VERIFYING MANITOBA'S 1994 DRAFT BARRED OWL HABITAT SUITABILITY INDEX MODEL

By

Amy E. Kearns

A practicum submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements for the degree of Master of Natural Resources Management

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FACULTY OF GRADUATE STUDIES
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ABSTRACT

The barred owl (*Strix varia*) is a forest-dwelling owl inhabiting a variety of forests with similar vegetative structures. It depends on older forests for nesting, roosting, and to a lesser extent, foraging habitat. Biologists designated the barred owl as an indicator species for these forests and in December 1994, they developed a draft habitat suitability index model (HSI) to describe this dependent relationship. Research was initiated in response to these actions. The primary purpose of the research was to evaluate Manitoba's 1994 draft HSI model in Manitoba. The specific objectives of the research were to describe habitat characteristics associated with barred owls in Manitoba; to verify the HSI model developed for the barred owl in Manitoba and; to make recommendations for modifying the HSI model in Manitoba. In order to accomplish these objectives, data from Manitoba's Nocturnal Owl Survey (NOS) and the Forest Resource Inventory (FRI) database were used. Inferences about habitat associations of barred owls were made by comparing locations at which barred owls were detected (DT) versus locations where they were not detected ≥4 years (UD). Habitat associations were examined at 6.25 ha and 400 ha scales using logistic regression (LR). The LR model predictive capability was 80%. The 6.25 ha

scaled LR model consisted of 4 variables: conifer forests, crown class 4, cutting class 4 and cutting class 5. The cutting classes were the most influential variable in the LR model, with -2 log likelihood ratios of 37.424 ($p = 0.000$) and 27.2430 ($p = 0.000$) for cutting classes 4 and 5, respectively. At the 400 ha scale, the LR model consisted of 3 variable sets: cutting class, species composition and unproductive forests. Cutting class was the most influential variable set with a -2 log likelihood ratio of 13.568 ($p = 0.0189$). The predictive capability of the LR model was 83%. The probability of detecting a barred owl given the model and data is $1/(1 + e^{-[4.6381 - 10.7387(Ct0) - 11.5728(Ct1) + 3.0912(Ct2) + 4.4255(Ct4) + 7.6832(Ct5) - 6.9382(Cm) + 3.1095(Hm) - 2.2952(H) - 9.2396(Unp)]})$ indicating the barred owl prefers older, hardwood dominated mixed wood forests and avoids unproductive and younger forests. The LR analysis refutes the HSI model assumptions that crown class is a more influential variable than species composition. It is recommended that crown class be eliminated from the HSI model in response to the LR model analysis. Future research should focus on further calibrating the remaining variables in the HSI model and developing a more precise measure of barred owl response to changes in these habitat variables.

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Thank you to Dennis Murphy, my statistical advisor and friend, who made sure I did not become just another ecologist with a p-value and a blind faith in the null. To paraphrase Cohen: I now know statistical significance tests do not tell me what I want to know, even though I really, really want them to and no matter how desperate I become I will not give up and believe they do anyway! Oh yeah, and the earth is round ($p < 0.05$)... I think I read that somewhere so it must be true.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

Forest resource use patterns influence the distribution of flora and fauna locally, regionally and globally. The magnitude of variation among neighboring habitats can create a beneficial or hostile environment for animals, influencing the persistence or demise of individuals, populations and meta-populations. Recognizing and understanding the interaction between these various elements and processes is critical to managing and mitigating their impacts.

Resource managers have developed many tools for making informed resource decisions. One of these management tools in use today is modeling. Modeling provides a mechanism for gaining a better appreciation of these impacts and how they influence flora and fauna through space and time. There are two broad approaches for developing models: building models using data analysis or building models from literature and expert opinion (Hall and Day 1977). Models can range in complexity from sophisticated population models to more parsimonious habitat suitability index models (HSI). Population models are often difficult and expensive to generate, requiring long-term research. HSI models were developed as a quick assessment tool in response to the need for less intensive modeling techniques (O'Neil et al. 1988; Brooks 1997).

The simplicity and wide applicability of HSI models have made these models one of the most popular resource management tools available (Brooks 1997). Currently, these models are experiencing a resurgence among resource managers (Bender et al. 1996; Brooks 1997; Breininger et al. 1998). Many of these models have generally been developed using expert opinion and literature, incorporating data analysis into the process after the models have been developed. For this reason, it is important to critically assess not only the processes used to develop the HSI models, but also the models themselves.

In 1994, the Manitoba Forestry/Wildlife Management Project (MFWMP) designated the barred owl (*Strix varia*) as an indicator species, and developed an HSI model as part of its ecosystem strategy utilizing the Forest Resource Inventory database(FRI)(MFWMP 1994). The HSI model has undergone preliminary stages of verification; however, more research was deemed necessary prior to implementing the model into management scenarios (Duncan 1995). A better understanding of the barred owl's ecological role and its habitat associations in Manitoba is essential to managing barred owl habitats in Manitoba.

The barred owl is one of many animals impacted by forest resource use patterns over time. However, the impact that forest resource use patterns have had on the barred owl has not been studied empirically. Allen (1987) hypothesized historical (1800-Present) forest clear-cutting and the suppression of fire increased the amount of mixed woods throughout western North America, thus allowing the barred owl to expand its North American breeding range. Conversely, Bosakowksi (1994) proposed recent (within 50 years) forest clear-cutting practices have caused declines in local and regional populations of barred owls in New Jersey, attributing these declines to habitat fragmentation and an increased interaction between the barred owl and the great horned owl (*Bubo viginanus*). These hypotheses stress the relevence time, space, and the level of competitive interactions have on inferences made about habitat selection by animals.

The barred owl occupies a variety of habitats sharing similar vegetative structures. It prefers mature, mixed woods, upland forests and lowland swamps (Johnsgard 1988). These older forests provide nesting cavities, abundant prey, protection from mobbing and predation, thermal insulation and allow the barred owl to move freely beneath the canopy (Bosakowski et al. 1987;

Burton 1992). It hunts along riparian corridors and small openings taking a wide variety of prey (Johnsgard 1988; Bosakowski and Smith 1992).

Senescent forests are essential to the reproductive success of the barred owl (Allen 1987; Johnsgard 1988; Bosakowski 1994; Duncan 1995). These senescent forests are characterized by the presence of large, dead and decaying trees (snags). The importance of these older forests for providing nesting cover for the barred owl has prompted owl biologists to designate the barred owl as an indicator species for North America's older forests (Allen 1987). According to McGeoch and Chown (1998), an indicator species is an organism whose "presence or absence reflects some measure of the habitat in which they are found". In response to this designation, several HSI models were written as an expression of this dependent relationship (Allen 1987; MFWMP 1994; Beck et. al. 1995).

1.2 ISSUE STATEMENT

The barred owl is considered a rare (COSEWIC status), year-round residential owl occupying older mixed wood and boreal forests in Manitoba (Duncan 1996). Despite the limited research that has been conducted on the species in Manitoba, the barred owl has been designated as an indicator species, and a draft HSI model has been developed to describe the relationship between barred owls and Manitoba's forests. The HSI model was designed to be a tool for managing barred owl habitat, but has undergone limited scrutiny.

1.3 OBJECTIVES

The primary purpose of this research was to evaluate Manitoba's 1994 draft HSI model for the barred owl. The specific objectives of the research were as follows:

1. to describe habitat characteristics associated with barred owls in southeastern Manitoba;
2. to verify the HSI model developed for the barred owl in Manitoba and;
3. to make recommendations for modifying Manitoba's 1994 draft HSI model.

CHAPTER 2

BARRED OWL DEMOGRAPHICS AND MODEL DESCRIPTION

2.1 BARRED OWL DEMOGRAPHICS

2.1.1 DISTRIBUTION AND MOVEMENT PATTERNS

The barred owl is a wide-ranging, forest-dwelling owl, found throughout the forested regions of North America (Figure 2.1). In the boreal forest, the barred owl prefers older, mixed wood forests (Takats 1995; Van Ael 1996; Mazur 1997)and in Manitoba, its range coincides with the forested regions(Figure 2.2).

Young disperse and define territories away from their natal territory occupying a larger, undefended home range prior to establishing and defending their own territory. The barred owl has a highly variable home range varying in size between 565 and 2524 ha (Duncan 1995). Nicholls and Warner (1972) reported a home range size of 226 hectares in Minnesota; while, Elody and Sloan (1985) report a similar home range size of 282 hectares in Michigan. Fuller (1979) estimated the home range for the barred owl to be 655 hectares in Minnesota. In Saskatchewan, home ranges for barred owls were between 91.4 ha and 363.5 ha during the breeding season, and between 573.4 ha and 2678.4 ha during

Figure 2.1 North American range of the barred owl as described by Johnsgard (1988). The map depicts residential ranges of the races *georgica* (ge), *helveola* (he), *sartorii* (sa) and *varia* (va). Light stippling indicates the recent range extension of the barred owl's range in western North America.

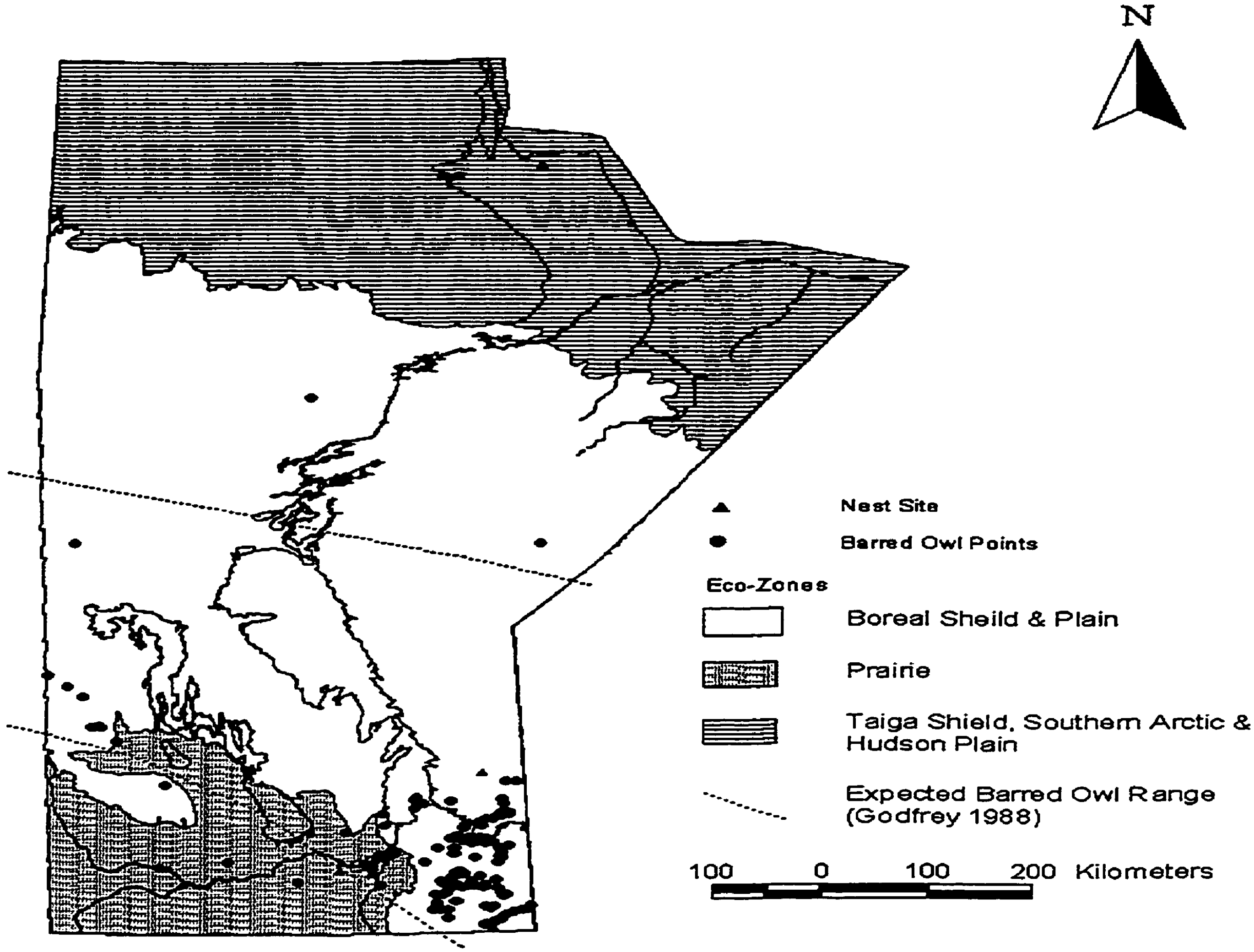

Figure 2.2 Expected (Godfrey 1986) and observed distribution of the barred owl (*Strix varia*) in Manitoba from 1892 to the present. The distribution is based on incidental records and the Nocturnal Owl Survey conducted from 1991-1997 (Duncan and Duncan 1997).

the non-breeding season (Mazur 1997). Barred owls are year-round residents throughout their range. Male barred owls tend to expand their range during winter when prey availability is low while females tend to occupy a core area surrounding the nest (Mazur 1997). Barred owl pairs have been documented remaining in the same general area for 10 years. Baekken et al. (1987) concluded the variability in the barred owl's home range might be influenced by the availability and continuity of preferred habitat; Schoener (1968) and Lindsteldt et al., (1986) speculated that seasonal fluctuations in prey availability as the primary reason for shifts in the owl's home range. Nicholls and Fuller (1987) speculated that protection of valuable nest sites was the primary motivation for the barred owl's high site fidelity.

2.1.2 REPRODUCTION AND REPRODUCTIVE HABITAT

The breeding season of the barred owl begins in late February to early March and ends in late May in Manitoba. When the young hatch, both adults care for them (Duncan 1995). Young remain in the nest for three weeks prior to leaving the nest and begin to venture further from the nest when they are four to five weeks old. Barred owl young fledge when they are six weeks old.

Very little is known about nestling mortality of the barred owl. Apfelbaum and Seelbach (1983) reported a success rate of 2.02 nestlings from 55 broods; while, Devereux and Mosher (1984) reported 1.9 nestlings per nest in seven nests with one nestling fledging per nest. The great horned owl is the primary predator of nestlings and sometimes adult barred owls (Laidig and Dobkin 1995).

2.1.3 FORAGING AND FORAGING HABITAT

The barred owl is a nocturnal predator that prefers to hunt in small openings and along riparian corridors. It consumes a wide variety of prey items it can readily subdue including mammals, birds, amphibians,invertebrates and even fish (Alcorn 1986; Bosakowki 1987; Bosakowski and Smith 1992). The barred owl also tended to be euryphagic, consuming wetland species such as frogs and crayfish (Bosakowski and Smith 1992). Takats (1995)concluded that red squirrels (*Tamiasciurus hudsonicus*) were an important mammalian species taken by the barred owl in Alberta.

2.1.4 ROOSTING COVER

Roosting sites are an important habitat component for the barred owl. According to Voous (1988), the barred owl commonly roosts 5 m off the ground. In winter, roosting trees provide thermal insulation. It is not uncommon to see a barred owl roosting in a tree during the day. Roosting trees are used for protection, cover and hunting perches (Bosakowski and Smith 1992).

2.2 THEORETICAL CONSTRAINTS OF HSI MODELING

2.2.1 BACKGROUND

Models can be as complex as spatially explicit population models (SEPM), population viability analysis models (PVA) or as parsimonious as a habitat suitability index model (HSI). However, even the most basic HSI model requires an appreciation of what drives species-habitat relationships. Most research dealing with HSI modeling has put the emphasis on habitat, treating suitability as a criteria for distinguishing between used and unused habitat. However, suitability has far reaching implications beyond defining usable and unusable habitat. Understanding the concept of suitability requires a rudimentary appreciation for life requisites and the cognitive processes an animal employs in acquiring these resources. In addition, the spatial and temporal distribution of various habitats should be considered. Both are paramount to successful modeling; at minimum, these concepts should be considered during modeling exercises. Ideally, they should be integrated directly into the models themselves.

HSI models were developed in the 1970's using a technique referred to as Habitat Evaluation Procedures (HEP) in response to the U.S. National Environmental

Protection Act (NEPA). Habitat evaluation procedures (HEP) and ecological land surveys (ELS) form the basis of HSI modeling and dictate the methods used to produce HSI models. Managers, wildlife biologists and environmental assessment committees developed these models as tools for conducting environmental impact assessments, the primary mandate stipulated under NEPA to relate generalized habitat features to a specific wildlife species or aggregate of species and their respective populations (Starfield 1997). HSI models allowed decision-makers to consider wildlife and their habitat requirements when developing impact assessments and during the planning stages of developing management plans (Stiehl 1995). The process for developing the model involves prioritizing the important life requisites of an animal into its most salient components. Food, water and shelter are considered to be the essential life requisites for all organisms. These life requisites are translated into a series of variables that describe suitable habitat. One or more life requisite can be developed into a model depending on the model developer's assumptions. Variables are chosen from a comprehensive database in order to build upon available resources, save money and facilitate the implementation of the model into management strategies. The model development testing and validation process should be documented and recorded.

Many of the procedures still rely heavily on readily available resources such as literature and expert advice. As a result, most models are based on literature review and some manifestation of an expert system analysis. Today, ecologists are recognizing the need to incorporate more scientific rigor and formal data analysis into HSI model development (Akcakaya 1992; Brieninger et al. 1997). Much of this realization has come as result of model testing and evaluation, which uses increasingly sophisticated statistical procedures (Schroeder 1990; Conway and Martin 1993). Starfield (1997) views flexibility and the use of adaptive management as key elements in the successful development and verification of HSI models. As these models evolve, it is important that the models remain flexible, but it is more critical, that they remain eloquent without becoming oversimplified (Starfield 1997). HSI models have wide appeal as a result of their simplicity and accessibility; many users appreciate the simple mathematics and graphical presentation (Brooks 1997). It is this simplicity (in part) that has caused a resurgence in their use (Brooks 1997). It is critical that HSI models be logical; as well as, technically sound. When it is time to verify and test the model's performance, these technical should be examined prior to statistical analyses. It is the first step in successful modeling.

HSI models have been widely criticized for their simplicity, limited applicability, and inaccuracy. Managers often develop and partially verify these models through extensive literature reviews and expert systems analysis (ESA). Field data is used in a substantive way during the verification stage rather than the formative stage. As a result, many models require much modification when used under field conditions (Schroeder 1990; Brooks 1997). Criticisms have centered on the response measurement used to evaluate and administer HSI models as well. Most model users persist in using animal abundance and density values as the response variable that Van Horne (1983) and Hobbs and Hanley (1990) have illustrated are not necessarily reflective of habitat quality. Holt et al. (1995), Turner et al. (1995) and Breininger et al. (1998) have advocated linking spatially explicit population models to vegetation models such as HSI models. Although Kareiva and Wennergren (1995) agree such links should be made, they contend it remains to be seen if these models can be incorporated into habitat management regimes profitably. Akcakaya et al. (1995) have developed software that links population viability analysis to HSI models. Breininger et al. (1998) have initiated research that has incorporated demographic information into the HSI validation process.

HSI models have also been criticized for reducing information about habitat use into suitable and unsuitable habitats where habitats are scored on a scale between 0 and 1. Lande (1988) criticized this approach citing the example of the spotted owl. Research conducted by Lande (1988) revealed local spotted owls populations became extinct even in the presence of suitable habitat. Lande (1988) concluded changes in habitat connectivity and heterogeneity were potential barriers to spotted owl persistence in this example and emphasized the need for incorporating these variables into suitability models. Lande (1998) suggested linking HSI models to productivity measures to accentuate the impact the spatial arrangement has on the persistence of species. By linking HSI models to productivity values, habitats could be scored by their demographic potential for a particular species.

2.2.2 HABITAT SUITABILITY INDEX MODEL FOR THE BARRED OWL

A draft HSI model was written for the barred owl in Manitoba during a 1994 workshop sponsored by the Manitoba Forestry/Wildlife Management Project (MFWMP).

The HSI model was organized into five main components. These components are described as follows:

1. Written Description
2. Tree Diagram
3. Variable Descriptions (Graphs)
4. Model Equation
5. Assumptions (MFWMP 1994).

The draft barred owl model consists of three variables: cutting class (V1), crown class (V2) and species composition (V3). Cutting class consists of five subcategories reflected in the variable graph. Crown class consists of four subcategories. The species composition graph consists of two curves. The first, lower curve depicts the array of suitability scores associated with forest stands without white spruce. The second curve depicts suitability scores for forest stands with white spruce. Model developers assumed white spruce enhanced barred owl nesting cover.

Cutting class is considered to be the variable most closely associated with the presence or absence of barred owls. Crown class is considered second to cutting class. Species composition is considered the least important in predicting the presence or absence of barred owls, and therefore is treated differently in the model than the other variables. Differences are reflected in the variable description and model equation.

The model equation is a geometric mean describing the relationship between the variables and their respective suitability scores. Separate equations were developed for stands with and without white spruce because the developers assumed white spruce would enhance barred owl nesting cover.

HSI Equation with white spruce = $(V1*V2*V3)^{1/3}$

Eq. 2.1

HSI Equation without white spruce = $(V1*V2*(V3^{1/2}))^{1/3}$

Eq. 2.2

2.2.3 MODEL ASSUMPTIONS

As with any model, the HSI model for the barred owl has many simplifying assumptions. These assumptions are necessary to produce a useful and effective management tool. The 1994 draft HSI model for the barred owl has several implicit and explicit assumptions. These assumptions include:

1. Habitat structure is more important than tree species
2. Crown closure is limiting in a linear fashion.
3. Cutting class is the most critical factor influencing the availability of the variables.
4. Prey and nest site availability are the two most limiting factors.
5. Habitat suitability can be expressed as a positive, linear relationship with a slope = 1 and y intercept of 0.

6. Barred owls prefer canopy heights greater than 20 m
7. Barred owls avoid cutting class 0 with increasing preference towards classes 2-4.
8. Forest Cover type is less important relative to the other two variables.
9. Simplifying species composition to percent conifer in overstory is justified.
10. Extensive stands of pure hardwood and pure conifer stands are avoided.
11. Barred owls prefer mixed wood forests.
12. Index relationships for all variables must be aggregated to get an overall suitability index value.
13. A weighted geometric mean should be used when variables are not equal in their significance
14. The presence of white spruce markedly improves the value of habitat to barred owls.
15. Species-habitat relationships can be translated into variables that are of value to both wildlife and humans.
16. The model assumes that meeting reproductive cover needs will ensure year round habitat requirements will be met.
17. Barred owls require a minimum of 500 ha of contiguous habitat before a pair will occupy an area.

2.3 SUMMARY

Barred owls are dependent on older forests in Manitoba for reproduction. An HSI model was written for the barred owl to describe this dependent relationship. The HSI model was developed to link forest resources uses

with the management of barred owl habitat. The intent of the research was to ensure the persistence and security of barred owl populations across Manitoba.

CHAPTER 3

METHODS

The habitat analysis was organized into two stages. The first stage involved determining the habitat characteristics associated with barred owl in Manitoba. The second stage involved evaluating the HSI model in light of these habitat associations.

3.1 DESCRIBING HABITAT CHARACTERISTICS

Data needed to accomplish the first task were provided by several individuals and government agencies described below. The data were derived, compiled and analyzed in four steps:

1. Data Derivation and Preliminary Evaluation: Data were derived from nocturnal owl survey data sheets provided by Duncan and Duncan (1997). Information from the data sheets was collected for use in the habitat analysis. Bearings and distances recorded by surveyors were used to plot barred owl locations on National Topographical Survey (NTS) maps. This step was performed by the author and Jim Duncan. Northings and Eastings were recorded from the NTS maps and recorded into a digital database. Only location data for survey routes conducted for 4 or more years were mapped.

2. Description of Habitat in Survey Area: The general habitat characteristics in the survey area were described prior to formal data analysis.

3. Scale and Site Selection: Habitat data were collected from forest inventory maps at two spatial scales: 6.25 ha blocks and 400 ha blocks. Undetected locations were selected randomly from surveyed areas. Habitat analysis was limited to survey routes conducted for 4 or more years. Therefore, undetected locations reflect locations where barred owls were undetected for four or more years.

4. Habitat Mapping: Habitat characteristics within the 6.25 ha and 400 ha blocks were mapped from forest inventory maps (1:50000) and these data were recorded into a database.

5. Habitat Analysis: Barred owl blocks were compared to undetected blocks using logistic regression. Mixed logistic regression was used to analyze data collected at the 400 ha block size.

3.1.1 DATA DERIVATION AND PRELIMINARY EVALUATION

Bearings and distances recorded by volunteers on the Nocturnal Owl Survey (NOS) data sheets were used to plot owl locations onto the NTS maps. Triangulation was used to map owl locations when forward and back bearings were provided by the surveyors. Once the owl locations were plotted on NTS maps, the location coordinates (Northings and Eastings) for each owl were recorded into a database. The Northings and Eastings were converted to latitudes and longitudes in GSRUG (program for converting spatial coordinates) prior to transfering the location data into Manitoba Conservation Data Centre's Biological Information Spatial System (BISS). An ArcInfo coverage layer was generated from BISS, and used by Manitoba Department of Natural Resources, Forestry Branch to merge the barred owl coverage layer with the FRI database. A series of township maps depicting the forest characteristics associated with barred owl locations were produced. A legend containing information on each stands' attributes was printed for each map series.

3.1.2 DESCRIPTION OF HABITAT IN SURVEY AREA

The survey area is primarily located in the southeastern region of Manitoba, Canada. It consists of three distinct ecozones: Aspen Parkland, Prairie, and Boreal Shield. Forest cover types include closed stands of coniferous forests, humid mixed wood forests and broadleaf forests. Manitoba's coniferous forests typically include white spruce (*Picea glauca*), black spruce (*Picea mariana*), and tamarack (*Larix lariciana*). The more humid, southeastern mixed wood forest include trembling aspen (*Populus tremuloides*), red pine (*Pinus *resinosa*) and jack pine (*Pinus banksiana*). In addition to forests, there are extensive areas of bogs and wetland areas (Ecological Stratification Working Group 1995).

A volunteer nocturnal owl survey has been conducted in southeastern and part of northern Manitoba in April from 1991 to 1997 (Duncan and Duncan 1997). The raw data collected from these surveys were used with permission of Jim and Patsy Duncan to conduct habitat analysis and make inferences about the HSI model. Data on the number and species of owls detected, the bearings and distances associated with each owl detected during the survey and weather conditions during the survey were collected during the survey. Bearings and distances from the survey data sheets were used to plot barred owl locations on maps.

3.1.3 SITE AND SCALE SELECTION

Two spatial scales were chosen to describe barred owl habitat associations: 6.25 ha and 400 ha blocks. The smaller spatial scale was used to assess habitat immediately surrounding locations where barred owls were detected versus locations where barred owls were not detected. The second spatial scale was used to examine the relative abundance of various habitats. Habitat data were provided by Manitoba Department of Natural Resources Forestry Branch in the form of forest inventory maps.

Locations at which barred owls were detected are referred to as detected locations, while locations at which barred owls were not detected are referred to as undetected locations. Detected and undetected locations used in the analysis were restricted to locations associated with surveys conducted for four or more years. This ensures that undetected locations reflected locations at which barred owls were not detected consistently for at least four consecutive years.

For the larger scale, undetected locations were limited to township maps where no barred owls were detected to avoid overlap with barred owl locations. Township maps with barred owl locations are referred to as barred owl maps, and township maps without barred owl locations are referred to as survey maps.

Each survey map was further subdivided into a series of 25, 400 ha blocks. These 400 ha blocks were further subdivided into 64, 6.25 ha blocks. A sub-sample of these 400 ha survey blocks was randomly selected. The sub-sample was limited to blocks within 4 km of the survey route to reflect the limited, effective strip width of the routes. It was assumed the range of a potential calling barred owl fell within this distance measure, and that blocks outside this distance were effectively unsurveyed.

The same 400 ha block size was used for the barred owl maps; however, blocks were centered on the barred owl locations. Like the survey maps, barred owl maps were sub-divided into 64, 6.25 ha blocks. Some blocks incorporated multiple barred owl locations. The multiple occurrences within these blocks were pooled and treated as one independent observation, reducing the number of mapped barred owl locations significantly.

3.1.4 HABITAT MAPPING

Cutting class, crown class, and species composition were recorded for each detected and undetected 6.25 ha block. Data were recorded as frequencies for each variable. Data were organized into a series of one way and two way contingency effects tables. Logistic regression was used to determine habitat associations.

The same variables were used for the larger spatial scale (Table 3.1). These data are organized into three variable sets: successional stage, crown closure, and species composition. Successional stage refers to the dominant cutting class present in each sub-block. Crown closure refers to crown class. Species composition was translated into five broad categories: hardwood dominated forests, hardwood dominated mixed wood, conifer dominated mixed wood, conifer dominated forests and unproductive forests. The total area (%) of each cutting class, crown class and species type was tabulated to establish the relative abundance of each habitat attribute within the 400 ha buffer. A brief description of these variables is contained in Table 3.1 with a more complete description in Appendix D.

3.1.5 HABITAT ANALYSIS

Location data for each scale were defined as one of two response classes (detected vs. undetected). Detected locations were coded as 1; undetected locations were coded as 0. Habitat data for the 6.25 ha scale were summarized into frequencies for the 6.25 ha blocks. These tables describe the absolute frequencies for each cutting class, crown class and species composition.
Absolute frequencies reflect the number of occurrences observed for each response class relative to the total number of occurrences observed for that cutting class, crown class or species type. Within response class frequencies (%) are not reported because these values are not independent. Data for the smaller scale were also entered into S+ as contingency tables and analyzed using logistic regression. The log likelihood ratios were examined for each variable step to determine which variable sets would be kept and eliminated at each step (Appendix C).

Habitat data derived from the 400 ha blocks were

Table 3.1. Abbreviations for habitat variables collected for the 400 ha scaled blocks associated with barred owl and undetected locations (Becker et al. 1996).

Variable	Description
Successional Stage	
UNP	Forested lands unsuitable for timber production. e.g. Black Spruce Bog
CUT0	Productive forest land with mostly grasses, some remnant trees and shrubs. e.g. clear cut
CUT1	Productive forested land with seedlings < 3 m in height
CUT2	Productive forested land with saplings > 3m and < 10 m
CUT3	Immature, productive forested land with trees > than 10 m and average DBH of 9.0 cm
CUT4	Mature, productive forest lands with trees > 20 m
CUT5	Overmature, forest land 10 to 20 years older than rotation age. Decay and disease are evident.
Dominant Crown Class	
CR0	Crown closure of 0-20 %
CR2	Crown closure of 21-50%
CR3	Crown closure of 51-70%
CR4	Crown closure > 71%
Species Composition	
UNP	See above
H	Forests dominated by hardwood and deciduous species. Includes Tamarack Larch.
HWM	Mixed wood forest dominated by hardwood and deciduous species (40-80% hardwood)
CM	Mixed wood forest dominated by conifer species (40-80% hardwood)
C	Forests dominated by conifer species

recorded as relative abundance values (%). Since habitat variables for the 400 ha blocks were recorded as percentages of a whole block (summing to 1.0 within each habitat variable set),the within set variables are not considered independent. Variable sets were re-parameterized to create a set of independent variables.

This re-parameterization was conducted prior to performing the mixed logistic regression model analysis. A ratio between a baseline variable and each variable was calculated to reparameterize the variables. Cutting class 3, crown class 3 and conifer were chosen as the baseline variables for successional stage, crown class and species composition respectively. Baseline variables were excluded from the mixed logistic regression analysis. The variable sets were entered into SPSS using a stepwise logistic regression procedure. Variable sets were eliminated based on the sum of the subcategory log likelihood ratios for each variable set. Degrees of freedom were derived from the number of variables within a variable set. The sum log likelihood and degrees of freedom were used to determine the statistical significance of the variable set. Variable sets with p levels above 0.10 were eliminated. Models for each variable set were created after the main model was fit. These models are refered to as sub-models. Sub-models were created using stepwise logistic regression in SPSS. Sub-models were created to examine the main effects of each variable set on the barred owl detection.

3.2 HABITAT SUITABILITY INDEX MODEL

HSI models have been modified using a variety of methods. O'Neil et al. (1988) modified many HSI models using expert knowledge and corroboration to enhance the fit of the HSI models. Starfield (1997) suggested a different approach by examining the structure and methodology used to develop the model including an investigation of the mathematical logic of the models. Brooks (1997) suggested a 5 step process for modifying HSI models.

For the barred owl HSI model, the logical and mathematical structure of the HSI model was examined prior to formal data analysis. These results are discussed briefly in Chapter 4. The individual components were then examined in light of the habitat analysis. The data sets used to describe the habitat associations of the barred owl prohibit an direct examination of the HSI model; therefore inferences concerning the HSI model were indirect and inferred from the logistic regression analysis.

CHAPTER 4

RESULTS

Several trends were apparent from the data analysis conducted. These trends were compared to the draft HSI model to determine if the habitat analysis corroborated with the HSI model description of barred owl habitat associations. Results from the logistic regression model analysis are presented first, followed by a description of the indirect inferences made about the performance of the HSI model. The ad hoc nature of the data analysis prohibits a direct verification of the model. Model refers to results generated from the logistic regression analysis (LR); the term HSI model is used when describing results pertaining to inferences made about the 1994 draft HSI model.

4.1 BARRED OWL HABITAT ASSOCIATIONS

4.1.1 HABITAT ASSOCIATIONS AT THE 6.25 HA SCALE

Habitat analysis at the smaller scale was performed to determine the relationship between barred owl detection and habitat immediately surrounding barred owl and survey locations. Overall, the logistic regression model (n=4 parameters) predictability was 80 %, but the within response class predictability varied greatly. The predictability for response class 0 was 87.70 %; whereas, the predictability for response class 1 was low at

62.82 %. This is illustrated in Figure 4.1 , which depicts the estimated probability of barred owl detection given the model and data.

For the logistic regression model, conifer forests were negatively associated with barred owl detection (Table 4.1). Older forests (Cutting Classes 4 and 5) and forests with high crown closure (Crown Class 4; 71 %+) were positively associated with barred owl detection (Table 4.1). The -2 log likelihood ratios for the mature and overmature forests indicate there is a strong relationship between these variables and barred owl detection (Table 4.2). The magnitude of the likelihood value indicates the strength of the relationship between the response variable and the model co variates; larger values indicate a stronger relationship. An examination of the residual deviance values for the data provides insight into the overall fit of the data to the model (Figure 4.2). The graph illustrates the poor fit of the data to the model at the smaller 6.25 ha scale.

Additional analyses were performed in S+. These results reiterated the results found in the SPSS model. A test of the main effects (single variable LR) models yielded no significant results (Table 4.3). An initial Akaike Information Criterion (AIC) was calculated and served as a value for comparison against a series of

Table 4.1. Description of the results of a logistic regression model (n=265) entered in SPSS. The model describes the relationship between a set of habitat variables and barred owl response along a series of nocturnal road survey routes conducted in southeastern Manitoba between 1991-1997 (Duncan and Duncan 1997). Habitat variables were collected at .25 ha scale.

Variable	Log Odds	Standard Error	Significance
Conifer Forests	-1.4499	0.6139	0.0182
Crown Class 4 (71 % +)	1.0449	0.3314	0.0016
Mature Age Class	2.1604	0.3643	0.0000
Overmature Age Class	2.5259	0.5130	0.0000
Constant	-2.0350	0.2598	0.0000

Table 4.2. Description of the -2 log likelihood ratio values for the logistic regression model describing habitat associations at the 6.25 ha scale.

Variable	-2 Log Likelihood Ratio	Significance
Conifer Forests	6.8370	0.0182
Crown Class 4 (71 %)	10.049	0.0015
Mature Age Class	37.424	0.0000
Overmature Age Class	27.430	0.0000

```
     160 +                                                          +
         |                                                          |
         |                                                          |
F        |                                                          |
R    120 +      1                                                   +
E        |      1                                                   |
Q        |      0                                                   |
U        |      0                                                   |
E     80 +      0                                                   +
N        |      0                                                   |
C        |      0                                                   |
Y        |      0         1                                         |
      40 +      0         1                                         +
         |      0         0                                         |
         |    0 0         0              1             1            |
         | 0  0 0         0              0     1       0   1        |
Predicted --------------+--------------+--------------+-------------
  Prob:   0            .25            .5             .75           1
  Group:  0                           0/1                          1

                  Predicted Probability is of Membership for 1.00
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Figure 4.1. Histogram depicting the estimated probabilities of barred owl detection for a logistic regression model with 4 habitat variables(6.25 ha scale). Each symbol represents 10 observations (n = 265 ; n_1 = 78 and n_0 = 187).

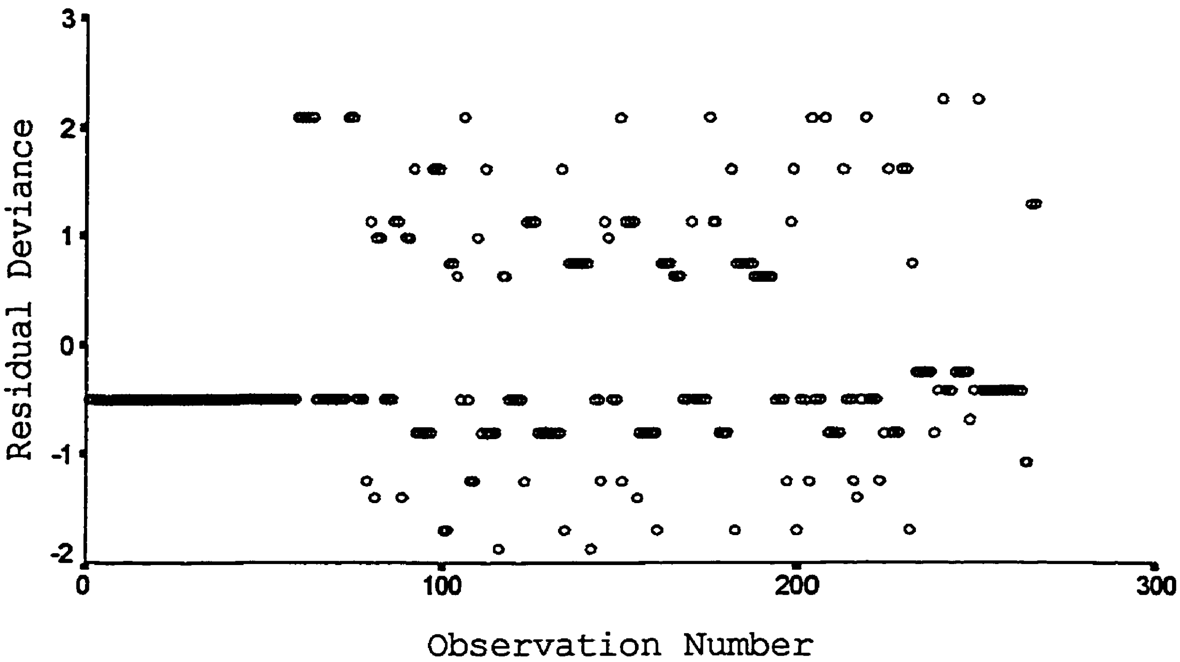

Figure 4.2. Graph depicting the residual deviance associated with each observation given the logistic regression model (n=4 parameters). The large number of observations with high residual deviance indicates the model is a poor fit to the data.

Table 4.3. Description of the results of main effects models for three habitat variables associated with detection and non detection along Manitoba Nocturnal Owl Surveys conducted in April from 1991-1997.

	Degrees of Freedom	Sum of Squares	Residual Sum of Squares	Cp
None			8.6622	20.6622
Crown Class	2	4.0936	12.7558	20.7558
Cutting Class	2	3.3313	11.9935	19.9935
Species	1	2.1916	10.8538	20.8538

covariate models. The initial AIC was 21.1817.

AIC is defined as:

AIC = -2 Maximum Log Likelihood + 2 * N parameters

(in the regression model) Eq. 4.1

A test statistic (Cp) was calculated for each main effect and compared to the initial AIC value. Logistic regression models yielding Cp values less than the AIC are considered improvements. Cp values were calculated as: Cp = RSS + 2* N parameters * Sigma ^2 Eq. 4.2

Where RSS = residual sum of squares and

Sigma^2 is an error term

When the two way effects models (two variable LR) were run all possible two way interactions were examined. Cp values were calculated for each two way model to determine which model resulted in the greatest improvement.

Variable cutting class produced the best results of the main effects regression models (Table 4.3). Crown class and species composition produced essentially the same results. When the variables were combined in two way effects regression models, the Cp values were higher than the initial AIC of 21.1817, indicating combining two variables did not explain any more error than the models only using one variable(Table 4.4).

Table 4.4. Description of the results of two-way effects models for three habitat variables associated with barred owl detection and non detection along Nocturnal Owl Survey routes in April 1991-1997.

	Degrees of Freedom	Sum of Squares	Residual Sum of Squares	Cp
None			8.6622	20.6622
Crown X Cut	4	3.0184	5.6437	25.6438
Crown X Species	2	0.1184	8.5437	24.5437
Cut X Species	2	3.4187	5.2434	21.2434

4.1.2 HABITAT ASSOCIATIONS AT THE 400 HA SCALE

Results from the larger, 400 ha scale were more apparent. Older forest classes occupied more area in barred owl 400 ha blocks than undetected locations (Figure 4.3). Undetected location had proportionally more unproductive forest within their 400 ha blocks than the barred owl blocks. On average barred owl blocks had proportionally more area devoted to higher crown classes (Figure 4.4). Barred owl blocks had proportionally more hardwood dominated forests than undetected blocks (Figure 4.5). Unproductive forests dominated the undetected blocks (Figure 4.5). Both the barred owl and undetected blocks had about the same amount of conifer dominated forests.

A set of logistic regression modeling exercises were performed for each variable. The abundance (% of block) of each subcategory were entered as the variables in the analysis. For example, the percent cutting class 0,1,2,4 and 5 were entered into the logistic regression model for cutting class, creating a submodel for variable cutting class. For the cutting class submodel, the mature and overmature subcategories were statistically significant and positive correlated with barred owl detection (Table 4.5). Cutting class 4 (mature cutting class) was more strongly associated with the barred owl blocks relative

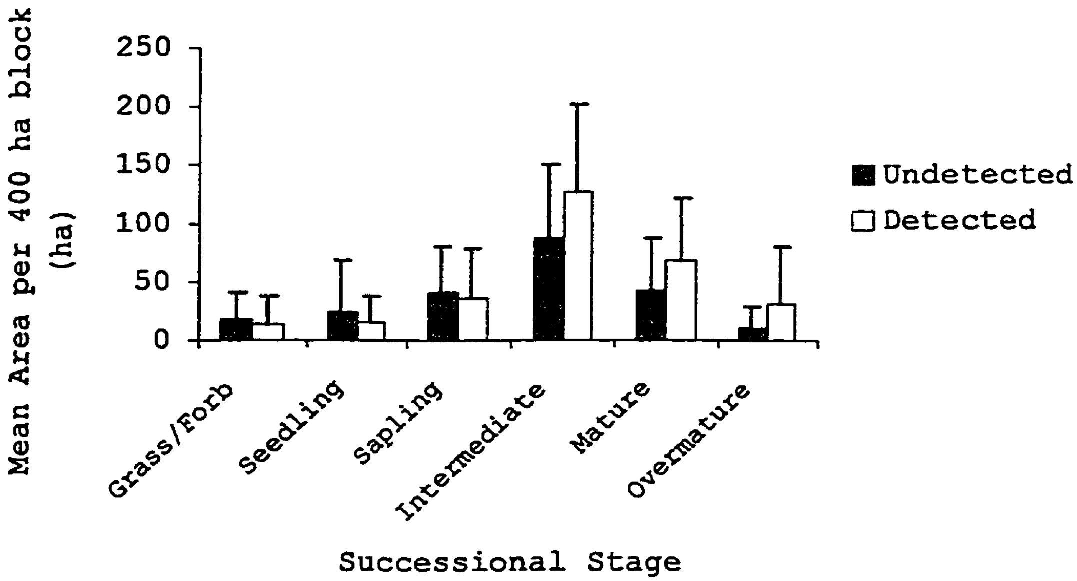

Figure 4.3. Comparison of mean area (ha) for a series of 400 ha blocks for detected and undetected locations for each cutting class. Error bars reflect standard deviations.

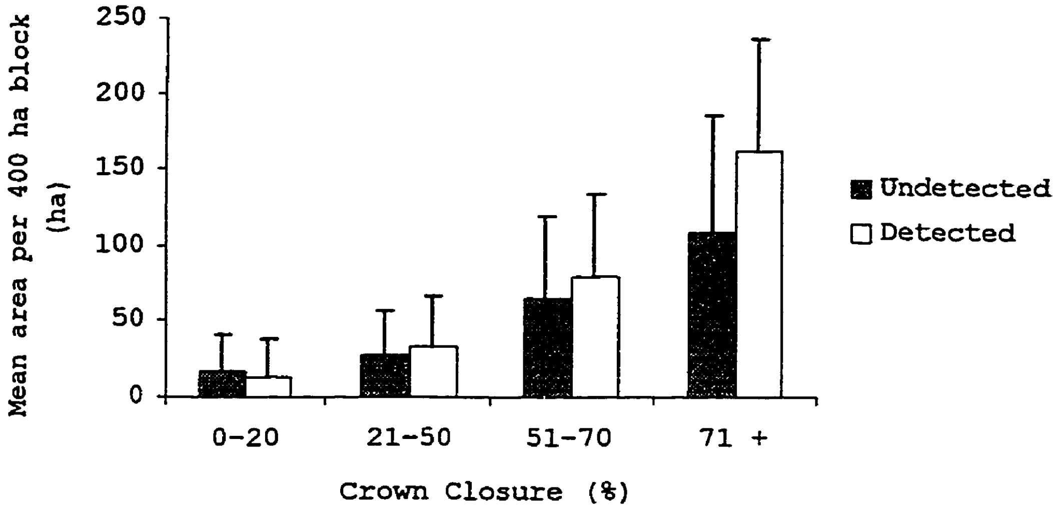

Figure 4.4. Comparison of mean area (ha) for a series of 400 ha blocks for detected and undetected locations for each crown class. Error bars reflect standard deviations.

Figure 4.5. Comparison of mean area (ha) for a series of 400 ha blocks for detected and undetected locations for each species composition. Error bars reflect standard deviations.

Table 4.5. Description of cutting class sub model variables entered into a mixed logistic regression model (n=70) in SPSS. Variables were re-parametrized as a ratio between a baseline variable (Vb) and the individual variable (Vn). The model describes the relationship between the habitat variables and barred owl response along a series of nocturnal road survey routes conducted in southeastern Manitoba between 1991-1997 (Duncan and Duncan 1997).

Variable	Log Odds	Standard Error	Significance
Establishment Age Class	0.6609	4.5213	0.8838
Seedling Age Class	-4.2100	3.0202	0.1633
Sapling Age Class	2.3078	2.6713	0.3876
Mature Age Class	9.0704	3.0654	0.00031
Overmature Age Class	7.7177	3.8981	0.0477
Constant	-1.2579	0.6910	0.0687

to cutting class 5 (overmature cutting class)(Table 4.6). This is evident by the log likelihood value and significance, which are larger for cutting class 4 than for cutting class 5. For the crown class submodel, both crown classes were statistically significant and positively correlated with barred owl blocks (Table 4.7). Crown class 4 had a higher log likelihood ratio, indicating it was more strongly associated with the barred owl blocks than for the undetected blocks(Table 4.8). For the species composition submodel indicates, hardwood dominated mixed wood forests were strongly associated with the barred owl blocks; while unproductive forests were negatively associated with the barred owl blocks (Table 4.9). With the exception of crown class, all of the relationships found in the submodels were reiterated in the overall logistic regression model (discussed later). When all of the variable sets were entered into a logistic regression model, the crown class variable set was not found to be significant and was not found to influence barred owl detection relative to the other two variables. Crown class was eliminated during the next step in the regression model.

Unproductive forests exhibited the strongest regression model relationship, with a log likelihood ratio of 6.038 (p=0.014), followed by hardwood dominated

Table 4.6. Description of the -2 log likelihood ratio values for cutting class in the model.

Variable	-2 Log Likelihood Ratio	Significance
Establishment Age Class	0.0210	0.8834
Seedling Age Class	2.1260	0.1448
Sapling Age Class	0.7630	0.3823
Mature Age Class	11.442	0.0007
Overmature Age Class	5.7800	0.0162

Table 4.7. Description of crown class sub model variables entered into a mixed logistic regression model (n=70) in SPSS. Variables were re-parametrized as a ratio between a baseline variable (Vb) and the individual variable (Vn). The model describes the relationship between the habitat variables and barred owl response along a series of nocturnal road survey routes conducted in southeastern Manitoba between 1991-1997 (Duncan and Duncan 1997).

Variable	Log Odds	Standard Error	Significance
Crown Class 2 (21-50%)	6.0521	3.5061	0.0843
Crown Class 4 (71 + %)	4.3248	1.5677	0.0058
Constant	-1.736	0.7306	0.0174

Table 4.8. Description of the -2 log likelihood ratio values for crown class in the model.

Variable	-2 Log Likelihood Ratio	Significance
Crown Class 2 (21-50%)	3.3600	0.0668
Crown Class 4 (71 + %)	8.7700	0.0031

Table 4.9. Description of species class sub model variables entered into a mixed logistic regression model (n=70) in SPSS. Variables were re-parametrized as a ratio between a baseline variable (Vb) and the individual variable (Vn). The model describes the relationship between the habitat variables and barred owl response along a series of nocturnal road survey routes conducted in southeastern Manitoba between 1991-1997 (Duncan and Duncan 1997).

Variable	Log Odds	Standard Error	Significance
Conifer Mixed Wood	-1.6263	2.2445	0.4687
Hardwood	1.57750	2.1094	0.4546
Hardwood Mixed Wood	4.72580	2.6164	0.0709
Unproductive Forests	-4.3981	1.0906	0.0204
Constant	0.79680	1.3195	0.5459

mixed wood forests with a log likelihood ratio of 3.57(p =0.0588)(Table 4.10).

When the mixed logistic regression (MLR)analysis was conducted using all three variable sets, the MLR model predicted 24 of 30 undetected observations to be members of the undetected response class or a prediction rate of 80 %. The model (n = 10 parameters) predicted 34 of 40 barred owl observations to be members of the barred owl response class 85 %. The overall fit of the model was 83 %. This fit is above the 80 % threshold required suggested by Mosher et al. (1984). Figure 4.6 can be used to examine the fit of the data given the logistic regression model. The plot presents the aforementioned classification rates graphically.

The initial -2 log likelihood value was 95.607. The regression model -2 log likelihood was 57.995. This value reflects a reduction in the log likelihood and is considered an improvement. An improvement in the regression model indicates the variables in the model explain some of the variation associated with the response variable (barred owl block vs survey block). The calculated Chi-square goodness of fit test was reported as 37.613, with a goodness of fit value of 55.940 (df = 9). This improvement was statistically significant at a p level of 0.000. The Chi-square value reflects the

Table 4.10. Description of the -2 log likelihood ratio values for species class in the model.

Variable	-2 Log Likelihood Ratio	Significance
Conifer Mixed Wood	0.5320	0.4657
Hardwood	0.5680	0.4509
Hardwood Mixed Wood	3.5700	0.0588
Unproductive Forests	6.0380	0.0140

difference between the observed log likelihood (regression model likelihood) and the expected log likelihood (initial log likelihood). The goodness of fit is a statistic associated with the Chi-square value that reflects the model improvement.

The log odds, standard errors, and significance values were reported for each co-variate (Table 4.11). With logistic regression analysis, it is important to look at the entire MLR model and not simply focus on reported significance values. The odds ratio reflects the ratio between observations associated with class 1 and class 0; therefore odds of 1 indicate "no difference". When the log odds associated with a variable begin to deviate from 1 it favors one response class over another. For log odds positive values indicate the probability of detection is greater than 50 %; while negative log odds indicates the probability of detection is less than 50 %.

In the case of the barred owl habitat model, log odds greater than 0 favored detection while log odds less than 0 favored non detection. Using this criteria to examine the MLR model, it becomes apparent conifer dominated mixed woods and younger forests (cutting classes 0 and 1) were strongly negatively associated with barred owl presence; while, older forests (cutting class

Table 4.11. Description of variables entered into a mixed logistic regression model (n=70) in SPSS. Variables were re-parametrized as a ratio between a baseline variable (Vb) and the individual variable (Vn). The model describes the relationship between the habitat variables and barred owl response along a series of nocturnal road survey routes conducted in southeastern Manitoba between 1991-1997 (Duncan and Duncan 1997).

Variable	Log Odds	Standard Error	Significance
Cutting (Age) Class			
Establishment Age Class	-10.7387	6.55	0.1015
Seedling Age Class	-11.5728	5.5154	0.0359
Sapling Age Class	-3.0912	3.6775	0.4006
Mature Age Class	4.4255	4.0894	0.2792
Overmature Age Class	7.6832	5.6891	0.1769
Species Class			
Conifer Mixed-wood	-6.9382	3.3261	0.0370
Hardwood Mixed-wood	3.1095	2.9236	0.2875
Hardwood Forests	-2.2952	2.9259	0.4328
Unproductive Forest	-9.2396	3.3223	0.0054
Constant	4.6381	2.5555	0.0695

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       8 +                                                          +
         |                                                          |
         |                                                          |
   F     |                                                          |
   R   6 +                                                          +
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   E   4 +                                                      1  1+
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   C     | 0          1                              1       1  1 11|
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       2 + 000        0    00    0          1   1    1  1 1  1 11111+
         | 000        0    00    0          1   1    1  1 1  1 11111|
         |0000 0001 0 00 110001 00 1 0   01111  1101 0 1001 10 11111|
         |0000 0001 0 00 110001 00 1 0   01111  1101 0 1001 10 11111|
Predicted --------------+--------------+--------------+-------------
  Prob:   0            .25            .5             .75            1
  Group:  0                           0/1

          Predicted Probability is of Membership for 1.00
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Figure 4.6. Histogram depicting the estimated probabilities of barred owl detection for a logistic regression model with 10 habitat variables (400 ha scale). Each symbol represents .5 observations (n = 70 ; n_1 = 30 and n_0 = 40).

4) with higher crown closure (crown class 4; 71 % +) were positively associated with barred owl presence. The importance of species composition towards detection is particularly noteworthy. One out of 3 of the variables associated with this co-variate set were statistically significant. Two out of 5 cutting class variables were statistically significant.

The summed log likelihood ratios for the cutting class, species composition and unproductive forest indicate these variable sets are important variables for predicting if a barred owl will be detected or not detected in a given habitat (Table 4.12). The summary log likelihood ratio for cutting class was 13.568 (df = 5; p =0.0189); while the summary log likelihood ratio for species composition was 6.910 (df = 3; p = 0.0788). Unproductive forests log likelihood ratio was 3.32 (df =1 ; p = 0.0054). Table 4.12 describes the log likelihood ratios for each subcategory within each variable set. These summary log likelihood values were used to determine which variable sets were removed. Variable sets with summary log likelihoods that were not statistically significant ($p < 0.1$) were removed in subsequent steps. For the MLR, crown class was non-significant and was removed during the third step of the regression analysis. The fit of the data given the

Table 4.12. Description of the -2 log likelihood ratio values for each variable in the model.

Term Removed	-2 Log Likelihood Ratio	Significance of Likelihood Ratio
Cutting (Age) Class		
Establishment Age Class	2.745	0.0976
Seedling Age Class	6.504	0.1080
Sapling Age Class	0.714	0.3980
Mature Age Class	1.197	0.2740
Overmature Age Class	2.408	0.1207
Cutting Class Sum	13.568	0.0189
Species Class		
Conifer Mixed-wood	5.112	0.0238
Hardwood Mixed-wood	0.622	0.4304
Hardwood	1.176	0.2783
Species Class Sum	6.910	0.0788
Unproductive Forest	11.302	0.0008

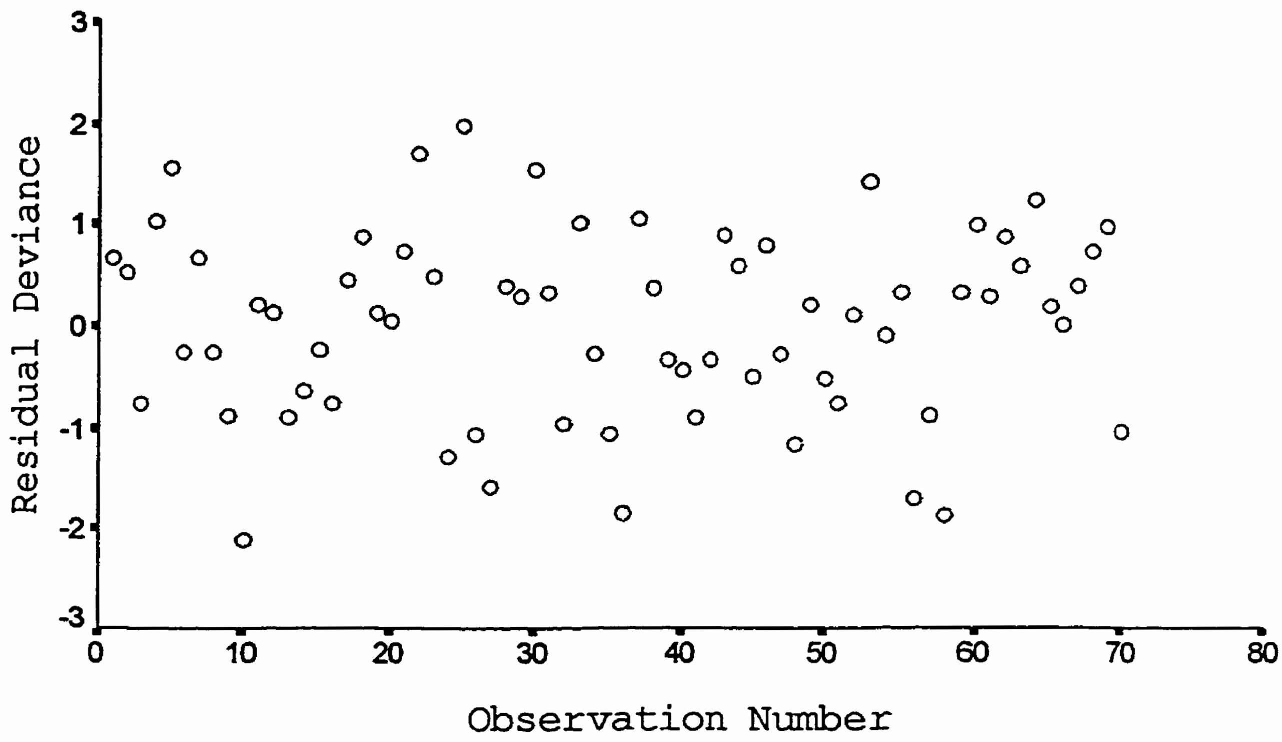

Figure 4.7. Graph depicting the residual deviance for each observation given the logistic regression model (n=10 parameters). The observations with large deviation values indicate there is the model is a poor fit to the data.

logistic regression model is illustrated in Figure 4.7.

4.2 VERIFYING THE HABITAT SUITABILITY INDEX MODEL

4.2.1 MECHANICAL ERRORS

Prior to formal analysis, the model was examined for mechanical and logical errors. During this stage in the verification process, a mechanical error was discovered. The error involved the third variable, species composition.

In the model description and equation, variable 3 (species composition) is weighted in two respects:

1. Model Relationships
2. Equation

The SI variable graph for species composition reflected a distinct difference in value between stands with and without white spruce. Stands without white spruce range in value between 0 and 0.5; whereas, stands with white spruce range in suitability between 0.2 and 1.0. The model stipulates that stands without white spruce should be weighted 50% less than stands with white spruce because the presence of white spruce is assumed to improve the suitability of the stand markedly. This stipulation is reflected in the variable graph where stands without white spruce are worth half the value of stands with white spruce. After the suitability index (SI) score is determined, the value is entered into the

HSI model equation. For stands without white spruce, an additional stipulation has been set. The square root of the SI score for stands without white spruce is taken before the score is entered into the HSI model equation. A careful examination of the square root transformation used to weight the variable in the equation reveals a different effect. Stands lacking white spruce are then subsequently weighted via a square root function. By taking the square root of a variable scaled between 0 and 1, the value increases rather than decreases (Table 4.13). Furthermore, the combined impact of the variable graph relationship and the square root function for species composition changes the weight of variable 3 only slightly relative to the others (Table 4.13).

4.2.2 INFERENCES CONCERNING THE HSI MODEL

The inferences concerning the HSI model are mixed. Some of the results of logistic regression substantiate assumptions and relationship made concerning the 1994 draft HSI model for the barred owl; while, other results contradict relationships described in the draft HSI model. A list of the assumptions examined in light of logistic regression analysis can be found in Table 4.14. This table is followed by a table comparing HSI model assumptions to the logistic regression analysis results (Table 4.15).

4.3 SUMMARY

In Manitoba, barred owls appear to be positively associated with older, hardwood dominated mixed wood forests and negatively associated with unproductive forests and younger forests. Crown class does not appear to be strongly associated with barred owl or non barred owl habitat.

Table 4.13 Comparison of suitability scores derived from species composition variable (V3) for a barred owl habitat suitability index model in Manitoba

Percent Conifer	Suitability Score (White Spruce Present)	Suitability Score (White Spruce Absent)	Square Root Transformation	Ratio (SIWSA:SIWSP)	Ratio (SRT:SIWSP)
0	0.00	0.00	0.00	0.00	0.00
10	0.30	0.15	0.39	0.50	1.29
20	0.60	0.30	0.55	0.50	0.92
30	0.80	0.40	0.63	0.50	0.79
40-80	1.00	0.50	0.71	0.50	0.71
90	0.50	0.25	0.50	0.50	1.00
100	0.00	0.00	0.00	0.00	0.00

Table 4.14. Description of assumptions made for the 1994 draft HSI model for the barred owl in Manitoba.

Crown Class Assumptions

Crown closure is limiting in a linear fashion

Barred owls prefer canopy heights greater than 20 m

Barred owls avoid crown class 0 with increasing preference towards classes 2-4.

Cutting Class Assumptions

Cutting class is the most critical factor influencing the availability of the variables.

Species Composition Assumptions

Species Composition is less important relative to the other two variables

Extensive stands of pure hardwood and pure conifer stands are avoided.

Barred owls prefer mixed wood forests

HSI Model Assumptions

A weighted geometric mean should be used when variables are not equal in their significance

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Table 4.15. Comparison of the 1994 draft barred owl HSI model assumption to habitat analysis.

Assumption	Inference from Habitat Analysis: 6.25 ha		400 ha	
	Yes	No	Yes	No
Crown closure is limiting in a linear fashion	X		X	
Barred owls prefer canopy heights greater than 20 m	X		X	
Barred owls avoid crown class 0 with increasing Preference towards classes 2-4.	X		X	
Cutting class is the most critical factor influencing The availability of the variables.	X		X	
Species Composition is less important relative to the Other two variables		X		X
Extensive stands of pure hardwood and pure conifer Stands are avoided. Barred owls prefer mixed wood forests	X		X	
A weighted geometric mean should be used when Variables are not equal in their significance		X		X

CHAPTER 5

DISCUSSION

5.1 DESCRIBING HABITAT ASSOCIATIONS

5.1.1 6.25 HA SCALE

The habitat analysis indicates there is not a strong interaction between the three FRI variables chosen for the HSI model and barred owl detection at the 6.25 ha scale. The logistic regression model has difficulty predicting the presence or absence of barred owls using the FRI variables at this scale. These confounding results may be due in large part to the low sample size and the large number of possible two way interactions. Individually, cutting class and species composition appear to be weakly associated with barred owl detection. This contradicts predictions proposed in the draft HSI model which predicts cutting class and crown class are the two main variables influencing barred owl presence and that species composition is less important than these two variables. In the logistic regression analysis, crown class confounds the results and is not strongly associated with barred owl detection when the variables are combined in the two way effects models.

5.1.2 400 HA SCALE

Model predictability improved at the larger 400 ha scale (Table 4.11 and Table 4.12). This scale more closely approximates a barred owl's minimum home range size which may explain the improved model predictability from smaller spatial scale to the larger scale. Using a larger block size may mask the effect of the measurement error associated with the barred owl locations creating a better fit. Laymon and Reid (1984), Collins and Glenn (1991)and Meyer et al. (1998) found scale had a tremendous impact on research results.

Conifer dominated mixed wood forests, unproductive forests and lower cutting class were negatively correlated with barred owl presence. Older, hardwood dominated mixed wood forests were positively associated with barred owl presence. Takats' (1995) research suggests the same dependent relationship between barred owls and mature, mixed wood forests. In Alberta, barred owls preferred forests with high canopy closure, tall trees, white spruce, balsam poplar, and trembling aspen (Takats 1995). Mazur et al. (1998) found barred owls in Saskatchewan had an affinity for mature, old growth and mixed wood forests as well. While, Bosakowski (1987) and Dunbar et al. (1991) found barred owls preferred mixed woods and coniferous upland forests for roosting, nesting and foraging.

Unproductive forests were negatively associated with barred owl presence. Mazur et al. (1998) found a negative association between barred owls and unproductive forests supporting this researcher's results. The positive correlation between cutting class 4 and 5 and barred owl detection makes sense intuitively since the barred owl is a forest-dwelling species that prefers mature, mixed woods nesting primarily in tree cavities. The barred owl requires large, decaying trees that provide nesting cavities to incubate and raise their young. In Alberta, Takats (1995) found more barred owls in areas with trees 35 cm DBH or greater; whereas, Johnsgard (1988) cited a minimum diameter of 51 cm for New Jersey. Mazur and James (1995) found a majority of barred owl nests in deciduous trees; nest tree species selected included white spruce (4), trembling aspen (3), balsam poplar (2) and white birch (1).

The positive correlation between hardwood dominated mixed wood forests and barred owl detection makes sense intuitively as well. Hardwood species have shorter life cycles and are more susceptible to fungal diseases causing trees to decay. Since hardwoods are more susceptible to diseases than most coniferous species, hardwoods create more nesting cover earlier in the life of a forest stand. The creation of quality nesting cover is essential for barred owl reproductive success.

The low sample size may have contributed to low significance values for some of the habitat variables. Twenty-one observations were not used in the analysis when the variables were re-parameterized. These observations lacked the baseline habitat and had to be removed from analysis to ensure all of the variables within each habitat set were independent. The importance of cutting class 5 was more apparent for the cutting class sub-model (Table 4.5). The relationship between barred owls and cutting classes 4 and 5 were less obvious when all of the variable sets were entered into the model. This may be due in large part to the sample size.

5.2. VERIFYING THE BARRED OWL HABITAT SUITABILITY INDEX MODEL

5.2.1 MECHANICAL ERRORS

There was only one mechanical error found in the 1994 draft HSI model for the barred owl. This error was associated with variable species composition and was easily fixed.

5.2.2 INFERENCES FROM THE HABITAT ANALYSIS

After the mechanical errors and logical flaws of the HSI model were examined, the HSI model and its individual components were examined in light of the habitat analysis. Some of the results confirmed relationships described in the HSI model; wheras, others contradicted predictions made in the HSI model.

The habitat analysis refuted the contention that species composition was less important than cutting class and crown class (Table 4.11 and Table 4.12). Species composition and cutting class had the most discriminatory ability with respect to barred owl detection. Tables 4.11 and 4.12 indicate that cutting class (-2 Log Likelihood 13.568; $p = 0.0189$; $df = 5$), species composition (-2 Log Likelihood 6.910; $df = 3$) and unproductive forest (-2 Log Likelihood 11.302; $df = 1$) were more effective in determining the presence or absence of barred owls.

As predicted by the HSI model, cutting class was positively associated with barred owl detection. This trend was apparent at both spatial scales, but was more obvious at the larger 400 ha scale, especially for the cutting class MLR sub-model. This makes sense intuitively, since barred owls require older forests for reproductive cover. The log odds, standard errors and significance values indicate barred owls are more likely associated with mature (cutting class 4) and over mature forests (cutting class 5)(Table 4.5 and Table 4.6). Conversely, barred owls are less likely to be detected in younger forests (cutting class 0 and 1).

Contrary to the HSI model's predictions, crown class was not a significant variable contributing to the overall fit of the two-way effects LR model. It reduced the degrees of freedom in the 6.25 ha scale model contributing to the poor fit of the model overall prior to its removal. Crown class was not very indicative of barred owl presence or absence when combined with the other variables. This trend was apparent at the 400 ha block scale as well.

The HSI model predicted mixed wood forests (expressed as percent conifer) would be more suitable than pure hardwood or conifer forests. The habitat analysis confirms this prediction; although, conifer dominated mixed wood forests seem to be negatively associated with barred owl detection.

Individually, all three variables were correlated with barred owl detection at both spatial scales. All three variables follow the positive linear trends hypothesized in the variable graphs section of the draft model. When these variables were brought together in a logistic regression model, the results did not agree with the proposed model relationship. The variable sets were not equal or compensatory as hypothesized in the draft HSI model. According to the analysis, crown class did not contribute to the overall fit of the logistic regression model. Crown class was eliminated from the statistical model at the 400 ha scale and detracted from the overall fit of the statistical model at the smaller 6.25 ha scale. These results suggest crown class is not as important for predicting barred owl presence or absence. Crown class is highly correlated with the other two variables; this strong correlation may have contributed to the aforementioned results.

It is important that the variables chosen for the model make sense when they are aggregated into the model equation.

The habitat analysis also suggests the relationship between the two remaining variable sets were not equal. This relationship is reflected in the log odds and summary log likelihood values for each variable set. Cutting class is the most effective variable set for explaining barred owl detection. Species composition is second.

5.2.3 THEORETICAL CONSTRAINTS OF HABITAT SUITABILITY INDEX MODELS

Habitat is one of many external environmental stimuli impacting animal populations. Variation in habitat quality and quantity greatly influences the persistence of populations over time (Harrison and Quinn

1989; Clarke et al. 1997).

Assessing the role habitat plays in the overall success of individual species is a contentious issue. There has been much speculation about what drives species to persist, languish or extinguish. This issue becomes more critical in light of human resource use patterns. The competitive and often antagonistic interaction between animals, resources and humans has influenced the development of modern applied ecology. Measuring and explaining animal responses to dynamic and variable landscapes is at the center of this controversy. Many scientists believe uncertainty only exacerbates this already controversial issue. According to Doak et al. (1992) conservationists and land managers are increasingly incorporating concepts of ecological theory to develop robust and meaningful strategies for managing species and multiple species. This has become particularly true for HSI modeling. The original generation of HSI models considered these theories in the research and development stages of the models but these theories were not directly incorporated into the HSI models. Recent generations of these models have incorporated elements of population ecology, landscape ecology and resource selection into these models (Breininger et al. 1998). To date, many of these elements have not been incorporated into the draft HSI model for the barred owl in Manitoba. These disparties in the current Manitoba barred owl HSI model and arguments for incorporating these elements into the HSI model will be discussed.

Scientists have suggested the temporal and spatial patterns of different habitats should be incorporated into these HSI models as well. Brand et al. (1984) state "forcasting change is essential for forcasting habitat suitability". This is another dimension that has not been incorporated in to the current draft HSI model for the barred owl.

Landscape heterogeneity, the interspersion of varying habitats, is often implicated as a key process influencing the survival of populations and individuals. Many scientists have encouraged HSI model users to incorporate landscape heterogeneity into HSI models. According to Clarke et al. 1997, this influential factor has frequently been ignored, citing early researchers assumed that habitat was uniform and constant through space and time. This simplifying assumption lead to many misinterpretations and inaccurate inferences about the long-term dynamics of animal-habitat relationships. Lancia et al. (1984) point out wildlife are spatially and temporally dynamic and suggest suitability should integrate these factors. Including attributes such as landscape heterogeneity and diversity into habitat analysis is critical. Parallel to this argument for incorporating landscape heterogeneity into animal-habitat analyses is the recognition of habitat connectivity (Kareiva and Wennergren 1995). They contend that if we can understand how landscape patterns influence population and ecosystem dynamics, populations can be managed more effectively. Habitat connectivity is crucial because it impacts intraspecific and interspecific interactions. Understanding the roles that connectivity and landscape heterogeneity have on animal populations and their movement patterns is critical for supply analysis and management. Currently, the draft HSI model for the barred owl does not incorporate the distribution of various habitats into the HSI model output. The exclusion of these habitat features makes it difficult to create a dynamic management tool. Incorporating these habitat features as model variables allows HSI model users to determine habitat quality and availability over space and time.

Incorporating measurements of variation into HSI model results is critical as well. Measurements of variation should be considered during and after the modeling process because these measurements greatly influence the interpretation of model results (Stauffer et al. 1984; Mosher et al. 1984).

Choosing a meaningful, robust and appropriate response variable to define the relationship between habitat and animal species is just as crucial as defining habitat characteristics associated with HSI models.

In the past researchers have compared the values for one or more habitats with abundance and density to evaluate habitat quality. However, in many instances the correlation between animal density and habitat quality is not concomitant (Van Horne 1988; Hobbs and Hanley 1990; Fryxell and Lundberg 1998). Social hierarchies, differences in competitive abilities of individuals, an animal's perception of habitat quality, and habitat connectivity greatly influence the distribution of populations and dispersion between individuals and populations despite habitat quality(Fretwell and Lucas 1970; Fryxell and Lundberg 1998). For this reason, Akcakaya (1992), Hobbs and Hanley (1990) and Van Horne (1988), suggest using productivity as a measurement for evaluating habitat quality. Ideally, HSI models should be linked to measures of productivity. The stochasticity and annual variation in population numbers makes linking HSI models with abundance or density measures misleading. In the absence of this productivity values, abundance values can serve as a baseline of information and provide direction for collection productivity values. HSI Models based on abundance values can serve as sub-models for increasingly complex spatial explicit population models. Holt et al. (1995) and Turner et al. (1995) advocate developing suitability models utilizing abundance values prior to developing more sophisticated spatially explicit populations models. Currently, the draft HSI model for the barred owl has only been verified using abundance as the response variable.

CHAPTER 6

MANAGEMENT RECOMMENDATIONS

Management recommendations describe suggestions derived from the research results and discussion. Recommendations for future research were derived from disparities found in described in the results and discussion. Recommendations are organized by research objectives. Recommendations for using the HSI model are addressed first, followed by recommendations concerning further verification of the HSI model, and finally research needs.

6.1 BARRED OWL HABITAT SUITABILITY INDEX MODEL

Barred owls prefer increasingly older forests and exhibit an affinity for mixed wood forests and an avoidance of unproductive forests. However, the HSI model diverge with the habitat analysis with respect to coniferous dominated mixed wood forests.

The species composition graph should be modified to reflect the barred owls affinity for hardwood dominated mixed wood forests rather than conifer dominated mixed wood forests (Appendix E). Crown class and its associated variable graph should be eliminated because the habitat analysis indicates it does not contribute to an improved model fit.

The habitat analysis and the examination of the HSI model suggests the model equation should be modified. The square root transformation for species composition should be eliminated to correct the mechanical error and because the evidence suggests species composition influences barred owl detection.

The habitat analysis does not suggest a compensatory relationship between the remaining variables (after crown class is removed) exists; therefore, the model equation should be modified according to the logistic regression model output. Variables should be weighted according to the relative relationship between the variables log odds and log likelihood values. Measurements of variation should be calculated and provided in addition to providing a mean value. This would allow users to calculate confidence intervals. This recommendation was originally suggested by Bender et al. (1996) and is considered appropriate. By providing these parameters, managers can assess the risk of using the HSI model output and conduct sensitivity analysis.

6.2 FUTURE RESEARCH

Additional field research should be conducted to further verify the model. Future research should focus on establishing the relationship between barred owl productivity, forest age and species composition. Field research should be conducted on other variables that may explain habitat use patterns by barred owls. There are a host of variables commonly used by forest industries that have not been considered in the HSI model and are not currently readily available in the FRI data base. Variables such as average DBH, basal area and volume are examples of variables collected by forest industries that may influence barred owl distribution patterns.

Future research should also focus on incorporating measurements of spatial and temporal pattern in the model. The distribution of suitable habitat over space and time and how these elements impact barred owl productivity and the productivity of their prey species should be researched. HSI models readily adapt to use with GIS and have recently been incorporated into a GIS driven program entitled Wildlife Habitat Assessment Mapping(WHAM).

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APPENDIX A: STATUS OF THE BARRED OWL

The barred owl is a wide-ranging species found throughout North America. Recent literature suggests the barred owl has expanded its North American range during the last century allowing it to come into contact with its North American congener, the Northern spotted owl (*Strix occidentalis*) (Houston 1959; Grant 1966; Rogers 1966; Taylor and Forsmen 1976, Boxall and Stephney 1982, Sharp 1989). Hamer et al. (1994) described the first four records of hybridization between the Northern spotted owl (*Strix occidentalis*) and Northern barred owl. A majority of the hybrids have occurred between juvenile male spotted owls and female barred owls (Hamer et al. 1994). Dark et al. (1998) recently documented the invasion of barred owls into Northern California citing an incident where a barred owl killed a rival spotted owl. The recent intrusion of the Northern barred owl into the Northern spotted owl's range may exacerbate pre-existing problems facing the endangered spotted owl compounding factors such as habitat loss (Hamer et al 1994). The recent proliferation of literature examining increasing interactions between barred owls and spotted owls has prompted researchers to examine the range extension issue more closely.

Many researchers speculate the range extension of the barred owl is a recent phenomenon; however, Seton (1886; 1908), Macoun and Macoun (1909) and Atkinson (1899) suggests the barred owl has been present in Canada prior to this century. Fossil records suggest a much longer historical occupation of Canada. In order to address the barred owl range extension issue, a wide variety of literature was consulted. The literature review was expanded to include anthropological records and other documents associated with archeological records to broaden the scope of the research.

BARRED OWL FOSSIL HISTORY

The North American fossil history of owls begins in the Paleocene with *Orgygoptynx* discovered in Colorado (Peters 1995). Although other Eocene owl species have been documented in North America, fossil records of owls are sparse and rare for this geological time period. According to Peters (1995), most early raptors were either uncommon or predominately forest dwellers eluding lake trap-effects.

The fossil history of the barred owl is relatively well documented, particularly in the southeastern part of its North American range. A species similar to the barred owl and spotted owl was found in California during the Pleistocene. The specimens were found at the Rancho la

Brea site and is referred to as *Strix brea* (Howard 1933). Parmalee and Klippel (1982) found evidence of boreal fauna remains including barred owl remnants in strata of Check Bend Cave, Tennessee. The flora remains found at the site reflect a forested habitat interspersed with prairie or savanna. Based on fossilized pollen remains, jack pine, spruce and fir dominated the forests between 19,000-16,300 BP followed by a mixed conifer deciduous assemblage from 16,500-12,500 year BP. Smith (1975) documented barred owl remains at the Lilbourn site, Missouri dating back to the Middle Mississippian (1100-1500 AD). There were several microzones associated with this site including a tupelo-oak climax forest, open water, back swamp cypress tupelo areas, hardwood ridge, bottom oak and hickory and hardwood-sweetgum areas.

The barred owl has been well documented in the northern part of its range as well. Churcher and Karrow (1963) and Wetmore (1958) documented the presence of barred owl remains in Hamilton, Ontario. Originally Wetmore (1958)placed the date of these remains in the Pleistocene (10,000-20,000 years ago); however, Churcher and Karrow (1963) determined these faunal remains were actually 5000 years old based on the assembledge of other fauna found at the site. Stewart (1974) documented the presence of barred owls at the Inverheron site, Bruce

County, Ontario and estimated the owl remains date back to 1150 +- 120 BC making the remains 3140 + years old. The barred owl remains were found in association with great blue herons, common loons (Gavia immer), passenger pigeons, red squirrels, marten and beaver. Human artifacts indicate the site was a seasonal site occupied during the spring and summer. Parmalee(1962) found barred owl remains at the Fisher Site in Illinois that dated back to the Upper Mississipian, 1200-1600 AD. Lennox and Dodd (1991) documented evidence of the barred owl near Detroit, Michigan at the Springwell Site. Like the Lake Huron/Inverheron site, the Springwell site was seasonally occupied during the spring and summer. There were three distinct vegetation zones: Oak-hickory forest, Ash-Elm Swamp and Prairie enclave at the Springwell site. The estimated date if the sites remains is 795 years (1200-1400 AD). Webster (1984) has documented barred owl remains in association with a village in the Susquehanna River valley dating back to 1630-1650.

BARRED OWL RESPONSE

A grand mean of 0.02 ± 0.009 (n = 7) barred owls per kilometer were detected during the seven year survey period. A maximum of 0.040 ± 0.06 (n = 26) were detected during 1993 (Table A.1). The data indicate a marked increase in the mean number of barred owl detected between 1993 and 1994. This phenomenon coincides with an increase in kilometers surveyed and an increase in the relative abundance of small rodents (Duncan pers comm).

During the survey, 75 barred owls were detected during the first minute of the survey. Nineteen were initially detected during the second minute and 24 were not detected until the third minute.

Table A.1. Mean number barred owls (*Strix varia*) detected per kilometer during the Manitoba Nocturnal Owl Survey 1991-1997.

Survey Year	Mean Barred Owls/Km	Standard Deviation	No. Routes Surveyed
1991	0.02	0.04	23
1992	0.01	0.03	26
1993	0.04	0.06	26
1994	0.02	0.04	36
1995	0.02	0.04	38
1996	0.01	0.04	57
1997	0.01	0.03	34

Table A.2. Description of museum specimens located in the University of Manitoba Zoology Museum (UMZM), Museum of Man and Nature (MM), the Sam Waller Museum (SWM) and other specimens (P).

Date Collected	Specimen Type	Sex	Age	Location Description
1892	Mount	Unknown (Seton 1892)*	Adult	Portage la Prairie
May 15, 1927	Skin-P	Unknown	Immature	St. Vital,Winnipeg
October 13, 1929	Skin-P	Female	Immature	3.2 km N. of Lockport
September 15,1941	Skin-SWM	Male	Adult	The Pas, Reader Lake
April 19, 1948	Skin-MM	Female	Adult	Charleswood, Winnipeg, MB
October 11, 1956	Skin-MM	Male	Adult	The Pas, Reader Lake
March 12, 1972	Skin-MM	Female	Adult	7.2 km E. of Birds Hill, MB
January 22, 1981	Skeleton-MM	Unknown	Adult	3.2 km N. & 3.2 km E. of East Braintree
March 6, 1982	Skeleton-MM	Unknown	Adult	Assiniboine Park Zoo
October 2, 1984	Complete-MM	Female	Adult	Swan River, MB Twp 37 R 29W
August 30, 1984	Skin-MM	Unknown	Adult	Highway # 1,near Prawda, MB
October 18, 1985	Skin-UMZM	Male	Adult	Swan River, MB
August 30, 1987	Skin-MM	Unknown	Adult	Prawda, Highway # 1
September 4, 1988	Skin-UMZM	Male	Adult	Garvin Rd near Vivian, MB
March 21, 1989	Skin-UMZM	Female	Adult	2.4 km E. of Sidney, MB
July 11, 1990	Skin-UMZM	Male	Immature	1.6 km W. of Falcon Lake on PTH #1

Spring 1991	Skin-UMZM	Male	Adult	Highland Park, Winnipeg, MB
January 1994	Mount-SRH	Unknown	Adult	3.2 km S of Barrows, MB
1996	Skin-DNR	Male	Adult	Hwy 44, 3.2 km W. of Hwy 11
July 7, 1997	Skin-DNR	Female	Adult	4.8 km E of Hwy 39 and 10; S. of Cranberry-Portage

Table A.3. Breeding records for the barred owl in Manitoba including records of pairs observed.

Date	Breeding Description	Location Description
June 12, 1927	2 young found; 1 young lived to maturity	St. Vital,Winnipeg
May 10, 1940	Pair observed year round	Victoria Beach
1941	1 young found	E. Kildonan Park, Winnipeg
1941	1 young found; young collected	Winnipeg Beach
May 6, 1959	2 young found in poplar tree 16.6 m	8 km from Dunrea
May 31, 1977	1 young, nest in balsam poplar 10 m from ground first owlet banded in Manitoba	4.8 km W. along Hwy. 304; 3.4 ml of Bissett
June 8, 1978	1 young observed	S.W. of Bissett
June 1978	3 young fledged and banded	PR 241, S. of PTH 1, W. of Assiniboine River
July 11, 1978	3 young found	Near Springstien, MB; S. of Beaudry
June 21, 1986	3 young found	Along Sprague River, in the municipality of Sprague
May 29, 1987	Nest in Elm tree 16.6 m from ground	St. Francois Xavier
1992-1994	Pair observed year round	Liz Lake and Paint Lake
1995	Pair observed year round	La Salle, St. Norbert
1996	Nest box used for 2 years	Whiteshell Provincial Park
1997	Pair observed, Balsam poplar 6 m from ground	Matheson Island, Lake Winnipeg

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APPENDIX B: DATA SOURCES FOR MAPPING THE MANITOBA DISTRIBUTION OF THE BARRED OWL

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APPENDIX C: DATA AND CONTIGENCY TABLES.

Cutting class 3 was the predominant cutting class for both response classes; however, the response classes began to diverge at older cutting class. Proportionally, cutting classes 4 and 5 occurred more frequently for barred owl locations than for non barred owl locations (Table C.3).

Forty-two percent of the barred owls were found in forests with high canopy closure (greater than 71 %). Undetected locations followed the same positive, linear trend.

In the two way interactions for cutting class and crown class, undetected locations dominated the lower crown and cutting class combinations. 9 out of 11 observations located in overmature (cutting class 5) forest with greater than 71 % crown closure were associated with barred owl locations (Table C.6). Conversely, 35 of 48 observations found in intermediate forests (cutting class 3) with greater than 71 % crown closure were associated with locations barred owls were not detected.

The data contained in the two way contingency tables yielded some noteworthy trends between species composition and crown class. Deciduous dominated forest with high crown closure appear to be indicative of barred owl presence; 11 out of 15 observations associated with these two categories were attributable to locations barred owls were detected. 16 out of 20 observations associated with conifer forests with crown closure greater than 71 % (crown class 4) were associated with locations barred owls were not detected. 14 out of 21 observations located in conifer dominated forest with 51-70 % crown closure were associated with undetected locations.

Older, deciduous dominated forest were strongly associated with barred owl detection. 10 out of 12 observations associated with deciduous forests in cutting class 5 were associated with barred owl locations. In contrast, 15 of 17 observations associated with conifer dominated forests of intermediate (cutting class 3) age were associated with locations barred owls were not detected. 13 out of 17 observations associated with cutting class 2 (across all species classes) were associated with locations barred owls were not detected.

Table C.1. Summary of the distribution of cutting classes for the locations barred owls were detected versus locations they were not detected during the Manitoba Nocturnal Owl Survey 1991-1997.

Cutting Class	Frequency Detected	Frequency Undetected	Frequency Detected (%)	Frequency Undetected (%)
Clear Cut	4	9	31	69
Seedling	4	13	23	77
Sapling	13	19	41	59
Intermediate	24	61	28	72
Mature	16	20	44	56
Overmature	13	7	65	35
Unproductive	7	62	10	90
Sum	81	190	100	100

Table C.2. Summary of the distribution of crown class for the locations barred owls were detected versus locations they were not detected during the Manitoba Nocturnal Owl Survey 1991-1997.

Crown Class	Frequency Detected	Frequency Undetected	Frequency Detected (%)	Frequency Undetected (%)
Clear Cut	4	9	31	69
21-50 % Crown Closure	5	23	18	82
51-70 % Crown Closure	22	37	37	63
71 % + Crown Closure	43	60	42	58
Unproductive	7	62	10	90
Sum	81	190	100	100

Table C.3. Summary of the distribution of species Composition for locations barred owls were detected Versus locations they were not detected during the Manitoba Nocturnal Owl Survey 1991-1997.

Species Composition	Frequency Detected (n)	Frequency Undetected (n)	Frequency Detected (%)	Frequency Undetected (%)
Clear Cut	4	8	33	67
Hardwood	17	24	41	59
Hardwood Dominated Mixed Wood	31	36	46	54
Conifer Mixed Wood	14	31	31	69
Conifer	8	29	22	78
Unproductive	7	62	10	90

Table C.4. Two-way contingency table for a model between cutting class and crown closure comparing locations where barred owls were detected versus locations where barred owls were not detected during the Manitoba Nocturnal Owl Survey 1991-1997.

Cutting class	Crown Class										
	0		2		3		4		UNP		Sum
	Response										
	UND	DET	UND	DET	UND	DET	UND	DET	UND	DET	
0	9	4	-	-	-	-	-	-	-	-	13
1	-	-	4	0	3	1	6	3	-	-	17
2	-	-	6	0	5	3	8	10	-	-	32
3	-	-	7	1	19	10	35	13	-	-	85
4	-	-	4	2	7	6	9	8	-	-	36
5	-	-	2	2	3	2	2	9	-	-	20
UNP	-	-	-	-	-	-	-	-	61	7	68
Sum	9	4	23	5	37	22	60	43	61	7	271

UNP = Unproductive forests

UND = Survey stops barred owls were undetected

DET = Survey stops barred owls were detected

Table C.5. Two-way way contigency table for a model between crown class and species composition comparing locations barred owls were detected versus locations barred owls were not detected during the Manitoba Nocturnal Owl Survey 1991-1997.

	Species Composition												
	Clear Cut		Conifer		CoMix		DeMix		Decid		UNP		
Resp	UND	DET	UND	DET	UND	DET	UND	DET	UND	DET	UND	DET	Sum
Crown Class													
0	9	4	-	-	-	-	-	-	-	-	-	-	13
2	-	-	2	0	11	1	5	1	6	3	-	-	29
3	-	-	3	1	14	7	15	3	4	11	-	-	58
4	-	-	16	4	16	11	7	8	21	20	-	-	103
UNP	-	-	-	-	-	-	-	-	-	-	61	7	68
Sum	9	4	21	5	41	19	27	12	31	34	61	7	271

UNP = Unproductive UND = Undetected Resp = Response
DET =Detected Conifer = 100 % Coniferous forest

CoMix = Conifer dominated mixed wood

DeMix = Deciduous dominated mixed wood

Decid = 100 % Deciduous forest

Table C.6. Two-way contingency table for a model between cutting class and species composition comparing survey locations barred owls were detected versus locations barred owls were not detected during the Manitoba Nocturnal Owl Survey 1991-1997.

Species Composition

	Clear Cut		Conifer		CoMix		DeMix		Decid		UNP		
Resp	UND	DET	UND	DET	UND	DET	UND	DET	UND	DET	UND	DET	Sum
Cutting Class													
0	9	4	-	-	-	-	-	-	-	-	-	-	13
1	-	-	2	0	3	0	1	3	7	1	-	-	17
2	-	-	1	2	10	7	5	1	3	3	-	-	32
3	-	-	15	2	18	9	5	3	23	10	-	-	85
4	-	-	3	1	7	3	3	2	7	10	-	-	36
5	-	-	0	0	3	0	2	3	2	10	-	-	20
UNP											61	7	68
Sum	9	4	21	5	41	19	16	12	42	34	61	7	271

UNP = Unproductive UND = Undetected Resp = Response

DET =Detected Conifer = 100 % Coniferous forest

CoMix = Conifer dominated mixed wood

DeMix = Deciduous dominated mixed wood

Decid = 100 % Deciduous forest

APPENDIX D: GLOSSARY OF FORESTRY TERMS

Crown Closure Class: Crown closure will be estimated from aerial photographs.

a. Crown Class 0: Stands with 0-20 % crown closure

b. Crown Class 2: Stands with 21-50 % crown closure

c. Crown Class 3: Stands with 51-70 % crown closure

d. Crown Class 4: Stands with 71 % or more crown closure.

Cutting Class: Cutting class is based in size, vigor, state of development and maturity of a stand for harvesting purposes.

a. Cutting Class 0: Productive forest land not restocked following fire, cutting, windfall or other major disturbances. Some reproduction or scattered residual trees with net merchantable volume less than 20 m^3 per hectare may be present.

b. Cutting Class 1: Stands that have been restocked naturally or artificially. There may be scattered residual trees present as in cutting class 0. The average height of trees in cutting class 1 must be less than 3 meters.

c. Cutting Class 2: Advanced young growth post size, with some merchantable volume. The average height of the stand must be over 3 meters.

d. Cutting Class 3: Immature stands with merchantable volume growing at or near their maximum rate, which definitely should not be cut. The average height of the stand should be over 10 meters and average diameter should be over 9.0 centimeters at DBH (1.3 m).

e. Cutting Class 4: Mature which may be cut as they have reached rotation age (+-) 10 years on Site Class 1 and (+-) 20 years on Site Class 2.

f. Cutting Class 5: Overmature stands, which be given priority in cutting.

DBH: Diameter breast height. Location on a tree where a circumference measurement is taken on a merchantable tree.

Productive Forest: Includes all forest lands capable of producing merchantable wood regardless of its existing stage of productivity.

Species Composition: The species composition of a stand is based on the tree count (basal area) for each species to the total tree count (basal area) of the stand expressed as a percentage. Values calculated to the nearest 10%.

a. Conifer: Stands with 90 % or more of the species composition consisting of conifer species.

b. Conifer Mix: Stands with 40 to 80 % of the species composition consisting of conifer species.

c. Hardwood: Stands with 90 % or more of the species composition consisting of hardwood species.

d. Hardwood Mix: Stands with 40 to 80 % of the species composition consisting of hardwood species.

Unproductive Forest: Forest lands incapable of producing merchantable timber due to low timber productivity. These forests include treed rock and treed muskeg.

* all definitions are from Becker et al. (1996).

APPENDIX E: VARIABLE GRAPHS FOR THE 1994 DRAFT BARRED OWL HABITAT SUITABILITY INDEX MODEL

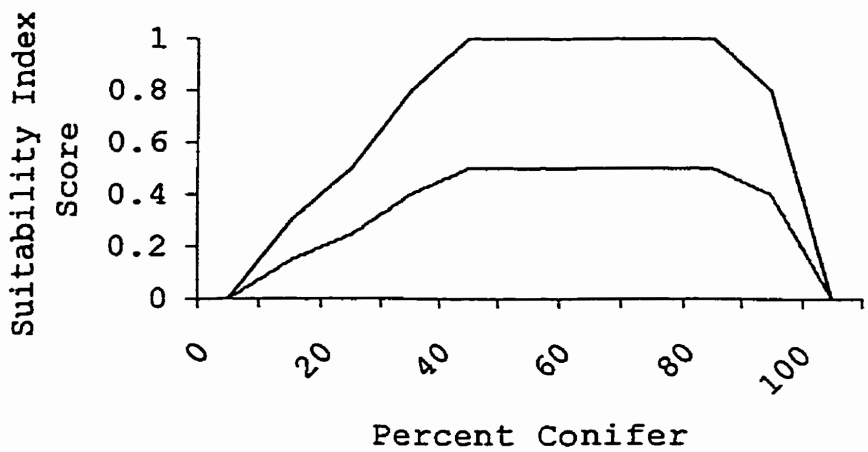

Figure E.1. Variable graph used to determine suitability scores for species composition. Lower line is used for stands without white spruce. Upper line is used for stands with white spruce.

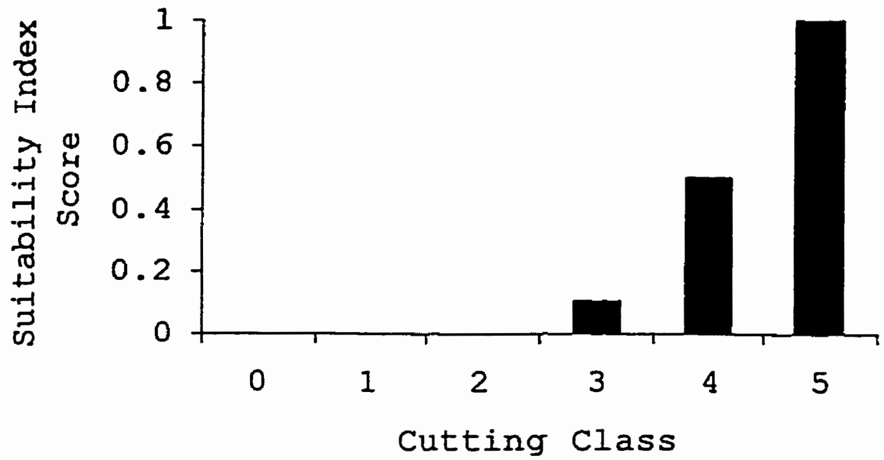

Figure E.2. Variable graph used to determine suitability scores for cutting class.

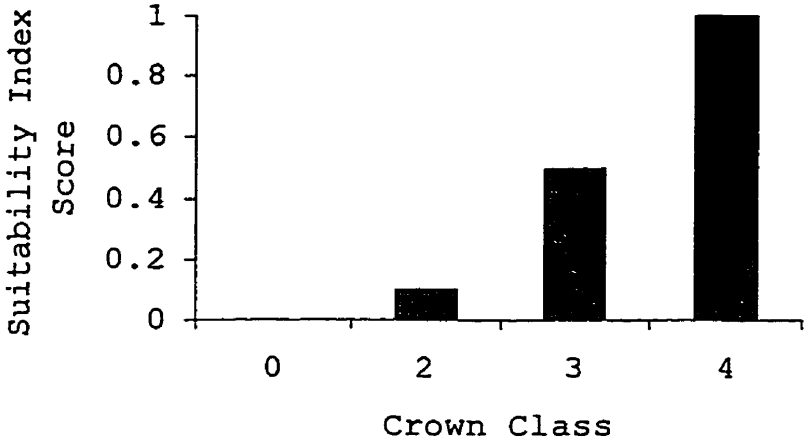

Figure E.3. Variable graph used to determine suitability scores for crown class.