

**Final Report
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**USDA/Forest Service
Superior National Forest**

Boreal Owl: Its Habitat and Prey in the Superior National Forest

by

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CHAPTER 1: HABITAT CHARACTERISTICS OF BOREAL OWL BREEDING SITES IN NORTHEASTERN MINNESOTA

ABSTRACT. – Vegetation characteristics surrounding Boreal Owl (*Aegolius funereus*) breeding sites in northeastern Minnesota were examined during 2000-2001. Data collected during 1987-1990 were combined with the 2000-2001 data and all sampling methods were standardized. During nocturnal surveys, 42 individual Boreal Owl singing territories were located. Vegetation was sampled at 0.04 ha plots surrounding Boreal Owl song perches. Identical measurements were taken at one random plot, which was paired with a song plot. The majority (93%) of song perches were located in coniferous species. Boreal Owl song sites had high basal area of both live and dead trees, higher percent coniferous canopy and a taller overstory canopy than those of random locations. Using Landsat Thematic Mapper satellite imagery, I compared the proportion of 13 land cover classes within 100 m (3.13ha), 500 m (78.14 ha), 1000 m (312.57 ha), 2000 m (1,256.27 ha), and 5000 m (7,814.17 ha) radii concentric circular plots surrounding cavity trees ($N = 31$) with random locations ($N = 41$) distributed throughout the SNF. Land cover differences between cavity and random locations were significant at all buffer levels. Upland mixed and upland conifer forests were significantly higher surrounding cavity locations, particularly within 100 m – 1000 m ($P < 0.05$). Lowland conifer stands were significantly higher ($P < 0.05$) surrounding cavity locations, particularly at larger landscape levels (>1000 m).

INTRODUCTION

The Boreal Owl or Tengmalm's Owl (*Aegolius funereus*) is a small northern forest owl that is distributed holarctically. In North America it is found to breed in the boreal or near boreal forests of Alaska, Canada and extreme northern regions of the United States (Hayward 1993). Breeding populations have been documented in the Rocky Mountain regions from Idaho through southern Colorado and northern New Mexico, with isolated populations located in the Cascade Mountains of Washington and Oregon (Palmer and Ryder 1984, Hayward 1987, O'Connell 1987, Whelton 1989, Holt and Ermatinger 1989, Stahlecker and Rawinski 1990).

One of the most common forest owls in Fennoscandia (Korpimäki 1981, Sonerud 1986, Hakkarainen 1997); little is known about the biology and ecology of the Boreal Owl in North America. This is due in part to the owl's small size and secretive nature, nocturnal habits, and association with remote forested areas (Johnsgard 1988). Furthermore, males are only vocal for a short time during late winter and early spring, limiting the detection period for this species (Bondrup-Nielsen 1984).

Although Boreal Owl distribution has probably not changed within recent decades, increased survey efforts have provided a more accurate representation of their distribution (Niemi and Hanowski

19xx, Hayward 1997). The majority of habitat studies come from the western regions of North America, where the Boreal Owl is associated with mixed coniferous-deciduous forests and higher elevation, mature, subalpine conifer forests (Meehan 1980, Palmer 1986, Hayward et al. 1993, Herran et al. 1996). A secondary cavity nester (Mikkola 1983), the Boreal Owl is dependent on species such as the Pileated Woodpecker (*Dryocopus pileatus*) and Northern Flicker (*Colaptes auratus*) and forest processes (e.g., pathogens and forest insects) that create and maintain large cavity trees (Hayward 1997).

In eastern North America, little information regarding Boreal Owl distribution and breeding status is available. Habitat use studies are limited to Ontario, Canada (Bonrup-Nielsen 1978) and extreme northeastern Minnesota (Lane 2001). In Canada, population size is characterized as fluctuating to stable, with insufficient information to assess status (Kirk and Hyslop 1998). While a confirmed breeding species in northeast Minnesota (Eckert and Savaloja 1979, Matthiae 1982, Lane 2001), information regarding habitat requirements and population status is scarce. Winter invasions, particularly during severe winters, are not uncommon (Bent 1938, Green 1966, 1969, Catling 1972, Eckert 1979). Boreal Owls are found to breed at low densities in northeast Minnesota (Lane 1997, Wilson pers comm); however, population trends are difficult to estimate due to the cyclic fluctuations of the species.

The listing of the Boreal Owl as a sensitive species on the Superior National Forest (SNF) has been a major impetus for further studies regarding habitat requirements in northeast Minnesota. Hayward (1997) states that, at least in western North America, "The Boreal Owl may represent the one holarctic raptor species that is most closely tied to the forest ecosystem." Acquiring a better understanding of habitat requirements in eastern North America, particularly those associated with breeding and foraging, is needed to design appropriate management practices for this species.

This study built upon one begun in 1987 by Steve Wilson of the Minnesota Department of Natural Resources. Wilson's original objective was to describe the habitat surrounding Boreal Owl singing locations, which represent potential breeding territory (Meehan 1980, Bonrup-Nielsen 1984, Hayward et al. 1993). I expanded the study to incorporate a landscape analysis of Boreal Owl breeding territory and added a radiotelemetry component to assess home range and habitat use (Chap. 2). The

objectives of this study were 1) identify and describe Boreal Owl song perches (trees) and the habitat characteristics surrounding these singing locations and 2) identify Boreal cavity trees and evaluate the habitat surrounding these sites at various spatial scales. Song perch sites were compared with random sites within the breeding territory. Primary focus was on forest structure surrounding Boreal Owl song perches relative to available habitat within the breeding territory. Boreal Owl cavity locations were plotted onto Landsat Thematic Mapper satellite imagery. I compared amount and configuration of land cover at cavity sites with those of random sites located throughout the SNF. To evaluate if Boreal Owl breeding sites were influenced by spatial scale, land cover surrounding cavity sites and random sites was analyzed at five concentric circular buffers ranging from 100 m to 5000 m in radius.

STUDY AREA

This study was conducted in Lake County and northern St. Louis County in northeast Minnesota, with the majority of the study area located within the Superior National Forest (Figure 1.1). Differential erosion of bedrock, due to glaciers and running water is responsible for the rugged terrain common in northeastern Minnesota. The landscape is characterized by deep, elongated lake basins and low-lying areas separated by more resilient ridges (Ojakangas and Matsch 1982). In the northern portion of the study area, glacial drift is minimal to absent, leaving abundant outcrops of exposed Precambrian bedrock. In contrast, glacial drift covers most of the southern portion of the study area (Ojakangas and Matsch 1982).

Two ecoregions (Laurentian Divide and Border Lakes; Albert 1995) are located within the study area. Approximately 80% of the Border Lakes and Laurentian Divide ecoregions are forested (Mladenoff et al. 1997), with boreal or near-boreal forest types such as white and black spruce (*Picea glauca* and *P. mariana*), pine (*Pinus resinosa*, *P. strobus*, and *P. banksiana*), balsam fir (*Abies balsamea*), northern white cedar (*Thuja occidentalis*), paper birch (*Betula papyrifera*), and trembling aspen (*Populus tremuloides*) dominating the landscape (Larsen 1980). Dominant land cover classes in the Border Lakes and Laurentian Divide ecoregions include: mixed forest (70-75% and 49.4%, respectively), water (13.3%

and 6-8%, respectively), forested wetlands (6-8% and 20-26%, respectively), and coniferous forest (2-4% and 6.8%, respectively). Deciduous forests and agricultural land are minimally represented in both ecoregions (Mladenoff et al. 1997).

Catastrophic events (e.g., windfall, fire and human-caused) have shaped the forest mosaic of this region (Pastor and Mladenoff 1992). Widespread removal of coniferous forests by European settlers has converted much of the landscape to mixed and deciduous forests (Heinselman 1973). These mixed coniferous-deciduous forests may be early or late successional, and typically occur on dry to wet-mesic sites (). Mixed pine-hardwood forest, white pine-hardwood forest, and boreal hardwood-conifer forest are the three most common mixed forest community types represented in this study area ().

Weather conditions are characterized by long, cold winters and mild summers. Average total snowfall for the area is 71.2 inches, with temperatures ranging from -15.3°C in January to 18°C in July, with a growing season of approximately 100 days (Frelich and Reich 1995, <http://www.climate.umn.edu>).

METHODS

Locating Owls. Nocturnal surveys were conducted on twelve routes between 1 March and 14 May 2000 and 2001 (Figure 1.2). Routes were surveyed as frequently as possible during five periods: 1-14 March, 15-31 March, 1-14 April, 15-30 April, and 1-14 May. Routes were not randomly selected, as emphasis was placed on locating potential breeding sites where Boreal Owls were previously observed (Wilson unpublished). Routes were either driven or skied, depending on snow conditions. Surveys were not conducted during moderate to heavy precipitation, or if wind speeds exceeded 16 kph. The start and end point of each route was alternated to reduce temporal bias, but maintain sampling efficiency. Surveys were initiated at least one half hour after sunset.

At the beginning of each survey the following weather data were recorded: temperature, percent cloud cover, moon phase, precipitation, snow depth, percent snow cover, and wind speed. Listening stations along each route were separated by 1.6 km intervals (Francis and Bradstreet 1987). Each listening station consisted of a three minute passive listening period to detect randomly calling owls, the

playback of a 20 second recording of a Boreal Owl call, and a final one minute passive listening period. If a Boreal Owl was detected within the first three minutes, playback was not used. When the staccato song of a male Boreal Owl was detected, a foot search was immediately conducted to locate the singing owl.

Bondrup-Nielsen (1984) reported that in calm conditions, Boreal Owls are easily heard from a distance of 1.5 km and as far away as 3.5 km. We considered singing locations to be potential breeding sites if 1) males were heard singing from the area on more than one occasion, 2) a female was seen or heard on the territory, or 3) an active nest was found (Hayward et. al 1993). Boreal Owls were located by circling a small area in which the male was singing, listening to the direction of the song and slowly approaching the singing bird. Bondrup-Nielsen (1978) reported that human presence did not appear to disturb the owls singing activity or behavior. We found this to be true as we were able to approach and locate the exact song tree for all individuals used in this study with minimal effect on the owl's behavior.

Once located, cartesian coordinates of the song tree were obtained with the use of a Garmin Global Positioning System (GPS) and the tree was flagged to expedite relocation for future vegetation sampling. At this time an attempt was made to locate the cavity tree. Differences in song were a good indicator of the owl's location. Typically, when occupying a cavity, the male owl will sing prolonged staccato, a rapid version of the staccato song (Bondrup-Nielsen 1984). Once located, GPS coordinates were collected for all cavity sites.

Vegetation Sampling - Song perches. Song perch vegetation data collected between 1987-1990 by Steve Wilson were combined with data gathered during 2000-2001 of this study. Sampling methods were standardized. Vegetation was sampled at 0.04 ha (11.3 m radius) plots (James and Shugart 1970), centered on the song tree. All trees within each plot were classified by species. The height (meters) and diameter (dbh) were measured for each tree in the plot >3 cm dbh and 2 m in height. Canopy height was calculated by taking the average height of the five tallest trees within the plot. Song tree species, song tree dbh, song tree height, and song tree condition were recorded. Vegetation measurements were taken for 13 variables within each plot (Appendix 1). Percent shrub cover (deciduous, coniferous, and total)

and percent canopy cover (deciduous, coniferous, and total) were calculated by taking five measurements in each of the cardinal directions using an ocular tube. A 10-factor prism was used to measure basal area (m^2/ha) of live, dead, deciduous and coniferous trees within each plot. Total number of downed logs >24 cm were recorded on each plot. Plot slope and plot aspect were calculated using a clinometer and compass respectively. In addition, distance from song perch to cavity, and distance between song perches were recorded. If more than one song perch was located for an individual owl, qualitative data were collected (e.g., tree species, tree dbh and tree height etc) on each tree used as a song perch. However, only the first of multiple song perch locations were used in the microhabitat (plot) analysis. For example, if three song perches were located for an individual Boreal Owl, all three were included in the qualitative description of song perches, but only the first song perch location was paired with a random location and used in the plot analysis.

Identical measurements were collected at one random plot, which was paired with a song plot (Appendix 2). Random plots were located by pacing approximately 70 m in an 'a priori' random direction from the song perch. Boreal Owls do not sing randomly throughout their home range, but instead tend to sing from trees within 100 m of a potential cavity site (Bondrup-Nielsen 1978, Palmer 1986, Hayward et.al 1993). I therefore assumed 70 m to be to be within a potential breeding territory, allowing me to determine whether owls were selecting for specific habitat features within their breeding territory.

Nesting sites: landscape analysis. Cavity locations ($N = 31$) were plotted using ArcView GIS (Version 3.2a). Landsat Thematic Mapper satellite imagery with a 28.5 x 28.5 m resolution was used to determine the land cover types surrounding each cavity location. Fifty-four land cover classes based on Landsat imagery (Wolter et al. 1995) were reclassified into 13 land cover classes found throughout the region (Table 1.1). The amount (ha) of each land cover class was measured within 100 m (3.13ha), 500 m (78.14 ha), 1000 m (312.57 ha), 2000 m (1,256.27 ha), and 5000 m (7,814.17 ha) radii concentric circular plots centered on the cavity tree. Random coordinates ($N = 41$) distributed throughout the SNF were plotted using ArcView GIS and identical land cover measurements calculated at each random

location. Cavity sites were then compared with random sites to determine whether Boreal Owls selected cavity sites different from random sites.

Statistical analysis. Song perches. A conditional logistic regression (procedure PROC PHREG, Allison, 1999) was used to test for differences in the 13 vegetation variables at Boreal Owl song and random sites. Regressions were independently run for the 13 variables. A conditional logistic regression was also used to compare densities of individual tree species, and the total amount of coniferous and deciduous species at Boreal Owl song and random sites. To test for multi-level patterns in the vegetation data, a stepwise multiple regression was performed on the vegetation variables.

An electivity index was used to quantify preference of song trees available within the song plot. The electivity index was calculated using the following formula modified by Jacobs (1974):

$$E_{ij} = \ln\left[\frac{(r_{ij})(1 - p_{ij})}{(p_{ij})(1 - r_{ij})}\right]$$

where r_{ij} is the proportion of trees used as song perches at time j that belonged to genus i and p_{ij} is the proportion of trees available at time j that belong to genus i . Electivity indices greater than 0 indicate selection for a genus; indices equal to 0 indicate random selection and indices less than 0 indicate selection against a genus. The formula

$$\chi^2 = E_{ij}^2 / [(1/x_{ij}) + (1/(m_j - x_{ij})) + (1/y_{ij}) + (1/(n_j - y_{ij}))]$$

was used to test the significance of E_{ij} , where x_{ij} is the number of trees of genus i used as a song perch and y_{ij} is the number of trees of genus i available on the plot at time j and m_j is the total number of trees used as song perches and n_j is the total number of trees available. χ^2 is compared with a Z^2 distribution with $df = 8$. Only trees with a diameter of 10 cm or greater were included in the analysis. Ten cm was considered the minimal size used by Boreal Owls as song perches in this study area.

Nesting sites – landscape analysis. To examine multivariate patterns, multi-response permutation procedure (MRPP) (PC-ORD Version 4.0 McCune and Medfford, 1999) was used to compare land cover

composition surrounding cavity and random locations at each of the five landscape scales. MRPP, a non-parametric procedure used to test the hypothesis of no difference between two or more groups was used because normality and homogeneity of variance assumptions were not met.

The MRPP was followed with a univariate analysis on each of the 13 land cover types at each of the five different landscape scales (100 m, 500 m, 1000 m, 2000 m and 5000 m). All variables were tested for univariate normality. Homogeneity of variance and normality assumptions were not met for most variables, even after log transformation of the data. Therefore, a non-parametric Wilcoxon test (procedure PROC NPAR1WAY WILCOXON, SAS Institute, 1998) was used for the analysis.

A classification tree was used to build models that predicted which land cover types best distinguish cavity sites from random sites at each of the five landscape scales. The classification and regression tree software, CART® (Steinberg and Colla, 1997) was used to construct the classification trees. A classification tree is a statistical method for predicting the class of an observation from the values of a number of predictor variables (Breiman et al., 1984). The trees derived from CART explain variation of a single response variable by one or more explanatory variables. Trees are constructed by repeatedly splitting the data, based on a single explanatory variable (e.g., land cover type), into two groups (e.g., cavity and random), with each group being as pure (homogenous) as possible. Splitting continues until an overly large tree is grown. The tree is then pruned back to an optimal size (De'Ath and Farbricius, 2000). Splits are represented by nodes in the tree. Trees are analogous to a dichotomous key, with a root or parent node at the top, and split nodes and terminal nodes below.

Default settings were used in the model. For example, ten-fold cross-validation was specified as the method to estimate the error rate. Additionally, I specified that there must be at least 10 locations in the parent nodes and five locations in the terminal nodes. I measured model performance by evaluating several measures derived from the confusion matrix (see Fielding and Bell 1997). These measures were: 1) sensitivity: the conditional probability that case X is correctly classified $p(X_{Alg} | X_{true})$, 2) specificity: the inverse of sensitivity $p(not X_{Alg} | X_{true})$, 3) correct classification rate and, 4) Kappa: the proportion of

specific agreement (Fielding and Bell, 1997). Landis & Koch (1977) suggested the following ranges of agreement for the Kappa statistic: poor $K < 0.4$; good $0.4 < K < 0.75$ and; excellent $K > 0.75$.

Example of a classification tree. As an example, I used the classification tree generated for the 1000 m buffer (Fig 1.5). The response variable is the presence or absence (random) of cavity sites.

Hexagons represent parent (non-terminal) nodes, while squares represent terminal nodes.

In this example, ericaceous brush (BR_ER_3) was the best explanatory variable to generate the most pure (homogenous) terminal nodes. If ericaceous brush was $\leq 10559.250 \text{ m}^2$ (approximately 1 ha) then sites were classified into Terminal Node 1 ($N = 35$). Thirty of 35 (85.7%) sites in Terminal Node 1 were random, with 73.1% of all random sites containing $\leq 105529.250 \text{ m}^2$ of ericaceous brush. Sites containing $> 105529.250 \text{ m}^2$ of ericaceous brush were categorized into Terminal Node 2 ($N = 37$). Twenty-six of 37 (70.3%) were cavity sites, with 83.8% of all cavity sites containing $> 105529.250 \text{ m}^2$ of ericaceous brush.

RESULTS

Song perches. Fifty-six individual Boreal Owl song perches were identified during this study. All song perches were located during ground foot searches. Of the 56 trees selected as song perches, 93% were coniferous species, with an average diameter and height of 35.6 cm and 18.5 m, respectively. Deciduous species represented 7% of song perches, with an average diameter and height of 39.7 cm and 19.7 m, respectively (Table 1.2). The average distance between song perch and cavity trees was 98.2 m ($n = 32$; range 5.6 m – 380 m). The average distance between song perches was 72.3 m ($n = 34$; range = 3.9 m – 290 m).

Microhabitat - song perches. Microhabitat level analyses were done on 42 individual Boreal Owl song territories (using one tree per site). Six of the 13 variables tested in the conditional logistic regression were significant predictors ($\alpha = 0.05$) of Boreal Owl song sites. These variables were: live basal area ($112.9 \text{ m}^2/\text{ha}$ vs. $75.8 \text{ m}^2/\text{ha}$; $P < 0.02$), dead basal area ($22.4 \text{ m}^2/\text{ha}$ vs. $11.9 \text{ m}^2/\text{ha}$; $P < 0.02$), total basal area ($135.2 \text{ m}^2/\text{ha}$ vs. $87.7 \text{ m}^2/\text{ha}$; $P < 0.01$), coniferous canopy cover (47.5% vs. 30.1%; $P < 0.01$), total canopy cover (65.7% vs. 52.9%; $P < 0.02$) and canopy height ($N = 29$) (18.2 m vs. 15.0 m; P

< 0.02). Balsam fir was the only tree species found in significantly higher proportions ($\alpha = 0.05$), on Boreal Owl song sites ($P < 0.05$). Although not significant, coniferous species in general appear to be proportionally higher on Boreal Owl song sites compared to random sites.

During the initial study (1987-1990), complete quantitative measurements were unable to be collected at all random locations making it impossible to include all variables in the multi-level regression. As a result, the variables percent deciduous shrub, percent coniferous shrub, percent total shrub, live coniferous basal area, dead coniferous basal area, live deciduous basal area, and dead deciduous basal area were not included in the stepwise regression. Total basal area was found to be the only significant ($P < 0.05$) variable in the multiple regression.

Electivity indices were calculated for 40 song perches and their surrounding plots. I was unable to distinguish the specific song tree at two plots and therefore did not include them in the analysis. With the exception of balsam fir and red pine, Boreal Owls showed a preference for coniferous species for use as song perches. Although white spruce was the only species significantly selected for, white pine and white cedar appear to be preferred species. Trembling aspen and paper birch were avoided for use as song perches (Table 1.3).

Nesting sites: landscape analysis. Significant differences ($P < 0.01$) between cavity and random sites were found at every landscape scale using the MRPP. With the exception of brush, lowland brush, and open areas, significant differences were present for all land cover variables in the univariate analysis. Furthermore, significant differences ($P < 0.05$) were present at all landscape scales for several land cover variables (Table 1.4).

Classification trees were constructed for each of the four landscape buffers. The variable “roads” was not included as an explanatory variable when constructing the classification trees. This was done primarily because Boreal Owl song sites, and in turn, cavity sites were located through roadside surveys and therefore were in close proximity to roads. I found that when roads were included in the model, they were the best predictor of differences between cavity and random sites at all landscape levels.

Model performance evaluations were good in general, however prediction success varied

depending on buffer size (Table 1.5).

100 m (3.14 ha) buffer – Twenty-four of 31 (77.4%) cavity sites and 27 of 41 (65.8%) random sites were correctly classified (classification rate = 71%; Kappa statistic = 0.42; Table 1.5). Upland mix forest was found to be the best explanatory variable to distinguish cavity sites from random sites. At this level 80.6% of cavity sites had >6.5% upland mix, <11.4% brush, and <9.1% lowland conifer compared with random sites (Fig 1.3).

500 m (78.5 ha) buffer – This was the poorest model, correctly classifying only 17 of 31 (54.8%) cavity sites and 26 of 41 (63.4%) random sites (correct classification rate = 60%; Kappa statistic = 0.18; Table 1.5). Upland conifer was the best explanatory variable for cavity sites at this level. Cavity sites had >12.5% upland conifer compared with random sites. Cavity sites also had higher proportions of upland mix (>27.4%) and open areas (>4.1%) compared with random sites (Fig 1.4).

1000 m (314 ha) buffer – At this level 24 of 31 (77.4%) cavity sites and 30 of 41 (73.1%) random sites were correctly classified (correct classification rate = 75%; Kappa statistic = 0.50; Table 1.5). Ericaceous brush was the best explanatory variable of cavity sites at this level. Cavity sites tended to have >3% ericaceous brush (Fig 1.5).

2000 m (1256 ha) buffer - This was the best model, correctly classifying 25 of 31 (80.6%) cavity sites and 36 of 41 (87.8%) random sites (correct classification rate = 81%; Kappa statistic = 0.69; Table 1.5). Eighty percent of cavity sites had >1% ericaceous brush, <5% lowland hardwood, and >20% upland mix forests (Fig 1.6).

5000 m (7850 ha) buffer – Nineteen of 31 (61.3%) cavity sites and 29 of 41 (70.7%) cavity sites were correctly classified (correct classification rate = 67%; Kappa statistic = 0.32; Table 1.5). At this level, sphagnum was the best predictor of cavity sites. Ericaceous brush was also higher at cavity sites (Fig 1.7).

DISCUSSION

Song perches. Limited information exists on song perch use by Boreal Owls. Studies in the western United States have shown that Boreal Owl singing locations are typically found at higher elevations in subalpine-fir (*Abies lasiocarpa*), mixed-conifer, Engelmann spruce (*Picea engelmannii*), and spruce-fir habitat types (Palmer 1986, Hayward et al. 1993, Herren et al. 1996). With conifers dominating the landscape in the western United States, it is extremely probable that the majority of song perches were in coniferous trees. Bondrup-Nielsen (1978) reported that almost all song perches used by Boreal Owls in Ontario, Canada were conifers. Similarly, the majority of song perches in this study area were found to be large diameter conifers. Electivity indices indicate that Boreal Owls preferred coniferous species, particularly white pine, white spruce, and white cedar for use as song perches compared to deciduous species. Structurally, white spruce and particularly white pine represent two of the taller coniferous species available within the study area. Advertising from a taller tree may be advantageous to males during courtship, as it may allow their song to be broadcast over a greater distance, thereby potentially attracting more females. Boreal Owls appeared to select against red pine for use as song perches, even though red pine is one of the taller conifers in this study area. Red pine, while offering the advantage of height, may not provide adequate concealment from predators.

Males are extremely vocal during the breeding season, often singing throughout the evening with few breaks (Bondrup-Nielsen 1984). In the process of advertising potential breeding sites to females, males may also make their location known to avian predators such as Great Horned Owls (*Bubo virginianus*), Barred Owls (*Strix varia*) and Great Gray Owls (*Strix nebulosa*) (Bent 1938). Hakkarainen and Korpimäki's (1996) study on competition and predation among Tengmalm's Owl (*Aegolius funereus*), Ural Owls (*Strix uralensis*) and Eagle Owls (*Bubo bubo*) in central and western Finland, showed male Tengmalm's Owls appeared to vocalize less, particularly near Ural Owl territories, thereby delaying mate location and breeding success. In North America, the Great Horned Owl, Barred Owl and Great Gray Owl may have a similar effect on the Boreal Owl as the Ural Owl and Eagle Owl. While it is impossible to know what effect these larger owl species had on Boreal Owl breeding success in this study, there may possibly be a tradeoff between vocalization and being preyed upon. This may be one reason

Boreal Owls prefer advertising from coniferous species, as the dense foliage of conifers may afford Boreal Owls protection from larger avian predators during this vulnerable time.

An interesting observation was the topographical location of song perches. Thirty-four of the 58 (59%) song perches were categorized as being between $\frac{1}{4}$ of the way or higher up a slope. Again, increased elevation may allow the males song to be broadcast a greater distance.

Boreal Owls appear to sing from trees in close proximity to one another and to a potential cavity, and may possibly have a preferred song perch. On two occasions, I observed a male vocalizing from the same tree on different evenings. I also had one instance where a male vocalized from one perch, flew to another (approximately 150 m away), vocalized for a short time, then returned to the original song perch and continued vocalizing. Both Bondrup-Nielsen (1978) and Wilson (pers comm.) observed similar behavior during the courtship period.

Microhabitat – song sites. In western North America, forest structural characteristics appear to be important for nest site selection (Hayward 1997). This appears to also be true of Boreal Owls in eastern North America. Microhabitat analysis of Boreal Owl song sites in this study area showed structural characteristics typical of mature, multi-storied forests stands. Taller overstory canopy, larger trees, large snags, and a higher percentage of coniferous canopy cover were found to be important predictors of song sites as compared to random sites in the conditional regression. Higher total basal area within song territories was identified as the most important habitat characteristic in the multi-level analysis. Studies in the western United States reported similar findings. Herran et al. (1996) found taller overstory canopy, taller snags, and a high basal area of Engelmann Spruce and subalpine fir to be among several important habitat features of Boreal Owl singing locations. Likewise, Hayward et al. (1993) observed stands used by singing male Boreal Owls to be in mature to older forests. In his analysis of 33 nesting and calling sites, high density of large trees, an open understory, and a multi-layered canopy were shown to be important habitat components.

Nesting sites – landscape analysis. Univariate and landscape analysis based on Landsat satellite imagery indicate upland mixed forests best distinguish Boreal Owl breeding sites from those of random

sites at the 100 m buffer in this study area. Mixed forests provide coniferous trees for song perches and deciduous trees for cavity sites. As secondary cavity nesters, Boreal Owls rely on species such as Pileated Woodpecker and Northern Flicker to excavate cavities (Hayward and Hayward 1993). Preferred nesting habitat of these species are large diameter deciduous trees (Brewer, McPeck, and Adams 1991, Bull and Jackson 1995). Accordingly, deciduous species such as trembling aspen and paper birch appear to be important nesting substrate for Boreal Owls, particularly in eastern North America. In Ontario, Canada, all six nests located by Bondrup-Nielsen (1978) were in trembling aspen. Lane and Andersen (1995) report 36 of 39 (92.3%) cavities located in Cook County Minnesota to be in trembling aspen. Results from this study are similar. Of ---- cavities located within this study area, ---- were in aspen. Differences in dominant forest cover make comparisons with the western United States difficult; however, of 19 nests located in central Idaho, 7 were in aspen, even though aspen represented <1% of forest cover (Hayward et al. 1993). Similarly, breeding sites in Alaska, Canada and northeastern Minnesota were found in deciduous, mixed conifer-deciduous, and upland mix stands (Bondrup-Nielsen 1978, Meehan and Ritchie 1984, Lane et al. 2001).

As scale increases, changes in land cover requirements become apparent. Upland conifer and upland mix forests appear to be the best predictors of Boreal Owl cavity sites within a 500 m buffer in both univariate and large-scale landscape analysis. Although the Kappa statistic for the 500 m model was considered poor, results from the univariate analysis support the model's findings of the importance of upland conifer and upland mixed forests. In addition to providing protection from predators and environmental conditions, conifers provide important roosting sites for Boreal Owls. Bondrup-Nielsen (1978), Palmer (1986), Hayward et al. (1993), and Lane (1997) all reported that Boreal Owls almost exclusively roosted in coniferous species within their respective study sites. Similarly all but one of the 32 roost sites located during this study were in conifers (Chap 2). Dense conifer stands may provide better protection from predators while owls are roosting. Moreover, conifer stands appear to provide cooler roosting sites for Boreal Owls, particularly during the summer months (Hayward et al. 1993).

Results from the CART model suggest that natural openings (bare ground, grass, agriculture) occurred more frequently within the 500 m buffer surrounding Boreal Owl cavity sites than those of random sites. Previous studies in North America have shown an association between Boreal Owl breeding sites and forest openings (Meehan and Ritchie 1982, Herran et al. 1996). Studies conducted in Fennoscandia have shown that forest openings provide alternative foraging habitat and prey species for Tengmalm's Owls, particularly in early spring when forested areas are still covered in snow (Korpimäki 1988, Sonerud 1993). The mosaic of forested areas interspersed with small openings may benefit Boreal Owls by providing additional prey species, particularly during poor vole years. Interestingly, seven of the 17 Boreal Owl cavity sites located in 2000-2001 were located near forest edges or within 20 m of a road, with one cavity actually being directly on the road edge. While it is possible that Boreal Owls may utilize these open areas for foraging purposes, it would be difficult to draw definitive conclusions on the possible foraging benefits of forest openings within this study area given that prey selection of Boreal Owls and prey availability were not quantified.

Importance of lowland areas becomes evident at a larger scale. Ericaceous brush (e.g., Labrador Tea (*Ledum groenlandicum*), Bog Rosemary (*Andromeda glaucophylla*) and Leather Leaf (*Chamaedaphne calyculata*)) typically associated with lowland conifer forests appear to be important landscape features surrounding cavity sites at the >1000 m radii in both univariate and multi-level analyses. Previous studies conducted in northeastern Minnesota have suggested that lowland areas provide important roosting and foraging habitat for Boreal Owls (Lane et al. 2001, Wilson pers comm.). Lane (1997) reported that over 92% of the roost sites located in Cook County Minnesota occurred in lowland conifer stands. I located 32 roost sites during the 2000-2001 field seasons. Quantitative measurements were not collected, as roosting habitat was not the focus of this study; however roost trees were identified to species and GPS coordinates were taken at each roost location and plotted onto Landsat TM satellite imagery data. Findings from this study did not conclusively support Lane's results, however there were striking similarities (Chap 2). Of the 32 roost sites, 18 (56.3%) were located in upland conifer stands, 7 (21.9%) were located in upland mixed stands, 6 (18.9%) were located in lowland conifer stands and 1 (3.1%) was located in lowland mixed stands. Eighty-five percent of the roost sites were within 100

m of a lowland conifer stand while 94% were located within 200 m of lowland conifer stands, indicating a possible association with lowland conifer.

In addition to roosting, conifer stands (both upland and lowland) may provide prime habitat for foraging activities (Chap 2). Roost locations, assumed to represent end of foraging bout areas (Hayward et al. 1993), were typically associated with upland conifer (generally spruce-fir) and lowland conifer stands. This habitat is ideal for red-backed voles, which are found to inhabit mesic, forested areas, particularly spruce-fir forests (Kays and Wilson 19xx, Hayward et al. 1993). Soneud (1986) reported that Tengmalm's Owls in Norway used forested areas for foraging during most of the year; except for a brief period immediately following snow melt. Snow conditions in dense conifer stands tended to be less compact, thereby facilitating access to prey (Hayward 1993).

CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

It may be difficult to develop sound management practices for this species in northeastern Minnesota as 1) habitat use studies have been short term (breeding season only) and were not designed to assess the effects of forestry practices, 2) small sample size makes it difficult to extrapolate the habitat requirements for an entire population, and 3) cyclic fluctuations (depending on prey availability and severity of winters) make it difficult to determine population trends for this species. However, the Boreal Owl, throughout its North American range, is associated with mature boreal and subalpine forests. Large scale loss of these forests will surely have a negative impact on the distribution and abundance of this species.

Landscape level. Management guidelines concerning Boreal Owl habitat should be approached at a landscape level. The diversity of land cover within their home range (Chap. 2) indicates that no single forest type is able to provide adequate habitat for daily activities (e.g., breeding, foraging, and roosting). The glacial topography of upland ridges juxtaposed with low-lying areas is a key feature of Boreal Owl habitat in northeastern Minnesota. The landscape mosaic of heterogeneously mixed upland forests, which are able to support high densities of cavity trees, interspersed with conifer (upland and

lowland) stands and small openings appear to provide the best quality habitat for Boreal Owls in northeastern Minnesota.

Breeding. Availability of suitable nest cavities may influence Boreal Owl abundance. Older aspen and birch appear to provide important nest sites for Boreal Owls in northeastern Minnesota (Lane 2001, Wilson pers comm). Boreal Owls rely on species such as Pileated Woodpeckers and Northern Flickers to create nesting sites. As a result, forests should be managed to enhance habitat for primary cavity excavators. Forest management practices that incorporate the retention of large snags and large diameter hardwoods (particularly aspen and birch) are suggested. Mature, uneven-aged upland mix stands with a high density of large trees (both coniferous and deciduous) and snags, taller overstory canopy, and a high proportion of coniferous canopy appear to be important microhabitat features surrounding cavity sites. Forestry practices that maintain structural characteristics of mature, uneven-aged stands are recommended.

Roosting and foraging. Conifer stands, both upland and lowland appear to be important habitat for roosting and foraging activities. Mature conifer stands (specifically spruce-fir) that are able to provide adequate cover and support principal prey species should be maintained. Loss of large tracts of lowland conifer, particularly stands contiguous to upland mix or upland conifer may negatively affect Boreal Owl distribution.

Timber harvesting. Mature forests appear to provide important habitat for nesting, roosting, and foraging activities. Removal of large areas of mature forests, particularly upland mixed, upland conifer, and lowland conifer may negatively impact Boreal Owl distribution on a regional scale. Group selection or single-tree harvests that leave large conifers and hardwoods (specifically aspen and birch) and maintain the structural integrity of these stands are advised for conservation of Boreal Owl habitat (Hayward 1997). If timber harvests are employed, Hayward (1997) postulates that small (1-5 ha) clear-cuts (localized within an area) in combination with long rotations may reduce the negative impacts. While it is possible that small openings may provide greater prey availability for Boreal Owls, additional studies on prey selection need to be employed.

Table 1.1. Description of 13 land cover variables used in the landscape habitat analysis of Boreal Owl cavity sites in northeastern MN. Land cover variables were reclassified from Landsat data based on Wolter et.al 1995. Land cover validated according to Society of American Foresters (SAF), United States Forest Service (USFS) and Department of Natural Resources (DNR) forest stand classification systems.

Land Cover Class	Dominant Cover Species	Scientific Name
Upland conifer	Jack pine	<i>Pinus banksiana</i>
	Red pine	<i>P. resinosa</i>
	Eastern white pine	<i>P. strobus</i>
	Balsam fir	<i>Abies balsamea</i>
	White spruce	<i>Picea glauca</i>
	Black spruce (upland)	<i>P. mariana</i>
	Miscellaneous conifer	
Upland hardwood	Aspen	<i>Populus spp.</i>
	Paper birch	<i>Betula papyrifera</i>
	Yellow birch	<i>B. lutea</i>
	Sugar maple	<i>Acer saccharum</i>
	Red maple	<i>A. rubrum</i>
	Balsam poplar	<i>Populus balsamifera</i>
Upland mix	American basswood	<i>Tilia americana</i>
	Northern hardwood-conifer	
Lowland Conifer	Aspen-birch-conifer	
	Northern white cedar	<i>Thuja occidentalis</i>
Lowland hardwood	Tamarack	<i>Larix laricina</i>
	Black spruce (lowland)	
	Acid bog conifer, stagnant	
Lowland mix	Black ash	<i>Fraxinus nigra</i>
	Miscellaneous lowland hardwood	
Brush	Northern white cedar-hardwood	
	Black ash-conifer	
Brush-lowland	Brush-alder	
	Brush-willow	
	Brush-miscellaneous	
	Brush alder-lowland	
Brush-ericaceous	Brush willow-lowland	
	Brush miscellaneous-lowland	
Sphagnum	Ericaceous brush	
Open	Sphagnum spp.	
	Grass	
Water	Bare ground	
	Bare upland	
	Agriculture	
	Water	
	Flooded	
	Emergent, aquatic	
	Emergent	
Roads		

Table 1.2. Characteristics of all song perches (n = 56) used by vocalizing male Boreal Owls in northeastern Minnesota, 2000-2001.

Tree species	Percent	N	Average dbh (cm)	SD	Average height (m)	SD
Coniferous	93	52	35.6	15.0	18.5	5.4
Balsam fir	18	10	22.6	6.8	16.4	3.5
Black spruce	16	9	24.0	9.7	16.4	4.3
Jack pine	16	9	26.1	15.2	15.8	4.6
Red pine	7	4	32.4	8.7	19.8	1.7
White cedar	4	2	45.5	9.2	13.7	1.6
White pine	12	7	64.6	16.2	30.0	7.3
White spruce	20	11	33.1	10.7	17.6	2.9
Deciduous	7	4	39.7	2.2	19.7	7.2
Paper birch	3	2	41.2	21.0	14.6	3.4
Trembling aspen	4	2	38.1	7.1	24.8	1.1

Table x.x Characteristics of song perches used by vocalizing male Boreal Owls in northeastern Minnesota, 2000-2001. Song perches (n = 40) were plot center of 0.04 ha plot used in analysis of breeding habitat characteristics.

Tree species	Percent	N	Average dbh (cm)	SD	Average height (m)	SD
Coniferous	90	36	36.1	14.7	18.0	4.8
Balsam fir	12.5	5	21.6	7.9	16.1	4.8
Black spruce	20	8	24.4	10.3	16.1	4.6
Jack pine	17.5	7	28.0	16.5	15.2	4.8
Red pine	7.5	3	34.4	9.5	20.1	1.9
White cedar	5	2	45.5	9.2	13.7	1.6
White pine	10	4	64.3	8.8	28.1	6.9
White spruce	17.5	7	34.4	12.6	17.0	2.7
Deciduous	10	4	39.7	2.2	19.7	7.2
Paper birch	5	2	41.2	21.0	14.6	3.4
Trembling aspen	5	2	38.1	7.1	24.8	1.1

Table 1.3. Electivity indices for tree species selected as song perches by vocalizing male Boreal Owls in northeastern Minnesota, 2000-2001. Availability is based on all trees ≥ 10 cm dbh within a 0.04 ha plot.

Genus	Electivity for song perches
White spruce	+1.75*
White pine	+1.37
White cedar	+1.77
Red pine	- 0.05
Trembling aspen	- 1.03
Paper birch	- 1.03
Jack pine	+0.04
Black spruce	+0.77
Balsam fir	- 0.35
Mountain ash	--
Red maple	--
Prunus	--
Mountain maple	--
Salix spp.	--
Yellow birch	--

* $P < 0.05$

Table 1.4. Wilcoxon test statistics from comparisons of 13 land cover variables within five concentric circular plots surrounding Boreal Owl cavity and random sites in northeastern Minnesota, 2000-2001.

Variable ^a	Buffer Size (m) ^b	Z statistic	Median (ha)	
			Cavity	Random
Brush-ericaceous	1000	4.20***	1.62	0.65
	2000	4.40***	11.86	2.60
	5000	4.39***	94.79	35.01
Lowland conifer	1000	2.04*	50.85	29.24
	2000	2.59*	210.78	142.39
	5000	3.39***	1414.94	864.23
Lowland hardwood	500	-2.60**	0	0.08
	1000	-2.88**	0.08	0.49
	2000	-2.85**	0.73	4.79
	5000	-2.96**	4.55	38.42
Lowland-mix	1000	2.21*	2.92	1.71
Roads	100	3.88***	0	0
	500	5.56***	3.00	0
	1000	4.81***	7.80	0.89
	2000	3.36***	17.46	8.37
Sphagnum	1000	3.87***	0	0
	2000	-4.76***	0.08	2.60
	5000	4.08***	2.19	0
Upland conifer	100	1.97*	0.41	0.08
	500	2.62*	16.89	7.15
	1000	2.90**	73.83	30.70
	2000	2.43*	265.85	124.11
	5000	2.73*	1382.94	868.70
Upland hardwood	2000	-2.04*	70.91	156.44
	5000	-2.43*	451.69	901.60
Upland mix	100	2.57*	1.46	0.49
	500	2.59*	30.95	19.81
	1000	2.09*	102.18	79.36
	2000	2.30*	400.52	311.25
Water	100	-2.25*	0	0
	1000	-2.18*	2.11	7.31
	2000	-2.18*	23.88	64.41

^aOnly variables and buffers showing a significant difference ($P < 0.05$) included in table.

^b100 m, 500 m, 1000 m, 2000 m, and 5000 m radii plots correspond to 3.13 ha, 78.14 ha, 312.57 ha, 1256.27 ha, and 7814.17 ha, respectively.

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

Table 1.5. Prediction accuracy of CART classification tree models for distinguishing presence or absence of Boreal Owl cavity sites in relation to land cover types at five concentric circular plots in northeastern Minnesota, 2000-2001. Models assessed using 10-fold cross validation settings.

Buffer Size (m)	Correct Presence (+)	False Presence (+)	False Absence (-)	Correct Absence (-)	Correct Classification Rate	Sensitivity	Specificity	Kappa
100	24	14	7	27	0.71	0.77	0.66	0.42
500	17	15	14	26	0.60	0.55	0.63	0.18
1000	24	11	7	30	0.75	0.77	0.73	0.50
2000	25	5	6	36	0.85	0.81	0.88	0.69
5000	19	12	12	29	0.67	0.61	0.71	0.32

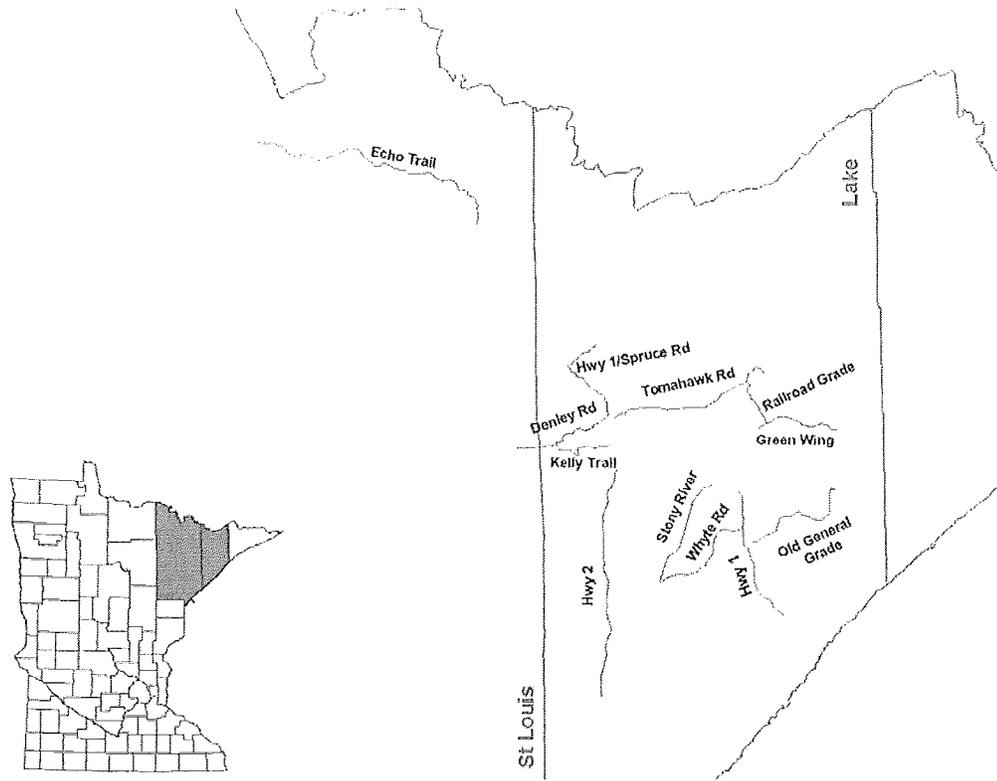


Fig. 1.2. Location of Boreal Owl survey routes within Lake and St. Louis counties in northeastern Minnesota during 2000-2001.

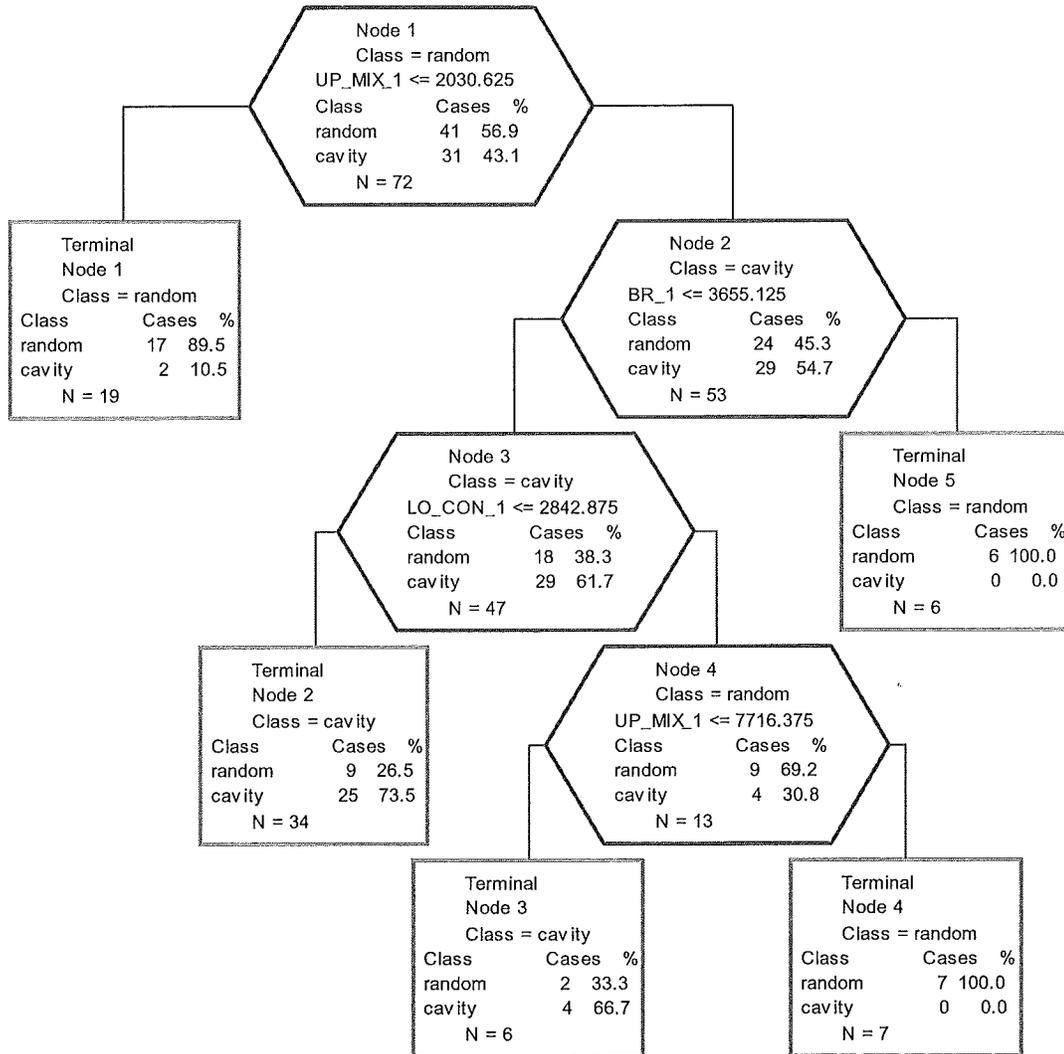


Fig. 1.3. CART classification tree explaining land cover variables that best distinguish Boreal Owl cavity locations from random locations throughout the SNF in northeastern Minnesota within a 100 m radii circular plot. The explanatory (land cover) variables include upland mixed forests (UP_MIX_1), brush (BR_1), and lowland conifer forests (LO_CON_1). Sites containing \geq the amount (m²) of land cover specified (e.g., 2030.625 for upland mixed) are placed in the box to the right of the parent node (hexagon shape).

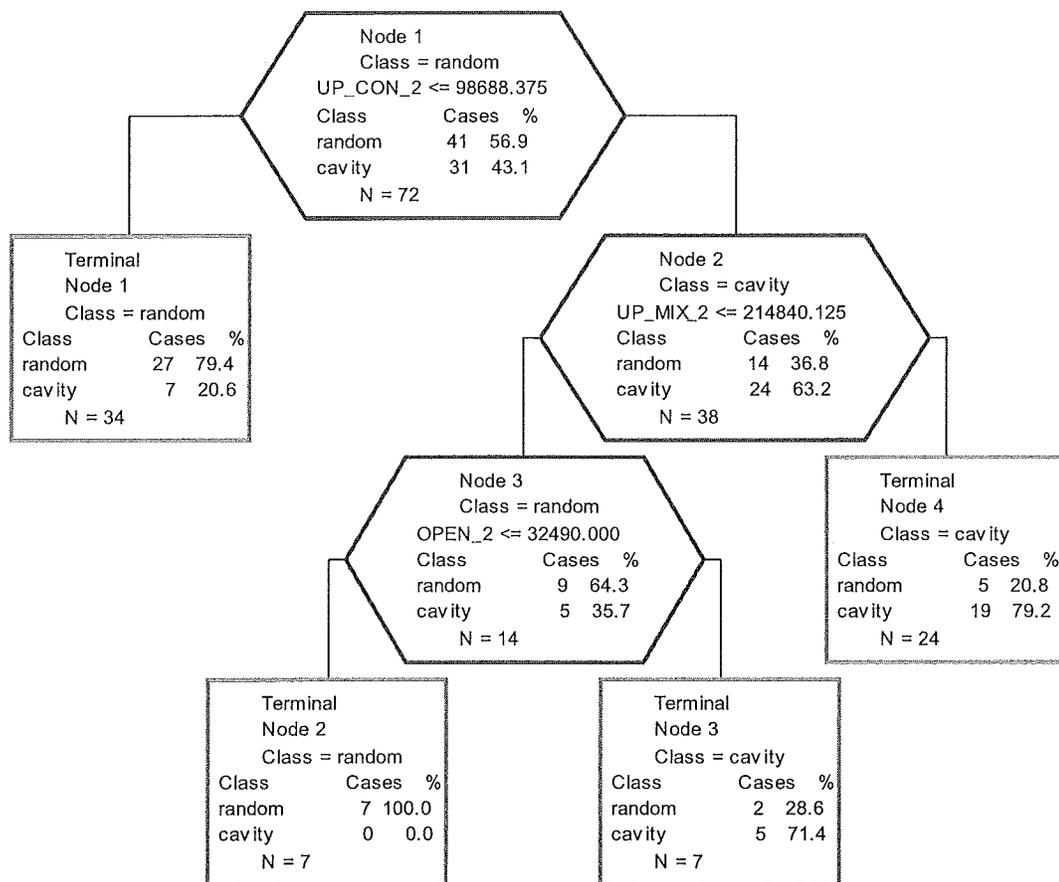


Fig. 1.4. CART classification tree explaining land cover variables that best distinguish Boreal Owl cavity locations from random locations throughout the SNF in northeastern Minnesota within a 500 m radii circular plot. The explanatory (land cover) variables include upland conifer forests (UP_CON_2), upland mixed forests (UP_MIX_2), and open areas (OPEN_2). Sites containing \geq the amount (m^2) of land cover specified (e.g., 98688.375 for upland conifer) are placed in the box to the right of the parent node (hexagon shape).

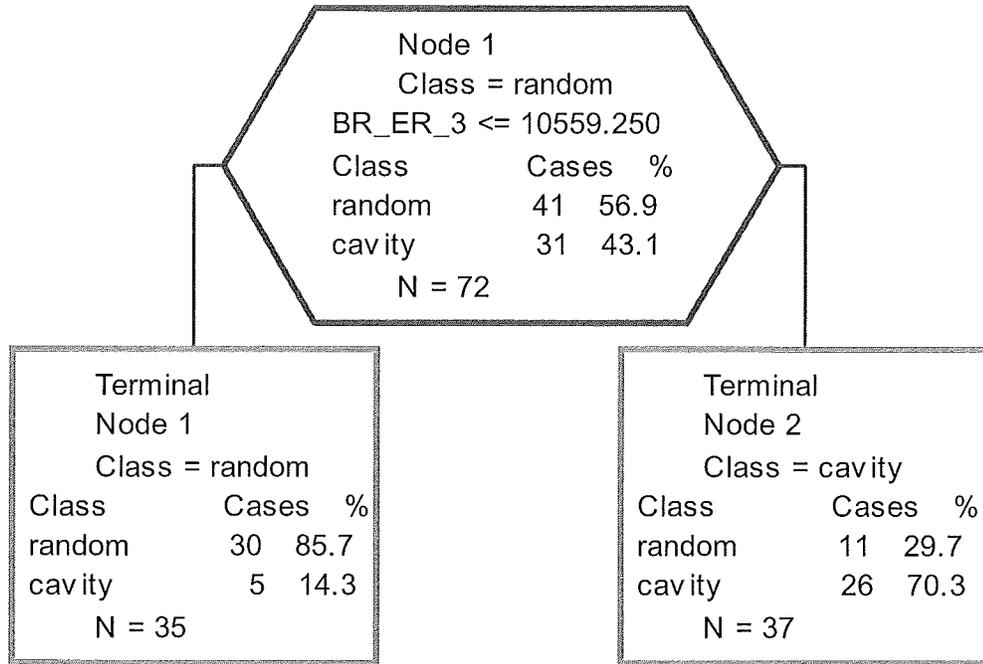


Fig. 1.5. CART classification tree explaining land cover variables that best distinguish Boreal Owl cavity locations from random locations throughout the SNF in northeastern Minnesota within a 1000 m radii circular plot. The explanatory (land cover) variable was ericaceous brush (BR_ER_3). Sites containing \geq the amount (m^2) of land cover specified (e.g., 10559.250 for ericaceous brush) are placed in the box to the right of the parent node (hexagon shape).

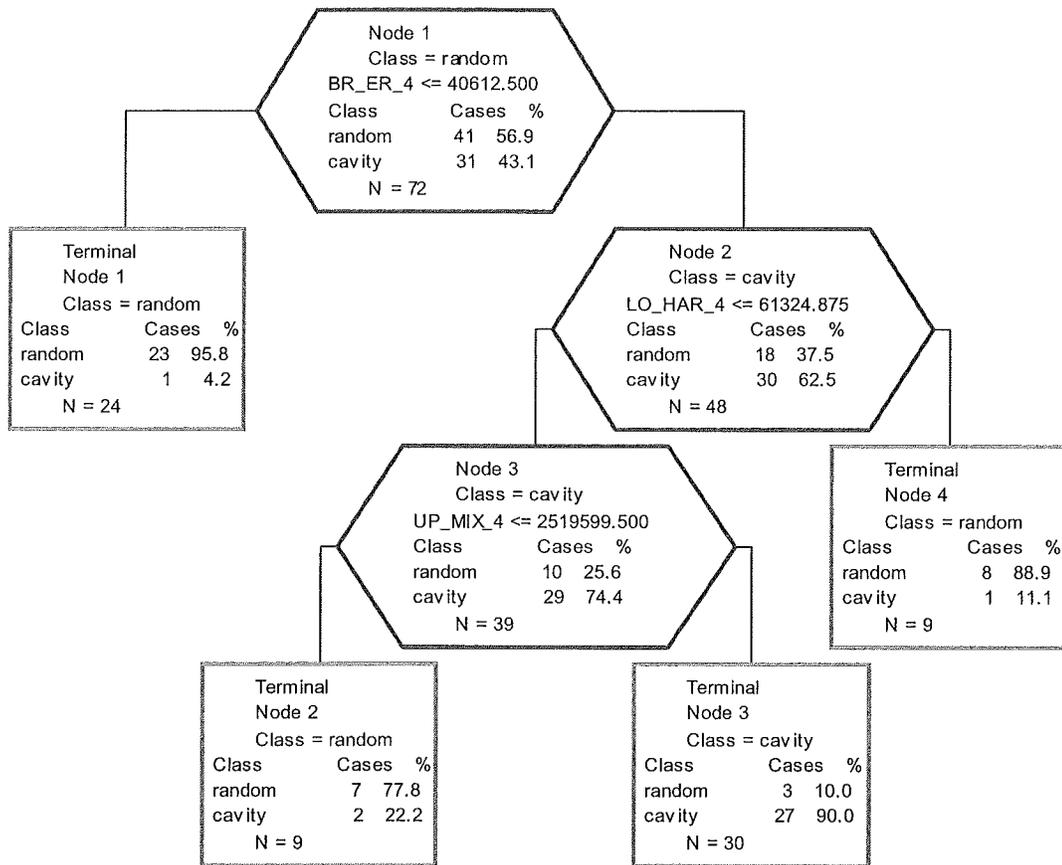


Fig. 1.6. CART classification tree explaining land cover variables that best distinguish Boreal Owl cavity locations from random locations throughout the SNF in northeastern Minnesota within a 2000 m radii circular plot. The explanatory (land cover) variables include ericaceous brush (BR_ER_4), lowland hardwood forests (LO_HAR_4), and upland mixed forests (UP_MIX_4). Sites containing \geq the amount (m²) of land cover specified (e.g., 40612.500 for ericaceous brush) are placed in the box to the right of the parent node (hexagon shape).

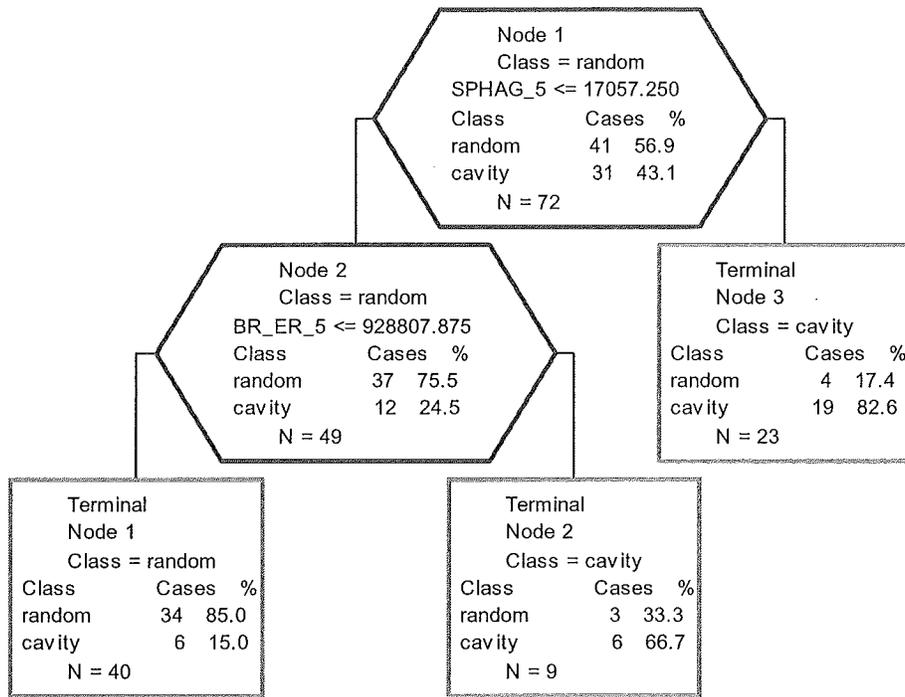


Fig.1.7. CART classification tree explaining land cover variables that best distinguish Boreal Owl cavity locations from random locations throughout the SNF in northeastern Minnesota within a 5000 m radii circular plot. The explanatory (land cover) variables include sphagnum spp. (SPHAG_5) and ericaceous brush (BR_ER_5). Sites containing \geq the amount (m²) of land cover specified (e.g., 17057.250 for sphagnum) are placed in the box to the right of the parent node (hexagon shape).

Appendix 1. Description of vegetation variables measured within the song perch plot. Each plot was 0.04 ha (22.6 m in diameter) and was centered on the tree used by a vocalizing male Boreal Owl. Each plot was separated into four quadrants according to the cardinal directions with each radii being 11.3 m in length.

Song perch measurements

Song perch species: Self-explanatory.

Song perch height: Measured with clinometer to nearest m.

Song perch dbh: Circumference (cm) of tree at breast height.

Crown classification of song perch: Song tree classified as either dominant, codominant, intermediate, or suppressed.

Condition of song perch tree: Song tree classified as either live, declining, dead (no apparent decomposition), decomposing (early stage), decomposing (late stage).

Location of song perch tree: Classified as either lowland, hollow or ravine, $\frac{1}{4}$ up slope, $\frac{1}{2}$ up slope, $\frac{3}{4}$ up slope, top of slope, generally level area, plateau, other

Distance/direction of song perch to cavity or other song perches: If close proximity, distance measured with forester's tape and recorded to nearest m. If distance was greater than 25 m, distance measured using GPS unit. Compass used to determine direction.

Plot measurements

Nearest neighbor: Four trees nearest song perch.

Nearest neighbor species: Self-explanatory.

Nearest neighbor dbh: Four trees nearest song perch > 8 cm and nearest conifer ≥ 16 cm.

Nearest neighbor distance: Distance from song perch to four nearest trees > 8 cm and conifer ≥ 16 cm, measured with forester's tape to nearest m.

Plot trees: Number and species of all saplings and trees ≥ 3 cm dbh, shrubs ≥ 8 cm dbh and > 2 m in height within plot; distinguish between live and dead trees.

Plot basal area: Using a 10-factor prism, meters squared per ha at breast height within plot

Plot canopy height: Heights of the five tallest trees within plot are estimated to the nearest m based on height of 11 m telescopic pole.

Shrub cover: Using an ocular tube, all shrubs > 1 m in height and < 8 cm dbh are recorded. Tube is aimed at ground and five readings are taken along each of the four radii. Shrub vegetation is recorded as presence (+) or absence (-) and distinguished by coniferous or deciduous species.

Dominant shrub species recorded and percent plot cover estimated.

Canopy cover: Using an ocular tube, all trees > 8 cm dbh are recorded. Tube is aimed at canopy and five readings are taken along each of the four radii. Canopy foliage is recorded as presence (+) or absence (-) and distinguished by coniferous or deciduous species.

Downfall: Number of downed logs > 24 cm dbh recorded.

Slope: Slope of plot measured with a clinometer

Aspect: Aspect of plot measured using a compass.

Appendix 2. Description of vegetation variables measured within each random plot. Each plot was 0.04 ha (22.6 m in diameter) and was centered on a point approximately 70 m in an 'a priori' random direction from a tree used by a vocalizing male Boreal Owl. Each plot was separated into four quadrants according to the cardinal directions, with each radii being 11.3 m in length. Only plot measurements were recorded, as a random song perch was not designated.

Plot measurements

Nearest neighbor: Four trees nearest song perch.

Nearest neighbor species: Self-explanatory.

Nearest neighbor dbh: Four trees nearest song perch > 8 cm and nearest conifer ≥ 16 cm.

Nearest neighbor distance: Distance from song perch to four nearest trees > 8 cm and conifer ≥ 16 cm, measured with forester's tape to nearest m.

Plot trees: Number and species of all saplings and trees ≥ 3 cm dbh, shrubs ≥ 8 cm dbh and > 2 m in height within plot; distinguish between live and dead trees.

Plot basal area: Using a 10-factor prism, meters squared per ha at breast height within plot

Plot canopy height: Heights of the five tallest trees within plot are estimated to the nearest m based on height of 11 m telescopic pole.

Shrub cover: Using an ocular tube, all shrubs > 1 m in height and < 8 cm dbh are recorded. Tube is aimed at ground and five readings are taken along each of the four radii. Shrub vegetation is recorded as presence (+) or absence (-) and distinguished by coniferous or deciduous species.

Dominant shrub species recorded and percent plot cover estimated.

Canopy cover: Using an ocular tube, all trees > 8 cm dbh are recorded. Tube is aimed at canopy and five readings are taken along each of the four radii. Canopy foliage is recorded as presence (+) or absence (-) and distinguished by coniferous or deciduous species.

Downfall: Number of downed logs > 24 cm dbh recorded.

Slope: Slope of plot measured with a clinometer

Aspect: Aspect of plot measured using a compass.

CHAPTER 2: HOME RANGE AND HABITAT USE BY MALE BOREAL OWLS IN NORTHEASTERN MINNESOTA DURING THE BREEDING SEASON

ABSTRACT.— Radiotelemetry was used to monitor the movements of three male Boreal Owls (*Aegolius funereus*) in northeastern Minnesota from April – August of 2000-2001. Using Landsat Thematic Mapper satellite imagery, proportions of 13 land cover types within Boreal Owl home ranges were compared with proportions available throughout the study area. Land cover at nocturnal relocations was compared with land cover available within the three home ranges. Both the Minimum Convex Polygon (MCP) method and the Fixed Kernel Method were used to estimate home range size. Home range estimates were based on both diurnal and nocturnal relocations. The mean 95% MCP was 607 ha (range = 430 – 931) while the 95% Fixed Kernel Method mean was 582 (range 407 – 864). Upland mixed forests were significantly higher ($P = 0.008$) within Boreal Owl home ranges than available habitat. Although not significant, proportions of upland conifer forests were within Boreal Owl home ranges. The majority of foraging locations occurred in heterogeneously mixed conifer and mixed coniferous/deciduous habitats. Boreal Owls appear to use lowland mixed forest significantly less frequently ($P = 0.04$) for foraging when compared with availability within home ranges.

INTRODUCTION

The Boreal Owl (*Aegolius funereus*) is distributed holarctically and found to breed in boreal and subalpine forests throughout North America (Hayward 1993). Boreal Owls are considered nomadic throughout their range, but may exhibit different movement patterns depending upon geographical features (topography and cover type), prey density, breeding status and sex (Wallin and Andersson 1981, Lofgren et al. 1986). Fluctuations in prey availability and snow depth are generally considered the driving force behind long distance movements (Korpimäki 1986). Where territories are established, the owls are generally year-round residents (Hayward 1987).

Few studies have been conducted on home range and habitat use in North America due primarily to the secretive nature and nocturnal behavior of this species. Most information comes from the Rocky Mountain regions of the United States (Palmer, 1986, Hayward 1993). In eastern North America, two principal studies have been conducted on Boreal Owl ecology (Bondrup-Nielsen 1978, Lane 1997). Both studies looked at home range size and habitat use of this species. However, use of foraging habitat was not the primary focus of either study.

Boreal Owls are primarily nocturnal foragers, relying on auditory clues for prey localization (Norberg 1970, Mikkola 1983). Beginning in 2000, I initiated a study to determine the home range size

and habitat use of Boreal Owls in northeastern Minnesota during the breeding season, with primary focus on nocturnal (foraging) habitat use. The objectives of the study were 1) radio-tag and monitor the movements of paired male Boreal Owls, as they are the primary food providers during courtship, incubation and nestling stages (Hayward 1993), 2) estimate the home range size for breeding male Boreal Owls using both diurnal and nocturnal relocations, 3) using Landsat Thematic Mapper satellite imagery, determine land cover composition within Boreal Owl home ranges and 4) using Landsat Thematic Mapper satellite imagery, determine foraging habitat used by male Boreal Owls.

STUDY AREA

This study was conducted in Lake and northern St. Louis counties of northeastern Minnesota, which lie within the Superior National Forest. Boreal Owls were widely distributed throughout both counties; therefore I defined a study area (available habitat) by generating a Minimum Convex Polygon (MCP) (Mohr 1947, White and Garrott 1990) around all known territorial singing, roosting and foraging locations of radio-marked and unmarked owls (Chapin 1995) (Fig 2.1). Approximately 75% of the study area was forested with boreal or near-boreal forest types (Chap. 1). Open areas and water comprised the remaining 25% (16% and 9%, respectively) of the study area. Long, cold winters and mild summers characterize weather conditions for the area, with a growing season of approximately 100 days (Frelich and Reich 1995). Average total snowfall for the area is 71.2 inches, with temperatures ranging from --15.3° C in January to 18° C in July (<http://www.climate.umn.edu>).

METHODS

Locating and trapping owls. Boreal Owls were located through nocturnal roadside surveys conducted 1 March – 14 May, 2000-2001 (see Chap 1). Routes were not randomly selected, as emphasis was placed on locating potential breeding sites where Boreal Owls were previously observed (Wilson unpublished). When a singing male boreal owl was detected, an immediate foot search was conducted to locate the song site. Sites were monitored from several nights to two weeks to determine activity. We

considered a location to be a potential breeding site if one of the following were true: 1) a male was heard advertising on more than one occasion, 2) we heard a male and female boreal owl or observed courtship behavior at a site, or 3) an active nest was located on a site (Hayward et. al 1993). Once we felt a territory had been established, we attempted to trap the males.

Owls were trapped at potential breeding sites by using two 12 x 6 m mist nets set up in a “V” formation near the owl’s cavity or singing location. A recording of the Boreal Owl’s primary staccato song was broadcast near the apex of the net to attract the owl to the area. (B. Lane pers. comm., Palmer 1986). Once captured, owls were weighed, banded, measured and equipped with a radio transmitter (Advanced Telemetry Systems; Isanti, MN). Transmitters were attached using a backpack style harness made of elastic ribbon (Wildlife Materials; Carbondale, IL) in the 2000 field season, and tubular teflon (Bally Ribbon Mills; Bally, PA) in the 2001 field season. Harnesses were attached using a 5mm piece of copper tubing crimped over the keel of the bird (Lane 1997). The total weight of the unit was approximately six grams.

Radio telemetry. When possible, we arrived prior to dusk and visually located the roosting owl. Owls were observed from 15 min to 2 h. GPS coordinates were collected for all roost and evening visual locations. When the owl became active, usually around sundown, we followed it until either: 1) it became too dark to visually locate, or 2) the strength of the radio signal (without antenna) decreased considerably, indicating that the bird had left the immediate vicinity. Typically, if a signal is picked up without the antenna (cable only), the transmitter is within 50-70 meters (C. Kochanny, pers. comm.). Vegetative characteristics within the study area (e.g., dense understory, downfall, boggy conditions) made it extremely difficult to follow the owls at close range throughout the night. We therefore moved to the road, relocated the signal and continued to take readings from the road. While we were still able to monitor the owl’s movements from the road, the error in the estimated bearing between the owl and researcher was increased. This resulted in large error polygons surrounding relocation points and subsequently the removal of several points from the home range analysis.

Nocturnal relocations were obtained through two-person triangulation using a portable receiver and a three-element hand-held yagi antenna. To eliminate triangulation error, we attempted to take bearings as close to 90° as possible (White and Garrott 1990). Hand-held radios were used to allow researchers to keep in continuous contact. Researchers were positioned at fixed locations (e.g., intersections or landmarks) along road or trail systems with GPS coordinates being collected for all fixed locations. If a nesting pair were located, a stationary observer equipped with a hand-held radio would record time of arrival and departure of both the male and female owl and the direction of flight from the nest. Owls were tracked an average of four hours per evening. Locations were immediately plotted on 1:24,000 topographical maps. To reduce autocorrelation, only readings separated by at least a 20 min interval were used in the analysis (Lane 1997, Sissons et al. 2001).

Habitat Analysis

Roost sites. Although diurnal roosting habitat of Boreal Owls was not the focus of this study, I attempted to locate roost sites to include in the home range estimate in order to obtain a more accurate representation of home range size. Owls were visually located and observed for at least 0.5 h. All roost locations were recorded using a Garmin Global Positioning System (GPS) and plotted onto Landsat Thematic Mapper (TM) satellite imagery. Quantitative measurements were not collected however; roost tree species were recorded at each site.

Home range. Relocations points were plotted using the computer program GTM (Sartwell 19xx) with default settings. Error polygons were generated for each location. Based on our field assessed error estimation, we used 5.5 as the bearing standard deviation. Triangulation relocations having an error polygon > 30 ha were not included in the analysis. Home range analysis was performed using the Arcview 3.1 Animal Movement Analysis extension (Hooze and Eichenlaub 1997). We used both the 95% MCP method and the 95% Fixed Kernel (FK) method (Worton 1989) to estimate home range size for Boreal Owls. Although there are several disadvantages associated with the MCP method (Samuel and Fuller 1994), I included MCP estimates to facilitate comparisons with previous studies. The 95% fixed kernel method (Worton 1989), a nonparametric home range estimator that accounts for the amount of

time an animal spends in a given location (Seaman and Powell 1996) was used to determine areas of frequent use within each home range.

Landsat Thematic Mapper (TM) satellite imagery, with a 28.5 x 28.5 m resolution was used to identify land cover classes within the study area. For the purpose of this analysis, 54 land cover classes based on Landsat imagery (Wolter et al. 1995) were reclassified into 13 land cover classes (Chap 1; Table 1.). Using Arcview 3.1, Boreal Owl relocation points (diurnal roost, singing locations, and foraging) and resulting home range polygons were plotted onto Landsat (TM) satellite imagery. Proportions of each land cover class were calculated within each individual Boreal Owl home range.

Statistical analysis. To examine Boreal Owl's selection of home range habitat, I compared the mean proportions of land cover types within the three home range boundaries to the proportion of land cover types available throughout the study area. I used a one-sampled t-test (procedure PROC TTEST, SAS 1998) for this analysis. To examine selection of foraging habitat, I assumed all nocturnal relocations to be potential foraging habitat as Boreal Owls are almost exclusively nocturnal hunters (). Nocturnal relocation points were plotted onto Landsat satellite imagery. The relative proportion of foraging habitat was determined by summing the number of nocturnal relocation points within each land cover type and dividing it by the total number of nocturnal relocation points within the home range. This proportion was compared to the proportion of each land cover type available within the home range using a paired t-test (procedure PROC UNIVARIATE, SAS 1998).

RESULTS

Trapping and radio telemetry. Six male Boreal Owls were equipped with radio transmitters during the 2000-2001 field seasons. All owls were trapped near their cavity trees using a mist net and playback of a Boreal Owl primary staccato song. No females were captured during this study. Due to the dispersion of three owls, we were only able to collect meaningful home range data for three individuals.

Two males were trapped during the 2000 field season. Neither male was known to be nesting, however a female was seen in or near the nest cavity of male #154 from early April through mid-April. Shortly thereafter, activity ceased at the cavity and the male was heard vocalizing near the cavity through

early May. The fate of the nest was undetermined. Owl #154 was recaptured on 28 May 2000 using a bal-chatri trap baited with mice and its transmitter removed. The owl was in good physical condition.

There was no documented nesting attempt for male #094, although a female was observed on the territory for two nights. After capture, he remained on his territory and continued vocalizing. On 30 April 2000, the transmitter and intact harness was located on the ground. There was no evidence to determine the fate of the owl.

Four males were trapped during the 2001 field season. Three of the four owls left the study area before sufficient data were collected to obtain an accurate representation of their home range. All three birds left the area between 29 April and 2 May (owl #982 – 29 April, owl #112 – 30 April, owl #992 – 2 May). An intensive aerial search was conducted on 2 May and again on 4 May across the Superior National Forest and into southern Ontario, Canada, however, I was unsuccessful at relocating any of the owls.

A nesting attempt was documented for owl #972. A female was observed in or near the nest cavity from 9 April – mid June. During this period, the male was observed delivering prey to the female several times throughout the evening. The female was also observed leaving the cavity for short periods of time (approximately 6-12 minutes) each evening. The male made his last visit to the cavity on 15 June. Thereafter he did not return to the cavity or the area within several hundred meters of the cavity. The fate of the nest was undetermined, as fledglings were not observed in cavity tree or the immediate vicinity of the cavity tree. No remains were found in the cavity or on the ground. After 15 June, the male remained in the area, but began to expand his home range. Owl #972 was recaptured on 31 August and the transmitter replaced. Shortly thereafter the signal was lost. Aberrant signals indicated a possible malfunction with the transmitter. An aerial search was also conducted, however, the signal was not detected.

Habitat Analysis

Roost sites. Thirty-four roost sites were located during the 2000–2001 field seasons. Coordinates for two sites were lost due to problems with the GPS unit. Roost locations plotted onto Landsat (TM)

satellite imagery showed 18 (56.3%) were located in upland conifer stands, 7 (21.9%) were located in upland mixed stands, 6 (18.9%) were located in lowland conifer stands and 1 (3.1%) was located in a lowland mixed stand. Eighty-five percent of the roost sites were within 100 m of a lowland conifer stand while 94% were located within 200 m of lowland conifer stands. Coniferous species represented 97% of roost trees. Twenty-four (73%) were in black spruce, three (9 %) were in red pine, two (6%) were in balsam fir and one (3%) each in jack pine, white cedar, tamarack, and aspen.

Home range. Boreal Owls were monitored an average of 53 days from April – August 2000–2001 (Table 2.1). Both diurnal (roost) and nocturnal relocations (singing and foraging locations) were included in the home range estimates. The mean 95% MCP home range estimate was 607 ha ($N = 3$, range = 430 – 931 ha, SE = 162). In comparison, the mean 95% fixed kernel home range estimate was 582 ha ($N = 3$ range = 407 – 864 ha, SE = 142) (Table 2.1). Owl #094's home range was twice the size of the other two males in this study even though fewer relocation points were used in the home range estimate (Fig 2.2). Owl #154 and #972 had similar home range sizes (460 ha and 430 ha, respectively) and had neighboring territories, although not occupied during the same year (Figs 2.3 and 2.4).

Upland-mixed forests were the most common land cover type within the study area (26.2%), followed by upland conifer forests (19.4%) and lowland conifer forests (17.7%) (Table 2.2). Similarly, these land cover types were the most common within the three Boreal Owl home ranges (upland mixed = 28.9%, upland conifer = 28.2%, and lowland conifer = 15.5%) (Table 2.2). Open areas, while minimally represented in owl's #154 and #972 home ranges (2.8% and 1.3%, respectively), accounted for nearly 16% of owl #094's home range (Table 2.2).

When compared with the proportion of land cover available within the study area, the proportion of upland mixed forests and roads was significantly higher within the three Boreal Owl home ranges ($P = 0.008$ and $P = 0.02$, respectively). Although not statistically significant, the proportion of upland conifer forests was higher within the three home ranges compared with available habitat (28.2% vs. 19.4%, respectively) and the proportion of upland hardwood forests was lower within the home ranges compared with available habitat (2.7% vs. 8.8%).

Two hundred and ninety-two nocturnal relocations were obtained for the three owls (range = 27 – 192). Lowland mixed forests were used significantly less for foraging compared with the proportion available within the home ranges ($P = 0.04$). The majority of nocturnal relocations were found in upland mixed forests, upland conifer forests and lowland conifer forests (34.9%, 31.8%, and 20.9%, respectively) (Table 2.3).

DISCUSSION

Home range. Minimum Convex Polygon (95%) estimates for Boreal Owls monitored during this study averaged 607 ha. This estimate varied considerably from previous studies conducted in both western and eastern regions of North America (Bondrup-Nielsen 1978, Palmer 1986, Hayward et al. 1993, Lane 1997). There are many factors that may account for the differences in home range size. For example, Palmer (1986) found the home range size of two non-breeding male Boreal Owls (summer months only) in Colorado to average 296 ha (100% MCP). This average is noticeably smaller than the average home range size found in this study. The smaller home range sizes in Colorado may be attributed to the fact that home range estimates were based solely on roost locations. Both diurnal and nocturnal relocations were included in the home range estimates, which may account for the larger home ranges found in this study. In Idaho, Hayward (1989) found considerably larger summer (snow-free period) home range sizes (harmonic mean 1182 ± 334 ha, adaptive kernel estimate 2269 ± 1644 ha). While differences in topographical features, breeding status and prey availability undoubtedly had strong influence on the owl's movements (Hayward 1993); these estimates were based on a much larger sample size ($N = 15$). Additionally, home range estimates in Idaho were based on both males and female movements. Typically, females are considered more nomadic than males (Lundberg 1979, Löfgren 1986), except during nesting when they are confined to the cavity tree. Hayward (1989) noted that seasonal movements were dramatic for some females in his study, especially immediately after leaving the nest cavity. These movements may account for some of the differences in home range size between the two areas.

In Ontario, Canada, Bondrup-Nielsen (1978) found a home range average of 283 ha ($n = 3$). Again, these home range estimates were based on roost locations and may explain the smaller home range size. In northeastern Minnesota, Lane (1997) found home range size of four owls (based on roost and nocturnal locations) to average 1438 ha. He noted however, that increased movements following nest failure might have influenced home range size as home range estimates averaged 425 ha prior to nest failure. This estimate is similar to the home range size found for the nesting male in this study (430 ha). However, the average home range for the non-nesting males in my study was 695 ha (95% MCP), still considerably smaller than Lane's findings of 1438 ha for home range size post nest failure.

There was a noticeable difference in home range size between the two owls (#154 and #972) in the northern portion of the study area compared with the owl (#094) in the southern portion of the study area (460 ha and 430 ha compared with 931 ha, respectively) (Fig 2.x). The two characteristics that separate these birds are 1) land cover composition within the home ranges and, 2) the presence of a female on the territory. While the proportion of forested areas, particularly upland mixed and upland conifer stands were high in all three home ranges; owl #094's home range contained a high proportion of open areas (Table 2.2). Open areas represented nearly 16% of owl #094's home range while accounting for <3% of the other two owl's home ranges (Table 2.2). Boreal owls are forest owls and are intimately linked with the dynamics of forest ecosystems. According to Landsat (TM) satellite imagery, 3 of 27 (11.1%) nocturnal relocations obtained for owl #094 were classified as open areas, while 23 of 27 (85%) were classified as forested areas, particularly upland mixed and upland conifer stands. The spatial distribution of forested and open areas may have influenced owl #094 daily movements, causing it to travel greater distances in search of prey. This may account for his unpaired status, as he may not have been able to provide enough prey to the female during the courtship period (Hakkarainen and Korpimäki, 1997).

Both males #154 and #972 had females on territory and nesting attempts were documented. While courtship behavior was observed on two nights for male #094, no other behaviors (e.g., frequent visits to the cavity, cessation of vocalization) indicated that he was paired. His unpaired status may

account for the larger home range size. While Hayward (1989) observed that non-nesting males in Idaho confined their movements to a smaller area than nesting males, both Palmer (1986) and Lane (1997) observed increased movements following nest failure or during the post-breeding season. Similarly, increased movements were also observed for three of the four owls radio-tagged in 2001. All three left the study area within days of one another (30 April – 2 May). Extensive aerial searches conducted within 24-48 hours following signal loss, throughout northeastern Minnesota and southern Ontario suggested that the owls had made a substantial movement. Transmitter failure seems unlikely, as all were less than two weeks old. All telemetry equipment was functioning properly as I was able to detect a test transmitter set out during the flights.

Although residency appears to be more beneficial for cavity nesting birds (v. Haartman 1968), nomadic movements are not uncommon for this species (Myserud 1970, Wallin and Andersson 1981, Lofgren et al. 1986). Pressures from lack of prey are often the cause of such long distance movements (Korpimäki 1986). During the winter of 2001, northeastern Minnesota experienced an invasion of northern forest owls (Wilson 2001). While many perish, the surviving owls may remain in the area and attempt to breed. Unsuccessful breeding attempts due to immature birds, lack of prey, sub-optimal habitat, or scarcity of females (Hakkarainen and Korpimäki, 1997) may instigate movements back to familiar territory, presumably north of the study area.

It is difficult to predict habitat associations for an entire population of Boreal Owls based on three birds. Land cover variation was evident among the three home ranges however; heterogeneously mixed conifer and mixed coniferous-deciduous forests appear to be important habitat features within the three Boreal Owl home ranges in northeastern Minnesota. Both upland and lowland conifer stands appear to provide important roosting habitat. Quantitative measurements were not collected at roost locations therefore results from this component of the study should be interpreted with care. Based on Landsat (TM) satellite imagery, 56.3% of roost locations occurred in upland conifer stands. The majority (85%) were located within 100 m from a lowland conifer stand, indicating a possible association with lowland conifer stands. Lane (1997) reported that 92% of roost sites located in his study area occurred in lowland

conifer stands.

Upland mixed forests and roads were found in significantly higher proportions within Boreal Owl home ranges than compared with available habitat within the study area (Table 2.2). The higher proportion of roads within home ranges is likely attributed to the fact that owls were located through roadside surveys. Upland mixed forests appeared to be an important habitat feature at both the microhabitat level (Chap 1) and at larger scales. The mean proportion of upland conifer stands, although not significant, was higher within Boreal Owl home ranges than with the proportion occurring within the study area (Table 2.2).

Although nocturnal relocations were separated by 20 minute intervals, data were still highly autocorrelated. In general, relocations are considered statistically independent if sufficient time has passed for the animal to move from one end of its home range to another (White and Garrot 1990). Boreal Owls are considered a sit-and-wait predator, flying short distances through the forest between perches, and hunting in a localized area (Norberg 1970, Hayward 19xx). Hayward (19xx) found that Boreal Owls waited for prey <5 min at 75% of 150 perches, and the average distance between foraging perches was 25 m ($n = 123$). This type of foraging strategy may not have allowed sufficient time for the owls to make any type of substantial movement between relocations, resulting in a higher proportion of relocations for certain forest type. With this in mind, it may be difficult to statistically determine preferred foraging habitat for Boreal Owls in northeastern Minnesota. However, most nocturnal foraging relocations occurred in mixed conifer or mixed coniferous-deciduous stands (Table 2.3). Use of coniferous forest for foraging has been documented in both western North America and Fennoscandia (Palmer 1986, Sonerud et al.1986, Hayward 1993). Less compact snow during winter months and reduced ground vegetation during summer months allow greater access to prey. Small mammals such as red-backed voles (*Clethrionomys gapperi*) and *Microtus* spp. are common prey items. These species are typically associated with forested areas (Kays and Wilson 19xx).

Only one owl (#094) showed any appreciable use of open areas and this may be due to the fact that open areas comprised a larger portion of its home range compared with the other two owls (Tables

2.2 and 2.3). In Fennoscandia, Korpimäki (1988) documented use of clear-cuts and agricultural field during hunting of Tengmalm's Owls. Similarly, Jacobsen and Sonerud (1993) recorded a shift in foraging habitat (from forest to clear-cuts) and prey species (from bank to root voles) of Tengmalm's Owls as snow disappeared. Results from this study seem to indicate that Boreal Owls do not use open areas for foraging.

CONCLUSIONS AND FUTURE STUDIES

Boreal Owls appear to use mixed coniferous (both upland and lowland) and upland mixed stands for foraging during the breeding season in northeastern Minnesota. Use of open areas for foraging does not appear to be important. Year round monitoring may be beneficial as movement patterns are likely to change following the breeding season. Monitoring of females may also provide better understanding of movement patterns.

Table 2.1. Home range size in hectares using the 95% Minimum Convex Polygon (MCP) method and 95% Fixed Kernel method for three male Boreal Owls in northeastern Minnesota, 2000- 2001.

Year	Owl	Sex	Dates Monitored	Number of relocations	95% MCP	95% Fixed Kernel
2000	094	M	30 March – 30 April	37	931	864
2000	154	M	7 April – 28 May	85	460	407
2001	972	M	14 May – 31 August	216	430	476
Mean (SE)					607 (162)	582 (142)

Table 2.2. Proportions of land cover variables based on Landsat (TM) satellite imagery within study area and Minimum Convex Polygon home ranges of Boreal Owls in northeastern, MN 2000-2001.

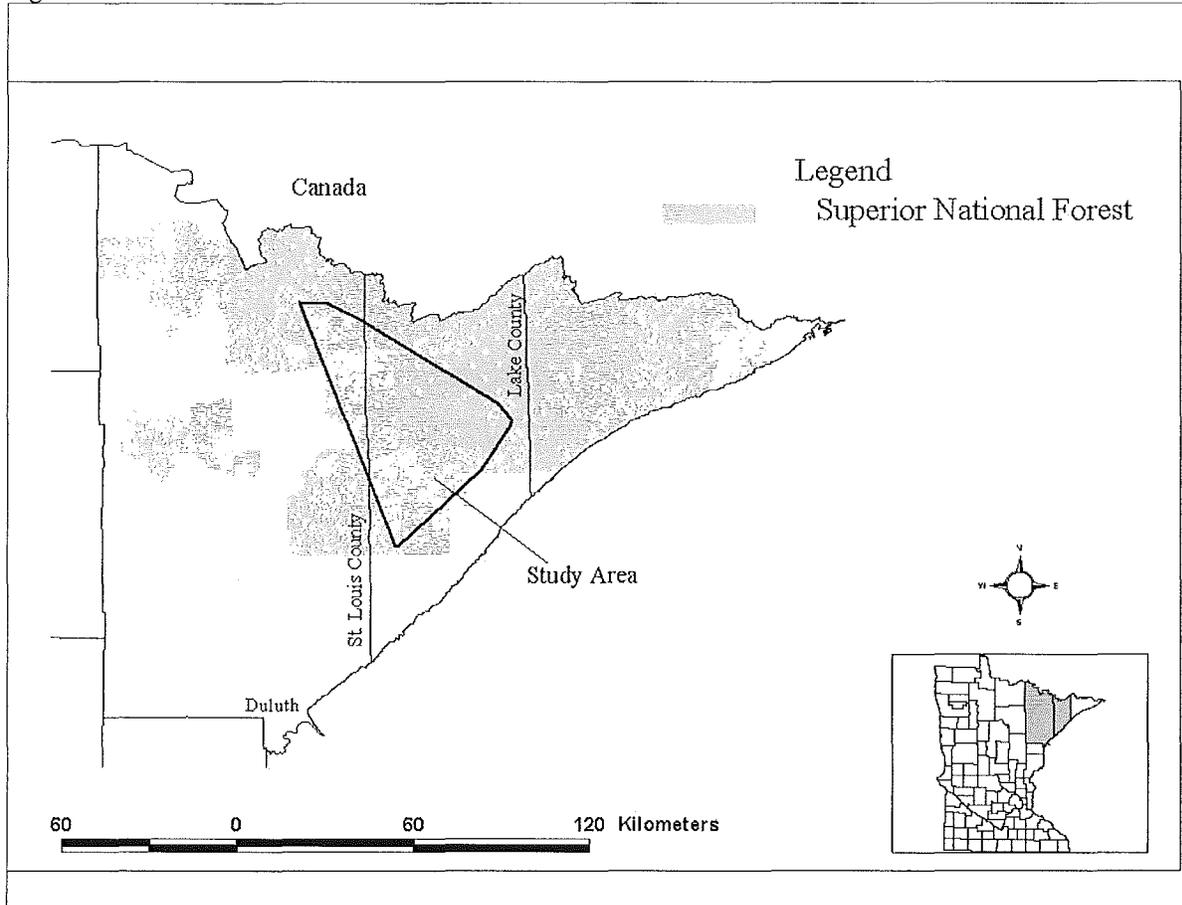
Land Cover	Availability (study area)		Owl 094		Owl 154		Owl 972		SD within home ranges			
	\bar{X}											
Area estimate (ha) ^a	307412		931		460		430		within home ranges			
	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
Upland-mix	80593.9	26.2	265	28.4	134	29.1	125	29.2	174.7	28.9	78.4	0.4
Upland-conifer	59627.0	19.4	139	15.0	191	41.7	121	28.1	151	28.2	36.8	13.4
Lowland-conifer	54561.3	17.7	96	10.3	67	14.6	93	21.7	85.3	15.5	15.9	5.8
Water	27972.5	9.1	72	7.7	20	4.3	45	10.5	45.7	7.5	26.0	3.1
Upland-hardwood	27127.5	8.8	57	6.1	4	<1	6	1.3	22.3	2.7	30.0	2.9
Open	22717.6	7.4	145	15.6	13	2.8	6	1.3	54.7	6.5	78.3	7.9
Brush-lowland	13846.7	4.5	83	8.9	3	<1	4	<1	30	3.5	45.9	4.7
Brush	9862.4	3.2	34	3.7	3	<1	3	<1	3	1.7	17.9	1.8
Brush-ericaceous	3552.1	1.2	1	<1	10	2.2	14	3.3	8.3	1.9	6.7	1.6
Lowland-mix	3510.9	1.1	3	<1	3	<1	3	<1	3	0.6	0	0.3
Roads	3248.0	1.1	22	2.4	10	2.2	8	1.9	13.3	2.2	7.6	0.3
Lowland-hardwood	715.5	<1	14	1.5		--	--	--	4.7	0.5	8.1	0.9
Sphagnum	76.9	<1	--	--	2	<1	2	<1	1.3	0.3	1.2	0.3

^a Home range estimate for study area was calculated using the 100% Minimum Convex Polygon; Boreal Owl home range estimates were calculated using the 95% Minimum Convex Polygon.

Table 2.3. Land cover types for nocturnal foraging relocations for three Boreal Owls in northeastern Minnesota, 2000-2001.
Land cover types based on Landsat (TM) satellite imagery.

Cover type	Owl 094		Owl 154		Owl 972		Total reloc.	Total Percent
	No. noc reloc	Percent	No. noc reloc	Percent	No. noc reloc	Percent		
Upland mix	12	44.4	28	38.4	62	32.3	102	34.9
Upland conifer	8	29.7	34	46.6	51	26.6	93	31.8
Lowland conifer	1	3.7	5	6.8	55	28.6	61	20.9
Ericaceous brush	0	0.0	0	0.0	11	5.8	11	3.8
Open	3	11.1	1	1.4	4	2.1	8	2.7
Brush	1	3.7	1	1.4	4	2.1	6	2.1
Lowland mix	0	0.0	4	5.5	2	1.0	6	2.1
Upland hardwood	1	3.7	0	0.0	2	1.0	3	1.1
Lowland brush	0	0.0	0	0.0	1	0.5	1	0.3
Lowland hardwood	1	3.7	0	0.0	0	0.0	1	0.3
Total	27	100.0	73	100.0	192	100.0	292	100.0

Figure 2.1



CHAPTER 3. POPULATION VIABILITY ANALYSIS FOR THE BOREAL OWL (*AEGOLIUS FUNEREUS*) IN THE SUPERIOR NATIONAL FOREST

INTRODUCTION

The Boreal Owl or Tengmalm's Owl (*Aegolius funereus*) is a small northern forest owl that is distributed holarctically from Scandinavia east across northern Siberia. In North America it is found to breed in the boreal forests of Alaska, Canada and extreme northern regions of the United States (Hayward 1993). Breeding populations have been documented in the Rocky Mountain regions from Idaho through southern Colorado and northern New Mexico, with isolated populations located in the Cascade Mountains of Washington and Oregon (Palmer and Ryder 1984, Hayward 1987, O'Connell 1987, Whelton 1989, Holt and Ermatinger 1989, Stahlecker and Rawinski 1990). In northeastern Minnesota they have been used by US Forest Service as a Sensitive Species.

Boreal Owl populations in northeastern Minnesota exhibit several characteristics that raise concern over the long-term viability of the species: patchily distributed, low abundance, high degree of annual variation and stenotypic habitat requirements. It has been well documented that populations of animals near the periphery of their range tend to be patchily distributed (Brown 1984, Brown and Maurer 1989, Maurer 1994). Brown and Maurer (1995) argue that this increased variability is due to the fact that as one moves from the core of a species' range, suitable habitat becomes increasingly patchy or that interspecific competition for resources increases and that the realized niche of a given species becomes narrower. Regardless of the proximate causes, such patchiness and increased variability in abundance lead to an increased risk of extinction for any given subpopulation (Gilpin and Soule 1986). Such extinctions can be the result of either demographic stochasticity (i.e., random events affecting demographic parameters) or environmental stochasticity (i.e., random events affecting a species' biotic and abiotic environment).

In addition to the natural stochasticity which effects all populations of animals, alterations to the landscape by man must be taken into account. Timber harvesting in Minnesota has increased over the last several decades to almost 4 million cords are harvested annually which potentially has altered the landscape matrix in which Boreal Owls exist. The general consequence of such increased timber harvest is an increase in the amount of forest fragmentation and a general reduction in the size of mature forest stands. It could be expected that the consequences of such alterations would be an increased isolation of suitable Boreal Owl habitat and increased variability in their abundance. Because of this species' life history characteristics and the potential changes in the quality and amount

of suitable habitat it is reasonable to suspect that Boreal Owl populations are behaving as metapopulations (Hanski and Gilpin 1991).

Most of the information regarding population dynamics and habitat use come from the western regions of North America, where Boreal Owls are associated with mixed coniferous-deciduous forests and higher elevation, mature, subalpine conifer forests (Meehan 1980, Palmer 1986, Hayward et al. 1993, Herran et al. 1996). In eastern North America, little information regarding Boreal Owl distribution and breeding status is available. Most observations are associated with erratic winter irruptions (Bent 1938, Green 1966, 1969, Catling 1972, Eckert 1979). Habitat use studies are limited to Ontario, Canada (Bonrup-Nielsen 1978) and extreme northeastern Minnesota (Lane 2001). In Canada, population size is characterized as fluctuating to stable, with insufficient information to assess status (Kirk 1998). While a confirmed breeding species in northeast Minnesota (Eckert and Savaloja 1979, Matthiae 1982, Lane 2001), information regarding habitat requirements and population status is scarce. Boreal Owls are found to breed at low densities in northeast Minnesota (Lane 1997, Wilson pers comm); however, population trends are difficult to estimate due to the cyclic fluctuations of the species

Using results obtained from a concurrent study assessing habitat use in the Superior National Forest (SNF) this study assessed the population viability of Boreal Owl on the SNF in northeastern Minnesota. We combined data acquired on habitat use, population demographic parameters and Landsat satellite imagery to conduct a spatially-explicit population viability analysis (PVA) using Ramas-GIS (Applied Biostatistics 19xx). Demographic parameters for this study were not acquired from radio-tagged individuals as originally proposed given the difficulty of doing so. Instead, demographic parameters were obtained from existing literature. Readers are cautioned that this has serious implications for the interpretation of results presented here (see Discussion for more detail).

Although there is some controversy over the effectiveness of PVAs (Boyce 1997?), when properly interpreted the results can prove beneficial in developing sound management guidelines for the conservation of a species. Given the spatial and temporal dynamics of Boreal Owl populations we modeled their dynamics using a PVA based on metapopulation dynamics. The theory behind metapopulation dynamics describes the spatial and temporal relationships between a regional set of sub-populations (Levins 1969, Hanski 1982, Hanski and Gilpin 1991). Implicit in this concept is the fact that the continued existence of local sub-populations is dependent on the population dynamics of a larger region.

METHODS

Study Area

This study area included most of northeastern Minnesota, with the majority of the study area located within the Superior National Forest (Figure 1). Differential erosion of bedrock, due to glaciers and running water, is responsible for the rugged terrain common in northeastern Minnesota. Deep, elongated lake basins and low-lying areas separated by more resilient ridges characterize the landscape of this area (Ojakangas and Matsch 1982). In the northern portion of the study area, glacial drift is minimal to absent, leaving abundant outcrops of exposed Precambrian bedrock. In contrast, glacial drift covers most of the southern portion of the study area (Ojakangas and Matsch 1982).

Two ecoregions (Laurentian Divide and Border Lakes; Albert 1995) are located within the study area. Approximately 80% of the Border Lakes and Laurentian Divide ecoregions are forested (Mladenoff et al. 1997), with boreal or near-boreal forest types such as white and black spruce (*Picea glauca* and *P. mariana*), pine (*Pinus resinosa*, *P. strobus*, and *P. banksiana*), balsam fir (*Abies balsamea*), northern white cedar (*Thuja occidentalis*), paper birch (*Betula papyrifera*), and trembling aspen (*Populus tremuloides*) dominating the landscape (Larsen 1980). Dominant land cover classes in the Border Lakes and Laurentian Divide ecoregions include: mixed forest (70-75% and 49.4%, respectively), water (13.3% and 6-8%, respectively), forested wetlands (6-8% and 20-26%, respectively), and coniferous forest (2-4% and 6.8%, respectively). Deciduous forests and agricultural land are minimally represented in these ecoregions (Mladenoff et al. 1997).

Catastrophic events (both natural and human-caused) have shaped the forest mosaic of this region. Widespread removal of coniferous forests by European settlers (either through logging or burning) has converted much of the landscape to mixed and deciduous forests (DNR Tech. Report 1993). These mixed coniferous-deciduous forests may be early or late successional, and typically occur on dry to wet-mesic sites (DNR Tech. Report). Mixed pine-hardwood forest, white pine-hardwood forest, and Boreal hardwood-conifer forest are the three most common mixed forest community types represented in this study area (DNR Tech. Report 1993).

Weather conditions in the area are characterized by long, cold winters and mild summers. Average total snowfall for the area is 71.2 inches, with temperatures ranging from -15.3°C in January to 18°C in July (<http://www.climate.umn.edu>).

PARAMETERIZATION OF PVA

Habitat suitability

Habitat suitability models were derived from habitat use data delineated using Boreal Owl 95% minimum convex polygon home ranges occurring in the SNF (Belmonte in prep; Table 1). Mean percent cover for each of 13 land cover classes were calculated for three home ranges. Using confidence limits derived from the associated standard deviation (SD) we were able to calculate the probability of a Boreal Owl home range containing a given proportion of that habitat. Confidence levels occurred in deciles ranging from 10% to 90%. In other words, the more similar a given proportion of land cover is to the mean proportion occurring in the home ranges of three radio-tagged birds, the more likely you are to have a Boreal Owl. By aggregating over the 13 land cover classes an approximate suitability index can be calculated (Figure 2).

A grid containing cells equal to the smallest home range measured in the SNF, 430 ha, was used to calculate proportion of each land cover type in each of 9,908 cells. A random starting point was selected to place the grid over the Landsat data to reduce any bias associated with grid placement. We acknowledge that a different starting point, random or otherwise, might give us different results. However, the processing time required to calculate a habitat suitability map requires additional resources not available to this study. All GIS operations were conducted in ArcView 3.2 (ESRI, Inc.).

Population demographics

Demographic parameters relating to fecundity, survival and lambda (λ) were obtained from existing literature (Table 2). The only study reporting these values is from western North America (Hayward et al. 1993) and may not be indicative of demographic parameters in northeastern Minnesota. However, parameterization of Ramas-GIS requires estimates of these and other demographic parameters. Estimates of dispersal rates between home ranges and/or metapopulations do not exist in the literature and were not obtained during the associated field study. The parameters *Noc* and *Ahs* allow demographic parameters to be linked to the habitat suitability map. *Noc* modifies each parameter by the number of cells in each subpopulation (i.e., home range) where *Ahs* modifies each parameter by the average habitat suitability for each subpopulation.

For each combination of lambda, 1000 replications of 100 years of population growth were simulated. Dispersal was modeled at relatively low rates based on 1) presumed site fidelity (B. Lane, pers. comm..) and 2)

relatively short life-span of most individuals. Dispersal values were set to 0.2 between all subpopulations and as an alternative at 0.25 for adjacent subpopulations and 0.01 for disjunct subpopulations.

RESULTS

A total of seven suitable areas for Boreal Owls were delineated on the basis of land cover characteristics described by Belmonte (in prep; Figure 2). However, since two sites were contiguous, Ramas-GIS treated those as one subpopulation (Figure 3). Under the six scenarios simulated as part of this project, the entire Boreal Owl population in the SNF went extinct within 24 years (Figure 4).

Altering the dispersal matrix nor increasing R_{max} did not prolong metapopulation persistence under these scenarios. We altered several of the demographic parameters by plus and minus 10 and 20 percent in an attempt to stabilize population persistence. None of these alternative scenarios resulted in increased population persistence. Without immigration into the system, the low abundance observed in northeastern Minnesota appears not to be sustainable.

DISCUSSION

Population persistence under metapopulation theory requires immigration from regional populations. The scenarios modeled in this study did not have access to Landsat imagery from a sufficiently large area to detect the existence of such "source" populations. It is quite possible that given SNF location on the southern periphery of the Boreal Owl range that suitable home ranges within its jurisdictional boundaries are indeed sinks (Pulliam 19xx). This does not imply that appropriate habitat within the SNF is not important. Subpopulations along the periphery of a species range may increase the species' ability to adapt to new environs.

If this study's assessment of the amount of suitable habitat is at least proportionally correct, then it is important to recognize the need to ensure at least this amount of habitat remains. Reducing the amount of available habitat within the SNF will only act to reduce population persistence time. An interesting question that was not explored due to time constraints would be to determine how much habitat would be necessary to increase population persistence. The underlying habitat suitability maps would have to be manipulated in order to artificially increase the number of metapopulation sites occurring in northeastern Minnesota.

It is unknown how well the demographic parameters used in this analysis correlate to the actual parameter values in northeastern Minnesota. Based on the amount of field work conducted in the companion study (Belmonte in prep), it is unlikely that more realistic parameter estimates will be determined. The results of this study do suggest that the continued persistence of Boreal Owls in the SNF depends not only on the continued existence of suitable habitat within the SNF and greater Arrowhead region, but also on immigration from the core area of the species' range to the north. Thus, continued existence of this species in the SNF may be dependent on forest management practices occurring in Canada.

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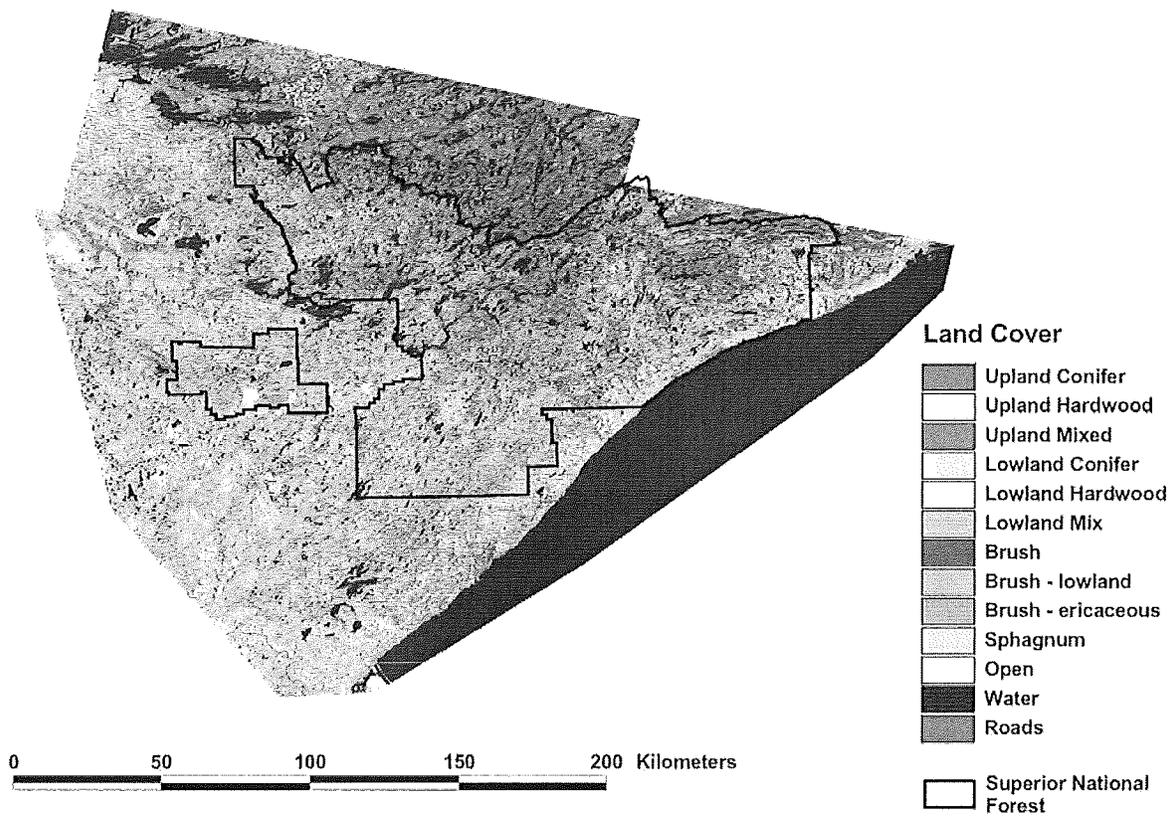


Figure 1. Land cover of study area used in population viability analysis of Boreal Owl in northeastern Minnesota

Table 1. Mean proportion of 13 land cover classes from three 95% minimum convex polygon home ranges of Boreal Owls in the Superior National Forest. Confidence limits ranging from 10% to 90% were derived from these data and used in developing a habitat suitability index.

Cell Value	Land Cover	Percent Cover	
		Mean	SD
7	Brush	1.7	1.8
9	Brush-ericaceous	1.9	1.6
8	Brush-lowland	3.5	4.7
4	Low-conifer	15.5	5.8
5	Low-hardwood	0.5	0.9
6	Low-mix	0.6	0.3
1	Up-conifer	28.2	13.4
2	Up-hardwood	2.7	2.9
3	Up-mix	28.9	0.4
11	Open	6.5	7.9
12	Water	7.5	3.1
13	Roads	2.2	0.3
10	Sphagnum	0.3	0.3

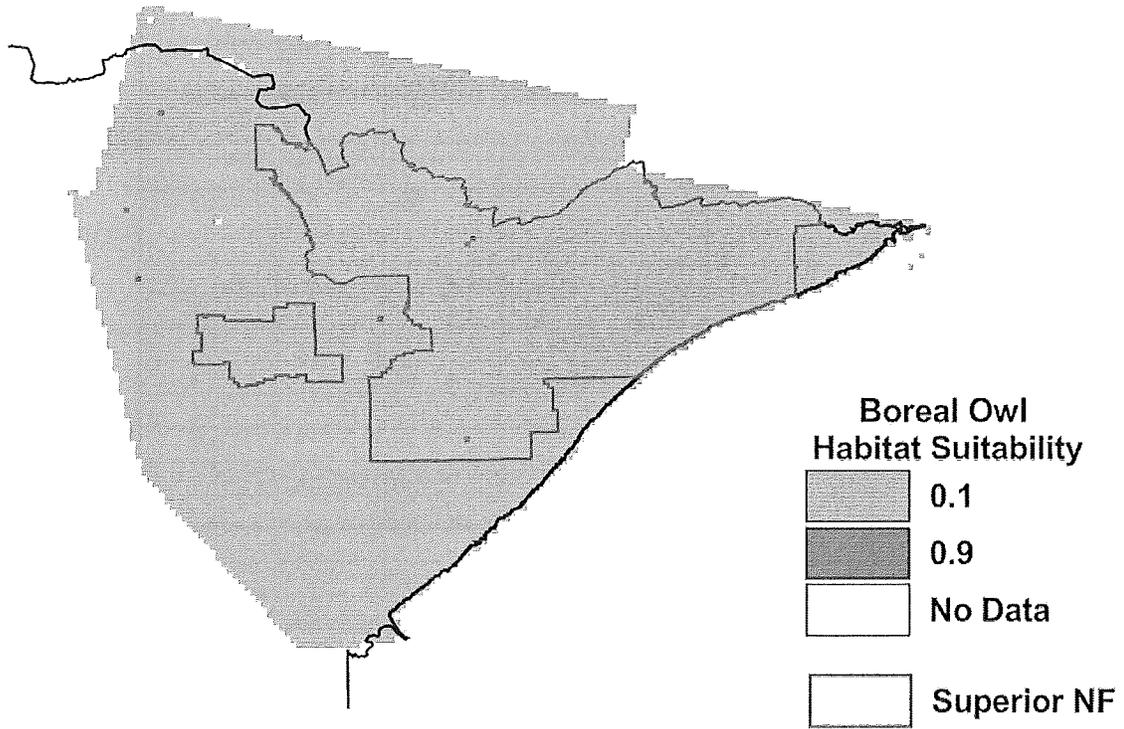
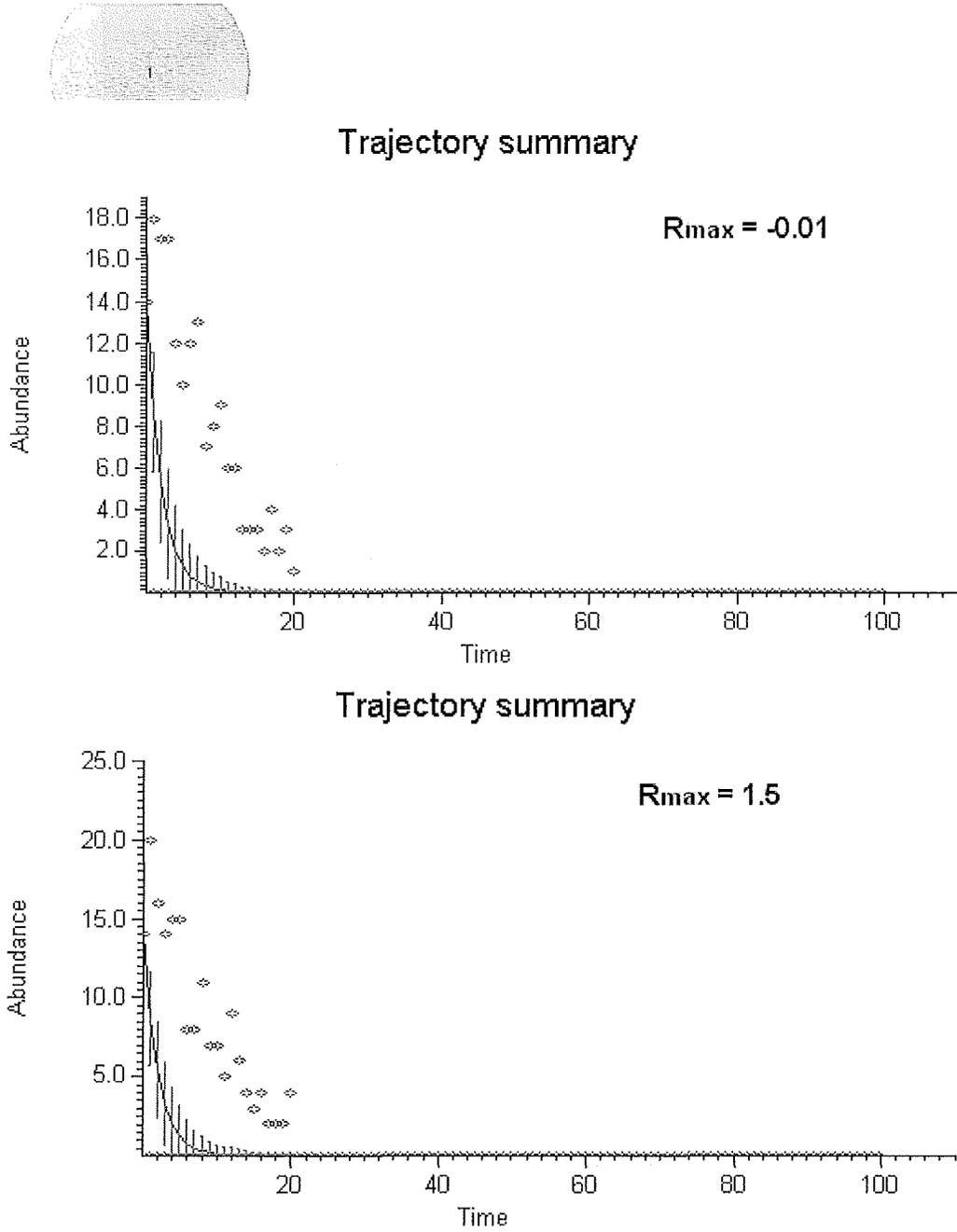


Figure 2. Habitat suitability map for Boreal Owl in northeastern Minnesota. Each cell (e.g., pixel) represents 430ha, the smallest 95% minimum convex polygon described by Belmonte (in prep).

Table 2. Demographic parameters used in parameterization of PVA in Ramas-GIS.			
Parameter	Value(s)		
	Starting	Alternative 1	Alternative 2
Cell Length	2.073 km (430ha)		
Habitat Suitability Threshold	0.5		
Neighborhood distance (# of cells)	2		
Carrying Capacity (K)	$Noc^1 * 2$		
R_{max}	-0.01	1.5	-0.43
Initial Abundance	$Noc^1 * 2$		
Relative Fecundity	$Ahs^2 * (2.3*0.3)$		
Relative Survival	$Ahs^2 * 0.46$		
¹ – Noc = number of cells in metapopulation patch ² – Ahs = average habitat suitability within a patch			

Figure 3. Set of subpopulations (i.e., metapopulations) delineated by Ramas-GIS for the Boreal population viability analysis.

Figure 4. Simulated population trajectories for R_{max} equal to -0.01 and 1.5 . The entire population in the study area went extinct within 24 years.



Proposed methods for habitat analysis (chapter 2)

Activity Level

All five minute intervals for free-ranging lynx were classified as active or inactive based on individual thresholds. The sum of X and Y activity counts were used to create two thresholds for each lynx for each collar deployment due to differences in collar sensitivity. Values below the lower threshold were classified as inactive; values above the upper threshold were classified as active. Value in between the two thresholds could not be classified as active or inactive. These two thresholds were determined from the average of the top 5% of sum X Y values. 18% and 43% of the average of the top 5% were the thresholds separating active and inactive behavior.

After individual thresholds based on Sum X Y were applied, the adjacent intervals were considered. The middle interval was reclassified if it did not equal adjacent intervals (i.e. I-A-I or A-I-A). Intervals at the start of collar wearing were not classified based on adjacent interval; only the threshold was used to classify these intervals.

Selection of GPS points

I will only consider successful location attempts taken when the lynx was not in a trap or within 24 hours of release. Only 3D fixes will be considered since the positional accuracy of a location decreases between 3D and 2D fixes (Rempel et al. 1995; Bowman et al. 2000; Moen et al. 2001; Cain et al. 2005). Of a possible 10,500 GPS locations taken with Lotek collars that have an activity count associated with them, I propose using locations separated by an average of 24 hrs. This would result in 1163 locations to consider for habitat analysis.

Each GPS location will be buffered to account for possible errors to due the GPS technology (Rettie and McLoughlin 1999). A buffer of 25 m will be used since several studies have found that the vast majority of location errors are less than this distance (Moen et al. 2001; Di'Orio et al. 2003; Cain et al. 2005; D'Eon and Delparte 2005)*.

Habitat characteristics at each location will be analyzed. Cover type will be classified by LULC. Stand age will be determined from aerial photos taken in 1991. If the location was clearcut in 1991, then the current stand age is about 15 years old. The

same can be done for aerial photos taken in 2003-2004. Habitat characteristics for locations of lynx activity and inactivity will be compared.

*Here are the actual positional errors reported.

Moen et al. 2001: 95% in 17 m

Cain et al. 2005: 2.5-75m, average 9.7m (review of 6 papers); 50%<5.7m, 95%<28.9m

D'Eon and Delarte 2005: 3.4-17.0m; 95% 28.9m

Di'Orio et al. 2003: 90%<25m

Ron Moen

Date sent: Wed, 01 Nov 2006 09:10:28 -0600
From: Julie Palakovich <palak004@d.umn.edu>
To: Ron Moen <rmoen@nrri.umn.edu>
Subject: free-ranging lynx

Regarding only including data from free-ranging lynx data that is within a few weeks of the WSC trial, there is only two lynx that meet this criteria and neither wore a collar for the entire duration of the trial.

L14: 3/29/04-9/36/04

L24: 10/2/04-1/13/05

Three other lynx starting wearing collars in November 2004:

L2: 11/25/04-2/27/05

L5: 11/2/04-3/2/05

L7: 11/29/04-3/04/05

Considering these dates in other years, two more lynx could be added:

L5: 11/5/05-3/21/06

L7: 11/2/05-3/4/06

I'm thinking that I will still make the comparison to L5 since it was the same collar even though the dates are different and also include L14 and L24.

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