1996

Modelling barred owl habitat in Northwestern Ontario

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MODELLING

BARRED OWL HABITAT

in

NORTHWESTERN ONTARIO

by

Susan M. Van Ael ©

A Graduate Thesis submitted in partial

fulfillment of the requirements for a

Master of Science in Forestry

Faculty of Forestry

Lakehead University

November, 1996

0-612-33461-9

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ABSTRACT

Van Ael, S.M. 1996. Modelling Barred Owl (*Strix varia*) habitat in Northwestern Ontario. 90 pp. Advisor: Dr. U.T. Runesson.

Key Words: Barred Owl, call playback survey, GIS applications, habitat, landscape management, Landsat TM data, logistic regression, Northwestern Ontario, *Strix varia*

With its large home range, dependence on large decadent trees for nest cavities, and association with mature mixedwoods, the Barred Owl (*Strix varia*) is vulnerable to habitat loss from forest harvesting. Study objectives were to document Barred Owl habitat associations and to determine whether habitat selection could be described in terms of land cover classes derived from satellite imagery. Owl locations were determined by call playback survey near Fort Frances, in Northwestern Ontario. Forest characteristics were measured on all selected and random non-selected sites. Regression analysis identified forest type, height and fragmentation as predictors of Barred Owl presence. Trembling aspen (*Populus tremuloides*), white birch (*Betula papyrifera*), red pine (*Pinus resinosa*) or white pine (*Pinus strobus*) mixedwoods were selected. Owl presence probability increased with canopy height and the proportion forested in 280 ha around a site. A GIS-based habitat map, created from satellite image-derived land cover classes, distinguished good and poor habitat regions. A long-term, landscape-level approach is required to ensure a continuing supply of Barred Owl habitat in Northwestern Ontario's working forest. This study demonstrated that Barred Owl habitat can be characterized by forest data widely available in digital format, and thus is well suited to supply assessment and forecasting in a GIS (Geographical Information System).

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ACKNOWLEDGEMENTS

LU-CARIS provided access to its GPS equipment, its collection of computing hardware and GIS software.

Funds and logistic support for the field portion of this study were provided by the Ontario Ministry of Natural Resources, the Center for Northern Forest Ecosystem Research in Thunder Bay and OMNR-Fort Frances District.

Technical assistants were employed thanks to the Environmental Youth Corps program.

Dr. R. Rempel generously supplied the Landsat TM data and landcover map. Mike Gluck graciously shared his expertise and resources. Gray Arnett and Bert Falk contributed route advice.

Special thanks to Henry, for our life together, our dreams, and our son.

Mortals dwell in that they receive the sky as sky.
They leave to the sun and moon their journey,
to the stars their courses,
to the seasons their blessing and their inclemency;
they do not turn night into day
nor day into a harassed unrest.

Martin Heidegger

INTRODUCTION

Since traditional timber harvesting tends to alter the forest landscape and reduce the quantity and distribution of mature and old growth, good management requires that species dependent upon late successional stages be identified. It is especially important to identify mature forest species with large home range requirements, since they are vulnerable to shortfalls in suitable habitat where timber harvesting and other disturbances have created gaps in the age distribution over the forest landscape. A remedy to this problem is to manage the forest at the landscape level, ensuring habitat supply by maintaining a natural distribution of forest ecosystems across the landscape.

Incorporating a species' needs into landscape-level management requires defining its habitat in terms of widely available data, such as the Ontario Forest Resources Inventory (FRI). Since ensuring mature forest ecosystems across the landscape is a long-term and extensive endeavour, an affordable way to acquire up-to-date information for a large area is necessary. Satellite imagery is a cost effective source of forest information for large areas (Leckie 1990). FRI data, forest data derived from satellite imagery, and wildlife habitat information can be compiled for large areas, integrated and analysed in a geographic information system (GIS).

The Barred Owl (*Strix varia*) is associated with old and mature deciduous-coniferous mixedwood in western Canada and the northern United States. Home ranges are typically 100's of hectares. In Ontario it inhabits the Great Lakes-St. Lawrence and southern Boreal forest regions (Weir 1987). Creating a GIS-based Barred Owl habitat map and describing habitat selection in terms of standard and easily obtainable forest data (height, species, forest area) would provide a basis for integrating its habitat needs into an ecosystem-based approach to forest management. This study was undertaken to document Barred Owl habitat associations and determine whether habitat selection can be described in terms of land cover classes derived from satellite imagery in northwestern Ontario.

The study area corresponded to a 90 X 90 km Landsat Thematic Mapper (TM) 1/4 scene near Fort Frances, Ontario (Figure 1) from which a land cover map had been derived (Rempel, unpublished data). Owl locations and vegetation data were obtained from the southeast section of this area in 1993 and northwest section in 1994.

Owl locations were determined by call playback survey. Forest structural and vegetative characteristics were measured at all sites where the owls were present and at a random sample of sites where they were absent. A logistic regression model was developed from data collected in 1993 and tested with the 1994 data. The regression equation was then used to develop Barred Owl habitat and non-habitat zones from forest classes derived from Landsat TM data. The output, a map of good and poor habitat, was assessed for its ability to predict Barred Owl presence.

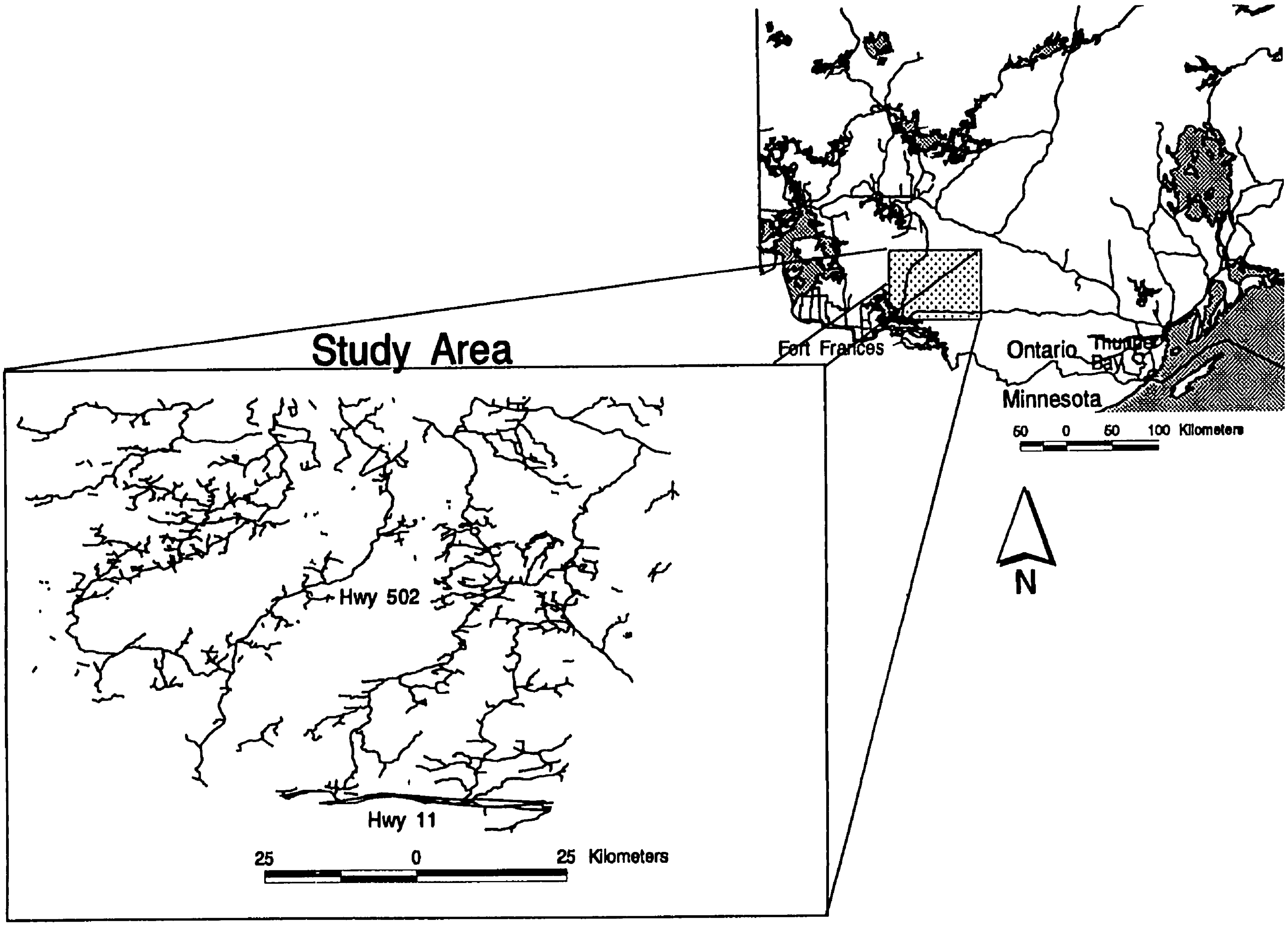


Figure 1. Map showing location of study area.

LITERATURE REVIEW

A paradigm shift in natural resource management from a single-species approach to an ecosystem approach has recently begun to change the way we think about meeting forest wildlife habitat requirements (Kessler 1992, Rowe 1994, Galindo-Leal and Bunnell 1995). The rise of the ecosystem management concept has been driven by developments working at many levels of society, from global realization of the importance of sustainable development and biodiversity to local wildlife conservation crises (Galindo-Leal and Bunnell 1995). At its root is the idea that the ecosystem should be the fundamental unit of resource management. In this context the word 'ecosystem', which traditionally refers to the system comprised by a biological community and its physical environment (Begon *et al.* 1986), often implies a large area (up to 500 km^2)(Belanger 1995, Galindo-Leal and Bunnell 1995).

Broadening the scope further, the spatially defined ecosystem is seen as one in a patchwork of ecosystems that make a landscape (Joyce 1992). Thus management at the ecosystem level implies consideration of landscape patterns. Also implied is a shift to long term research, monitoring and planning. The long time frame is essential for predicting landscape level change through disturbances, human intervention, ecological succession, acid rain and global warming.

Commitment to sustainable development and maintaining biodiversity are natural consequences of thinking of the ecosystem as the management unit. Management is undertaken to ensure that long-term ecosystem function is not compromised for short-term gains (Booth *et al*. 1993). Since an ecosystem is defined in part by its living members, ecosystem management implies that populations of all native species persist.

The usual approach to North American forest wildlife management is to develop a timber plan, then shape it for wildlife and other values (Welsh 1988). The habitat needs of ecological indicators, game, non-game of special interest, species sensitive to certain management activities, and threatened or endangered species are used to constrain forest management practices (Wedeles *et al*. 1991). But this single-species and reactive approach is problematic. Monitoring is often difficult and expensive. Other species supposedly represented by an indicator species may respond differently to disturbance (Welsh 1988). Protecting existing habitat as an 'area of concern', as is done in Ontario for featured species, is not enough to ensure that an adequate supply will exist over time in the landscape (Naylor *et al.* 1994). Attempting to manage a forest simultaneously for a number of featured species could lead to a logistical mess, as multiple and perhaps conflicting habitat needs were assembled as postscripts to the timber plan (Welsh 1988).

Because it is concerned with the persistence of a single species to maintaining ecosystem integrity at the landscape level, the ecosystem management concept is changing how we think of meeting wildlife habitat needs. Because wildlife habitat is recognized as a product of managing the landscape, the approach is inherently proactive and forward looking. Commercial forestry is transformed from being seen as a human activity to be constrained here and there by non-timber values, to one that can act in the service of ecology (Solway 1993). Ensuring habitat supply is emphasized over monitoring an indicator's population (Welsh 1988), addressing the needs of members of a species guild without relying on the representativeness of an indicator. Focussing on maintaining a natural distribution of forest ecosystem types provides 'growing room' for changing values and unforeseen circumstances.

Forest wildlife habitat information is as important to the ecosystem management concept as it is to the indicator species approach, but as material that defines the management unit it would enter the planning process on a more fundamental level. Forest habitat for species groups could be identified by vegetation type and age, then built into the plan to ensure their future (Welsh 1988).

Because forest management is a dynamic agent of extensive and long term change, redefining it as a tool for ecosystem management requires an approach to habitat recognition which can keep pace, handle large areas and is cost effective. Using satellite image data is an affordable way to compile and maintain an up-to-date digital database for large geographic areas (Pierce 1989). Interpretation of satellite data can yield information about forest type, stand density, percent cover and stand size (Horler and Ahern 1986, Mann *et al.* 1989, Green and Congalton 1990, Leckie 1990) and has been demonstrated to be useful for classifying bird habitat (Hewitt *et al.* 1986, Konrad *et al.* 1990, Miller and Conroy 1990, Smith 1990, Sader *et al.* 1991, Usher *et al.* 1992).

Complementing the advantages of satellite data for landscape study, a GIS permits analysis of spatial information for large areas. Digital data can be integrated with information from existing maps and field observations in a GIS. The GIS facilitates inventory management, map creation, spatial and statistical analysis of the data and forecasting under multiple scenarios (Shaw and Atkinson 1990).

In Ontario, a shift to ecosystem-based forest management was announced in May 7, 1991 as the Ontario Ministry of Natural Resources' Sustainable Forestry Initiative (SF) (Welsh *et al.* 1992). As public concern about the status of old growth forest grew, an Old Growth Conservation Initiative was established as an SF program in 1992. The Old Growth Policy Advisory Committee (PAC) was formed to develop recommendation for conserving old growth ecosystems in Ontario (Kidd 1993). Although the PAC focussed on red and white pine in its interim report because of the level of public concern on these species, many of its recommendations would apply to the management of any forest ecosystem. The PAC recommended that Ontario develop an information system compatible with a GIS, which incorporates digital FRI and Forest Ecosystem Classification systems. Ecological research recommendations included determining the impacts of forest fragmentation on species diversity and which plants and animals are dependent on old growth red and white pine (Kidd 1993). This was echoed in research recommendations from biologists surveyed for the Ontario Forest Research Institute (Welsh *et al.* 1992), who advised that the ecological importance of old growth pine forests to selected vertebrate species be determined.

These recommendations directed at the red and white pine issue could be extended sensibly to any forest ecosystem as forest policy moves toward ecosystem management. Evident in the public's concern over old growth red and white pine is anxiety regarding the state of mature and old growth forests in general (Solway 1993). Since timber harvesting tends to limit its amount and distribution, species dependent upon all types of mature forest must be identified and the nature of the relationship determined (Meslow *et al.* 1981, Schoen *et al.* 1981). It is especially important to identify mature forest species with large range requirements, since they are vulnerable to shortfalls in suitable habitat where forest maturation lags behind turnover.

The Barred Owl is a species which might be dependent on mature forest in northwestern Ontario. It is distributed in Canada from eastern British Columbia east to Nova Scotia, through the Pacific northwestern and eastern United States, to the central plateau of Mexico (Johnsgard 1988). It is a recent immigrant to eastern British Columbia (Grant 1966), the northwestern United States (Taylor and Forsman 1976, Marks *et al.* 1984) and Alberta (Boxall and Stepney 1982). In west-central Canada, the Barred Owl's range coincides with the range of mixedwood forest in central

Saskatchewan and from the west to southeastern corner of Manitoba (Duncan 1994). In Ontario, the Barred Owl inhabits mature hardwood and coniferous mixed woodland of the Great Lakes-St. Lawrence and southern boreal forest regions (Weir 1987). With its range increasingly restricted in southern Ontario due to habitat loss, it has been almost extirpated south of 44°N (Weir 1987, Austen *et al.* 1994).

The Barred Owl is a non-migratory permanent resident and is presumed to occupy the same territory for as many as 30 years (Bent 1961). Radio-tracking evidence suggests that Barred Owl home range boundaries are constant for decades, even when occupants change (Nicholls and Fuller 1987).

Preferred habitat is large (100's of ha) contiguous undisturbed forest with abundant mature timber (Nicholls and Warner 1972, McGarigal and Fraser 1984, Sutton and Sutton 1985, Bosakowski *et al.* 1987, Johnson 1987, Mazur and James 1995). Because of its observed habitat preferences in the northern United States, it has been designated an indicator species for the management of mature/old growth forests in both Minnesota and the national forest of the southern Appalachians (Bosakowski *et al.* 1987, Johnson 1987).

Preference for mature forest has been proposed to be related to requirements for nesting cavities, perches, unimpeded travel, and hunting. Devereux and Mosher (1984) reported diameters of 42 to 88 cm at breast height (dbh) for seven trees with Barred Owl cavity nests. Mazur and James (1995) reported an average dbh of 49.1 cm for ten nest trees. Nicholls and Warner (1972) suggested that the structural characteristics of preferred habitats in Minnesota were ideal for hunting prey. The lack of brush, and abundance of available perches in upland oak woods and mixed hardwood and conifer types enabled owls to see, fly and capture prey.

Preferred forest types may have higher prey densities than others. Nagorsen and Peterson (1981) found small mammals to be more abundant in upland mixed forest than in lowland conifer types. Jones and Naylor (1994) found small mammals to be slightly more abundant in old growth white pine and boreal mixedwood than in lowland conifer. Comparing mammalian prey abundance in mature mixedwood to mature aspen in Saskatchewan, Mazur and James (1995) found red squirrels to be more abundant in mature mixedwood, and voles and mice to be more abundant in mature aspen. They suggested that the open flyways and understoreys of mature mixedwood enhance ground-dwelling prey availability, while the typically dense shrubs of aspen forests might impede hunting ground dwellers.

Reported densities of Barred Owl vary from 7.3 pairs/ 100 km^2 in New Jersey (Bosakowski *et al.* 1987), to 35.5

pairs/100 km^2 in northern Michigan (Elody 1983).

The Barred Owl is territorial, exhibiting exclusive home ranges (Nicholls and Fuller 1987). It has been demonstrated to respond readily to vocal imitations or tape recorded broadcasts of conspecific calls during the breeding season (Johnson *et al.* 1981, McGarigal and Fraser 1985, Bosakowski 1987, Mosher *et al.* 1990). These characteristics make call broadcasts useful to elicit responses for Barred Owl surveys (Fuller and Mosher 1987).

Barred Owl home ranges are larger in winter to compensate for lower prey availability (Elody 1983, Bosakowski *et al.* 1987). Elody and Sloan (1985) reported an average annual territory size of 282 ha, which decreased to 188 ha in summer, for 7 Barred Owls in Michigan. A radio-tagged pair in this study occupied 286 ha in summer. In Minnesota, home ranges for 7 radio-tagged owls averaged 655 ha (Fuller 1979), with breeding females using 508 ha. Also in Minnesota, Nicholls and Warner (1972) reported an average home range of 229 ha for 9 owls (86 to 369 ha). Sex and season tracked were not reported in conjunction with home range size; however, one owl of unknown sex had a 104 ha home range between July and September (Nicholls and Warner 1972). In Saskatchewan, home ranges averaged 148 ha (n=12) in the breeding season, 1,234 ha (n=12) during the non-breeding season, and 956 ha (n=8) annually (Mazur and

James 1995). Non-breeding home ranges were on average 11.3 times larger (3.7 to 17.9, n=10) than breeding ranges, and the authors estimated a minimum requirement of 583 ha of mature/old mixedwood for a pair of Barred Owls (Mazur and James 1995).

As a cavity nesting bird with large home range requirements, the Barred Owl may be at risk in the portions of its range where forest management limits mature mixedwood. Describing its habitat in terms of forest types that can be obtained from satellite imagery and FRI would provide a basis for integrating the Barred Owl into ecosystem management in northwestern Ontario. Using a GIS to facilitate habitat analysis and mapping would be consistent with the PAC's recommendations concerning the future of Ontario's forest information system. Demonstrating that forest characteristics (type, height, area) selected by the Barred Owl can be readily obtained and entered into a GIS would suggest that the Barred Owl could benefit from careful habitat management at the landscape level.

METHODS

Barred Owl locations were determined by nocturnal call playback survey. Forest structural and vegetative characteristics were measured at all sites where owls were observed and at a random sample of sites where owls were absent. Data collected in the first year of the study (1993) were used to develop a logistic model predicting Barred Owl occurrence from forest characteristics. This model was tested on the data collected in the second year (1994).

The relationship between Barred Owl occurrence and forest type described in the model, informed the process of obtaining good and poor habitat zones from general forest classes derived from Landsat TM data. Poor Barred Owl habitat was mapped by aggregating non-selected land cover classes, and the remaining land area was mapped as good habitat. This map's representation of Barred Owl habitat was assessed by evaluating its ability to predict selected and non-selected sites.

SURVEY AREAS AND ROUTE SELECTION

Owl survey areas were selected from an area corresponding to the LANDSAT TM scene from which the land cover map was derived. It is located north of Highway 11, southeast of Dryden in the Fort Frances Administrative District of the Ontario Ministry of Natural Resources (Figure 1), spanning a transition zone from the Great Lakes-St. Lawrence Region to the Boreal Region (Rowe 1972). The survey areas were chosen for their extensive road networks and for encompassing tracts of typical boreal conifer, hardwood and mixedwood forests. Forest composition was determined from FRI maps and by consultation with Ontario Ministry of Natural Resources (OMNR) personnel familiar with the area.

The southeast section of the map was chosen as the focus of the 1993 field season. Initially all accessible roads were chosen for the nocturnal owl survey routes. With advice from Fort Frances OMNR personnel, 2 lakeshore routes, Heron Lake and Pettit Lake, Manion Lake and Moosetrack Lake (Appendix I), were added to expand the coverage of hardwood-mixedwood forest.

The northwest section of the map was studied in 1994. Four 20 to 55 km routes were assigned for Cedar Narrows, North Penassi, East Penassi Roads and selected forest access roads (Appendix II).

NOCTURNAL SURVEY

Call Playback

The call playback method, as described in Fuller and Mosher (1987) and Shepherd (1992), was used to determine Barred Owl locations on the survey routes. A tape recorded Barred Owl call was broadcast at 1.6 km intervals on a survey route to encourage owls to respond vocally, or fly in to investigate.

A portable cassette tape recorder with a frequency response of 100 Hz to 10 kHz (Sanyo® CFS-1030) and two 8 ohm 10 cm trumpet speakers (Realistic® All-weather Powerhorn) were used to broadcast vocalizations. Speakers were placed on the roof of the vehicle 2 m from the ground and directed at both sides of the road, or held 2 m from water level and directed at 45° and 135° to the nearest shore. The call recording was copied from Walton and Lawson (1989) and arranged on a cassette tape to occur 18 times over 2 minutes in 3 groups of 6 calls, 15 seconds apart.

Survey Logistics

Survey routes were usually run on calm, clear nights from 30 minutes after sunset to 30 minutes before sunrise. Surveys were never conducted with precipitation or winds greater than about 15 km/h (Fuller and Mosher 1987). In 1993 unusually poor weather in mid-summer interfered with route timing, which meant that some surveying had to be performed on cloudy nights. In 1994 the number of planned sites was reduced to facilitate surveying in the best conditions within a shorter time, thereby reducing response variation due to weather and season (Shepherd 1992). Additionally, routes were planned such that dissimilar forest types were covered in similar moon phases to distribute possible moon phase effects evenly (Shepherd 1992). In both years, moon phase, cloud cover, wind and ambient noise were noted for each route and site (Appendix III).

Over the 2 years, 268 unique sites were surveyed. In 1993, 178 sites were established and revisited between June 5 and August 15 in the southeast study area. In 1994, 83 of the previous year's sites were revisited between May 15 and June 1, and 90 new sites were established in the northwest study area from June 7 to June 26.

Survey Site Procedure

A site visit was a timed 10 to 30 min. stop, consisting of 2 min. call playback and 3 min. listening, repeated once (Shepherd 1992). If no response was elicited within the first 10 min, the visit was terminated and the site was designated non-selected. If a response was elicited, the site was designated selected and additional time (10 min. in 1993, 20 min. in 1994) was used for response description and owl location.

The change in follow up time from 10 min. in 1993 to 20 min. in 1994 was motivated by a desire to determine the number of owls involved in responses at neighbouring stops. The extra time allowed the survey team to listen for pairs and distant neighbours, recognize individual voices, triangulate to determine distance, and map an approaching owl. This information was required for determining whether adjacent selected sites were occupied by one or more owls or mated pairs.

Upon identifying a Barred Owl response at a site, the survey team halted the call playback to hear the owl better. Elapsed time to first contact was noted. If the owl was not visible, two team members dispersed to points roughly 200 m apart, and coordinated by a third person, took a series of simultaneous compass bearings to the calling owl. Bearings were assumed to be accurate to within 2°. When the site and bearing origins were known, they were mapped on an FRI map and used to triangulate the owl's position. The owl's location was mapped as the polygon defined by the intersection of the ±2° confidence limits of each bearing recorded. At sites that could not be reliably mapped, the divergence of the bearings and call loudness were used to estimate the distance of the owl. A GPS (Global Positioning System) unit was used in differential mode to collect location coordinates.

To enable the field team to find sites again, vehicle odometer readings from nearby intersections were recorded and every site was marked with flagging tape and a pylon. For each owl encounter, the number of respondents, the promptness, speed and direction of approach, the relative pitch and rhythm of the call and other noteworthy behaviours (e.g., swooping) were recorded.

VEGETATION PLOTS

All selected sites and a random sample of forested non-selected sites were designated for recording vegetation characteristics that might correlate with Barred Owl occurrence. At each site, 3 plots, 100 m apart, were located on a transect run perpendicular to the road. At selected sites the transect was centred on the owl location. The road side was chosen by coin toss. Plot dimensions (10 X 10 m) conformed to the Northwestern Ontario Forest Ecosystem Classification (NWO FEC) sample plot (Sims *et al.* 1989). Descriptions of the field data collected in each year, and methods used are presented in Table 1. Examples of vegetation sample plot field notes are in Appendix IV.

Table 1. Vegetation plot data and collection methods.

Information	Instrument	Method
Site position	Map and Global Positioning Unit	≥ 120 points differential mode
Vegetation type	Field Guide to the Forest Ecosystem Classification for Northwestern Ontario (Sims *et al.* 1989)	Per guide instructions
Canopy and subcanopy height	Suunto clinometer	4 to 6 of the tallest and shortest trees ≥10 m tall and ≥10 cm dbh
Basal area; Stem density	$2m^2$/ha wedge prism; diameter tape	1993: point sample 1994: modified point sample
Subcanopy closure	In 1993, by scale; none to 20 % 21 to 40 % 41 to 60 % 61 to 100%	Visual estimation

VARIABLE DEFINITION

Ten variables were derived from the field data, and two were derived from the land cover map (Appendix V)(Table 2).

The NWO FEC classifies mature undisturbed forest stands into 38 vegetation types (Sims *et al*. 1989). These vegetation types were grouped by the major tree species, as delineated in the NWO FEC Field Guide(Sims *et al*. 1989 p.119), to create a categorical variable (MAJSP) describing forest type on a sample plot. Vegetation types which could be in 2 groups were grouped according to the species most abundant in the tree layer on the sample plot.

Forest type on a 3 plot transect (SET) was defined from the MAJSP groups observed on the plots. A boreal conifer transect had ≥2 plots dominated by black spruce (*Picea mariana*) or jack pine (*Pinus banksiana*). A deciduous mixedwood transect had ≥2 plots dominated by trembling aspen (*Populus tremuloides*) or white birch (*Betula papyrifera*). A red/white pine mixedwood transect had ≥1 plot dominated by red pine (*Pinus resinosa*) or white pine (*Pinus strobus*).

Table 2. Abbreviated names, values and definitions of variables.

Abbreviation	Value	Definition
OWL	1	owl present
	0	owl absent
MAJSP		Major tree species on plot
	0 (reference category)	Unforested
SB	1	Black spruce
	0	otherwise
PJ	1	Jack pine
	0	otherwise
POT-BW	1	Trembling aspen or white birch
	0	otherwise
PR-PW	1	Red or white pine
	0	otherwise
SET		MAJSP composition of 3 plots on 300 m transect
	0 (reference category)	Boreal conifer ($\geq$ 2 SB or PJ)
DEMIX	1	Deciduous mixedwood ($\geq$ 2 POT-BW)
	0	otherwise
PINEMIX	1	Red/White pine mixed ($\geq$ 1 PR-PW)
	0	otherwise
CANHT	Metres	Average height of tallest trees

Table 2. (Continued)

Abbreviation	Definition	Value
INTERHT	Metres	Space between tops of tallest and shortest trees ≥ 10 m and ≥ 10 cm dbh.
SUBCAT		Subcanopy closure category
-	0 (reference category)	0 %
TO20	1 0	1 to 20 % otherwise
TO40	1 0	21 to 40 % otherwise
TO60	1 0	41 to 60 % otherwise
TO100	1 0	61 to 100% otherwise
BA	m^2/ha	Basal area of live trees
BASNAG	m^2/ha	Basal area of standing dead trees
TPERHA	Trees/ha	Density of live trees
TGT30	Trees/ha	Density of trees ≥ 30 cm dbh
LCUT [1]	Proportion from 0 to 1	Proportion unforested in 280 ha around survey site
SCUT [1]	Proportion from 0 to 1	Proportion unforested in 2 ha around survey site

[1] variables derived from land cover map

A sample of the prepared data is given in Appendix VI.

DEFINING BARRED OWL HABITAT

Linear regression analysis (Chatterjee and Price 1977) was used to screen the 1993 data set for habitat characteristics related to Barred Owl presence. For this preliminary exploration, the categorical variables (SET, MAJSP and SUBCAT) were treated in a linear fashion, an arrangement which assumed that a step up in one of these variables was worth a fixed increment in Barred Owl presence. The SET categories were 1 (boreal conifer), 2 (DEMIX) and 3 (PINEMIX). The MAJSP categories were 1 (unforested), 2 (SB), 3 (PJ), 4 (POT-BW) and 5 (PR-PW). The SUBCAT categories were 1 (0 %), 2 (TO20), 3 (TO40), 4 (TO60) and 5 (TO100). Results were examined for collinearity and insight into which variables accounted for the greatest proportion of the variance in owl presence.

Further insight was sought from an exploratory logistic regression on the same (1993) data set. Logistic regression is a multivariate technique for estimating the probability of an event occurring, which performs well for data consisting of a binary response and an assortment of continuous and categorical explanatory variables. For two independent variables predicting Barred Owl occurrence, the regression equation can be written as:

$$P(owl)=\frac{1}{1+e^{-z}}$$

where Z is the linear combination,

$$Z=B_o+B_iX_i+B_jX_j$$

B_o is a constant and B_i and B_j are the coefficients for the variables X_i and X_j respectively. The parameters were estimated by the maximum-likelihood method, which uses an iterative algorithm to compute coefficients that make the observed results most likely (Norusis 1989). A logistic regression typically produces coefficients, their standard errors and associated significant levels for each parameter in the equation. Also returned is the odds ratio, which is the factor by which the odds (of Barred Owl presence, for example) change when the explanatory variable increases by one unit (Norusis 1989).

For the logistic regression the categories of SET, MAJSP and SUBCAT were represented by indicator variables, with values of 0 and 1 to signify category membership (Table 2). Note that the number of indicator variables required to represent a set of categories is one less than the number of categories. For example, a boreal conifer transect would be represented by the indicator variables for the other two possibilities, DEMIX and PINEMIX, defaulting to 0. Thus no boreal conifer coefficient is produced by the regression procedure, and the probability associated with boreal conifer transects is determined by the constant and values for the other parameters. With the indicator variables arrangement, a non-linear relationship between SET, MAJSP or SUBCAT and OWL can be detected.

Non-redundant variables related to Barred Owl habitat selection were entered into a forward stepwise logistic regression procedure using the likelihood-ratio criterion, in the SPSS for Windows software package (SPSS Inc. 1994). The predictive accuracy of the equation obtained from the 1993 data was tested on the 1994 data.

FROM MODEL TO HABITAT MAP

With Barred Owl habitat selection described by the regression equation, the final task was to demonstrate the utility of general forest classes derived from satellite imagery in characterizing Barred Owl habitat. A map of terrestrial and wetland classes derived from LANDSAT TM data from the spring of 1991 and summer of 1992, was obtained (Gluck 1994).

The land cover map had been produced by performing an unsupervised classification to identify 250 distinct spectral signatures. Wetland and recently disturbed classes were isolated for reclassification by 'lifting' them from the landscape with general wetland polygons obtained from aerial photo derived FRI maps. The 250 spectral signatures on the entire landscape, wetland and disturbed strata were re-classified into specific land cover classes that could be detected from all scales of remotely sensed data. Finally, the strata were re-assembled into one map and accuracy was evaluated with reference to colour infrared photography interpretation (Gluck 1994). Because recently disturbed classes had been separated from the landscape before classification, there was no confusion between them and the forest classes. Within the five forest classes KHAT accuracy (Bishop et al. 1975) was 0.728.

Results from the logistic regression model were used to make a map of potential Barred Owl habitat. Non-selected habitat types were assumed to be poor habitat, and selected types were assumed to be good habitat. A flow chart (Appendix VII) summarizes how the land cover map was redefined as good and poor Barred Owl habitat.

Non-selected classes were recoded as 1 and the rest were recoded 0. The non-selected class was scanned with a circular window (r = 5 pixels), which returned the class value representing the majority of pixels within the window. This step removed thread-like formations, typically found along road corridors, that could interfere with a meaningful contiguity analysis by linking effectively isolated clumps of forest.

The map was next subjected to a contiguity analysis with a connectivity radius of 1. This operation identified clumps of flanking pixels of the non-selected class. Clumps less than a minimum Barred Owl territory of 280 ha were eliminated. Although probably small for a typical territory, 280 ha was the largest size that didn't overlap most neighbouring sites. This was intended to be a moderately coarse filter for good (selected) habitat, effectively proposing that Barred Owls weren't expected to be deterred by poor (non-selected) habitat areas less than a small territory.

The output from the clump and minimum clump elimination routine was a map of two classes representing areas of good and poor Barred Owl habitat. However, because poor habitat polygons were dotted with isolated pixels of good habitat, it was difficult to interpret. To solve this problem a second contiguity analysis with a connectivity radius of 1.5 was performed to identify clumps of immediate neighbours of the good habitat class. Clumps less than 28 ha (10 % of the smallest poor habitat polygon) were eliminated. The output map was recoded to poor and good Barred Owl habitat.

Survey results were overlaid on the habitat map to assess how well it identified potential Barred Owl habitat.

A 280 ha square was centred on each survey site's coordinates, giving the selected class priority where neighbours overlapped.

All selected sites and a subset of non-selected sites were used to assess the habitat map. Of the 69 non-selected boxes that were excluded, 32 were redundant, being entirely overlapped by neighbouring non-selected boxes. The other 37 were excluded because they were at least 20 % overlapped by selected boxes, and were thus too close to an owl location to signify a non-selected site. The remaining 171 boxes were superimposed on the map and tallied by the amount they coincided with the good and poor habitat areas.

RESULTS

SURVEY

Over the 2 years, 51 Barred Owls responded at 43 of the 268 survey sites; 43 of these were detected during survey route runs, 4 were found during other field work and 4 during the 1994 re-visiting of 1993 routes (Table 3).

Table 3. Barred Owl encounters in study.

Area	Occasion	Survey sites	Sites with owl response	Barred OwlS ENCOUNTERED Single	Pair	Total
SE	1993 survey	178	32	15	7	29
	field work		3	2	1	4
	1994 re-visit	83	23	12	7	26
NW	1994 survey	90	11	10	2	14
SURVEY TOTAL		268	43	25	9	43

From the routes that were run twice in 1993, 77 sites were visited in calm, clear weather both times with an overall between runs classification accuracy of 97.4% (Table 4).

Table 4. Barred Owl status at double-checked 1993 survey sites.

Barred Owl status	SECOND VISIT Absent	Present	Total	Percent unchanged
FIRST VISIT				
Absent	66	1	67	98.5
Present		9	10	90.0
Total			77	97.4

On sites established in 1993 and re-visited in 1994, the overall year to year classification accuracy was 92.8 % (Table 5).

Table 5. Year to year Barred Owl response fidelity at road survey sites.

Barred Owl status	1994 Absent	Present	Total	Percent unchanged
1993				
Absent	57	3	60	95.0
Present		20	23	87.0
Total			83	92.8

Of the 480 call playback visits over the 2 years, 135 individual responses were recorded from 109 visits. The owls were identified by hearing (n = 102, 76%) seeing (n = 3, 2%) or by both hearing and seeing (n = 30, 22%).

Owl responses were also categorized as: (1) visited site without calling (n = 3, 2%); (2) called from within 100 m of the site (n = 58, 44%); (3) called from distance, then flew to within 100 m of site (n = 25, 19%); and, (4) called from beyond 100 m from the site (n = 47, 35%). Duetting, a raucous cackling vocalization given simultaneously by both members of a pair, was heard in 13 (12%) of the responses.

During the 10 min. survey period, responses accumulated steadily (Figure 2). About half (52.5%) of owls contacted within the survey period responded in the first three minutes.

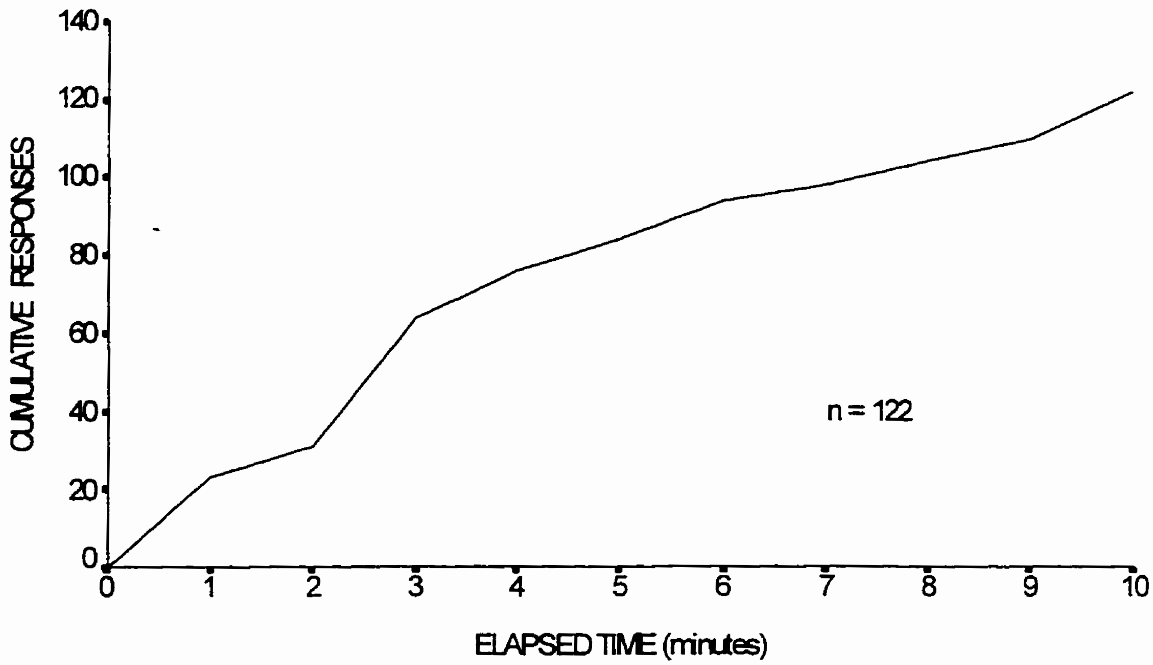


Figure 2. Barred Owl responses within 10 minute survey period.

Thirteen (10%) of the 135 individual responses were detected after conclusion of the survey period either because they could be heard from another location or because the survey team lingered after the site visit (Figure 3).

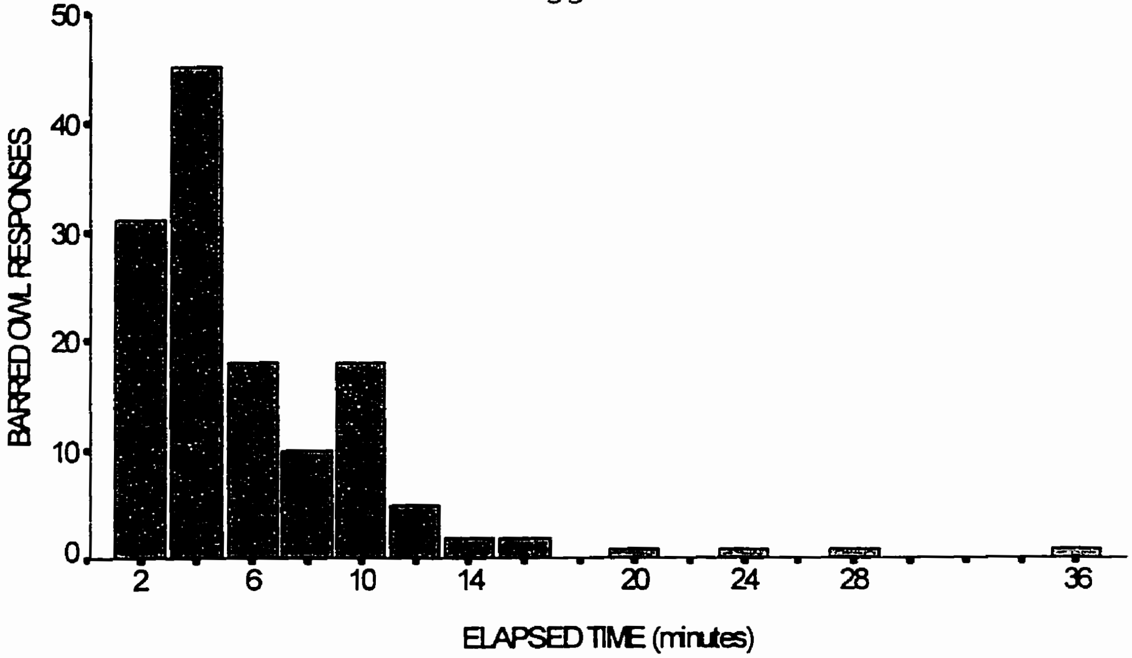


Figure 3. Elapsed time to all Barred Owl responses.

Nine of these were mates of owls that had responded within the survey period, and three were previously detected owls revisited for mapping confirmation. Only one response outside the 10 min. period, a pair heard 35 min. after call playback began, altered a site from non-selected to selected. In this case, a lakeshore site was visited just before sunset for safety reasons. No response was heard within 10 min., but 25 min. later a pair of duetting Barred Owls perched within 30 m of the call playback site.

HABITAT CHARACTERISTICS

Exploratory analysis

The linear regression analysis indicated that SET ($T = 6.41$, $p < 0.001$) and LCUT ($T = -2.36$, $p = 0.005$) accounted for most of the variance in Barred Owl presence. Highly correlated variable pairs were CANHT and INTERHT ($r^2 = 0.77$) LCUT and SCUT ($r^2 = 0.52$) and SET and MAJSP ($r^2 = 0.60$). Of the nonsignificant variables, SUBCAT ($T = 1.96$, $p = 0.052$) and CANHT ($T = 1.32$, $p = 0.188$) were most related to Barred Owl presence.

DEMIX, PINEMIX and CANHT were identified as predictors of Barred Owl occurrence by the exploratory logistic regression analysis (Table 6).

Stepwise Logistic Regression

DEMIX, PINEMIX, CANHT, LCUT, and the SUBCAT categories were entered as explanatory variables of Barred Owl presence into a stepwise logistic regression. MAJSP was excluded because it was by definition closely related to SET. It was also less likely to agree with FRI and satellite image derived data since it described the vegetation type more specifically and on a smaller scale than SET. INTERHT and SCUT were excluded because they were

Table 6. Explanatory variable odds ratios and probabilities from exploratory logistic regression.

Variable	Probability	Odds ratio
SET		
DEMIX	<0.005	8.82
PINEMIX	<0.001	66.41
MAJSP		
SB	<0.100	0.05
PJ	<0.100	0.04
POT-BW	<0.250	0.10
PR-PW	<0.250	0.02
LCUT	<0.100	0.02
SCUT	<0.750	1.66
CANHT	<0.025	1.22
INTERHT	<1.000	0.97
SUBCAT		
TO20	<0.250	3.93
TO40	<0.250	5.77
TO60	<0.250	7.87
TO100	<0.250	5.84
BA	<1.000	1.00
BASNAG	<1.000	0.97

closely related to CANHT and LCUT respectively and unrelated to Barred Owl occurrence. BA and BASNAG were excluded because the exploratory analyses revealed no relationship with Barred Owl occurrence.

DEMIX, PINEMIX, CANHT and LCUT were selected as predictors of Barred Owl presence by the logistic regression analysis (Table 7).

Table 7. Explanatory variable coefficients, probability values and odds ratios in final logistic model of Barred Owl presence.

Variable	Coefficient	Probability	Odds ratio
Constant	-2.954	<0.001	
DEMIX	3.018	<0.001	20.441
PINEMIX	4.124	<0.001	61.827
CANHT	0.130	<0.005	1.140
LCUT	-3.323	<0.025	0.036

The logistic equation

The odds of encountering a Barred Owl increased with increasing canopy height (CANHT) and decreased with increasing proportion unforested in 280 ha (LCUT). Relative to the odds of encountering a Barred Owl in boreal coniferous forest, the odds were 20 times larger in hardwoods and approximately 60 times larger in red/white pine mixedwood (Table 7).

Barred Owl habitat selection as expressed in the regression model can be illustrated by plotting 3 simplified equations (Table 8) for a range of values for each parameter.

Table 8. Equations representing probability of Barred Owl presence (OWL) as a function of canopy height (CANHT) and proportion of unforested land in a 280 ha area (LCUT) by forest type.

Forest type	Equation
Boreal conifer	$OWL = 1/(1 + e^{(-2.95 + 0.13CANHT - 3.32LCUT)})$
Deciduous mixed	$OWL = 1/(1 + e^{(0.06 + 0.13CANHT - 3.32LCUT)})$
Red/white pine mixed	$OWL = 1/(1 + e^{(1.17 + 0.13CANHT - 3.32LCUT)})$

Barred Owls favoured taller canopies (Figure 4). For boreal conifers, owl probability exceeded 0.5 for canopy heights > 24 m where the proportion unforested in 280 ha was 0. Otherwise, boreal conifers were not selected by the Barred Owl. Where the proportion unforested was 0.10, deciduous mixedwood was selected for all canopy heights > 15 m. With an unforested proportion of 0.75, deciduous mixedwood was selected for canopy heights > 19 m. With an

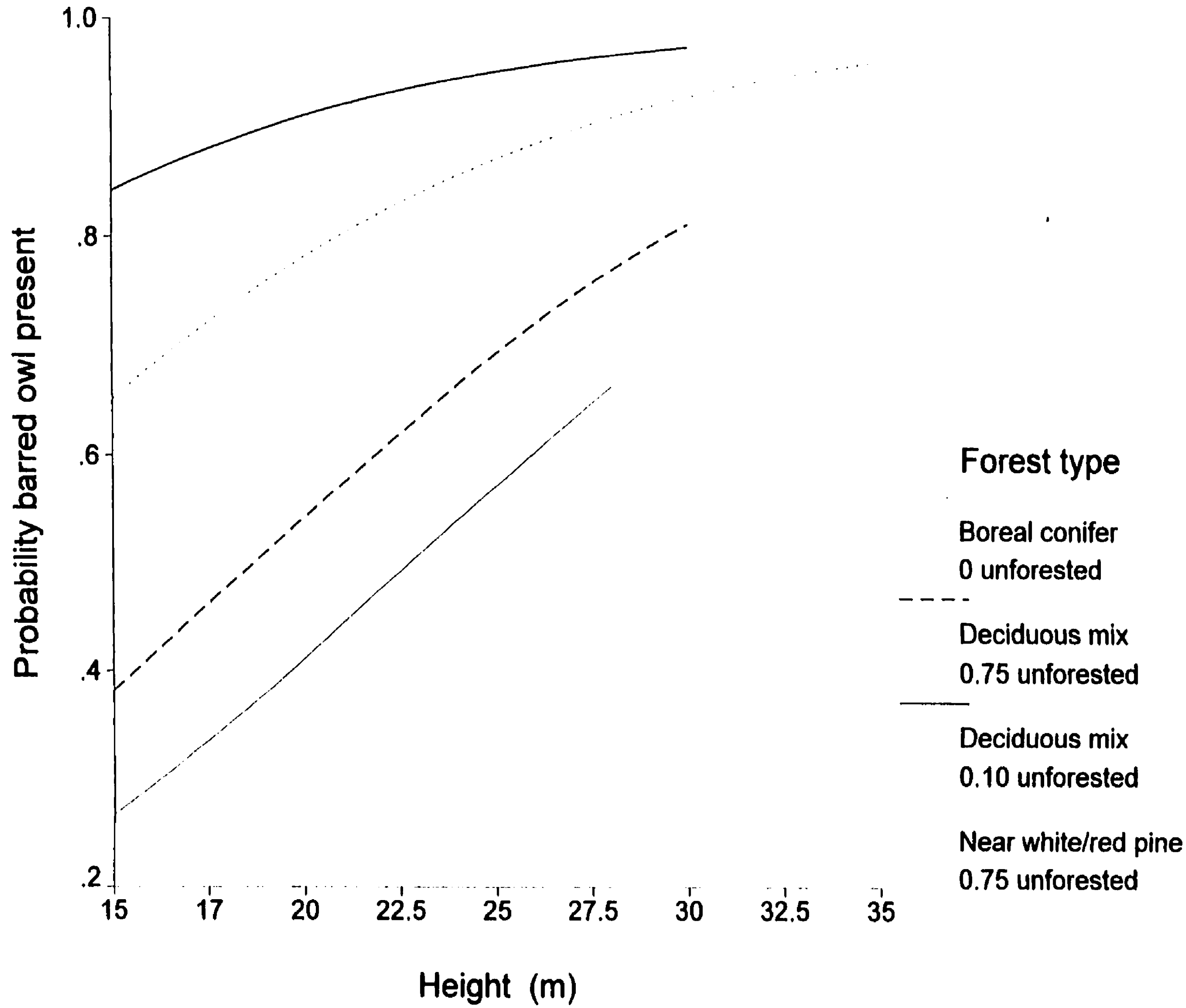


Figure 4. Barred Owl presence as a function of canopy height.

unforested proportion of 0.75, a red or white pine stand within 300 m confered high probability of Barred Owl presence on any forested site with canopy height > 15 m. As the proportion unforested in 280 ha around a survey site increased from 0 to 0.75, Barred Owl presence probability decreased (Figure 5). For a 17 m stand in deciduous mixedwood, owl probability dropped below 0.65 as the proportion unforested exceeded 0.5. For a 23 m stand in deciduous mixedwood, owl probability declined to 0.65 as the unforested proportion increased to 0.75. For a 23 m stand within 300 m of a red or white pine stand, owl probability was > 0.88 up to 0.75 unforested.

Stem density

Because TPERHA and TGT30 were measured only in 1994, they were not included in the regression analysis. However, because Barred Owl habitat selection could have been related to these variables, their relationship with forest type was explored. Black spruce sites had considerably more trees per ha than other forest types and red and white pine sites had the highest number of trees ≥30 cm dbh (Table 9).

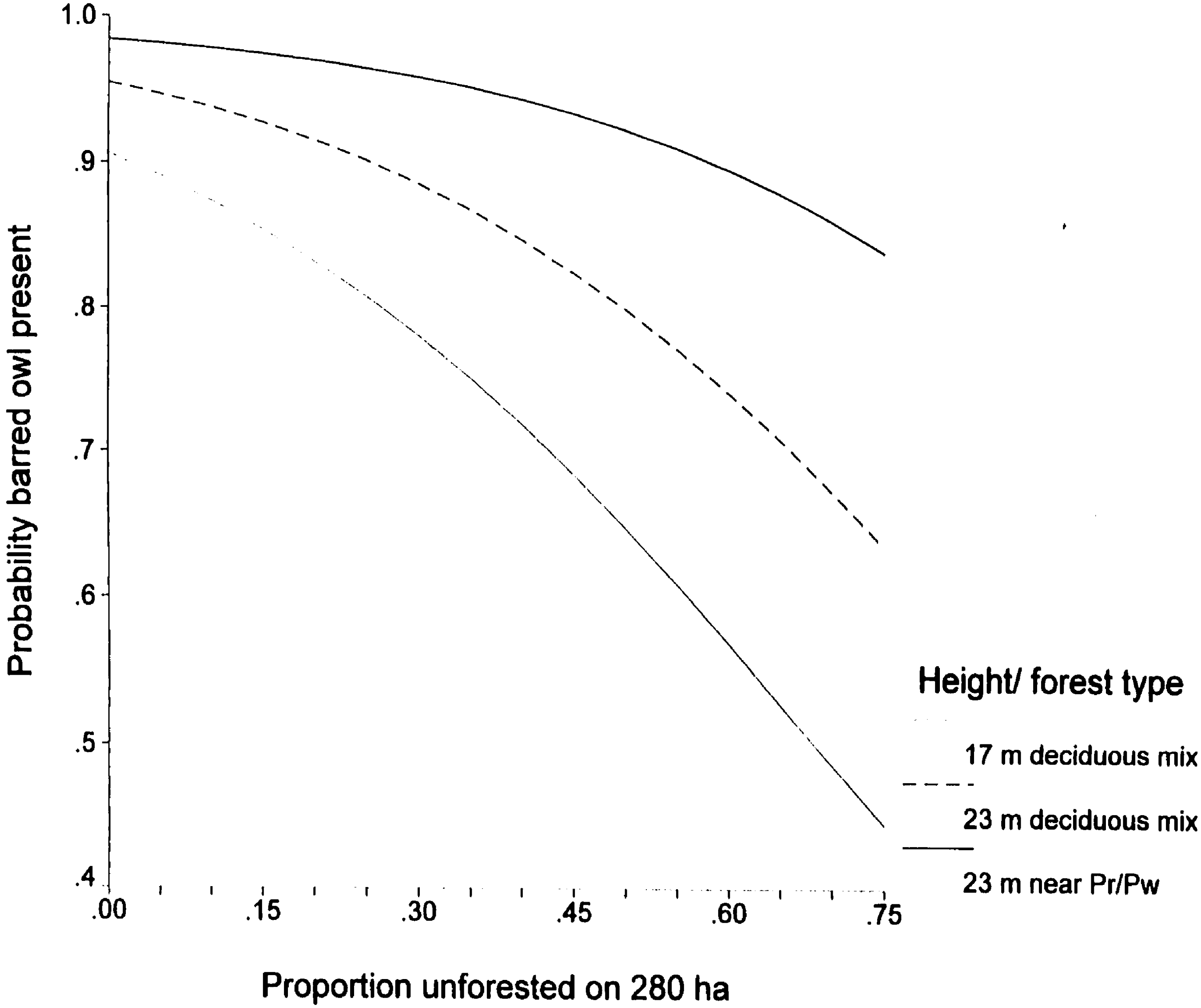


Figure 5. Barred Owl presence as a function of proportion unforested in 280 ha around survey location.

Table 9. Trees per ha and trees ≥30 cm dbh per ha by MAJSP category.

MAJSP	TPERHA trees/ha	TGT30 trees ≥30 cm dbh/ ha
SB	2168	34.3
PJ	1075	81.4
POT-BW	1473	78.4
PR-PW	705	86.6

Logistic regression model performance

The probability of the observed data given the estimated coefficients is called the likelihood. A customary measure of logistic model fit is -2 times the log of the likelihood (-2LL)(Norusis 1989). For the equation containing only the constant, -2LL was 202.69. For the final equation with the constant and other parameters (Table 7), -2LL was 98.24, df = 145, p = 0.999. The decrease in -2LL indicated that including the other parameters improved fit relative to the equation containing only the constant. The model chi-square, a test of whether the coefficients for all the parameters, except the constant, are 0, was 104.45, df = 4, $p < 0.001$.

Classification accuracy is determined as the percentage of sites that are predicted correctly by the model. Overall classification accuracy of the final model on the 1993 data was 87.3 %, with 86.7 % for non-selected sites and 87.6 % for selected sites (n = 150).

Test of logistic regression model

To test the final model's generality (i.e. usefulness in describing Barred Owl occurrence in another area) it was applied to the 1994 data, which were collected at sites not used for model development. The overall classification accuracy was 84.3 %, with 79.0 % for non-selected sites and 94.0 % for selected sites (n = 89).

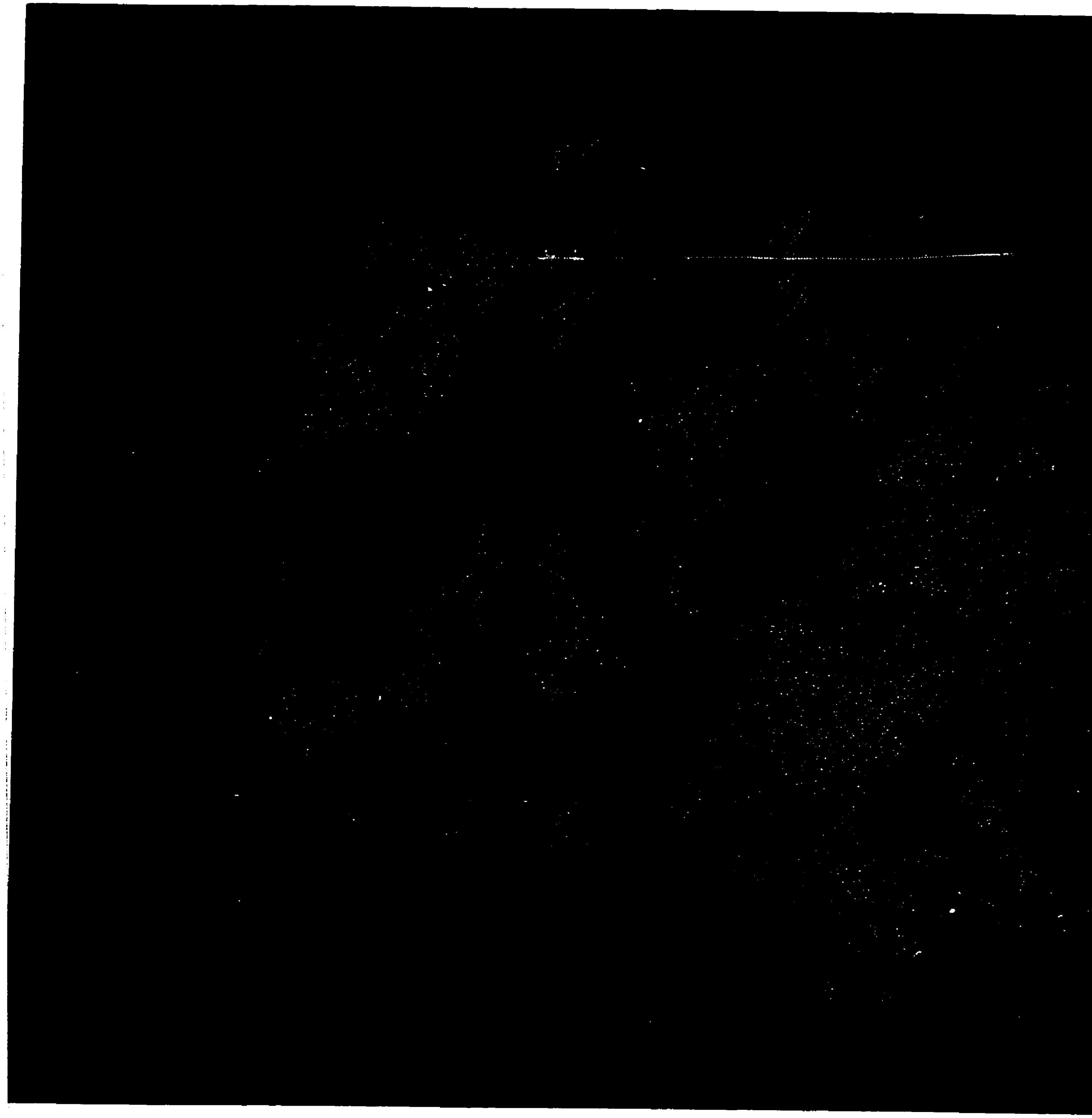
HABITAT MAP

Translating regression equations to habitat map.

The logistic regression equations led to the following conclusions regarding Barred Owl habitat selection: (1) boreal coniferous forest, alder, new clearcuts, shrubs and young trees were non-selected; (2) deciduous mixed, white pine and red pine forest was selected; (3) taller trees were selected, and (4) less fragmented forest was selected.

Landcover map classes corresponding to vegetation types avoided by the Barred Owl were identified as thicket swamps, shrubs, young trees, dense conifer and conifer on bedrock. These were recoded to one class and entered into the process described in Appendix VII to create a map of good and poor habitat (Figure 6).

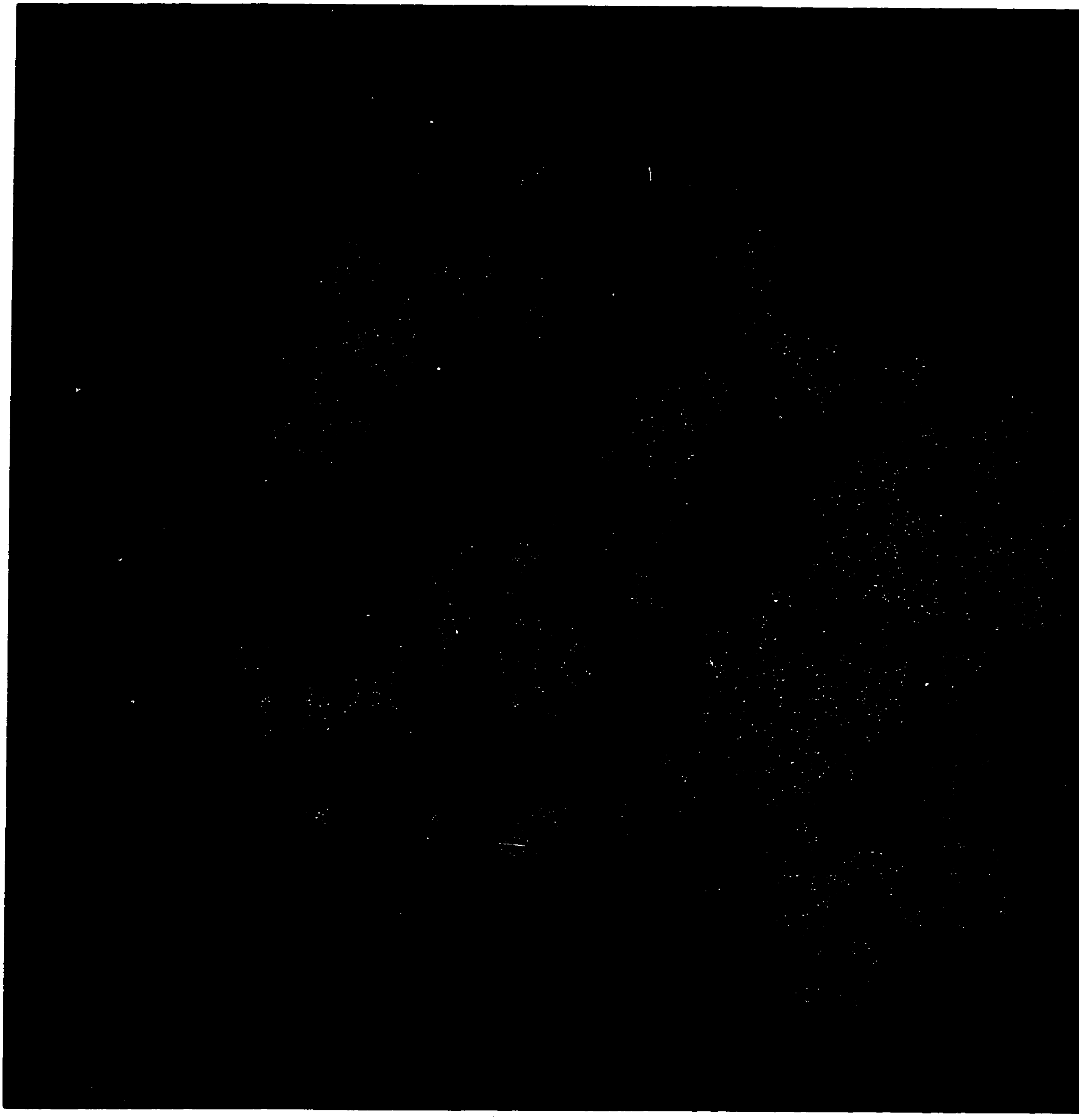
Figure 6. Barred Owl habitat map.



Assessing habitat map with survey data

The survey sites (Figure 7) coincided well with the mapped Barred Owl habitat classes (Table 10). Of the 43 owl selected sites, 28 were at least 75 % comprised of good habitat. Of 128 non-selected sites, 83 were at least 75 % comprised of poor habitat.

Figure 7. Survey sites superimposed on Barred Owl habitat map.



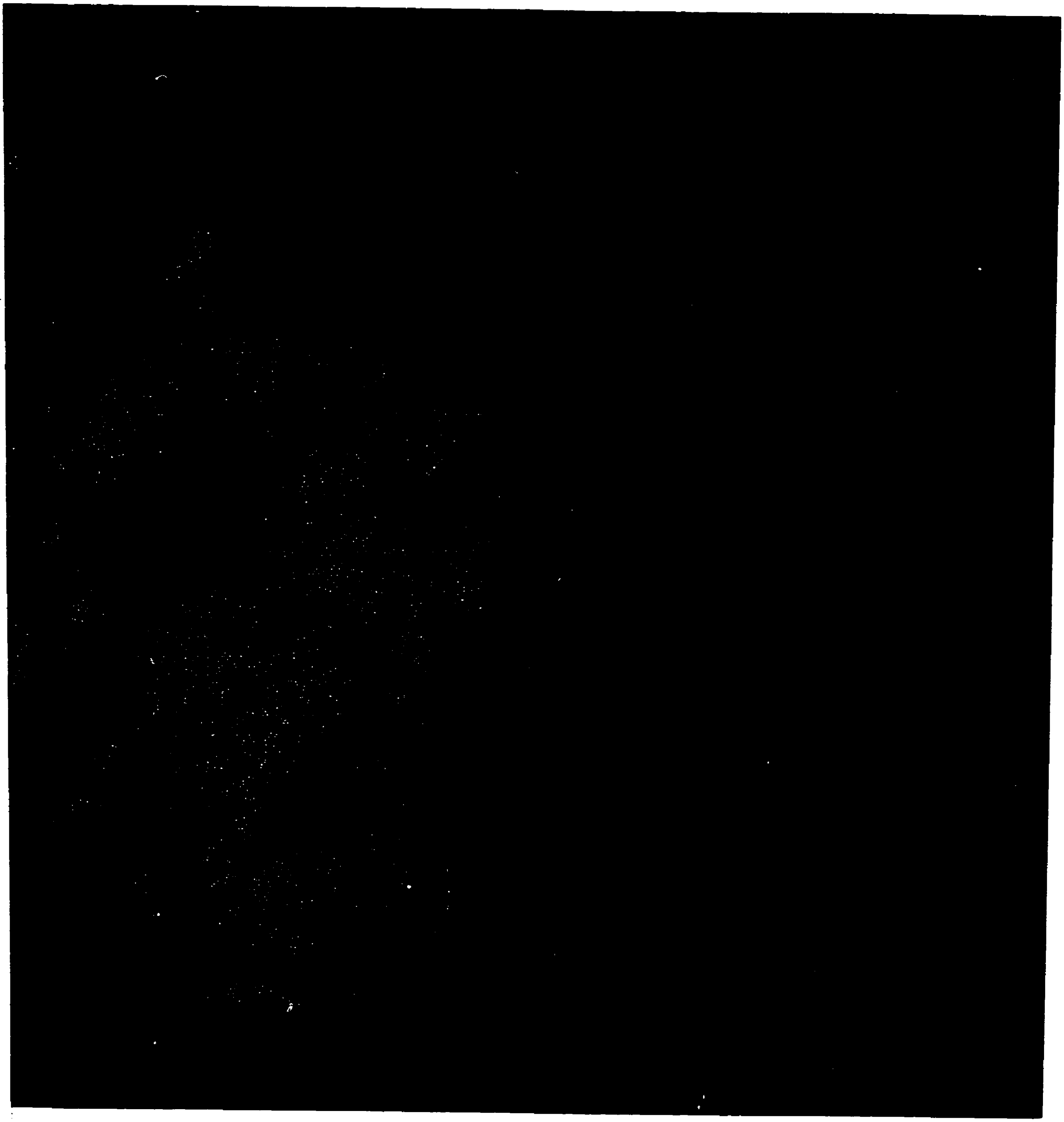


Table 10. Overlap between 280 ha areas around Barred Owl survey sites and mapped good and poor habitat classes.

% of 280 ha area around site	Survey Site: Selected by Barred Owl	Survey Site: Not selected by Barred Owl
50 - 100 % good habitat	31	29
51 - 100 % poor habitat	12	99

DISCUSSION

HABITAT MAP

The Barred Owl habitat map (Figure 6) performed well at the landscape level by distinguishing large areas where the Barred Owl would not occur from where it might occur, but did not distinguish between neighbouring selected and non-selected sites. It is a simple presentation of the kind of geographically referenced habitat information necessary for ensuring a continuing supply of Barred Owl habitat across the landscape.

The map demonstrated that Barred Owl distribution can be explained in large part by broad forest type. Areas dominated by shrubs, young trees, thicket swamps, dense conifer and conifer on exposed bedrock were usually not selected. Some of what remained after areas comprised of these classes were accounted for was selected. In the southeast section of the map the largest clusters of selected sites were in the deciduous mixed forest around the eastern lakes, and in the diverse mixture of forest types west of Heron Lake. In the western section the selected sites were concentrated in a large belt of deciduous mixed forest (Figure 7).

A noteworthy feature of the habitat map is that a substantial proportion of the land cover map was identified as good habitat, in which many non-selected sites occurred (Table 10). One explanation for this is that the good habitat class might be too inclusive. The logistic regression identified canopy height as an important predictor of Barred Owl presence in combination with forest type. Much of the forested landscape that remained once non-selected areas were identified might not be tall enough. Incorporating height, available on FRI maps, into the creation of habitat classes might have accounted for some of the non-selected sites located in good forest type.

Other explanations for the non-selected sites in good habitat are that the Barred Owl population was below capacity or that owls were present but didn't respond. If the population or responsiveness to call playback had been low, then some apparently non-selected sites might have been suitable or occupied. If this had been the case then the Barred Owl's selection of some forest types might have been underestimated, but the overall picture of suitable habitat would hold. For instance, that the Barred Owl encounter rate was higher in deciduous mixedwood than in coniferous forest would suggest that deciduous mixedwood is better habitat, regardless of the proportion of the potential population encountered.

Scattered selected sites and half of those in the Heron Lake area occurred on poor habitat (Figure 7). As mentioned previously, some of these might have been explained if height had been considered in the habitat class creation. Others may have resulted from giving too much weight to the effect of unforested classes in mapping. While nearby (≤ 300 m) red and white pine stands compensated for high levels of forest fragmentation, no distinction was made between recently disturbed forest near non-selected and highly selected types.

The habitat map's failure to classify some survey sites (Table 10) suggests that the regression equation could have been better translated into habitat classes. Canopy height would have been a useful addition to the mapping process, since it was an important Barred Owl presence predictor in the regression equation. Integrating

FRI data with the land cover map would have enabled height to be included. Because it confers a very high probability of encountering the owl on neighbouring sites, incorporating proximity to red and white pine may have accounted for more selected sites. The forest fragmentation effect (Figure 5) was dealt with loosely by including recently disturbed land classes (shrubs and young trees) in non-selected classes, then by defining poor habitat as non-selected areas ≥ 280 ha. An approach which considered the impact of unforested areas on Barred Owl presence in the context of the other factors might have yielded a better habitat map.

BARRED OWL HABITAT SELECTION

The regression analyses reduced 9 potential predictors of Barred Owl presence to 3; forest type, canopy height and the proportion unforested in 280 ha. Hardwood dominated forest and red and white pine mixedwoods were selected by the Barred Owl in the study area while boreal coniferous forest was unused. Taller canopy trees and less fragmented forest were also selected.

That these were the best explanatory variables for Barred Owl presence doesn't mean the owls necessarily used them to assess habitat quality. The logistic model is a statement of probability, not of cause. Forest type, height and fragmentation may have been associated with nest site availability, prey density or availability, cover, clear flight paths and suitable hunting perches.

In New Jersey, Bosakowski *et al.* (1987) found Barred Owls associated with mature (> 30 cm dbh) stands of oak, northern hardwoods and hemlock. Shrubs, young forest, spruce, cedar, and areas with extensive clearings were avoided.

Mazur and James (1995) found more mature (≥80 years) mixedwood on 700 ha circular buffers around Barred Owl locations than around survey locations in Saskatchewan. Mature and immature (50 to 79 years) mixedwood were used in greater proportion than their availability by 11 owls carrying radio-transmitters. Open areas, mature and young deciduous, and all age classes of coniferous forest were used less than expected based on availability (Mazur and James 1995).

Nicholls and Warner (1972) used about 27,000 radio-telemetry locations over 18 months from 9 Barred Owls near the University of Minnesota's Automatic Radio-tracking

Station for habitat use analysis. Preferred habitats were oak woods, mixed hardwoods, and conifers. Cedar swamps were used less than expected. Oak-savannas, alder swamps, marshes, and open fields were avoided.

Elody and Sloan (1985) reported that 7 radio-tracked Barred Owls in Michigan preferred old-growth hemlock and maple. Other cover types; marsh, aspen, pine, spruce, and swamp, were used in propotion to availability.

In the literature, Barred Owl habitat is described as a mature assemblage of hardwood and coniferous species that attain large diameters. Regional variations on this theme include oak-pine mixedwoods in Minnesota (Nicholls and Warner 1972), hemlock-maple mixedwoods in Michigan (Elody and Sloan 1985), hemlock-northern hardwoods in New Jersey (Bosakowski *et al.* 1987), mixed oak in southwestern Virginia (McGarigal and Fraser 1984), and boreal mixedwood in Saskatchewan (Mazur and James 1995). The apparent preference observed in this study for deciduous mixedwood is consistent with the Barred Owl's association with mixedwoods of other regions. The strong association with red and white pine, observed 24 of 25 times on selected sites, is notable in this respect.

Nest sites

Although they comprise a small percentage of the study area (3.4 %), mature red and white pine stands may be important repositories of large diameter stems with cavities or broken tops suitable for nesting. Seven of ten nests Mazur and James (1995) located were cavities in trees with an average 54.5 cm dbh (37.8 to 74.5 cm dbh). Devereux and Mosher (1984) found 8 nest trees from 42 to 88 cm dbh, more trees > 50 cm dbh, and fewer trees < 26 cm dbh at nest sites than at random plots. They offered 25 cm dbh as a minimum for nest trees. Allen (1987) suggested that ≥51 cm dbh as the best size range for Barred Owl nest trees.

With more trees > 30 cm dbh (Table 9), white and red pine mixedwood would be more likely to have Barred Owl-sized cavities than forest types of smaller girth. Because it takes longer for decay to destabilize them, large snags last longer (Cline *et al.* 1980). Being tall, white and red pine are susceptible to lightning, which breaks tops and limbs and compromises the tree's bark barrier to pathogens. Six of eight nests discovered by Devereux and Mosher (1984) were in the tops of hollow tree stubs. Mazur and James (1995) found 5 of their 10 nests in broken tree tops. The one nest discovered in this study was in the top of a 50 cm dbh white pine snag.

The Barred Owl probably selects habitat in part for its potential nest sites. Deciduous species are generally more likely to develop decay cavities than conifers (Hunter 1990). Tall, large diameter trembling aspen would therefore offer more suitable cavities from decay than jack pine of similar size. Mature red and white pine stands are probably rich sources of suitable cavities. Because they are tall and long-lived they are likely to sustain damage. Because they attain large diameters, they will persist longer as snags than smaller trees, and cavities they develop can become large enough for the Barred Owl.

Cover

Barred Owls may select forest on the basis of available cover and perches. They seem to prefer to fly with cover, typically flying below the canopy rather than above it where there is more maneuvering room. When traversing large open areas they often fly quite low (personal observation), possibly to avoid revealing themselves against the horizon.

In summer, deciduous trees would offer good canopy coverage. Coniferous trees with tall, sturdily branched and thick crowns would provide protection from predators or mobbing by other birds (Elody 1983). While jack pine develops a long full crown when open grown, in mainly coniferous even-aged stands its crown is short, compact and offers relatively little canopy coverage or concealed roosting sites. Black spruce offers little canopy coverage. Deciduous and pine mixedwoods would provide a greater assortment of cover types than would boreal conifers.

Stem density

Stem density is likely another habitat quality determinant. Elody and Sloan (1985) proposed that old growth pine was preferred because it offered clear flight paths. Nicholls and Warner (1972) suggested that the owls avoided cedar swamps and alder because maneuvering and seeing prey would be difficult in thick foliage and high stem density.

Stem density was lowest in red and white pine forest (Table 9) in the study area. Because tall shrubs (>1.3 m) often contributed to a large stem tally on trembling aspen and white birch sites (Table 9), stem density of canopy trees was likely considerably lower. Where black spruce sites were shrub rich, most were shorter than the tally height (1.3 m) and recorded stem densities thus apply to the tree layer. On average, jack pine sites were of intermediate density (Table 9) and black spruce sites were most dense. While not measured, alder thickets and overgrown clearcuts were also likely too dense for Barred Owls to use.

Perches

Cover and large branches might be important for fledglings. Roughly 2 weeks before they can fly, young Barred Owls leave the nest and the adults urge them to climb to large horizontal branches in the lower portion of the canopy (Dunstan and Sample 1972). Trees with open and sturdy branching have been suggested as critical features of a Barred Owl's habitat because it hunts by watching from perches (Dunstan and Sample 1972). Nicholls and Warner (1972) attributed the owl's preference for oak and mixedwoods to an abundance of perches.

Trembling aspen, white pine, red pine mixedwood, and jack pine mixedwood appeared to have more available perches than other vegetation types in the study area. Trembling aspen or white birch usually accompanied the dominant species in the canopy layer, augmenting perching opportunities by contributing to a variety of forms and branching habits. Trembling aspen and white pine appeared to be exceptional perch trees, with tall, full and robustly branched crowns. All but red pine mixedwood were typically layered, with white birch, balsam fir (*Abies balsamea*) and red maple (*Acer rubrum*) constituting the shorter tree layer.

By contrast, mainly coniferous jack pine and black spruce stands were perch poor. The black spruce crown is typically narrow and finely branched. In dense, even-height stands jack pine tends to 'self-prune' as lower branches succumb to light competition, leaving a short compact crown.

Forest types selected by Barred Owls in the study area were typically more vertically complex than non-selected types. A well stratified forest probably benefits the Barred Owl by providing a wealth of daytime roosts, cover for fledglings and hunting perches.

Prey availability

The number of prey available to the Barred Owl is a function of prey population, hunting perches and forest floor conditions which can hinder or help the owl to hear, see and catch the prey. The Barred Owl preys primarily on small mammals, but it also takes amphibians, fish, birds, and invertebrates (Bent 1961, Elderkin 1981, Devereux and Mosher 1984, Johnsgard 1988, Bosakowski and Smith 1992). The reliability of absolute prey numbers as an indicator of habitat quality would depend on the owl's hunting success in that environment. Nicholls and Warner (1972) observed that while prey were abundant in oak-savanna and open fields, they were unavailable to the Barred Owl probably because of the lack of cover and hunting perches. They suggested the clear understorey, abundance of perches and dry leaf litter in upland oak and mixedwoods were ideal hunting conditions.

Lowland boreal coniferous sites may be non-selected both because their structural characteristics are unsuitable for hunting and prey density is generally lower than in upland sites. Nagorsen and Peterson (1981) found small mammals to be more abundant in upland mixed forest than in lowland conifer sites. The lack of vertical layering in some even-aged coniferous stands may limit bird diversity and density (Dickson and Segelquist 1979). Jones and Naylor (1994) found small mammals to be slightly more abundant in old growth white pine and boreal mixedwood than in lowland conifer.

While the dense tall shrub layer typical of aspen forests might interfere with hunting ground-dwelling prey (Mazur and James 1995), other characteristics may increase hunting success on the ground. Dry leaf litter on upland mixedwood and deciduous sites is likely superior for prey detection to the damp moss carpeting lowland coniferous sites. Crucial habitat for many small animals (Thomas 1979), downed wood was abundant and diverse on deciduous and red and white pine mixedwood sites. Barred Owl selected sites in the study area were often a jungle of white birch or trembling aspen logs and balsam fir slash. Abundant downed wood, while offering cover for prey, might boost Barred Owl hunting success by supporting a large prey population.

Barred Owl habitat selection: summary

Mature upland mixedwoods offer the Barred Owl an optimal combination of nesting, prey abundance and hunting conditions. Mature and old red pine, white pine and deciduous trees likley offer more suitable cavities than boreal conifers. The high number and variety of perches, diverse and abundant prey, and dry leaf litter likely increase hunting success. A dense shrub layer may impede catching ground-dwelling prey, while a moderate shrub cover probably supports a diverse and abundant small animal population.

CALL PLAYBACK METHOD

To deduce habitat selection from owl locations determined by call playback survey, one assumes that the survey technique is effective. Conspecific calls are supposed to elicit a vocal and sometimes physically aggressive territorial response from a resident owl (Fuller and Mosher 1987).

The Barred Owl has been said to respond sluggishly to call broadcasts (McGarigal and Fraser 1985, Shepherd 1992). While over half of contacts were within the first 3 min., responses accumulated steadily from 3 to 10 min. after the call broadcast began (Figure 2). A substantial proportion of owls responded at or after 10 min. (Figure 3). Yet, of the 13 owls detected after the sampling period, 9 were apparently mates of previously detected owls. This suggests that while a longer period might have detected more pairs, habitat use conclusions would have been similar. The 10 minute survey period was therefore a good compromise between detecting owls and covering a larger area.

Using responses to call playback surveys to identify selected habitat assumes that the Barred Owl responds only to calls within its territory. If they often flew to sites not otherwise used in order to respond to call broadcasts, poor habitat might erroneously be identified as good. It is reasonable to assume a defended territory is the best that an owl can acquire. It follows that the most conspicuous responses to another Barred Owl's invasion should occur in good habitat because highly used sites would be more likely occupied at the time of the survey, a response would come more quickly from the nearby inhabitant and the owl might more aggressively investigate the tape recording. Since over half of responses were within 3 min. and ≥ 95 % of selected sites still had respondents when a route was rerun in the same or following year (Tables 4 and 5), the assumption that most responses occurred in selected habitat is reasonable. Since their home ranges in the boreal forest are large (Mazur and James 1995) and they are reported to be highly territorial (Bent 1961, Nicholls and Fuller 1987), Barred Owls probably do not stray from their territories to investigate others on poorer sites. Locations determined by call playback survey, therefore, are likely adequate to identify Barred Owl habitat selection.

The corollary to the first assumption is that no response means that no owl is present. The Barred Owl is thought to respond best to call broadcasts in early spring. Most surveys in the United States have begun in February or early March (Devereux and Mosher 1984, McGarigal and Fraser 1984, Bosakowski *et al.* 1987, Mosher *et al.* 1990). Shepherd (1992) suggested surveying in late February and early March, during pre-breeding behaviour (Dunstan and Sample 1972). Survey dates for this study (June to mid August 1993, mid-May to June 1994) were late relative to other Barred Owl surveys. If responsiveness were lower due to the late survey timing, some of the apparently unoccupied sites classified as good habitat by the map may in fact have been occupied by unresponsive owls.

In central Ontario, Francis and Czerwinski (1995) suggested that responses to call playback compensate for Barred Owls calling spontaneously less in April than in March. While the Barred Owl may be less spontaneously vocal in summer, they would be expected to respond to a simulated encroachment on breeding habitat. However, responses from radio-tagged owls have been observed to drop off rapidly after the spring (James, personal communication).

If feeding young or a seasonal variation in vocal behaviour affected the usefulness of the call playback method in summer, then a change in response behaviour should have been observed. McGarigal and Fraser (1985) reported that 55 % of owls flew in before calling, 30 % called only from a distance and 12.5 % flew in while calling. Smith (1978) reported that 47 % of owls flew to the site before calling and 12 % called from a distance first. In this study, typical behaviour was to call for the first time within about 100 m of the survey site (44 %), to call from a distance without approaching (35 %) or to call before or during an approach (19 %). Response behaviour was, therefore, consistent with that reported in springtime surveys.

If responsiveness were lower in summer, the general understanding of habitat selection would be unaffected. Since there is no reason to suspect that Barred Owls would be less vocal in better habitat, the higher contact rate in mixed hardwood forest likely reflected that it was selected more often. Rare forest types selected by the Barred Owl might not be detected if responsiveness were low. Since the rarest forested class on the surveyed areas, red and white pine mixedwood (3.22 %), was clearly selected by the Barred Owl, this was apparently not a problem.

Although the call playback survey was performed later than recommended, response behaviour was normal, prompt and reliable. Locating the owls by this method was therefore an effective way to obtain a general understanding of Barred Owl habitat selection.

CONCLUSION

This study documented that the Barred Owl in Northwestern Ontario is strongly associated with white pine, red pine and trembling aspen dominated mixedwoods. Boreal conifers, shrubs and young trees appear to be avoided. Taller and less fragmented forests are more frequently selected by the Barred Owl.

Its association with white pine, red pine and deciduous mixedwood in Northwestern Ontario means that the Barred Owl might be susceptible to the loss of good habitat through traditional forest management. White pine and red pine are rare relative to other tree species and stands are typically small, yet they are strongly associated with Barred Owl presence. If small pockets of mature white and red pine are important repositories of nest cavities, their loss could limit Barred Owl distribution. Converting deciduous mixedwood to conifer plantations would also reduce the amount of suitable habitat available. Because the Barred Owl avoids early successional stages, truncating the natural age distribution of the forest would further limit its potential habitat.

A Barred Owl habitat map for the study area was obtained by redefining forest classes derived from satellite imagery into good and poor habitat classes (Figure 6). The map performed well at the landscape level, distinguishing large areas where the Barred Owl was likely to occur from areas where it was rare.

While it is a highly simplified representation of Barred Owl habitat, this map is an example of the kind of information required for landscape level forest management. It employs forest information from an affordable and easily updated source (satellite imagery) and can be integrated with other digitized geographic information in a GIS environment. Characterizing forest wildlife habitat in terms of widely available digital data in a GIS makes large scale habitat supply assessments and forecasts feasible.

Because it requires large home ranges with mature deciduous, red pine and white pine mixedwoods for nest sites and hunting success, the Barred Owl's needs conflict with traditional forest harvesting. Ensuring a continuing adequate supply of suitable habitat in Northwestern Ontario will require foresight and planning at the spatial scale of landscapes and the time scale of ecological succession.

RESEARCH RECOMMENDATIONS

Locating owls by call playback survey is a good way to determine general habitat selection trends over a large area, but yields no information about how much area is required and how it is used. Effective habitat management requires an understanding of the relationship between habitat quality and area requirements. For example, while an average annual home range in an area might be 500 ha, a Barred Owl might require 1000 ha of jack pine mixedwood or 250 ha of mature aspen and white pine mixedwood.

Radio-tracking Barred Owls in Northwestern Ontario would yield valuable understanding of their use of various forest types, home range, choice of nest sites and reproductive success. Examining these aspects of Barred Owl habitat requirements in conjunction with FRI and satellite-image derived forest data in a GIS would facilitate integrating them with large-scale and long-term forest planning.

LITERATURE CITED

Allen, A.W. 1987. Habitat suitability index models: barred owl. U.S. Fish Wild. Serv. Bio. Rep. No. 82(10.143). 17 pp.

Austen, M.J.W., M.D. Cadman and R.D. James. 1994. Ontario birds at risk: status and conservation needs. Federation of Ontario Naturalists with Long Point Bird Observatory. 165 pp.

Bent, A.C. 1961. Life histories of North American birds of prey. Part 2. U.S. Natl. Mus. Bull. No. 170. Dover, NY. 482 pp.

Begon, M., J.L. Harper and C.R. Townsend. 1986. Ecology: individuals, populations, and communities. Sinauer Assoc., Inc. Sunderland, Mass. 876 pp.

Belanger, L. 1995. Landscape management perspectives and production of "usable" research *in* Workshop on Landscape Management: summary of presentations. For. Chron. 71(4): 520-523.

Bishop, Y., S. Fienberg and P. Holland. 1975. Discrete Multivariate Analysis: Theory and Practice. MIT Press. Cambridge, Mass. 575 pp.

Booth, D.L., D.W.K. Boulter, D.J. Neave, A.A. Rotherham and D.A. Welsh. 1993. Natural forest landscape management: a strategy for Canada. For. Chron. 69(2):141-145.

Bosakowski, T. 1987. Census of barred owls and spotted owls. pp. 307-8 *in* R.W. Nero, R.J. Clark, R.J. Knapton, R.H. Hamre (eds.) Biology and conservation of northern forest owls: symposium proceedings. Feb. 3-7, 1987. Winnipeg, Manitoba. Tech. Rep. RM-142. Fort Collins, CO: U.S. Dept. Agric. For. Serv., Rocky Mt. For. Exp. Sta. 309 pp.

Bosakowski, T. and D.G. Smith. 1992. Comparative diets of sympatric nesting raptors in the eastern deciduous forest biome. Can. J. Zool. 70:984-992.

Bosakowski, T., R. Spelser, and J. Benzinger. 1987. Distribution, density, and habitat relationships of the barred owl in northern New Jersey. pp. 135-143 *in* R.W. Nero, R.J. Clark, R.J. Knapton, R.H. Hamre (eds.) Biology and conservation of northern forest owls: symposium proceedings. Feb. 3-7, 1987. Winnipeg, Manitoba. Tech. Rep. RM-142. Fort Collins, CO: U.S. Dept. Agric. For. Serv., Rocky Mt. For. Exp. Sta. 309 pp.

Boxall, P.C. and P.H.R. Stepney. 1982. The distribution and status of the barred owl in Alberta. Can. Fld. Nat. 96:46-50.

Chatterjee, S. and B. Price. 1977. Regression analysis by example. John Wiley & Sons. Toronto. 228 pp.

Cline, S.P., A.B. Berg, and H.M. Wight. 1980. Snag characteristics and dynamics in douglas-fir forests, western Oregon. J. Wildl. Mgmt. 44:773-786.

Devereux, J.G. and J.A. Mosher. 1984. Breeding ecology of barred owls in the central Appalachians. Raptor Res. 18(2):49-58.

Dickson, J.G. and C.A. Segelquist. 1979. Breeding bird populations in pine and pine-hardwood forest in Texas. J. Wildl. Mgmt. 43:549-555.

Duncan, J.R. 1994. Barred owl habitat use literature review. Unpublished report for the Manitoba Forestry/Wildlife Management Project, Manitoba Nat. Resour. 23 pp.

Dunstan, T.C. and S.D. Sample. 1972. Biology of barred owls in Minnesota. Loon 44(4):111-115.

Elderkin, M.F. 1981. The breeding and feeding ecology of a barred owl population in Kings County, Nova Scotia. M.S. Thesis. Acadia Univ., Wolfville, Nova Scotia.

Elody, B.I. 1983. Techniques for capturing, marking, montoring and habitat analysis for the barred owl in the Upper Peninsula of Michigan. M.S. Thesis. Michigan Tech. Univ., Houghton. 103 pp.

Elody, B.B., and N.F. Sloan. 1985. Movements and habitat use of barred owls in the Huron Mountains of Marquette County, Michigan as determined by radiotelemetry. Jack-Pine Warbler 63(1):3-8.

Francis, C.M. and E. Czerwinski. 1995. Nocturnal owl survey: 1995 pilot study. Unpublished report by Long Point Bird Observatory for Ont. Min. Nat. Resour. 33 pp.

Fuller, M.R. 1979. Spatiotemporal ecology of four sympatric raptor species. Ph.D. dissertation. Univ. Minnesota, St. Paul, Minn. 396 pp.

Fuller, M.R. and J.A. Mosher. 1987. Raptor survey techniques. pp 37-65 *in* B.A. Giron, B.A. Millsop, K.W. Cline and D.M. Bird (eds.) Raptor management techniques manual. Natl. Wildl. Fed. Washington, DC.

Galindo-Leal, C. and F.L. Bunnell. 1995. Ecosystem management: implications and opportunities of a new paradigm. For. Chron. 71(5):601-606.

Gluck. M.J. 1994. An evaluation of remotely sensed wetland mapping. M.Sc.F. Thesis. Lakehead Univ., Thunder Bay, Ont. 79 pp.

Grant, J. 1966. The barred owl in British Columbia. Murrelet 47(2):39-45.

Green, K. and R.G. Congalton. 1990. Mapping potential old growth forests and other resources on national forest and park lands in Oregon and Washington. Proc. GIS/LIS '90 Nov. 7-10, 1990. Anaheim, CA. Vol 2: 712-723.

Hewitt III, M.J., J.R. Eby, and L.W. Brewer. 1986. The role of LANDSAT multi-spectral scanner data in the analysis of northern spotted owl habitat. pp. 937-942 *in* proc. 10th Canadian symposium on remote sensing. May 5-8, 1986. Edmonton, Alberta.

Horler, D.N.H. and F.J. Ahern. 1986. Forestry information content of Thematic Mapper data. Int. J. Remote Sensing 7(3):405-428.

Hunter, M.L. 1990. Wildlife, Forests, and Forestry: principles of managing forests for biological diversity. Prentice-Hall, Inc. Toronto. 370 pp.

Johnsgard, P.A. 1988. North American Owls: Biology and Natural History. Smithsonian Institution Press, Washington, 295 pp.

Johnson, D.H. 1987. Barred owls and nest boxes- results of a five-year study in Minnesota. pp. 129-134 *in* R.W. Nero, R.J. Clark, R.J. Knapton, R.H. Hamre (eds.) Biology and conservation of northern forest owls: symposium proceedings. Feb. 3-7, 1987. Winnipeg, Manitoba. Tech. Rep. RM-142. Fort Collins, CO: U.S. Dept. Agric. For. Serv., Rocky Mt. For. Exp. Sta. 309 pp.

Johnson, R.R., B.I. Brown, C.T. Haight and J.M Simpson. 1981. Playback recordings as a special avian censusing technique. pp. 68-75 *in* G.J. Ralph and J.M. Scott (eds.) Estimating numbers of terrestrial birds. Stud. Avian Biol. 6.

Jones, S.L. and B.J. Naylor. 1994. A comparison of small mammal communities in old pine forests and other common forest types in Sault Ste. Marie District. Ont. Min. Nat. Resour., Ont. For. Res. Inst. Report No. 12. 20 pp.

Joyce, L. 1992. Ecosystem management workgroup findings. pp. 32-34 *in* E.T. Bartlett and J.R. Jones (eds.) Rocky Mountain New Perspectives: proceedings of a regional workshop. U.S. Dept. Agric. For. Serv. Gen. Tech. Report RM-220.

Kessler, W.B. 1992. A parable of paradigms. J. For. 90:18-20.

Kidd, J. 1993. Interim report on conserving old growth red and white pine. Ont. Min. Nat. Resour. report from The Old Growth Policy Advisory Committee, The Old Growth Conservation Initiative. 35 pp.

Konrad, S-L.R., B. Kazermik, and P. Kollasch. 1990. Use of remotely sensed data and geographic information for waterfowl habitat management in Agro-Prairie Canada. Manitoba Natural Resources Newsletter. Remote Sensing in Manitoba (winter 1990) pp. 2-3.

Leckie, D.G. 1990. Advances in remote sensing technologies for forest surveys and management. Can. J. For. Res. 20(4):464-483.

Mann, L.J., R.G. Congalton, K. Green and M.J. Cosentino. 1989. Mapping forest vegetation type and structure on the Okanogan National forest using LANDSAT Thematic Mapper data. Proc. Symp. Image Processing '89. Sparks, Nevada. Am. Soc. Photogrammetry and Remote Sensing. pp. 156-165.

Marks, J.S., D.P. Hendricks, and V.S. Marks. 1984. Winter food habits of barred owls in western Montana. Murrelet 65(1):27-28.

Mazur, K.M. and P.C. James. 1995. Ecology of the barred owl in the Prince Albert Model Forest. Interim Report prepared for the Prince Albert Model Forest Inc. 18 pp.

McGarigal, K., and J.D. Fraser. 1984. The effect of forest stand age on owl distribution in southwestern Virginia. J. Wildl. Mgmt. 48(4):1393-1398.

McGarigal, K., and J.D. Fraser. 1985. Barred owl responses to recorded vocalizations. Condor 87:552-553.

Meslow, E.C., C. Maser, and J. Verner. 1981. Old-growth forest as wildlife habitat. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 46:329-335.

Miller, K.V. and M.J. Conroy. 1990. SPOT satellite imagery for mapping Kirtland's warbler wintering habitat in the Bahamas. Wildl. Soc. Bull. 18:252-257.

Mosher, J.A., M.R. Fuller, and M. Kopeny. 1990. Surveying woodland raptors by broadcast of conspecific vocalizations. J. Fld. Orn. 61(4):453-461.

Nagorsen, D.W. and R.L. Peterson. 1981. Distribution, abundance and species diversity of small mammals in Quetico Provincial Park, Ontario. Nat. Can. 108:209-218.

Naylor, B., A. Todd and S. Christilaw. 1994. A nonspatial habitat suitability index model for red-shouldered hawks in the Great Lakes-St. Lawrence Forest of Ontario. Ont. Min. Nat. Resour., Cent. Reg. Sci. and Tech. Report 38. 8 pp.

Nicholls, T. H., and D.W. Warner. 1972. Barred owl habitat use as determined by radiotelemetry. J. Wildl. Mgmt. 36(2):213-224.

Nicholls, T.H. and M.R. Fuller. 1987. Territorial aspects of barred owl home range and behavior in Minnesota. pp 121-134 *in* R.W. Nero, R.J. Clark, R.J. Knapton, R.H. Hamre (eds.) Biology and conservation of northern forest owls: symposium proceedings. Feb. 3-7, 1987. Winnipeg, Manitoba. Tech. Rep. RM-142. Fort Collins, CO: U.S. Dept. Agric. For. Serv., Rocky Mt. For. Exp. Sta. 309 pp.

Norusis, M.J. 1989. SPSS/PC+ Advanced Statistics• 4.0. SPSS Statistical Data Analysis, SPSS Inc. Chicago, Illinois. 382 pp.

Pierce, R.N. 1989. Analysis of LANDSAT TM imagery: an approach for the collection of forest cover data for mapping forest bird habitat in northern Ontario. 12th Can. Symp. on Remote Sensing. Vol 3:1577-1579.

Rempel, R. Stratmap: a landcover map of terrestrial and wetland classes. Unpublished data.

Rowe, J.S. 1972. Forest regions of Canada. Can. For. Serv. Publication No. 1300. 172 pp.

Rowe, J.S. 1994. A new paradigm for forestry. For. Chron. 70: 565-568.

Sader, S.A., G.V.N. Powell and J.H. Rappole. 1991. Migratory bird habitat monitoring through remote sensing. Int. J. Remote Sensing 12(3):363-372.

Schoen, J.W., O.C. Wallmo and M.D. Kirchhoff. 1981. Wildlife-forest relationships: is a re-evaluation of old-growth necessary? Trans. N. Amer. Wildl. and Nat. Resour. Conf. 46:531-545.

Shaw, D.M. and S.F. Atkinson. 1990. An introduction to the use of geographic information systems for ornithological research. Condor 92:564-570.

Shepherd, D. 1992. Monitoring Ontario's owl populatiions: a recommendation. Unpublished report by Long Point Bird Observatory for Ont. Min. Nat. Resour. 82 pp.

Sims, R.A.,K.A. Baldwin and G.M. Wickware. 1989. Field guide to the forest ecosystem classification for northwestern Ontario. Ont. Min. Nat. Resour., Toronto, Ontario. 191 pp.

Smith, C.F. 1978. Distributional ecology of barred and great horned owls in relation to human distribution. M.S. Thesis. Univ. Connecticut.

Smith, J. 1990. Ecological consequences of land use change: a study of the potential to derive useful bird habitat information from satellite imagery. Final Report to the Dept. of the Environment. Natl. Remote Sensing Cen., Farnborough, Hampshire, UK. 21 pp.

Solway, J. 1993. What we heard- a summary of public consultations on conserving old growth red and white pine. Ont. Min. Nat. Resour. report from The Old Growth Policy Advisory Committee, Old Growth Conservation Initiative. 43 pp.

SPSS Inc. 1994. SPSS for Windows. Release 6.1. SPSS statistical data analysis, SPSS Inc. Chicago, Illinois.

Sutton, C.C. and P.T. Sutton. 1985. The status and distribution of barred owl and red-shouldered hawk in southern New Jersey. Cassinia 61:20-29.

Taylor, A.L. Jr, and E.D. Forsman. 1976. Recent range extensions of the barred owl in western North America, inlcuding the first records for Oregon. Condor 78(4):560-561.

Thomas, J.W.(ed.) 1979. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. U.S. Dept. Agric. For. Serv. Agricultural Handbook No. 552. Washington, D.C. 512 pp.

Usher, R., J.A. Dechka and G.L. Holroyd. 1992. Assessment of critical prairie falcon foraging habitat in Southern Alberta using satellite imagery and GIS technology. 4 pp. *in* Proc. 15th Can. Symp. on Remote Sensing. Toronto, Ont.

Walton, R.K. and R.W. Lawson. 1989. Birding by ear. A guide to bird-song identification. Peterson Field Guide Series. Houghton Mifflin Co. Boston. Tape 1, Side 2.

Wedeles, C.H.R., P.N. Duinker and M.J. Rose. 1991. Wildlife-habitat management strategies: a comparison of approaches for integrating habitat management and forest management. Prepared for the Ont. Min. Nat. Resour. by ESSA Ltd., Richmond Will, Ont. 66 pp.

Weir, R.D. 1987. Barred Owl. pp 208-209 *in* M.D. Cadman, P.F.G. Eagles and F.M. Helleiner (eds). Atlas of the breeding birds of Ontario. Univ. Waterloo Press, Waterloo, Ont.

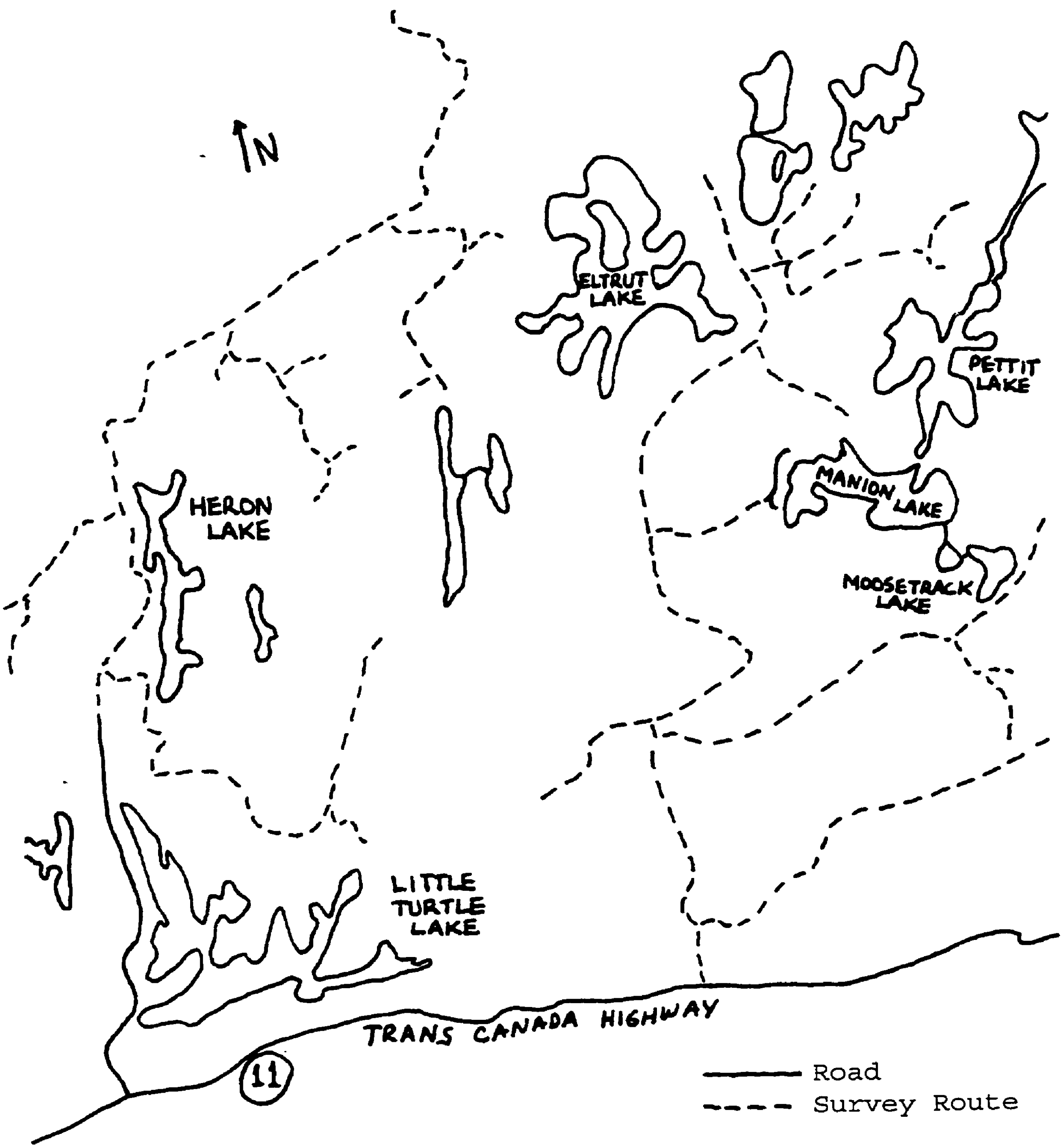
Welsh, D.A. 1988. Meeting the habitat needs of non-game forest wildlife. For. Chron. 64(3):262-266.

Welsh, D.A., T. Clark and K. Clark. 1992. Fauna of red and white pine old-growth forests in Ontario: issues and recommendations for research. Ont. Min. Nat. Resour., Ont. For. Res. Inst. Report No. 3. 56 pp.

APPENDICES

APPENDIX I

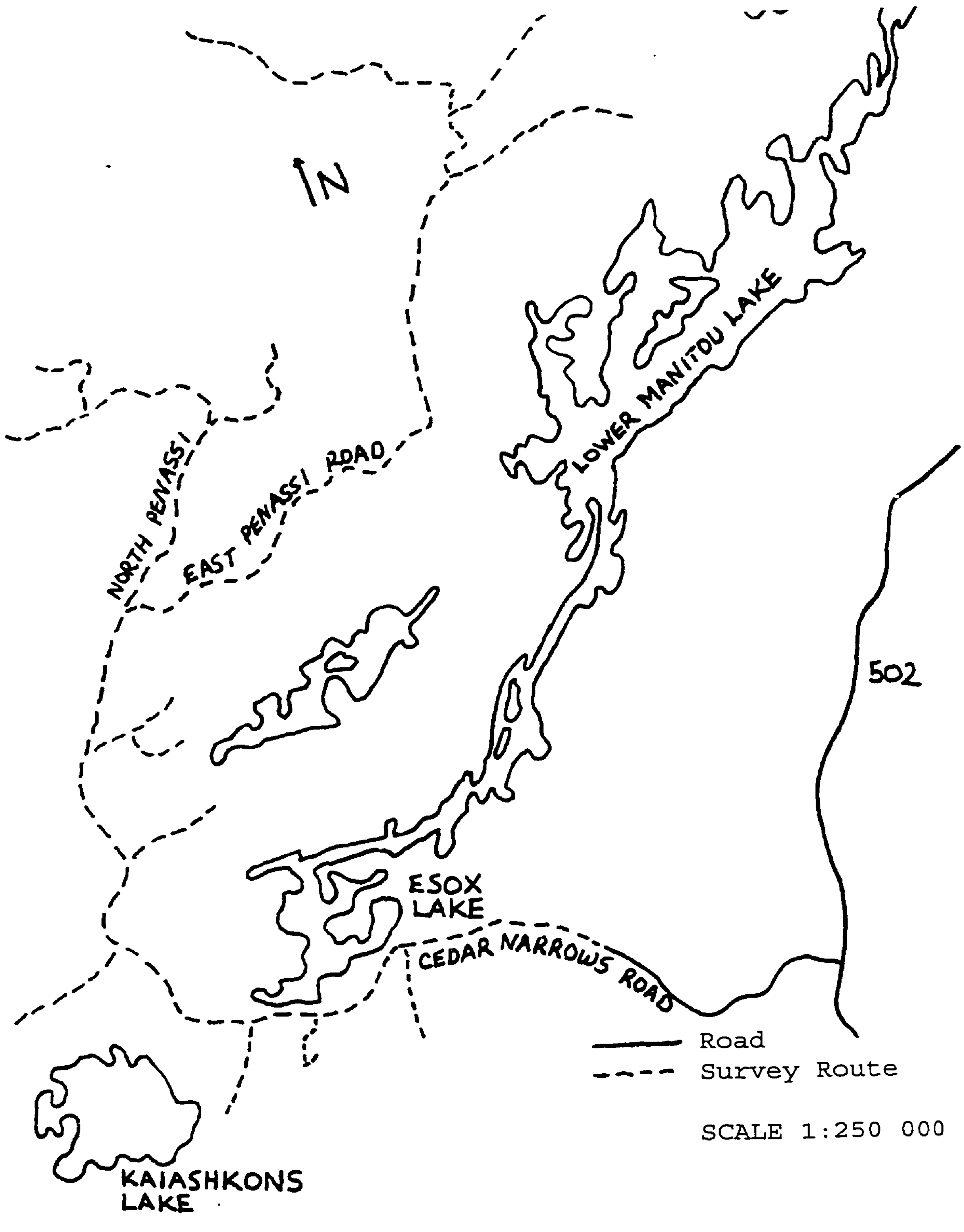
MAP OF SOUTHEAST STUDY AREA



SCALE 1:250 000

APPENDIX II

MAP OF NORTHWEST STUDY AREA



APPENDIX III

SAMPLE OWL SURVEY NOTES

JUNE 23 CLEAR, CALM, WARM, FULL MOON

* will need GPS to map CEDAR NARROWS ROAD

*275 11:11 pm
1.6 km S of 248
Sw, Pot, Sb mix to SW
thin Bw to NE
probably cut behind
600m N of 30 k marker

276 11:29 pm
100m S of Cedar Narrows
Pot. Spruce, Pw, Pr mix both sides
road N-S here

*277 11:45 pm
1.6 km S of 276
1.45 km S of Esox Jct
road E-W here
Pot, Pw to S ~25m to bushline
Pot, Pw, Sb to N
response @ <10 s ♂ (low voice)
very close, @ bushline 158°-160°
from flagging tape
at 11:51 pm, after Sue called twice,
we got a 2nd owl duetting c̄ first
at 142-143° from flagging tape
2nd owl also on bushline
2nd owl's voice sounds higher

APPENDIX IV

EXAMPLES OF VEGETATION SAMPLE PLOT DATA TEMPLATES AND FIELD NOTES

1993 DATA TEMPLATE

DATE:

BEARINGS TO PLOTS?

ROAD:

OWL PRESENT/ABSENT?

SITE:

RECORD:

1. FEC V-TYPE
2. Canopy height
3. Subcanopy height
4. Prism sweep

% Cover...

5. Sub-canopy
6. Shrub
7. Ground vegetation
8. Downwood
9. Litter

% COVER SCALE

1. OPEN	2. 1 - 20	3. 21 - 40
4. 41 - 60	5. 61 - 100	

EXAMPLE OF 1993 VEGETATION PLOT FIELD NOTES

June 25/93
Site 53 Plot 1 14° from pilon
Oasis Rd OWL ABSENT
(1) V37
(2) -2, +12 Sb
-1 +12 Sb
(3) -2, +6 Sb
-2, +4.5 Sb
(4) 4 Sb
(5) 2
(6) 4
(7) 6 (100% moss)
(8) 2- not much
(9) None 1.

1994 VEGETATION PLOT DATA TEMPLATE

DATE:

ROAD:

SITE:

BEARINGS TO PLOTS?

OWL PRESENT/ABSENT?

10 X 10 m PLOT

FEC V-TYPE

CANOPY STRUCTURE/HEIGHTS

SHRUB COVER, LITTER, MOSS AND DOWN WOOD

MODIFIED POINT SAMPLE

tally by species and snags by species and type;

2 = DYING

3 = DEAD

4 = LOOSE BARK

5 = CLEAN

6 = BROKEN

7 = SOFT DECOMPOSED ≥ 70 %

EXAMPLE OF 1994 VEGETATION PLOT NOTES

Modified Point Sample Tally Sheet

Crew names: ______
Location: 274(2) Hector Rd
Stand number: ______
Point number: ______
Prism BAF m^2/ha): ______
Working Group Species: ______

KRIS   owl present

Dbhob (cm)	Pot	SNAG	SPECIES Sb
2			
4			
6		: Bf C6 • Bf C3 •	
8		• Bf C3	
10		• Bf C6	
12			
14			
16		• Bf C3	
18			
20			
22			
24			•
26			
28	•		
30			
32		• Pot C6	
34			
36			
38	•		
40	•		
44	:		
48	•		
52	:		
54	•		
56	:		
58	:		
64	•		
72	•		
TOTAL	15	(7)	1

Hector Rd
Owl present
274(2) 910
July 19/94

Canopy Pot 55%
Sub Bf 5%

Shrub Corycor } 25%
Acerspic
Bf
Blue-bead lily
Sarsp.

Moss on downwood < 5% (feather)

Litter Pot 90% leaves

Downwood Bf skinny

heights
Canopy Pot -1, +31
Pot -1, +32
Sub Bf -1.5, +14
Bf -1, +13

V7 Trembling Aspen - Balsam Fir
- very large trees in here (Pot)

APPENDIX V

DERIVATION OF FOREST FRAGMENTATION VARIABLES FROM LAND COVER MAP

LCUT = proportion unforested on 280 ha around survey site

SCUT = proportion unforested on 2 ha around survey site

Calculation of proportion unforested

LANDSAT TM DERIVED
LAND COVER MAP CLASSES

1. Emergent marsh	
2. Open wetlands	
3. Thicket swamps	
4. Conifer wetland	
5. Herbs and shrubs....................	
6. Shrubs and young trees	
7. Young trees and shrubs	Unforested land classes
8. Deciduous trees.....................	
9. Mixedwood > 50% deciduous-----------	
10. Dense conifer	
11. Conifer on exposed bedrock	*Forest land classes*
12. Red and white pine mixedwood--------	

Proportion unforested = areas in classes.....

$$\frac{5 + 6 + 7 + 8}{5 + 6 + 7 + 8 + 9 + 10 + 11 + 12}$$

APPENDIX VI

SAMPLE SPREADSHEET OF HABITAT DATA

a:\works.sav

site	plt	owl	v	set	demix	pinemix	majsp	sb	pj	potbw	prpw	canht	lcut	scut	interht	subcat	to20	to40	to60	to100	ba	basnag	tperha	tgt30
224	1	0	5	2	1	0	4	0	0	1	0	27.625	.4913	1.000	9.250	5	0	0	0	1	24	2	1264	20
224	2	0	4	2	1	0	4	0	0	1	0	22.500	.4913	1.000	3.375	2	1	0	0	0	.	.	146	0
224	3	0	5	2	1	0	4	0	0	1	0	16.500	.4913	1.000	5.250	3	0	1	0	0	20	14	1540	38
226	1	1	8	2	1	0	4	0	0	1	0	24.750	.3184	1.000	11.375	2	1	0	0	0	24	8	408	118
226	2	1	9	2	1	0	4	0	0	1	0	24.125	.3184	1.000	8.625	2	1	0	0	0	26	0	354	205
226	3	1	17	2	1	0	3	0	1	0	0	21.000	.3184	1.000	6.750	3	0	1	0	0	26	2	883	90
230	1	0	32	1	0	0	2	1	0	0	0	23.000	.2640	.0000	9.000	2	1	0	0	0	30	8	1118	103
230	2	0	0	1	0	0	1	0	0	0	0	.000	.2640	.0000	.	1	0	0	0	0	.	.	0	0
230	3	0	0	1	0	0	1	0	0	0	0	.000	.2640	.0000	.	1	0	0	0	0	.	.	0	0
234	1	0	38	1	0	0	2	1	0	0	0	9.625	.3215	.0000	.	1	0	0	0	0	12	0	4067	0
234	2	0	38	1	0	0	2	1	0	0	0	10.125	.3215	.0000	.	1	0	0	0	0	12	2	9749	0
234	3	0	33	1	0	0	2	1	0	0	0	20.500	.3215	.0000	9.375	2	1	0	0	0	42	8	2047	0
239	1	0	8	2	1	0	4	0	0	1	0	20.500	.3125	.4000	8.500	2	1	0	0	0	24	4	899	66
239	2	0	5	2	1	0	4	0	0	1	0	19.125	.3125	.4000	4.875	3	0	1	0	0	16	2	627	28
239	3	0	37	2	1	0	2	1	0	0	0	15.500	.3125	.4000	.000	1	0	0	0	0	28	6	2054	0
240	1	1	26	3	0	1	5	0	0	0	1	32.125	.2184	.0000	17.500	3	0	1	0	0	14	2	1431	18
240	2	1	6	3	0	1	4	0	0	1	0	26.125	.2184	.0000	8.250	2	1	0	0	0	14	2	392	22
240	3	1	26	3	0	1	5	0	0	0	1	34.500	.2184	.0000	21.500	3	0	1	0	0	6	2	19	19
242	1	1	4	3	0	1	5	0	0	0	1	23.375	.0000	.0000	6.875	3	0	1	0	0	6	16	154	0
242	2	1	12	3	0	1	5	0	0	0	1	24.125	.0000	.0000	12.375	2	1	0	0	0	20	4	741	70
242	3	1	12	3	0	1	5	0	0	0	1	30.625	.0000	.0000	13.375	2	1	0	0	0	22	4	362	86

APPENDIX VII

METHOD FOR REDEFINING LAND COVER CLASSES INTO BARRED OWL HABITAT WITH ERDAS® GIS MODELLING COMMANDS

```
LANDSAT TM DERIVED
LAND COVER MAP CLASSES
1.  Emergent marsh
2.  Open wetlands
3.  Thicket swamps-------------------->
4.  Conifer wetland
5.  Herbs and shrubs
6.  Shrubs and young trees------------>         [RECODE]
7.  Young trees and shrubs------------>         1 = non-selected (poor)
8.  Deciduous trees                             0 = selected (good)
9.  Mixedwood > 50% deciduous                         |
10. Dense conifer--------------------->               |
11. Conifer on exposed bedrock-------->               |
12. Red and white pine mixedwood                      |
                                                      |
                                                [SCAN]
                                          scan class 1
                                          majority analysis
                                          circular window
[CLUMP]<<<<<----------------------------- r= 5 pixels
clump class 1                             majority threshold = 1
connectivity r = 1                        include zero input values
      |
      |
[SIEVE]
clumps of poor habitat class (1)
min. clump size = 3500 pixels
      |
      |
[CLUMP]----------------------------->>>>[SIEVE]
clump class 0                             clumps of good habitat
connectivity r = 1.5                      min. clump size = 3500 pixels
                                                |
                                                |
      BARRED OWL <<<<-------------------- [RECODE]
      HABITAT MAP                          1 = poor habitat
                                           0 = good habitat
```