Service 2005) currently being

implemented in the Ashland Watershed beginning summer 2009. My data will serve as

the pre-treatment sample that will ultimately be compared to a post-treatment sample

collected after fuels treatments are complete. The data gathered from this project will

assist land managers in implementing fuels management strategies that are consistent

with historic fire disturbance regimes and spotted owl habitat requirements.

My objective was to describe habitat selection and home range size of northern

spotted owls in the Klamath region and to determine if their home ranges and habitat

selection differed from studies conducted elsewhere in Oregon and Washington. I

predicted that northern spotted owl home range size would (1) be smaller than estimates from the northern range of the subspecies and comparable to other areas in southern Oregon and northern California, (2) be negatively correlated with the amounts of old and intermediate forest within the individual home range, (3) be positively related to the amount of edge between suitable and unsuitable habitat and total core area of old forest, and that (4) owls would select for old and intermediate forest types more than available on the landscape, and (5) owls would select habitats that were closer to forest edges and perennial streams.

METHODS

Study Area

The Ashland Forest Resiliency Project is centered on the City of Ashland Municipal Watershed, Jackson County, Oregon (Figure 3.1). The Ashland Creek sub-watershed is approximately 6,388 ha and one of the primary tributaries to Bear Creek. It is bordered by Mount Ashland to the south, the city of Ashland to the North, and the Neil Creek sub-watershed to the East. Beyond its western edge lies the Little Applegate watershed. The Ashland Watershed is located primarily on the Ashland Ranger District of the Rogue River-Siskiyou National Forest, with small blocks of private and City of Ashland ownership interspersed (U. S. Department of Agriculture 2005)

The study area was within the Siskiyou Range of the Klamath Mountains and the Mixed-Conifer and Shasta Red Fir (*Abies magnifica* var *shastensis*) vegetation zones (Franklin and Dyrness 1973). Among North American ecoregions, the Klamath Mountains equal only the southern Appalachians in terms of floristic diversity and

concentrations of 'narrowly endemic' species (Whittaker 1960) . The most common tree species were ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), incense cedar (*Calocedrus decurrens*), white fir (*Abies concolor*), Shasta red fir, Oregon white oak (*Quercus garryana*), California black oak (*Quercus kellogii*), and Pacific madrone (*Arbutus menziesii*).

Management practices within the Ashland watershed were limited to small-scale timber harvest and other forms of vegetation modifications that benefited the management of the municipal watershed (U. S. Forest Service 2005). Fires were the most common forms of disturbance in red fir forests, occurring at short intervals (Agee 1993), with lightning as the main source of ignition. Mixed-conifer forests occur in geographic areas characterized by hot, dry summers and mild, wet winters, and they also burn on short intervals (50 years) at low to moderate severity (Agee 1993). A pronounced rain shadow existed from the Oregon coast to the Ashland watershed and resulted in precipitation ranging from 25 - 89 cm annually, increasing with elevation (U. S. Forest Service 2005). Elevations within the study area ranged from 760 – 1,830 m. The topography was characterized by moderate to steep (20 - 70 percent) slopes that were highly dissected and characterized by high rates of erosion (U. S. Forest Service 2005).

Figure 2.1. Location of the Ashland Watershed in southwestern Oregon.

The project area was located within the Mt. Ashland Late Successional Reserve

(LSR) and contained over 3,600 ha of mature and late-successional forest (U. S. Forest

Service 2005). Limited management within the watershed resulted in contiguous and

less fragmented blocks of late-seral forests than other areas of the Mt. Ashland LSR (U.

S. Forest Service 2005). My study focused on spotted owl territories within the

boundaries of the Ashland Forest Resiliency Project, as well as the Little Applegate

River, Neil Creek, and upper Wagner Creek sub-watersheds.

Radiotelemetry

Owls were captured from September 2006 through September 2008 and fitted

with a 5g backpack mounted radio transmitter (Holohil Systems Ltd. Model RI-2C)

with an expected life span of 12 months. All owls within the Ashland, Neil Creek, and

Upper Little Applegate Watersheds that occupied territories convenient for radio-

telemetry were radio-marked. Owls were relocated using a directional yagi antennae

and a Telonics model TR-2 receiver (Telonics, Inc., Mesa, Arizona, USA) or a

Communication Specialists model R-1000 receiver (Communication Specialists, Inc.,

Orange, California, USA). Owls were monitored for approximately 12 months unless

the bird died or left the study area. The location and fate of each owl was determined

approximately every other night for nocturnal locations and once per week for diurnal

roost locations.

Locations were determined for 12 months to obtain a total of approximately 75

nighttime locations and 25 daytime locations for each owl. Owl locations were

determined by taking a compass bearing on the strongest signal from at least 3 different

stations during the shortest possible time interval (maximum = 1 hour). Receiving

stations were accessed by 4-wheel drive truck, snowmobile, skis, or on foot. Receiving

stations were marked and their locations fixed with known Universal Transverse

Mercator (UTM) coordinates using a Global Positioning System (GPS) unit capable of

5 - 10 m accuracy (Garmin Inc., Olathe, KS, USA). Telemetry bearings were entered

into a modified version of the XYLOG program (Dodge and Steiner 1986) to calculate a

95% confidence ellipse for each location based on the standard deviation of the bearing

intercepts around a mean location. Locations with an ellipse ≤ 2.0 ha were used in the

analysis. I assessed location error by comparing estimated telemetry locations at

daytime roosts with actual locations determined by locating the owls in their roosts. The

mean difference between estimated and actual locations was 105 m (SE = 10.95, n = 57,

range = 8.4 – 266.3 m), which is comparable to previous research on spotted owls

(Carey et al. 1992 = 68m, Zabel et al. 1995 = 111m, Glenn et al. 2004 = 164m, Clark

2007 = 136m).

Habitat Classification

For my analysis of home range and habitat selection, I used an ArcGIS (ESRI,

Redlands, CA, USA) map layer created by Geographic Resource Solutions (GRS; Hill

1996), which used Landsat Thematic Mapper (TM) data acquired August, 1993, and

described canopy closure (%), average tree diameter at breast height (dbh), and

dominant vegetation type for each 25 m^2 pixel. The accuracy of this satellite based map

was 86, 92, and 88 % for canopy closure, average DBH, and cover type, respectively

(Hill 1996). I reclassified the GRS vegetation layer into 7 cover types for the habitat

selection analysis, but then further combined these classes into 3, more general

classifications (late-seral forest, intermediate-aged forest, and non-habitat) used to

investigate home range size (Table 3.1). Factors affecting habitat selection of owls,

such as understory structural quality associated with late-seral forest (Solis and

Gutierrez 1990, North et al. 1999, Irwin et al. 2000), are fine in scale. In contrast,

factors affecting home range sizes are coarser in scale, such as the aggregation of late-seral habitats on the landscape (Carey et al. 1990, Forsman et al. 2005, Hamer et al. 2007) . Young and pole cover types were combined because the young forest category comprised a very small percentage of available habitats within the study area.   For the same reason sapling, early seral, and non-forest categories were combined into a non-habitat cover type. These habitat classes were based on the system developed by Wagner and Anthony (1999) for habitat selection by spotted owls in southwestern Oregon.

Fragmentation metrics identified as important to the ecology of spotted owls (Franklin and Gutiérrez 2002) were derived from the map layers using FRAGSTATS (McGarigal and Marks 1995) and included total core area of late-seral forest (TCA_L), mean patch size of old forest (MPS_L), number of late-seral patches (NUMP_L), mean nearest neighbor of old forest (MNN_L), and amount of edge in meters (EDGE; Table 3.1). Edge was defined as the interface between suitable (intermediate and late forest types) and non-habitat habitat. I classified intermediate-aged forest types as "suitable" habitat because previous research in southwestern Oregon indicated that owls used these forest types in proportion to availability (Wagner and Anthony 1999).

Home Range Analysis

I used the program KERNELHR (Seaman et al. 1998) to estimate 95% fixed kernel home ranges for the, breeding season (1 March - 31 August), non-breeding season (1 September - 28 February), and annual periods. KERNELHR estimates densities using nonparametric kernel smoothing methods, which have less sample-size

bias than harmonic mean or minimum convex polygon methods (Worton 1989). Within each owl's home range, I estimated core use areas by using the greater than average observation density contour generated by KERNELHR.

All habitat covariates were generated from the individual 95% contour of the fixed kernel home range estimated by KERNELHR (Seaman et al. 1998) using ArcGIS 9.2 (Appendix A). Home range size was modeled using three functional relationships for each habitat variable: linear, pseudo-threshold, and mean-centered quadratic. Variables were transformed appropriately for each structural model and used in my modeling procedure.

I used mixed model multiple regression analysis in SAS (PROC MIXED; SAS 2009) to evaluate factors that may influence home-range and core use area size of individual owls based on a set of a *priori* models that included sex, season, and habitat covariates (Table 3.2). An information theoretic approach was used to select the best models and most important effects on home range size (Burnham and Anderson 2002). Models were ranked according to AIC_c adjusted for small sample size and AIC_c weights, and the model with the lowest AIC_c and highest AIC_c weights was generally considered the "best" model (Burnham and Anderson 2002). All models having an AIC_c value within 2.0 of the top model were considered competitive, and 95% confidence intervals on slope coefficients were used to determine the strength of specific effects. I made specific predictions regarding the affects of different habitat covariates on home range size (Table 3.2), so the direction and strength of effects was also evaluated. My final model set included 3 functional forms for each of my habitat

variables (linear pseudo-threshold, quadratic), but only the best of these structures for each covariate were retained in the final model selection results.

Habitat selection Analysis

I used logistic regression in SAS (PROC LOGISTIC; SAS 2009) to compare telemetry locations (used) to random (available) locations within home ranges of individual owls. To estimate the availability of cover types to owls, I generated 700 random locations within the 99% fixed kernel home range for each owl. I used the mean telemetry error to draw 105 m circular buffers around each used and available location in ArcMap. Percentages of 7 habitat classes were calculated within each buffer and were used as habitat covariates in the modeling process (Table 3.1). This resulted in habitat being modeled as a continuous covariate rather than a categorical. Buffers were used instead of estimated owl locations because telemetry locations were not precise enough to be represented as points. The mean error for telemetry locations (105 m) exceeded the pixel size (25 m^2) When this occurs, the likelihood of miscalculating the habitat used is great (Rettie and McLoughlin 1999), so the buffers are intended to account for telemetry error that may inaccurately describe habitat use.

Table 3.1 Acronyms and descriptions of habitat cover types and fragmentation metrics used to model home range estimates and habitat selection for northern spotted owls in the Siskiyou Mountains in southern Oregon from October 2006 - October 2008. All covariates are values generated within the 95% and 99% fixed kernel home range area for home range, and habitat use, respectively.

Variable	Description	Unit
LATE (LATE)	combined proportion of the following two subclasses:	%
Old (OLD)	Conifer dominated stands having total canopy closure $\geq$ 40% and DBH $\geq$ 75 cm	
Mature (MAT)	Conifer dominated stands having total canopy closure $\geq$ 40% and DBH 50.8-74.9	
Intermediate (INTER)	combined proportion of the following two subclasses:	%
Pole/Young (YG)	Conifer stands with total canopy closure $\geq$ 40% and DBH 12.7 - 50.7 cm	
Hardwood (HARD)	Stands dominated by upland and riparian hardwoods or mixed hardwood and conifer stands with total canopy closure $\geq$ 40%	
Non-Habitat (NON)	combined proportion of the following three subclasses:	%
Sapling[a]	Conifer, mixed, or hardwood stands with canopy closure $\geq$ 40 % and DBH 5 - 12.6 cm	
Early-Seral[a]	Regenerating forest land dominated by herbaceous vegetation and shrubs with $\leq$ 40% canopy closure.	
Non-forest[a]	Areas not capable of producing a stand of trees $\geq$ 40% canopy closure. Includes barren ground, water, and grass/forbs	
Landscape-level metrics		
NUMP_L	Number of patches of LATE forest	#
MPS_L	Mean patch size of LATE forest in hectares	ha
EDGE	meters of edge between suitable habitat (intermediate and LATE forest) and non-habitat	m
MNN_L	Mean nearest neighbor. The average of the shortest distances (edge to edge in meters) between LATE-seral patches	m
PERIM_L	Perimeter Density. Meters of perimeter of old-conifer forest patches divided by hectares of LATE conifer forest	m/ha
TCA_L	Total Core Area. Total hectares of LATE forest core area with a 100 meter buffer	ha
Abiotic Variables[b]		
DIST_L	linear distance to nest or cite center	m
DIST_P	third order polynomial (distance + distance2 + distance3) distance to nest or cite center	m
d _EDGE	Distance to the nearest interface between suitable and non-habitat habitat	m
d_STR	Distance to the nearest stream	m

[a] Not used as a separate covariate. Combined with other non-habitat categories to model home range and habitat selection
[b] Covariates used to model habitat selection only

Table 3.2. Model structure and predictions for habitat covariates used for home range size (HR) analysis of northern spotted owls in the Siskiyou Mountains of southern Oregon from October 2006 - October 2008. Acronyms for all covariates are described in table 3.1.

Model	Linear	Pseudothreshold	Quadratic
HR_{LATE}	$\beta_{LATE}<0$	$\beta_{lg\_LATE}<0$	$\beta_{lg\_LATE}<0, \beta_{(LATE)}^2>0$
HR_{INTER}	$B_{INTER}<0$	$\beta_{lg\_INTER}<0$	$\beta_{lg\_INTER}<0, \beta_{(INTER)}^2>0$
HR_{NON}	$B_{NON}>0$	$\beta_{lg\_NON}>0$	
HR_{NUMP_L}	$\beta_{NUMP\_L}<0$	$\beta_{lg\_NUMP\_L}<0$	$\beta_{NUMP\_L}<0\ \beta_{(NUMP\_L)}^2>0$
HR_{MPS_L}	$\beta_{MPS\_L}<0$	$\beta_{lg\_MPS\_L}<0$	$\beta_{MPS\_L}<0, \beta_{(MPS\_L)}^2>0$
HR_{EDGE}	$\beta_{EDGE}>0$	$\beta_{lg\_EDGE}>0$	$\beta_{EDGE}>0, \beta_{(EDGE)}^2<0$
HR_{MNN_L}	$\beta_{MNN\_L}>0$	$\beta_{lg\_MNN\_L}>0$	
HR_{PERIM_L}	$\beta_{PERIM\_L}>0$	$\beta_{lg\_PERIM\_L}<0$	
HR_{TCA_L}	$\beta_{TCA\_L}<0$	$\beta_{lg\_TCA\_L}<0$	
$HR_{LATE+EDGE}$	$\beta_{LATE}<0$	$\beta_{lg\_LATE}<0$	$\beta_{LATE}<0, \beta_{(LATE)}^2>0$
	$\beta_{EDGE}>0$	$\beta_{lg\_EDGE}>0$	$\beta_{EDGE}>0, \beta_{(EDGE)}^2<0$
$HR_{INTER+EDGE}$	$B_{INTER}<0$	$\beta_{lg\_INTER}<0$	$\beta_{INTER}<0, \beta_{(INTER)}^2>0$
	$\beta_{EDGE}>0$	$\beta_{lg\_EDGE}>0$	$\beta_{EDGE}>0, \beta_{(EDGE)}^2<0$

I also calculated the distance from each owl location and random points to the nearest perennial stream and to the nearest edge in meters (Table 3.1). Because owls are central place foragers and use habitats that are closer to the nest or site center, the probability of use was expected to decline as the distance from the nest or site center increased (Rosenberg and McKelvey 1999, Glenn et al. 2004, Clark 2007). Therefore, the distance to the nest or site center was included in all habitat selection models for the breeding and annual time periods. Before modeling general habitat characteristics, I investigated two separate distance functions for each bird; a linear and a third order polynomial to account for non-linear trends. The best distance covariate was retained and incorporated into the model set including habitat covariates for each individual owl.

A set of *a priori* models (Table 3.3), based on habitat features and abiotic factors, was developed and used to compare owl locations with random locations. I used an information theoretic approach to rank models (Burnham and Anderson 2002) as previously described for the home range analysis. All models having values within 2 AIC_c of the top model were considered competitive, and 95% confidence intervals on slope coefficients were used to determine the strength of specific effects. The maximum generalized R^2, which is a generalization of the conventional R^2 statistic was used to measure predictive power of each model (Allison 1999). I could not hypothesize *a priori* which habitat covariates and which abiotic covariates would have the strongest support and might best be combined in multi-factor models. Consequently, I combined *a posteriori* the best abiotic model within 2 AIC_c values of the top model with the top two single habitat models within 2 AIC_c values of the best model for each owl. Only covariates that were not correlated (r<0.60) were combined in the same models together.

Table 3.3: The *a priori* model set generated for the habitat selection (HS) analysis of northern spotted owls in the Siskiyou Mountains of southern Oregon from October 2006 - October 2008. All models below included best distance covariate for each owl (DIST_P, DIST_L). Intercept-only model (no covariates) and a model with the best distance covariate only, were also included. Acronyms for all covariates are described in Table 3.1.

Model	Prediction
HS $_{OLD}$	$\beta_{OLD} > 0$
HS $_{MAT}$	$\beta_{MAT} > 0$
HS $_{LATE}$	$\beta_{LATE} > 0$
HS $_{HARD}$	$\beta_{HARD} > 0$
HS $_{YG}$	$\beta_{YG} > 0$
HS $_{INTER}$	$\beta_{INTER} > 0$
HS $_{NON}$	$\beta_{NON} < 0$
HS $_{LATE*DIST\_L}$	$\beta_{LATE} > 0$, $\beta_{DIST\_L} < 0$, $\beta_{LATE*DIST\_L} > 0$
HS $_{INTER*DIST\_L}$	$\beta_{INTER} > 0$, $\beta_{DIST\_L} < 0$, $\beta_{INTER*DIST\_L} > 0$
HS $_{d\_EDGE}$	$\beta_{d\_EDGE} > 0$
HS $_{STR}$	$\beta_{d\_STR} > 0$
HS $_{d\_EDGE + d\_STR}$	$\beta_{d\_EDGE} > 0$, $\beta_{d\_STR} > 0$
HS[a]	

[a] intercept only model

RESULTS

I tracked seven pairs of owls in seven territories for various lengths of time from September 2006 to November 2008 (Figure 3.2). Of the 7 pairs, 3 successfully nested during the 2007 breeding season. On average, owls were tracked for 262 days (Figure 3.2), and I averaged 76 annual re-locations per owl. Eleven owls were included in the annual analysis for both home range and habitat selection. Thirteen and 12 owls were included in the breeding and non-breeding season analyses of home range size and habitat selection, respectively.
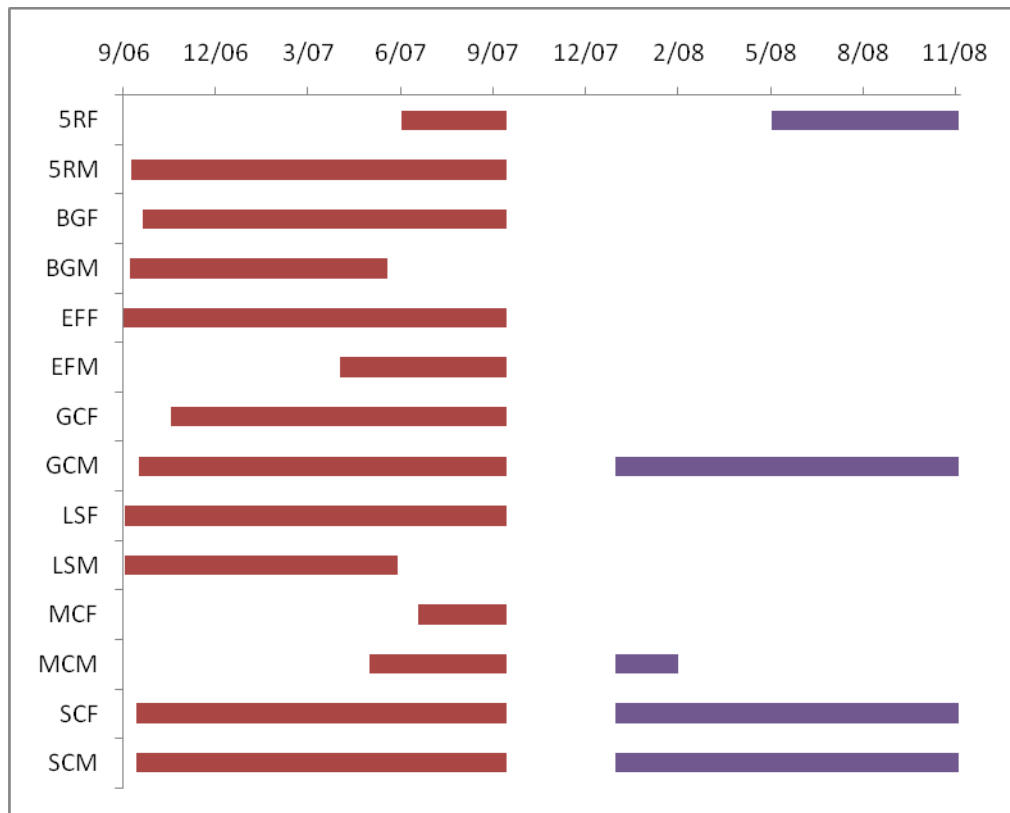
Figure 3.2. Timeline of radio-telemetry tracking for 14 northern spotted owls in the Ashland watershed and surrounding area from September 2006 to November 2008.

Annual Home Ranges

The mean annual home range size for all individual owls was 576 ha but there was considerable variability among individuals (n = 11, SE = 75, range = 192 – 894, 95% CI = 429.10 – 722.90; Table 3.4). Annual home ranges were on average 120 ha larger for males (n = 6, $\bar{x}$ = 630, range = 376 – 892, 95% CI = 465.93 – 794.60) than for females (n = 5, $\bar{x}$ = 511, range = 192 – 894, 95% CI = 267.16 – 755.55).

Table 3.4. Annual, breeding, and non-breeding season 95% fixed kernel home range estimates (ha) and core area estimates for northern spotted owls tracked with radio-telemetry in the Oregon Siskiyou Mountains from September 2006 - November 2008.

Owl	Annual	Breeding	Non-Breeding	Core
500 Road Female	779	589	665	115
500 Road Male	728	516	693	96
Bull Gap Female	894	1517	478	125
Bull Gap Male	892	794	838	92
East Fork Female	192	279	187	20
East Fork Male	-	342	-	-
Greeley Creek Female	-	-	158	-
Greeley Creek Male	376	593	330	33
Lighting Strike Female	428	367	380	71
Lightning Strike Male	397	390	311	53
McDonald Creek Female	-	96	-	-
McDonald Creek Male	849	459	675	125
Sheep Creek Female	264	138	397	36
Sheep Creek Male	540	298	522	81
Mean	576	491	469	94
Range	192 - 894	279 - 1517	158 - 838	20 – 125
S. E.	74.95	96.59	59.12	10.84
95% CI	429.10 - 722.90	301.38 - 679.98	353.53 – 585.30	55.74 – 98.23

Differences in annual home range size were best described by a model that included a pseudo-threshold effect of edge (lg_EDGE) and a pseudo-threshold effect of the amount of intermediate habitat (lg_INTER; Table 3.5). Home range size increased in relation to increased amounts of edge up to a point, then leveled off ($\beta = 655.90$, SE $= 72.78$, C.I. $= 493.43 – 818.37$; Figure 3.3 a). In addition, home range size decreased

with increased amounts of intermediate forest, again to a threshold beyond which home

range size did not decrease any farther (β = -414.87, SE = 145.66, C.I. = -749.32 to -

86.36; Figure 3.3 b). Competitive models supported the importance of edge habitat on

annual home range size (β = 545.25, SE = 82.95, C.I. = 361.33 – 729.17).

Table 3.5 Best models from analyses of annual and seasonal home range sizeof northern
spotted owls in the Siskiyou Mountains of southern Oregon, 2006--2008. Best models
for annual estimates were based on analyses at the home range scale (95% FK) and the
core area scale (greater than average observation density contour).

Season	Model	AIC_c[a]	ΔAIC_c[b]	w_i[c]	Model Likelihood[d]
Annual	lg_EDGE + lg_INTER	141.97	0.00	0.59	1.00
	lg_EDGE	142.83	0.86	0.39	0.65
Breeding	LATE +EDGE	163.21	0.00	0.92	1.00
Non-breeding	EDGE	152.90	0.00	0.85	1.00
Core Area	lg_EDGE	103.33	0.00	0.87	1.00

[a] Akaike's information criteria
[b] Difference between model AIC_c and lowest AIC_c in the model set.
[c] Akaike weights.
[d] the exponentiated multiplication of the ΔAIC and -0.5

Seasonal Home Ranges

Mean home range size was very similar between the breeding and non-breeding

season (Table 3.4). The mean breeding season home range size was 491 ha (n = 13, SE

= 97, Range = 279 - 1516, 95% CI = 301.38 – 679.98) and was larger than mean non-

breeding season home ranges (n = 12, $\bar{x}$ = 469, SE = 59, Range = 158 – 838, 95% CI =

353.53 – 585.30), however 95% confidence limits overlapped extensively, so

differences were not significant and this result can be attributed to influence of the large

home range of the Bull Gap Female, whose

a).
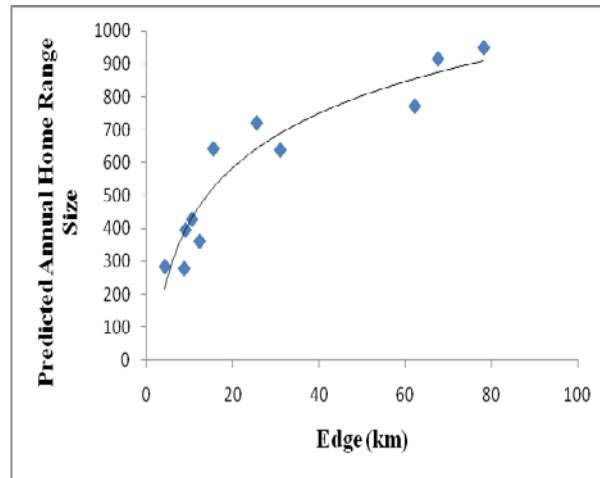
b).
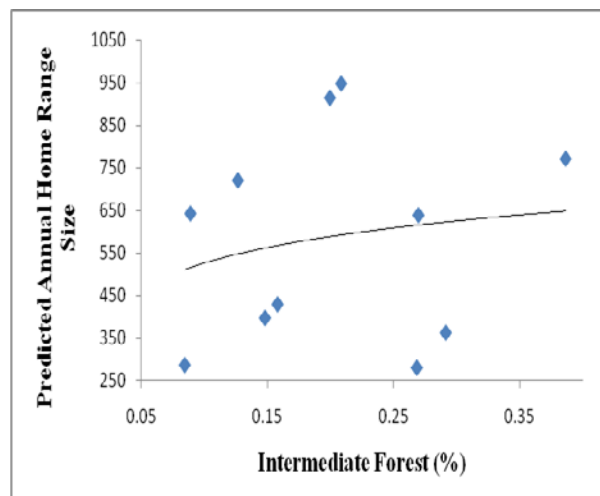
Figure 3.3. Annual home range size estimates from the best model (HR $_{\text{lg\_EDGE}}$ + $_{\text{lg\_INTER}}$) plotted against the amount of a) edge and b) intermediate habitat for 11 northern spotted owls from 2006 - 2008 in the Siskiyou mountains of Oregon.

breeding home range was three times her non-breeding home range size and was

unusually large (1516 ha) when compared to the mean of the breeding seasons ($\bar{x} =$

491). The Greeley Creek Male also had a significantly larger (80%) home range during

the breeding season than during the non-breeding season.

There was strong support (AICc wt = 0.92) for a single model describing differences in breeding home range sizes (Table 3.5). This model suggested that home range size increased with the addition of edge (β = 12.97, SE = 0.60, C.I. = 11.58 – 14.37; Figure 3.4), and the amount of late forest (β = 1209.84, SE = 259.52, C.I. = 642.70 – 1776.99 Figure 3.4). The relationship between home range size and amount of older forest is contrary to what I predicted.

Similar to annual and breeding season home range size, the best predictor of non-breeding home range size was the amount of edge, and home range size was positively correlated with the amount of edge (β = 9.48, SE = 1.43, C.I. = 6.226 –12.74; Figure 3.5).   There were no other competing models for this season.

Core Areas

Mean size of annual core areas was 94 ha and there was considerable variation in these areas of concentrated use (SE = 11, Range = 20 – 125, 95% CI = 55.74 – 98.23). The best model indicated that core area size was positively correlated with the amount of edge in the core up to a point, where the increases in core area leveled off in response to more edge (β = 11.37, SE = 3.37, C.I. = 3.84 – 18.89; Figure 3.6). This model accounted for a substantial amount of AIC_c weight, and there were no competing models (Table 3.5).

a)
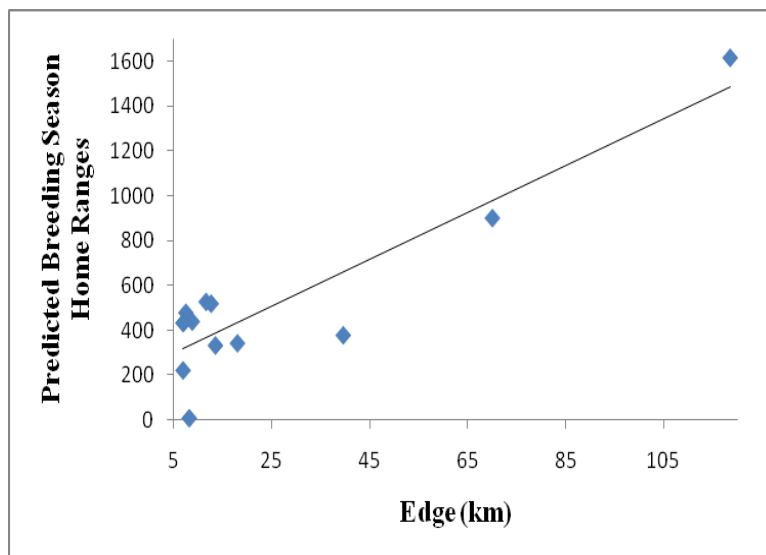
b).
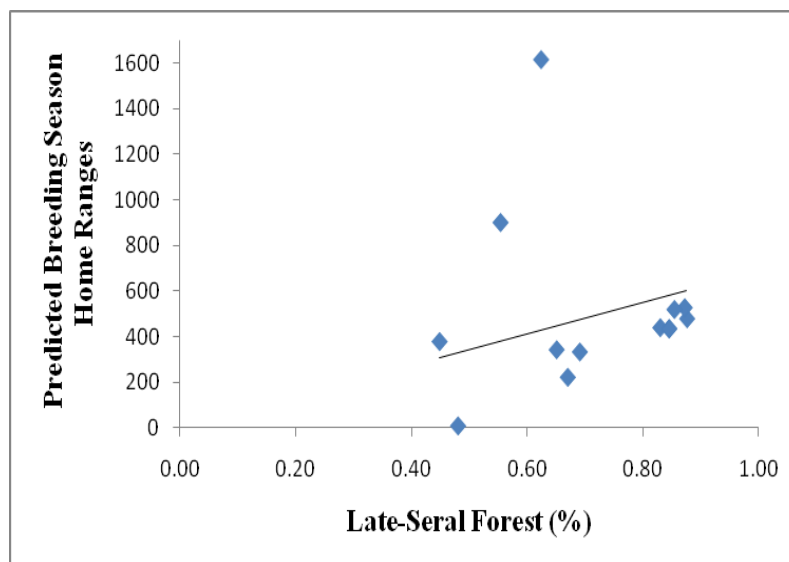
Figure 3.4. Breeding season home range size estimates from the best model (HR$_{LATE}$ $_{+EDGE)}$ plotted against a) the amount of old and mature forest combined and b) edge for 13 northern spotted owls from 2006 - 2008 in the Siskiyou mountains of Oregon.
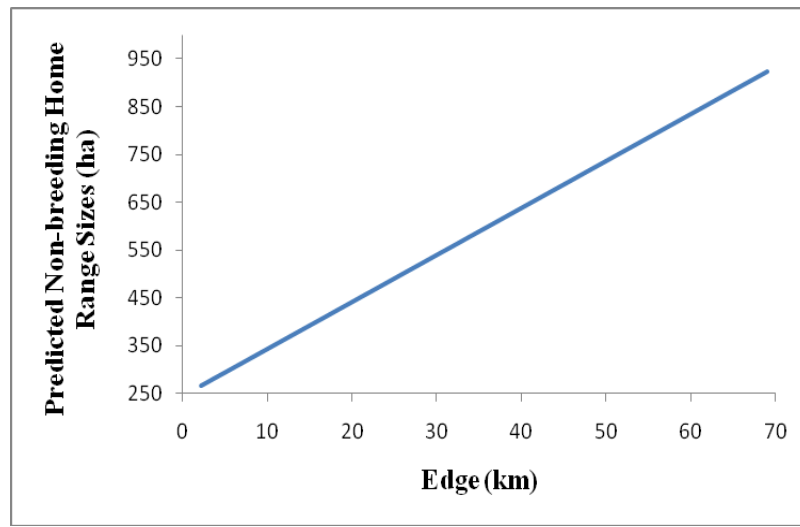
Figure 3.5. Non-breeding season home range size estimates from the top model (HR $_{EDGE}$) plotted against the amount of edge for 12 northern spotted owls from 2006 - 2008 in the Siskiyou mountains of Oregon.
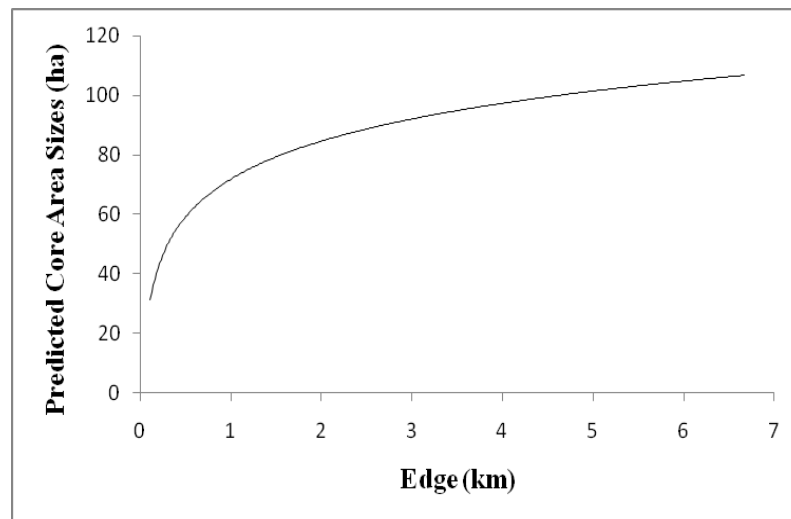
Figure 3.6. Estimates of core area size from the best model (HR$_{lg\_EDGE}$) for 11 northern spotted owls plotted against the amount of edge from 2006 - 2008 in the Siskiyou mountains of Oregon.

Home Range Overlap

I calculated the percentage of territory that an owl shared with its mate. Ranges overlapped more in the breeding season than in the non-breeding season (Table 3.6).

Annually, males did not share as much of their territories with females as females did with males for all seasons. I also calculated overlap of individual owl home ranges with owls occupying neighboring territories. Individual owl ranges overlapped neighboring owl territories an average of 42% (SE = 8.89) in summer, 39% (SE = 9.56) in winter, and 37% (SE = 8.96) annually. In addition, I determined the percentage of overlap between the breeding and non-breeding seasons for 11 owls. Non-breeding season home ranges overlapped breeding season home ranges by 63% (+/- 6%), and breeding season home ranges overlapped non-breeding season home ranges by 63% (+/- 5%).

Table 3.6. Mean percent overlap (SE) of seasonal and annual home ranges of paired northern spotted owls in the Siskiyou Mountains of southern Oregon during 2006 - 2008. Estimates were based on the 95% fixed kernel home ranges.

Breeding	Non-breeding	annual
F/M[a]	F/M	F/M
71.88 (5.08)	72.54 (9.54)	79.05 (7.75)
M/F[b]	M/F	M/F
63.9 (10.93)	54.53 (8.40)	67.76 (8.58)

[a] The mean percentage of female owls' territories that are shared with their mates.
[b] The mean percentage of male owls' territories that are shared with their mates.

Habitat Selection

I collected 545 roosting and foraging locations during the breeding season and 521 locations during the non-breeding season (Appendix C1 – C3). The percentages of each cover type available to each owl, based on the average annual 99% fixed kernel estimate of the home range, were not consistent among territories (Appendix D). Mature forest was the most available cover type, comprising on average 50% of owls' home ranges (SE = 5.6, range = 1.5% - 74.7%) followed by old forest ($\bar{x}$ = 19.5%, SE = 3.8%, range = 9.9% - 54.9%) and pole and young forest ($\bar{x}$ = 19.3, SE = 2.4, range =

7.3 - 32.1)(Appendix D). Hardwood forest was the least common cover type ($\bar{x} =$ 2.4%, SE = 0.46% range = 0.03% - 5.8%) and non-habitat was relatively rare as well (Appendix D).

Habitat selection varied among owls and across seasons (Appendix E1-E3). The most commonly represented distance function in the top models was distance to nest as a third order polynomial function (Appendix E1-E3). This relationship was positive and indicated that owl selection significantly decreased as location distance from the nest increased. The best models describing annual habitat selection varied by sex and season, although there were some generalities (Table 3.7). Models that contained the abiotic covariates distance to stream and distance to edge best explained annual habitat selection for 6 owls. Models that separately contained distance to edge or distance to stream were the second best models for 3 and 5 of the 11 owls, respectively (Table 3.7). Most of the relationships between habitat selection and distance to edge were positive, meaning that owls selected habitat that was further away from edge than randomly selected points. In contrast, owls tended to select locations that were closer to streams than random locations.

For 2 owls, the top models indicated that there was a positive relationship between habitat selection and mature forest stands (Table 3.7). In addition, pole and young forest was negatively associated with habitat selection by one owl, and was negatively, but weakly associated with the selection of one other bird (Table 3.7). Non-habitat was negatively associated with habitat selection of only one owl and all owls

had habitat or abiotic models with more support than the intercept-only model.

However, maximum generalized R^2 values suggested none of these models explained

Table 3.7: Model selection results of competitive models (<2 AIC_c) that related annual habitat selection to habitat covariates for individual northern spotted owls in the Siskiyou Mountains of southern Oregon during 2006 - 2008. Intercept only models for each individual were included for comparison. Sign refers to regression coefficients of the habitat variables. A positive (+) or negative (-) indicates confidence intervals that do not overlap zero and zero indicates otherwise.

Owl	Models	Sign	K[a]	ΔAIC_c[b]	w_i[c]	R^{2}[d]
500 ♀	DIST_P + d_EDGE + d_STR	-,-,+	6	0.000	0.857	0.163
	Intercept only	-	1	50.543	0.000	
500 ♂	DIST_P + YG	-,-	5	0.000	0.249	0.147
	DIST_P + INTER	-,-	5	0.232	0.222	0.147
	DIST_P + LATE	-,+	5	1.197	0.137	0.145
	DIST_P + d_EDGE	-,+	5	1.381	0.125	0.144
	Intercept only	-	1	57.437	0.000	
Bull ♀	DIST_L + d_EDGE	-,+	3	0.000	0.519	0.204
	DIST_L + d_EDGE + d_STR	-,+,0	4	0.677	0.370	0.207
	Intercept only	-	1	79.840	0.000	
Bull ♂	DIST_P + d_STR	-,-	5	0.000	0.578	0.149
	DIST_P + d_EDGE + d_STR	-,0,-	6	1.293	0.303	0.151
	Intercept only	-	1	43.079	0.000	
E. Fork ♀	DIST_P + d_STR + MAT	-,+,+	6	0.000	0.366	0.156
	Intercept only	-	1	60.042	0.000	
Greeley ♂	DIST_P + d_EDGE + d_STR	-,+,+	6	0.000	0.968	0.142
	Intercept only	-	1	55.021	0.000	
Light. ♀	DIST_P + d_STR + NON	-,-,-	6	0.000	0.143	0.049
	DIST_P + d_STR	-,0	5	0.377	0.119	0.043
	DIST_P + d_STR + HARD	-,0,0	6	0.546	0.109	0.048
	DIST_P + d_STR + HARD + NON	-0,0,0	7	1.064	0.084	0.052
	DIST_P + NON	-,0	5	1.219	0.078	0.041
	DIST_P + d_EDGE	-,0	5	1.276	0.076	0.041
	DIST_P	-	4	1.412	0.071	0.036
	DIST_P + d_EDGE + d_STR	-,0,0	6	1.459	0.069	0.046
	DIST_P + HARD	-,0	5	1.849	0.057	0.040
	Intercept only	-	1	9.760	0.001	
Light. ♂	DIST_P + d_EDGE	-,+	5	0.000	0.686	0.102

	Model					
	DIST_P + d_EDGE + d_STR	-,+,0	6	1.728	0.289	0.103
	Intercept only	-	1	28.259	0.000	
McD ♂	DIST_L + d_EDGE + d_STR	-,+,-	4	0.000	0.673	0.150
	Intercept only	-	1	46.617	0.000	
Sheep ♀	DIST_L + d_EDGE	-,0	3	0.000	0.135	0.062
	DIST_L	-	2	0.217	0.121	0.057
	DIST_P + MAT	-,0	5	0.619	0.099	0.070
	DIST_P + YG	-,0	5	0.634	0.098	0.070
	DIST_L + d_EDGE + d_STR	-,0,0	4	0.735	0.093	0.065
	DIST_P + INTER	-,0	5	1.231	0.073	0.069
	DIST_P + LATE	-,0	5	1.348	0.069	0.068
	DIST_L + d_STR	-,0	3	1.513	0.063	0.059
	DIST_L + HARD	-,0	3	2.002	0.050	0.058
	Intercept only	-	1	23.170	0.000	
Sheep ♂	DIST_P + MAT	-,+	5	0.000	0.482	0.163
	Intercept only	-	1	63.986	0.000	

[a] number of parameters in the model
[b] Difference between model AIC$_c$ and lowest AIC$_c$ in the model set.
[c] Akaike weights
[d] maximum generalized R^2

a large proportion of the variance in habitat selection for any of these owls (range 0.04 - 0.21) (Table 3.7).

Models that best described habitat selection by owls during the breeding season were not as consistent as they were for annual habitat selection. Very few of the top covariates had confidence limits that did not overlap zero (Table 3.8), although habitat models performed better than the intercept only models in all cases. No model or individual factor predominated, and the best distance covariates were both the linear or third order polynomial function depending on the owl. Distance to stream and distance to edge were among competing models, but the effect of these covariates were generally much weaker for most owls during the breeding season than they were for annual habitat selection patterns, since confidence limits included zero for most owls (Table

3.8). The next most common covariates occurring in competitive models were the amount of pole and young forest and habitats that were dominated by stands of mature forest. Owl's associations with these forest types were weak, however, since 95% confidence intervals overlapped zero for most of the models containing mature and young forest types (Table 3.8). There were several exceptions, as the 500 Road male selected for mature forest, and the 500 Road female had confidence intervals for mature forest in the top models that barely overlapped zero (Table 3.8). And the Greeley Creek Male avoided young conifer as indicated by a negative coefficient with confidence limits that barely overlapped zero.

Table 3.8. Model selection results of competitive models (<2 AIC_c) that related habitat selection during the breeding season to habitat covariates for individual northern spotted owls in the Siskiyou Mountains of southern Oregon during 2006 - 2008. Intercept only models for each individual were included for comparison. Sign refers to regression coefficients of the habitat variables. A positive (+) or negative (-) indicates confidence intervals that do not overlap zero and zero indicates otherwise.

Owl	Models	Sign	K^a	ΔAIC_c^b	w_i^c	R^{2d}
500 ♀	DIST_P + MAT+ d_STR	-,0,0	6	0.000	0.216	0.146
	DIST_P + NON	-,0	5	1.297	0.113	0.132
	DIST_P + MAT	-,0	5	1.308	0.112	0.132
	DIST_P + NON + d_STR	-,0,0	6	1.327	0.111	0.140
	DIST_P + d_STR	-,0	5	1.958	0.081	0.129
	Intercept only	-	1	24.167	0.000	
500 ♂	DIST_L + d_EDGE	-,0	3	0.000	0.269	0.119
	DIST_L + MAT	-,0	3	0.751	0.185	0.110
	DIST_L + d_EDGE + d_STR	-,+,0	4	1.999	0.099	0.112
	Intercept only	-	1	32.220	0.000	
Bull ♀	DIST_L*YG + HARD	-,+,-,+	5	0.000	0.640	0.221
	DIST_L + HARD	-,+	3	1.613	0.286	0.200
	Intercept only	-	1	49.251	0.000	
Bull ♂	DIST_L	-	2	0.000	0.119	0.164
	DIST_L + NON + d_STR	-,0,0	4	0.271	0.104	0.184
	DIST_L + MAT + d_STR	-,0,0	4	0.710	0.083	0.182

	Model		K			
	DIST_L + MAT	-,0	3	0.743	0.082	0.170
	DIST_L + d_STR	-,0	3	0.792	0.080	0.170
	DIST_L + NON	-,0	3	0.815	0.079	0.170
	DIST_L + HARD	-,0	3	0.860	0.077	0.170
	DIST_L + LATE	-,0	3	1.367	0.060	0.167
	DIST_L + d_EDGE	-,0	3	1.770	0.049	0.165
	DIST_L + YG	-,0	4	1.774	0.049	0.165
	DIST_L + d_EDGE + d_STR	-,0,0	4	1.916	0.046	0.175
	DIST_L + INTER	-,0	3	1.962	0.045	0.164
	DIST_L + OLD	-,0	3	1.986	0.044	0.164
	Intercept only	-	1	27.636	0.000	
E. Fork ♀	DIST_L + d_EDGE + d_STR	-,0,0	4	0.000	0.236	0.213
	DIST_L + d_STR	-,0	3	0.887	0.151	0.204
	DIST_L + d_EDGE	-,0	3	1.233	0.127	0.203
	Intercept only	-	1	62.278	0.000	
E. Fork ♂	DIST_L + d_STR + NON	-,0,0	4	0.000	0.152	0.095
	DIST_L + d_STR	-,0	3	0.393	0.125	0.087
	DIST_L + NON	-,0	3	0.617	0.112	0.086
	DIST_L + d_STR + LATE	-,0,0	4	0.685	0.108	0.093
	DIST_L	-	2	0.997	0.093	0.078
	DIST_L + LATE	-,0	3	1.273	0.080	0.084
	DIST_L + YG	-,0	3	1.703	0.065	0.083
	DIST_L * LATE	0,0,0	4	1.754	0.063	0.089
	DIST_L + OLD	-,0	3	1.836	0.061	0.082
	DIST_L * YG	-,0,0	4	1.937	0.058	0.089
	Intercept only	-	1	6.228	0.007	
Greeley ♂	DIST_L + d_EDGE + d_STR	-,0,+	4	0.000	0.515	0.136
	DIST_L + d_STR	-,+	3	1.268	0.273	0.125
	Intercept only	-	1	35.597	0.000	
Light ♀	DIST_P	-	4	0.000	0.188	0.104
	DIST_P + OLD	-,0	5	1.300	0.098	0.106
	DIST_P + MAT	-,0	5	1.598	0.085	0.105
	DIST_P + NON	-,0	5	1.709	0.080	0.105
	DIST_P + LATE	-,0	5	1.884	0.073	0.104
	DIST_P + INTER	-,0	5	1.976	0.070	0.104
	DIST_P + YG	-,0	6	1.984	0.070	0.104
	DIST_P + d_EDGE	-,0	5	1.995	0.069	0.104
	Intercept only	-	1	22.007	0.000	
Light ♂	DIST_P + NON	-,0	5	0.000	0.241	0.139

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	Model		K[a]	ΔAIC$_c$[b]	[c]	R²[d]
	DIST_P + d_EDGE	-,0	5	1.033	0.144	0.134
	DIST_P	-	4	1.852	0.095	0.121
	Intercept only	-	1	21.905	0.000	
McD ♀	DIST_L + * YG	-,-,+	4	0.000	0.197	0.062
	DIST_L + YG*dist + d_STR	-,-,+	5	0.910	0.125	0.068
	DIST_L + * LATE	0,+,-	4	0.984	0.121	0.057
	DIST_P + HARD	-,0	5	1.572	0.090	0.065
	DIST_P	-	4	1.912	0.076	0.052
	Intercept only	-	1	5.383	0.012	
McD ♂	DIST_P + LATE	-,0	5	0.000	0.118	0.103
	DIST_P + INTER + d_STR	-,0,0	6	0.032	0.116	0.111
	DIST_P + LATE + d_STR	-,0,0	6	0.188	0.107	0.111
	DIST_P + d_STR	-,0	5	0.640	0.086	0.100
	DIST_P	-	4	0.988	0.072	0.091
	DIST_P + d_EDGE	-,0	5	1.086	0.069	0.099
	DIST_P + d_EDGE + d_STR	-,0,0	6	1.153	0.066	0.107
	DIST_P + MAT	-,0	5	1.241	0.063	0.098
	DIST_P + INTER	-,0	5	1.248	0.063	0.098
	DIST_P + OLD	-,0	5	1.251	0.063	0.098
	DIST_P + YG	-,0	5	1.465	0.057	0.097
	Intercept only	-	1	16.86	0.000	
Sheep ♀	DIST_P	-	4	0.000	0.184	0.066
	DIST_P + INTER	-,0	5	0.326	0.156	0.071
	DIST_P + YG	-,0	6	0.561	0.139	0.071
	DIST_P + d_EDGE	-,0	5	0.770	0.125	0.070
	DIST_P + HARD	-,0	5	1.209	0.101	0.069
	DIST_P + MAT	-,0	5	1.286	0.097	0.069
	DIST_P + LATE	-,0	5	1.455	0.089	0.068
	DIST_P + NON	-,0	5	1.600	0.083	0.068
	DIST_P + d_STR	-,0	5	1.772	0.076	0.067
	Intercept only	-	1	14.386	0.000	
Sheep ♂	DIST_P + d_EDGE	-,0	5	0.000	0.312	0.100
	DIST_P	-	4	1.292	0.164	0.089
	DIST_P + HARD	-,0	5	1.305	0.162	0.095
	Intercept only	-	1	21.432	0.000	

[a] number of parameters in the model
[b] Difference between model AIC$_c$ and lowest AIC$_c$ in the model set.
[c] Akaike weights
[d] maximum generalized R^2

Models including the amount of old and mature forest combined (LATE) and non-habitat were competitive for 6 of the 13 birds during the breeding season (Table 3.8). However, the relationship between the amount of these habitats and the probability of owl selection was weak, as indicated by confidence intervals that included zero. Old, intermediate, and hardwood forest types were the least common covariates found in competitive models, and all associations with these forest types were weak, except for 1 owl, whose habitat selection increased with increased proportions of hardwood forests (Table 3.8). The Bull Gap Female and the McDonald Creek Female had the strongest associations with habitat of the 13 owls in this analysis. The probability of habitat selection for the Bull Gap female increased with increased amounts of young forest and hardwood forest types; in contrast to the McDonald Creek female who did not select pole and young forest, but used more late-seral forest (Table 3.8). Maximum generalized R^2 values suggested none of these models explained a large proportion of the variance in habitat selection for any owls during the breeding season (range = 0.06 - 0.22) (Table 3.8).

Habitat selection during the non-breeding season was most associated with distance to stream or edge (Table 3.9). Models indicating a preference or avoidance for these two abiotic factors were competitive for 8 and 7 birds, respectively. Northern spotted owls commonly roosted and foraged in habitats farther from edges, and they also used habitats closer to streams more often. Models containing mature forest were the best predictors of habitat selection during the winter for 2 of the 12 owls (Table 3.9) and probability of owl selection increased with the amount of mature forest. The

covariate combining old and mature forest types (LATE) was important for habitat

selection by 4 of the 12 birds, and owls were more likely to select these forests than

randomly selected locations (Table 3.9). Pole and young forest influenced habitat

selection for 3 of the 12 birds included in the non-breeding season analysis, but each

bird had a different association with these forest types. Hardwood forest influenced

habitat selection for 3 of the 12 birds, but the association was weak as indicated by

confidence intervals that included zero (Table 3.9). As for my other analyses, models

described a relatively small proportion of the total variance in habitat selection (R^2

range = 0.04 - 0.20).

Table 3.9: Model selection results of competitive models (<2 AIC_c) that related habitat selection during the non-breeding season to habitat covariates for individual northern spotted owls in the Siskiyou Mountains of southern Oregon during 2006 - 2008. Intercept only models for each individual were included for comparison. Sign refers to regression coefficients of the habitat variables. A positive (+) or negative (-) indicates confidence intervals that do not overlap zero and zero indicates otherwise.

Owl	Models	Sign	K[a]	ΔAIC_c[b]	w_i[c]	R^{2}[d]
500 ♀	DIST_L + HARD	-,0	3	0.000	0.170	0.050
	DIST_L + INTER	-,0	3	0.555	0.129	0.048
	DIST_L + LATE	-,0	3	1.245	0.091	0.045
	DIST_L + YG	-,0	4	1.255	0.091	0.046
	DIST_L	-	2	1.445	0.082	0.037
	DIST_L + * INTER	-,0,0	4	1.778	0.070	0.051
	DIST_L + HARD + LATE	-,0,0	4	1.846	0.067	0.051
	DIST_L HARD + d_STR	-,0,0	4	1.943	0.064	0.051
	Intercept only	-	1	12.444	0.000	
500 ♂	DIST_P + LATE	-,+	5	0.000	0.314	0.088
	DIST_P + INTER	-,0	5	0.953	0.195	0.084
	DIST_P + HARD	-,0	5	1.654	0.137	0.082
	Intercept only	-	1	15.905	0.000	
Bull ♀	DIST_L + d_EDGE + d_STR	-,+,-	4	0.000	0.692	0.196
	Intercept only		1	49.478	0.000	
Bull ♂	DIST_L + d_STR	-,-	3	0.000	0.688	0.058
	DIST_L + d_EDGE + d_STR	-,0,-	4	2.003	0.253	0.058

	Intercept only	-	1	10.825	0.003	
E. Fork ♀	DIST_P + NON + d_STR	-,0,0	6	0.000	0.268	0.123
	DIST_P + NON	-,0	5	0.649	0.194	0.114
	DIST_P + LATE + d_STR	-,0,0	6	1.959	0.101	0.116
	Intercept only	-	1	25.510	0.000	
Greeley ♀	DIST_L + MAT	-,+	3	0.000	0.999	0.207
	Intercept only	-	1	45.033	0.000	
Greeley ♂	DIST_L + OLD +d_EDGE + d_STR	,+,0,-	3	0.000	0.597	0.140
	Intercept only	-	1	35.033	0.000	
Light ♀	DIST_P + d_EDGE	-,+	5	0.000	0.337	0.044
	DIST_P + d_EDGE + d_STR	0,+,0	6	0.225	0.301	0.058
	Intercept only	-	1	6.348	0.014	
Light ♂	DIST_P + d_EDGE	-, +	5	0.000	0.657	0.161
	DIST_P + d_EDGE + d_STR	-,+,-	6	1.922	0.251	0.161
McD ♂	DIST_L*YG + HARD	-,+,0,0		0.000	0.426	0.097
	DIST_L + * YG	0,+,0		1.278	0.225	0.082
	DIST_L + YG	-,+		1.681	0.184	0.071
	Intercept only	-		12.843	0.001	
Sheep ♀	DIST_L + MAT	-,+		0.068	0.309	0.104
	DIST_P + d_EDGE	-,0		0.343	0.273	0.116
	Intercept only	-		26.119	0.000	0.134
Sheep ♂	DIST_L + LATE	-,+	3	0.000	0.161	0.121
	DIST_L + YG + d_EDGE	-,0,0	4	0.214	0.145	0.128
	DIST_L + MAT	-,+	3	0.242	0.142	0.121
	DIST_L + d_EDGE	-,+	3	0.328	0.136	0.120
	DIST_L + d_EDGE + d_STR	-,+,0	4	0.903	0.102	0.125
	DIST_L + YG	-,-	3	1.564	0.074	0.116
	DIST_L + * LATE	-,0,0	4	1.622	0.071	0.123
	DIST_L + YG + LATE	-,0,0	4	1.725	0.068	0.122
	Intercept only	-	1	32.102	0.000	

[a] number of parameters in the model
[b] Difference between model AIC_c and lowest AIC_c in the model set.
[c] Akaike weights
[d] maximum generalized R^2

DISCUSSION

Home Range Size

As expected, the mean home range size from this study reflects the trend of smaller home ranges in the southern portion of the northern spotted owl's range (Carey et al. 1990, Zabel et al. 1995, Clark 2007) (Figure 3.7). The smaller home ranges in the southern portion of the northern spotted owls' distribution are likely related to the more abundant and diverse prey base available to the owls in these regions (Carey et al. 1992, Zabel et al. 1995); however, this relationship is speculative, since I did not conduct any analysis of owl diets or prey availability.

Spotted owls generally have larger home ranges in the non-breeding season than during the breeding season (Glenn et al. 2005, Forsman et al. 2007, Clark 2007). However, in contrast to most previous studies, I found little evidence for seasonal variation in home range size. Limited access to telemetry stations and difficulty of travel during the winter months may have contributed to an underestimation of non-breeding season home ranges.

The amount of edge was the best indicator of annual, breeding and non-breeding home range sizes as well as core area size. Home range size increased in linear and log-linear fashions related to increased amounts of edge between combined amounts of old forest, mature forest, pole/young stands and non-habitat, which was a measure of increased fragmentation of forest habitat for the species. This is consistent with my predictions as well as results from another study in southwestern Oregon (Clark 2007). The inclusion of more prey rich edge sites within the home range may

provide an energetic benefit to spotted owls; however, these edges increase the amount

of fragmentation on the landscape. They also increase the distance an owl must travel

to acquire prey, which may result in the need for increased home range size, at least up

to a point. Carey and Peeler (1995) equated fragmentation with the loss of a preferred

prey species that occurred in high densities in the Oregon Coast Range. Furthermore,

spotted owls cannot indefinitely expand their home range without a significant

reduction in fitness. Thus, the loss of fitness associated with fragmentation and the

resulting home range expansion must somehow be offset by the increased energy gained

in procuring food sources at greater distance from the site center. Edge was highly and

positively correlated with the number of patches found within the breeding, non-

breeding, and annual home ranges (Appendix F1-F3), which would be expected since

more fragmented patches of late-seral forest would increase the amount of edge on the

landscape.

Figure 3.7. Annual mean home range size estimates and 95% confidence intervals from various studies[a] across the range of the Northern Spotted Owl, including estimates from this current study.
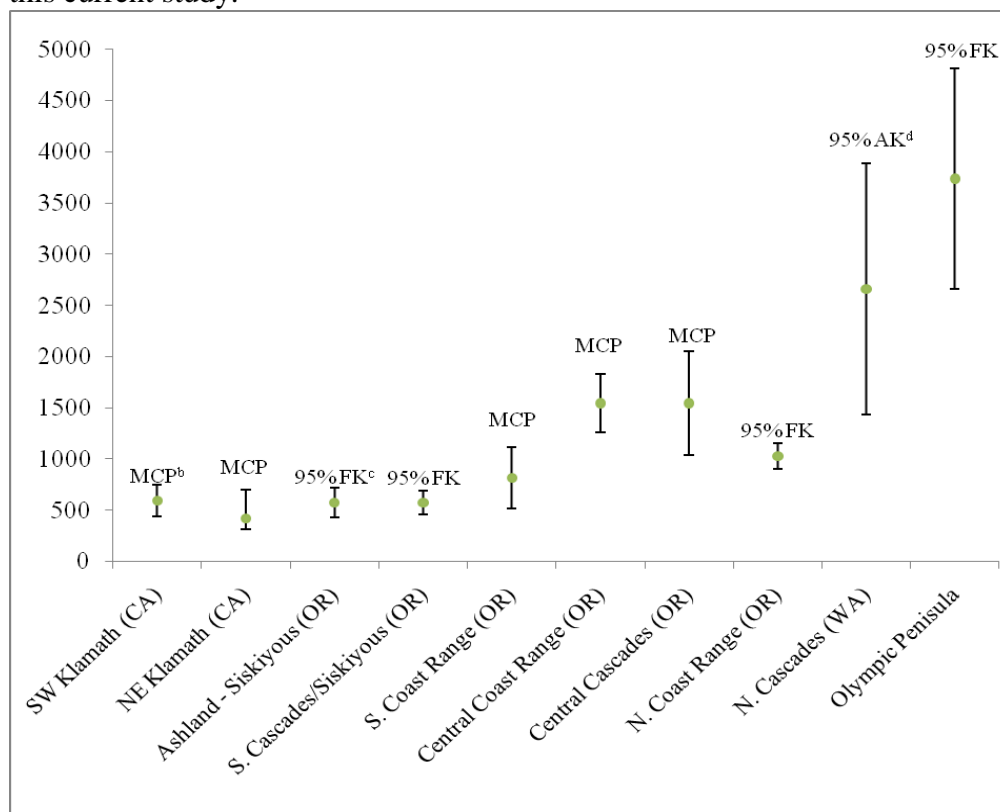
[a] Home ranges from the following published rearch: SW Klamath (Zabel et al. 1995), NE Klamath (Zabel et al. 1995), Ashland-Siskiyou (this study), S. Cascades/Siskiyous (Clark 2007), S. Coast Range (Zabel et al. 1995), N. Coast Range (Glenn et al. 2004), Central Coast Range (Carey et al. 1992), N. Cascades (Hamer et al. 2007), Olympic Peninsula (Forsman et al. 2005).
[b] Home range estimate based on Minimum Convex Polygon analysis
[c] Home range estimate based on 95% Fixed Kernel analysis
[d] Home range estimate based on 95% Adaptive Kernel analysis

Home range size decreased as the proportion of intermediate forest (pole-young and hardwood forests) increased annually. Northern spotted owls in southwestern Oregon are associated with intermediate aged forest that was structurally similar to old forest (Carey et al. 1992, Wagner and Anthony 1999), but previous studies in this region have not found strong relations between home range size or demographic rates

and intermediate habitats (Zabel et al. 1995, Dugger et al. 2005, Clark 2007). The

relatively high densities of dusky footed woodrats (*Neotoma fuscipes*) found in pole

stands within mixed-conifer forests of the Klamath Mountains of southwestern Oregon

(Carey et al. 1992, Carey et al. 1999) and northwestern California (Sakai and Noon

1993) may be the reason more intermediate habitat was associated with smaller home

ranges during our study, but we have no direct evidence of prey availability on our

study area. Intermediate forest was annually correlated with every fragmentation

metric except mean nearest neighbor of late forest (Appendix F1), thus, as

fragmentation increased within home ranges, the amount of intermediate forest also

increased. Although fragmentation metrics other than edge were not included with

intermediate forest in explaining annual home range size, their correlation with

intermediate forest provides weak evidence for an indirect influence on home range

size.

Home range size was positively correlated with the amount of late-seral forest

(old and mature forest types) for the breeding season home range, which was

inconsistent with my prediction as well as results from most other studies (Carey et al.

1990, Glenn et al. 2004, Hamer et al. 2007). The reasons for this relationship are not

clear, but one possibility is that amounts of old forest are directly related to home range

size in areas where woodrats figure prominently in spotted owl diets (Zabel et al. 1995).

Dusky-footed woodrats comprise a major portion of owl diets within the Klamath

region (Zabel et al. 1995, Ward et al. 1998, Forsman et al. 2004, Clark 2007) and are

abundant in the study area (U. S. Forest Service 1996). Woodrats are potentially more

abundant in forests outside of late-seral habitats, and owls may have expanded their ranges to find more intermediate forest types or edges between intermediate and late forest types where woodrats were more abundant (Sakai and Noon 1993, Zabel et al. 1995, Ward et al. 1998). The proportions of late forest are high in my study area and are negatively correlated with edge (Appendix F1-F4), which means that there is less edge habitat in home ranges with high amounts of late forest. Because the amount of late forest is so high ($\bar{x}$ = 72% in annual home ranges; Appendix D), it is possible that a fitness threshold has been reached for most of our birds, meaning that additional amounts of late-seral forest are not necessary to increase survival and reproduction. It is also possible that the contiguous nature of habitat within home ranges was responsible for the correlation I observed between home range size and late-seral forest. Owls that had large blocks of late-seral forest within their home ranges may have been more likely to travel throughout these stands and increase their home range size than they would in more fragmented habitat or in stands of different forest types.

None of the other fragmentation metrics beyond influenced home range size which may reflect the relatively contiguous tracts of late-successional forest available in the Ashland watershed. The influence of these indices on home range size may only be revealed if the prescribed forest thinning results in greater fragmentation and increased amounts of non-habitat.

Other factors not included in this analysis that may have influenced home range size include home range overlap with those of other spotted owls (Carey et al. 1990) and the presence of predators and competitors. Numerous incidental detections of Great

Horned owls were observed in one spotted owl territory (Bull Gap) whose inhabitants had the largest annual and breeding home ranges of all owls in the study area. The presence of barred owls could also have affected home range size. Barred owls were detected in 2 territories, 500 Road and McDonald Creek (see Table 2.4, chapter 2), but were not included in the analysis. The 3 radio-marked owls in these territories had the 3rd, 4th, and 5th largest annual home ranges of the 11 birds, indicating that barred owl presence may have positively influenced home range size. Lastly, habitat analysis that is based on satellite images is not fine scaled enough to detect differences in sub-canopy characteristics. Downed woody debris and presence of snags are important structures in owl foraging habitats (Solis and Gutierrez 1990, North et al. 1999, Irwin et al. 2000), but these components were not detectable using remotely-sensed data. If it were possible to detect and quantify woody debris in this analysis, that might have been another important habitat classification dimension to include.

Habitat Selection

Patterns of habitat selection varied among owls both seasonally and annually. However, the abiotic factors including distance to edge and distance to stream were generally the best indicators of habitat selection for owls during all times of the year. Owls in my study selected habitats that were closer to streams than random locations, which is consistent with my hypothesis. Streams support high densities of dusky-footed woodrats in some mixed-conifer forests of southwestern Oregon (Carey et al. 1999), but not in others (Johnston 2006) Streams are also associated with the presence of northern flying squirrels (*Glaucomys sabrinus*) in some parts of their range (Meyer et al. 2007),

but not others (Zabel et al. 1995, Ritchie et al. 2009). Furthermore, microclimates
found in stream drainages are hypothesized to be favorable to the northern spotted owls
for thermoregulatory purposes during the summer months(Forsman 1976, Barrows
1981).

Distance from edge was another abiotic factor that was prominent indicator of
habitat selection (Table 3.8). Owls selected habitats that were further away from edge
than random locations, which is the opposite of what I had predicted. This association
is puzzling and is inconsistent with other habitat selection studies in the region (Zabel et
al. 1995, Ward et al. 1998, Clark 2007), which found a positive correlation between owl
selection and distance to edge in southwestern Oregon. However, my results were
consistent with results from the northern Oregon coast range (Glenn et al. 2004) and
northern Washington (Forsman et al. 2005, Hamer et al. 2007). Most suitable/non-
habitat habitat edge in the study area was associated with clearcuts or rocky and grassy
subalpine meadows. These habitat types likely decreased cover from predators and
provided no structural diversity, which are important components for foraging owls
(Solis and Gutierrez 1990, North et al. 1999, Irwin et al. 2000). It is also possible that
owls were avoiding edge because prey, such as flying squirrels, a prey type not
associated with edge habitats in the Klamath region (Carey et al. 1992, Zabel et al.
1995), were more plentiful in the core of late-seral forest habitats, where they occur in
higher densities than in younger forests in some studies (Carey et al. 1992, Carey 1995,
Waters and Zabel 1995, but see Rosenberg and Anthony 1992, Lemkuhl et al. 2006). In
addition, in Northwestern California, woodrats moved >50 m into late-seral stands that

were adjacent to unsuitable habitat (Zabel et al. 1995), so it's possible edge habitats were sources of prey items, but were more available to owls when they occurred in other habitats adjacent to edges.

My definition of edge may have also influenced its association with habitat selection of owls. For this analysis, I used the definition of edge developed by Clark (2007), which was different than that of other studies (Zabel et al. 1995, Glenn et al. 2005). For this study, edge included the interface between suitable (intermediate and late-seral forest) and non-habitat habitat, whereas in other studies, edge was defined as the interface between late-seral forest (mature and old growth) and all other habitat types. I chose the Clark (2007) definition of edge because intermediate habitat types have been important to owl habitat selection in this region (Wagner and Anthony 1999). Also, owls may have also selected for intermediate/late-seral edges, which were not included in this analysis.

Distance from edge was also highly negatively correlated with the amount of non-habitat and young conifer habitat and positively correlated with mature forest during each analysis period (Appendices G – G3). Thus, an increase in the probability of use with distance from edge could reflect a preference for mature forest or avoidance of non-habitat and young conifer, which would be consistent with other studies (Carey et al. 1992, Forsman et al. 2005, Hamer et al. 2007).

Old forest was not as influential a factor for owl habitat selection as I expected. This was likely because a large proportion of my owl territories were comprised of late-successional forest (Appendix D), and a large percentage of owl locations were in late-

seral forest types (Appendix H1-H3). This means that in order to show "preference" on average, more than 90% of our locations would need to be in old forest in order for me to determine that older forest was used in a greater proportion than it was available.

However, while old forest was not selected as expected, mature forest was important for annual and winter habitat selection, which was consistent with my hypotheses and other studies in the Klamath Region (Carey et al. 1990) and other parts of Oregon (Forsman 1984, Glenn et al. 2004). Mature forest was abundant in the study area (Appendix D) and also occurred at greater distances from edge (Appendix G1-G3) consistent with patterns observed for annual habitat use. The effect of mature forest on habitat selection was generally positive for both males and females during the annual and non-breeding time periods. Mature forest contained a high diversity of spotted owl prey in other areas of the Klamath Mountains (Carey and Peeler 1995, Ward et al. 1998) including the dusky footed woodrat and flying squirrel, which comprise the bulk of spotted owl diets in the region (Forsman et al. 2004, Clark 2007). The structural diversity necessary for owls to hunt prey may be an important component provided by mature forest types for spotted owls (Solis and Gutierrez 1990, North et al. 1999, Irwin et al. 2000).

I expected that owls would display some level of preference for intermediate forest types based on previous research (Carey et al. 1992, Wagner and Anthony 1999); however, parameter estimates generally indicated no relationship with the amount of intermediate forest. Survival and reproductive success in southern Oregon were found to have no relationship (positive or negative) with intermediate habitats (Dugger et al.

2005), so our results are not totally unexpected. Intermediate forests occurred closer to edge annually and during the breeding season (Appendix G1 - G2). This proximity of intermediate forest to edge, which was generally avoided, may explain why intermediate forest was also avoided by several owls.

The strongest association of owls with non-habitat habitat was during the breeding season; however, this relationship was weak and the direction inconclusive, as was the case with other studies in Oregon (Glenn et al. 2004, Clark 2007). Non-habitat comprised a relatively small percentage ($\bar{x} = 8.88$, range $= 2.11$ to 20.11) of available habitats (Appendix D), and it was strongly negatively associated with distance from edge (i.e., more non-habitat closer to edges), which may account for this weak relationship. It is possible that planned management activities in the study area will create more non-habitat (U. S. Forest Service 2005). However, it is more reasonable to predict an increase in intermediate-aged forest types and that potential relationships between these forest types and spotted owl selection will be stronger when this habitat class is more common in the study area.

Maximum generalized R^2 for the models ranged between 4 - 22 percent, indicating that habitat selection patterns were generally not well explained by the habitat characteristics I investigated. In addition, I found weaker relationships between habitat and abiotic characteristics and breeding season habitat use. Very few of the habitat covariates associated with habitat selection during the breeding season included confidence limits that excluded zero. This may be a symptom of our relatively small sample sizes or the generally increased importance of distance from the nest site during

the breeding season.   Also, by using 99% contours of the home range estimate, my results may be biased towards selected habitats. The 100% contour of the home range may have better represented habitat selection, but are not available in the program KERNELHR.

Prey availability is another important factor that could potentially explain more about habitat selection of northern spotted owls in the study area and southwestern Oregon (Zabel et al. 1995), but which we currently have no way to quantify. In addition, the presence of competitors and predators, and intra-specific interactions, particularly during the breeding season, likely affects habitat selection (Hamer et al. 2007), when owls are more likely to display territorial behavior (Gutiérrez and Lahaye 1995).

CHAPTER 4

SUMMARY AND RESEARCH AND MANAGEMENT
RECOMMENDATIONS

Jason W. Schilling

Dry forest ecosystems within the range of the northern spotted owl are at risk to large scale wildfires. The unique fire regime of the Klamath Mountains has led managers to propose fuels management programs in certain areas that are intended to reduce the risk of wildfire. These preventative measures have the potential to protect spotted owl habitat by making them more fire resilient. However, it is not certain how the removal of hazardous fuels within spotted owl territories will affect the survival, home range size, habitat selection and fitness of the spotted owl. The Ashland forest Resiliency Project (Service 2008) provides an opportunity to study the effects of fuels reduction on these parameters. My study focused on owls within and adjacent to the Ashland Watershed before the implementation of the project.

I monitored 15 owls over the course of two years in the Ashland Watershed and adjacent watersheds. Each spotted owl was tracked for approximately 11 months and I gathered approximately 75 foraging and 25 roosting locations per bird. I estimated monthly survival, home range size, and determined habitat selection patterns for the owls.

During the course of the study, 33% of the radiomarked birds died and one owl left the study area. I used program MARK to estimate monthly survival for owls from September 2006 through October 2008. The best model for estimating owls' survival linked monthly survival to the number of late-seral forest patches on a log transformed scale. Survival increased as the number of late-seral forest patches increased until a threshold was reached (around 33 patches) where survival increases were then minimal with addition of more late forest patches($\beta = 2.51$, SE $= 1.22$ 95% C.I. $= 0.12 - 4.90$).

The only other competing model whose 95% confidence interval did not overlap zero indicated that monthly survival decreased as the mean-nearest neighbor distance between late-seral forest increased (β = -4.35, SE = 2.10, 95% C.I. = -8.47 to -0.22). Monthly survival rates according to the top model ranged from 0.89 (SE = 0.07, 95% C.I. = 0.65 - 0.97) to 1 (SE = 0.00, 95% C.I. = 0.96 - 1.00). I also determined occupancy and reproduction for owls in the study area by conducting demographic surveys during the breeding season of 2007 and 2008. These demographic results were compared with similar surveys from 1993-1997 and 2005-2006 as well as with similar indices of fitness from the Southern Cascades Northern Spotted Owl demographic study area. Occupancy in the Ashland Watershed Density area declined steadily from 1993 to 2008, but there were no consistent differences in reproduction between the 2time periods. The study area did exhibit alternating years of low and high reproduction in an odd/even fashion from 1993 to 1997, and in an even/odd fashion from 2006 to 2008, which was consistent with trends in the southern Oregon Cascades.

I estimated annual, breeding, and non-breeding home ranges as well as core areas for 7 pairs of owls (14 individuals) using the 95% fixed Kernel method in the program KERNELHR. Mean annual home ranges ($\bar{x}$ = 576 ha, range 192 to 894) were comparable to other estimates from the Klamath Mountains (Zabel et al. 1995, Clark 2007) and were smaller than home ranges estimated in other areas of the northern spotted owl's distribution (Carey et al. 1990, Glenn et al. 2004, Forsman et al. 1984, 2005, Hamer et al. 2007). Annual home range size increased in relation to increased amounts of hard edge up to about 40 km of edge, then additional increases in the

amount of edge produced smaller increases in home range size($\beta = 655.90$, SE = 72.782, C.I. = 493.43 - 818.37). In addition, home range size increased with decreased amounts of intermediate forest, again to a threshold where home range size did not increase any farther ($\beta = -414.87$, SE = 145.66, C.I. = -749.32 to -86.359).

The mean breeding season home range size was 491 ha (n =13, Range = 279 – 1,516) and was slightly larger than mean non-breeding season home ranges (n =12, $\bar{x} =$ 469, SE = 59, Range = 158 - 837). Home range size increased with the addition of hard edge ($\beta = 12.973$, SE = 0.60, C.I. = 11.581 - 14.366), and old and mature forest combined ($\beta = 1209.84$, SE = 259.52, C.I. = 642.70 - 1776.99). The mean size of annual core areas was 77 ha (SE =11, Range =19 - 125). The best predictor of both non-breeding home range size and core area size was hard edge. While home range size was positively related to the amount of hard edge within non-breeding home ranges in a linear fashion ($\beta = 9.484$, SE = 1.428, C.I. = 6.226 - 12.743), core area size increased with increasing amounts of hard edge, but only up to a threshold point, where further increases in edge did not increase core area size ($\beta =11.367$, SE = 3.369, C.I. = 3.843 - 18.889).

Habitat selection for individual owls was determined for the breeding, non-breeding and annual time periods. I used logistic regression to model habitat selection as a function of abiotic and habitat covariates. The only factors that consistently affected habitat selection for individual owls across all seasons were distance to streams and edges. Owls selected for habitat that was further away from hard edge and closer to streams. Annual habitat selection was best predicted by these factors and to a lesser

extent pole and young and mature forest. The most variability in habitat selection was found during the breeding season.

Future Research and Management Recommendations

The amount of late-seral forest was weakly but positively associated with spotted owl monthly survival, but survival was more strongly associated with the configuration of late-seral forest (i.e., number of patches). Based on these relationships, managers should strive to maintain at least 20 patches of late forest within each home range for owls in the Ashland Watershed. Fewer patches could result in decreased monthly survival for owls in this area. While minimum patch size of late forest was not associated with survival in this study, discretion should be used when determining the size of late forest patches within home ranges. The average distance between late forest patches should be maintained well below 50 meters, at which point survival of owls in my study declined.

Although there was no evidence that late-seral forest was beneficial to owl survival or conclusively linked to habitat selection of owls in this study, caution should be exercised in removing legacy trees and structural diversity of these forests, which have proven to be essential components of owl nesting and foraging areas (Solis and Gutierrez 1990, North et al. 1999, Irwin et al. 2000). The Ashland Watershed contains some of the most contiguous and diverse stands of late-seral forest remaining in the Siskiyou Mountains (Hill 1996), and this area may be important to the viability of the regional northern spotted owl population. The possibility exists that this area serves as

a source population for the larger Klamath Region, particularly areas with mixed land-ownership and checkerboard patterns of owl habitat available.

Experimental studies that include a moderate partial harvest of spotted owl's habitat could be beneficial to long-term health of the spotted owl population in the region, or it could be detrimental to the fitness of the population. Such studies have been conducted on other forest wildlife (Hayes et al. 2003, Suzuki and Hayes 2003, Gomez et al. 2005), but these effects on spotted owls has been limited to one bird (Meiman et al. 2003).

Habitat selection in my study was highly variable among individual birds. A single "best" model for habitat selection does not appear to be broadly applicable to all owls in this area, consistent with other regional studies that suggest spotted owl habitat selection relationships are complex and not solely explained by factors such as habitat classes and other abiotic features (Glenn et al. 2004, Clark 2007). Late-seral forest or its sub-categories were not obvious predictors of habitat selection in this study. However, reduction in late-seral forest types would likely create edge habitat, which was generally avoided by owls in this study and caused their home ranges to expand. Studies that monitor larger samples of owls for longer time periods time may find more conclusive evidence of habitat selection. The scale at which habitat availability is measured, may also be important. Ideally, habitat management prescriptions would be generated on an individual owl basis. Since this is not feasible logistically and economically, care should be taken when applying broad habitat prescriptions at the stand or landscape level to owl territories. Where non-treatment is not an option,

attention should be paid to preserving vertical structure and to maintaining habitat that is suited for the preferred prey in this region, particularly the dusky footed woodrat (*Neotoma fuscipes*) and northern flying squirrel (*Glaucomys sabrinus*). Owl habitat that is near perennial streams should also be maintained. I recommend that current owl sites in the study area as well as habitat displaying qualities conducive to northern spotted owl occupancy be protected within 1.35 kilometers (based on mean annual home range size) of the nest or site center. Despite the generally contiguous nature of the landscape in my study area, the effects of fragmentation on home range size and survival in this study were apparent. Although fragmentation metrics other than edge were not included in my habitat selection analysis, future studies should consider the effects of these metrics on the roosting and foraging preferences of the spotted owl. In addition, future home range and habitat selection studies in this region should account for small mammal populations within owl's home ranges and at the very least should strive to collect owl pellets for information on diets. Inclusion of these additional factors in analyses could possibly explain some of the variability that was unaccounted for in my study and other studies in the region (Clark 2007).

It is also important to realize that although habitat selection studies based on satellite imagery are convenient in their efficiency, they lack the fine scale that can reveal characteristics beneath the forest canopy. Vegetation plots are time consuming and expensive, but can reveal the number of canopy layers and presence of snags and downed woody material; components which contribute to foraging habitat for owls (Solis and Gutierrez 1990, North et al. 1999, Irwin et al. 2000). Recent technological

innovations such as Lidar (Hyde et al. 2006) may provide more cost-effective

opportunities for characterizing owl foraging habitat at finer scales than satellite images

would allow. The evolution of wildlife tracking technology may also enable a more

detailed analysis of movements and habitat selection of owls in the future. GIS satellite

tracking of birds is a relatively new method that could provide more accurate location

data that could improve the estimation of home ranges and habitat selection (Mrykalo et

al. 2007, Strandberg et al. 2009).

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APPENDICES

Appendix A. Percentages of forest classes and fragmentation metrics within the 95% fixed kernel home range used in monthly survival analysis of northern spotted owls in Siskiyou Moutnains, Oregon during 2006-2008.

Site	late%	inter%	non%	NUMP_late (#)	MPS_late (ha)	Edge (m)	MNN_late (m)	Perim_late (m/ha)	TCA_late (ha)
Bull Gap Male	0.59	0.21	0.20	85.00	6.26	78.14	33.93	261.41	55.48
Bull Gap Female	0.62	0.20	0.18	61.00	9.24	67.55	30.94	232.86	65.93
East Fork Male	0.72	0.20	0.08	46.0	16.71	29.55	39.70	228.05	67.36
East Fork Female	0.88	0.08	0.03	5.00	33.89	4.30	40.97	162.19	26.09
Greeley Creek Male	0.69	0.27	0.04	33.00	8.19	8.77	43.48	258.52	6.38
Greeley Creek Female	0.76	0.20	0.03	11.00	11.28	2.14	156.24	245.84	46.90
Lighting Strike Female	0.82	0.16	0.03	14.00	25.48	10.57	46.00	166.88	60.14
Lightning Strike Male	0.83	0.15	0.02	17.0	19.70	9.06	27.51	160.12	61.00
McDonald Creek Male	0.48	0.39	0.13	159.00	2.61	62.17	34.72	386.03	12.55
McDonald Creek Female	0.72	0.20	0.08	46.00	16.71	29.55	39.70	228.05	67.36
Sheep Creek Male	0.63	0.27	0.10	54.00	6.23	31.02	40.30	302.73	17.62
Sheep Creek Female	0.65	0.29	0.06	39.00	4.33	12.34	35.65	341.05	9.20
Southeast View Male	0.72	0.20	0.08	46.00	16.71	29.55	39.70	228.05	67.36
500 Road Male	0.82	0.13	0.06	19.00	31.93	25.56	76.46	134.90	159.39
500 Road Female	0.88	0.09	0.04	19.00	35.94	15.53	26.76	101.83	267.19
Mean	0.72	0.20	0.08	46.00	16.71	29.55	39.70	228.05	67.36
SE	.03	.04	.02	12.79	3.73	7.73	3.94	26.14	22.80
Minimum	0.48	0.09	0.03	5	2.61	2.14	26.76	101.83	6.38
Maximum	0.88	0.39	0.18	159	35.94	78.14	156.24	341.05	267.19

Appendix B. Regression coefficients, standard errors, and 95% confidence intervals for the best functional forms of all habitat and abiotic covariates from monthly survival analysis of spotted owls in the Siskiyou Mountains, Oregon during 2006 - 2008.

Parameter	Estimate	SE	Lower C.I.	Upper C. I.
S(lg_NUMP_L)	2.51	1.22	0.13	4.90
S(lg_LATE)	-17.28	9.70	-36.30	1.74
S(lg_EDGE)	2.39	1.27	-0.09	4.88
S(lg_MNN_L)	-4.35	2.10	-8.47	-0.22
S(NON)	28.99	20.89	-11.96	69.94
S(INTER)	11.32	6.87	-2.15	24.78
S(lg_MPS_L)	-2.54	1.67	-5.82	0.73
S(PERIM_L)	0.01	0.01	0.00	0.02
S(winter)	-1.21	1.13	-3.41	1.00
S (area)	-0.88	0.92	-2.69	0.93
S (sex)	0.64	0.92	-1.17	2.45
S (T)	-0.03	0.07	-0.17	0.11
S(mcq_TCA_L)	0.00	0.00	0.00	0.00
S(BAOW)	0.05	1.13	-2.16	2.27

Appendix C.

1). Number of annual telemetry locations eestimated within each cover type for 11 northern owls from 2006 - 2008 in the Siskiyou Mountains of Southern Oregon.

Cover type	500 ♂	500 ♀	Bull ♀	Bull ♂	East ♀	Greeley ♂	Lit. ♀	Lit. ♂	Mcd. ♂	Sheep ♀	Sheep ♂
sapling	1	1	0	2	0	1	0	0	1	1	2
early seral	1	1	11	14	1	1	3	0	7	2	3
non-forest	0	0	0	0	0	0	0	0	1	0	0
hardwood	2	1	1	0	1	3	0	2	3	7	10
pole	9	5	15	8	2	21	8	5	18	23	22
young	1	0	0	0	0	3	1	3	1	0	1
mature	73	59	39	25	88	69	47	39	26	51	43
old	15	8	19	14	11	10	30	20	9	19	19

2). Number of breeding season telemetry locations estimated within each cover type for 13 northern spotted owls from 2006 - 2008 in the Siskiyou Mountains of Southern Oregon.

	500 ♀	500 ♂	Bull ♀	Bull ♂	East ♀	East ♂	Greeley ♂	Lit. ♀	Lit. ♂	McD ♀	McD ♂	Sheep ♀	Sheep ♂
sapling	0	1	0	1	0	0	1	0	0	0	1	1	1
early seral	1	1	9	6	0	2	1	0	0	4	4	2	1
non-forest	0	0	0	0	0	0	0	0	0	0	0	0	0
hardwood	0	1	0	0	1	4	1	0	1	0	2	4	8
pole	2	5	8	3	0	3	7	3	2	6	6	13	10
young	0	0	0	0	0	0	2	0	2	0	1	0	1
mature	29	43	17	11	48	34	35	21	17	14	16	23	16
old	2	7	5	2	6	6	3	19	8	0	6	11	13

3). Number of non-breeding season telemetry locations estimated within each cover type for 12 northern spotted owls from 2006 - 2008 in the Siskiyou Mountains of
Southern Oregon.

	500 ♀	500 ♂	Bull ♀	Bull ♂	East ♀	Greeley ♀	Greeley ♂	Lit. ♂	Lit. ♀	Mcd. ♂	Sheep ♀	Sheep ♂
sapling	1	0	0	1	0	0	0	0	2	0	0	1
early seral	0	2	2	8	1	0	0	0	4	3	0	2
non-forest	0	0	0	0	0	0	0	0	0	1	0	0
hardwood	1	1	1	0	0	0	2	1	0	1	3	2
pole	3	4	7	5	2	4	14	3	4	12	10	12
young	0	1	0	0	0	0	1	1	1	0	0	0
mature	30	30	21	14	40	26	31	22	23	10	28	27
old	6	8	14	12	5	4	5	12	12	3	8	6

Appendix D. Percentages of cover types found within the annual 99% fixed kernel home ranges for 11 spotted owls in the Siskiyou Mountains, Oregon during 2006 - 2008.

Owl	non	hard	pole/young	mature	late
500 ♂	6.56	1.86	12.77	61.49	17.32
500 ♀	4.25	1.06	9.94	69.40	15.34
Mcd. ♂	12.24	5.80	32.09	39.84	10.04
Sheep ♂	14.12	3.43	25.02	47.51	9.92
Sheep ♀	7.60	4.19	27.62	46.44	14.15
Lit ♂	2.11	1.75	13.14	55.60	27.40
Lit ♀	2.39	1.65	13.31	55.39	27.27
Greeley ♂	4.79	2.93	26.58	53.39	12.31
East ♀	3.94	1.59	7.33	74.70	12.44
Bull ♂	19.58	1.55	20.54	45.54	12.79
Bull ♀	20.11	0.03	23.46	1.46	54.93
mean	8.88	2.35	19.25	50.07	19.45
S.E	1.90	0.46	2.38	5.52	3.81
Range	2.11 to 20.11	.03 to 5.80	7.33 to 32.09	1.46 to 74.70	9.92 to 54.93

Appendix E.
1). Results for all annual habitat selection models for individual northern spotted owls in the Siskiyou Mountains of southern Oregon during 2006 - 2008. Intercept only model for each individual was also included for comparison.

	model	k	ΔAICc	Akaike Wt.	R^2
500 fem	**DIST_P d_EDGE d_STR**	**6**	**0.000**	**0.857**	**0.160**
	DIST_P d_EDGE	5	4.901	0.074	0.142
	DIST_P d_STR	5	5.287	0.061	0.141
	DIST_P MAT	5	12.023	0.002	0.124
	DIST_P LATE	5	12.750	0.001	0.122
	DIST_P YG	5	12.850	0.001	0.122
	DIST_P INTER	5	13.285	0.001	0.121
	DIST_P	4	14.014	0.001	0.114
	DIST_P NON	5	14.402	0.001	0.118
	DIST_P OLD	5	15.592	0.000	0.115
	DIST_P HARD	5	15.932	0.000	0.114
	DIST_L * INTER	4	17.249	0.000	0.105
	DIST_L * LATE	4	18.554	0.000	0.102
	intercept only	1	50.543	0.000	
500 ♂	**DIST_P YG**	**5**	**0.000**	**0.176**	**0.147**
	DIST_P INTER	**5**	**0.232**	**0.157**	**0.147**
	DIST_P YG d_EDGE	**6**	**0.878**	**0.114**	**0.150**
	DIST_P LATE	**5**	**1.197**	**0.097**	**0.145**
	DIST_P d_EDGE	**5**	**1.381**	**0.088**	**0.144**
	DIST_P YG LATE	**6**	**1.867**	**0.069**	**0.147**
	DIST_P LATE d_EDGE	**6**	**1.904**	**0.068**	**0.147**
	DIST_L * YG	4	2.665	0.047	0.137
	DIST_P YG LATE d_EDGE	7	2.903	0.041	0.150
	DIST_P MAT	5	2.956	0.040	0.141
	DIST_P d_EDGE d_STR	6	3.268	0.034	0.144
	DIST_L * LATE	4	4.877	0.015	0.132
	DIST_P	4	4.892	0.015	0.133
	DIST_P NON	5	5.168	0.013	0.136
	DIST_P HARD	5	5.815	0.010	0.135
	DIST_P d_STR	5	6.342	0.007	0.133
	DIST_P OLD	5	6.624	0.006	0.006
	intercept only	1	57.437	0.000	

Bull ♀	**DIST_L d_EDGE**	**3**	**0.000**	**0.519**	**0.204**
	DIST_L d_EDGE d_STR	**4**	**0.677**	**0.370**	**0.207**
	DIST_L LATE	3	4.348	0.059	0.190
	DIST_L * LATE	4	5.534	0.033	0.196
	DIST_L NON	3	7.862	0.010	0.186
	DIST_L MAT	3	10.288	0.003	0.180
	DIST_P NON	5	10.402	0.003	0.189
	DIST_L d_STR	3	12.648	0.001	0.175
	DIST_L INTER	3	13.335	0.001	0.173
	DIST_L OLD	3	13.684	0.001	0.172
	DIST_L * YG	4	14.395	0.000	0.174
	DIST_L	2	16.283	0.000	0.162
	DIST_L HARD	3	18.292	0.000	0.162
	intercept only	1	79.840	0.000	
Bull ♂	**DIST_P d_STR**	**5**	**0.000**	**0.578**	**0.149**
	DIST_P d_EDGE d_STR	**6**	**1.293**	**0.303**	**0.151**
	DIST_P HARD	5	6.933	0.018	0.130
	DIST_P	4	7.511	0.014	0.122
	DIST_P YG	5	8.129	0.010	0.126
	DIST_P OLD	5	8.453	0.008	0.125
	DIST_P INTER	5	8.978	0.006	0.124
	DIST_P MAT	5	9.233	0.006	0.123
	DIST_P NON	5	9.478	0.005	0.122
	DIST_P LATE	5	9.505	0.005	0.122
	DIST_P d_EDGE	5	9.531	0.005	0.122
	DIST_L * LATE	4	13.140	0.001	0.122
	DIST_L * INTER	4	13.851	0.001	0.104
	intercept only	1	43.079	0.000	
East Fork ♀	**DIST_P d_STR MAT**	**6**	**0.000**	**0.322**	**0.156**
	DIST_P d_STR MAT NON	**7**	**1.977**	**0.120**	**0.156**
	DIST_P d_STR NON	6	3.000	0.072	0.150
	DIST_P d_STR	5	3.542	0.322	0.144
	DIST_P d_EDGE d_STR	6	5.420	0.126	0.145
	DIST_L MAT	3	6.625	0.069	0.129
	DIST_L NON	3	6.650	0.068	0.129

	DIST_P LATE	5	7.351	0.048	0.136
	DIST_L * LATE	6	7.465	0.045	0.140
	DIST_P	4	8.175	0.032	0.139
	DIST_P MAT NON	6	8.348	0.005	0.138
	DIST_L * YG	6	8.477	0.027	0.138
	DIST_P INTER	5	8.712	0.024	0.133
	DIST_P HARD	5	8.723	0.024	0.133
	DIST_P YG	5	9.258	0.018	0.134
	DIST_P d_EDGE	5	10.062	0.012	0.130
	DIST_P OLD	5	10.163	0.012	0.130
	intercept only	1	60.042	0.000	
Greeley ♂	**DIST_P d_EDGE d_STR**	**6**	**0.000**	**0.968**	**0.142**
	DIST_P d_STR	5	6.853	0.031	0.124
	DIST_P MAT	5	15.833	0.000	0.104
	DIST_L INTER	3	18.392	0.000	0.090
	DIST_L YG	3	18.718	0.000	0.090
	DIST_P * YG	4	19.021	0.000	0.093
	DIST_P LATE	5	19.042	0.000	0.097
	DIST_L * LATE	4	21.154	0.000	0.089
	DIST_P	4	22.722	0.000	0.085
	DIST_P d_EDGE	5	23.145	0.000	0.089
	DIST_P OLD	5	23.477	0.000	0.088
	DIST_P HARD	5	23.583	0.000	0.088
	DIST_P NON	5	23.825	0.000	0.087
	intercept	1	55.021	0.000	
				1.000	
Light ♀	**DIST_P, d_STR, NON**	**6**	**0.000**	**0.143**	**0.049**
	DIST_P d_STR	**5**	**0.377**	**0.119**	**0.043**
	DIST_P d_STR HARD	**6**	**0.546**	**0.109**	**0.048**
	DIST_P d_STR HARD NON	**7**	**1.064**	**0.084**	**0.052**
	DIST_P NON	**5**	**1.219**	**0.078**	**0.041**
	DIST_P d_EDGE	**5**	**1.276**	**0.076**	**0.041**
	DIST_L p	**4**	**1.412**	**0.071**	**0.036**
	DIST_P d_EDGE d_STR	**6**	**1.459**	**0.069**	**0.046**
	DIST_P HARD	**5**	**1.849**	**0.057**	**0.040**
	DIST_P YG	5	2.312	0.045	0.039
	DIST_P HARD NON	6	2.472	0.042	0.043

	DIST_P INTER	5	3.064	0.031	0.037
	DIST_P OLD	5	3.400	0.026	0.036
	DIST_P MAT	5	3.401	0.026	0.036
	DIST_P LATE	5	3.438	0.026	0.036
	DIST_L * LATE	4	4.564	0.015	0.028
	DIST_P * YG	4	4.877	0.012	0.027
	intercept only	1	9.760	0.001	
Light. ♂	**DIST_P d_EDGE**	**5**	**0.000**	**0.686**	**0.102**
	DIST_P d_EDGE d_STR	**6**	**1.728**	**0.289**	**0.103**
	DIST_P MAT	5	8.418	0.010	0.079
	DIST_P LATE	5	10.297	0.004	0.074
	DIST_P INTER	5	11.302	0.002	0.071
	DIST_P YG	5	11.339	0.002	0.071
	DIST_P d_STR	5	11.700	0.002	0.070
	DIST_P NON	5	12.045	0.002	0.069
	DIST_L p	4	13.033	0.001	0.060
	DIST_P HARD	5	13.634	0.001	0.064
	DIST_P OLD	5	14.052	0.001	0.063
	DIST_L * LATE	4	22.530	0.000	0.034
	DIST_L * YG	4	23.432	0.000	0.031
	intercept only	1	28.259	0.000	
				1.000	
McD ♂	**DIST_L d_EDGE d_STR**	**4**	**0.000**	**0.690**	**0.150**
	DIST_L d_EDGE	3	2.550	0.193	0.137
	DIST_L NON	3	6.214	0.031	0.127
	DIST_L d_STR	3	6.853	0.022	0.125
	DIST_L HARD	3	7.372	0.017	0.124
	DIST_L LATE	3	8.245	0.011	0.121
	DIST_L MAT	3	8.452	0.010	0.121
	DIST_L	2	8.995	0.008	0.114
	DIST_L * LATE	6	9.742	0.005	0.123
	DIST_L YG	3	10.685	0.003	0.115
	DIST_L OLD	3	10.737	0.003	0.114
	DIST_L * YG	6	10.757	0.003	0.120
	DIST_L INTER	3	11.011	0.003	0.114
	intercept only	1	46.617	0.000	
Sheep ♀	**DIST_L d_EDGE**	**3**	**0.000**	**0.123**	**0.062**

	DIST_L	**2**	**0.217**	**0.110**	**0.057**
	DIST_P MAT	**5**	**0.619**	**0.090**	**0.070**
	DIST_P YG	**5**	**0.634**	**0.089**	**0.070**
	DIST_L d_EDGE d_STR	**4**	**0.735**	**0.085**	**0.065**
	DIST_P INTER	**5**	**1.231**	**0.066**	**0.069**
	DIST_P LATE	**5**	**1.348**	**0.063**	**0.068**
	DIST_L d_STR	**3**	**1.513**	**0.058**	**0.059**
	DIST_L HARD	**3**	**2.002**	**0.045**	**0.058**
	DIST_L d_EDGE MAT	4	2.021	0.045	0.062
	DIST_L NON	3	2.113	0.043	0.058
	DIST_P OLD	5	2.116	0.043	0.067
	DIST_L * YG	4	2.468	0.036	0.061
	DIST_L * LATE	4	2.771	0.031	0.061
	DIST_P MAT YG	6	2.776	0.031	0.061
	DIST_L d_EDGE YG	4	3.418	0.022	0.064
	DIST_L d_EDGE MAT YG	5	3.444	0.022	0.064
	intercept	1	23.170	0.000	
Sheep ♂	**DIST_P MAT**	**5**	**0.000**	**0.410**	**0.163**
	DIST_P MAT YG	**6**	**2.002**	**0.151**	**0.163**
	DIST_P LATE	5	2.998	0.091	0.156
	DIST_P YG	5	3.462	0.073	0.155
	DIST_P HARD	5	3.718	0.064	0.155
	DIST_P NON	5	3.802	0.061	0.155
	DIST_L p	4	4.801	0.037	0.148
	DIST_P d_STR	5	5.245	0.030	0.152
	DIST_P INTER	5	5.427	0.027	0.151
	DIST_P OLD	5	5.852	0.022	0.150
	DIST_P d_EDGE	5	6.667	0.015	0.148
	DIST_P d_EDGE d_STR	6	7.219	0.011	0.152
	DIST_L * LATE	6	8.852	0.005	0.139
	DIST_P * YG	6	9.152	0.004	0.137
	intercept only	1	63.986	0.000	

2). Results for all breeding season habitat selection models for individual northern spotted owls in the Siskiyou Mountains of southern Oregon during 2006 - 2008. Intercept only model for each individual was also included for comparison.

500 ♀	Models	k	ΔAICc	AIC weights	R^2
	DIST_P MAT d_STR	**6**	**0.000**	**0.196**	**0.145**
	DIST_P NON	**5**	**1.297**	**0.102**	**0.132**
	DIST_P MAT	**5**	**1.308**	**0.102**	**0.132**
	DIST_P NON d_STR	**6**	**1.327**	**0.101**	**0.140**
	DIST_P NON MAT d_STR	**7**	**1.477**	**0.094**	**0.148**
	DIST_P d_STR	**5**	**1.958**	**0.074**	**0.129**
	DIST_P NON MAT	6	2.156	0.067	0.137
	DIST_P LATE	5	2.844	0.047	0.127
	DIST_P	4	2.938	0.045	0.117
	DIST_P YG	6	3.428	0.035	0.123
	DIST_P d_EDGE d_STR	6	3.486	0.034	0.131
	DIST_L HARD	3	3.934	0.027	0.104
	DIST_P d_EDGE	5	4.126	0.025	0.120
	DIST_P OLD	5	4.220	0.024	0.120
	DIST_P INTER	5	4.262	0.023	0.120
	DIST_L * LATE	4	8.725	0.002	0.092
	DIST_L * YG	4	9.433	0.002	0.089
	intercept only	1	24.167	0.000	0.111
500 ♂	**DIST_L d_EDGE**	**3**	**0.000**	**0.183**	**0.112**
	DIST_L d_EDGE MAT	**4**	**0.016**	**0.181**	**0.118**
	DIST_L MAT	**3**	**0.751**	**0.125**	**0.110**
	DIST_L d_EDGE MAT YG	**5**	**1.830**	**0.073**	**0.119**
	DIST_L d_EDGE YG	**4**	**1.993**	**0.067**	**0.112**
	DIST_L d_EDGE d_STR	**4**	**1.999**	**0.067**	**0.112**
	DIST_L YG MAT	4	2.622	0.049	0.110
	DIST_L OLD	3	2.671	0.048	0.104
	DIST_L YG	4	3.103	0.039	0.103
	DIST_L	2	3.174	0.037	0.096
	DIST_L INTER	3	3.682	0.029	0.101
	DIST_L LATE	3	4.001	0.025	0.100
	DIST_L * YG	4	4.216	0.022	0.105
	DIST_L NON	3	4.896	0.016	0.097
	DIST_L HARD	3	5.076	0.014	0.097

	DIST_L d_STR	3	5.180	0.014	0.096
	DIST_L * LATE	4	5.913	0.009	0.100
	intercept only	1	32.220	0.000	0.116
Bull ♀	**DIST_L * YG HARD**	**5**	**0.000**	**0.443**	**0.221**
	DIST_L HARD	**3**	**1.613**	**0.198**	**0.200**
	DIST_L * YG HARD d_EDGE	**6**	**1.761**	**0.184**	**0.222**
	DIST_L * YG	4	3.142	0.092	0.201
	DIST_L	2	3.408	0.081	0.185
	DIST_L HARD d_EDGE	4	3.571	0.074	0.200
	DIST_L OLD	3	4.128	0.056	0.190
	DIST_L *YG d_EDGE	5	4.357	0.050	0.204
	DIST_L d_EDGE	3	4.858	0.039	0.187
	DIST_L INTER	3	4.951	0.037	0.187
	DIST_L LATE	3	5.209	0.033	0.186
	DIST_L YG	4	5.350	0.031	0.186
	DIST_L MAT	3	5.379	0.030	0.185
	DIST_L d_STR	3	5.405	0.030	0.185
	DIST_L * LATE	4	6.121	0.021	0.190
	DIST_L d_EDGE d_STR	4	6.728	0.015	0.188
	intercept only	1	49.251	0.000	0.207
Bull ♂	**DIST_L**	**2**	**0.000**	**0.114**	**0.164**
	DIST_L NON d_STR	**4**	**0.271**	**0.100**	**0.184**
	DIST_L MAT d_STR	**4**	**0.710**	**0.080**	**0.182**
	DIST_L MAT	**3**	**0.743**	**0.079**	**0.170**
	DIST_L d_STR	**3**	**0.792**	**0.077**	**0.170**
	DIST_L NON	**3**	**0.815**	**0.076**	**0.170**
	DIST_L HARD	**3**	**0.860**	**0.074**	**0.170**
	DIST_L LATE	**3**	**1.367**	**0.058**	**0.167**
	DIST_L d_EDGE	**3**	**1.770**	**0.047**	**0.165**
	DIST_L YG	**4**	**1.774**	**0.047**	**0.165**
	DIST_L d_EDGE d_STR	**4**	**1.916**	**0.044**	**0.175**
	DIST_L INTER	**3**	**1.962**	**0.043**	**0.164**
	DIST_L NON MAT d_STR	**5**	**1.966**	**0.043**	**0.186**
	DIST_L OLD	**3**	**1.986**	**0.042**	**0.164**
	DIST_L MAT NON	4	2.550	0.032	0.172
	DIST_L * LATE	4	2.741	0.029	0.171
	DIST_L * YG	4	3.749	0.017	0.165

	intercept only	1	27.636	0.000	0.190
East ♀	**DIST_L d_EDGE d_STR**	**4**	**0.000**	**0.216**	**0.213**
	DIST_L d_STR	**3**	**0.887**	**0.138**	**0.204**
	DIST_L d_EDGE	**3**	**1.233**	**0.116**	**0.203**
	DIST_L d_EDGE d_STR LATE	**5**	**1.870**	**0.085**	**0.213**
	DIST_L d_EDGE d_STR NON	5	2.001	0.079	0.213
	DIST_L	2	2.368	0.066	0.194
	DIST_L NON	3	2.817	0.053	0.198
	DIST_L LATE	3	3.348	0.040	0.197
	DIST_L MAT	3	3.445	0.039	0.197
	DIST_L d_EDGE d_STR LATE NON	6	3.901	0.031	0.213
	DIST_L YG	3	4.128	0.027	0.194
	DIST_L INTER	3	4.185	0.027	0.194
	DIST_L OLD	3	4.380	0.024	0.194
	DIST_L HARD	3	4.384	0.024	0.194
	DIST_L LATE NON	5	5.395	0.015	0.197
	DIST_L * YG	4	5.935	0.011	0.207
	DIST_L * LATE	4	6.407	0.009	0.206
	intercept only	1	62.278	0.000	0.222
East ♂	**DIST_L d_STR NON**	**4**	**0.000**	**0.139**	**0.095**
	DIST_L d_STR	**3**	**0.393**	**0.114**	**0.087**
	DIST_L NON	**3**	**0.617**	**0.102**	**0.086**
	DIST_L d_STR LATE	**4**	**0.685**	**0.098**	**0.09**
	DIST_L	**2**	**0.977**	**0.085**	**0.078**
	DIST_L LATE	**3**	**1.273**	**0.073**	**0.084**
	DIST_L YG	**3**	**1.703**	**0.059**	**0.083**
	DIST_L * LATE	**4**	**1.754**	**0.058**	**0.089**
	DIST_L OLD	**3**	**1.836**	**0.055**	**0.082**
	DIST_L * YG	**4**	**1.937**	**0.053**	**0.089**
	DIST_L d_STR NON LATE	5	2.025	0.050	0.095
	DIST_L d_EDGE d_STR	4	2.033	0.050	0.088
	DIST_L HARD	3	2.368	0.042	0.080
	DIST_L INTER	3	2.372	0.042	0.080
	DIST_L d_EDGE	3	2.577	0.038	0.078
	DIST_L NON LATE	4	2.636	0.037	0.086
	DIST_L MAT	3	2.704	0.036	0.080
	intercept only	1	6.228	0.006	0.094

Greeley ♂	**DIST_L YG d_EDGE d_STR**	**5**	**0.000**	**0.479**	**0.146**
	DIST_L d_EDGE d_STR	**4**	**1.159**	**0.268**	**0.136**
	DIST_L d_STR	3	2.428	0.142	0.125
	DIST_L YG	4	4.995	0.039	0.117
	DIST_L INTER	3	5.820	0.026	0.114
	DIST_L * YG	4	7.621	0.011	0.115
	DIST_L	2	8.406	0.007	0.099
	DIST_L MAT	3	8.589	0.007	0.105
	DIST_L LATE	3	8.756	0.006	0.104
	DIST_L d_EDGE	3	9.661	0.004	0.101
	DIST_L NON	3	10.005	0.003	0.100
	DIST_L OLD	3	10.364	0.003	0.099
	DIST_L HARD	3	10.422	0.003	0.099
	DIST_L * LATE	4	10.709	0.002	0.104
	intercept only	1	35.597	0.000	0.118
Light. ♀	**DIST_P**	**4**	**0.000**	**0.188**	**0.104**
	DIST_P OLD	**5**	**1.300**	**0.098**	**0.106**
	DIST_P MAT	**5**	**1.598**	**0.085**	**0.105**
	DIST_P NON	**5**	**1.709**	**0.080**	**0.105**
	DIST_P LATE	**5**	**1.884**	**0.073**	**0.104**
	DIST_P INTER	**5**	**1.976**	**0.070**	**0.104**
	DIST_P YG	**6**	**1.984**	**0.070**	**0.104**
	DIST_P d_EDGE	**5**	**1.995**	**0.069**	**0.104**
	DIST_P HARD	5	2.023	0.068	0.104
	DIST_P d_STR	5	2.025	0.068	0.104
	DIST_P OLD NON	6	3.171	0.039	0.107
	DIST_P OLD d_EDGE	6	3.327	0.036	0.106
	DIST_P NON d_EDGE	6	3.732	0.029	0.105
	DIST_P d_EDGE d_STR	6	4.022	0.025	0.104
	DIST_P OLD NON d_EDGE	7	5.190	0.014	0.107
	DIST_L * YG	4	8.035	0.003	0.074
	DIST_L * LATE	4	8.706	0.002	0.072
	intercept only	1	22.007	0.000	
Light ♂	**DIST_P NON**	**5**	**0.000**	**0.193**	**0.139**
	DIST_P d_EDGE	**5**	**1.033**	**0.115**	**0.134**

	DIST_P NON d_EDGE	**6**	**1.133**	**0.110**	**0.143**
	DIST_P NON MAT	**6**	**1.576**	**0.088**	**0.141**
	DIST_P	**4**	**1.852**	**0.077**	**0.121**
	DIST_P MAT d_EDGE	6	2.372	0.059	0.137
	DIST_P NON MAT d_EDGE	7	2.706	0.050	0.145
	DIST_P d_EDGE d_STR	6	2.851	0.046	0.135
	DIST_P MAT	5	2.970	0.044	0.125
	DIST_P LATE	5	2.995	0.043	0.125
	DIST_P HARD	5	3.086	0.041	0.125
	DIST_P d_STR	5	3.245	0.038	0.124
	DIST_P INTER	5	3.595	0.032	0.122
	DIST_P YG	6	3.756	0.030	0.122
	DIST_P OLD	5	3.804	0.029	0.121
	DIST_L* LATE	4	8.491	0.003	0.091
	DIST_L* YG	4	8.954	0.002	0.089
	intercept only	1	21.905	0.000	0.146
McD. ♀	**DIST_L * YG**	**4**	**0.000**	**0.182**	**0.062**
	DIST_L * YG d_STR	**5**	**0.910**	**0.115**	**0.068**
	DIST_L * LATE	**4**	**0.984**	**0.111**	**0.057**
	DIST_P HARD	**5**	**1.572**	**0.083**	**0.065**
	DIST_L * LATE DIST_L*YG	**6**	**1.707**	**0.078**	**0.075**
	DIST_L p	**4**	**1.912**	**0.070**	**0.052**
	DIST_P INTER	5	2.894	0.043	0.057
	DIST_L * LATE d_STR	5	2.999	0.041	0.057
	DIST_P d_STR	5	3.179	0.037	0.056
	DIST_P LATE	5	3.376	0.034	0.055
	DIST_P MAT	5	3.407	0.033	0.055
	DIST_P YG	6	3.460	0.032	0.055
	DIST_L * LATE DIST_L * YG d_STR	7	3.505	0.032	0.076
	DIST_P d_EDGE	5	3.573	0.030	0.054
	DIST_P OLD	5	3.850	0.027	0.052
	DIST_P NON	5	3.935	0.025	0.052
	DIST_P d_EDGE d_STR	6	4.996	0.015	0.057
	intercept only	1	5.383	0.012	0.071
McD. ♂	**DIST_P LATE**	**5**	**0.000**	**0.112**	**0.103**
	DIST_P INTER d_STR	**6**	**0.032**	**0.111**	**0.111**

DIST_P LATE d_STR	**6**	**0.188**	**0.102**	**0.111**
DIST_P d_STR	**5**	**0.640**	**0.082**	**0.100**
DIST_P	**4**	**0.988**	**0.069**	**0.091**
DIST_P d_EDGE	**5**	**1.086**	**0.065**	**0.099**
DIST_P d_EDGE d_STR	**6**	**1.153**	**0.063**	**0.107**
DIST_P MAT	**5**	**1.241**	**0.060**	**0.098**
DIST_P INTER	**5**	**1.248**	**0.060**	**0.098**
DIST_P OLD	**5**	**1.251**	**0.060**	**0.098**
DIST_P YG	**5**	**1.465**	**0.054**	**0.097**
DIST_P LATE INTER d_STR	**7**	**1.733**	**0.047**	**0.113**
DIST_P NON	5	2.013	0.041	0.095
DIST_P LATE INTER	6	2.064	0.040	0.103
DIST_P HARD	5	2.493	0.032	0.093
DIST_L* LATE	4	12.283	0.000	0.043
DIST_L* YG	4	15.509	0.000	0.031
intercept only	1	16.864	0.000	0.114
Sheep ♀ **DIST_P**	**4**	**0.000**	**0.153**	**0.066**
DIST_P INTER	**5**	**0.326**	**0.130**	**0.071**
DIST_P YG	**6**	**0.561**	**0.116**	**0.071**
DIST_P d_EDGE	**5**	**0.770**	**0.104**	**0.070**
DIST_P HARD	**5**	**1.209**	**0.084**	**0.069**
DIST_P MAT	**5**	**1.286**	**0.081**	**0.069**
DIST_P LATE	**5**	**1.455**	**0.074**	**0.068**
DIST_P NON	**5**	**1.600**	**0.069**	**0.068**
DIST_P d_STR	**5**	**1.772**	**0.063**	**0.067**
DIST_P OLD	5	2.020	0.056	0.066
DIST_P INTER d_EDGE	6	2.066	0.055	0.073
DIST_P d_EDGE d_STR	6	2.127	0.053	0.072
DIST_P MAT INTER	6	2.243	0.050	0.072
DIST_P MAT d_EDGE	6	2.583	0.042	0.071
DIST_P MAT INTER d_EDGE	7	4.051	0.020	0.073
DIST_L * LATE	4	8.495	0.002	0.039
DIST_L * YG	4	9.781	0.001	0.035
Sheep ♂ **DIST_P d_EDGE**	**5**	**0.000**	**0.242**	**0.100**
DIST_P	**4**	**1.292**	**0.127**	**0.089**
DIST_P HARD	**5**	**1.305**	**0.126**	**0.095**
DIST_P d_EDGE HARD	**6**	**1.481**	**0.115**	**0.101**

DIST_P d_EDGE MAT	**6**	**1.568**	**0.110**	**0.100**
DIST_P d_EDGE d_STR	6	2.025	0.088	0.100
DIST_P MAT	5	3.002	0.054	0.090
DIST_P LATE	5	3.162	0.050	0.089
DIST_P OLD	5	3.183	0.049	0.089
DIST_P INTER	5	3.194	0.049	0.089
DIST_P d_STR	5	3.272	0.047	0.089
DIST_P NON	5	3.280	0.047	0.089
DIST_P d_EDGE HARD MAT	7	3.327	0.046	0.102
DIST_P HARD MAT	6	3.329	0.046	0.095
DIST_P YG	6	3.350	0.045	0.089
DIST_L * YG	4	10.979	0.001	0.056
DIST_L * LATE	4	11.624	0.001	0.054
intercept only	1	21.432	0.000	0.091

3). Results for all non-breeding season habitat selection models for individual northern spotted owls in the Siskiyou Mountains of southern Oregon during 2006 - 2008.

500 ♀	model	k	ΔAICc	Akaike Wt.	R^2
	DIST_L HARD	**3**	**0.000**	**0.150**	**0.050**
	DIST_L INTER	**3**	**0.555**	**0.113**	**0.048**
	DIST_L LATE	**3**	**1.245**	**0.080**	**0.045**
	DIST_L YG	**4**	**1.255**	**0.080**	**0.046**
	DIST_L	**2**	**1.445**	**0.073**	**0.037**
	DIST_L * INTER	**4**	**1.778**	**0.062**	**0.051**
	DIST_L HARD LATE	**4**	**1.846**	**0.059**	**0.051**
	DIST_L HARD d_STR	**4**	**1.943**	**0.057**	**0.051**
	DIST_L MAT	3	2.209	0.050	0.042
	DIST_L * LATE	4	2.802	0.037	0.047
	DIST_L NON	3	3.083	0.032	0.038
	DIST_L LATE d_STR	4	3.200	0.030	0.046
	DIST_L d_STR	3	3.202	0.030	0.038
	DIST_L d_EDGE	3	3.237	0.030	0.038
	DIST_L OLD	3	3.442	0.027	0.037
	DIST_L HARD LATE d_STR	4	3.792	0.022	0.051
	INTER	2	3.965	0.021	0.027
	YG	2	4.582	0.015	0.025
	DIST_L d_EDGE d_STR	4	5.037	0.012	0.039
	LATE	2	5.341	0.010	0.022
	HARD	2	7.462	0.004	0.014
	MAT	2	7.589	0.003	0.013
	NON	2	10.224	0.001	0.003
	d_STR	2	10.678	0.001	0.001
	d_EDGE	2	10.816	0.001	0.001
	OLD	2	10.932	0.001	0.000
	intercept only	1	12.444	0.000	0.056
	d_EDGE d_STR	2	12.514	0.000	0.002
500 ♂	**DIST_P LATE**	**5**	**0.000**	**0.311**	**0.088**
	DIST_P INTER	**5**	**0.953**	**0.193**	**0.084**
	DIST_P HARD	**5**	**1.654**	**0.136**	**0.082**
	DIST_P NON	5	2.165	0.106	0.080

	DIST_P OLD	5	3.163	0.064	0.076
	DIST_P	4	3.175	0.064	0.069
	DIST_P MAT	5	4.176	0.039	0.073
	DIST_P d_STR	5	5.047	0.025	0.069
	DIST_P d_EDGE	5	5.202	0.023	0.069
	DIST_L YG	3	7.074	0.009	0.047
	DIST_P d_EDGE d_STR	6	7.079	0.009	0.069
	DIST_L * YG	4	7.888	0.006	0.052
	DIST_L * LATE	4	7.920	0.006	0.052
	LATE	2	8.925	0.004	0.033
	INTER	2	10.096	0.002	0.029
	YG	2	10.748	0.001	0.027
	MAT	2	12.326	0.001	0.021
	NON	2	12.528	0.001	0.020
	HARD	2	14.118	0.000	0.014
	intercept only	1	15.905	0.000	0.102
	d_STR	2	17.697	0.000	0.001
	OLD	2	17.800	0.000	0.000
	d_EDGE	2	17.807	0.000	0.000
	d_EDGE d_STR	2	19.646	0.000	0.001
Bull ♀	**DIST_L d_EDGE d_STR**	**4**	**0.000**	**0.912**	**0.196**
	DIST_L * LATE	4	5.762	0.051	0.176
	DIST_L LATE	3	7.930	0.017	0.162
	DIST_L d_EDGE	3	8.864	0.011	0.159
	DIST_L NON	3	9.427	0.008	0.157
	DIST_L d_STR	3	15.025	0.000	0.137
	DIST_L OLD	3	16.281	0.000	0.133
	DIST_L MAT	3	21.695	0.000	0.114
	DIST_L * YG	4	21.784	0.000	0.121
	DIST_L INTER	3	22.792	0.000	0.110
	DIST_L YG	4	23.316	0.000	0.109
	DIST_L HARD	3	25.192	0.000	0.102
	DIST_L	2	25.786	0.000	0.093
	d_EDGE d_STR	2	26.856	0.000	0.096
	d_EDGE	2	30.324	0.000	0.077
	LATE	2	33.970	0.000	0.064
	NON	2	38.100	0.000	0.049
	OLD	2	40.983	0.000	0.038

	YG	2	41.231	0.000	0.023
	INTER	2	44.571	0.000	0.025
	d_STR	2	46.177	0.000	0.019
	HARD	2	47.795	0.000	0.014
	MAT	2	48.145	0.000	0.012
	intercept only	1	49.478	0.000	0.171
Bull ♂	**DIST_L d_STR**	**3**	**0.000**	**0.633**	**0.058**
	DIST_L d_EDGE d_STR	**4**	**2.003**	**0.233**	**0.058**
	d_STR	2	5.110	0.049	0.030
	d_EDGE d_STR	2	7.086	0.018	0.030
	DIST_L	2	8.625	0.008	0.017
	DIST_L YG	4	9.082	0.007	0.023
	DIST_L HARD	3	9.189	0.006	0.022
	DIST_L * YG	4	9.364	0.006	0.029
	DIST_L INTER	3	9.664	0.005	0.020
	DIST_L LATE	3	10.429	0.003	0.017
	DIST_L * LATE	4	10.450	0.003	0.025
	DIST_L OLD	3	10.474	0.003	0.017
	DIST_L MAT	3	10.581	0.003	0.017
	DIST_L d_EDGE	3	10.590	0.003	0.017
	DIST_L NON	3	10.637	0.003	0.017
	intercept only	1	10.825	0.003	0.032
	HARD	2	11.440	0.002	0.006
	YG	2	11.545	0.002	0.008
	INTER	2	11.589	0.002	0.005
	OLD	2	11.953	0.002	0.004
	LATE	2	12.616	0.001	0.001
	d_EDGE	2	12.805	0.001	0.000
	MAT	2	12.816	0.001	0.000
	NON	2	12.817	0.001	0.000
East ♀	**DIST_P NON d_STR**	**6**	**0.000**	**0.268**	**0.123**
	DIST_P NON	**5**	**0.649**	**0.194**	**0.114**
	DIST_P LATE d_STR	**6**	**1.959**	**0.101**	**0.116**
	DIST_P NON LATE d_STR	7	2.037	0.097	0.123
	DIST_P LATE	5	2.475	0.078	0.108
	DIST_P NON LATE	6	2.674	0.070	0.114
	DIST_P d_STR	5	4.046	0.035	0.102

	DIST_L * LATE	4	4.399	0.030	0.108
	DIST_P MAT	5	4.811	0.024	0.100
	DIST_P INTER	5	5.052	0.021	0.099
	DIST_P	4	5.129	0.021	0.092
	DIST_P YG	6	5.187	0.020	0.098
	DIST_P d_EDGE d_STR	6	6.043	0.013	0.102
	DIST_P HARD	5	6.611	0.010	0.093
	DIST_P OLD	5	6.810	0.009	0.093
	DIST_P d_EDGE	5	7.143	0.008	0.092
	DIST_L * YG	4	10.358	0.002	0.074
	NON	2	16.650	0.000	0.038
	MAT	2	20.214	0.000	0.026
	LATE	2	20.627	0.000	0.024
	d_STR	2	24.570	0.000	0.010
	INTER	2	24.635	0.000	0.010
	YG	2	24.841	0.000	0.009
	d_EDGE d_STR	2	25.198	0.000	0.015
	intercept only	1	25.510	0.000	0.109
	HARD	2	26.408	0.000	0.004
	d_EDGE	2	26.424	0.000	0.004
	OLD	2	27.364	0.000	0.001
Greeley ♀	**DIST_L MAT**	**3**	**0.000**	**0.818**	**0.207**
	MAT	2	3.020	0.181	0.186
	DIST_L LATE	3	13.415	0.001	0.152
	DIST_L * LATE	4	15.352	0.000	0.169
	DIST_P NON	5	18.729	0.000	0.146
	DIST_L INTER	3	18.755	0.000	0.129
	DIST_P HARD	5	21.557	0.000	0.135
	DIST_L * YG	4	21.801	0.000	0.125
	DIST_L YG	3	21.960	0.000	0.116
	DIST_P OLD	5	23.329	0.000	0.127
	LATE	2	24.159	0.000	0.098
	DIST_P d_EDGE d_STR	6	26.422	0.000	0.123
	DIST_P d_EDGE	5	26.634	0.000	0.113
	DIST_P d_STR	5	27.005	0.000	0.112
	DIST_P	4	27.246	0.000	0.102
	INTER	2	27.445	0.000	0.084
	YG	2	29.535	0.000	0.075

	OLD	2	33.022	0.000	0.061
	HARD	2	41.583	0.000	0.024
	NON	2	42.022	0.000	0.022
	d_EDGE	2	45.030	0.000	0.007
	intercept only	1	45.033	0.000	0.221
	d_STR	2	46.765	0.000	0.001
	d_EDGE d_STR	2	47.251	0.000	0.008
Greeley ♂	**DIST_L OLD d_EDGE d_STR**	**5**	**0.000**	**0.597**	**0.140**
	DIST_L OLD	3	2.880	0.141	0.118
	DIST_P d_EDGE d_STR	6	3.140	0.124	0.136
	DIST_L MAT	3	4.546	0.061	0.112
	DIST_L	2	7.688	0.013	0.096
	DIST_L HARD	3	7.866	0.012	0.102
	DIST_L d_EDGE	3	7.868	0.012	0.102
	DIST_L d_STR	3	7.992	0.011	0.101
	DIST_L NON	3	8.830	0.007	0.099
	DIST_L LATE	3	8.897	0.007	0.098
	DIST_L INTER	3	9.497	0.005	0.097
	DIST_L YG	4	9.694	0.005	0.096
	DIST_L * LATE	4	10.464	0.003	0.100
	DIST_L * YG	4	11.693	0.002	0.096
	MAT	2	20.40	0.000	0.055
	OLD	2	22.90	0.000	0.047
	d_EDGE d_STR	2	29.09	0.000	0.033
	INTER	2	30.20	0.000	0.023
	YG	2	30.42	0.000	0.022
	LATE	2	32.04	0.000	0.016
	d_EDGE	2	32.91	0.000	0.014
	d_STR	2	33.30	0.000	0.012
	intercept only	1	35.033	0.000	0.135
	HARD	2	36.17	0.000	0.003
	NON	2	37.03	0.000	0.000
Light. ♀	**DIST_P d_EDGE**	**5**	**0.000**	**0.251**	**0.044**
	DIST_P d_EDGE d_STR	**6**	**0.225**	**0.225**	**0.058**
	d_EDGE d_STR	2	2.052	0.090	0.030
	DIST_P d_STR	5	2.113	0.087	0.044

	d_STR	2	2.527	0.071	0.021
	d_EDGE	2	3.291	0.048	0.018
	DIST_L * YG	4	4.121	0.032	0.030
	DIST_P YG	6	4.646	0.025	0.035
	DIST_L * LATE	4	4.713	0.024	0.028
	DIST_P	4	4.854	0.022	0.027
	DIST_P NON	5	5.299	0.018	0.033
	NON	2	5.654	0.015	0.010
	DIST_P INTER	5	5.865	0.013	0.031
	DIST_P HARD	5	5.970	0.013	0.030
	intercept only	1	6.348	0.011	0.053
	DIST_P LATE	5	6.732	0.009	0.028
	DIST_P MAT	5	6.850	0.008	0.027
	DIST_P OLD	5	6.857	0.008	0.027
	YG	2	7.062	0.007	0.005
	HARD	2	7.752	0.005	0.002
	INTER	2	7.802	0.005	0.002
	OLD	2	8.278	0.004	0.000
	MAT	2	8.307	0.004	0.000
	LATE	2	8.356	0.004	0.000
Light. ♂	**DIST_P d_EDGE**	**5**	**0.000**	**0.655**	**0.161**
	DIST_P d_EDGE d_STR	**6**	**1.922**	**0.251**	**0.161**
	DIST_P MAT	5	4.057	**0.086**	0.145
	DIST_P LATE	5	12.442	**0.001**	0.113
	d_EDGE d_STR	2	12.453	**0.001**	0.098
	DIST_P d_STR	5	12.488	**0.001**	0.113
	d_EDGE	2	12.775	**0.001**	0.089
	DIST_P OLD	5	13.074	**0.001**	0.111
	DIST_P YG	6	13.133	**0.001**	0.111
	DIST_P INTER	5	13.595	**0.001**	0.109
	DIST_P NON	5	14.346	**0.001**	0.106
	DIST_P HARD	5	16.851	**0.000**	0.096
	d_STR	2	28.051	**0.000**	0.029
	MAT	2	28.618	**0.000**	0.027
	LATE	2	30.126	**0.000**	0.021
	INTER	2	30.940	**0.000**	0.017
	YG	2	30.991	**0.000**	0.017
	DIST_L * LATE	4	31.950	**0.000**	0.029

	NON	2	32.667	**0.000**	0.011
	DIST_L * YG	4	33.253	**0.000**	0.024
	intercept only	1	33.283	**0.000**	0.148
	DIST_L	2	33.422	**0.000**	0.008
	HARD	2	33.863	**0.000**	0.006
	OLD	2	34.551	**0.000**	0.003
McD. ♂	**DIST_L*YG HARD**	**5**	**0.000**	**0.404**	**0.097**
	DIST_L * YG	**4**	**1.278**	**0.213**	**0.082**
	DIST_L YG	**4**	**1.681**	**0.174**	**0.071**
	DIST_L HARD	3	4.475	0.043	0.058
	YG	2	4.660	0.039	0.048
	DIST_L NON	3	4.871	0.035	0.056
	DIST_L	2	6.600	0.015	0.039
	DIST_P INTER	5	6.919	0.013	0.066
	DIST_L d_EDGE	3	7.236	0.011	0.045
	DIST_L * LATE	4	7.353	0.010	0.054
	INTER	2	7.685	0.009	0.034
	DIST_L LATE	3	7.982	0.007	0.042
	DIST_L MAT	3	8.131	0.007	0.041
	DIST_L d_STR	3	8.443	0.006	0.040
	DIST_L OLD	3	8.475	0.006	0.039
	DIST_L d_EDGE d_STR	4	10.338	0.002	0.040
	LATE	2	10.938	0.002	0.018
	MAT	2	11.876	0.001	0.014
	intercept only	1	12.843	0.001	0.100
	OLD	2	13.641	0.000	0.006
	HARD	2	13.726	0.000	0.005
	d_EDGE	2	14.786	0.000	0.000
	NON	2	14.795	0.000	0.000
	d_STR	2	14.805	0.000	0.000
	d_EDGE d_STR	2	16.728	0.000	0.001
Sheep ♀	**DIST_L MAT**	**4**	**0.000**	**0.308**	**0.104**
	DIST_P d_EDGE	**5**	**0.254**	**0.271**	**0.116**
	DIST_P d_EDGE d_STR	**6**	**1.989**	**0.114**	**0.117**
	DIST_L d_EDGE NON	4	2.716	0.079	0.101
	DIST_P NON	5	3.044	0.067	0.107
	DIST_L LATE	3	4.550	0.032	0.088

	DIST_P	4	4.943	0.026	0.094
	DIST_L d_STR	3	5.327	0.021	0.086
	DIST_P YG	6	5.835	0.017	0.098
	DIST_L OLD	3	5.917	0.016	0.084
	DIST_P INTER	5	6.400	0.013	0.096
	DIST_P HARD	5	6.452	0.012	0.096
	DIST_L * LATE	4	6.513	0.012	0.089
	DIST_L * YG	4	7.551	0.007	0.085
	MAT	2	10.152	0.002	0.063
	LATE	2	10.377	0.002	0.062
	d_EDGE d_STR	2	12.934	0.000	0.060
	NON	2	15.418	0.000	0.045
	d_EDGE	2	15.591	0.000	0.044
	YG	2	17.160	0.000	0.039
	INTER	2	19.524	0.000	0.030
	d_STR	2	20.062	0.000	0.029
	intercept only	1	26.030	0.000	0.134
	OLD	2	27.755	0.000	0.002
	HARD	2	28.265	0.000	0.000
Sheep ♂	**DIST_L LATE**	**3**	**-0.214**	**0.191**	**0.121**
	DIST_L p/y d_EDGE	**4**	**0.000**	**0.172**	**0.127**
	DIST_L MAT	**3**	**0.028**	**0.170**	**0.121**
	DIST_L d_EDGE	**3**	**0.114**	**0.163**	**0.120**
	DIST_L d_EDGE d_STR	**4**	**0.689**	**0.122**	**0.125**
	DIST_L YG	**3**	**1.350**	**0.088**	**0.116**
	DIST_L * LATE	**4**	**1.408**	**0.085**	**0.123**
	DIST_L YG LATE	**4**	**1.511**	**0.081**	**0.122**
	DIST_L * INTER	4	2.729	0.044	0.118
	DIST_L INTER	3	3.224	0.034	0.110
	DIST_L d_STR	3	4.609	0.017	0.106
	DIST_L	2	5.133	0.013	0.097
	DIST_L HARD	3	6.784	0.006	0.098
	DIST_L OLD	3	7.084	0.005	0.097
	d_EDGE d_STR	2	12.636	0.000	0.079
	d_EDGE	2	13.101	0.000	0.071
	LATE	2	13.852	0.000	0.068
	NON	2	16.963	0.000	0.058
	MAT	2	22.783	0.000	0.038

OLD	2	26.053	0.000	0.027
YG	2	26.770	0.000	0.024
d_STR	2	28.329	0.000	0.019
INTER	2	29.323	0.000	0.016
intercept only	1	31.888	0.000	0.132
HARD	2	32.958	0.000	0.003

Appendix F.

1). Pearson correlation coefficients for habitat and fragmentation variables used to model annual home range size for 11 northern spotted owls (n =11) from 2006 - 2008 in the Siskiyou Mountains of Southern Oregon. Acronyms for all covariates are described in Table 3.1. Bold values indicates coefficients with significant (p < 0.05) p- values.

	edge	TCA	MPS	NUMP	per	MNN	non	inter	old
EDGE	-	-0.10	-0.54	**0.78**	0.44	-0.18	**0.97**	0.40	**-0.75**
TCA_L		-	**0.69**	-0.33	**-0.71**	0.10	-0.20	**-0.63**	0.54
MPS_L			-	**-0.69**	**-0.91**	0.31	**-0.61**	**-0.90**	**0.92**
NUMP_L				-	**0.77**	-0.24	**0.70**	**0.79**	**-0.89**
PER_L					-	-0.22	0.49	**0.96**	**-0.91**
MNN_L						-	-0.22	-0.16	0.22
NON							-	0.41	**-0.76**
INTER								-	**-0.90**
OLD									-

2). Pearson correlation coefficients for habitat and fragmentation variables used to model breeding season home range size for 13 northern spotted owls (n = 13) from 2006 - 2008 in the Siskiyou Mountains of Southern Oregon. Acronyms for all covariates are described in Table 3.1. Bold numbering indicates coefficients with significant ($p < 0.05$) p- values.

	edge	TCA	MPS	NUMP	per	MNN	non	inter	old
EDGE	-	0.22	-0.35	**0.83**	0.15	-0.34	**0.67**	0.25	-0.44
TCA_L		-	**0.81**	-0.17	**-0.77**	-0.17	-0.30	**-0.73**	**0.61**
MPS_L			-	**-0.63**	**-0.85**	0.11	**-0.64**	**-0.86**	0.83
NUMP_L				-	0.52	-0.37	**0.81**	**0.65**	**-0.77**
PER_L					-	-0.18	**0.69**	**0.97**	**-0.92**
MNN_L						-	-0.22	-0.25	0.25
NON							-	**0.73**	**-0.89**
INTER								-	**-0.96**
OLD									-

3) Pearson correlation coefficients for habitat and fragmentation variables used to model non-breeding season home range size for 12 northern spotted owls (n = 12) from 2006 - 2008 in the Siskiyou Mountains of Southern Oregon. Acronyms for all covariates are described in table 3.1. Bold numbering indicates coefficients with significant (p < 0.05) p values.

	edge	TCA	MPS	NUMP	per	MNN	non	inter	old
EDGE	-	0.03	-0.48	**0.71**	0.35	-0.32	**0.86**	0.30	**-0.61**
TCA_L		-	0.40	-0.27	**-0.67**	-0.24	-0.18	**-0.59**	0.53
MPS_L			-	**-0.66**	**-0.79**	-0.06	**-0.53**	**-0.79**	**0.84**
NUMP_L				-	**0.82**	-0.24	**0.64**	**0.79**	**-0.89**
PER_L					-	0.03	0.45	**0.96**	**-0.93**
MNN_L						-	-0.23	-0.04	0.14
NON							-	0.32	-0.69
INTER								-	**-0.91**
OLD									-

4). Pearson correlation coefficients for habitat and fragmentation variables used to model core area size for 11 northern spotted owls (n = 11) from 2006 - 2008 in the Siskiyou Mountains of Southern Oregon. Acronyms for all covariates are described in table 3.1. Bold numbering indicates coefficients with significant (p < 0.05) p values.

	edge	TCA	MPS	NUMP	per	MNN	non	intermed	old
EDGE	-	-0.12	-0.04	0.58	0.46	-0.19	**0.88**	**0.63**	**-0.83**
TCA_L		-	**0.76**	-0.37	**-0.60**	-0.50	-0.28	-0.45	0.46
MPS_L			-	-0.39	-0.57	-0.50	-0.18	-0.44	0.42
NUMP_L				-	**0.91**	-0.08	0.36	**0.95**	**-0.88**
PER_L					-	0.06	0.31	**0.95**	**-0.86**
MNN_L						-	0.13	-0.14	0.06
NON							-	0.39	**-0.69**
INTER								-	**-0.94**
OLD									-

Appendix G.

1). Pearson correlation coefficients for mean habitat and abiotic variables used to model annual habitat selection for 11 northern spotted owls (n =11) from 2006 - 2008 in the Siskiyou Mountains of Southern Oregon. Acronyms for all covariates are described in table 3.1. Bold numbering indicates coefficients with significant ($p < 0.05$) p-values.

	NON	HARD	YG	INTER	MAT	OLD	LATE	d_EDGE	D_STR
NON	-	0.20	0.53	0.49	**-0.65**	-0.56	**-0.79**	**-0.77**	0.22
HARD		-	**0.84**	**0.88**	**-0.60**	-0.45	**-0.70**	-0.46	-0.45
YG			-	**1.00**	**-0.88**	-0.44	**-0.93**	**-0.74**	-0.28
INTER				-	**-0.86**	-0.45	**-0.91**	**-0.72**	-0.32
MAT					-	0.14	**0.89**	**0.90**	0.12
OLD						-	0.57	0.21	0.04
LATE							-	**0.84**	0.12
d_EDGE								-	0.07
d_STR									-

2). Pearson correlation coefficients for mean habitat and abiotic variables used to model breeding season habitat selection for 13 northern spotted owls from 2006 - 2008 in the Siskiyou Mountains of Southern Oregon. Acronyms for all covariates are described in table 3.1.Bold numbering indicates coefficients with significant (p < 0.05) p-values.

|	NON	HARD	YG	INTER	MAT	OLD	LATE	d_EDGE	D_STR
NON	-	0.51	**0.70**	**0.68**	**-0.77**	-0.45	**-0.85**	**-0.75**	0.03
HARD		-	**0.87**	**0.91**	**-0.73**	-0.47	**-0.84**	**-0.70**	-0.40
YG			-	**1.00**	**-0.90**	-0.43	**-0.96**	**-0.86**	-0.42
INTER				-	**-0.89**	-0.45	**-0.96**	**-0.85**	-0.42
MAT					-	0.09	**0.92**	**0.94**	0.31
OLD						-	0.49	0.13	0.03
LATE							-	**0.88**	0.28
d_EDGE								-	0.40
d_STR									-

3). Pearson correlation coefficients for mean habitat and abiotic variables used to model Non-breeding season habitat selection for 12 northern spotted owls from 2006 - 2008 in the Siskiyou Mountains of Southern Oregon. Acronyms for all covariates are described in table 3.1. Bold numbering indicates coefficients with significant (p < 0.05) p-values.
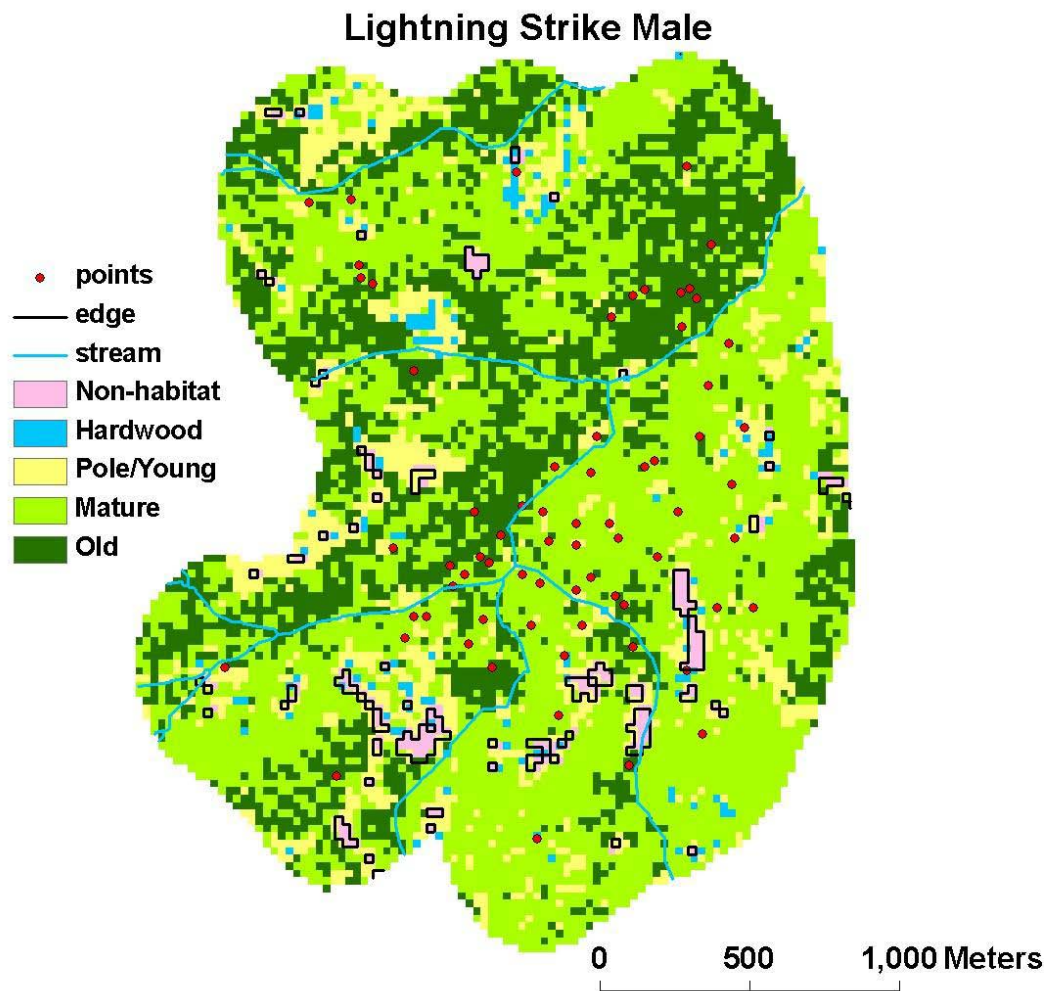
	NON	HARD	YG	INTER	MAT	OLD	LATE	d_EDGE	D_STR
NON	-	0.39	-0.04	0.25	**-0.63**	-0.36	**-0.68**	**-0.73**	0.35
HARD		-	-0.37	0.36	-0.31	-0.49	-0.47	-0.43	-0.22
YG			-	**0.73**	**-0.56**	-0.14	**-0.53**	-0.13	-0.22
INTER				-	**-0.80**	-0.49	**-0.88**	-0.45	-0.38
MAT					-	0.16	**0.91**	**0.81**	0.07
OLD						-	0.55	0.04	0.16
LATE							-	**0.70**	0.12
d_EDGE								-	-0.04
d_STR									-

Appendix H
1). Estimated 99% fixed kernel annual home range for the 500 Road Female

500 Road Female
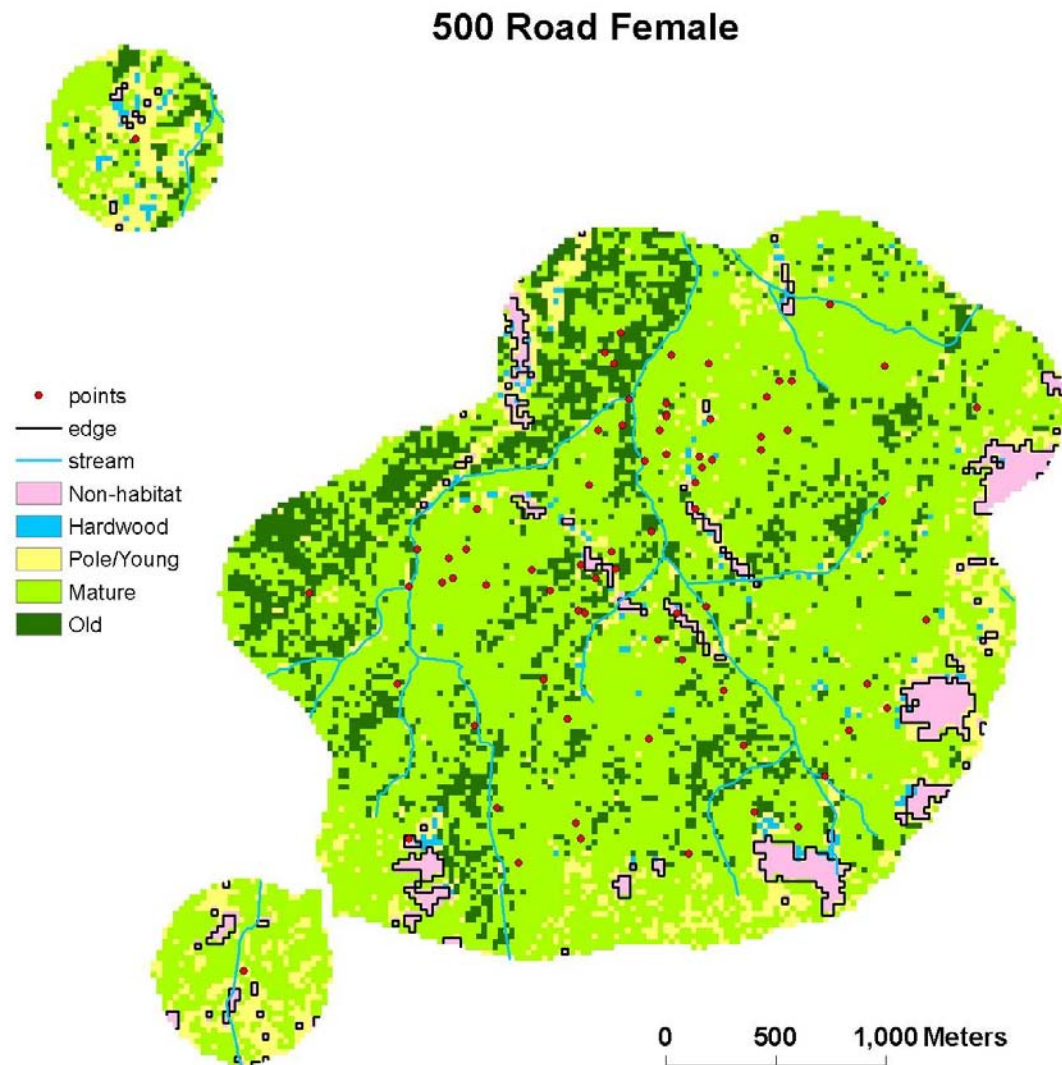
2). Estimated 99% fixed kernel annual home range for the Lightning Strike Male

Lightning Strike Male

3). Estimated 99% fixed kernel annual home range for the Bull Gap Female

Bull Gap Female

- points
- edge
- stream
- Non-habitat
- Hardwood
- Pole/Young
- Mature
- Old

0   500   1,000 Meters