HOME RANGE AND HABITAT CHARACTERISTICS OF BOREAL OWLS IN NORTHEASTERN MINNESOTA

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This is to certify that I have examined this copy of a master's thesis by

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CHAPTER 1: HABITAT CHARACTERISTICS OF BOREAL OWL SINGING AND CAVITY LOCATIONS IN NORTHEASTERN MINNESOTA

ABSTRACT. – Habitat characteristics surrounding 42 Boreal Owl (*Aegolius funereus*) singing locations located between 1987 and 2001 through nocturnal surveys in northeastern Minnesota were examined. Vegetation was sampled at 0.04 ha plots surrounding each Boreal Owl song perch and one paired random plot located within the same stand. The majority (93%) of song perches were located in coniferous tree species. Boreal Owl singing locations had higher basal area, higher percent coniferous canopy and a taller overstory canopy compared with random locations. Using Landsat Thematic Mapper (TM) satellite imagery, 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) were compared with random locations (n = 41) distributed throughout the Superior National Forest. Lowland conifer, hardwood and mixed hardwood, upland conifer; ericaceous brush, sphagnum, open water, and roads were significantly different ($P < 0.05$) at all buffer levels between cavity and random locations. Classification and regression tree models (CART®) showed the landscape mosaic surrounding Boreal Owl cavity sites changes at varying spatial scales. Upland mixed forests were more common at cavity sites compared with random sites, particularly within 100 m of cavity trees. Upland conifer stands were more common at cavity sites compared with random sites at the 500 m buffer. Lowland conifer stands and ericaceous shrubs were more common surrounding cavity locations, especially at larger landscape scales (>1000 m).

INTRODUCTION

The Boreal Owl or Tengmalm's Owl is a small northern forest owl that is distributed holarctically. In North America it breeds in the boreal or near boreal forests of Alaska, Canada and extreme northern regions of the United States (Hayward 1993). Breeding populations have also been documented in the Rocky Mountains 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, O'Connell 1987, Hayward 1989, Whelton 1989, Holt and Ermatinger 1989, Stahlecker and Rawinski 1990).

Although a common forest owl in Fennoscandia (Korpimäki 1981, Sonerud 1986), 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, 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 (Hayward 1997, Niemi and Hanowski 1997).

The majority of habitat studies come from the western regions of North America where the Boreal Owl, a secondary cavity nester (Mikkola 1983), is associated with mixed coniferous-deciduous forests and high 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. Habitat use studies are limited to Ontario, Canada (Bonrup-Nielsen 1978) and extreme northeastern Minnesota (Lane et al. 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 northeastern Minnesota (Eckert and Savaloja 1979, Matthiae 1982, Lane et al. 2001), information regarding habitat requirements and population status is scarce. Boreal Owls breed at low densities (Lane 1997, Wilson pers. comm.); however, trends are difficult to estimate due to population fluctuations. Winter invasions, particularly during severe winters, are common (Bent 1938, Green 1966, 1969, Catling 1972, Eckert 1979).

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 northeastern

Minnesota. 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. Singing locations are considered nesting habitat as Boreal Owls do not sing randomly throughout their home range but instead tend to sing from trees located within 100 m of a potential cavity site (Bondrup-Nielsen 1978, Mikkola 1983, Palmer 1986, Hayward et al. 1993). While continuing to collect data on singing locations, I expanded the study to incorporate a landscape analysis of Boreal Owl nesting habitat and added a radiotelemetry component to assess home range and habitat use (Chapter 2). The objectives of this study were to (1) identify and describe Boreal Owl song trees and the habitat characteristics surrounding these singing locations, (2) determine if Boreal Owls were selecting for certain structural features relative to what is available within the nesting site, and (3) identify cavity trees and evaluate the habitat surrounding cavity sites at various spatial scales.

STUDY AREA

This study was conducted in Lake County and northern St. Louis County in northeastern Minnesota. The majority of the study area was located within the SNF (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. Conversely, glacial drift covers most of the southern portion of the study area (Ojakangas and Matsch 1982).

Two ecoregions, the Laurentian Divide and Border Lakes regions (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 tree species such as white and black spruce (*Picea glauca and P. mariana*), red, white and jack 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 (wind, fire and human-caused) have shaped the forest mosaic of this region (Pastor and Mladenoff 1992). Widespread removal of coniferous forests has converted much of the landscape to mixed and deciduous forests (Heinselman 1973, Aaseng et al. 1991). Strong seasonal variation including short, mild summers and long, extremely cold winters characterize the climate of the area (Bonan and Shugart 1989). Average total snowfall for the area is 181 cm, with average 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 beginning in 1987, with routes being surveyed more intensively during 2000 and 2001 (Figure 1.2). Each route was surveyed at least once during five periods: 1-14 March, 15-31 March, 1-14 April, 15-30 April, and 1-14 May. 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 and continued until the route was complete. Listening stations along each route were separated by 1.6 km intervals (Francis and Bradstreet 1987). Bondrup-Nielsen (1984) reported that in calm conditions Boreal Owls can be heard from a distance of 1.5 km and as far away as 3.5 km. Each listening station consisted of a three-minute passive listening period, the broadcast of a 20 sec recording of a Boreal Owl primary staccato call using a portable tape player, and a final one-minute passive listening period. If a Boreal Owl was detected within the first three minutes call broadcast was not used. When a singing male was detected, an immediate foot search was conducted to locate the singing owl. This was accomplished by walking toward the owl until the tree the owl was singing from was located. UTM coordinates of the song tree were collected with the use of a Garmin Global Positioning System (GPS). Sites were monitored from several nights to approximately two weeks to determine activity.

Singing locations. Habitat variables were measured at Boreal Owl singing locations and compared with identical variables measured at one random location located approximately 70 m from the song tree. Habitat at singing and random locations was measured using the James and Shugart (1970) method. Habitat was sampled at 0.04 ha (11.3 m radius) plots centered on the song tree. All trees within each plot were identified to species. Height (m) and diameter at breast height (dbh) were measured for each tree in the plot >3 cm dbh and 2 m in height using a telescopic pole with a maximum height of 7 m for small trees or a clinometer for use on taller trees and a diameter tape, respectively. Canopy height was calculated by taking the average height of the five tallest trees within the plot. Song tree species, dbh, height, and condition (e.g., live, declining, dead, decomposing-early stage, decomposing late stage) were recorded. Thirteen habitat measurements were taken within each plot (Appendix 1). Percent shrub and canopy cover were calculated by taking five measurements at approximately 3 m intervals 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. The total number of downed logs >24 cm was recorded on each plot. Plot slope and plot aspect were calculated using a clinometer and compass, respectively. The distance between a song perch and cavity location was also recorded. If multiple song locations were identified for an individual owl only the first location discovered was used in the plot analysis

Cavity sites. UTM locations were collected at 31 cavity locations found between 1987 and 2001. All cavity sites were located during roadside surveys. Individual cavity sites were located by revisiting sites with singing males and listening for changes in singing frequency. Bondrup-Nielsen (1978) reported that singing frequency increases (referred to as prolonged staccato) when male advertise from a cavity site versus a song perch. The site was then visited during the day to verify the cavity location. Cavity locations were plotted using ArcView GIS (Version 3.2a). Landsat Thematic Mapper (TM) 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 were 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 at varying spatial scales.

Statistical analysis – singing locations. A conditional logistic regression (procedure PROC PHREG, Allison 1999) was used to test for differences in the 13 habitat variables (Appendix 1) at Boreal Owl song and random sites. I also compared densities of individual tree species and the total proportion of coniferous and deciduous species at Boreal Owl song and random sites. Regressions were independently run for the 13 habitat variables. An electivity index was used to quantify preference of song tree genera 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. Those species having an index ≥ 1.0 are considered preferred while species having an index < 1.0 are considered to be avoided. χ^2 is compared with a χ^2 distribution with $df = 8$. Only trees with a diameter of ≥ 10 cm were included in the analysis as all trees used as song perches in this study were ≥ 10 cm in diameter.

Cavity sites. To examine multivariate patterns, a 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 spatial 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 for these data.

The MRPP was followed with a univariate analysis on each of the 13 land cover types at each of the five different spatial scales (100, 500, 1000, 2000, 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. 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 spatial 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 for a number of predictor variables (Breiman et al. 1984). The trees derived from CART® explain variation for 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 a 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 in CART® were used to construct trees (e.g., 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, $p(X_{Alg} \mid X_{true})$, (2) specificity: the inverse, $p(not\ X_{Alg} \mid X_{false})$, (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 $K > 0.75$.

RESULTS

Fifty-six individual Boreal Owl singing locations were identified between 1987 and 2001. All song trees were located by walking to the singing owl. Of the 56 trees used as song perches, 93% were coniferous species, with an average dbh and height of 35.6 cm and 18.5 m, respectively. Deciduous species represented 7% of song perches, with an average dbh 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 used by individual owls was 72.3 m (n = 34; range = 3.9 m – 290 m). Thirty-four (61%) of the 56 song perches were situated ¼ of the way or higher on a slope.

Singing locations. With the exception of plot canopy height (n = 29), habitat variables were measured at 42 individual Boreal Owl singing locations (using one tree per site). Six of the 13 conditional logistic regressions were significantly different ($P < 0.05$) between Boreal Owl singing locations and random locations. These variables were: live basal area (112.9 m^2/ha vs. 75.8 m^2/ha; $P < 0.02$), dead basal area (22.4 m^2/ha vs. 11.9 m^2/ha; $P < 0.02$), total basal area (135. 2 m^2/ha vs. 87.7 m^2/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 (18.2 m vs. 15.0 m; $P < 0.02$). Balsam fir was found in significantly higher proportions ($P < 0.05$) at Boreal Owl song sites.

Electivity indices were calculated for 40 song perches and their surrounding plots. White spruce was the only species showing a significant preference for use by Boreal Owls (Table 1.3).

Cavity sites. Fifty-four cavity sites were located between 1987 and 2001. Eighty-three percent of cavity sites were in deciduous tree species (Table 1.4). Significant differences ($P < 0.01$) between cavity and random sites were found at every spatial scale in the multivariate analysis. With the exception of brush, lowland brush, and open areas, significant differences were present for all land cover variables in the univariate analysis. Significant differences ($P < 0.05$) were present at several spatial scales for 10 of the 13 land cover variables (Table 1.5).

Classification trees were constructed for each of the five spatial buffers. In general, model performance evaluations were good; however prediction success varied depending on buffer size (Table 1.6). The variable "roads" was not included as an explanatory variable when constructing classification trees. This was done primarily because Boreal Owl singing locations 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 best predicted the differences between cavity and random sites at all landscape levels.

100 m (3.14 ha) buffer – Twenty-four (77.4%) of 31 cavity sites and 27 (65.8%) of 41 random sites were correctly classified in CART® (classification rate = 71%; Kappa statistic = 0.42; Table 1.6). Upland mixed forest was the explanatory variable that best distinguished cavity sites from random sites. Within 100 m, 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 (54.8%) of 31 cavity sites and 26 (63.4%) of 41 random sites (correct classification rate = 60%; Kappa statistic = 0.18; Table 1.6). Upland conifer was the best explanatory variable for cavity sites. Cavity sites had >12.5% upland conifer compared with random sites. Cavity sites also had higher proportions of upland mixed (>27.4%) and open areas (>4.1%) compared with random sites (Fig 1.4).

1000 m (314 ha) buffer – Twenty-four (77.4%) of 31 cavity sites and 30 (73.1%) of 41 random sites were correctly classified (correct classification rate = 75%; Kappa statistic = 0.50; Table 1.6). Ericaceous brush was the best explanatory variable of cavity sites with cavity sites having >3% ericaceous brush (Fig 1.5).

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

5000 m (7850 ha) buffer – Nineteen (61.3%) of 31 cavity sites and 29 (70.7%) of 41 random sites were correctly classified (correct classification rate = 67%; Kappa statistic = 0.32; Table 1.6). The presence of Sphagnum, often associated with lowland or boggy areas was the best predictor of cavity sites. Ericaceous brush was also higher at cavity sites (Fig 1.7).

DISCUSSION

The majority of song perches in this study were found to be large diameter conifers. Coniferous tree species, particularly upland types, were a common forest component of Boreal Owl song and cavity sites. Bondrup-Nielsen (1978) reported that almost all song perches used by Boreal Owls in Ontario were conifers. Similarly, studies in the western United States have shown Boreal Owl singing locations are typically found in higher elevation subalpine fir (*Abies lasiocarpa*), mixed-conifer, Engelmann spruce (*Picea engelmannii*), and spruce-fir types (Hayward 1993, Herran et al. 1996). Dense coniferous forests may provide protection from avian predators (Mikkola 1983).

Males are extremely vocal during the breeding season (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 (1996) documented that male Tengmalm's Owls (*Aegolius funereus*) in central and western Finland appear to vocalize less frequently, particularly near Ural Owl (*Strix uralensis*) territories, thereby delaying mate location and breeding success. While it is impossible to know what effects larger owl species had on Boreal Owl breeding success in this study, there may be a tradeoff between vocalization and depredation. The dense foliage provided by coniferous trees may afford Boreal Owls protection during this vulnerable time.

Electivity indices from this study indicate that Boreal Owls avoided deciduous tree species for use as song perches. Lack of foliage on deciduous species during the courtship period

(March and April) may be one reason Boreal Owls avoid deciduous trees. Boreal Owls appear to use song perches that are in close proximity of one another and to a potential cavity tree and may use a preferred song perch. On four occasions I observed a male vocalizing from the same tree on different evenings. Both Bondrup-Nielsen (1978) and Wilson (pers. comm.) observed similar behavior during the courtship period.

Boreal Owl singing locations in this study showed structural characteristics typical of mature, multi-storied forests stands. Taller overstory canopy, higher basal area, large snags and a higher percentage of coniferous canopy cover were found to be important predictors of song sites as compared with random sites. Balsam fir was also an important component at song sites. 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 common habitat components.

Both univariate and multivariate analyses based on Landsat satellite imagery indicated the forest matrix surrounding Boreal Owl cavity sites differed from those of random sites in all buffers used in this study. Upland mixed forests appear to be an important component immediately surrounding Boreal Owl cavity sites (100 m buffer). Similarly, breeding sites in Alaska, Canada and northeastern Minnesota were found in deciduous, mixed conifer-deciduous, and upland mixed stands (Bondrup-Nielsen 1978, Meehan and Ritchie 1984, Lane et al. 2001). Mixed forests provide coniferous trees for use as song perches and deciduous trees for nesting. As secondary cavity nesters, Boreal Owls rely on species such as Pileated Woodpecker (*Dryocopus pileatus)* and Northern Flicker (*Colaptes auratus*) to excavate cavities (Hayward and Hayward 1993). Preferred nesting substrate for these woodpecker species are large diameter deciduous trees (Bull and Jackson 1995, Moore 1995). Accordingly, deciduous tree species such as trembling aspen and paper birch appear to be important nesting substrate for Boreal Owls in northeastern Minnesota. Eighty-three percent of cavities located in this study were in deciduous trees. In Ontario all six nests located by Bondrup-Nielsen (1978) were in trembling aspen. Lane and Andersen (1995) report 36 (92.3%) of 39 cavities located in Cook County, Minnesota, to be in trembling aspen. Differences in the availability of 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).

As scale increases, changes in land cover requirements become apparent. Upland conifer forests appear to be the best predictors of Boreal Owl cavity sites within a 500 m buffer in both univariate and multivariate analyses. 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 forests. In addition to providing protection from predators and environmental conditions, conifers provide important roosting sites for Boreal Owls. Thirty-one (97%) of 32 roost sites located during this study were in coniferous tree species (Chapter 2). Bondrup-Nielsen (1978), Palmer (1986), Hayward et al. (1993), and Lane (1997) all reported that Boreal Owls almost exclusively roosted in coniferous tree species within their respective study areas. 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® models suggested 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). Similarly, studies conducted in Fennoscandia have shown that forest openings provide foraging habitat and prey species for Tengmalm's Owls, particularly in early spring when forested areas are still covered in snow (Korpimäki 1988, Jacobsen and Sonerud 1993).

Hakkarainen et al. (1997) also noted that fledgling production of Boreal Owls was higher on territories that contain more intensive clear-cuts. The mosaic of forested areas interspersed with 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 during 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, it is difficult to draw definitive conclusions on the possible foraging benefits of roadway openings within this study area, primarily because of the bias imposed by locating owls through roadside surveys. The methods used to locate owls in this study, namely roadside surveys, may explain why the "road" variable best distinguished cavity sites from random sites in the CART® models. Proximity to roads was not considered when selecting random sites and therefore may explain why roads, when included in the CART® analysis, was best explanatory variable for cavity sites. Unfortunately, the study area is only able to be sampled in a reasonably efficient manner during March and April via roads.

Importance of lowland areas becomes evident at a larger scale (1000, 2000 m). Ericaceous brush [(e.g., Labrador tea (*Ledum groenlandicum*), bog rosemary (*Andromeda glaucophylla*) and leather leaf (*Chamaedaphne calyculata*)] typically associated with lowland conifer forests are common landscape features surrounding cavity sites at >1000 m buffer in both univariate and multivariate 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 locations were taken at each roost location and plotted onto Landsat TM satellite imagery data. Findings from this study were similar to Lane's results (see next chapter). 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 probable association with lowland conifer.

In addition to roosting, conifer stands (both upland and lowland) may serve as foraging habitat (Chapter 2). Hayward et al. (1993) presumed roost locations to represent end-of-foraging-bout areas. Roost locations located in this study were typically associated with upland conifer (generally spruce-fir) and lowland conifer stands. This habitat is ideal for red-backed voles (*Clethrionomys gapperi*), the primary prey of Boreal Owls, which are found to inhabit mesic, forested areas, particularly spruce-fir forests (Hayward et al. 1993, Kays and Wilson 2002). Sonerud (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).

Table 1.1. Description of 13 land cover variables used in the landscape habitat analysis of Boreal Owl cavity sites in northeastern Minnesota. Land cover variables were reclassified from Landsat (TM) satellite imagery based on Wolter et al. 1995.

Land Cover Class	Dominant Cover and/or Species	Scientific Name
Upland conifer	Jack pine	*Pinus banksiana*
	Red pine	*P. resinosa*
	Eastern white pine	*P. strobus*
	Balsam fir	*Abies balsamea*
	White spruce	*Picea glauca*
	Black spruce (upland)	*P. mariana*
	Miscellaneous conifer	
Upland hardwood	Aspen	*Populus spp.*
	Paper birch	*Betula papyrifera*
	Yellow birch	*B. lutea*
	Sugar maple	*Acer saccharum*
	Red maple	*A. rubrum*
	Balsam poplar	*Populus balsamifera*
	American basswood	*Tilia americana*
Upland mixed	Northern hardwood-conifer	
	Aspen-birch-conifer	
Lowland Conifer	Northern white cedar	*Thuja occidentalis*
	Tamarack	*Larix laricina*
	Black spruce (lowland)	
	Acid bog conifer, stagnant	
Lowland hardwood	Black ash	*Fraxinus nigra*
	Miscellaneous lowland hardwood	
Lowland mixed	Northern white cedar-hardwood	
	Black ash-conifer	
Brush	Brush-alder	
	Brush-willow	
	Brush-miscellaneous	
Brush-lowland	Brush alder-lowland	
	Brush willow-lowland	
	Brush miscellaneous-lowland	
Brush-ericaceous	Ericaceous brush	
Sphagnum	Sphagnum spp.	
Open	Grass	
	Bare ground	
	Bare upland	
	Agriculture	
Water	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, 1987 - 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 1.3. Electivity indices for tree species used as song perches by vocalizing male Boreal Owls in northeastern Minnesota, 1987 - 2001. Availability is based on all trees ≥ 10 cm dbh within a 0.04 ha plot centered on a song perch.

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

* $P < 0.05$

Table 1.4. Characteristics of cavity trees ($n = 54$) used by male Boreal Owls in northeastern Minnesota during 1987 – 2001.

Species	N	Percent	Average dbh (cm)	SD	Average height (m)	SD
Deciduous	**45**	**83.4**	**43.7**	**8.1**	**13.0**	**2.9**
Trembling Aspen	28	51.9	45.2	6.7	15.5	6.2
Paper Birch	13	24.1	33.2	8.4	8.9	2.0
Balsam Poplar	3	5.6	43.3	15.2	12.8	5.9
Yellow Birch	1	1.8	53.0	—	14.7	—
Coniferous	**9**	**16.6**	**56.5**	**7.1**	**18.7**	**7.2**
White Pine	5	9.3	49.7	13.6	15.3	6.4
Red Pine	2	3.7	63.8	13.0	27.0	0.8
Jack Pine	1	1.8	56.0	—	13.9	—
Northern White Cedar*	1	1.8	—	—	—	—

* dbh and height not collected

Table 1.5. 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, 1987 - 2001.

Variable[a]	Buffer Size (m)[b]	Z statistic	Median (ha) Cavity	Median (ha) 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-mixed	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 mixed	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

[a]Only variables and buffers showing a significant difference ($P < 0.05$) included in table.
[b]100 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 1.6. 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, 1987 – 2001.

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

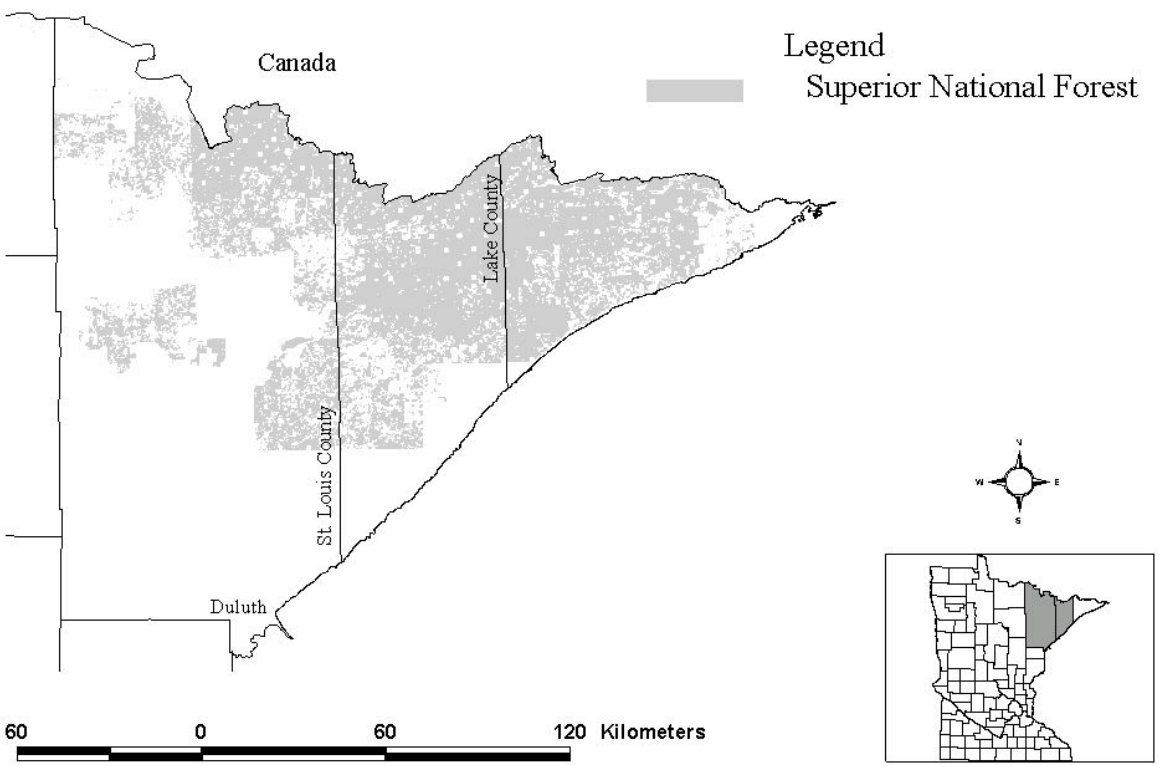

Fig 1.1 Distribution of the Superior National Forest within Lake and St. Louis in northeastern Minnesota.

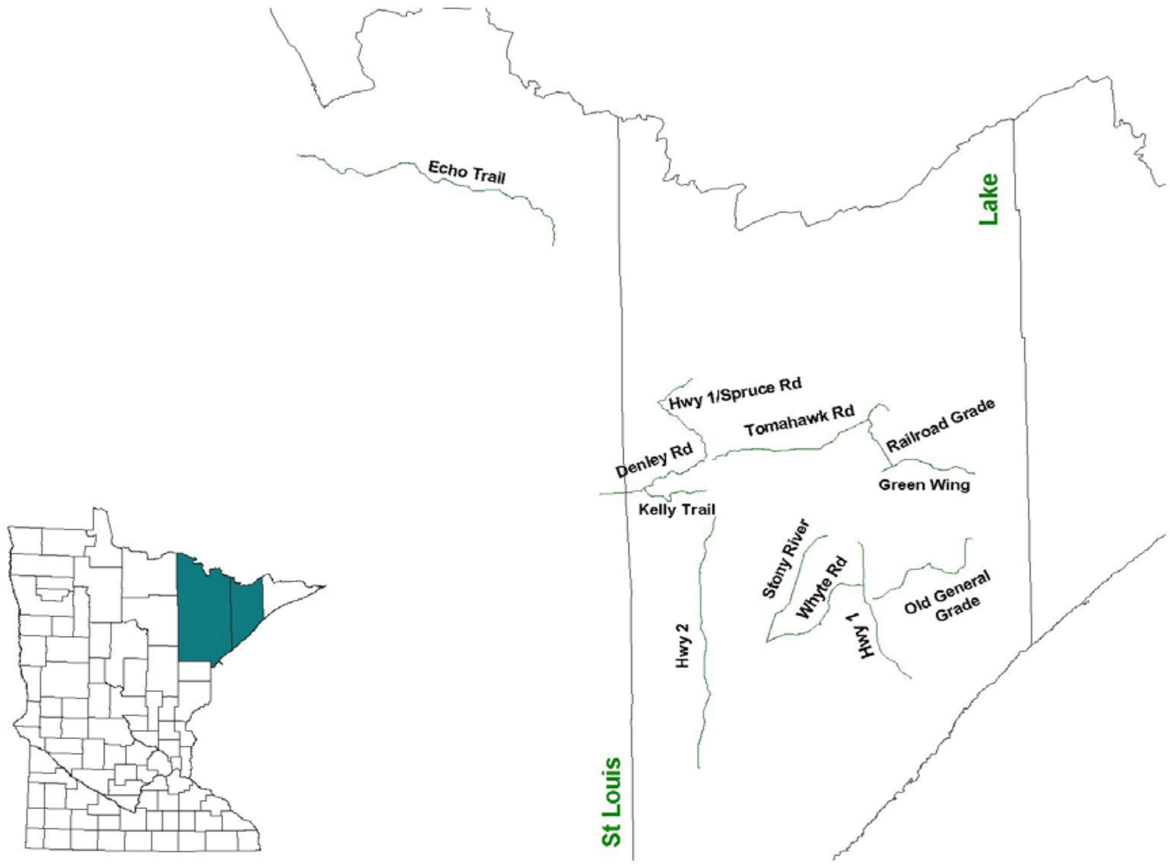

Fig. 1.2. Location of Boreal Owl survey routes within Lake and St. Louis counties in northeastern Minnesota during 1987 - 2001.

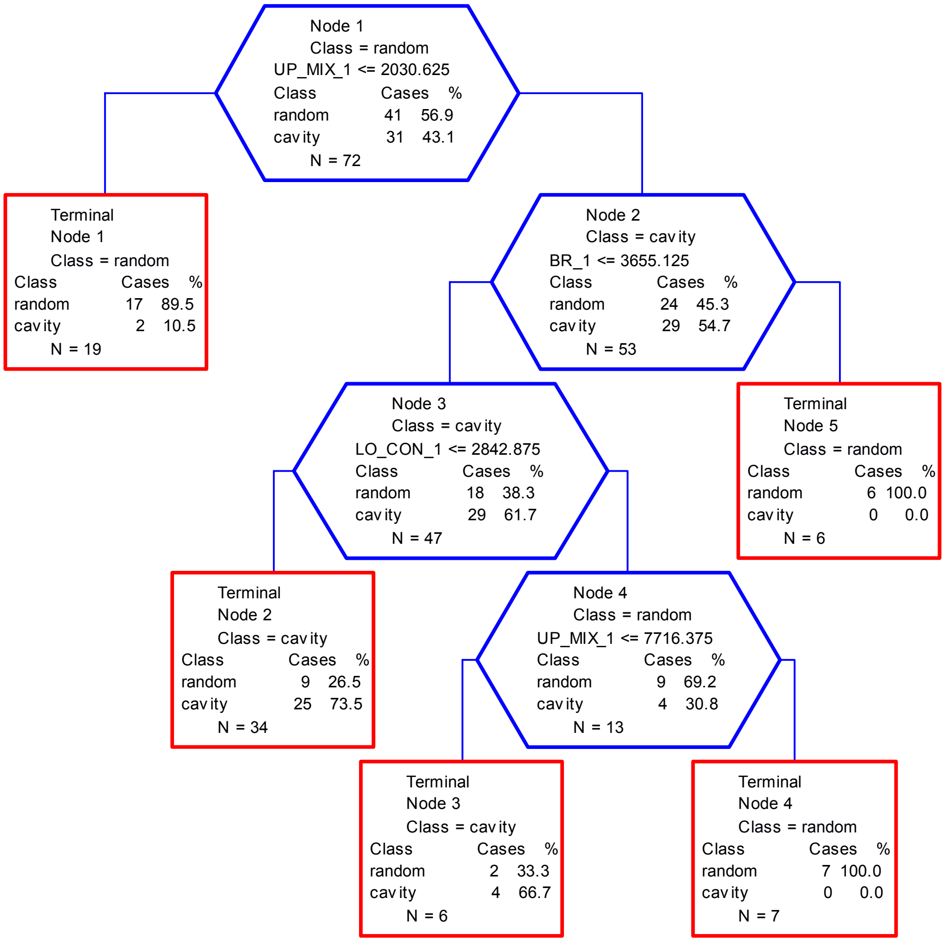

Fig. 1.3. CART® classification tree explaining land cover variables that distinguished 27 of 31 Boreal Owl cavity locations and 27 of 41 random locations throughout the SNF in northeastern Minnesota within a 100 m radii circular plot. The explanatory (land cover) variables include upland mixed forests (UP_MIX_1), brush (BR_1), and lowland conifer forests (LO_CON_1). Sites containing ≥ the amount (m^2) of land cover specified (e.g., 2030 for upland mixed) are placed in the box to the right of the parent node (hexagon shape).

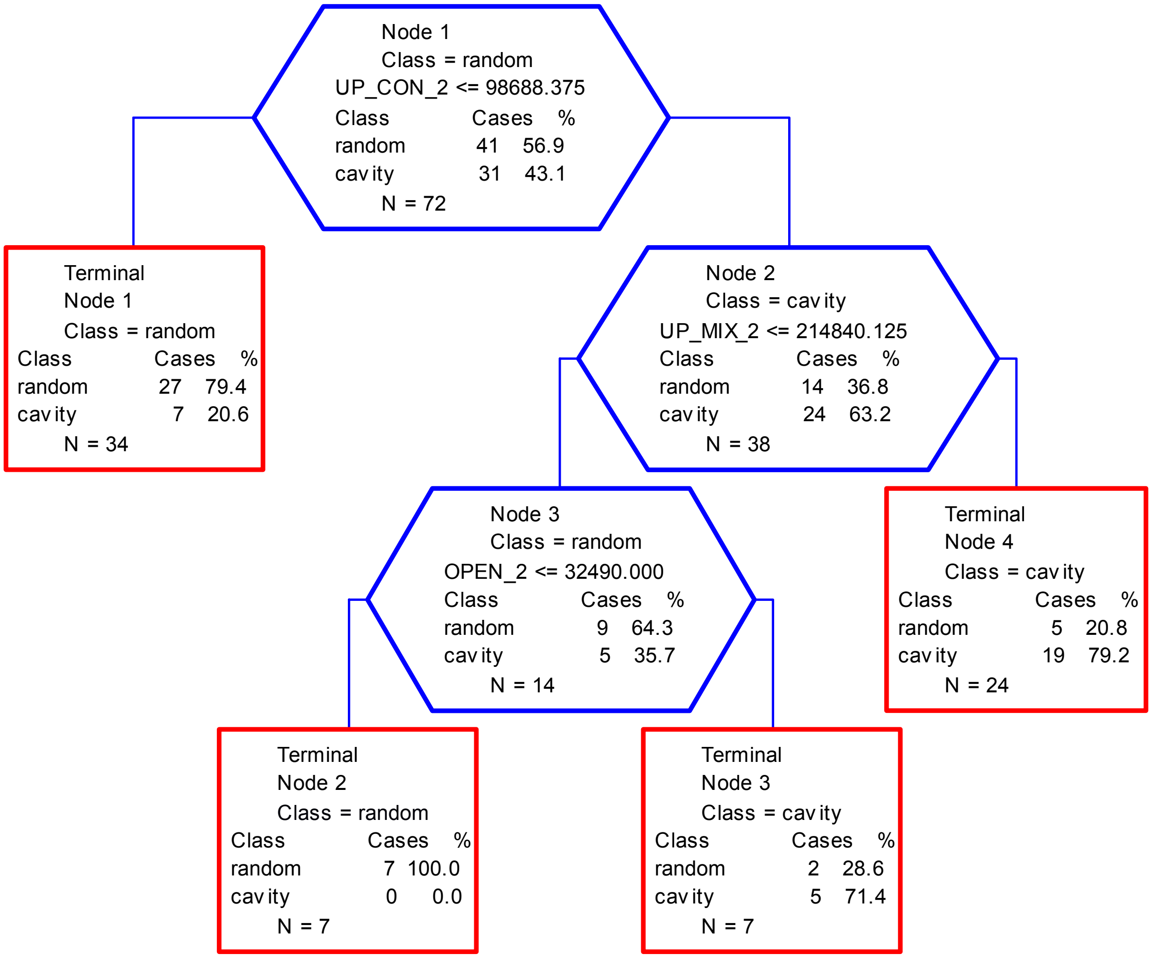

Fig. 1.4. CART® classification tree explaining land cover variables that distinguished 17 of 31 Boreal Owl cavity locations and 26 of 41 random locations throughout the SNF in northeastern Minnesota within a 500 m radii circular plot. The explanatory (land cover) variables include upland conifer forests (UP_CON_2), upland mixed forests (UP_MIX_2), and open areas (OPEN_2). Sites containing ≥ the amount (m^2) of land cover specified (e.g., 98,688 for upland conifer) are placed in the box to the right of the parent node (hexagon shape).

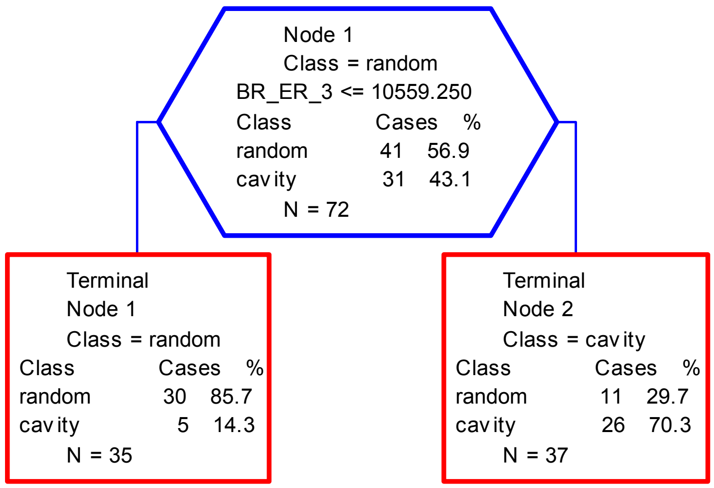

Fig. 1.5. CART® classification tree explaining land cover variables that distinguished 24 of 31 Boreal Owl cavity locations and 30 of 41 random locations throughout the SNF in northeastern Minnesota within a 1000 m radii circular plot. The explanatory (land cover) variable was ericaceous brush (BR_ER_3). Sites containing ≥ the amount (m^2) of land cover specified (e.g., 10,559 for ericaceous brush) are placed in the box to the right of the parent node (hexagon shape).

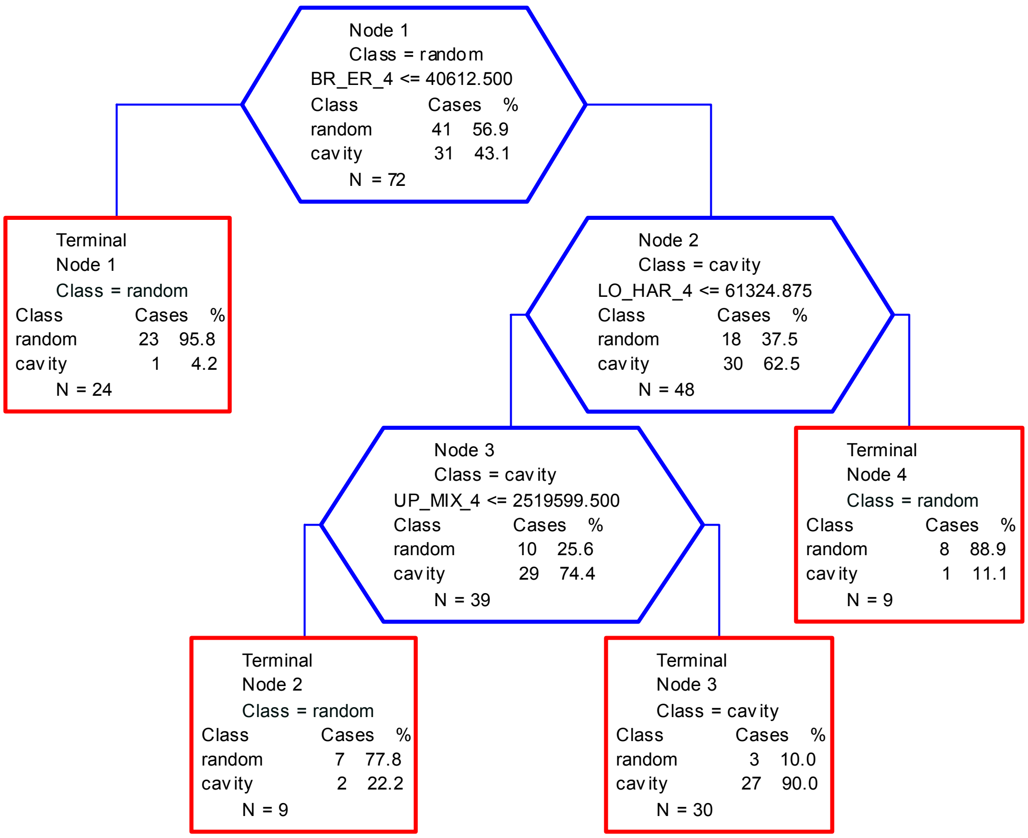

Fig. 1.6. CART® classification tree explaining land cover variables that distinguished 25 of 31 Boreal Owl cavity locations and 36 of 41 random locations throughout the SNF in northeastern Minnesota within a 2000 m radii circular plot. The explanatory (land cover) variables include ericaceous brush (BR_ER_4), lowland hardwood forests (LO_HAR_4), and upland mixed forests (UP_MIX_4). Sites containing ≥ the amount (m^2) of land cover specified (e.g., 40,612 for ericaceous brush) are placed in the box to the right of the parent node (hexagon shape).

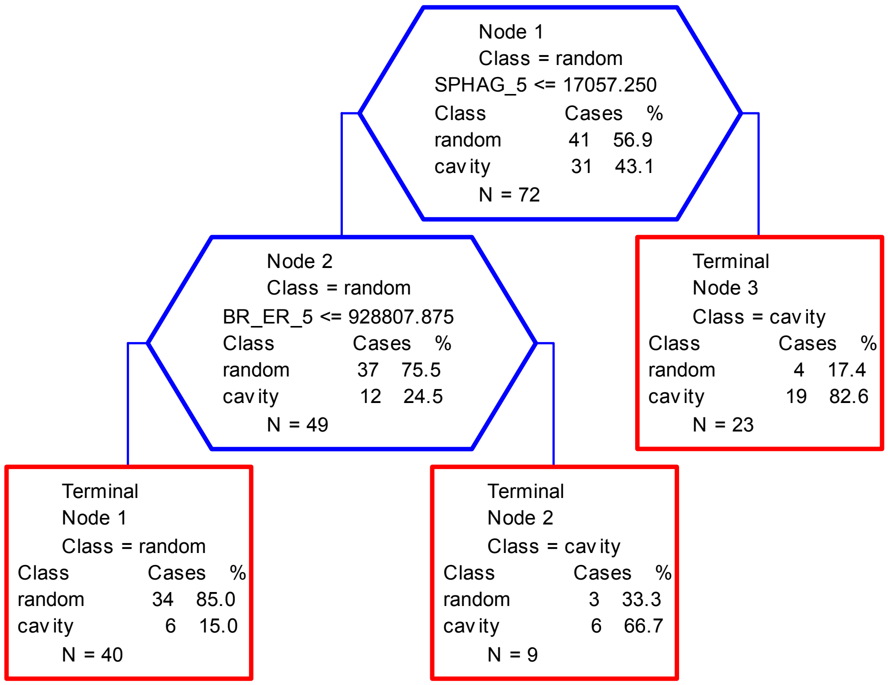

Fig.1.7. CART® classification tree explaining land cover variables that distinguished 19 of 31 Boreal Owl cavity locations and 29 of 41 random locations throughout the SNF in northeastern Minnesota within a 5000 m radii circular plot. The explanatory (land cover) variables include sphagnum spp. (SPHAG_5) and ericaceous brush (BR_ER_5). Sites containing ≥ the amount (m^2) of land cover specified (e.g., 17,057 for sphagnum) are placed in the box to the right of the parent node (hexagon shape).

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Apendix 1. Description of vegetation variables measured within the song perch plot. Each plot was 0.04 ha (11.3 m radius) 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, ¼ up slope, ½ up slope, ¾ 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 (11.3 m radius) 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.— I used radiotelemetry to monitor the movements of three male Boreal Owls (*Aegolius funereus*) in northeastern Minnesota from April – August of 2000-2001. Using Landsat Thematic Mapper (TM) satellite imagery, proportions of 13 land cover types within Boreal Owl home ranges were compared with proportions available throughout the study area. 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). The majority of foraging locations occurred in heterogeneously mixed conifer and mixed coniferous-deciduous habitats.

INTRODUCTION

The Boreal Owl is distributed holarctically and breeds 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 forces behind long distance movements (Korpimäki 1986).

Due primarily to the rarity and nocturnal behavior of this species, few studies have been conducted on home range and habitat use in North America. 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, both focused primarily on roost site use.

Beginning in 2000, I initiated a study to determine home range size and habitat use based primarily on nocturnal relocations of Boreal Owls in northeastern Minnesota during the breeding season. The objectives of this study were (1) estimate the home range size of radio-tagged male Boreal Owls to determine land cover composition within their home ranges, and (2) describe foraging habitat used by male Boreal Owls.

STUDY AREA

This study was conducted in Lake and northern St. Louis counties of northeastern Minnesota. The majority of the study area is located within the Superior National Forest (SNF) (see Chap 1, Fig 1.1). Approximately 75% of the study area was forested with boreal or near-boreal forest types (Chapter 1). Open areas and water comprised the remaining 25% (16% and 9%, respectively) of the study area. Long, cold winters and mild summers characterize the climate of the area. Average total snowfall for the area is 181 cm, with average 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 and trapping owls. Boreal Owls were located through nocturnal roadside surveys conducted 1 March – 14 May 2000-2001 (see Chapter 1). When a singing male Boreal Owl was detected, an immediate foot search was conducted to locate the singing owl. Sites were monitored from several nights to approximately two weeks to determine activity. We considered a location to be a probable breeding area if one of the following was true: (1) a male was heard advertising on more than one occasion, (2) a male and female Boreal Owl were heard or courtship behavior was observed at a site, or (3) an active nest was located on a site (Hayward et. al 1993).

At identified breeding areas, we attempted to trap males using two mist nets set up in a "V" pattern near the owl's cavity or singing location. A recording of a Boreal Owl's primary staccato song was broadcast near the apex of the net to attract the owl into the area (B. Lane pers. comm). 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 ribbon (Bally Ribbon Mills; Bally, PA) in the 2001 field season. Harnesses were attached using a five mm piece of copper tubing crimped over the keel of the bird (Lane 1997). The total weight of the unit was approximately six grams. Radio-marked owls were recaptured with a bal-chatri trap baited with live mice set near a roost site to remove the radio transmitter at the end of the study.

Home range analysis was based on data collected from both nocturnal and diurnal relocations. Although diurnal roosting habitat of Boreal Owls was not the focus of this study, roost locations were included in the home range estimate to obtain a more accurate representation of home range size.

Nocturnal relocations. Nocturnal relocations were obtained through two-person, and when possible, three-person triangulation using portable receivers and a three-element hand-held yagi antenna. Researchers were positioned at known locations (e.g., intersections or landmarks) along road or trail systems. UTM locations were collected for all known locations using a Garmin GPS unit. To reduce triangulation error, researchers were positioned as close to 90° from one another as possible (White and Garrott 1990). Hand-held communication radios were used to facilitate synchronous readings by allowing researchers to keep in continuous contact. Owls were relocated every other night and were monitored an average of six hours per night (sundown – sunrise). In an attempt to reduce autocorrelation, readings were separated by 20 min intervals (Lane 1997, Sissons et al. 2001).

When possible, observers arrived prior to dusk to visually locate radio-marked owls. When the owl became active, usually around sundown, it was followed until either (1) it became too dark to visually locate, or (2) the strength of the radio signal decreased considerably, indicating that the bird had left the immediate vicinity. Vegetative characteristics within the study area (e.g., dense understory, downfall, boggy conditions) and potential disturbance to the individual owl made it difficult to follow the owls at close range throughout the night. We therefore moved to the nearest road, relocated the radio signal and continued to take readings from the road. The increased distance between the owl and researcher often led to a large error in the bearing estimate. This resulted in larger error polygons surrounding relocation points and subsequently the removal of several locations from the home range analysis.

Diurnal (roost) relocations. Radio-marked roosting owls were located using a portable receiver and a three-element hand-held yagi antenna. Two consecutive bearings (separated by <10 min) were obtained from known locations along a road or trail system. The owl's likely position was plotted onto 1:24,000 topographical maps to obtain an approximate roost location. We then walked into the area (based on the strength of the transmitter signal) and visually located the roosting owl. Owls were located between the hours of 0600 and 1800 and observed for at least 0.5 h. To reduce influencing the owls' behavior, visual observations were made from a minimum distance of 15 m using binoculars. All roost locations were recorded using a Garmin Global Positioning System (GPS) and plotted onto Landsat TM satellite imagery. Roost tree species was recorded at each roost location. However, quantitative habitat measurements were not collected, as this was not the primary focus of this study.

Aerial telemetry. Aerial flights were conducted when a transmitter signal was unable to be located from a ground search. Aerial telemetry flights were conducted from a fixed-wing aircraft. Prior to each flight a test transmitter was set and out and located to ensure all telemetry equipment was functioning properly.

Home range. Relocations points were plotted using the computer program GTM (Sartwell 1999) with default settings. Error polygons were generated for each location. 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 (Hooge and Eichenlaub 1997). Both the 95% MCP method and the 95% Fixed Kernel (FK) method (Worton 1989) were used to estimate home range size for Boreal Owls. In addition, I calculated the home range size using the 100% MCP to facilitate comparisons with previous studies, however, land cover composition was analyzed using the 95% MCP. While there are some disadvantages associated with the MCP method (Samuel and Fuller 1994), most previous studies used this method to report home range size.

Landsat 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.). Boreal Owl home range polygons were plotted onto Landsat TM satellite imagery using Arcview 3.1. Proportions of each land cover class were calculated within each individual Boreal Owl home range.

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 cavity trees using a mist net and playback of a Boreal Owl primary staccato song. No females were captured during this study. Two males were trapped during the 2000 field season. Only one male was known to be nesting. A female was seen in the nest cavity from 4 April through 19 April. Shortly thereafter, activity ceased at the cavity and the male was heard vocalizing near the cavity through 23 May. The fate of the nest was undetermined. The owl was recaptured on 28 May 2000 using a bal-chatri trap baited with mice and its transmitter removed. It was in good physical condition based on body condition and weight at the time of capture. There was no documented nesting attempt for the second male, however a female was observed near the cavity for two nights. After capture he remained near the cavity and continued vocalizing. On 30 April 2000, the transmitter and intact harness were 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 owls dispersed beyond the study boundaries before sufficient data were collected to estimate home range characteristics. All three birds left the area between 29 April and 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, covering a distance approximately 110 km from their previous locations. All relocation efforts were unsuccessful. Transmitter failure seems unlikely, as all transmitters were less than two weeks old. All telemetry equipment was functioning properly as I was able to detect both a test transmitter and the transmitter of the remaining owl during the aerial search.

A nest was located for the remaining owl. A female was observed in the nest cavity from 9 April to 13 June 2001. 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 observed. I last observed the male at the cavity on 15 June. The fate of the nest was undetermined. Fledglings were not observed in the cavity tree or the area surrounding the cavity tree. No remains were found underneath the cavity. Due to the deteriorated condition of the tree, I was unable to access the cavity until early August. Through the use of a cherry picker provided by Lake County Power, cavity contents were collected. No remains of young were found in the cavity. The owl remained in the area and was recaptured on 31 August at which time the transmitter was 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

Roost sites. Thirty-two roost sites were located for six owls during the 2000–2001 field seasons. Roost locations were plotted onto TM satellite imagery. Eighteen (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 located in upland conifer stands within 100 m of a lowland conifer stand while 94% were located within 200 m of lowland conifer stands. Coniferous species comprised 97% of roost trees. Twenty-four (73%) were in black spruce (*Picea mariana)*, three (9 %) were in red pine (*Pinus resinosa)*, two (6%) were in balsam fir (*Abies balsamea*) and one (3%) each in jack pine (*Pinus banksiana*), white cedar (*Thuja occidentalis*), tamarack (*Larix laricina*), and trembling aspen (*Populus trembuloides*).

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 were included in the home range estimates (Table 2.1). The mean 95% MCP home range estimate was 607 ha (n = 3, range = 430 – 931 ha, SE = 162) and the mean 100% MCP home range estimate was 667 ha (n = 3 range = 473 – 949 ha, SE = 144). In comparison, the mean 95% fixed kernel home range estimate was 582 ha (n = 3 range = 407 – 864 ha, SE = 142) (Table 2.1). The unpaired male'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. Both paired males had similar home range sizes (460 ha and 430 ha, respectively) and had neighboring territories, however they were not occupied during the same year (Fig 2.2).

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). The percentage of upland-conifer forests was slightly higher within the three Boreal Owl home ranges than that of the study area (Table 2.2). Upland-hardwood forests represented approximately 9% of the study area but represented on average <3% within the three home ranges (Table 2.2). Two hundred and ninety-two nocturnal relocations were obtained for the three owls (range = 27 – 192). 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

Minimum Convex Polygon home range estimates for Boreal Owls monitored during this study averaged 607 ha (95% MCP) and 667 ha (100% MCP). Home range size observed in this study differed from that in previous studies conducted in both western and eastern regions of North America (Bondrup-Nielsen 1978, Palmer 1986, Hayward et al. 1993, Lane 1997). Palmer (1986) found the home range size of two non-breeding male Boreal Owls (summer months only) in Colorado averaged 296 ha (100% MCP). In Ontario, Canada, Bondrup-Nielsen (1978) reported an average home range size of 283 ha (n = 3). These averages are noticeably smaller than the average home range size found in this study. The smaller home range sizes in Colorado and Canada are most likely attributed to home range estimates being based solely on roost locations. Both diurnal and nocturnal relocations were included in the home range estimates for this study, which may account for the larger home ranges. In Idaho, Hayward (1989) found considerably larger summer (snow-free period) home range sizes (harmonic mean 1,182 ± 334 ha, adaptive kernel estimate 2,269 ± 1,644 ha). These home range estimates were based on movements of 15 owls, which included both males and females. 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 (mid-summer). Differences in topographical features, breeding status and prey availability undoubtedly had strong influence on the owl's movements (Hayward 1993).

In Cook County, Minnesota, Lane (1997) reported average home range size of four owls (based on roost and nocturnal locations) to be 1,438 ha (100 % MCP). He noted, however, that increased movements following nest failure might influence home range size. His home range estimates averaged 425 ha prior to nest failure. This estimate is similar to the home range size found for the paired males in this study (430 and 460 ha). In Lane's study, home range estimates following nest failure, although larger, are more comparable to the non-paired male in this study (1,438 ha vs. 931 ha).

There was a noticeable difference in home range size between the paired males compared with the unpaired male (460 ha and 430 ha vs. 931 ha, respectively). The owl's unpaired status may account for the larger home range size. Male Boreal Owls are the primary food provider during the nesting phase (Hayward 1993). Unpaired males may not be as confined to a central location (i.e., nest cavity) allowing them greater movements during daily activities. 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.

Differences in forest cover were also evident between the paired and unpaired males although this is more than likely attributable to location rather than paired or unpaired status. The paired males were located in the northernmost portion of the study area while the unpaired male was located in the southeastern corner. Although the proportion of forested areas, particularly upland mixed and upland conifer stands were high in all three home ranges, the unpaired male's home range contained a high proportion of open areas (Table 2.2). Open areas represented nearly 16% of this owl's home range while accounting for <3% of the paired owls home ranges (Table 2.2). Based on TM satellite imagery, only 3 (11.1%) of 27 nocturnal relocations obtained for the unpaired owl were classified as open areas, while 23 (85%) of 27 were classified as forested areas. It would be difficult to assess, based on a sample size of three, if increased movements are an artifact of unpaired status or differences in spatial distribution of forested and open areas between the northern and southern portions of the study area.

Increased movements were also documented for three unpaired males radio-tagged in 2001. The owls were monitored for several weeks, however, courtship behavior was never observed. 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. Although residency appears to be more beneficial for cavity nesting birds (v. Haartman 1968), nomadic movements are not uncommon for Boreal Owls (Mysterud 1970, Wallin and Andersson 1981, Lofgren et al. 1986). Scarcity of prey is often the cause of such long distance movements (Korpimäki 1986). During the winter of 2001, northeastern Minnesota experienced an irruption of northern forest owls (Wilson pers. comm., pers. observation). It is possible the 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 et al. 1997, Hakkarainen and Korpimäki 1998) may prompt movements back to more familiar areas, presumably north of the study area.

Land cover variation was evident among the three home ranges. However, heterogeneously mixed conifer and mixed coniferous-deciduous forests are common habitats within the three Boreal Owl home ranges in northeastern Minnesota. Upland mixed forests are typically found at both the microhabitat level (Chap 1) and at larger scales. Upland conifer stands provide roosting habitat. Quantitative measurements were not collected at roost locations however, based on TM satellite imagery, 56.3% of roost locations occurred in upland conifer stands, particularly those adjacent to lowland conifer tracts. Eighty-five percent of roost sites were located within 100 m of 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. The higher proportion of roads within home ranges is likely a consequence of owls being located through roadside surveys.

There are several limitations to foraging data that should be addressed, most importantly the accuracy of the relocation points. Dense vegetation and the nocturnal activity of this species made it difficult to follow these birds at close range throughout the evening. White and Garrot (1990) showed that increasing the distance between the transmitter and the receiver also increases the error in the estimated bearing, resulting in a larger error polygon for a given point. These large error polygons made it difficult to accurately determine land cover for some points. Second, although nocturnal relocations were separated by 20-minute intervals, data were never statistically independent. 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, Bye et al. 1992, Hayward et al.1993). Hayward et al. (1993) 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 foraging strategy may not have allowed sufficient time for the owls to make any type of substantial movement between relocations. Therefore, subsequent locations may not be statistically independent.

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 in this forest type allow greater access to prey. Small mammals such as red-backed voles (*Clethrionomys gapperi*) and *Microtus* spp. are common prey items of the Boreal Owl. These species are typically associated with forested areas (Kays and Wilson 2002).

Table 2.1. Home range size in ha using the 95% and 100% Minimum Convex Polygon (MCP) method and 95% Fixed Kernel method for three male Boreal Owls in northeastern Minnesota, 2000- 2001.

			Number of Relocations					
Year	Owl ID	Dates Monitored	Diurnal	Nocturnal (No. of nights)	Total	95% MCP Area Estimate	100% MCP Area Estimate	95% Fixed Kernel
2000	094	30 March – 30 April	4	33 (8)	37	931	949	864
2000	154	7 April – 28 May	6	79 (15)	85	460	580	407
2001	972	14 May – 31 August	12	214 (21)	216	430	473	476
Mean (SE)						607 (162)	667 (144)	582 (142)

Table 2.2. Proportions of land cover variables based on Landsat (TM) satellite imagery within study area and 95% Minimum Convex Polygon home ranges of Boreal Owls in northeastern, Minnesota 2000-2001.

Land Cover	Availability (study area)		Owl 094		Owl 154		Owl 972		$\overline{X}$ within home ranges		SE within home ranges
Area estimate (ha)[a]	307412		931		460		430				
	ha	%	ha	%	ha	%	ha	%	ha	%	ha
Upland-mixed	80593.9	26.2	265	28.4	134	29.1	125	29.2	174.7	28.9	45.2
Upland-conifer	59627.0	19.4	139	15.0	191	41.7	121	28.1	151	28.2	21.0
Lowland-conifer	54561.3	17.7	96	10.3	67	14.6	93	21.7	85.3	15.5	9.2
Water	27972.5	9.1	72	7.7	20	4.3	45	10.5	45.7	7.5	15.0
Upland-hardwood	27127.5	8.8	57	6.1	4	<1	6	1.3	22.3	2.7	17.3
Open	22717.6	7.4	145	15.6	13	2.8	6	1.3	54.7	6.5	45.2
Brush-lowland	13846.7	4.5	83	8.9	3	<1	4	<1	30	3.5	26.5
Brush	9862.4	3.2	34	3.7	3	<1	3	<1	3	1.7	10.3
Brush-ericaceous	3552.1	1.2	1	<1	10	2.2	14	3.3	8.3	1.9	3.8
Lowland-mixed	3510.9	1.1	3	<1	3	<1	3	<1	3	0.6	0
Roads	3248.0	1.1	22	2.4	10	2.2	8	1.9	13.3	2.2	4.4
Lowland-hardwood	715.5	<1	14	1.5	--	--	--	--	4.7	0.5	8.1
Sphagnum	76.9	<1	--	--	2	<1	2	<1	1.3	0.3	0.8

[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 over types based on Landsat (TM) satellite imagery.

Cover type	Owl 094		Owl 154		Owl 972		Total reloc	Total Percent
	# Relocations	Percent	# Relocations	Percent	# Relocations	Percent		
Upland mixed	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 mixed	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

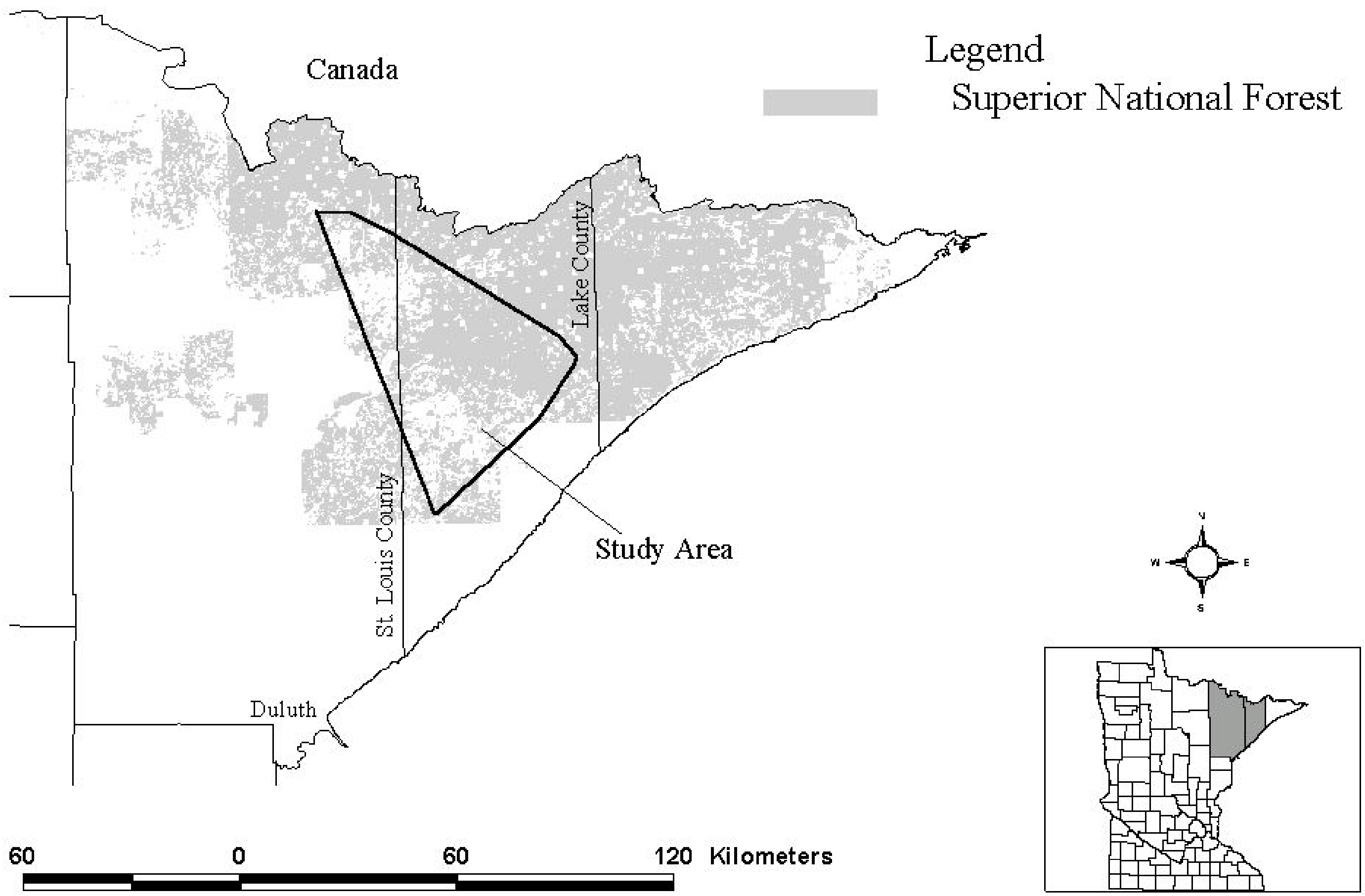

Fig 2.1. Location of study area within Lake and northern St. Louis Counties in northeastern Minnesota.

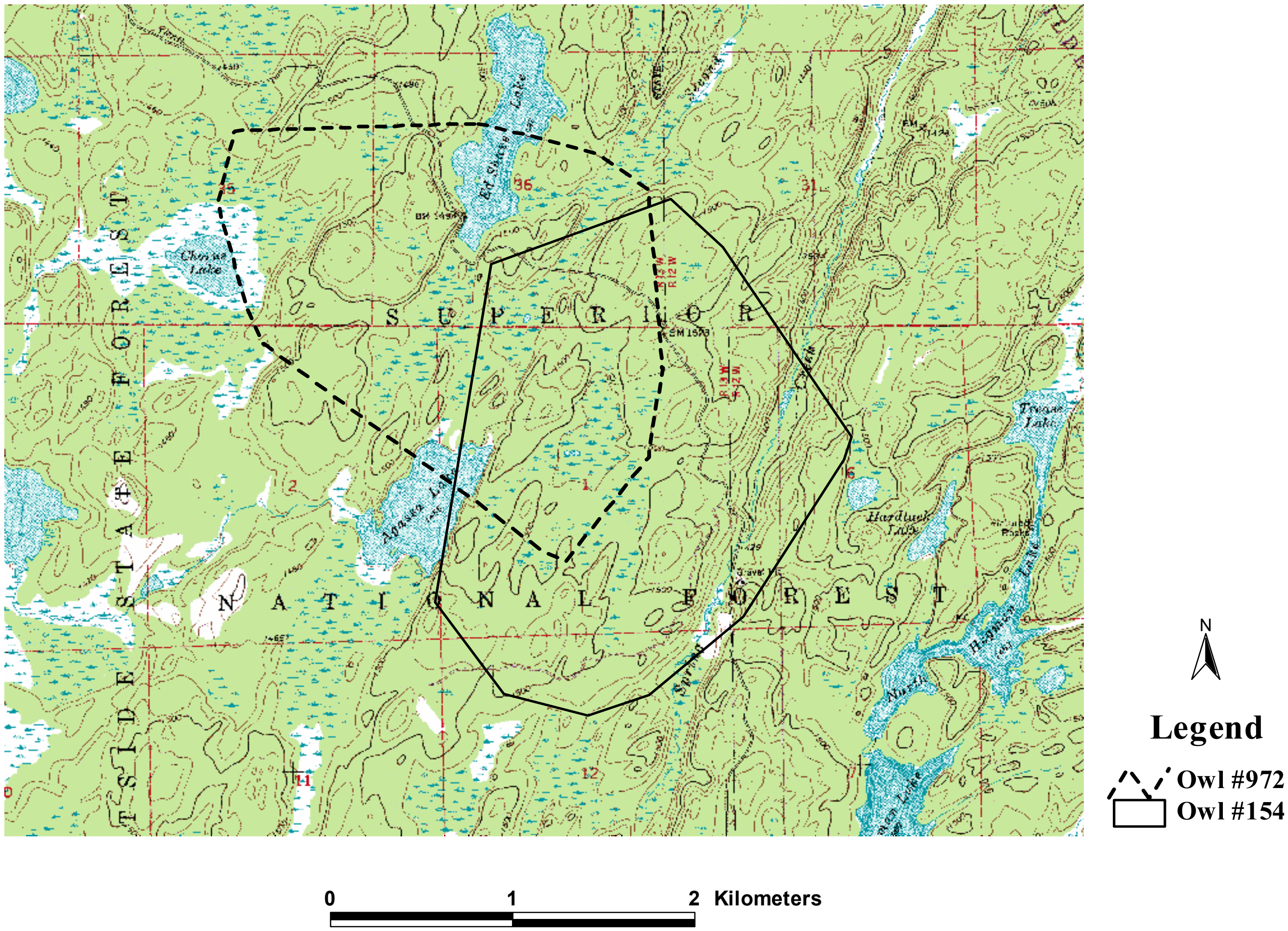

Fig. 2.2 Minimum Convex Polygon (95%) home range illustration for two male Boreal Owls in northeastern Minnesota. Owl #154's territory was active during 2000, Owl #972's territory was active during 2001.

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