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DISTRIBUTION AND ECOLOGY OF

BOREAL OWLS IN NORTHEAST MINNESOTA

A THESIS

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BY

William Henry Lane

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Acknowledgments

Ten years ago, had someone told me I would one day be completing my Master's Program at the University of Minnesota, I would have lowered my eyebrows, looked skyward, and muttered something unintelligible under my breath. Back in 1987, I initiated my research with the intent of satisfying my personal curiosity about the boreal owl. My first few nights in the field were highlighted by fears of the encompassing darkness and the totality of the winter-time silence. Today, however, as the suns' increasing angle again brings us back to spring, I am reminded that not only' will boreal owls soon be singing again, but that there are many people that I should thank for the place I now find myself.

Foremost among them is my wife Oksana. I met Oksana after owls had become anobsession and yet, she continues to allow me to journey north (or west) each spring with an understanding of what the boreal owl, the night, and northern Minnesota mean to me. I want to thank my advisor Dr. David E. Andersen for his high scientific and research standards, and committee members Dr. Peter Jordan, for having faith in me as a potential grad student and providing ,me with a greater appreciation of the boreal forest ecosystem, and Dr. Tom Nicholls for his steadfast support and Dr. Jerry Niemi.

Others, too, should be mentioned. I thank the valued field assistants and volunteers who came on board even when funding was muddled in uncertainty, allowing me the much needed respite from the cold, darkness, and sometimes, the silence. They include Carrie Anderson, Tamera Anderson, Lisa Dittbenner, Bernie Engels, Ron Jeremy, 'David McCormick, Tom Sutter, Tina Sutter, and especially Loren Ayers and Tiffany Church. Dave "Fud" Evans was a valued companion during those early trapping nights when we hoped aloud that inclement weather would arrive so we would have an excuse to watch the Stanley Cup playoffs. Wayne Russ served as a liaison between bureaucracy and reality, and was an important source of encouragement. Terry Gokee provide his time and data from the Gunflint Ranger District.

My parents believed in my work even as my conservative Republican brothers had embraced Rush Limbaugh. Additionally, I want to thank Chuck Meyer, Nick Stathis, and Gib Ostheimer for introducing me to the realities of a grad student lab, the way it should be, and unfortunately, the way it will never be again. In a jaded way, I need to thank Homer, Barney, Grandpa, and Krusty for their daily escapes from reality via syndication.

Thanks to other grad students in the guise of Pat Campbell, Tom Gelatt, Rob "Clog Boy" Jensen, Bill McCarthy, and Jerry Grant. Also, Keith Warnke, Jim Manolis, Ann Bellemah, Dave Plumpton, Dorothy Bowers, and Mary Anne Mcleod. None of my pets will be mentioned.

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Symposium Research Grant Program; and the Dayton-Wilkie Trust, Fund and Gordon Gullion Scholarship at the University of Minnesota.

If I failed to mention someone, I apologize. It was unintentional, then again, maybe it wasn't. Lastly, I want to finish this chapter of my life, and begin the next with these Words from A. C. Bent:

> "We common mortals, who cannot see in the dark, know very little about the courtship performance of the owls, except what we can learn from listening to their springtime voices" (1937).

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Introduction

Once described as the "rarest of Canadian owls" [Taverner, cited in Bent (19381)], evidence now suggests that the boreal owl (*Aegolius funereus*) is more widespread and common in the New World than originally thought. The first documented nesting of : boreal owl in Ontario, Canada was recorded as recently as 1975 (Bondrup-Nielsen 1976), and shortly thereafter the first nesting of boreal owls south of the United! States-Canadian border was recorded in 1978, in Cook County, Minnesota (Eckert and Savaloja 1979). Since then breeding boreal owl populations have been documented in Idaho (Hayward and Garton 1983), Colorado (Palmer and Ryder 1984), and Montana (Holt and Ermatinger 1989), and they are suspected of breeding .in Washington (O'Connell 1987), Oregon (Whelton 1989), and New Mexico (Stahlecker and Rawinski 1990). Rather than reflect an expansion of the owls' distribution, these recent observations likely reflect the increased efforts undertaken to locate the species.

Although recent investigations have provided a better understanding of boreal owls in western North America, in eastern North America, little information is available pertaining to the species' distribution and ecology. In part, the paucity of data in eastern North America may be attributed to the following factors:

1) Boreal owls occur in areas with few human inhabitants
'2) They are primarily nocturnal
3) Boreal owls are vocal during only a brief period each year
4) Efforts to locate boreal owls are time and labor intensive

Boreal owls are obligate, secondary cavity nesters (Mikkola 1983) and are closely associated with the abandoned excavations of common flickers (*Colaptes auratus*) and pileated woodpeckers (*Dryocopus pileatus*) (Johnsgard 1988). Nesting typically occurs in trees classified as mature or old growth, and especially in forest species susceptible to pathological vectors, insect infestation, and natural cavity formation (Hayward 1994). Also, boreal owls appear to preferentially select homogeneous coniferous tracts for non-nesting activities (Bondrup-Nielsen 1978, Palmer 1986, Hayward 1989).

Northeast Minnesota appears to be the southern extension of the breeding range of boreal owls in eastern North America [American Ornithologists' Union (AOU) 1983]. Historically, Roberts (1932) suggested that boreal (Richardson's) owls "may breed in the far north of Minnesota," but provided no conclusive evidence of nesting attempts. Following the first documented nesting by boreal owls in 1978, several additional nest sites were recorded in Minnesota (Eckert 1979, Matthiae 1982). As a result, boreal owls were categorized as an accidental (Johnson 1982) or a rare nesting species (Janssen 1987). Additionally, the Superior National Forest (SNF) proposed listing boreal owls as a candidate sensitive species and derived preliminary habitat guidelines for management purposes (SNF 1986). However, despite the increased attention the species was attracting, few efforts were made to determine the boreal owl's distribution and habitat requirements in Minnesota. Accordingly, -the status, distribution, and breeding ecology of boreal owls in the state are not well documented, and at best, conjectural.

Given the recent documentation of nesting by boreal owls in northeast Minnesota, I initiated this study in 1987 in an attempt to determine whether boreal owls could be found, and if so, to identify the habitats used by the species for nesting and non-nesting activities. 'Specifically, I addressed the following:

1) *Distribution and habitat use by breeding boreal owls in northeast Minnesota.*

Document the occurrence and distribution of breeding boreal owls in a portion of northeast Minnesota, and evaluate temporal and spatial patterns in occurrence. In addition, identify habitats used by boreal owls during courtship activities and determine their frequency of occurrence within the landscape.

2) Record the movements and habitats used by boreal owls during non-nesting activities

Monitor radio-tagged boreal owls and identify habitats used by the owls for roosting and foraging

Boreal owls are described as tireless singers (Bondrup-Nielsen 1978) that can readily be detected if observers are in the field during the owl's courtship activities (Holmgren 1979). Surveys to detect voluntarily calling boreal owls have been used successfully to locate the species in areas where they were not previously documented (Hayward and Garton 1983, Palmer and Ryder 1984, Whelton 1989). Radio telemetry, meanwhile, facilitates identification of the movement patterns and habitats used *by* tagged animals, and is especially effective for nocturnally-active species such as the boreal owl (Bondrup-Nielsen 1978, Palmer 1986, Sonerud et al. 1986, Jacobsen and Sonerud 1987, Hayward 1989).

Based on recent estimates, the boreal owl population is projected to decrease in portions of northern Minnesota under both medium and high timber harvest scenarios [Minnesota Generic Environmental Impact Statement (MNGEIS), Jaakko Pöyry Consulting, Inc. 1992]. Accordingly, this study will provide critical information pertaining to the biology and ecology of the species in Minnesota. Herein, I report on the results ofd my study designed to provide a preliminary understanding of the distribution and habitat use by boreal owls in northeast Minnesota.

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Chapter 1: Distribution, Abundance, and Habitat Use of Territorial Male Boreal* Owls *in Northeast Minnesota

Abstract

Nocturnal surveys were conducted in northeast Minnesota from 1987 to 1992 (inclusive), to locate singing territorial male boreal owls *(Aegolius funereus)*. Vocalizing owls were detected on 234 occasions, with 1 71 of the detections (73.1 %) categorized as unique (i.e., individual owls), and 63 detections (26.9%) categorized as owls previously detected (heard during > 1 survey effort). The rate of encountering singing owls ranged from a low of 0.028 owls heard/km surveyed (all detections) in 1991, to 0.091 owls/km surveyed in 1989. Indices for the abundance of individual owls located per route length ranged from 0.056 in 1987, to 0.219 owls/linear km of survey rote in 1989. Boreal owl singing activity increased towards 15 April, and decreased', thereafter. Territorial boreal owls used pole-sized trees in upland-mixed forest stands greater than expected and open/brush/regenerative stands significantly less than expected for courtship activities. Stands supporting vocalizing male owls were generally located in mature, mixed forest tracts, containing sawtimber-sized quaking aspen (*Populus tremuloides)*.

The boreal owl *(Aegolius funereus) is* distributed holarctically (Tengmalm's owl in Europe and Asia) and occurs as a breeding species throughout the boreal forest zone of North America and within alpine variants of the boreal forest in the Rocky Mountains

[American I,, Ornithologists' Union (AOU) 1983] (Fig. 1.1). Boreal owls are obligate, secondary cavity nesters (Mikkola 1983) and are associated with mature and oldgrowth forest stands for nesting (Hayward 1994). The abandoned excavations of common flickers (*Colaptes auratus*) and pileated woodpeckers (*Dryocopus pileatus*) are most often described as nesting substrates for the species in North America (Johnsgard 1988.

Within their North American breeding range, nocturnal surveys to locate breeding boreal owls during the spring have been used to describe the species' distribution, population status, and habitat requirements (Bondrup-Nielsen 1978, Eckert and Savaloja 1979, Meehan 1980, Hayward and Garton 1983, Palmer and Ryder 1984, Palmer 1986, O'Connell 1987, Lane 1988, Hayward 1989, Holt and Ermatinger 1989,] Whelton 1989, Stahlecker and Rawinski 1990). Results of these surveys indicate that boreal owls are more common in western North America and more habitat specific than originally thought.

Considerably less information is available regarding the owl's breeding distribution and habitat use in eastern North America. Instead, most observations of boreal, owls in eastern North America have occurred during irregular winter-time irruptions south of the boreal forest (Roberts 1932, Bent 1938, Green 1966, 1969, Catling 1972, Eckert 1982, Eckert 1989, Eckert 1992). There are comparatively few studies, of the breeding ecology of boreal owls within the southern extent of the boreal forest in eastern North America.

Beginning in 1987, I initiated an investigation to determine if territorial male boreal owls could be located, and if so, to provide seasonal indices of abundance and identify the habitats associated with breeding in Minnesota. Herein, I report on the results of a

6-year study (1987-1992) to document the distribution, abundance, and habitat use by territorial male boreal owls in northeast Minnesota.

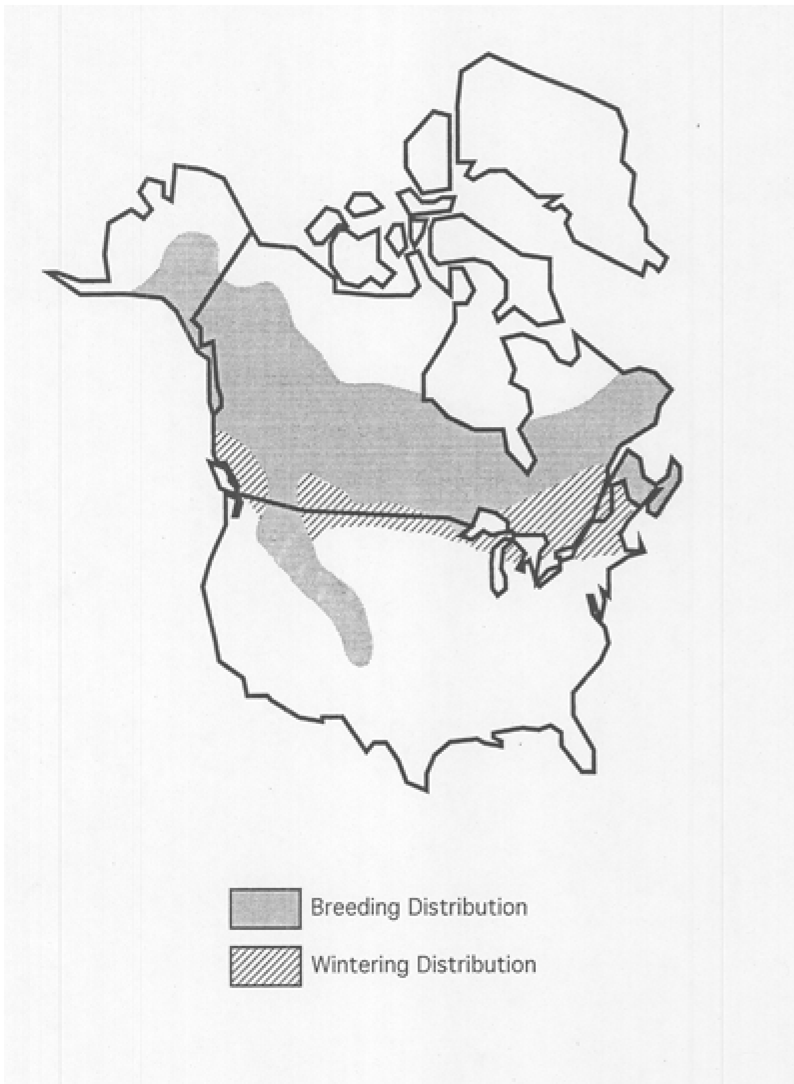
Study Area

This study was conducted in the northeast portion of Minnesota, within Cook County and along the eastern quarter of Lake County (Fig. 1.2). Combined, Lake and Cook Counties extend over an area of 800,000 ha, the majority contained within the Superior National Forest (SNF) and the Boundary Waters Canoe Area Wilderness (BWCAW). Approximately 80% of the land area is forested and nearly 18% is covered by water bodies. Urban or developed land is minimally represented (Spadaccini and Whiting 1985).

The area is geologically defined by exposed Precambrian bedrock to the north (Border Lakes Region) and by the Sawtooth Mountain Range (along the north shore of Lake Superior) to the south, while the central portion is dominated by thick glacial drift that covers all but the most prominent structural features (Austin 1961). The climate in northeast Minnesota is influenced by seasonally generated Continental and Pacific air masses, and is dominated during the winter by strong Arctic flows. Accordingly, mild summers and a short growing season (May to September) and an average rainfall of 45 cm, are countered by severe winters and an average annual snowfall of 152 cm. The mean temperature in the region ranges from -17° C in January to 17° C in July, and snow remains on the ground in most years well into April (Ahlgren 1969).

Northeast Minnesota supports forest types representative of three biotic communities. The southern-most extent of the boreal forest life zone (Rowe 1972) extends into northeast Minnesota and is characterized by forests consisting of balsam fir *(Abies* *balsamea),* jack pine *(Pinus banksiana),* black spruce *(Picea mariana),* white spruce *(Picea glauca),* quaking aspen *(Populus tremuloides),* and paper birch *(Betula papyrifera)*. The boreal forest is transitional to the broadleaf, deciduous forest ecotone to the south and west (Larsen 1980) and is represented in the study area by sugar maple *(Acer saccharum)* along the Sawtooth Mountain Range, and minimally by yellow birch

Figure 1.1 Approximate breeding and wintering distribution of the boreal owl in North America (adapted from Johnsgard 1988).



Breeding Distribution
Wintering Distribution

(Betula lutea). Farther east, the Great Lakes-St. Lawrence forest biome (Rowe 1972) is represented by white pine *(Pinus strobus)* and red pine *(Pinus resinosa)*. Combined, pockets of boreal, hardwood, and softwood forests persist regionally, although fire, fire suppression, and timber harvests have had considerable impacts in shaping the present day forest mosaic (Heinselman 1973).

Aspen in particular has benefited from anthropogenic disturbances, and the management of aspen as a pulp resource is encouraged by silvicultural practices within the study area (SNF 1986). When compared to the forests present in northern Minnesota at the time of European settlement (Flader 1983), forests today are characterized by both diminished timber-species diversity and a homogeneity of forest ages (Mladenoff and Pastor 1993).

Survey Routes and Methods

In 1987, I initiated nocturnal surveys during the late winter/early spring breeding', season to locate vocalizing boreal owls. Specifically, I listened for the broadcast staccato song (Bondrup-Nielsen 1984), uttered by male owls from within 100 m of a potential nest cavity to attract females (Hayward and Hayward 1993). The staccatos song is the loudest vocalization of the species, with a range of detection approaching 3.5 km (Bondrup-Nielsen 1984). The staccato song is distinctive, consisting of an average of 16.1 notes (± 0.19 SD) per bout, with each bout lasting an average of 1.8 s (± 0.02 SD) (Bondrup-Nielsen 1984). The boreal owl is described as a tireless, singer and singing bouts exceeding 3 h, with infrequent pauses have been reported (Hayward and Hayward 1993).

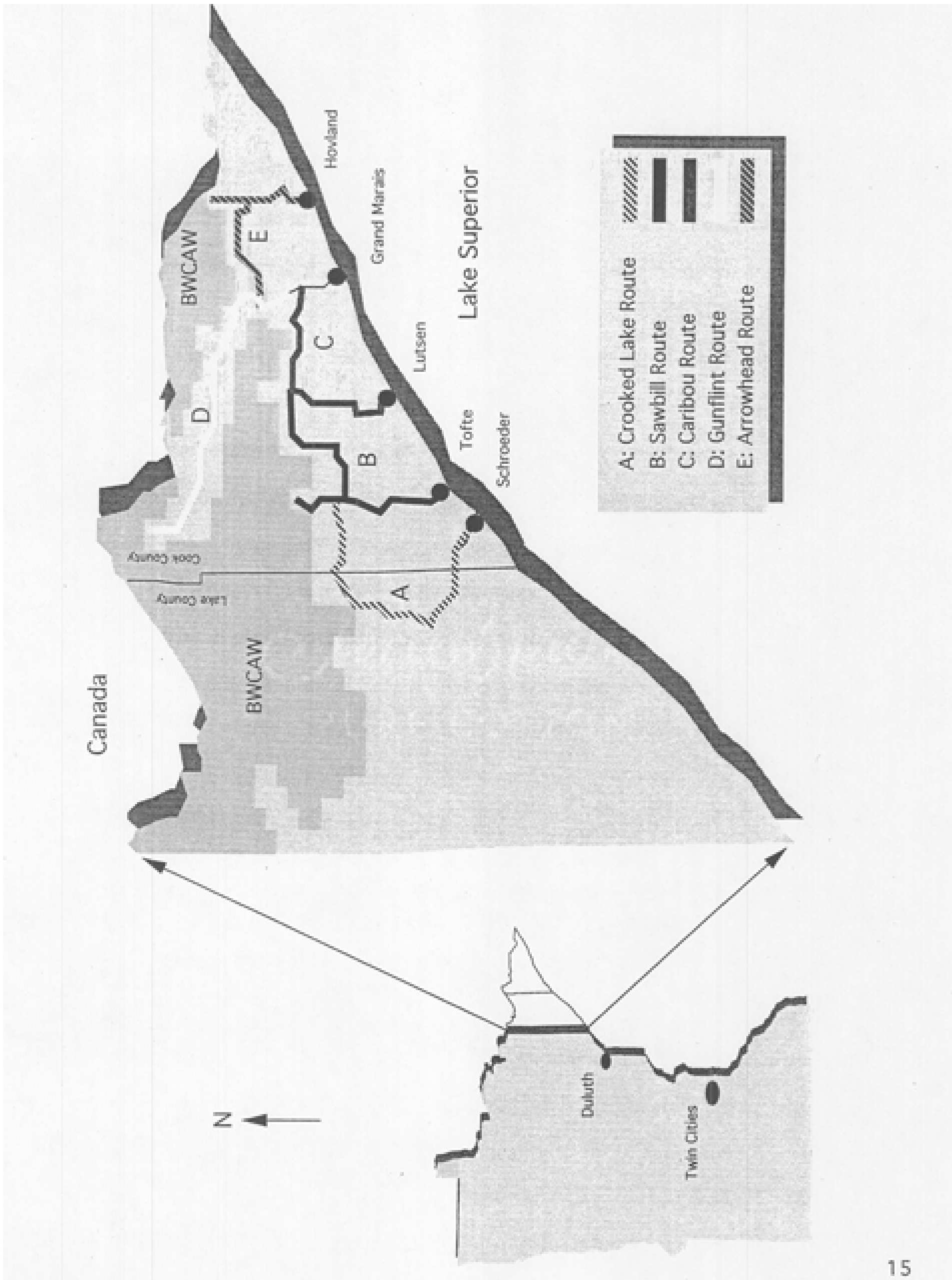
I concentrated my survey efforts within the eastern portion of the SNF, and in areas that included documented nesting attempts by the owl (Eckert and Savaloja 1979, Eckert 1979, Matthiae 1982). Survey routes were established, based on the following criteria: lll (1) Routes were maintained for winter-time access by motor vehicle; and (2) Routes traversed all habitat types found within the study area.

Five survey routes were used throughout this study (Fig. 1.2). During surveys conducted from 1987-1989, the average route length was 60.9 km (range = 41.9 to 71.7 km, Appendix 1.1). Following the 1989 field season, an assessment of the distribution of boreal owls was made (based on 1987-1989 survey results), and portions Of each route where vocalizing owls had not been detected (primarily deciduous uplands along the Sawtooth Mountain Range) were eliminated, reducing the average route length to 48.6 km (range = 38.062.6 km, Appendix 1.2). During 1992, two routes (Gunflint and Arrowhead) were not surveyed. Instead, the three remaining routes (Crooked Lake, Sawbill, and Caribou) were divided in half and treated as six individual routes (Xl = 21.5 km, range = 15.7 to 27.4 km, Appendix 1.3).

Along each route I conducted nocturnal, auditory surveys (Bondrup-Nielsen 1978, Holmgren 1979, Palmer 1986) to locate male boreal owls uttering the broadcast staccato song. Surveys were conducted each year from 1987 to 1992, and were generally !initiated by 15 March with variable completion dates. In 1988 and 1989, surveys were standardized to incorporate the same time frame each year and to provide seasonal comparisons of singing activities by boreal owls. During 1991 and 1992, surveys were initiated in February and concluded by early April.

Surveys were initiated at least one-half hour after sunset and continued until the route was completed or daylight occurred. Surveys were not conducted in moderate to heavy precipitation or in winds exceeding 23 km/h. If weather conditions deteriorated while a route was being surveyed and < 1 /2 of the route was completed, I waited for at least 1 h before abandoning surveys for the evening. I would continue the abbreviated route during the following evening, or when conditions again were conducive for

Figure 11,.2 Location of study area in northeast Minnesota and the five survey routes used to detect vocalizing boreal owls from 1987-1992.


N
Canada
BWCAW
BWCAW
Lake County
Cook County
A
B
C
D
E
Schroeder
Tofte
Lutsen
Grand Marais
Hovland
Lake Superior
A: Crooked Lake Route
B: Sawbill Route
C: Caribou Route
D: Gunflint Route
E: Arrowhead Route
Duluth
Twin Cities
15

detecting singing owls. Survey efforts with > 1 /2 of the route surveyed when interrupted by deteriorating weather conditions were not completed subsequently.

At 0.8 km intervals, I listened for 3 min for vocalizing boreal owls. When an owl wars heard, I recorded a directional azimuth to the bird and estimated the distance qualitatively (i.e., barely perceptible, moderate, loud). Additional directional azimuths from subsequent listening stations were recorded for owls heard at previous stops to facilitate a more accurate placement of the owls' location. The location of owls detected during ',initial surveys were plotted on U.S. Geological Survey (USGS) 1:24,000 topographic maps. If on subsequent surveys an owl was heard within 1.6 km (based upon Minimum Convex Polygon (MCP) home range size; See Chapter 2) of the original detection point, I categorized it as the same individual, unless there was evidence of more than one owl within a given location (i.e., multiple simultaneous vocalizations).

Two abundance indices were calculated, one based on all owl detections/total km surveyed/route (representing the encounter rate of owls during surveys), and one based on the cumulative number of unique (individual) owls located along the length of each survey route. Annual encounter rates were calculated by summing the total number of owls herd and dividing by the total km surveyed along the five survey routes. Annual unique abundance indices were calculated by dividing, the total number of unique detentions along each route by that route length. For 1992 data, annual abundance indices were calculated by combining the two segments of routes that previously had been surveyed as a single route. To make data comparable through time, the portions of each route that were eliminated after 1989, were not included in calculations.

Location of boreal owls and habitat available

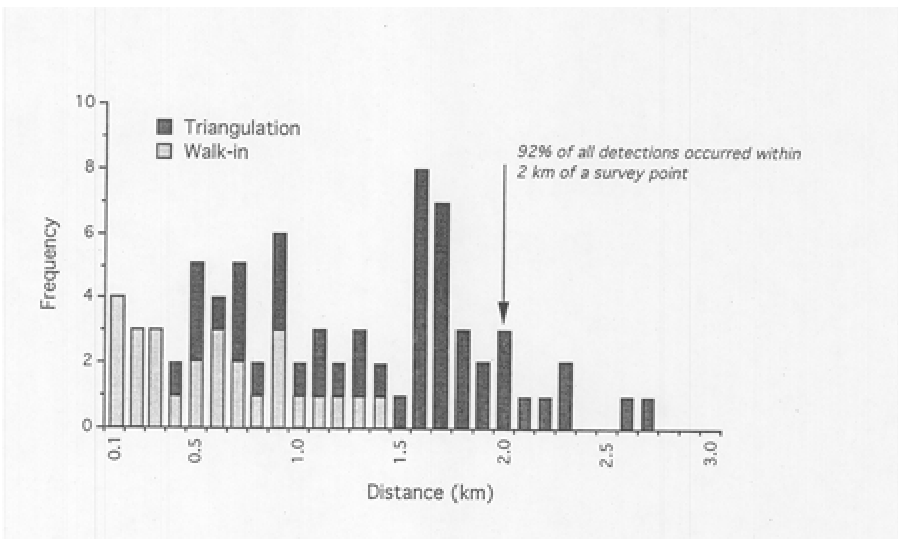
Searches on foot to identify the stand or potential nesting cavities were conducted for a proportion of owls heard calling. During 1988, on-the-ground search efforts were most likely to occur for birds located closer to the road (i.e., < 0.6 km), reflecting my unfamiliarity with both the owl and the study area. Thereafter (1989 and beyond), foot search effort largely depended upon the type of vocalizations being elicited by the male owl, and were primarily directed towards locating nest sites. For instance, if a territorial male was heard during surveys, it was monitored for several nights in an attempt to detect vocalizations that indicated a female was on territory [i.e., *prolonged* staccato (Bondrup-Nielsen 1984)]. Once vocalizations indicated the presence, of a pair, I emphasized foot searches for those owls.

To determine the habitat used by boreal owls during courtship activities, I plotted locations of vocalizing boreal owls derived from foot searches on USGS (1:24,00) topographic maps. In combination with aerial photographs and Forest Service compartment maps (both 1:15,840), I estimated the location of the owl within an identified forest stand.

To evaluate habitat available to boreal owls along the survey routes, I first constructed a frequency distribution of distances of owls from the survey route, based on triangulation estimates of owl locations from survey points and on distances from detection points to known locations (identified by ground searches). Ninety-two percent of singing owls detected were within 2.0 km of the survey route, with no obvious decrease in detection probability out to this distance (Fig. 1.3). A scaled 4 km2 grid (based upon a 2.0 km detection distance in each cardinal direction from a survey point) was drawn on mylar and used as the basis for obtaining habitat samples along each of the five survey routes. Sampling locations were determined randomly by multiplying the route length by a series of randomly generated numbers between 0 and 1, and centering the 4 km^2 grid about the resulting point: If two grids overlapped, I selected the next number in the sequence until subsequent grids did not overlap.

Two methods of extracting habitat data were required. For the western portion of my study area [within the Tofte Ranger District (SNF)], the 4 km^2 mylar overlay was placed atop U.S. Forest Service (USFS) compartment maps. Individual stand data within the grids were extracted from Timber Stand Inventory (TSI) records. If a stand transected the grid border, an estimate of acreage within the plot was made using a modified acreage grid. Water body acreage was estimated in a similar manner, using both USFS data and dot-grid estimates. In the eastern portion of my study area [Gunflint Ranger, District (SNF)], random habitat grid locations and four Universal Transverse Mercator (UTM) coordinates (representing the corners of each 4 km2 habitat grid) were established. Forest Service TSI data stored in ARC-INFO® were extracted and transferred into an electronic database. For both the western and eastern portions of my study area, habitat data under State ownership were extracted from R-Data Base® files and converted for compatibility with Forest Service data. Habitats in grids that included private, land ownership or that were within the BWCAW (no compartment data available) were evaluated using aerial photographs in conjunction with adjacent stand information. For my analysis, I compiled three variables included in TSI data: acreage, Forest Survey Type (FST), and Stand Size Density (SSD). Forest survey types were grouped into seven categories: upland conifer, upland-mixed (conifer/deciduous timber component), upland hardwood, lowland conifer, lowland-mixed, lowland hardwood, and open/bush (Appendix 1.4), with permanent water bodies comprising an eighth category. Three density classes were used for analysis: Density 1 included water bodies and open areas and represented minimal or regenerative forest vegetation; Density 2

Figure 1.3 Frequency distribution of the distances of detection from survey points to vocalizing boreal owls in northeast Minnesota from 1987-1992 for both triangulation estimates and on-the-ground foot searches.



Triangulation
Walk-in
92% of all detections occurred within
2 km of a survey point
Frequency
Distance (km)
0
2
4
6
8
10
0.1
0.5
1.0
1.5
2.0
2.5
3.0

included poletimber; and Density 3 included sawtimber-sized forest tracts (Appendix 1.5). The proportion of each habitat type and density was tabulated on both a per grid and per route basis. Habitat data depicted the forest features present in the study area in 1992, an 'd did not account for annual changes in the habitat composition along survey routes.

I used a Chi-square goodness of fit test and Bonferroni Confidence Intervals (Neu *et al.* 1974, Byers *et al.* 1984) to determine if a difference ($\alpha \leq 0.05$) existed between observed habitat use by boreal owls and expected use based on habitat availability. Habitat availability was determined by pooling the habitat features across routes (based on random samples) to provide a composite summary of habitat available within the study area. Habitat used was determined by identifying the forest stands (based on foot searches only) supporting vocalizing owls. Because all observations of territorial owls ';'used for this analysis occurred in forested tracts, I eliminated non-forested categories (Density 1) and performed an additional Chi-square analysis on habitat use based on Density 2 and Density 3 data.

Results

Owl Surveys

From 1987 to 1992, singing male boreal owls were detected on 234 occasion during 4991.2 km (adjusted to exclude areas where owls were not detected prior to 1990) of surveys, averaging 0.047 detections/km surveyed. The lowest annual detection rate was recorded in 1991 (0.030), and the highest in 1989 (0.089) (Table 1.1). When indices of abundance for individual owls/route length were calculated, the lowest indices occurred in -1987 (0.059 owls/linear km) and 1990 (0.068

Table 1.1 Yearly summaries of the detection rate and the number of boreal owls located along s rvey routes in northeast Minnesota from 1987 -1992. In 1992, the Gunflint and Arrowhead routes were not surveyed;

Year	Survey Route	km Surveyed	Total Owls	Detection Rate[2]	Individual Owls[3]
1987	Crooked Lake	142.8	1	0.007 .	0.025
	Sawbill	146.3	4	0.027	0.078
	Caribou	72.7	5	0.069	0.132
	Gunflint-	61.5	1	0.016 .	0.016
	Arrowhead	101.6	5	0.049	0.068
	Totals (mean):	524.9	16	(0.030)	(0.059)
1988	Crooked Lake	156.4	7	0.045	0.172
	Sawbill	206.0	6	0.029	0.097
	Caribou	132.7	1 -	0:008	0.026
	Gunflint	226.8	21	0.093	0.240
	Arrowhead	204.0	6	0.029	0.085
	Totals (mean):	925.9	41	(0.044)	(0.131)
1989	Crooked Lake	186.1	17	0.091	0.271
	Sawbill	206.0	17	0.083	0.194
	Caribou	152.0	14	0.092	0.231
	Gunflint	249.4	32	0.128	0.304,
	Arrowhead	200.2	8	0.040	0.102
	Totals (mean):	993.7	88	(0.089)	(0.219)
1990	Crocked Lake	146.5	4	0.027	0.099
	Sawbill	134.7	5	0.037	0.097
	Caribou	50.0	3	0:060	0.079
	Gunflint	102.9	5	0.049	0.064
	Arrowhead	78.4	1	0.013	0.017
	Totals (mean):	512.5	18	(0.035)	(0.068)
1991	Crooked Lake	264.5	12	0.045	0.197
	Sawbill	247.3	9	0.036	0.136
	Caribou	186.4	5	0.027	0.079
	Gunflint	218.8	5	0.023	0.080
	Arrowhead	256.9	4	0.015	0.068
	Totals (mean):	1173.9	35	(0.030)	(0.107)
1992	Crooked Lake	293.2	12	0.041	0.222
	Sawbill	362.2	18	0.050	0.252
	Caribou	211.9	6	0.028	0.079:
	Totals (mean):	867.3	36	(0.042)	(0.192)

1 Includes only survey efforts along revised routes (Appendix 1.2)
2 Total owl detections/total km surveyed
3 Number of Individual owls detected/route length (km)

owls/liner km), and the highest occurred in 1989 (0.219 owls/linear km) and 1992 (0.192 owls/linear km) (Fig. 1.4).

Unique (individual) owl detections comprised 171 (73.1.%) of 234 total detections. Previously detected owls accounted for 63 (26.9%) of 234 detections and were most prevalent during 1989, when 33 of 88 (37.5%) boreal owls heard were categorized as previously detected. . The proportion . of owls. heard that had been previously detected increased through the survey .period :and after 15 April,. 26 (65:0%)I of 4.O owls .detected .had been located during earlier surveys (Fig. 1.5). Individual owls located during initial surveys and monitored during subsequent survey efforts suggested that the duration of singing by territorial males was approximately 30 days.

Owls were widely distributed throughout the study area although differences in abundance along individual routes were evident. During the 5 years that all routes were surveyed (1987-91), the Crooked Lake, Sawbill, .and Gunflint routes accounted for 146 (73.7%) of 198 boreal owl detections. The highest detection rate occurred along the Gunflint route (0.074), and the highest abundance of individual owls/route length was observed) along the Crooked Lake route (0..153 owls/km). Both the detection rate (0.029) ;and abundance index .(0.068 owls/km) during the same 5 yr period were lowest along the Arrowhead route.

During 1992, 30-(83.3%) of 36 detections were recorded along the Crooked Lake and, Sawbill routes, while the Caribou route '.accounted for the remaining six (16.7%) detections. The highest abundance of individual owls/route length in 1992 occurred along the Sawbill route (0.252 owls/linear km), and the lowest abundance was recorded along the Caribou route (0.079 owls/linear km). For all years reported, survey stops where > one boreal owl was heard simultaneously vocalizing occurred at 21 locations, land at two locations four individual owls were heard singing simultaneously.

Surveys were initiated in mid- to late-March from 1987 through 1990, and in February during 1991 and 1992. In 1991, I located 11 individual owls by 14 March (0.020

owls/km surveyed). In 1992, only three owls were detected by 14 March (0.009 owls/km surveyed). The earliest date a boreal owl was heard during surveys

Table 11.2 Summary of Density 1 (open/brush/water), Density 2 (poletimber) and Density) 3 (sawtimber) habitat features found within the study area in northeast Minnesota from 1987.-1992. . Habitat availability represents the cumulative proportion of habitat features in the study area and is based upon random sampling along each of, the five survey routes. Bonferroni intervals were constructed to test if habitat features were under- or over-represented in use by territorial male boreal owls

Habitat Category	Area (ha)	Proportion of Total Area	Expected Number of boreal owls per habitat-type	Number of boreal owl observations per habitat type	Proportion of owls observed per habitat type	Proportion of owls expected per habitat-type	Bonferroni Intervals	Significance (0.05)
Density 1	10704	0.367	20.56	3	0.036	0.367	0 s p :5 0.095	Less Use
Density 2	12901	0.442	24.75	17	0.321	0.442	0.174 5 p:5 0.468	
Density 3	5578	0.191	10.70	36	0.643	0.191	0.498 5 p:5 0.798	Greater Use
Totals	29182		56	56				

occurred in 1992 (16 February), and the latest date was in 1989 (10 May) (Appendix 1.6).

Seasonal comparison of boreal owl singing activity suggested that encounter rates peaked hear 15 April,, and gradually decreased. until singing became infrequent by early May (Figs; 1.6). During the 2 years when survey, protocol was standardized (1988 and 1989), 90 (69.7%) of 129 boreal owls (all detections) were located prior to 15 April (Fig. 1.7).

Habitat sampled along survey routes comprised, .on average, 34.9% (range=30.8-47.0%) of the area within 2 km of the routes. Forest features varied considerably throughout the study area. Upland conifers (range=10.5-29.9%,), upland hardwoods (range=19.1-38.8%), upland-mixed (range=1 6.0-26.3%), and lowland conifers (,(range=8.6-13.1 %) comprised the largest proportions of forest types, while lowland hardwoods and lowland mixed forests were minimally represented (each < 1 %) (Fig. 1.8). Density 1 size classifications ranged from 31.044.5%, Density 2 from

Table 1.3 Composite summary of Density 2 (poletimber) and Density 3 (sawtimber) habitat categories found within the study area from 1987-1992 in northeast Minnesota. Habitat availability represents the cumulative proportion of habitat features in the study area and is based upon random sampling along each of the five survey reputes. Bonferroni intervals were constructed to test if habitat categories were under- car over-represented in use by boreal owls. Habitat features included within the Density ',1 classification were excluded from analysis.

Habitat Category	Area . (ha)	Proportion of Total Area	Expected Number of boreal owls per habitat-type	Number of boreal owl observation / habitat-type	Proportion of owls observed per habitat-type	Proportion of owls expected per habitat-type	Bonferroni Intervals	Significance (0.05)
Upland Conifer	3454	0.187	10.47	8	0.143	0.187	0.019 <_ p <_ 0.267	
Upland-Mixed	5495	0.297	16.63	30	0.536	0.297	0.360 :5 p 5 0.712	Greater
Upland Hardwood	6906	0.374	20.94	17	0.304	0.374	0.142 s p _< 0.466	
Lowland Conifer	2159	0.117	6.55	1	0.018	0.117	0.029 5 p :5 0.068	Less Use
Lowland-Mixod Hardwood	448	0.024	1,34	0	0	0.024	0.022 5 p :5 0.072	
Totals	18840		56	56				

39.2-52.0%, and Density 3 from 15.6-26.9% of the area along survey routes (Appendix 1.7).

Stands used by boreal owls occurred in either Density 2 or Density 3 categories, although discrepancies between the forest stand I observed the owl in and the FST denoted in USFS compartment records occasionally occurred. Density 1 habitat features were used significantly less, and Density 3 significantly more (both at P = 0.05) than expected based on availability (Table 1.2). Chi-square analysis of Density 2 and Density 3 habitat features indicated that the use of upland-mixed forests by vocalizing boreal owls was significantly greater than expected (P = 0.05), while the use of lowland conifer habitats was significantly less than expected based on availability (P = 0.05)

Discussion

Boreal owls appear to be widely distributed, occur at low densities as a regular breeding species, and select older aspen located in mixed-type forests for nesting activities in much of northeast Minnesota. Boreal owl abundance indices suggest a 3 yr periodicity (Fig. 1.4), and a documented winter invasion of boreal owls (Eckert 1989) may have contributed to the increases in the number and detection rates of singing owls reported in 1989. The increase in singing owls in 1989 appears to contradict Catling's (1972) suggestion that winter-irruptive owls in eastern North America are unlikely to initiate courtship activities during the subsequent breeding season. Instead, when conditions are favorable (increased prey availability, less severe winter conditions) boreal owls that emigrate from populations farther north may stay to breed in northeast Minnesota.

The occurrence of territorial/breeding boreal owls at low densities is suggested by investigations in other parts of the species' North American distribution. For example, Bondrup-Nielsen (1978) reported that boreal owl numbers in Kapukasing, Ontario (160 latitudinal km north of Minnesota) ranged from one owl per 11 km^2 (1.8 owls per 20 km^2) in 1974, to one owl per 32 km^2 (0.63 owls per 20 km^2) in 1975. Meehan III,(1980) located five male boreal owls in 1977, and 10 in 1978 in a 200 km^2 Alaskan study area (0.5 owls per 20 km^2 and 1.0 owls per 20 km^2, respectively), and Palmer (1986) located nine boreal owls during 1983 (2.0 owls per 20 km^2), and 27 (6.1 owls per 20 km^2) in 1984, in a Colorado study area of 90 km^2 If I assume near

100% detection of vocalizing owls within 2 km of the survey routes, then minimum density estimates for territorial singing male owls may be derived for my study area. Minimum densities of 0.28, 0.66, 1.1, 0.34, 0.54, and 0.96 owls/20 km^2 were recorded in northeast Minnesota, and are slightly lower than the densities reported in other portions of the owls' North American distribution.

As a simple comparative tool, Hayward *et al.* (1993) suggested that surveys for boreal owls be standardized for effort. They reported annual indices that ranged from 0.02 to 0.24 boreal owls per km surveyed in Idaho, and a regional Rocky Mountain average of 0.038 owls per km surveyed. Their results compare favorably with my study, although the proportion of owls that go undetected is not known. When combined, the investigations in Idaho and Minnesota support the occurrence of boreal owls at low densities in two disjunct portions of its North American distribution.

Previous studies have employed a variety of methods to detect boreal owls. For examples Palmer (1986) used passive (point count) surveys, Whelton (1989) utilized broadcast of recorded conspecific vocalizations, and Bondrup-Nielsen (1978), Meehan (1980), and Hayward (1989) used a combination of the two techniques to describe the local distribution, identify breeding individuals, and identify habitat preferences of boreal owls. Hayward *et al.* (1992) however, suggested that call broadcast techniques provide presence/ absence indices, but that individual owl physiology, habitat, and ambient conditions could influence responses, and therefore, limit interpretation of data. In addition, non-vocal responses to call broadcasts (i.e. unobserved approaches or avoidance of the broadcast area) may bias results (Smith 1987).

To facilitate a distribution-wide understanding of the owl in North America, survey methods should be uniform throughout its distribution. Passive listening surveys, for vocalizing boreal owls (standardized for effort) provide a measure of owl distribution and breeding phenology, and can readily be compared to other investigations. Furthermore, passive surveys involve no equipment expenses, and represent habitat selected by boreal owls at a landscape level.

Most previous studies of boreal owls in North America have reported cumulative annual totals rather than separating individual from previously detected owls. This could, however, result in a biased index of the number of owls in a particular landscape, especially when survey efforts are repeated. For example, in 1992, survey efforts were increased, with an average of 7.8 replications for each of the six routes. Increased efforts allowed an identification of most individual owls, but as efforts continued into the field season, the proportion of owls heard previously increased. This suggests that there is an optimal number of survey replications before new detections are replaced by previously detected owls.

Hayward *et al.* (1993) used searches on foot to identify individual owls, and determined that 15 of 63 (23.8%) owls were previously located along established survey routes in Idaho. Because of my large study area, I was only able to conduct searched, by foot for approximately 25% of the owls heard, and supplemented direct observations of owl locations with triangulation estimates. Because precision in identifying owl locations by triangulation decreased with the distance of an owl from a detection point, I separated owl locations by 1.6 km (i.e., an owl heard on subsequent surveys within 1.6 km of a previous detection point was considered the same owl).

As is evidenced by this and other studies, the occurrence of boreal owls can vary markedly from year to year. Throughout its distribution, boreal owl movement and reproductive patterns are closely tied to 3-4 year microtine cycles (Mysterud 1970, Bondrupt-Nielsen 1978, Lundberg 1979, Korpimaki 1986, Palmer 1986, Hayward 1989, Korpimaki and Norrdahl 1989, Hakkarainen and Korpimaki 1994). In the northern latitudes of Europe, boreal owls are described as a nomadic, microtine specialist but are considered a resident generalist predator to the south (Korpimaki 1986). ',As a result, European populations are more stable at the southern extent of their distribution and less impacted by vole cycles than owl populations farther north (Korpimaki 1986). However, given the 3 yr periodicity suggested by my study, it appear that small mammal cycles may in fact, affect owl populations in northeast Minnesota, and specifically, at the southern extent of the boreal forest zone. To address this relationship, the collection of data pertaining to small mammal abundance in northeast Minnesota is warranted.

The localized distribution of boreal owls is directly affected by the availability of preferred habitat features within the landscape. Korpimaki (1986) described both favorable habitat patches and unfavorable interpatch areas that were either used or avoided by boreal owls in Finland. Because,my study area was located within a transition area for three ecotones, distinct pockets of boreal forest, deciduous hardwoods, and eastern softwoods were widespread. Accordingly, habitat composition varied considerably in the study area and patterns of use by boreal owls were related to the presence of specific habitat types. In areas where older boreal forest (Heinselman 1973) Occurred, owls were regularly found. Conversely, little or no owl activities were observed in areas not representative of boreal forest (i.e., upland forests with a minimal lowland component), and especially with forested tracts affected by anthropogenic change (Density 1).

A comparison of available vs. used habitat features,, however, was constrained by k several factors. First, accuracy in placing an owl in a specific forest stand would be limited when locations were derived using only triangulation azimuths obtained from survey points. To reduce this potential bias, I used only owl locations recorded by direct observations (derived from on-the-ground searches) in the Chi-square analysis, albeit at the expense of sample size. Second, forest stand information and stand boundaries contained in USFS compartment data folders often inaccurately described features present within the stands that were selected by the owls. Based on the results of my habitat analysis, it appears that boreal owls in northeast Minnesota are closely associated with stands of mixed, deciduous/conifer stands for breeding and nesting
activities, and especially with stands containing older aspen.

Results of nocturnal surveys indicated that singing activity by boreal owls in Minnesota increased toward the second week of April, and decreased thereafter, although territorial boreal owls were heard after survey efforts were completed in the study area through June during several years. A similar chronology of vocalization activity in eastern 'North America was suggested by Bondrup-Nielsen (1978), who reported that boreal owl singing activity decreased once the minimum mean temperature exceeded 0° C (mid- to late- April in my study area). By identifying individual owls and monitoring their vocalization activity during subsequent surveys, the duration of singing by territorial owls in Minnesota was approximately 30 days (unpublished data). In Colorado, Palmer (1986) suggested that boreal owl singing averaged 26 days, and Meehan (1980) indicated an average vocalization period of 38 days for owls in Alaska.

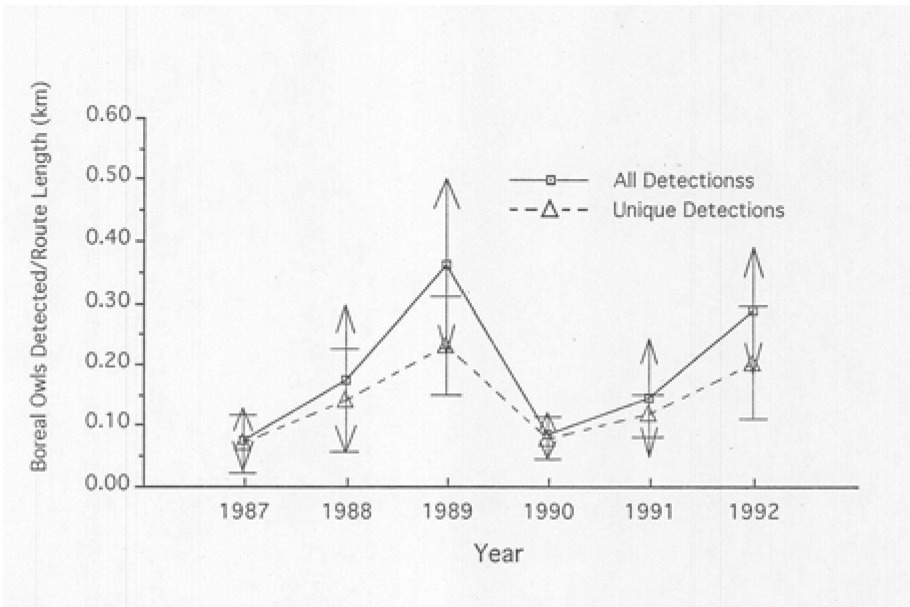
Korpimaki (1986) and Palmer (1986) indicated that day length is the primary factor influencing courtship singing by boreal owls. Although daylength may regulate the initiation and duration of the courtship period, other factors can have a negative effect on singing activity, or the observer's ability to detect vocalizing owls. Sonerud

(1986) reported that boreal owl breeding activities were influenced by snow cover, and Palmer (1986) found a negative correlation between increases in wind speed, and precipitation, and vocalization activity by boreal owls in Colorado. Although not quantified, I found that increased wind speed (especially in conifer stands) and precipitation lessened boreal owl broadcast singing activity in Minnesota. However, during the a initial phases of courtship and pair-bond formation, my observations suggest that vocalization activity around the cavity tree was unaffected by adverse weather. Rather, weather conditions may restrict an observer's ability to detect vocalizing owls, particularly for those located distant from a survey point.

During favorable conditions (no wind, clear skies, cold temperatures) I detected the broadcast staccato song (Bondrup-Nielsen 1984) from distances exceeding 3.2 km. Other breeding-associated vocalizations employed by male owls such as the subdued staccato song, or the prolonged staccato song (Bondrup-Nielsen 1984) are less audible, and therefore, limit the range of detection for observers. In addition to the vocalization type and ambient conditions, owl detections could be affected by several observable factors; first, if the location of the owl was obstructed by local geology (i.e., a ridgeline between observers and owl); and second, the position of the owl (e.g., facing away) from an individual singing perch or cavity in relation to the survey point.

In summary, this study has provided strong evidence that boreal owls are widely distributed, occur at low densities as a .regular breeding species, and have specific, habitat's requirements for their nesting activities in northeast Minnesota. Timber harvest , volumes, especially in the mature, upland-mixed type forests are increasing, and there is a significant shift towards short-rotation aspen stands for pulp production. Management prescriptions that affect the quality of breeding habitat may contribute to a decline in boreal owl populations in portions of northern Minnesota [Minnesota Generic Environmental Impact Statement (MNGEIS) Jaakko Poyry Consulting, Inc. 1992], and If could negatively affect their distribution across the landscape.

Figure 1.4 Annual abundance indices for territorial male boreal owls in northeast Minnesota from 1987 through 1992. Individual owls detected per km of survey route is represented by the dashed line and the total number of detections per km surveyed is; represented by the solid line. Error bars represent SD of detection rates, using survey routes as replicates.



Boreal Owls Detected/Route Length (km)
0.60
0.50
0.40
0.30
0.20
0.10
0.00
All Detectionss
Unique Detections
1987
1988
1989
1990
1991
1992
Year

Figure 1.5 Proportion of total detections of male boreal owls that were unique or previously detected during auditory surveys from road during three time periods in northeast Minnesota from 1987-1992.

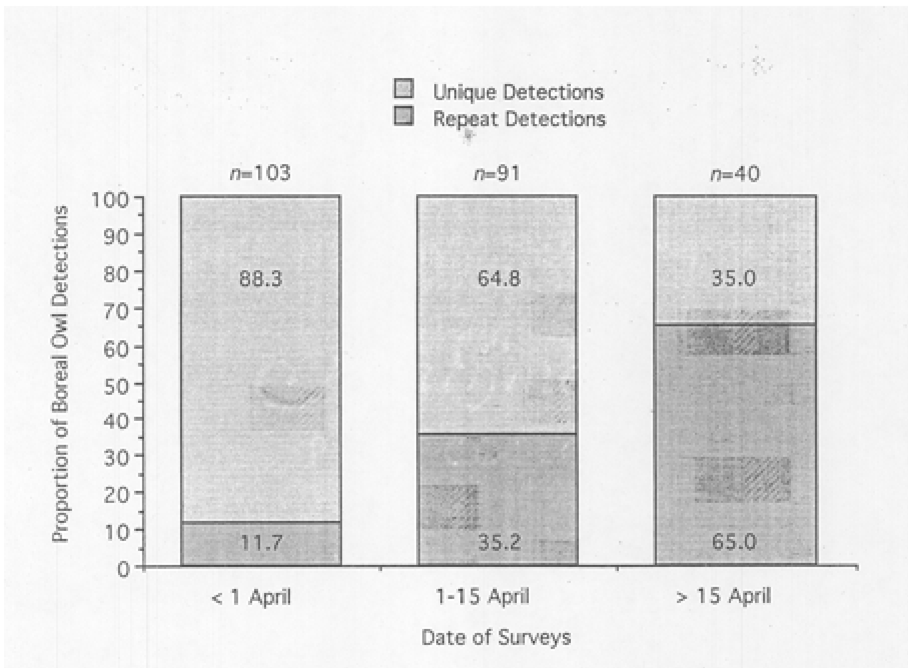

Unique Detections
Repeat Detections
n=103
n=91
n=40
Proportion of Boreal Owl Detections
100
90
80
70
60
50
40
30
20
10
0
88.3
11.7
64.8
35.2
35.0
65.0
< 1 April
1-15 April
> 15 April
Date of Surveys

Figure 1.6 Average encounter rate of singing male boreal owls as a function of the time surveys were conducted in northeast Minnesota from 1987-1992. Numbers above bars represent total km surveyed along routes described in Appendix 1.2. Surveys were not conducted along the Gunflint and Arrowhead routes in 1992.

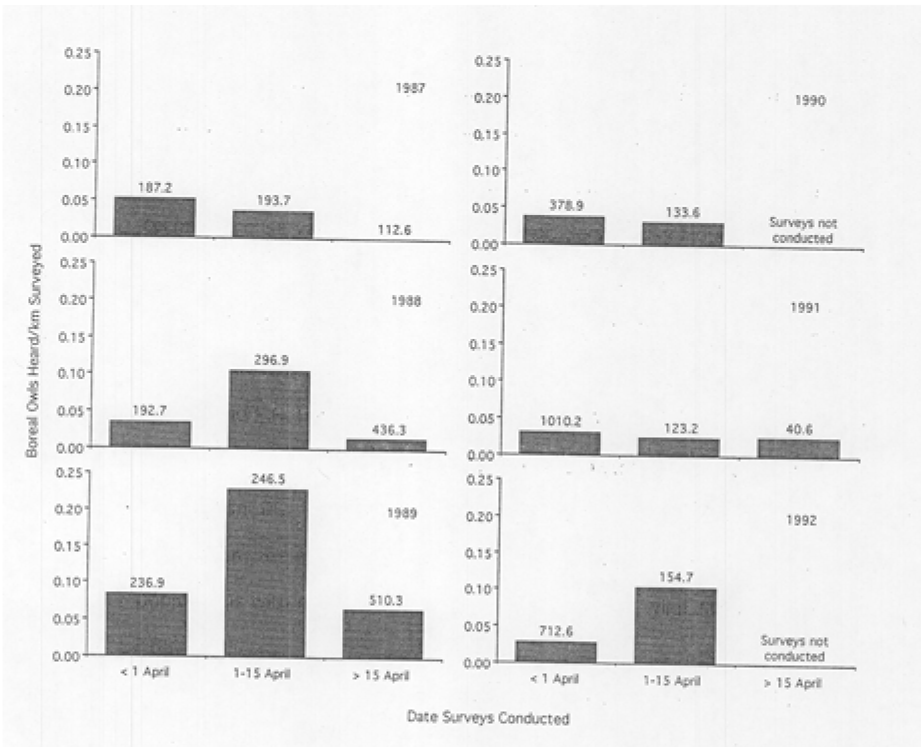
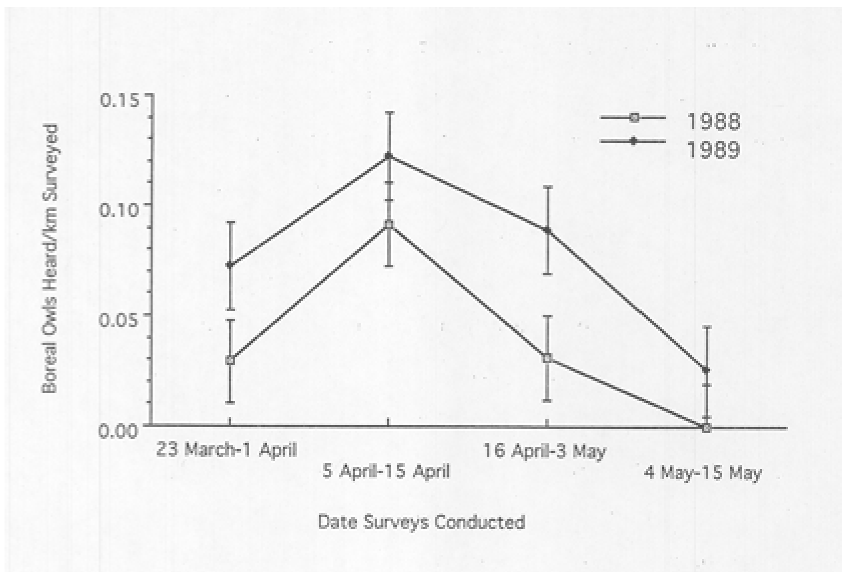
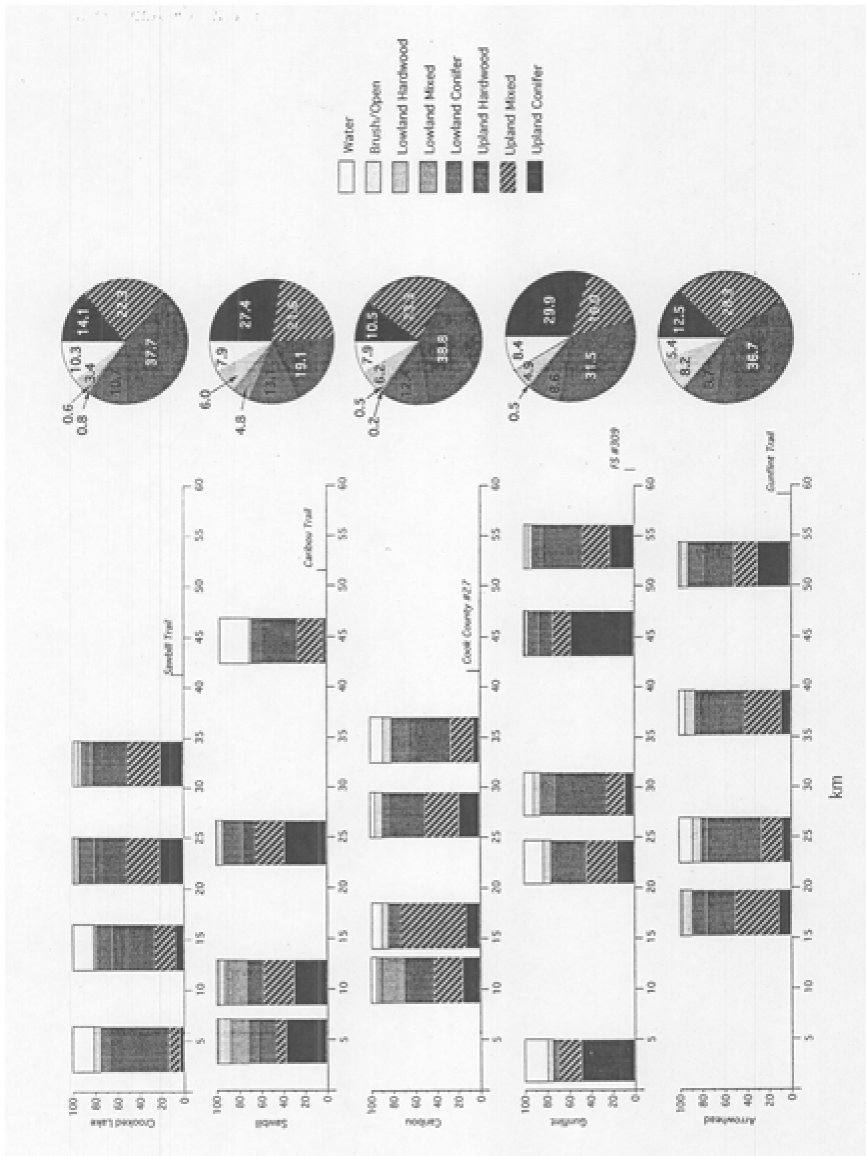

Boreal Owls Heard/km Surveyed
1987
187.2
193.7
112.6
1990
378.9
133.6
Surveys not conducted
1988
192.7
296.9
436.3
1991
1010.2
123.2
40.6
1989
236.9
246.5
510.3
1992
712.6
154.7
Surveys not conducted
< 1 April
1-15 April
> 15 April
Date Surveys Conducted

Figure 1.7 Average encounter rate of singing male boreal owls per km surveyed during 1988 and 1989 in northeast Minnesota. Each of the five routes was surveyed once during the four depicted time blocks. Error bars represent 1 SD, based on survey routes as replicates.



Boreal Owls Heard/km Surveyed
0.15
0.10
0.05
0.00
1988
1989
23 March-1 April
5 April-15 April
16 April-3 May
4 May-15 May
Date Surveys Conducted

Figure 1.8 Composition of habitat sampled along each of the five survey routes and used to detest singing male boreal owls in northeast Minnesota from 1987-1992. Bars represent the landscape features present within a 4 km2 grid, centered on the survey route and the approximate position along the route. Pie charts represent the cumulative proportions of habitat features along each route.


Water
Brush/Open
Lowland Hardwood
Lowland Mixed
Lowland Conifer
Upland Hardwood
Upland Mixed
Upland Conifer
Crooked Lake
Sawbill
Caribou
Gunflint
Arrowhead
Sawbill Trail
Caribou Trail
Cook County #27
FS #309
Gunflint Trail
km

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Chapter 2: Habitat Use and Movements of Male Boreal Owls in Northeast Minnesota

Abstract

I monitored 10 radio-equipped male boreal owls in northeast Minnesota from *1990-1992;* four in *1990,* four in *1991,* and two in *1992. Owls* were captured at singing perch or cavity site locations and monitored while they remained within the study area or until transmitters were removed following the breeding season. Owls most often roosted in lowland conifer forests, even though these forest-types represented only 8.3% of the study area. Black spruce *(Picea mariana)* was identified as the roost tree on *94* (81.7%) of 115 observations. Only three marked owls remained in the study area into the summer: six owls presumably left. the study area and one was killed by an avian predator, most likely a, great-horned owl, *(Bubo virginianus). All* monitoring efforts of owls that ended in loss of signal were males that were either unpaired, or had experienced nest failure shortly after egg laying. Minimum Convex Polygon (MCP) home range estimates for four male owls in 1991 averaged 1202, ha (range=7421,444 ha), but when limited to movements prior to nest failure, the average MCP estimate was 425 ha (range=203-74 ha). Fifty percent Harmonic Mean Transformation-Activity Areas (HMT-AA) averaged 141 ha (n=4, range=101-208 ha), also indicating that boreal owls restricted their movements to relatively small areas during the breeding season.

Boreal owls *(Aegolius funereus)* are distributed holarctically and found as a breeding species in North America throughout the boreal forest zone (American

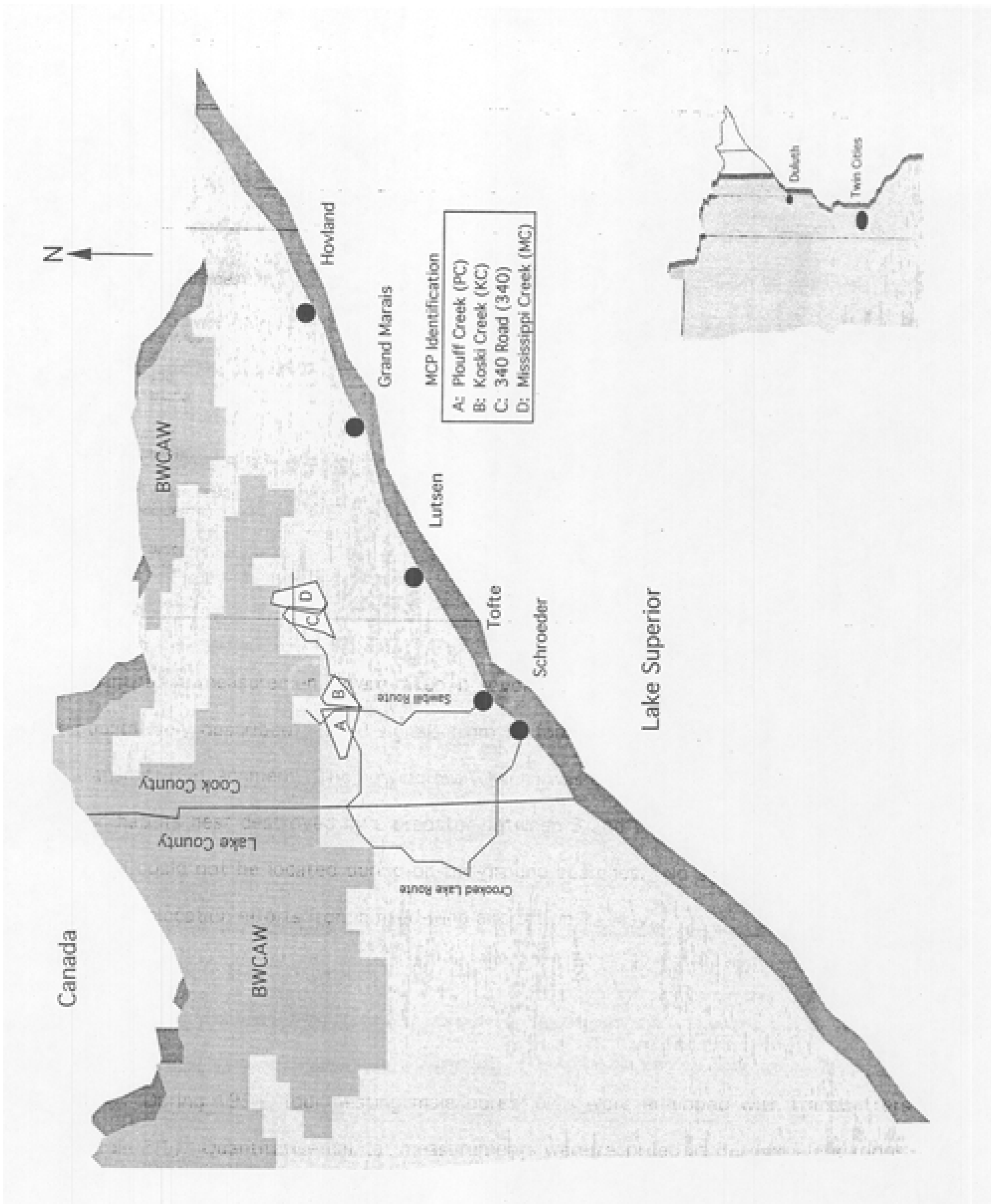
Ornithologists' Union [AOU] 1983). Previous radio telemetry investigations of habitat use and movements of boreal owls have been conducted within contiguous -tracts of the boreal forest in Canada (Bondrup-Nielsen 1978), and within alpine variants of the boreal forest in Colorado (Palmer 1986) and-Idaho (Hayward 1989). However, little information is available pertaining to boreal owl ecology and habitat use at the southern extent of the boreal forest in eastern North America.

Northern Minnesota is situated within the transition area of three ecotones: boreal forest, deciduous hardwood, and Great Lakes pine (Heinselman 1973). Of these,;` boreal forest is widely distributed yet comprises only 16% of the forest mosaic (Kingsley 1991). In these landscapes, the importance of conifer forests for breeding boreal owls is not known, and may be different compared to use of these habitats by owls in other landscapes: Herein, I report on the results of radio-telemetry monitoring to identify habitats :used by boreal owls and patterns of habitat use by territorial male boreal owls in northeast Minnesota.

Study Area

This study occurred in Cook and Lake Counties in northeast Minnesota. The study area was roughly bounded by the Boundary Waters Canoe Wilderness Area (BWCAW) to the north, and by the Sawtooth Mountain Range and Lake Superior to the south (Fig. 2.1). Climate in the region is influenced by seasonally-generated Continental and Pacific air masses, and is dominated during the winter by strong Arctic flows. Accordingly, mild summers and a short growing season (May to September) and an average rainfall of 45 cm, are countered by severe winters and an average annual snowfall of 152 cm. The mean temperature in the region ranges from -17° C in January to 17° C in July, and snow remains on the ground in most years well into April (Ahlgren 1969).

Figure 2.1 Location of study area in northeast Minnesota and the Minimum Convex Polygon (MCP) home ranges of four radio-tagged male boreal owls monitored along the Crooked Lake and Sawbill call-survey routes during 1991.


N
Canada
BWCAW
BWCAW
Lake County
Cook County
Crooked Lake Route
Sawbill Route
Hovland
Grand Marais
Lutsen
Tofte
Schroeder
Lake Superior
MCP Identification
A: Plouff Creek (PC)
B: Koski Creek (KC)
C: 340 Road (340)
D: Mississippi Creek (MC)
Duluth
Twin Cities

Three biotic communities are present within the study area. The southern-most extent of the boreal forest zone (spruce *[Picea* spp.*],* balsam fir *[Abies balsamea],* jack pine [Pines *banksiana],* quaking aspen [Populus *tremuloides],* paper birch *[Betula papyrifera])* extends into northeast Minnesota and is transitional to the broadleaf, deciduous forest ecotone (sugar maple *[Acer saccharum],* yellow birch *[Betula lutea])* to the south and west (Larsen 1980), and to the Great Lakes-St. Lawrence forest region (white pine *[Pines strobes],* red pine [*Pines resinosa*]) to the east (Rowe 1972). As a result, pockets of boreal, hardwood, and softwood forests persist locally within the study area, although fire, fire suppression, and timber harvests have had considerable impacts on the present-day forest mosaic (Heinselman 1.973).

Methods

Radio Telemetry

I used mist nets, bal-chartris, and the taped playback recording of the primary song of the boreal owl to trap territorial male owls during their nocturnal active period (Bull 1987, Hayward 1989). Territorial male owls were located based on nocturnal, auditory surveys (Chapter 1). Following trapping, birds were banded with U. S. Fish and Wildlife Service (USFWS) aluminum lock-on leg bands and fitted with a radio transmitter, prior to release at the site of capture. Following release, owls suspected of being unpaired were monitored for several nights to document nesting status. In 1990, 6 g backpack-type transmitters (Nicholls and Warner 1972) (Advanced Telemetry Systems [ATS], Isanti, MN) were attached to the owls with a 0.64 cm elastic harness, fastened with nylon stitches over the keel of the bird (C.D. Hayward pers. comm.). The attachment technique was modified later in the 1990 field season and the nylon stitches were replaced with a 5 mm width of copper tubing to secure the harness strands, resulting in decreased handling time between capture and release. The transmitter design itself was modified for 1991 and 1992, reducing the total weight of transmitter, harness, and copper crimp to approximately 5.2 g. In 1991; I used a lab mouse and a dip net (Bull 1987) during daylight hours to retrap radio-tagged boreal owls and remove radio transmitters.

Diurnal radio relocations were obtained using a scanning receiver and a hand held, three-element Yagi antenna. Diurnal locations were obtained based on $\geq$ two non-simultaneous sequential azimuths (White and Garrott 1990) recorded, from landmark locations (e.g., road intersections) identifiable on aerial photographs and U.S. Geological Survey (USGS) 1:24,000 topographic maps. Following triangulation, a rough estimate of an owl's location was determined from aerial photographs. Owls were then located by following transmitter signals to the roost site, where the owls were visually observed. Relocation efforts were placed into two, .6 hr time blocks (0600-1200 or 1200-1800), with consecutive observations of an individual owl separated by at least one day, and occurring in the time, block not used during a previous relocation. For example, if an owl was observed on Monday at 1030, the next relocation effort would occur on Tuesday (or later) but within the 1200-1800 time block. Relocation efforts, by fixedwing aircraft (Gilmer et al. 1981) were used to identify the location of transmitter signals that could not be detected during on-the-ground monitoring, and did not fall within the diurnal tracking schedule.

Only multi-observer relocations were used to record nocturnal movement patterns of radio-tagged owls. Two observers equipped with radio receivers were positioned at pre-determined locations. Using hand-held portable radios (to facilitate synchronized readings), observers recorded directional azimuths to the owl for a varying number of relocations (i.e., 1-15), with a minimum of 10 min separating relocation efforts: Successive nocturnal relocation data were tested for autocorrelation (Schoener 1981, Swihart and Slade 1985).

Diurnal and multi-observer, nocturnal azimuths were then transposed to USGS 1:24,000 maps and overlaid with a Universal Transverse Mercator (UTM) grid sheet. UTM coordinates were recorded to the nearest grid intersection (based on 100 m grids), and two non-parametric home range depictions were generated using McPAAL (Stowe and Blahowiak 1992). A Minimum Convex Polygon (MCP) (Mohr 1947) was generated to describe the boundary within which owl movements were recorded, and a 50% Harmonic Mean Transformation (HMT-AA) (Dixon and Chapman 1980) was used to depict areas of concentrated use.

Habitat Evaluation/Measurement

Both qualitative and quantitative assessments were used to record diurnal roost sites used by boreal owls. During the initial relocation efforts in 1990 (n=13), roost site characteristics (roost location, roost tree species, vegetation-types, topography) were described qualitatively and supplemented with physical measurements of the roost tree diameter at breast height (dbh), height, canopy height, and the roost perch height. The remaining roost locations in 1990 *(n=6),* and all roost sites observed in 1991 and 1992 were assessed quantitatively, and habitat measurements were recorded at each roost site within a 0.04 ha circular plot (James and Shugart 1970), centered on the roost tree. Measurements included the roost tree species; roost tree dbh; roost tree height; roost perch height; distance of owl to the bole of tree; plot slope; basal area;

point quarter-species, -distance, and -dbh; plot canopy heights, and tree count (Appendix 2.1). When possible, the ground underneath the owl was checked for egested pellets, except if efforts were likely to disturb the bird. The roost site location was recorded on an acetate overlay placed atop the aerial photograph.

To estimate the habitat composition within the four MCP boundaries of nesting male owls in 1991, I drew MCP boundaries (based on roost site locations) on mylar overlays atop Forest Service compartment maps (1:15,480). Individual stand data located within the MCP boundaries were extracted from USFS compartment records and tabulated according to acreage, Forest Survey Type (FST), and Stand Size Density (SDD). State land holdings data were extracted from R-DataBase® files located in regional Minnesota Department of Natural Resources (MNDNR) offices and converted for compatibility with Forest Service data. Private land holdings were assessed by aerial photograph interpretation, with acreage estimates derived for stands or water bodies bisecting the MCP boundary using a dot grid estimate.

Habitat used by the four nesting male boreal owls in 1991 was compared with the habitat available along two call-survey routes (Chapter 1) adjacent to where the MCP's were located. Four, 4 km2 grids were randomly placed along each survey route, and habitat composition was extracted from federal and state sources. Habitat data for each survey route were pooled to provide a measure of habitat availability (Chapter 1). Habitat-types within the MCP's and along the survey routes were placed into eight categories: Upland Conifer, Upland-Mixed, Upland Hardwood, Lowland Conifer, Lowland Mixed, Lowland Hardwood, Open/Brush, and Water (Appendix 1.3). Three density classes were used to categorize forest features: Density 1 included permanent water bodies and open areas and represented minimal or regenerative forest vegetation; Density 2 included poletimber; and Density 3 included sawtimber-sized forest tracts (Appendix 1.4).

Because of the small sample sizes, I eliminated habitat types that were minimally, or unlikely to be used by owls (according to Chi-square tests, Chapter 1) and used four categories to compare use vs. availability: lowland conifers, upland-mixed and hardwoods, upland conifers, and open/brush. The proportion of habitat features within the MCP's (habitat used) and along the two survey routes (habitat available) were, ranked and preference determined according to average rank standing (Johnson 1980) .

Results

1990

Four male boreal owls were outfitted with transmitters in 1990 (Table 2.1). Three males (Owl 1, Owl 2, and Owl 3) continued to vocalize after transmitter attachment suggesting that they did not nest during the monitoring period, while one

Table 2.1 Summary data for 10 radio-tagged male boreal owls monitored from 1990 - 1992 in northeast Minnesota.

Owl Identification	Date Trapped	Date Last Observed	Date of Last Radio Signal	Nest Site Located?	Transmitter Removed
Owl 1	1 April 1990	18 April 1990	20 April	No	No
Owl 2	12 April 1990	23 April 1990	2$ April	No	No
Owl 3	20 April 1990	1 May 1990	3 May	No	No
Owl 4	20 April 1'990	3 May 1990	7 May	Yes	No
Plouff Creek (PC)	12 April 1991	17 June 1991	17 June	Yes	17 June 1991
Koski Creek (KC)	18 April 1991	10 June 1991	10 June	Yes	10 June 1991
340 Road (340)	18 April 1991	12 June 1991	12 June	Yes	12 June 1991
Mississippi Creek (MC)	13 April 1991	7 May 1991	7 May	Yes	No
KC	1 May 1992	2 June 1992	5 June	No	No
Temper	9 May 1992	11 June 1992	17 June[1]	No	No[1]

1 A partially intact transmitter was recovered along with the remains of the owl

male (Owl 4) was observed making food deliveries to a female at a nest cavity. Owls 1, 2, and 3 were each observed at four diurnal roost sites, and Owl 4 at seven sites ($\sum$ = 19). Black spruce *(Picea mariana)* was used as the roost tree at 12 of 19 (63.2%) locations; balsam fir three times (15.8%), northern white cedar twice (10.5%), and white spruce *(Picea glauca)* and quaking aspen once each (5.3% each) (Table 2:2).

Table 2.2 Species of tree used for roosting by male boreal owls (n=10) in northeast Minnesota from 1990-92.

	Owl Identifcation										
	1990				1991				1992		
Tree Species	Owl 1	Owl 2	Owl 3	Owl 4	PC	KC	340	MC	KC	Temper	Total
Quaking aspen (*Populus tremuloides*)				1							1
Balsam fir (*Abies balsamea*)	1			2	1	4	2				10
Black spruce (*Picea mariana*)	3	2	4	3	27	21	15	7	8	4	94
White spruce (*Picea glauca*)	1				1		2				4
Northern white cedar (*Thuja occidentalis*)		1		1			1			2	5
Speckled alder (*Alnus rugosa*)						1					1
Total:	4	4	4	7	29	26	20	7	8	6	115

Quantitative measurements were taken at seven locations. The remaining 11 sites were qualitatively described. Radio signals from all four owls were lost within 3 weeks of transmitter attachment. The nesting owl (Owl 4) was equipped with a radio on 20 April, and had its nest destroyed by a predator between 3 and 5 May 1990. By 7 May, the signal could not be located during on-the-ground searches. No signals were detected during relocation efforts from a fixed-wing aircraft on 11 May.

1991

During 1991, four nesting male boreal owls were equipped with transmitters (Table 2.1). Quantitative habitat measurements were recorded at 82 diurnal locations. The Plouff Creek (PC) male was observed at 29, Koski Creek (KC) at 26, the 340 Road (340) at 20, and the Mississippi Creek (MC) male at seven diurnal roost locations. Combined, relocation efforts for PC, KC, and 340 accounted for 75 (91.4%) of 82 total observations in 1992. Seventy (85.4%) of the 82 observed roost perch trees were identified as black spruce; seven as balsam fir (8.5%); three as white spruce (3.6%); and one. as speckled alder (*Alnus rugosa*) (1 .2%) (Table 2.2).

The MC male was located approximately 5 km north of his nest shortly after nest failure on the evening of 5 May, was observed on 7 May, and could not be relocated on 8 May. An aerial search covering the study area and a large portion of northeast Minnesota was conducted on 9 May, but the missing signal was not relocated. Two other nests failed (PC and 340), with the loss of both nests attributed to predation. These birds, however, remained in the study area into June. The PC owl was heard broadcast vocalizing for 2 weeks from an aspen stand approximately 3 km southeast of its original nest site following nest failure, while the 340 owl sang for several nights at the nest site after nest failure, but was not heard vocalizing thereafter. An undetermined number of young were fledged from the Koski Creek (KC) site during the first week of June. Following completion of the field season in mid-June, the three owls remaining in the study area (PC, 340, and KC) were retrapped at diurnal roost sites and their transmitters removed.

1992

Two male boreal owls were trapped and equipped with radio transmitters in 1992 (Table 2.1). One of the owls (KC) was previously radio-tagged in 1991, when it successfully nested. He was retrapped on 1 May 1992, less than 1 km from his 1991 nest site. Quantitative habitat measurements were recorded at 14 roost sites, eight for KC, and six for the Temperance River (Temper) owl. All roost sites occurred in lowland conifer stands (Table 2.2). Attempts to identify nesting status by following the birds during their evening movements were unsuccessful and both owls were believed to be unpaired. No signal was detected from KC after 5 June 1992.. The second owl (Temper) was found dead on 17 June in a red pine stand containing a nesting pair of great-horned owls *(Bubo virginianus),* and I assumed it was predated by the larger owls.

Roost Sites

Boreal owls were observed roosting at 115 locations from 1990 to 1992 (Table 2.2). At 102 of those sites, quantitative measurements were recorded and included in habitat analyses (Table 2.3). Roost sites were most often located in lowland areas that were characterized by thick coniferous growth and a high tree density. Deciduous forests were minimally represented at roost sites; although a mixed deciduous/ coniferous component was observed at sites I classified as upland (5 of 102; 4.9%). Black spruce was used for roosting at 84 (82.4%) of 102 quantified sites, and at 94 (81.7%) of 115 of the total observed locations.

Table 2.3 Roost site characteristics [mean and (standard deviation)] of 1 02 .roost sites selected by radio-tagged male boreal owls in northeast Minnesota from 1990-92. Measurements were recorded within a 0.4 ha radius, with the roost tree serving as plot-center.

	1990		1991				1992		
Owl Identification .	Owl 2	Owl 4	PC	KC	340	MC	KC	Temper	Average[1]
Number of roosts	1	5	29	26	20	7	8	6	12.8
Roost tree dbh (cm)	22.1	35 (22.3)	18.7 (4.8)	17.3 (5.3)	17.1 (6)	15.1 (3.7)	19.1 (4.5)	17.6 (3.4)	20.6 (6.3)
Roost tree height (m)	15	15 (9.0)	11.9 (2.6)	10.3 (3.6)	12.1 (2.9)	10.8 (2.5)	12.2 (2.9)	10.4 (1 .6)	12.2 (1 .9)
Roost perch height (m)	8	6.8 (5.6)	5.2 (2.7)	3.7 (1 .5)	4.2 (1.9)	4.1 (1.9)	4.6 (1.3)	3.0 (1)	5.0 (1.7)
Deciduous basal area (m2/ha)	0	8.3 (6.8)	0.16 (0.85)	0.71 (1.7)	2.4 (4.1)	0	0.29 (.82)	0	1.5 (2.9)
Coniferous basal area (m2/ha)	48.2	27.1 (8.2)	36.4 (9.4)	28.2 (6.9)	30.1 (10.5)	28.3 (7.9)	31.9 (-8.5)	32.9 (5.4)	32.9 (6.9)
Average slope (%) within 0.4 ha roost plot	0	2 (4.5)	1.52 (5.2)	3.1 (5.3)	2.3 (3.4)	0.4 (0.9)	1.3 (2.7)	0	1.3 (1.1)
Roost plot canopy height (m)	18.6	16.6 (5:1)	13.2 (2.8)	13.5 (3.2)	13.8 (3.2)	12.8 (2.9)	14.5 (2.1)	13.4 (3.0)	14.6 (2.0)
Tree count/0.4 ha plot	43	39.4 (16.7)	228.5 (80.5)	179.9 (75.6)	205 (85.9)	170.3 (76.5)	166 (55.1)	192.5 (31.3)	153.1 (71.9)
Distance of owl to bole of roost tree (cm)	*	*	8.8 (13.9)	10.5 (14.5)	7.4 (10.1)	17.8 (30.3)	3.5 (5.1)	7.6 (10.9)	9.3 (4.8)

* Variable not measured
[1]Owls as replicates

Home Range

The average MCP home range estimate for nesting male boreal owls was 1202 ha (n=4; range=742 -1444 ha). However, increases in home range size were evident

Table 2.4 Summary of radio-telemetry monitoring of four nesting male boreal owls in northeast Minnesota during 1991. Areal estimates were computed using the McPAAL HomeRange Program (Stüwe and Blahowiak 1992).

Owl Identification	Dates of Radio Monitoring	Number of Diurnal Relocations	MCP Area Estimate (ha)	Nocturnal Relocations* (Nights)	MCP Area Estimate (ha)	Total Relocations	MCP Area Estimate (ha)	50 % HMT-AA Estimate (ha)	Diurnal Roosts Recorded Prior to Loss of Nest	MCP Area Estimate (ha)	Diurnal Roosts Recorded After Loss of Nest	MCP Area Estimate (ha)
PC	12 April-17 June	41	1326	25 (9)	1821	66	1908	208	11	203	29	1255
KC	18 April-10 June	26	742	23 (7)	561	49	863	147	Not Applicable		Not Applicable	
340	18 April-12 June	30	1444	32 (8)	391	62	1445	108	15	279	15	1144
MC	13 April-8 May	12	1297	28 (6)	1029	40	1536	101	10	475	2	

* Only simultaneous, multi-observer relocations are included

Table 2.5 Habitat composition of two survey routes (**bold**) and the four MCP home ranges of radio-tagged male boreal owls located along those routes during 1991 in northeast Minnesota:

		Density Categories			Habitat Type							
Survey Route	Owl	Density 1	Density 2	Density 3	Up Con	Up Mix	Up Hard	Low Con	Low Mix	Low Hard	Open Brush Regen	Water
Crooked Lake		**41.2**	**39.2**	19.6	14.1	22.3	37.7	10.7	< 1 %	< 1'%	3.4	10.3
	PC	47.3	32.5	19.6	17.3	25.0	18.6	33.0	< 1 %	< 1 %	3.4	< 1 %
Sawbill		44.5	39.8	15.6	**27.4**	**21.6**	19.1	13.1	< 1 %	< 1 %	6.0	7.3
	KC	40.8	46.1	13.1	51.5	16.1	1.3	20.6	1.2	< 1 %	7.5	1.9
	340	23.1	55.0	21.9	5.0	34.5	27.3	22.3	2.9	< 1 %	3.0	5.1
	MC	30.8	64.4	4.8	9.6	44.2	16.9	15.5	< 1 %	< 1 %	4.2	9.5

following the loss of nests for the PC, 340, and MC owls. Taken individually, PC increased the area used prior to, and after nest failure from 203 to 1255 ha; and 340 from 279 to 1 144 ha (Table 2.4). Pre- and post-nest failure comparisons of MC were limited due to a low post-failure sample size, although its movement approximately 5 km north of the nest site after failure suggests a similar increase in home range size. The single male that successfully fledged young (KC) exhibited a minimal (20%) increase in MCP area after the eleventh diurnal location (Fig. 2.2).

Tests for independence of sequential nocturnal relocations indicated that successive positions of owls were highly autocorrelated ($P < 0.015$). To reduce autocorrelative effects, all locations < 20 min apart were eliminated. However, even after setting this criteria, data remained highly autocorrelated. This resulted in undue weight of nocturnal tracking data in HMT-AA analysis, although only 3-4 locations (based on $\geq$ 20 min separating sequential relocations) per night were included in analyses. Fifty percent HMT-AA estimates suggested that the owls concentrated their activities within relatively small areas in comparison to MCP home range sizes (Figs 2.3, 2.4), The average 50% HMT-AA size in 1991, using both diurnal and nocturnal, multi-observer relocations was 141 ha (n = 4; range=101-208 ha), but included limited movements that occurred after nest failure for the PC, 340, and MC owls.

Habitat composition within home range perimeters varied considerably from random habitat samples of the two call-survey routes. Density 2 and 3 forest stands were most abundant at the 340 and MC sites. Home ranges supporting the greatest extent of managed tracts occurred at the PC and KC sites (Table 2.5). Rank tests for habitat usage and availability suggested that lowland conifers were the most preferred, and upland hardwoods and conifers the least preferred habitat features used for roosting in the landscape, although differences were not statistically significant.

Figure 2.2 Minimum Convex Polygon (MCP) size as a function of the number of diurnal relocations for four nesting male boreal owls in northeast Minnesota in 1991. A vertical bar depicts the approximate date of the loss of nest for the PC, 340, and MC owls. The KC male successfully fledged young.

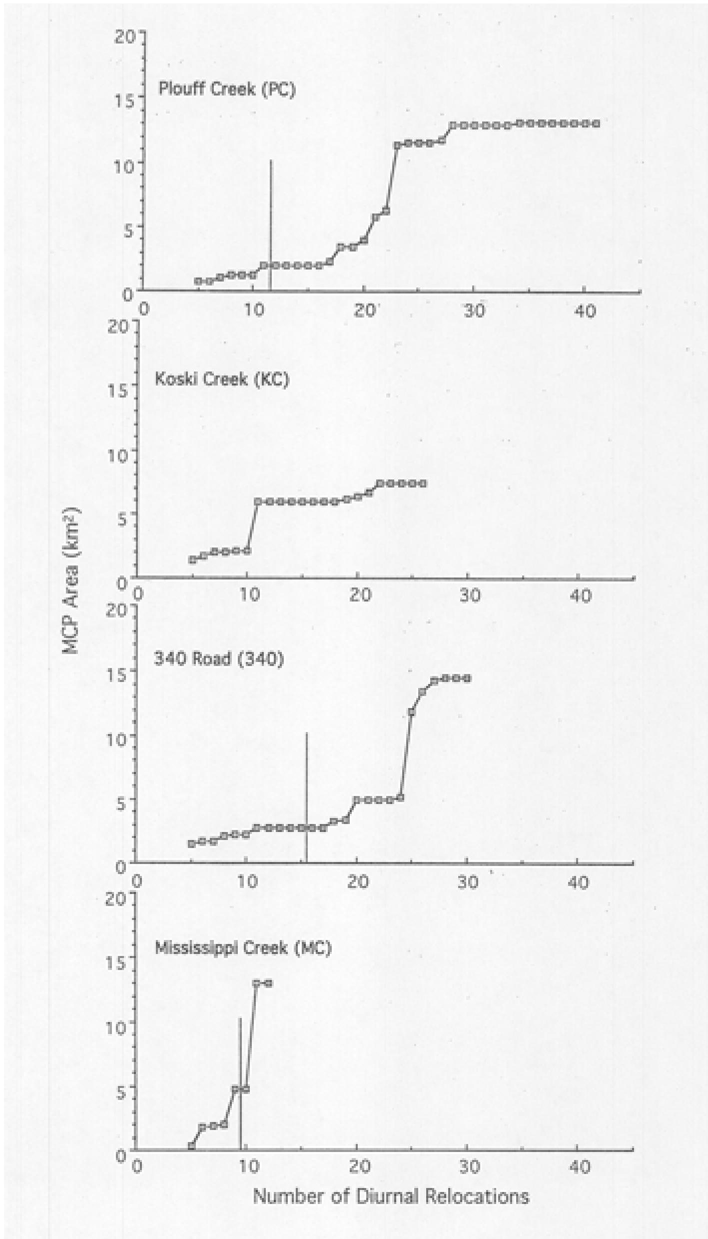

Plouff Creek (PC)
Koski Creek (KC)
340 Road (340)
Mississippi Creek (MC)
MCP Area (km²)
Number of Diurnal Relocations
0
5
10
15
20
30
40

Figure 2.3 Minimum Convex Polygon (MCP) and 50% Harmonic Mean Transformation-Activity Area (HMT-AA) (shaded area) depictions for two nesting male boreal owls in northeast Minnesota in 1991. The PC owls' nest is designated by an asterisk and its MCP by a dashed line; the KC owls' nest by a square and a solid line.

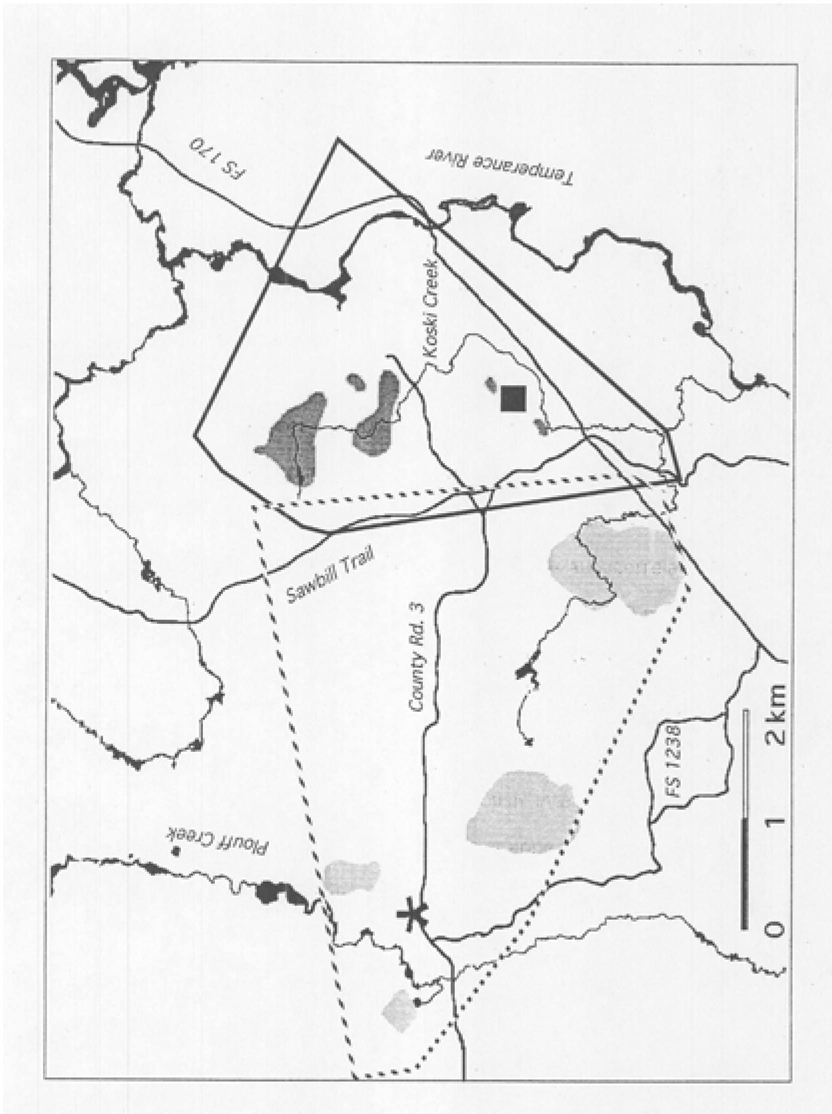
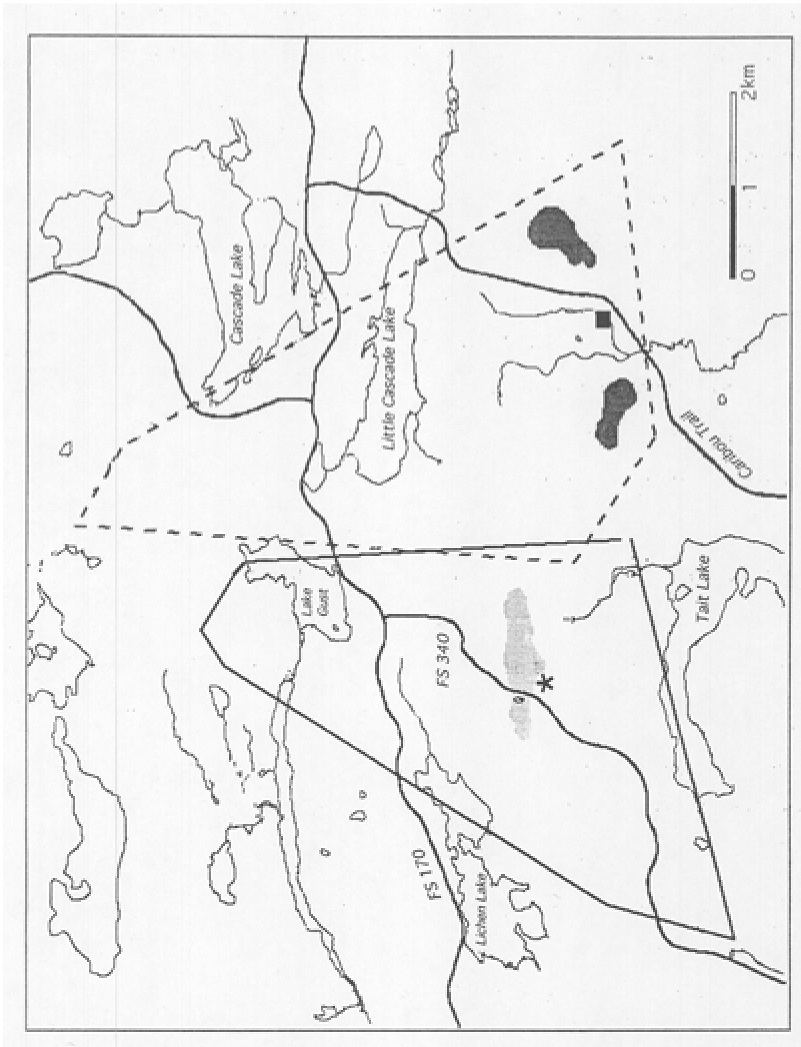

FS 170
Temperance River
Koski Creek
Sawbill Trail
County Rd. 3
Plouff Creek
FS 1238
0 1 2km

Figure 2.4 Minimum Convex Polygon (MCP) and 50% Harmonic Mean Transformation Activity Area (HMT-AA) (shaded area) depictions for two nesting male boreal owls in northeast Minnesota in 1991. The 340 owls' nest is designated by an asterisk and its MCP by a solid line; the MC owls' nest by a square and a dashed line.


Cascade Lake
Little Cascade Lake
Lake Gust
FS 340
FS 170
Lichen Lake
Tait Lake
Caribou Trail
0
1
2km

Discussion

Over 92% of the roost sites located during this study occurred in lowland spruce-type forests. Lowland conifer forests, whether a dominant or minimal landscape component, appear to be an important habitat feature influencing the home range characteristics and habitat use of boreal owls in northeast Minnesota. Lowland conifers comprise approximately *16%* of the forest mosaic throughout northeast Minnesota (Kingsley *1991),* but within the study area .represented only *8.3%* of the available habitat (Chapter 1). However, lowland spruce forests comprised *22.9%* of the forest types present within the four MCP's. The use of conifer forests is indicated not only for roosting by boreal owls, but for foraging as well (Sonerud *et al.* 1986, Palmer 1986, Hayward 1994). Roost sites located in thick conifer forests are believed to provide owls concealment from predators, offer thermodynamic advantages (especially during summer months), and diurnal .foraging opportunities (Hayward and Garton 1984). Foraging locations are generally associated with mature conifer stands; and are selected because of reduced compaction of the snow pack during the winter (facilitating prey survival and access by boreal owls), and reduced ground vegetation during snow-free seasons (Sonerud *et al.* 1986). Microtines, and especially red-backed voles *(Clethrionomys gapperi)* are described as a common prey species of boreal owls (Bondrup-Nielsen 1978, Palmer 1986*,* Hayward *et al.* 1993) and are generally associated with the boreal forest zone in Minnesota (Hazard 1982).

Areal estimates of the home range movements for nesting male boreal owls *(n=4)* monitored during this study averaged 1,202 ha (diurnal relocations). However, it appears this value may be highly influenced by movements after nest failure. For instance, MC left the study area, while the PC male increased the area of his movements by 618%, and the 340 owl by 410%, following nest failure. When home range estimates were limited to successful or pre-failure nests, the- home range size averaged 425 ha.

The comparative value of previous investigations (Bondrup-Nielsen 1978, Palmer 1986, Hayward .1989) of boreal owls in North America .to this study may be limited for several reasons. First, previous telemetry studies were experimental and included the statistical assessment of roosting habitats and home, range movements, whereas the objectives of my study were primarily descriptive. Second, study sites in Canada (Bondrup-Nielsen 1978), Colorado (Palmer 1986), and Idaho (Hayward 1989) were dominated by conifer forests whereas my study site was composed largely of heterogeneous conifer/deciduous-mixed. forests. Third, topographic landscape features in western study areas may restrict movements and influence areas and habitats utilized by the owls (Palmer 1986, Hayward 1989). Finally, owls in this study area are at the southern extent of their breeding distribution, which may influence habitat use and owl behavior. With these constraints in mind; however; it may still be informative to compare my results with published results from other studies in North America.

In Ontario, Canada, Bondrup-Nielsen (1978) reported a home range size of 283 ha for three radio-tagged owls during the spring breeding season. Palmer (1986) reported overall home ranges of 1,486 ha (n=2) in Colorado, but suggested that MCP estimates derived during the nesting season more closely approached those of Bondrup- Nielsen (1978). In Idaho, Hayward (1989) suggested that boreal owls exhibited seasonal shifts in home ranges, averaging 1,451 ha (n=13) during the winter, and 1,182 ha (n=15) during the summer. Contrary to my findings and those of previous studies, however, he suggested that non-nesting male owls in Idaho were more likely to concentrate their movements to a relatively few forest stands while nesting males exhibited more extensive movement patterns.

There appear to be several similarities between European and eastern North American boreal owl populations, foremost among them being the owls' propensity for "nomadic" movements (Mysterud 1970, Lofgren *et* al. 1986, Korpimaki *et* al. 1987). Of the 10 males I radio-tagged between 1990-1992, six ended in a loss of signal, suggesting extensive movements by the owls. Transmitter malfunction or predation (with subsequent loss of transmitter integrity) seems unlikely. During my 1990 aerial search for the four lost transmitter signals, I acquired the signal of a transmitter placed within the study area earlier in the field season. During 1991, I located the signals of PC, KC, and 340 during relocation efforts from a fixed-wing aircraft, but could not reacquire the signal *of* the missing MC owl, despite conducting the air search within 48 hours *of* the loss of its signal. During 1992, I located a dead boreal owl and its still functioning transmitter, even though the antenna had been separated from the transmitter body.

Biologically, there would appear to be few advantages for owls undertaking significant movements during the breeding season. First, their chances of reproduction during that breeding season may be limited. Second, their movements would be from areas with known resources into areas with unknown resources; and third, the advantages of residency to cavity nesting species (von Haartman 1957) would seem to be contradicted. However, it appears that in northern Minnesota, a portion of the boreal owl population makes long-distance movements during the breeding season, especially following nest failure.

Most previous studies of boreal owls have concentrated on home range estimates based on diurnal roost relocations. In part this is because roost sites are associated with the location of the owls' last foraging bout and therefore, foraging sites should generally occur near areas defined by diurnal locations (Hayward 1994). When diurnal relocations were supplemented with nocturnal relocations, results of my study suggest that owl movements were confined to relatively small areas within the MCP. Several factors, however, may limit the value of 50% HMT-AA estimates obtained from this study. First, nocturnal relocations were often .collected in "bursts" (Dunn and Gipson 1977, Samuel and Garton 1987, Andersen and Rongstad 1989) resulting in significant autocorrelation. Second, sample sizes of nocturnal relocation efforts were small.

Jacobsen and Sonerud (1987) suggested that between 10 and 20 diurnal relocations were necessary to estimate home range size for boreal owls in Norway. Only the KC owl, however, demonstrated a similar relationship in my study, with a minimal increase in home range area beyond 20 relocations. It appears that 10 relocations would significantly underestimate home range size.

White and Garrott (1990) suggested that statistical independence of relocation points could be assumed if "sufficient time has elapsed for the animal to move from one end of its home range to the other, although application to- avian species was not addressed. To minimize problems associated with autocorrelation among successive locations I restricted the, interval between locations to $\geq$ 20 min. However, boreal owls are described as "sit and wait" predators (Norberg 1987), suggesting that even a >_ 20 min interval between successive relocations may not result in appreciable movement by the owls. Because nocturnal relocation data were highly autocorrelated, the results from this component of my study should be cautiously interpreted. When supplemented with diurnal relocations, however, nocturnal efforts appear to corroborate the association of boreal owls with lowland conifers for non-nesting activities in northeast Minnesota.

The effects of forest management prescriptions on boreal owl populations is not well understood. Sonerud et al. (1986) reported boreal owls avoided highly fragmented forest tracts in Norway and Hayward (1994) suggested that disruptions to the forest mosaic would limit roost-site availability, prey availability, and access to those sites used for non-nesting activities. Furthermore, he suggested that these disturbances could significantly impact metapopulation stability. Given both the present and projected volume of timber harvests in my study area, a similar effect on boreal owls is likely in northeast Minnesota. Recent projections of timber harvest levels may result in a decrease in boreal owl populations in portions of northern Minnesota during the next 50 years under both a medium and high harvest scenario [Minnesota Generic Environmental Impact Statement (MNGEIS) Jaakko Poyry Consulting, Inc. 1992].

Conclusion

Boreal owls in northeast Minnesota use a diversity of habitat types for nesting and non-nesting activities, with an association of late successional aspen-type forests for courtship and nesting activities (Chapter 1), and lowland spruce forests for roosting and foraging. I Although the species is prone to annual population fluctuations, probably due to prey cycles and the severity of winter conditions, continued depletion of forest features selected by the owls will likely affect both the population size and distribution of the species in northeast Minnesota.

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Appendices

Appendix 1.1 Route descriptions of the five survey routes used to detect boreal owls in northeast Minnesota from 1987-1992. Routes were modified following the 1989 field season and a portion of each route eliminated.

Route	Description
Crooked Lake	Cook County # 1 (6.7 km west of Schroeder, MN) to Lake County # 8; west to Lake County # 7; north on County # 7 and then east to Cook County # 3. Route terminated at junction of Cook County # 3 and Cook County # 2. Route length: 62.2 km.
Sawbill	Cook County # 2 (4.9 km north of Tofte, MN) to Sawbill Lake; U.S.F.S. Road 170 north and east to junction of 170 and Cook County # 4. Route length: 64.8 km.
Caribou	Cook County # 4 (7.8 km north of Lutsen, MN) north to junction with U.S.F.S. Road 170; east to Cook County # 27; south to Cook County # 8. Route length: 41.9 km.
Gunflint	Cook County # 12 from Trail's End south to junction with U.S.F.S. 140. Route length: 71.7 km.
Arrowhead	Cook County # 16 (7.2 km north of Hovland, MN) north to McFarland Lake; U.S.F.S. 313 west to U.S.F.S. 1386; south to U.S.F.S. 309; west to Cook County # 12 Route length: 63 8 km

Appendix 1.2 Revised route descriptions of the five primary survey routes utilized during surveys conducted in 1990 and 1991, in Lake and Cook Counties, Minnesota.

Route	Description
Crooked Lake:	Lake County # 7 (0.8 km east of Crooked Lake); north and east to Cook County # 3 Route terminated at junction of Cook County # 3 and Cook County # 2. Route length: 40.6 km.
Sawbill:	Cook County # 2 (9.6 km north of Tofte, MN) to Sawbill Lake; U.S.F.S. Road 170 north and east to function of 170 and Cook County # 4. Route length: 51.5 km.
Caribou:	Cook County # 4 (7.8 km north of Lutsen, MN) north to junction with U.S.F.S. Road 170; east to Cook County # 27; south 4.8 km on Cook County # 27. Route length: 38 km.
Gunflint:	Cook County # 12 from Trail's End south to junction with U.S.F.S. 309. Route length: 62.6 km.
Arrowhead:	Cook County # 16 (12.5 km north of Hovland, MN) north to McFarland Lake; U.S.F.S. 313 west to U.S.F.S. 1386; south to U.S.F.S. 309; west to Cook County # 12. Route length: 59 km.

Appendix 1.3 Revised route descriptions of the six survey routes utilized during surveys conducted in 1992, in Lake and Cook Counties, Minnesota.

Route	Description
Crooked Lake A:	Lake County # 7 (0.8 km east of Crooked Lake); north to U.S.F.S. 353. Route length: 24.3 km.
Crooked Lake B:	Lake County # 7 (at junction with U.S.F.S. 3530.8 km east of Crooked Lake); east to Cook County # 3. Route terminated at junction of Cook County # 3 and Cook County # 2. Route length: 15.7 km.
Sawbill A:	Cook County # 2 (9.6 km north of Tofte, MN) to Sawbill Lake. Route length: 27.4 km.
Sawbill B:	U.S.F.S. Road 170 (at junction with Cook County # 2) north and east to junction of 170 and Cook County #4. Route length: 23.4 km.
Caribou A:	Cook County # 4 (7.8 km north of Lutsen, MN) north to junction with U.S.F.S. Road 170. Route length: 19.4 km.
Caribou B:	U.S.F.S. Road 170 (at junction with Cook County # 4); east to Cook County # 27; south 4.8 km. Route length: 18.6 km.

Appendix 1.4 Descriptions of Forest Survey Types (FST) used to categorize habitats located within the study area along the five survey routes used to detect boreal owls in northeast Minnesota from 1987-1992. Forest-types were categorized according to guidelines found in the Region 9 Silviculture Handbook (1983).

Upland Conifer:

Jack pine *(Pinus banksiana)*
Red pine *(Pinus resinosa)* .;
Eastern white pine (Pinus *strobus)*
White spruce (Picea glauca)
Balsam fir *(Abies balsamea)*
Norway spruce (Picea *abies)*
Jack pine/black spruce *(Picea mariana)*

Upland Mixed:

Balsam fir/Aspen (Populus spp.)/Paper birch *(Betula papyrifera)*
Aspen/white spruce/balsam fir

Upland Hardwood:

Quaking aspen (Populus *tremuloides)*
Paper birch
Sugar maple *(Acer saccharum)*
Sugar maple/basswood *(Tilia americana)*
Sugar maple/yellow birch *(Betula lutes)*
Red maple-dry'site *(Acer rubrum)*
Balsam poplar (Populus *balsamifera)*

Lowland Conifer:

Black spruce
Northern white cedar *(Thuja occidentalis)*
Tamarack *(Larix* laricina)
Mixed swamp conifer (black spruce/northern white cedar/tamarack)

Lowland Mixed:

Northern white cedar/quaking aspen/paper birch

Lowland Hardwood:

Black ash *(Fraxinus n*igra)/American elm (Ulmus americana)/red maple
Red maple (wet site)
Brush/Open:
Lowland brush
Upland brush
Open
Wetland
Wetland sedge meadow
Wetland shallow marsh
Wetland deep marsh
Wetland shrub swamp
Wetland swamp

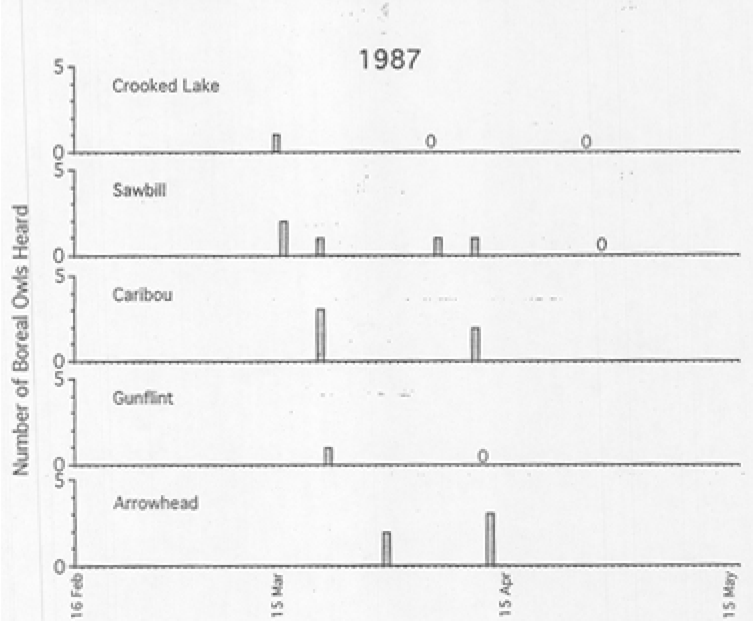
Appendix 1.5 Criteria used for Stand Size Density (SSD) classification. Information was contained within Timber Stand Inventory (TSI) data and based on guidelines found in the Region 9 Silviculture Handbook (1983). Basal Area (BA) is based upon square feet/acre at diameter-breast height.

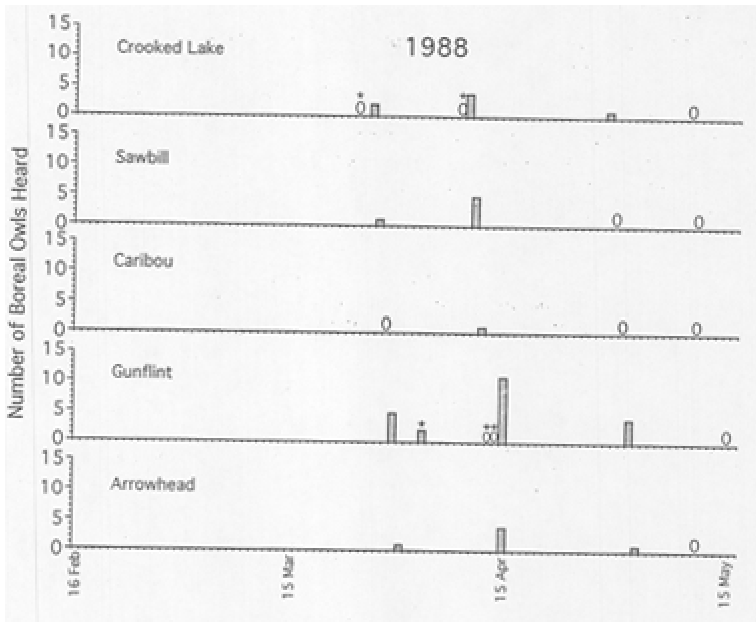
Density 1:
- Permanent Water Bodies
- Nonstocked (less than 16% stocked)
- Seedling-Sapling (16% to 39% stocked)
- Seedling-Sapling (40% to 69% stocked)
- Seedling-Sapling (> 70% stocked)

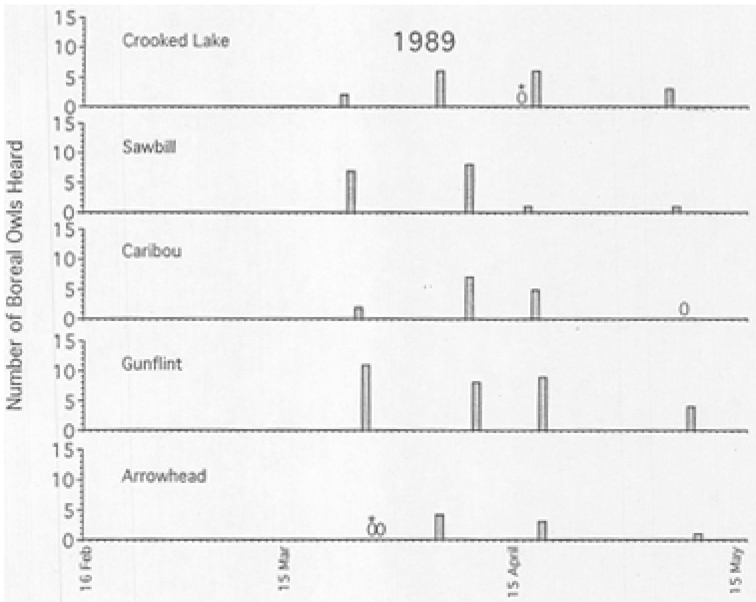
Density 2:
- Poletimber Stand (16 to 39 BA) .
- Poletimber Stand (40 to 69 BA)
- Poletimber Stand (> 70 BA)

Density 3:
- Sawtimber Stand (16 to 39 BA)
- Sawtimber Stand (40 to 69 BA)
- Sawtimber Stand (> 70 BA)

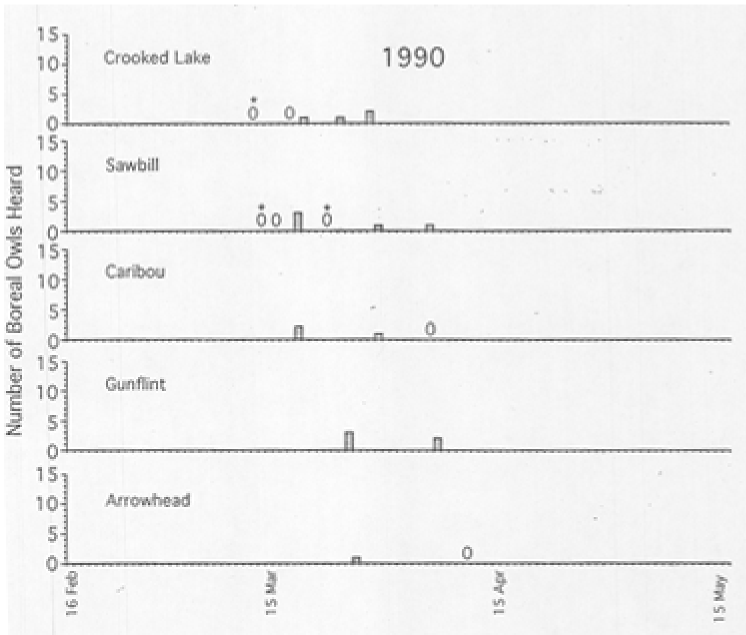
Appendix 1.6 Results of owl surveys along five routes in northeast Minnesota from 1987-1992. Zero indicates the entire route was surveyed, but no owls were detected. An asterisk above a zero indicates surveys were started but canceled due to weather. The Gunflint and Arrowhead routes were not surveyed in 1992.

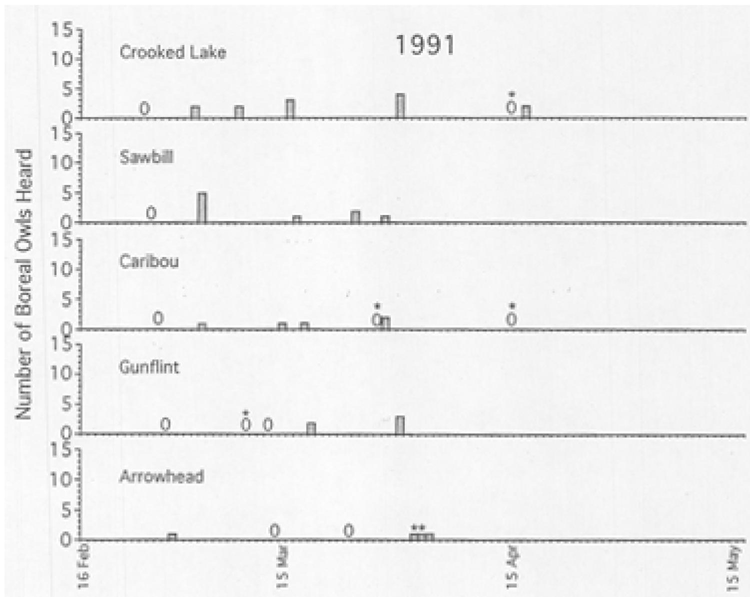



1988
Crooked Lake
Sawbill
Caribou
Gunflint
Arrowhead
Number of Boreal Owls Heard
16 Feb
15 Mar
15 Apr
15 May

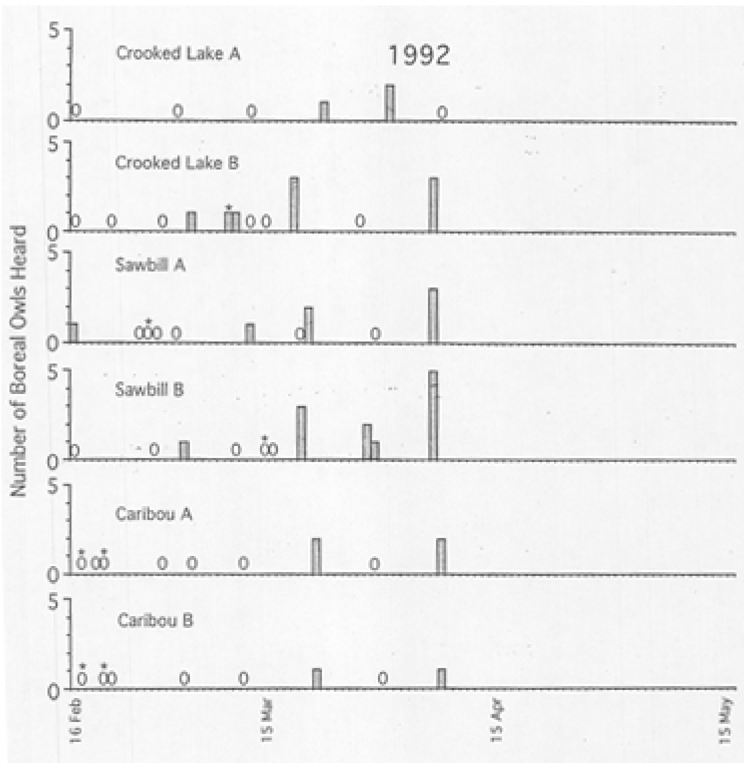


1989
Crooked Lake
Sawbill
Caribou
Gunflint
Arrowhead
Number of Boreal Owls Heard
16 Feb
15 Mar
15 April
15 May

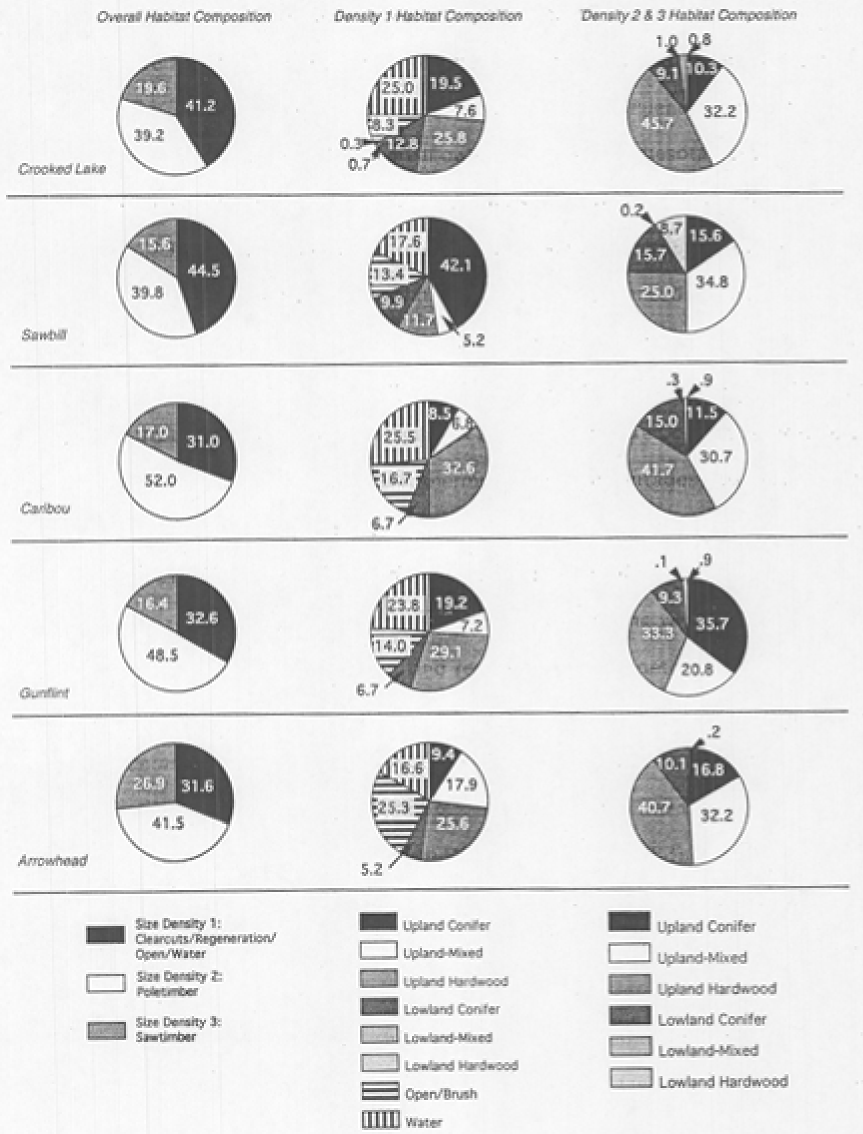

1990
Crooked Lake
Sawbill
Caribou
Gunflint
Arrowhead
Number of Boreal Owls Heard
16 Feb
15 Mar
15 Apr
15 May



1991
Crooked Lake
Sawbill
Caribou
Gunflint
Arrowhead
Number of Boreal Owls Heard
16 Feb
15 Mar
15 Apr
15 May


1992
Crooked Lake A
Crooked Lake B
Sawbill A
Sawbill B
Caribou A
Caribou B
Number of Boreal Owls Heard
16 Feb
15 Mar
15 Apr
15 May

Appendix 1.7 Representation of habitat coverages (based on size density) along the five survey routes used to detect vocalizing male boreal owls in northeast Minnesota from 1987-1992. Route summaries are based on random habitat samples and are composites of the habitat-types present along each route.



Appendix 2.1 Quantitative habitat measurements recorded at observed roost sites from 1990-1992 in northeast Minnesota.

Roost sites are centered on the roost tree with quadrants assigned according to cardinal direction radii; each radii being 11.3 m in length (James and Shugart 1970).

- Roost tree species: self-explanatory
- Roost tree dbh: circumference of roost tree at breast height (cm)
- Roost tree height: estimated with a clinometer to the nearest m
- Roost perch height: estimated with a clinometer or measured directly with a tape measure to the nearest m
- Distance of owl to bole of tree: distance was visually estimated and placed into one of four categories:
  1) 0-15 cm
  2) 16-30 cm
  3) 31-45 cm
  4) ≥ 46 cm
- Slope: slope of overall plot was estimated with a clinometer or compass
- Basal area (deciduous and coniferous): using a 10-factor prism, the square footage/acre at breast-height within the plot is estimated according to forest-type and converted to m^2/ha

Point Quarter

- Four quarters centered on the roost tree radiating in cardinal directions
- Quarter species: tree species used as point-quarter tree is recorded
- Quarter distance: tree nearest the roost tree > 6 cm; distance measured using a foresters tape and recorded to the nearest m
- Quarter dbh: tree nearest the roost tree > 6 cm, measured at breast-height using a foresters tape
- Plot canopy heights: measured with a clinometer, the heights of the five tallest trees within the 22.6 m plot are estimated to the nearest m
- Tree count: all trees > 6 cm within the 22.6 m plot are counted