Landscape level habitat alterations can have different effects on different species. Species that are more highly specialized for some important aspect of their natural history are expected to be more sensitive to habitat alteration than are those that are generalists. The Northern Pygmy-Owl (*Glaucidium gnoma*) has been suggested as a research and conservation priority due to the presumed negative effects of recent habitat alterations such as forest fragmentation and partial forest clearing. However, Pygmy-Owls are considered to be habitat and food generalists and may have an affinity for forest openings and edges. We tracked nine radio-marked male Northern Pygmy-Owls during the breeding seasons of 1996 and 1997 on the Olympic Peninsula, WA to examine three aspects of their natural history: cover type selection for foraging, nest location with respect to edges and dietary composition. Predictions of the generalist model were that use of resources would reflect availability. Cover types were divided into seven categories generally reflective of seral stage development. Individual owls were located an average of 3.7 times per week (45
times overall) and cover types used for foraging were compared to those available within home ranges. Pygmy-Owls used all of the available cover types for foraging but preferred structurally complex and mature cover types over structurally simple and young cover types. There was no evidence of preferential use of edges for foraging, but there was suggestive evidence that nests tended to be near edges. The diet was dominated by birds and mammals. Estimates of dietary composition varied depending on the method used. Pygmy-Owls appear to forage on those prey species that are most abundant or most easily captured. Our results suggest that Northern Pygmy-Owls may be relatively insensitive to habitat alterations affecting prey species assemblages and relatively more sensitive to habitat alterations affecting structural characteristics.
Habitat Selection by Northern Pygmy-Owls on the Olympic Peninsula, WA.

by

Alan R. Giese

A THESIS

submitted to

Oregon State University

In partial fulfillment of
The requirements for the
Degree of

Master of Science

Presented May 14, 1999
Commencement June 2000
Master of Science thesis of Alan R. Giese presented on May 14, 1999

APPROVED:

Signature redacted for privacy.
Major Professor, representing Wildlife Science

Signature redacted for privacy.
Chair of Department of Fisheries and Wildlife

Signature redacted for privacy.
Dean of Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

/ \ \\
Signature redacted for privacy.

/ Alan R. Giese, Author
ACKNOWLEDGMENTS

This research was made possible by a grant from the Washington State Department of Natural Resources (FY97-021) and generous in-kind support from the United States Forest Service’s Pacific Northwest Research Station. I would like to thank Eric Forsman for being my boss, mentor and friend. Elissa Arnheim’s field assistance was worth more than her paycheck reflected, and her companionship was invaluable. Volunteers from the Sequim Audubon Club cheerfully watched nests from dawn until dusk, and only occasionally glimpsed owls. I am grateful to D. Erran Seaman for reviews of the study proposal in its infancy. Dr. Fred Ramsey and Dr. Robert Jarvis served on my graduate committee and provided helpful guidance. Ellen Burnes proofread each draft, improving clarity. I would like to thank my parents for giving me strength and my fellow graduate students for making this fun. Lastly, I owe a special debt of gratitude to Dave Manson, the other half of the A-team.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>METHODS</td>
<td>4</td>
</tr>
<tr>
<td>Study Area</td>
<td>4</td>
</tr>
<tr>
<td>Detection and Capture of Owls</td>
<td>6</td>
</tr>
<tr>
<td>Patch Selection for Foraging</td>
<td>8</td>
</tr>
<tr>
<td>Nest Site Selection</td>
<td>13</td>
</tr>
<tr>
<td>Dietary Composition</td>
<td>13</td>
</tr>
<tr>
<td>RESULTS</td>
<td>15</td>
</tr>
<tr>
<td>Patch Selection for Foraging</td>
<td>15</td>
</tr>
<tr>
<td>Nest Site Selection</td>
<td>18</td>
</tr>
<tr>
<td>Dietary Composition</td>
<td>19</td>
</tr>
<tr>
<td>DISCUSSION</td>
<td>21</td>
</tr>
<tr>
<td>Home Range Size</td>
<td>21</td>
</tr>
<tr>
<td>Patch Selection for Foraging</td>
<td>21</td>
</tr>
<tr>
<td>Nest Site Selection</td>
<td>27</td>
</tr>
<tr>
<td>Dietary Composition</td>
<td>28</td>
</tr>
<tr>
<td>Summary</td>
<td>31</td>
</tr>
<tr>
<td>BIBLIOGRAPHY</td>
<td>32</td>
</tr>
</tbody>
</table>
LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>Log-ratio differences (x, SE) and relative ranks for cover type selection by Northern Pygmy-Owls on the Olympic Peninsula, WA, 1996-1997, with Late Seral and Mixed Forest cover types lumped into Complex.</td>
<td>17</td>
</tr>
<tr>
<td>3.</td>
<td>Log-ratio differences (x, SE) and relative ranks for cover type selection by Northern Pygmy-Owls on the Olympic Peninsula, WA, 1996-1997, with Late Seral and Mixed Forest treated separately.</td>
<td>18</td>
</tr>
<tr>
<td>5.</td>
<td>Species of mammals and birds identified as prey of Northern Pygmy-Owls on the Olympic Peninsula, WA, 1996-1997.</td>
<td>20</td>
</tr>
</tbody>
</table>
DEDICATION

This thesis is dedicated to Jim Shear and the memory of Jacques Yves Cousteau,

each inspired me in their own way.
INTRODUCTION

Forest ecosystems of the western United States have undergone accelerating anthropogenic alteration during the last century. Resultant changes include reduced late successional forest cover, increased discontinuity among cover types, a proliferation of discrete edges, fewer large snags and changes in species composition (FEMAT 1993). The effects of these changes on animals in upper trophic levels are difficult to predict or assess. Declines in several well known species such as the Northern Spotted Owl (*Strix occidentalis*), Marbled Murrelet (*Brachyramphus marmoratus*) and Pileated Woodpecker (*Dryocopus pileatus*) have been attributed to the destruction of old-growth and removal of coarse woody debris (U.S. Department of Interior 1992, Bull and Jackson 1995, Gaston and Jones 1998). However, all species are not expected to react in the same way. Some species, such as the Barred Owl (*Strix varia*) and members of the family *Corvida* have expanded their ranges in recent years and may have benefited from forest alterations (Andren 1992, Dark et al. 1998).

The ability to predict a given species' reaction to habitat alterations would facilitate conservation planning. Unfortunately, manipulative experiments to examine the effects of landscape level changes on animal populations are impractical. In the absence of such specific information, prediction may be based on broad ecological
principles. An example is that of the generalist-specialist continuum; species that are specialists in some important aspect of their natural history are expected to be more sensitive to habitat alteration than those that are generalists. Respective examples include the Northern Spotted Owl and Barred Owl mentioned above. Similarly, a given species is expected to be more sensitive to habitat changes affecting specialized aspects of its natural history than changes affecting aspects for which it is a generalist. For example, obligate cavity nesting birds may be highly sensitive to changes in cavity availability, but relatively unaffected by changes affecting foraging cover or food type. Conservation measures targeted at those areas where species are most sensitive have the greatest promise of success.

The Northern Pygmy-Owl (*Glaucidium gnoma*) is an obligate cavity nester and secondary consumer inhabiting coniferous forests throughout the western United States (Bent 1938, AOU 1983). Concerns regarding its conservation status have been raised due to recent fragmentation and loss of late successional forests (Marshall 1992, Bednarz and Hoffman 1993). However, it is considered by some to be a food and habitat generalist (Hayward and Garton 1988, Reynolds et al. 1989) and several authors have suggested that Northern Pygmy-Owls do well in fragmented forests. Johnsgard (1988) suggested that partial forest clearing would improve foraging opportunities, Bent (1938) stated that nests are preferentially located near edges and Verner and Boss (1980) and Webb (1982) refer to an association with meadows and openings. Unfortunately, few field studies have focused on the Northern Pygmy-Owl (but see Holt and Leroux 1996) and the majority of available information is in the form
of anecdotal observations. Anticipating the reaction of this species to habitat alteration is problematic due to a general lack of knowledge and conflicts in the available information.

We radio-marked male Northern Pygmy-Owls during two nesting seasons on the Olympic Peninsula, WA to examine habitat selection for three important aspects of their natural history: third-order selection of cover types for foraging (Johnson 1980), nest site selection and dietary composition. Our working hypothesis was that Northern Pygmy-Owls were generalists. As such, they were expected to access resources in proportion to their availability rather than show strong preferences. We tested the hypotheses that owls would use all or most of the available cover types for foraging and that nests would be located at random with respect to forest edges. We also described dietary composition to address the prediction that diet would reflect availability.
METHODS

STUDY AREA

The study was conducted on the Olympic Peninsula, north of Olympic National Park and West of Port Angeles, WA. The area is hilly to mountainous, ranging in elevation from 50 - 1350 m. The vegetation is dominated by coniferous forests of Western Hemlock (*Tsuga heterophylla*) in association with Douglas-fir (*Pseudotsuga menziesii*), Western Red-cedar (*Thuja plicata*) and Silver Fir (*Abies amabilis*) (Henderson et al. 1989). Valley bottoms typically include mixed forests of conifers, Bigleaf Maple (*Acer macrophyllum*) and Red Alder (*Alnus rubra*). Logged areas are typically replanted with Douglas-fir. Mean annual precipitation varies from 150 cm at the eastern end of the study area to 250 cm at the western end (Henderson et al. 1989). Ownership in the study area is a mix of United States Forest Service, Washington State Department of Natural Resources and private land. A history of clear-cut logging has resulted in a mosaic pattern of generally discrete cover-type patches.

We divided cover types into seven categories that were generally reflective of seral stage development (Figure 1). Cover type names are capitalized throughout this paper for clarity. Patches of Open cover were typically recent clear-cuts and were characterized by ample open ground, with few trees to provide elevated perches. Patches of Young, Medium and Mature cover were even-aged conifer stands that typically resulted from older clear-cuts replanted with Douglas-fir, but also resulted
from natural disturbances such as storms or fire. Young patches were those where young trees provided elevated perches but greater than 25% of the ground remained “open.” Medium patches were those where the regenerating trees formed a closed canopy close to the ground. Mature cover differed from Medium in that the tree crowns were higher, resulting in a generally open understory. Patches of Late Seral and Mixed Forest cover were characterized by high structural diversity. Late Seral patches were dominated by conifer species and occurred in areas not subject to recent catastrophic disturbance while Mixed Forest patches included both conifer and deciduous tree species and occurred in areas such as river bottoms where flooding and erosion are frequent. Edge cover was defined as a strip extending 30 m on either side of the interface between patches of Open or Young cover and patches of any of the other cover types. Although the cover type classifications were generally reflective of seral stage development, the determination of cover type for each patch was based on structural characteristics rather than age.

DETECTION AND CAPTURE OF OWLS

We used acoustic-lure surveys to detect Northern Pygmy-Owls during April and May of 1996 and 1997. Surveys were conducted while walking logging roads. Surveys typically began at sunrise and continued until an owl was detected, the road system was exhausted, or we were exhausted. Our prior experience indicated that owls detected in the above manner would predominately be males (unpublished data). Male Pygmy-Owls deliver food to the nest while the female incubates and broods. By
working with males during the breeding season we sought to focus on patch selection for foraging and avoid confounding the data with differential selection for multiple behavior types.

We attempted to capture each owl detected. Owls were generally captured with a pair of mist nets set in a ‘V’ formation. A live, domestic House Mouse (*Mus musculus*) or Zebra Finch (*Taeniopygia guttata*) was placed between the nets, toward the apex of the ‘V,’ as a lure. We used 50 denier, 38 mm mist nets. On two occasions owls were captured with a noose pole that was constructed by affixing a noose (flyfishing line) to the end of a telescoping fishing pole.

Owls were banded with a USFWS #3A band, and fitted with a Holohil Systems Ltd. (Carp, Ontario) BD-2G radio transmitter. Transmitters were attached using a back-pack style harness made of 5 mm wide tubular Teflon ribbon (Bailey Ribbon Mills, Bailey, PA). Transmitters were removed at the end of the season in 1996. In 1997, harnesses were designed to fall off over time and owls were not retrapped. Transmitters weighed approximately 2.5 gm, including harness. This corresponded to 4.6% and 3.4% of minimum and maximum body masses respectively for Northern Pygmy-Owls as reported by Earhart and Johnson (1970).

Classifications of sex and nesting status were based on behavioral observations when possible. Owls observed delivering food to another adult owl were classified as males. Owls observed incubating, brooding or receiving food from another owl were classified as females. Observations of copulatory behavior were also used to determine sex. In two cases we were unable to determine sex from behavioral observations. One
of these owls was classified as male based on its mass (< 64 gm) while the other was intermediate between maximum male and minimum female masses (74 gm and 64 gm respectively, Earhart and Johnson 1970) and could not be classified. Male owls observed delivering food to a nest after the onset of incubation, or to juveniles, were classified as nesting. Behavioral observations were recorded daily in field journals.

PATCH SELECTION FOR FORAGING

Used cover

We attempted to locate male owls daily between April and July. All locations were determined by homing in on an owl with a hand-held TR-2 receiver and RA-14K antenna (Telonics Inc., Mesa, AZ) until the owl was located visually, or until triangulation indicated that the owl was directly overhead. We varied the order in which owls were located such that locations for each owl ranged over all times of the day. We occasionally located the same owl twice in the same day (5.4% of all locations). In such cases consecutive locations were separated by a minimum of five hours.

The geographic position and cover type for each owl location were recorded in the field on paper copies of aerial photographs. Geographic positions were later digitized in ARC/INFO geographic information system (GIS)(ESRI, Redlands, CA). When an owl was located < 50 m from an edge, the distance to that edge was measured with a tape measure. Owls that were < 30 m from an edge were classified as using
edge cover. Locations that were < 50 m from an active nest were not included in the analysis because we felt that those locations likely represented visits to the nest rather than foraging locations.

Available cover

The area "available" to each owl was defined as the area within the minimum convex polygon (MCP) defining its home range. We used program CALHOME (Kie et al. 1996) and ARC/INFO software to generate home ranges and delineate cover type patches. Cover type classifications were based on aerial photographs and field observation. All patches were visited at least once to determine patch characteristics.

In general, owls in this study occupied well-defined home ranges. However, individuals were occasionally observed to move large distances and occupy an area for a brief period (e.g. several days) before either moving on or returning to their core use area. In order to avoid erroneously high estimates of home range due to what was presumably exploratory behavior, we made subjective decisions to exclude from home range estimation those points that seemed to characterize temporary forays. Points removed in this manner were not used more than once and were separated from the core use area by large tracts of land where we never found the owl.
Accuracy of radio-locations

Pygmy-Owls appear undisturbed by the presence of humans (pers. obs.). We saw no indication that owls moved in response to our approach. Therefore, we believe that our visual locations of owls represent actual foraging locations. To estimate the error associated with triangulation locations we placed 12 transmitters in trees and had two field assistants attempt to pinpoint each transmitter. The slope distance between the estimated and true locations were recorded by ARG. The relationship between transmitter height and estimated error was examined with linear regression.

Statistical analyses

We used compositional analysis (Aebischer et al. 1993) to compare relative preferences among cover types. Compositional analysis was chosen because it treats the individual as the sampling unit, accounts for lack of independence among proportions and allows unique availability for each individual. The proportional use and availability were calculated for each owl and program RESELECT (Leban, Univ. of Idaho, 1994) was used to run the analyses. We report the results of the F-test for study-wide deviation from random usage and the results of pairwise t-tests for significant differences between ranks.
Missing values

We dealt with missing values following the guidelines of Aebischer et al. (1993). Missing values occurred when availability was zero (a cover type did not occur in a home range: Type I), or when use was zero (no recorded use of a cover type: Type II). Type I missing values were associated with the Open cover type while type II missing values were associated with Open, Young, Medium, Edge and Mixed Forest cover types (Table 1). Type I missing values were eliminated by lumping Open and Young cover into a single category, Young. Use patterns for these two cover types were similar, as were their structural characteristics. Several type II missing values occurred due to zero use of Mixed Forest cover. These were initially eliminated by lumping Mixed Forest and Late Seral cover into a single category, Complex. Lumping these two types was based primarily on their shared structural complexity, but use of Mixed Forest cover was variable. In an attempt to tease out any differential preferences between Late Seral and Mixed Forest cover the data were reanalyzed treating those two types separately. Type II missing values not eliminated by lumping cover types were replaced with 0.0016, which was an order of magnitude smaller than the smallest recorded proportional use.

Nine males with 32 or more locations each were used in the analysis (Table 1). All males except Owl 4 were confirmed to be nesting. Because the inclusion of non-nesting owls in the sample weakens confidence in the assumption that all locations are foraging locations, we ran the analyses with and without Owl 4. Removal of Owl 4 caused the rank order of two cover types, Edge and Mature, to be switched. Pairwise
t-tests indicated that these ranks did not differ \( t = 0.18, P = 0.86 \). In addition, the effect of removing Owl 4 was the same whether Late Seral and Mixed Forest cover types were lumped or treated separately. Therefore, the results are reported with Owl 4 included.

**TABLE 1.** Proportions of available cover and use locations for Northern Pygmy-Owls on the Olympic Peninsula, WA, 1996 - 1997. The total area available to each owl was defined by its minimum convex polygon home range.

<table>
<thead>
<tr>
<th>Owl</th>
<th>Open</th>
<th>Young</th>
<th>Medium</th>
<th>Mature</th>
<th>Late Seral</th>
<th>Mixed Forest</th>
<th>Edge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.00</td>
<td>0.17</td>
<td>0.14</td>
<td>0.18</td>
<td>0.25</td>
<td>&lt;0.01</td>
<td>0.25</td>
</tr>
<tr>
<td>2</td>
<td>&lt;0.01</td>
<td>0.10</td>
<td>0.13</td>
<td>0.02</td>
<td>0.58</td>
<td>0.01</td>
<td>0.16</td>
</tr>
<tr>
<td>3</td>
<td>0.07</td>
<td>0.24</td>
<td>0.01</td>
<td>0.07</td>
<td>0.34</td>
<td>0.04</td>
<td>0.24</td>
</tr>
<tr>
<td>4</td>
<td>0.00</td>
<td>0.03</td>
<td>0.05</td>
<td>0.48</td>
<td>0.23</td>
<td>0.08</td>
<td>0.12</td>
</tr>
<tr>
<td>5</td>
<td>&lt;0.01</td>
<td>0.08</td>
<td>0.10</td>
<td>0.07</td>
<td>0.49</td>
<td>&lt;0.01</td>
<td>0.26</td>
</tr>
<tr>
<td>6</td>
<td>0.00</td>
<td>0.04</td>
<td>0.03</td>
<td>0.50</td>
<td>0.16</td>
<td>0.11</td>
<td>0.17</td>
</tr>
<tr>
<td>7</td>
<td>0.03</td>
<td>0.12</td>
<td>0.06</td>
<td>0.21</td>
<td>0.27</td>
<td>0.01</td>
<td>0.30</td>
</tr>
<tr>
<td>8</td>
<td>&lt;0.01</td>
<td>0.02</td>
<td>0.08</td>
<td>0.21</td>
<td>0.34</td>
<td>0.11</td>
<td>0.24</td>
</tr>
<tr>
<td>9</td>
<td>0.08</td>
<td>0.31</td>
<td>0.02</td>
<td>0.07</td>
<td>0.18</td>
<td>0.05</td>
<td>0.29</td>
</tr>
<tr>
<td>Used</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.00</td>
<td>0.02</td>
<td>0.02</td>
<td>0.24</td>
<td>0.59</td>
<td>0.00</td>
<td>0.13</td>
</tr>
<tr>
<td>2</td>
<td>0.00</td>
<td>0.00</td>
<td>0.13</td>
<td>0.03</td>
<td>0.76</td>
<td>0.03</td>
<td>0.05</td>
</tr>
<tr>
<td>3</td>
<td>0.00</td>
<td>0.05</td>
<td>0.00</td>
<td>0.02</td>
<td>0.74</td>
<td>0.00</td>
<td>0.19</td>
</tr>
<tr>
<td>4</td>
<td>0.00</td>
<td>0.00</td>
<td>0.06</td>
<td>0.53</td>
<td>0.25</td>
<td>0.11</td>
<td>0.06</td>
</tr>
<tr>
<td>5</td>
<td>0.00</td>
<td>0.00</td>
<td>0.04</td>
<td>0.11</td>
<td>0.56</td>
<td>0.00</td>
<td>0.30</td>
</tr>
<tr>
<td>6</td>
<td>0.00</td>
<td>0.00</td>
<td>0.05</td>
<td>0.23</td>
<td>0.28</td>
<td>0.15</td>
<td>0.28</td>
</tr>
<tr>
<td>7</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.15</td>
<td>0.56</td>
<td>0.00</td>
<td>0.29</td>
</tr>
<tr>
<td>8</td>
<td>0.00</td>
<td>0.00</td>
<td>0.05</td>
<td>0.04</td>
<td>0.53</td>
<td>0.21</td>
<td>0.18</td>
</tr>
<tr>
<td>9</td>
<td>0.02</td>
<td>0.08</td>
<td>0.02</td>
<td>0.15</td>
<td>0.24</td>
<td>0.21</td>
<td>0.29</td>
</tr>
</tbody>
</table>
NEST SITE SELECTION

The distance from each nest to the nearest edge \((d_n)\) was measured in the field with a 50 m tape. This distance was compared to the mean distance-to-nearest-edge for 100 random points in the same stand \((\bar{d}_r)\). Random points and associated distances were generated using ARC/INFO GIS. Nest stands ended at cover type breaks. In cases where patches of like cover type were connected by narrow corridors of unbroken cover we truncated the nest stand at the narrowest point of the connecting corridor. A studentized Z-statistic was calculated for each nest (Eq. 1)

\[
Z = \frac{(d_n - \bar{d}_r)}{s_r}
\]

(1)

where \(s_r\) is the standard deviation of the random point distances (Ramsey, pers. com.). This standardizes to account for patches of variable size. A one-tailed t-test was used to test \(H_0: Z = 0\) against \(H_a: Z < 0\).

DIETARY COMPOSITION

Diet data were collected opportunistically. Pellets, pellet fragments and prey remains were collected and field observations of owls with prey were recorded. The bulk of the diet data were collected near nests. However, we also frequently observed free ranging owls carrying prey or regurgitating pellets. Prey items were identified to species when possible. In many cases, especially when owls were flying with prey, identification was only possible at the class level.
Pellets and pellet fragments collected in close temporal and spatial proximity were combined to reduce double counting of prey items. Pellet contents were sorted by hand and identifiable remains were classified and counted. Classification was facilitated by comparisons to museum collections at Oregon State University. The number of prey items represented by a pellet or combined collection of pellets was recorded as the minimum number of prey items that could result in the observed assortment of remains. The presence of insect exoskeleton in a pellet was recorded as a single insect prey item. In only one case was there enough exoskeleton in a pellet to suggest that multiple insects had been consumed. Due to the difficulty of identifying specific body parts from exoskeleton remains we did not attempt to estimate the number of insects consumed in the latter case and 1 insect prey item was recorded. We counted the number of prey items identified as mammal, bird or insect and present summaries of these categories.
RESULTS

We radio-marked 17 Northern Pygmy-Owls over 2 field seasons, including 9 males that were tracked during the nesting period. Of those 9 males, 6 nested and fledged young, 1 nested and failed, 1 nested and was thought to have failed and the nesting status of 1 was undetermined. Of the remaining 8 owls, 4 left the area, 2 died, 1 was female, and 1 was unknown sex and unknown nesting status.

On average, radio-marked males \((n = 9)\) were located 3.7 times per week \((\text{range} = 1.9 - 4.4)\). Total locations per owl averaged 45 \((\text{range} = 32 - 66)\). The mean size of the MCP home range was 296 ha \((\text{range} = 169 - 561, \text{SE} = 42, n = 9)\). Home range size increased with number of locations. However, the mean home range size calculated with only the first 32 locations \((\text{minimum number of locations for any owl used in analyses})\) was 257 ha \((\text{SE} = 37, n = 9)\), suggesting that our home range estimates represented adequate determinations of available cover.

PATCH SELECTION FOR FORAGING

Accuracy of radio-telemetry locations

Of the total locations, 49% were confirmed visually and 51% were estimated by triangulation, without seeing the owl. Mean error for transmitters placed between 14 - 45 m high in trees was 11.58 m \((\text{range} = 2 - 33, \text{SE} = 2.31, n = 12)\). Linear
regression of error \((e)\) on transmitter height indicated that error increased as height \((h)\)
increased (Eq. 2).

\[ e = 0.49h - 2.63 \]  

(2)

**Compositional analysis**

Use of cover types for foraging was nonrandom regardless of whether late and mixed forest cover were lumped \((F_{4,5} = 29.41, P < 0.003)\) or treated separately \((F_{5,4} = 14.35, P < 0.03)\). Foraging behavior was observed in all available cover types, indicating that observations in rarely used cover types cannot be attributed to instances of owls caught in transit between patches of favored cover types.

When Late Seral and Mixed Forest cover types were lumped into a single category (Complex), it was the most preferred cover type followed by Mature, Edge, Medium and Young cover types (Table 2). Confidence in the rank assignment for Young cover was high, as indicated by consistently low \(P\)-values for pairwise comparisons of rank with other cover types. Confidence in the rank for Complex cover was also high whereas confidence in the relative ranks of the remaining three cover types, Mature, Edge and Medium was low (Table 2).
When Late Seral and Mixed Forest cover were treated separately, Late Seral was the most preferred cover type, followed by Mature, Edge, Mixed Forest, Medium and Young (Table 3). Confidence in the rank assignment for Young cover was again high while confidence in the remaining rank assignments was variable. Relative preference for Mixed Forest cover was not different than any cover type except Young at \( \alpha = 0.05 \). Confidence in the rank assignment for Late Seral cover was high relative to Young, Medium and Edge, but low relative to Mature and Mixed Forest cover. Confidence in the relative ranks of Medium, Edge and Mature cover was low (individual \( P \)-values in Table 3).

TABLE 2. Log-ratio differences (x, SE) and relative ranks for cover type selection by Northern Pygmy Owls on the Olympic Peninsula, WA, 1996-1997 with Late Seral and Mixed Forest cover types lumped into Complex. A positive difference between log-ratios indicates that preference for the row cover type exceeded that of column cover type. Cover types are ranked from most (4) to least (0) preferred by adding the number of positive log-ratio differences across rows.

<table>
<thead>
<tr>
<th>Cover type</th>
<th>Young</th>
<th>Medium</th>
<th>Edge</th>
<th>Mature</th>
<th>Complex</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young</td>
<td>-2.02** (0.51)</td>
<td>2.02** (0.51)</td>
<td>2.68** (0.40)</td>
<td>2.74** (0.47)</td>
<td>3.44** (0.33)</td>
<td>0</td>
</tr>
<tr>
<td>Medium</td>
<td>-2.68** (0.40)</td>
<td>0.66 (0.48)</td>
<td>-0.72 (0.51)</td>
<td>-1.42* (0.49)</td>
<td>1.42* (0.51)</td>
<td>1</td>
</tr>
<tr>
<td>Edge</td>
<td>-2.74** (0.47)</td>
<td>0.72 (0.51)</td>
<td>0.06 (0.35)</td>
<td>-0.70 (0.31)</td>
<td>0.70 (0.31)</td>
<td>2</td>
</tr>
<tr>
<td>Mature</td>
<td>-3.44** (0.33)</td>
<td>1.42* (0.49)</td>
<td>0.76** (0.17)</td>
<td>0.70 (0.31)</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

P-values from two-tailed t-tests for pairwise differences in log-ratios; *, \( P < 0.05 \); **, \( P < 0.005 \).
TABLE 3. Log-ratio differences (x, SE) and relative ranks for cover type selection by Northern Pygmy Owls on the Olympic Peninsula, WA, 1996-1997, with Late Seral and Mixed Forest cover types treated separately. A positive difference between log-ratios indicates that preference for the row cover type exceeded that of column cover type. Cover types are ranked from most (5) to least (0) preferred by adding the number of positive log-ratio differences across rows.

<table>
<thead>
<tr>
<th>Cover type</th>
<th>Young</th>
<th>Medium</th>
<th>Mixed Forest</th>
<th>Edge</th>
<th>Mature</th>
<th>Late Seral</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young</td>
<td>-3.05*</td>
<td>-3.15*</td>
<td>-4.21**</td>
<td>-4.28**</td>
<td>-4.97**</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.04)</td>
<td>(1.17)</td>
<td>(0.73)</td>
<td>(0.74)</td>
<td>(0.67)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>3.05*</td>
<td>-0.10</td>
<td>-1.17</td>
<td>-1.23</td>
<td>-1.92*</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.04)</td>
<td>(0.44)</td>
<td>(0.77)</td>
<td>(0.74)</td>
<td>(0.80)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed Forest</td>
<td>3.15*</td>
<td>0.10</td>
<td>-1.07</td>
<td>-1.13</td>
<td>-1.82</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.17)</td>
<td>(0.44)</td>
<td>(0.87)</td>
<td>(0.84)</td>
<td>(0.89)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edge</td>
<td>4.21**</td>
<td>1.17</td>
<td>1.07</td>
<td>-0.06</td>
<td>-0.75**</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.73)</td>
<td>(0.77)</td>
<td>(0.87)</td>
<td>(0.35)</td>
<td>(0.17)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mature</td>
<td>4.28**</td>
<td>1.23</td>
<td>1.13</td>
<td>0.06</td>
<td>-0.69</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.74)</td>
<td>(0.74)</td>
<td>(0.84)</td>
<td>(0.35)</td>
<td>(0.33)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Late Seral</td>
<td>4.97**</td>
<td>1.92*</td>
<td>1.82</td>
<td>0.75**</td>
<td>0.69</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.67)</td>
<td>(0.80)</td>
<td>(0.89)</td>
<td>(0.17)</td>
<td>(0.33)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

P-values from two-tailed t-tests for pairwise differences in log-ratios; *, P < 0.05; **, P < 0.005.

NEST SITE SELECTION

We located eight nests over four years from 1994 - 1997 including two years of pilot study prior to this study. All nests were in cavities excavated by woodpeckers. The mean distance from nests to the nearest edge was 59 m (range = 5 - 128, SE = 16.0, n = 8). The mean studentized difference between nests and random points for distance to nearest edge was Z = -0.51 (SE = 0.31, n = 8). There was suggestive evidence that nests were located closer to edges than were random points (One-tailed t7 = 1.64, P = 0.07).
We observed Pygmy-Owls with prey 79 times and we were able to identify the prey item as a mammal, bird or insect in 59 cases. We also identified 83 prey items from 37 pellets, and eight prey items from remains found near nests. The estimate of dietary composition varied depending on which method of data collection was used. Pellet analysis and visual analyses of owls with prey both indicated that mammals and birds predominated in the diet but pellet analysis indicated a higher proportion of insects than did visual analysis (Table 4). The small sample of prey items found near nests included mostly feathers from birds (Table 4). We identified 10 species of birds and 5 species of mammals from pellets, direct observations and prey remains (Table 5).

<table>
<thead>
<tr>
<th>Method</th>
<th>n</th>
<th>Birds</th>
<th>Mammals</th>
<th>Insects</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct observation</td>
<td>59</td>
<td>45.8</td>
<td>50.8</td>
<td>3.4</td>
<td>100.0</td>
</tr>
<tr>
<td>Pellet analysis</td>
<td>83</td>
<td>59.0</td>
<td>18.1</td>
<td>22.9</td>
<td>100.0</td>
</tr>
<tr>
<td>Prey remnants</td>
<td>8</td>
<td>12.5</td>
<td>87.5</td>
<td>0.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Mammals</th>
<th>Birds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coast Mole (Scapanus orarius)</td>
<td>Brown Creeper (Certhia americana)</td>
</tr>
<tr>
<td>Deer Mouse (Peromyscus maniculatus)</td>
<td>Chestnut-backed Chickadee (Parus rufuscens)</td>
</tr>
<tr>
<td>Red-backed Vole (Clethrionomys gapperi)</td>
<td>Dark-eyed Junco (Junco hyemalis)</td>
</tr>
<tr>
<td>Shrew (Sorex spp.)</td>
<td>Golden-crowned Kinglet (Regulus satrapa)</td>
</tr>
<tr>
<td>Townsend’s Chipmunk (Tamias townsendii)</td>
<td>Golden-crowned Sparrow (Zonotricia atricapilla)</td>
</tr>
<tr>
<td>Vole (Microtus sp.)</td>
<td>Gray Jay (Perisoreus canadensis)</td>
</tr>
<tr>
<td></td>
<td>Thrush (Catharus sp.)</td>
</tr>
<tr>
<td></td>
<td>Varied Thrush (Ixoreus naevius)</td>
</tr>
<tr>
<td></td>
<td>White-crowned Sparrow (Zonotricia leucophrys)</td>
</tr>
<tr>
<td></td>
<td>Winter Wren (Troglodytes troglodytes)</td>
</tr>
</tbody>
</table>
DISCUSSION

HOME RANGE SIZE

We know of no other study that has estimated home range size for Northern Pygmy-Owls. Hayward and Garton (1988) used a circle of radius 0.5 km (area = 79 ha), based on their own unpublished data, as a standard home range for the Northern Pygmy-Owl. This value is about a quarter of the mean home range size in our study. However, their purpose was not to estimate home range size, but rather to delineate an area for vegetation sampling around potential nests. Moreover, landscape level anthropogenic disturbance was minimal in their study area, whereas ours was characterized by heavy disturbance. Owls in fragmented areas may increase their MCP home range size in order to access diffuse patches of preferred cover types (Carey and Peeler 1995). Estimates of home range size for the Eurasian Pygmy-Owl range from 20 ha to 400 ha (Mikkola 1983, Cramp 1985). Mean MCP territory size for 50 pairs in Germany was 140 ha (Scherzinger 1974).

PATCH SELECTION FOR FORAGING

Although Pygmy-Owls used all available cover types, differences in relative preferences among cover types were not consistent with the pattern predicted for a habitat generalist. Complex and Mature were the most preferred types while Young was the least preferred type. Mature, Edge and Medium cover types occupied the
middle of the preference structure, with relative ranks that were not statistically
distinguishable from one another. Among structurally simple cover types, relative
ranks followed seral stage development, with older seral stages having greater relative
preference.

When lumped together, Late Seral and Mixed Forest cover types (Complex
cover) were preferred relative to other cover types examined. When treated separately,
Late Seral was the most preferred cover type while Mixed Forest cover was ranked
fourth. Additionally, the rank assignment for Mixed Forest cover was not statistically
distinguishable from any other cover type except Young. Low overall confidence in
the relative rank of Mixed Forest cover appears to be an artifact of the sampling
procedure and treatment of missing values. Four owls had less than two percent of
their available cover represented by Mixed Forest cover. Thus, use of Mixed Forest
cover by these owls is likely to be a rare event, even if Mixed Forest cover has a
relatively high preference. Our sampling procedure (point-in-time sampling) was poor
at detecting rare events. If no use was detected (i.e. Owls 1, 5 and 7) an artificially
small value of proportionate use was inserted, making the resultant selection ratio
smaller than that for each cover type with detected use. If, on the other hand, use was
detected (i.e. Owl 2), low proportionate availability in the denominator resulted in a
high preference ratio. In the case of Owl 2, a single use location in mixed cover
resulted in a preference ratio higher than for any other cover type. This variability in
selection ratios appears to prevent compositional analysis from ranking the relative
preference of Mixed Forest cover with high confidence. We inspected the data for
owls that had five percent or more of their available cover as Mixed Forest and noted that in all cases selection ratios for Late Seral and Mixed Forest cover were similar. Our decision to lump Late Seral and Mixed Forest cover, although precipitated by the need to treat missing values, was based primarily on their structural similarities. The close alignment of use patterns for those owls with a reasonable amount of available Mixed Forest cover further supports this decision.

Young, and Open cover types were the least preferred. Lumping these categories was again based primarily on structural similarities. In separating these cover types initially, we felt that they differed primarily in the availability of elevated perches; young forests had many small trees, whereas recent clear-cuts lacked trees greater than 1.5 m tall. However, perches existed in recent clear-cuts in the form of isolated trees and "slash," and we observed Pygmy-Owls foraging from these structures. Thus, the chief structural difference that we felt existed between Open and Young cover does not appear to exist from the perspective of a Pygmy-Owl. Again, inspection of the data indicated that use patterns for these cover types were similar.

Although it has been suggested in the literature that the Northern Pygmy-Owl is associated with edges (Johnsgard 1988 and references therein), we found no evidence that edges were preferred. Compositional analysis indicated that Edge was ranked third out of five categories and that this rank was not distinguishable from Medium or Mature cover types. If owls select areas near openings and edges, presumably they use those cover types for something. Foraging seems like the most likely behavior to take place in openings or along edges, but our data are consistent with a pattern of foraging
without respect to edges. Owls may select home ranges in areas with clearings (second-order selection) and Johnson (1980) advocates addressing selection at multiple scales. However, our data do not address the presence or absence of owls in areas surrounding the home ranges we documented. Northern Pygmy-Owls are territorial and the placement of home ranges is likely to be strongly influenced by the proximity of other pairs. Thus, to assume that the owls we radio-marked selected home ranges based only on landscape mosaic patterns could lead to spurious results. Sater (in prep.) examined second-order selection by Northern Pygmy-Owls using acoustic-lure surveys. She found a positive correlation between the frequency of Northern Pygmy-Owl responses and overstory tree size. Her results, coupled with ours, suggest an association between the Northern Pygmy-Owl and older or more structurally complex cover types for Johnson’s (1980) second and third-order selection.

Among structurally simple cover types, relative preferences paralleled seral stage development. Preference was least for stands with early seral physiognomy and greatest for stands with late seral physiognomy. Mature cover was the only structurally simple type that did not differ from Complex cover at the $\alpha = 0.05$ level (Table 2). The inclusion of Mixed Forest cover with Late Seral cover precludes extrapolation of this trend to late successional forests. However, we would argue that structural complexity, or alternatively, species diversity, is the salient ecological variable, rather than stand age.

Hayward and Garton (1988) recorded Northern Pygmy-Owl responses in The River of No Return Wilderness Area in Idaho, and concluded that the Pygmy-Owl is a
habitat generalist. Their conclusions are based on response locations, which they used as the basis for both macrohabitat (0.5 km radius circle) and microhabitat (within homogeneous cover) vegetation sampling. Our results call into question the use of response locations as indications of microhabitat usage. Four of the owls we radio-marked left our study area, moving several miles, and 2 made extensive forays away from the place where we first located them. Thus, the response location was not always indicative of a high use area of the home range, as Hayward and Garton (1988) assume. Furthermore, Pygmy-Owls in our study typically responded from forest edges (pers. obs.). It was our impression that they had moved toward us until encountering an edge before responding, yet subsequent analyses did not indicate preferential use of edges. Although calling locations no doubt represent Northern Pygmy-Owl macrohabitat associations, caution should be used in extrapolating to finer levels of selection.

Hayward and Garton (1988) did not find significant differences between use and availability for the Northern Pygmy-Owl at the macrohabitat level, which supports their statement that the Northern Pygmy-Owl is a habitat generalist. Our results suggest a greater degree of specialization. Two interpretations are possible. First, Northern Pygmy-Owls in their study may have established home ranges in patchy areas yet focused their activity in a subset of the available cover types. This interpretation is consistent with our results. Second, cover types in the two studies may not be analogous from the perspective of a Pygmy-Owl. An important distinction between their study and ours is that recent human impact in their study area was minimal,
whereas our study area was highly fragmented by clear-cut logging. Thus, either interpretation is reasonable.

It is interesting to note that Hayward and Garton (1988) found fewer Northern Pygmy-Owls (N = 2) in their Chamberlain Basin Study Area than in their Taylor Study Area (N = 5). They describe the Chamberlain Basin Study Area as being dominated by even-aged Ponderosa Pine (*Pinus ponderosa*) forest, which had relatively uniform structure. Although their sample size is small, their data are intriguing given that we observed low preference for structurally simple cover at a finer scale of selection.

There is comparatively more written concerning habitat use by the Eurasian Pygmy-Owl (*Glaucidium passerinum*) which has been suggested as conspecific with the Northern Pygmy-Owl (Voous 1988, Johnsgard 1988). Most authors acknowledge broad habitat associations for the Eurasian Pygmy-Owl. Mikkola (1983) stated that Pygmy-Owls in Europe are found in all types of woodland. However, several authors emphasize the importance of structural diversity. Scherzinger (1970) found that homogeneous stands and dense plantations were avoided for nesting, while harvested areas were occasionally used for foraging. Scherzinger (1974), Glutz von Blotzheim (1980) and Cramp (1985) each emphasized the importance of structural diversity over species composition and Solheim (1984a) found more consistent breeding in more structurally diverse forests in Norway. Although several studies have apparently used radio-telemetry to examine diurnal activity, home range size and hunting techniques of Eurasian Pygmy-Owls (Mikkola 1983 and references therein, Kullberg 1995), we are
aware of no studies that have focused on third-order selection in the Eurasian Pygmy-Owl as we have with the Northern Pygmy-Owl.

While there appears to be considerable variation among Northern Pygmy-Owl habitat associations regionally, as supported by historical breeding records (Bent 1938), extrapolation to generalized use of cover types for foraging is not supported. Our results suggest that the perceived affinity for edges and openings in the literature may be a result of sampling bias, given that owls are more easily seen when in openings or along edges, and may fly to an edge when challenging a suspected intruder. Our own impressions, based on casual observations prior to completion of this study, were consistent with an association with edges and openings. Alternatively, openings created by clear-cut logging may be perceived differently by Pygmy-Owls than other types of openings. In either case, our findings indicate that anthropogenic partial forest clearing may negatively impact Northern Pygmy-Owls.

NEST SITE SELECTION

Bent (1938) stated that Northern Pygmy-Owls select nests near openings and edges and we are unable to confidently reject this hypothesis. Given that owls in our study did not preferentially use edges for foraging, it is puzzling why an association between nest location and forest edge should occur. Bent’s (1938) statement is based on an ad hoc collection of observations and communications from a variety of sources. It is easy to imagine a sampling bias toward proximity to edges and openings in those data, given greater visibility and human activity in such areas. We located nests using
radio-telemetry which should have eliminated any bias based on differential visibility, and while we searched for owls in areas with many openings, our comparisons were within the nest stand. This should have eliminated bias based on targeting owls in areas with many openings.

Our analyses are based on the assumption that the distribution of available nest cavities is uniform within each stand. We saw no reason to doubt this during the course of our fieldwork. Potential woodpecker cavities seemed abundant and evenly distributed. If woodpeckers tend to drill cavities near edges or openings then the apparent preferences of owls for these structural characteristics would be explained. However, we know of no studies that have documented such a preference by woodpeckers. Moreover, openings and young stands, as defined in our study, were generally the result of clear-cut logging less than 10 years in the past. Therefore, many of the nest cavities available to Northern Pygmy-Owls during the study would have been excavated by woodpeckers prior to the existence of the edge.

DIETARY COMPOSITION

Northern Pygmy-Owl diets vary greatly depending on region and season. Holt and Leroux (1996) used pellets and direct observations to classify 194 prey items from Northern Pygmy-Owls in Missoula, Montana during winter and found a diet that consisted entirely of mammals and birds in approximately equal proportions (53% and 47% respectively). Bull et al. (1987) identified 33 prey items from pellets and prey remains from one pair of nesting Northern Pygmy-Owls in northeastern Oregon and
found an approximately even distribution of mammals (36%) birds (33%) and insects (30%). In contrast, Marshall (1957) examined the stomach contents of 20 Northern Pygmy-Owls from southern Arizona and northern Mexico and found no mammals, one bird, 12 lizards and 13 large insects. Moreover, four of the stomachs examined by Marshall (1957) contained small insects only. Because small insects were not tallied by Marshall (1957) calculation of dietary composition by percentage is not appropriate. Our results are more closely aligned with those of Holt and Leroux (1996) and Bull et al. (1987) than with those of Marshall (1957). This likely represents the geographic similarity between the more northern study areas (Washington, Montana and Oregon) as opposed to the more southern areas (Arizona and Mexico). However, some of the differences may be due to methodological sampling biases.

Different methods of quantifying dietary composition are subject to different biases (Errington 1932). Our data exemplify some of the different biases between the three techniques that we used. A small sample of prey remains was heavily weighted toward avian prey and included no insect prey remains. This is understandable given that Pygmy-Owls pluck avian prey but eat insects and mammals whole. Direct observations included few insects. A plausible explanation is that owls take longer to eat larger prey, and may be more likely to deliver it to the nest, thus they are more likely to be observed with larger prey. Pellet analyses are thought to give relatively good estimates of owl diets (Errington 1932) but may underrepresent soft-bodied insects relative to analyses of stomach contents. While the methods used by Holt and Leroux (1996), Bull et al. (1987) and this study might underestimate the proportion of
insects in the diet relative to those of Marshall (1957), variation in the numbers of mammals and birds are not attributable to sampling bias.

Bent (1938) reported that the diet of the Northern Pygmy-Owl changes seasonally. The absence of insects in the diets of owls studied by Holt and Leroux (1996) may be the result of such a seasonal shift. Earhart and Johnson (1970) present evidence that birds, reptiles and insects are each taken in greater proportions by Northern Pygmy-Owls during summer than winter. Similar seasonal changes have been reported for the Eurasian Pygmy-Owl (Mikkola 1983). Solheim (1984b) observed year-to-year changes that appear to be driven by vole abundance and concluded that the Eurasian Pygmy-Owl exhibits a functional response to prey availability.

Holt and Leroux (1996) noted that the most prevalent species of avian prey in the diet of Northern Pygmy-Owls from suburban areas around Missoula, Montana during winter was the European House Sparrow (*Passer domesticus*). Holt (pers. com.) feels that there is an influx of Northern Pygmy-Owls into suburban areas around the city of Missoula during winter and that these individuals prey opportunistically on House Sparrows. House Sparrows did not occur in our study area, nor were they recorded as a prey species, but they are common in urban and suburban areas throughout western Washington.

The considerable variation in dietary composition among areas and seasons suggests that Northern Pygmy-Owls are relatively flexible with respect to prey selection, taking those species that are most abundant or easiest to capture in a particular area or season. The low number of insects in our sample likely reflects the
relatively depauperate community of large-bodied insects in the cool, damp forests of
the Olympic Peninsula.

SUMMARY

Previous authors have characterized the Northern Pygmy-Owl as a habitat
generalist, a food generalist, or both. Our results are consistent with predictions for a
food generalist, but inconsistent with predictions for a habitat generalist at Johnson’s
(1980) third-order level of selection. Northern Pygmy-Owls appear to be tolerant of
substantial habitat alteration at multiple levels of selection. We located Northern
Pygmy-Owls nesting in heavily fragmented areas (second-order selection), observed
usage of all available cover types (third-order selection) and documented broad dietary
composition (fourth-order selection). However, the owls we tracked showed strong
relative preferences for cover types in which to forage, indicating that although they
may occur in diverse and highly fragmented areas, all available cover types may not be
equally attractive to them. Thus, while changes in prey species assemblages that
accompany changes in forest structure might not negatively affect Northern Pygmy-
Owls, structural changes that replace complex forests with simple stands may.

We recommend future research focusing on: (1) the relative preference of Late
Seral vs. Mixed Forest cover types, (2) sensitivity to varying degrees of forest
fragmentation, and (3) the possible existence of a minimum threshold for the amount of
Complex cover. Lastly, we recommend caution in interpreting acoustic-lure survey
data relative to finer levels of selection than Johnson’s (1980) second-order selection.


SATER, D. M. (in prep.). Distribution, Abundance and Habitat Associations of Northern Pygmy-Owls in Oregon. MS Thesis, Oregon State University, Corvallis, OR.


