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thesis entitled

Analysis of Habitat Suitability Models for Primary Cavity-nesting Birds in Michigan's Upper Peninsula

presented by

Stephen J. Negri

has been accepted towards fulfillment of the requirements for

Master of Science degree in Fish. & Wildl.

Major professor

Date 27 September 1995

ANALYSIS OF HABITAT SUITABILITY MODELS FOR PRIMARY CAVITY-NESTING BIRDS IN MICHIGAN'S UPPER PENINSULA

By

Stephen J. Negri

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Fisheries and Wildlife

1995

ABSTRACT

ASSESSMENT OF HABITAT SUITABILITY MODELS FOR PRIMARY CAVITY-NESTING BIRDS IN MICHIGAN'S UPPER PENINSULA

By

Stephen J. Negri

Many forest management planning efforts use cavity-nesting bird species as indicators of mature forests, with the assumption that if indicator species are maintained, then these forests are adequately maintained for other species. To monitor the relative habitat quality of indicator species, habitat models are often used. While many habitat models exist, little work has addressed the reliability of models to predict resulting populations. Therefore, considerable planning emphasis may be directed towards untested habitat models. This study tested habitat models for the pileated woodpecker *(Dryocopus pileatus)*, hairy woodpecker *(Picoides villosus)*, downy woodpecker *(Picoides pubescens)* and black-capped chickadee *(Parus atricapillus)*. Birds were censused on twenty-four 70 ha study areas during 1993 and 1994. Twelve habitat variables were quantified by cover type and programmed into the geographic information system ARC/INFO to calculate HSI values. Spearman rank correlations were performed between calculated HSI scores and bird abundance indices. Results indicate that pileated (r_s=0.69, p≤0.001) and hairy woodpecker (r_s=0.32, p≤0.10) models described habitat conditions used by each species and have good potential as evaluation tools for forest management planning efforts in Michigan's Upper Peninsula. The downy woodpecker and black-capped chickadee models need to be tested in a broader range of early-successional forest stages and habitats with more open canopies before rejecting their reliability as a habitat evaluation tool.

ACKNOWLEDGMENTS

Funding for this project was provided by the Huron Mountain Wildlife Foundation, Michigan Agricultural Experiment Station, and Michigan State University. Special thanks are extended to the Huron Mountain Club for providing not only funding but the opportunity to conduct this research in such a wonderfully unique area and to Dr. David Gosling for his support of the project and good conversation. Thanks are also extended to Mr. Philip "Flip" Paul and Mr. and Mrs. Manierre for their wealth of knowledge on the history of the Huron Mountain Club and surrounding area.

I would like to thank my committee members for vastly broadening my knowledge base in which to build upon. I have been enlightened by your knowledge and insight regarding this project. To Dr. Haufler, I thank you for accepting me into the program and for your continued support on this project. To my major advisor Dr. Henry Campa, I extend my sincere thanks for offering to take me under your wing in Dr. Haufler's absence, for all the advice, patience, friendship, support, and for having confidence in my abilities. Thanks to Dr. Scott Winterstein for his advice on data analysis and Dr. Don Beaver for his agreeing to become involved in this project and for the wealth of knowledge I gained assisting you in teaching the Ornithology and Mammalogy labs for Zoology 360.

Special thanks are extended to Bryan Smith for his diligent work in the field and in the vault. The days really do run together. Also, thanks go out to Leon Runicki for his assistance in vegetation sampling. Thanks to Dr. Gary Roloff for your friendship, insight, patience and concern regarding this project, and also for your bravery and steadfastness in battling the swamp alders. Thanks to Dr. Ed Baker for allowing me to occasionally win at racquetball and for your friendship. Thanks to Rich Minnis for your advice, humor, assistance in data analysis and for the good deals I received on outdoor supplies. Thanks to Tim VanDeelen for always lending an ear and for introducing me to the art of flyfishing. For that alone, I am thankful!

There are numerous other people at Michigan State who have greatly influenced my perspective on the wildlife profession and I am truly grateful for the opportunity to have associated myself with the following individuals: Brian Kernohan, Bruce Peffers, Kelly "Francine" Millenbah, Maya Hamady, Cathy Cook, John Niewoonder, Christine Hannaburgh, Donna Minnis, Meg Clark, Katherine Braun, Mark Moore, Teresa Macky, Delia Raymer, Ali Pearks, Gina Karasek, Jennifer Dorset, Mike Whitt, Mike Monfils, Janice Clark, and Tammy Newcomb. Thanks for the laughs and good conversation.

Heartfelt gratitude goes out to my father, Albert Negri and to my mother, the late Jeanne Negri and my brothers and sister, John, Matt, and Julie for their unending support and encouragement throughout this process. Last and most importantly, I would like to thank my wife, Tina. Thank you for your patience, encouragement, and support of my decision to continue my education. Thank you for tolerating the weird hours and the lonely summers. From my very soul I thank you for your continued love and understanding.

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INTRODUCTION

Many forest management planning efforts use cavity-nesting bird species as indicators of mature or old growth forest stand conditions, with the assumption that if these species are maintained, then these stand types are adequately maintained for other species. Root (1967) defined a guild as a group of species that exploit environmental resources in a similar way, regardless of taxonomic positions. Administratively grouping species into guilds purportedly facilitates the process of assessing and predicting the effects of natural and human-induced habitat modifications on faunal communities (Jarvinen and Vaisanen 1979, Thomas 1979, Severinghaus 1981, Short and Burnham 1982, Verner 1984).

When using guilds for management purposes, biologists assume that species in a guild respond similarly to environmental changes (Verner 1984). Guild species may broadly use similar resources but have a different set of specific habitat requirements. One might expect guild members to respond differently to relatively subtle changes in their environment (Mannan and Meslow 1984). Although differential responses to forest management practices are common, guild members should respond similarly when habitat changes are severe (Verner 1984). The lack of consistent responses to habitat alterations among species eliminates the possibility of predicting the responses of individual guild members by monitoring the abundance of a single "indicator" species (Severinghaus 1981). Mannan et al. (1984) stressed a potential danger of examining only the summed response of all guild members in that if intraguild responses are inconsistent, a large increase in one or two species could mask the decline or absence of others. The guild management approach should look at how management practices affect individual species before looking at the species when aggregated into guilds (Szaro 1986). Therefore, resource managers should maintain populations of endemic species and should not rely solely on guild analysis to provide information on the impacts of perturbations in forests (Mannan et al. 1984).

To quantify the impacts of management practices on indicator species, a commonly used technique for habitat assessment is the Habitat Evaluation Procedures (HEP) (U.S.D.I Fish and Wildlife Service 1981). The HEP approach is extensively used by federal and state resource management agencies (Morrison et al. 1992). Integral to HEP are Habitat Suitability Indices (HSI's), which are best used to represent relative relationships rather than definitive statements of cause-and-effect relations or reliable predictions of species response to management practices (Schamberger and Krohn 1982, Morrison et al. 1992). An HSI of 1.0 represents optimum habitat conditions and indicates the potential to support relatively the highest density of species. Unsuitable habitat is associated with an HSI of 0.0.

One primary value of HSI's lie in documenting a repeatable assessment procedure and providing an index to particular environmental characteristics that can be compared with alternative management plans (Morrison et al. 1992). The ideal HSI model is one that accurately predicts species response to measurable habitat attributes which can be mathematically combined into an index score ranging from 0.0 to 1.0 (U.S.D.I. Fish and Wildlife Service 1981, Blake and Karr 1984, Laymon and Barrett 1986, Van Horne and Wiens 1991).

Wildlife-habitat relationship models (e.g. HSI models) are taking many forms, but a near-universal premise of models is that distribution and abundance of wildlife species can be predicted from habitat components (Marcot et al. 1983). Habitat based models have evolved from theories dealing with wildlife populations and their habitats since the turn of the century (Morrison et al. 1992). Developments of habitat models as management tools involve attempts to: (1) quantify wildlife-habitat relationships (U.S.D.I. Fish and Wildlife Service 1981, Nelson and Salwasser 1982); (2) establish computerized databases of this information (Salwasser 1982); (3) integrate wildlife-habitat relationships models into dynamic vegetation models (Barrett and Salwasser 1982); and (4) integrate such models with Geographic Information Systems (GIS), incorporating relevant habitat characteristics (Davis 1980, Laymon and Barrett 1986, and Flather et al. 1989). Wildlife-habitat models that predict species' occurrence in relation to environmental conditions is the critical link in monitoring impacts of land management practices on wildlife.

To manage forest ecosystems for a diversity of wildlife species (Hurley et al. 1982), biologists and ecologists typically use these wildlife-habitat relationship models to quantify if existing habitat requirements of particular species are being met or to predict the impact of land-use practices on wildlife. A plethora of habitat models exist (Verner et al. 1986, Morrison et al. 1992). Assumptions are used in modeling relationships between wildlife and the habitat components which are thought to be important to the maintenance of a species. The assumptions used to describe the relationships between wildlife and its habitat may include some or all of the following: (1) a species distribution is dependent on and can be predicted by environmental habitat parameters (Marcot et al. 1983);

(2) linearity of relationships exist between wildlife densities and individual habitat attributes (Meents et al. 1983); (3) invariability of habitat use regardless of life stage or season (Patterson 1976); (4) similar patterns or configurations of habitat should reflect similar patterns of animal abundance (Flather and Hoekstra 1985); (5) minimal effects of predation and other interspecific interactions (Morin 1981); and (6) adequacy of a species' observed density as an indicator of habitat quality (Van Horne 1983, Best and Stauffer 1986). The aforementioned assumptions used in wildlife-habitat relationships modeling have been questioned in the literature and in some cases have been shown to be false.

Van Horne (1983) scrutinized the assumption that species density is a direct measure of habitat quality and ascertained that the most accurate measure of estimating wildlife density and habitat quality relationships are dependent on an understanding of population demographics and factors that influence survival and reproduction. Predation may influence the abundance and distribution of a species more than the habitat quality of an area (May 1977, Nelson and Mech 1981, Flather and Hoekstra 1985). However, until databases link population demographic information to specific measurable habitat attributes and landscape patterns, the most efficient and cost-effective means of estimating wildlife potentials across a landscape(s) is through habitat measurements.

While numerous habitat models have been developed, the implementation of many models have been hampered by a lack of field validation (Cole and Smith 1983). Therefore, considerable planning emphasis may be directed towards untested habitat models (Lancia et al. 1982, Cole and Smith 1983, Marcot et al. 1983, Laymon and Barrett 1986). Some studies have found positive correlations between model output and various measures of wildlife abundance and distributions (Lancia et al. 1982, Cole and Smith 1983, Cook and Irwin 1985, Dedon et al. 1986, Hammill and Moran 1986, Latka and Yanhke 1986, Laymon and Barrett 1986, Laymon and Reid 1986, Raphael and Marcot 1986, Stauffer and Best 1986), whereas others have found negative or no correlations (Seitz et al. 1982, Clark and Lewis 1983, Bart et al. 1984, Johnson and Temple 1986, Lancia et al. 1986, Larson and Bock 1986, Seng 1991, and Robel et al. 1993). The inconsistency in model results may be explained by including inadequate or unrepresentative sampling (Cole and Smith 1983), model equations that are not representative of actual wildlife-habitat relationships (Farmer et al. 1982, Cole and Smith 1983, Van Horne and Wiens 1991), misinterpretation of results (Brower and Zar 1984, Capen et al. 1986), or application of models to inappropriate spatial scales (Wiens 1986).

Useful habitat models should be valid, general enough that a single model can apply to a wide range of situations without major modifications, and usable by land managers (Van Horne and Wiens 1991). The goal of this project was to evaluate the following 4 primary cavity-nesting bird HSI models: pileated woodpecker *(Dryocopus pileatus)* (Schroeder 1982a), hairy woodpecker *(Picoides villosus)* (Sousa 1987), downy woodpecker *(Picoides pubescens)* (Schroeder 1982b), and the black-capped chickadee *(Parus atricapillus)* (Schroeder 1982c), in the Upper Peninsula of Michigan. A second aspect of the project was to evaluate the effectiveness of using these species as indicators of mature forest stand conditions.

HYPOTHESIS AND OBJECTIVES

Hypothesis:

H_0: There will be no significant ($p \leq 0.10$) correlation ($R=0$) between computed habitat quality values and the relative abundance of primary cavity-nesting bird abundance.

H_1: There will be a significant ($p \leq 0.10$) correlation between computed habitat quality values and the relative abundance of primary cavity-nesting bird abundance.

Specific objectives of the project include the following:

1. Investigate the accuracy of current habitat suitability models for the primary cavity-nesting bird guild species in Michigan's Upper Peninsula by determining if habitat quality calculated from HSI models correlate with measures of bird abundance, and
2. Evaluate the effectiveness of using primary cavity-nesting bird species as indicators of a mature forest stand conditions in the Upper Peninsula of Michigan.

STUDY AREAS

This study was conducted in the Huron Mountain Club (HMC) and the western region of the Hiawatha National Forest (HNF). These 2 study areas were located in Marquette, Alger and Schoolcraft counties (Figure. 1).

Huron Mountain Club area

The HMC is privately owned and includes approximately 7200 ha of mature/late-successional stage forests in the Huron Mountain region of northwestern Marquette County, Michigan. Excluding 9 inland lakes on the property, approximately 90% of the Huron Mountain landscape is heavily forested. Percentages of dominant forest communities include: hardwood-hemlock (49%), predominately, sugar maple *(Acer saccharum)* and eastern hemlock *(Tsuga canadensis)*; white pine *(Pinus strobus)*-hemlock-northern hardwood (13.7%); white pine-red pine *(Pinus resinosa)*-red *oak (Quercus rubra)* (12.4%); and pine (7.3%), predominately, jack pine *(Pinus banksiana)* with lesser amounts of white and red pine (Simpson et al. 1990). Other distinct communities classified by Simpson et al. (1990) include marshes, shrub swamps, meadows, and beaches.

The Michigan Natural Areas Council recommended in 1961 that a portion of the HMC be set aside as a nature research area. In 1962, a "preserved area" was designated by the HMC, which comprises approximately 45% of the property (3239 ha). Most of this designated area has not been logged in the past. Much of the land surrounding the "preserved area" was clear-cut in the 1920's, 1930's, and 1940's, before it was acquired by the HMC (Manville 1942, Todd 1959, Huron Mountain Wildlife Foundation 1967). This area was a mature, mixed forest of hemlock, sugar maple, and yellow birch

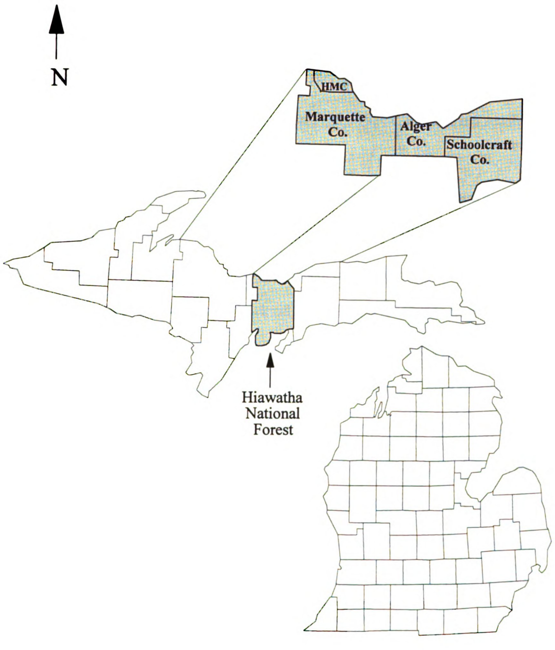


Figure 1. Location of study areas in the Hiawatha National Forest within Alger and Schoolcraft Counties and at the Huron Mountain Club (HMC) in Marquette County, Michigan.

*Upper Peninsula not drawn to scale.

(Betula alleghaniensis) in presettlement times. Areas clear-cut approximately 55-75 years ago presently support stands of sugar maple, red maple *(Acer rubrum)* and yellow birch, while hemlock is discernibly absent (Simpson et al. 1990). With the exception of a 20% selective cut made for white pines in the 1890's and some peripheral clear-cuts of hemlock, sugar maple, and yellow birch, from 1939 - 1950's, the area has received few silvicultural treatments (Simpson et al. 1990).

Cover types are mostly northern hardwood forests with hardwood conifer and conifer swamps scattered throughout the area (Albert et al. 1986). Scattered white pine, red pine, red oak, and trembling aspen *(Populus tremuloides)* are the dominant tree species on much of the exposed bedrock ridges (Albert et al. 1986). Swampy depressions in the bedrock, some of which were former glacial drainageways, now support hardwood-conifer and conifer forests which include northern white cedar *(Thuja occidentalis)*, white pine, tamarack *(Larix laricini)*, white spruce *(Picea glauca)*, balsam fir *(Abies balsamea)*, hemlock, red maple, black ash *(Fraxinus nigra)*, and trembling aspen. Deeper well-drained mineral soils support northern hardwood forest, including sugar maple, yellow birch, basswood *(Tilia americana)*, hemlock, and occasionally red maple and red oak. American beech *(Fagus grandifolia)* is absent (Albert et al. 1896). The well-drained medium sands deposited along Lake Superior's beach ridges support jack pine *(Pinus banksiana)*, red pine, white pine and also scattered red oak (Simpson et al. 1990). The Michigamme Highlands define the area comprising the HMC. This area is characterized as granitic bedrock with elevations rising from 312 m at the shore of Lake Superior to 495 m above sea level atop Ives Hill (Westover 1971). Bedrock is at or near the surface throughout much of the district, but there are also many outwash plains and areas of steep, sandy soils (Albert et al. 1986).

Monthly precipitation for this region of Michigan's Upper Peninsula is relatively uniform throughout the year. Annual precipitation averages approximately 88 cm per year with a mean temperature of approximately 5.5 C. Average precipitation for the summer months June, July and August is 6.99 cm, and the mean temperature is approximately 18.33 C (U.S. Department. of Commerce 1991).

Hiawatha National Forest area

The HNF encompasses approximately 350,000 ha of predominantly northern hardwood, aspen and coniferous forest within portions of Delta, Schoolcraft, and Alger counties (Soo Line Railroad Co. 1964). The HNF lies within the Escanaba, Luce, and Dickinson physiographic districts (Albert et al. 1986).

Site conditions range from poorly drained sand lake plains, sandy end moraine, shoreline, and outwash plains in the east to drumlins and ground moraines in the west (Albert et al. 1986). Soil types in the HNF include excessively well drained and well drained sandy loams in the upland areas and poorly drained soils in the low lying areas (Albert et al. 1986). Excessively well drained soils are characterized by red pine, white pine, and jack pine stands (Albert et al. 1986). Well drained soils are associated with beech, sugar maple, hemlock, basswood, and yellow birch communities (Albert et al. 1986). Plant species associated with poorly drained soils include white cedar, tamarack, black ash, red maple, balsam poplar *(Populus balsamifera)*, balsam fir, trembling aspen, and paper birch *(Betula papyrifera)* (Albert et al. 1986). The climate in the HNF is temperate with an average May-September temperature of 15.7 C and an annual precipitation of 80 cm (Albert et al. 1986).

METHODS

Experimental design

Research was conducted on twenty-four 70 ha study areas (11 in the HMC and 13 in the HNF) during the spring and summer of 1993 and 1994. Twenty areas were sampled both years. Each area was used to assess relative bird abundance and vegetative characteristics for the pileated woodpecker (Schroeder 1982a), hairy woodpecker (Sousa 1987), downy woodpecker (Schroeder 1982b), and black-capped chickadee (Schroeder 1982c) HSI models. Seventy hectare block areas were used because it is approximately the average home range size of the pileated woodpecker found in other midwest studies (Tanner 1952, Kilham 1976, and Renken and Wiggers 1989). It was assumed that if pileated woodpecker habitat requirements were met at this spatial scale, then this assessment area and its associated forest structure and composition may provide habitat for the other primary cavity-nesting species being evaluated, and represent a mature tree stage in forest succession.

Vegetation data used to calculate HSI models were collected from a randomized block sampling design using line intercept (Canfield 1941) and plot techniques. All 70 ha study areas were selected based on U.S.D.A. Forest Service and Huron Mountain Club vegetation type maps and by ground truthing. All study areas contained predominately mature cover types listed in each of the models which included: upland deciduous forest, lowland deciduous forest, upland coniferous forest and lowland coniferous forest (Appendix A). Each major cover type was replicated a minimum of 2 times.

Vegetation sampling

A variety of vegetative sampling procedures were used to quantify the vegetative structure and composition associated with each 70 ha study area (Table 1). Vegetative data were collected from randomly located points throughout all study areas from early July through early August, 1993 and 1994. Habitat variables measured were those outlined in each model for the calculation of HSI values (Figures 2-5).

Percent canopy closure and pine canopy closure, defined as all vegetation > 5 m tall, were measured using the line intercept method. All line intercepts were run North from each randomly located point. Plots (10x50 m) were used to quantify the availability of snags of various size classes on each study area. For the purpose of conducting vegetative sampling to calculate HSI values for the 4 cavity-nesting bird species, a snag was defined as any standing dead tree suitable as a nest site for a cavity nesting bird with a minimum height of 1.8 m (U.S. Department of Agriculture 1973). A biltmore stick was used to measure the dbh of trees and snags and to calculate basal area. The formula used to calculate basal area (M^2) is $\left[\frac{\text{DBH(in.)} \times 2.54\ \text{cm} / 100}{2}\right]^2 \times \Pi$

The number of trees > 51 cm dbh, logs, stumps, and overstory tree (e.g. >80% of the tallest tree) measurements were conducted using 10 x 25 m plots. The canopy height was estimated by measuring the height of all trees with a Haga altimeter (Get from Rique!). Arithmetic means of vegetation attributes for each cover type were used as input data for habitat models.

Table 1. Description of habitat variables measured for the pileated woodpecker, hairy woodpecker, downy woodpecker, and black-capped chickadee HSI models, and their associated sampling method conducted in 1993 and 1994.

Vegetation variable[a]	Sampling technique
% Canopy Closure	25 m Line Intercept
No. Trees > 51 cm (20") dbh / 0.4 ha	10x25 m Plot
No. Snags > 38 cm (15") dbh / 0.4 ha	10x50 m Plot
No. Snags ≥ 25 cm (10") dbh / 0.4 ha	10x50 m Plot
No. Snags ≥ 10-25 cm (4-10") dbh / 0.4 ha	10x50 m Plot
No. Snags > 15 cm (6") dbh / 0.4 ha	10x50 m Plot
No. Logs / 0.4 ha	10x25 m Plot
No. Stumps / 0.4 ha	10x25 m Plot
Average dbh Snags > 38 cm	10x50 m Plot; Biltmore Stick
Average dbh Overstory Trees	10x25 m Plot; Biltmore Stick
Average height Overstory Trees	10x25 m Plot; Haga Altimeter
% Pine Canopy Closure	25 m Line Intercept
Basal Area (m^2 / ha)	10x25 m Plot; Biltmore Stick

[a]Canopy Closure = All trees > 5 m tall; Pine Canopy Cover = *Pinus spp.* > 5 m tall; Stumps = stumps > 0.3 m tall and 18 cm diameter breast height (Dbh); Logs = Logs > 18 cm in diameter; Overstory trees = trees > 80% of height of tallest tree; Snags = snags ≥ 10 cm dbh and > 1.8 m tall.

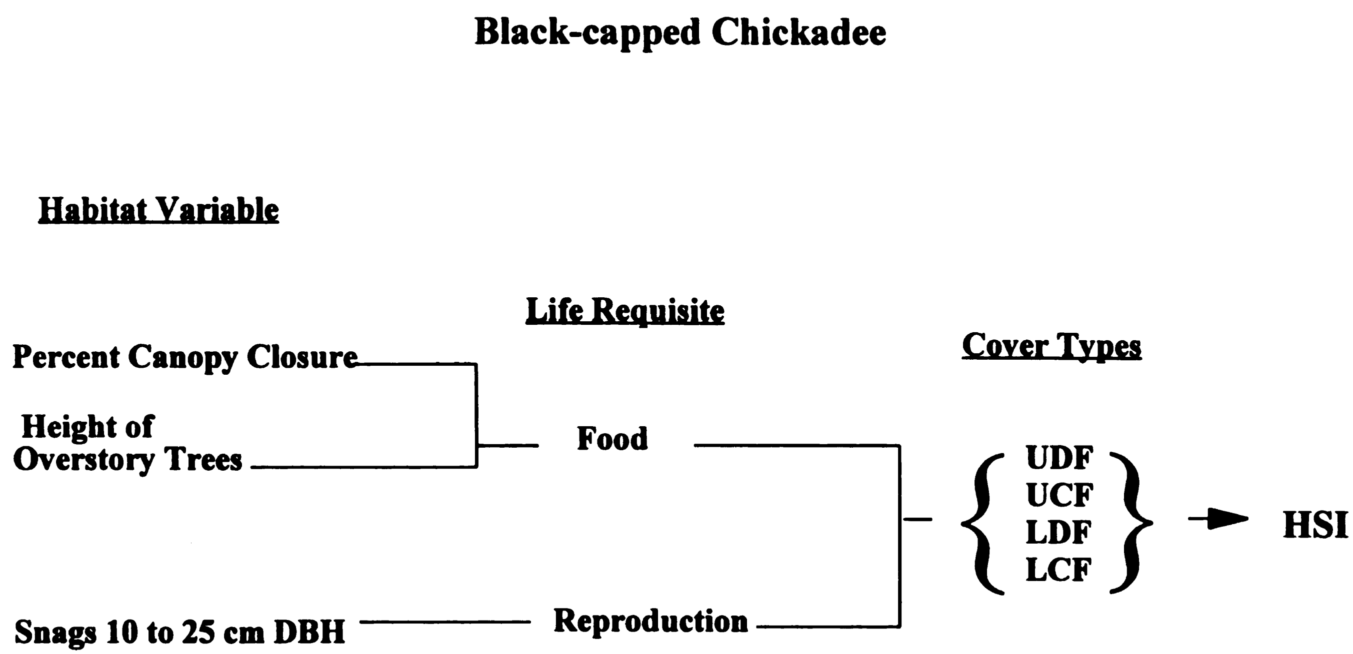


Figure 2. Habitat variables measured for the black-capped chickadee habitat suitability model (Schroeder 1982c). UDF=Upland Deciduous Forest, UCF=Upland Coniferous Forest, LDF=Lowland Deciduous Forest, and LCF=Lowland Coniferous Forest.

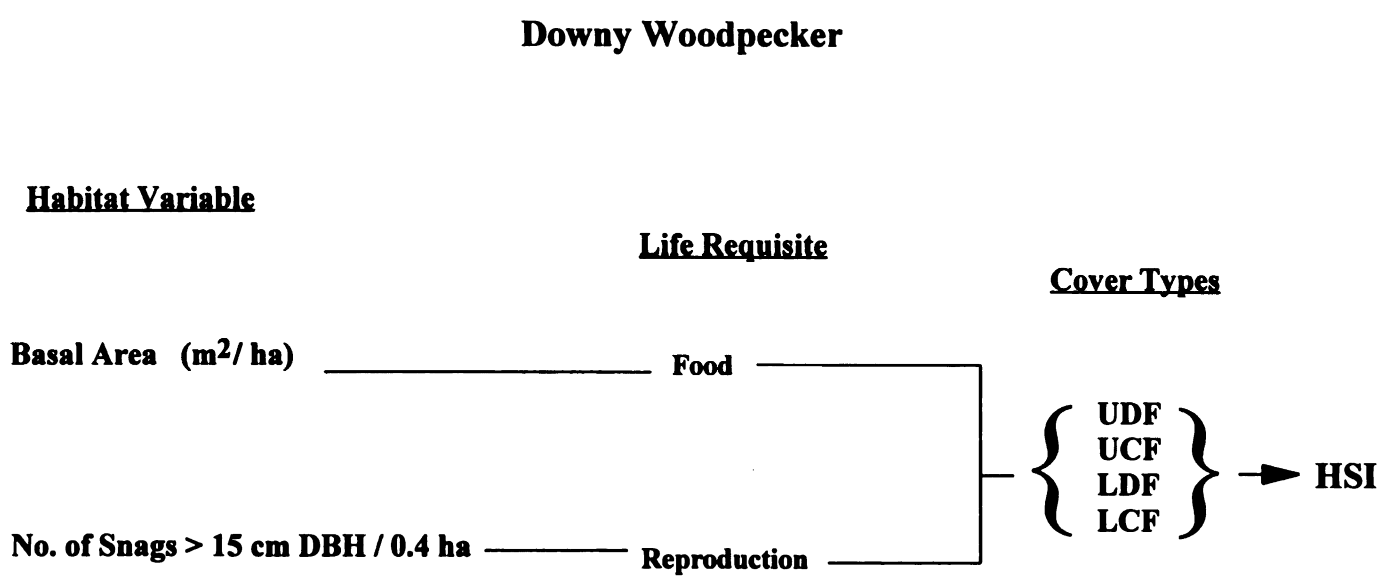


Figure 3. Habitat variables measured for the downy woodpecker habitat suitability model (Schroeder 1982b). UDF=Upland Deciduous Forest, UCF=Upland Coniferous Forest, LDF=Lowland Deciduous Forest, and LCF=Lowland Coniferous Forest.

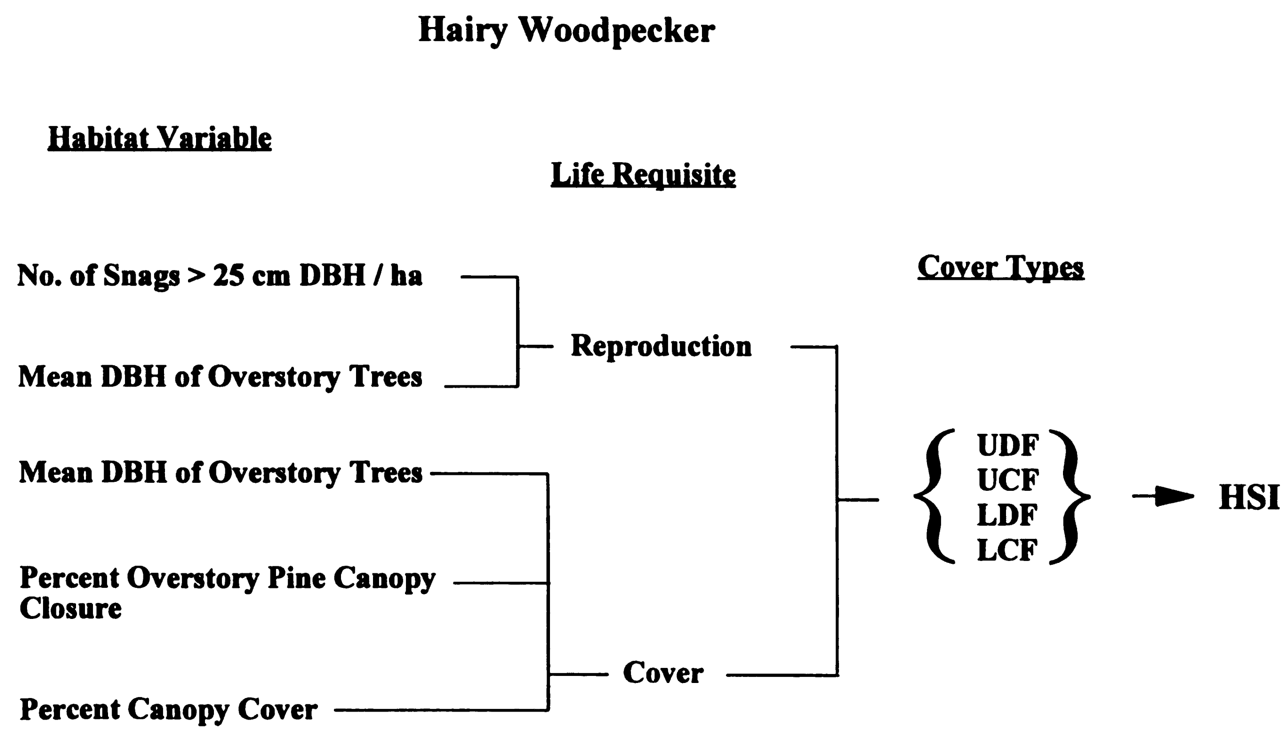


Figure 4. Habitat variables measured for the hairy woodpecker habitat suitability model (Sousa 1987). UDF=Upland Deciduous Forest, UCF= Upland Coniferous Forest, LDF=Lowland Deciduous Forest, and LCF=Lowland Coniferous Forest.

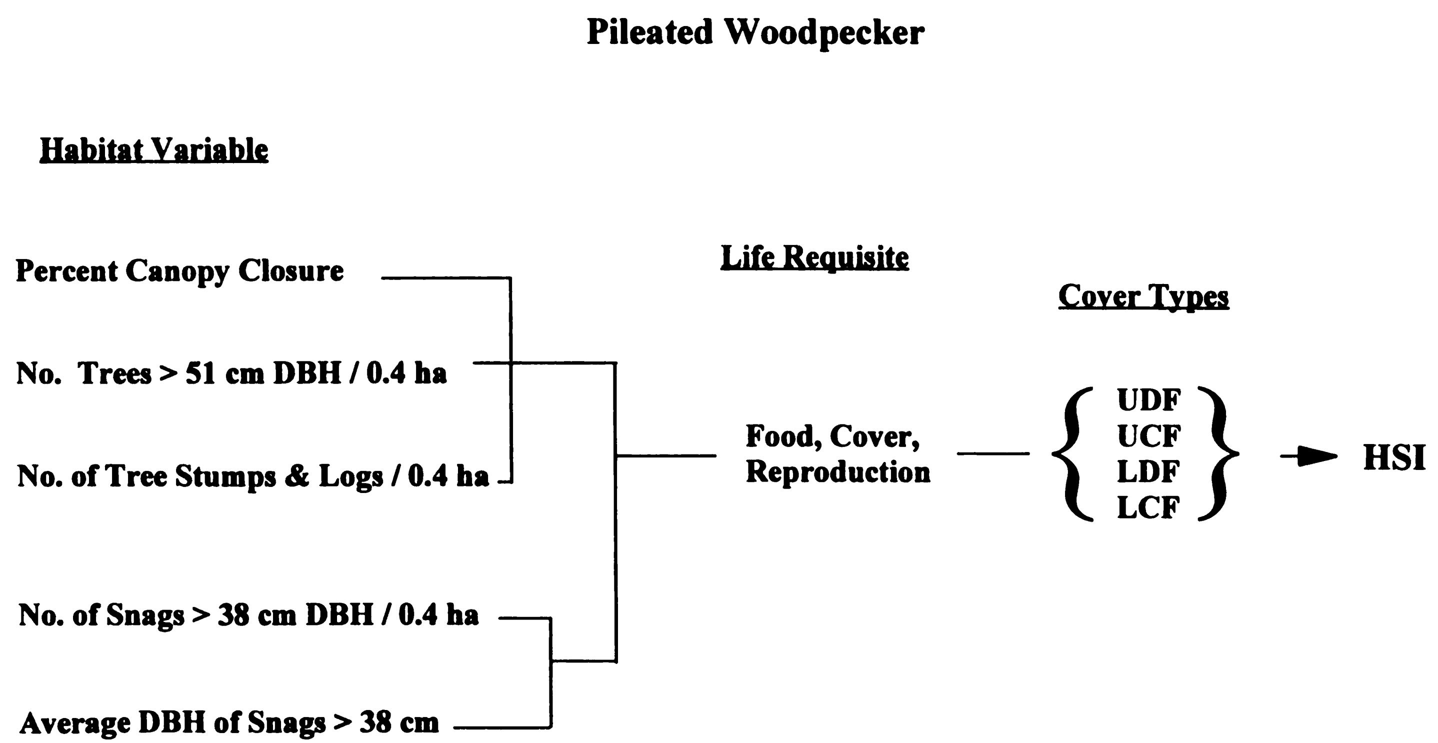


Figure 5. Habitat variables measured for the pileated woodpecker habitat suitability model (Schoeder 1982a). UDF=Upland Deciduous Forest, UCF=Upland Coniferous Forest, LDF=Lowland Decideuous Forest, and LCF=Lowland Coniferous Forest.

Bird censusing

Study areas were censused a minimum of 3 times from early-May through late-June using the fixed area-plot method (Bond 1957) in 1993 and 1994. To quantify the relative abundance of birds in various forest cover types throughout the breeding season, 1 census was conducted in early-May (excavation), 1 in early to mid-June (incubation), and 1 in late-June (feeding young). In addition, all study areas were censused at 3 different time periods during May and June, once at dawn (0530 - 0700 hrs E.D.T.), once at mid-morning (0700 - 0900 hrs E.D.T.), and once in the late morning (0900 - 1100 hrs E.D.T.) to insure each species was represented for the purposes of estimating abundance indices for each selected cavity nesting bird species (Skirvin 1981).

Bird censuses were conducted from a minimum of 3 randomly established points per study area. Census points were located at least 200 m apart to reduce the possibility of recording a bird more than once. All bird species seen or heard within a 70 m radius from census points were recorded during 15 minute census periods (Appendix B). The census period was determined from several 30 minute pre-counts. During pre-counts, the number of species observed was plotted against time and the period at which the addition of new species began to level off over time was used as the counting time period.

Since different bird species respond differently to extraneous environmental conditions, censusing did not take place on mornings with extreme fog, steady drizzle, prolonged rain, extreme temperature deviations from the mean, or winds in excess of 20 kmph (Robbins 1981).

HSI modeling procedure

To simplify the computation of HSI values, U.S. Forest Service compartment and HMC vegetation maps were digitized and habitat models were programmed into a geographic information system (GIS) PC-ARC/INFO. Resolution of the aforementioned maps were to 0.4 ha or 1 acre. Base map coverages (e.g. roads, lakes, rivers, drainages, railroads, etc.) for Alger, Marquette, and Schoolcraft Counties were obtained from Michigan State University, Center of Remote Sensing. Cover types within the HNF compartment maps were verified at each sample point, and discrepancies were updated. Vegetation maps for the HMC were verified by ground truthing.

Evaluation of relative habitat quality for the 4 primary cavity-nesting species was addressed using 2 methods. HSI values were calculated for each respective bird species within 70 ha study areas and subsequently compared to the maximum number of each species censused on all sample points within a single census period. Evaluation areas corresponding to the mean home range sizes of the black-capped chickadee, downy and hairy woodpeckers were also used to assess any spatial scale effects on HSI calculations (Table 2). Different home range-sized squares were centered over each vegetation sampling point and an HSI was computed for comparison with abundance indices. HSI values were calculated at home-range spatial scales ranging from 2.0 to 70 ha to determine proper spatial scales for habitat model applicability of each primary cavity nesting bird species.

Results were plotted on histograms with "percent of total area evaluated" on the ordinate, "HSI values" (grouped by 0.10's) on the abscissa, and "spatial scale" on the z-axis. The spatial scale at which the most habitat quality categories were delineated (e.g. visually) was determined to be the proper scale for model applicability for this study. Individual habitat components of each model were evaluated using the calculated HSI output and correlating each habitat component to the number of birds censused in an area. Area-weighting procedures as described by the U.S.D.I. Fish and Wildlife Service (1981) were used to compute HSI values.

Table 2. Home range estimates for primary cavity-nesting bird species and acknowledgments.

Bird species	Home range estimate (ha)[a]	Acknowledgment
pileated woodpecker	70.0	Kilham (1976), Renken and Wiggers (1989)
hairy woodpecker	8.0	Evans and Conner (1979)
downy woodpecker	4.0	Schroeder (1982b)
black-capped chickadee	2.0[b]	Galli et al. (1976)

[a] Estimated minimum amount of contiguous habitat.
[b] The black-capped chickadee model (Schroeder 1982c) assumes that forest size is not an important factor in assessing habitat quality.

Some cover types were determined to be unsuitable if any variable within a model would produce an HSI value of 0.0 (e.g. open bogs, lakes, open meadows) and, therefore, were given attribute values of 0.0. Some vegetation types within the HMC were pooled because ground truthing provided no discernible difference between hemlock (cover type 10), the northern hardwood-hemlock (cover type 11), and hemlock dominated northern hardwood (cover type 12). Sugar maple (cover type 13) was also collapsed into the unharvested-upland deciduous general cover type because pure stands were sparsely interspersed throughout the club area.

Statistically adequate sample sizes for all vegetative characteristics were determined using Freese's (1978) formula. Where: n = sample size, t = critical value from t tables (1.96), s = sample deviation, and E = allowable error of 0.20 of the mean.

$$n = \frac{t^2 s^2}{E^2}$$

Statistical analysis

Comparisons of all model variables among general cover type classes were made using Kruskal-Wallis one-way ANOVA (Seigel 1956) and ranked ANOVA's (Conover and Iman 1981). To determine which general cover types were significantly different ($p < 0.10$), Tukey's multiple comparisons (Systat, Inc. 1992) in conjunction with the ranked ANOVA's were used to examine significant differences between the habitat variables measured and cover type classes.

Principal components analysis (PCA) was used (SAS Institute 1985) to examine relationships among 6 forest cover types and 12 habitat variables associated with each of the 4 cavity-nesting bird models. Because the habitat variables measured for the models may be related, PCA was used to reduce the number of variables to fewer independent variables. The new variables (e.g. principal components), were linear combinations of the original habitat variables. These linear combinations were rotated using varimax and eqimax functions to view data in different ordinations that may help in interpretation. These data manipulations did not offer additional insight into the internal structure of this data set and, therefore, interpretation of the original variables most significant in describing a particular forest cover type was based on unrotated axes. The number of principal components to retain was determined by using only eigenvalues greater than or equal to 1 ($\lambda \geq 1$) (Jackson 1993). Analysis was done using a correlation matrix. Results from PCA and the ranked ANOVA's were used to make comparisons among different cover type classes and examine any interactions between vegetation characteristics and cover types.

Association between HSI values and bird abundance were tested using Spearman rank correlations (Siegel 1956). Correlations were performed separately for 1993 and 1994. Kruskal-Wallis one-way ANOVA (Seigel 1956), Mann-Whitney U tests (Seigel 1956) and ranked ANOVA's (Conover and Iman 1981) were used to determine if the range of HSI values could predict species occurrence. All analyses were performed separately for 1993 and 1994.

RESULTS

Habitat cover types

Vegetative characteristics of 16 cover types (Appendix C) were sampled among all 70 ha study areas and the means generated were subsequently used to calculate mean-weighted HSI values for each study area (Table 3). Of the 16 distinct cover types sampled, means of percent canopy closure ranged from 5.7% to 99.6%, number of trees > 51 cm dbh ranged from 0.0 to 30.9 trees / 0.4 ha, number of down woody material (e.g. stumps and logs) ranged from 0.0 to 87.7 / 0.4 ha, number of snags > 38 cm dbh ranged from 0.0 to 8.8 / 0.4 ha, average dbh of snags > 38 cm ranged from 0.0 to 64.26 cm (25.3 in.), number of snags ≥ 25 cm dbh ranged from 0.9 to 14.6 / 0.4 ha, mean dbh of overstory trees ranged from 23.11 cm dbh to 46.99 cm dbh, percent pine canopy closure ranged from 0.0 to 76.1 / 0.4 ha, basal area ranged from 14.40 to 55.36 m^2 / ha, number of snags > 15 cm dbh ranged from 4.9 to 43.0 / 0.4 ha, height of overstory trees ranged from 10.1 to 23.9 m, and number of snags ≥ 10-25 cm ranged from 7.9 to 70.8 / 0.4 ha.

To describe the dominate vegetative composition of each study area, the 16 cover types (Appendix C) were delineated into 10 vegetative classes that comprised the entire area of each study site (Appendix A). Reduction in the number of cover types from 16 to 10 resulted from areas where cover types were < 1% of a study area or found on 2 or fewer study areas and were therefore classified as miscellaneous (Appendix A). Six dominant vegetative classes were then constructed from the 10 primary cover types listed in Appendix A, and included: 5 study areas dominated by mature upland coniferous forest types, 3 study areas dominated by mature lowland coniferous forest types, 2 study areas dominated by upland deciduous pole-timber forest types, 5 study areas dominated by previously harvested mature upland deciduous forest types, 3 study areas dominated by mature lowland deciduous forest types, and 6 of the study areas dominated by unharvested (late-successional) upland deciduous forest types. Comparisons were made using only the dominant cover types per study area, which ranged from 44-100% ($\bar{X}$ = 78%).

Table 3. Means ($\bar{X}$) and standard errors (SE) of all measured variables for vegetation cover types on twenty-four 70 ha study areas sampled in Michigan's Upper Peninsula, 1993 and 1994.

Cover Type[b]	Variables[a]											
	Can		Tgt20		Down		Snaggt15		Sndbh15		Snag10	
	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
1	76.1	4.2	3.6	4.4	64.5	7.4	0.9	1.5	15.5	0.0	6.3	2.4
4	5.7	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	3.1
5	78.5	11.3	2.0	3.4	34.3	7.8	3.0	2.0	16.7	1.3	11.1	2.9
6	95.1	3.3	3.6	3.6	48.4	6.6	7.2	2.1	18.2	0.6	11.3	2.0
7	85.2	7.6	17.6	4.9	79.2	9.0	8.8	2.6	21.4	4.4	14.6	2.5
11	97.3	1.4	30.9	3.2	52.7	4.2	5.8	1.0	21.4	2.5	7.8	1.1
17	99.6	0.2	22.2	6.5	64.5	9.2	5.0	2.4	19.2	0.6	11.1	2.1
22	98.1	1.9	13.4	5.7	35.0	7.5	2.7	2.3	21.8	---[c]	4.0	2.4
28	94.9	2.2	18.4	4.9	84.0	6.5	5.2	1.7	19.9	1.1	13.8	2.4
029	90.0	3.3	5.4	5.4	48.4	8.5	0.0	0.0	0.0	0.0	0.9	1.5
149	74.0	6.1	3.2	2.7	83.9	7.8	2.2	3.3	18.0	3.3	8.1	2.2
189	86.7	4.0	1.8	2.9	114.7	7.7	1.8	1.7	20.3	2.6	12.6	3.0
769	96.6	1.4	8.1	3.8	37.6	6.1	2.0	1.5	25.3	6.2	12.1	2.6
816	78.2	3.2	1.0	1.7	38.6	4.5	1.0	1.7	16.0	---	2.7	1.8
819	92.5	2.0	10.4	2.0	71.6	5.2	1.6	0.9	20.3	2.7	4.3	1.1
849	96.2	1.9	5.4	3.8	87.7	8.7	0.9	1.5	15.5	---	7.2	2.1

Table 3 (cont'd).

Cover Type[b]	Variables[a] Dbhost $\bar{X}$	SE	Pine $\bar{X}$	SE	Ba $\bar{X}$	SE	Snaggt6 $\bar{X}$	SE	Ht $\bar{X}$	SE	Snag410 $\bar{X}$	SE
1	24.9	0.7	76.1	4.2	29.16	2.86	43.0	3.4	19.5	0.5	70.8	5.2
4	23.4	1.2	3.0	2.2	14.40	10.9	6.1	3.9	10.1	1.3	12.1	3.9
5	39.6	0.9	30.7	8.1	35.69	4.61	19.3	3.4	20.5	1.2	9.1	3.3
6	34.8	0.6	28.7	7.8	34.52	3.26	15.3	2.4	20.0	1.0	16.1	3.5
7	37.6	0.9	8.3	5.9	40.71	5.85	22.0	2.9	20.1	0.6	15.4	3.1
11	47.0	0.5	4.5	2.3	55.36	3.38	11.1	1.3	23.9	0.4	70.8	1.2
17	42.7	0.6	0.0	0.0	52.25	6.73	20.2	2.1	21.6	0.3	19.2	2.9
22	38.1	0.7	3.9	3.0	43.27	5.46	8.7	3.1	20.9	0.3	14.8	4.1
28	41.2	0.7	0.0	0.0	39.33	4.55	21.9	2.5	20.6	0.4	13.8	2.6
029	38.6	0.4	67.6	6.6	40.70	3.90	8.1	2.5	20.8	0.2	16.1	2.7
149	24.1	0.4	0.3	0.3	27.22	3.93	23.6	3.1	15.9	0.3	28.0	2.9
189	24.4	0.4	0.0	0.0	32.17	3.24	34.9	2.7	15.8	0.2	32.3	3.3
769	31.0	0.5	2.7	2.7	36.61	2.82	30.9	3.5	19.7	0.3	41.7	3.7
816	23.1	0.2	0.0	0.0	16.19	0.6	4.9	1.9	19.0	0.2	18.4	3.8
819	34.8	0.3	3.6	1.1	31.99	1.35	9.4	1.3	23.2	0.2	17.2	2.7
849	28.2	0.6	0.0	0.0	37.40	6.00	23.3	3.2	18.8	0.3	27.7	3.9

[a] Variable descriptions are as follows: Can = percent tree canopy closure, Tgt20 = No. of live trees > 51 cm dbh/0.4 ha, Down = No. of Stumps and logs/0.4 ha, Snaggt15 = No. of snags > 38 cm dbh/0.4 ha, Sndbh15 = mean dbh of snags >38 cm, Snag10 = Snags ≥ 25 cm dbh/0.4 ha, Dbhost = mean dbh (cm) of overstory trees (Trees > 80% of the tallest tree), Pine = percent pine canopy closure, Ba = Basal area (m^2/ha), Snaggt6 = No. of snags > 10 cm dbh/0.4 ha, Ht = mean height of overstory trees (meters), Snag410 = No. of snags ≥10 to 25 cm dbh/0.4 ha.

[b] Cover type descriptions can be found in Appendix C.

[c] Standard error could not be calculated due to low snag numbers.

Comparisons of habitat variables among dominant cover types

Several significant differences in vegetative composition and structure associated with the HSI models (Kruskal-Wallis, $p < 0.10$) (Table 4) were detected among the 6 dominant cover types. All unharvested upland deciduous stands associated with the HMC study areas had greater percent canopy closure than both the upland and lowland coniferous sites and upland deciduous pole-timber sites located in the Hiawatha National Forest (HNF), but did not differ with previously harvested upland and lowland deciduous sites found in the HNF. The percentage of pine canopy closure was greatest on the upland coniferous sites (*Pinus spp.*) than other sites. Also, the previously harvested upland deciduous sites appeared to be different than both the upland pole-timber and lowland coniferous sites. Basal area was significantly greater in HMC's unharvested upland deciduous/late-successional forest type than all other cover type classes. Previously harvested upland and lowland deciduous and upland coniferous sites exhibited relatively greater basal area than the upland deciduous pole-timber sites.

The unharvested upland deciduous sites had significantly more trees > 51 cm dbh/ 0.4 ha than any other general cover types, whereas, the previously harvested upland deciduous sites were significantly different than the upland deciduous pole-timber sites and the lowland and upland conifer sites. The number of snags > 38 cm dbh / 0.4 ha was significantly greater within the unharvested sites than all other cover types, with the exception of the lowland deciduous sites. For the habitat variable, number of snags > 25 cm dbh, significantly lower numbers were associated with the upland pole-timber sites when compared to unharvested upland deciduous and lowland deciduous sites. There

Table 4. Means ($\bar{X}$) and standard errors (SE) of habitat variables on 6 general cover type delinations that dominated twenty-four 70 ha study areas sampled in the Upper Peninsula of Michigan, 1993 and 1994.

	Forested Cover Types (n)					
Habitat Variables[a]	Lowland Deciduous (3)	Previously Harvested Upland Deciduous (5)	Unharvested Upland Deciduous (6)	Upland Deciduous Poletimber (2)	Lowland Coniferous (3)	Upland Coniferous (5)
Percent canopy closure	95.3 AB[b]	92.5 AB	95.3 B	78.2 C	85.1 AC	78.8 AC
	(1.0)	(2.2)	(2.5)	(4.6)	(3.8)	(7.3)
Percent pine canopy closure	2.0 AB	3.6 A	2.7 AB	0.0 B	0.1 B	44.8 C
	(1.4)	(1.0)	(2.0)	(0.0)	(0.1)	(6.4)
Basal area (m^2 / ha)	33.14 A	32.0 A	50.05 B	16.0 C	29.3 A	36.0 A
	(0.06)	(1.60)	(2.7)	(0.72)	(2.88)	(3.24)
Trees > 51 cm dbh / 0.4 ha	7.1 AB	10.4 B	26.6 C	0.9 A	3.0 A	5.7 A
	(1.8)	(1.6)	(3.3)	(0.9)	(1.3)	(2.3)
No. snags > 38 cm dbh / 0.4 ha	2.7 AB	1.4 A	5.3 B	0.0 A	1.8 A	2.3 A
	(0.9)	(0.6)	(0.8)	(0.0)	(0.8)	(0.9)
No. snags > 25 cm dbh / 0.4 ha	8.4 A	3.9 AB	9.3 AC	2.2 B	7.8 AB	6.5 AB
	(1.4)	(1.3)	(1.0)	(1.3)	(1.5)	(1.4)
No. snags > 15 cm / 0.4 ha	27.5 A	9.5 BC	15.5 B	4.9 C	26.0 AB	19.0 AB
	(3.1)	(2.0)	(1.8)	(1.8)	(4.2)	(3.6)
No. snags ≥ 10-25 cm dbh / 0.4 ha	31.1 A	11.3 B	11.6 B	9.4 B	28.4 A	23.2 AB
	(5.5)	(1.9)	(1.5)	(2.0)	(3.8)	(6.3)
No. of down / 0.4 ha (stumps/logs)	72.3 AB	62.0 A	62.4 AB	38.5 A	84.8 B	44.1 A
	(10.0)	(7.6)	(6.3)	(8.0)	(14.8)	(6.0)
Dbh of overstory trees (cm) / 0.4 ha	32.3 AB	36.8 A	45.7 C	24.0 B	27.4 B	36.5 A
	(1.1)	(1.2)	(1.7)	(0.9)	(1.7)	(2.5)

Table 4 (cont'd).

Habitat Variables[a]	Forested Cover Types (n)					
	Lowland Deciduous (3)	Previously Harvested Upland Deciduous (5)	Unharvested Upland Deciduous (6)	Upland Deciduous Poletimber (2)	Lowland Coniferous (3)	Upland Coniferous (5)
Height of overstory trees (m) / 0.4 ha	19.5 AB	23.6 C	22.9 C	19.2 A	17.0 A	20.1 B
	(0.4)	(0.5)	(0.7)	(0.3)	(0.7)	(0.9)
Avg. dbh snags > 38 cm dbh / 0.4 ha[c]	36.3 A	20.6 B	45.7 A	0.0 B	21.1 B	18.8 B
	(3.9)	(2.7)	(1.5)	(0.0)	(3.3)	(2.5)

[a] Histograms of the means of the above 12 habitat variables across all twenty-four 70 ha areas can be found in Appendix D.

[b] Significantly different among general cover type classifications (Kruskal-Wallis, $p < 0.04$). Means within the same row having the same letter are not significantly different (ranked ANOVA, Tukey multiple comparisons $p < 0.10$) (Conover and Iman 1981).

[c] Average dbh of snags < 38 cm resulted from plots where no large snags were recorded.

were also significantly more snags > 25 cm dbh within the unharvested than previously harvested upland deciduous sites.

The number of snags > 15 cm dbh did not differ on the managed upland deciduous sites and upland deciduous pole-timber sites. Also, lowland deciduous sites had significantly greater numbers of snags > 15 cm than either previously harvested and unharvested upland deciduous sites. Snags that ranged from 10 to 25 cm dbh differed among cover type classes. Lowland deciduous sites had a greater number of snags 10-25 cm than previously harvested, unharvested, and pole-timber upland deciduous sites. Lowland conifer sites had significantly more snags 10-25 cm dbh than harvested, unharvested and pole-timber upland deciduous sites (Table 4).

The amount of down woody material was greatest within the lowland coniferous sites and was significantly greater than upland deciduous pole-timber and upland coniferous sites. No difference was apparent between previously harvested upland deciduous, unharvested upland deciduous, or lowland deciduous sites in terms of amount of down woody material.

Unharvested upland deciduous sites had significantly larger dbh's of overstory trees than all other cover types. Previously harvested deciduous overstory tree dbh's were different than those of lowland conifer and upland deciduous pole-timber sites, whereas, lowland conifer sites differed from upland conifer sites.

Mean overstory tree heights were not different for previously harvested and unharvested upland deciduous sites, however, all other sites were significantly different from both the previously harvested and unharvested upland deciduous sites. Lowland coniferous sites also differed from upland coniferous sites in terms of overstory tree height (Table 4).

Average dbh of snags > 38 cm dbh resulted from some plots having no large snags, and therefore for this analysis, figures may be < 38 cm dbh. Again, the size of snags on the unharvested upland deciduous sites within the HMC significantly differed from all other cover types, with the exception of the lowland deciduous sites. Also, these lowland sites had significantly more large snags than the upland deciduous pole-timber sites.

Principle component analysis

The first 3 principal components were retained and accounted for 76.6% of the variance in the 12 vegetative variables (Appendix E). Principal component 1 (PRIN1), explaining 40.1% of the variance, is a gradient from earlier successional pole-timber aged forests and small snags to late-successional forest cover types and large snags. The second principal component (PRIN2) explained 24.5% of the variance within the data set and is a gradient of fewer numbers of snags to greater numbers of snags. Finally, principal component 3 (PRIN3), explaining 11.1% of the variance, is a gradient from very little percent pine canopy closure to a greater percent of pine canopy closure.

Upland deciduous pole-timber sites were characterized by a low weighting toward small snags (PRIN1), fewer numbers of snags (PRIN2), and no pine canopy cover (PRIN3) (Fig. 6). Study areas dominated by previously harvested mature upland deciduous forests tended to be moderately weighted with intermediate numbers and size of snags (PRIN1-2), with relatively little percent pine canopy cover (PRIN3). Unharvested upland deciduous (late-successional) forest types were heavily weighted and

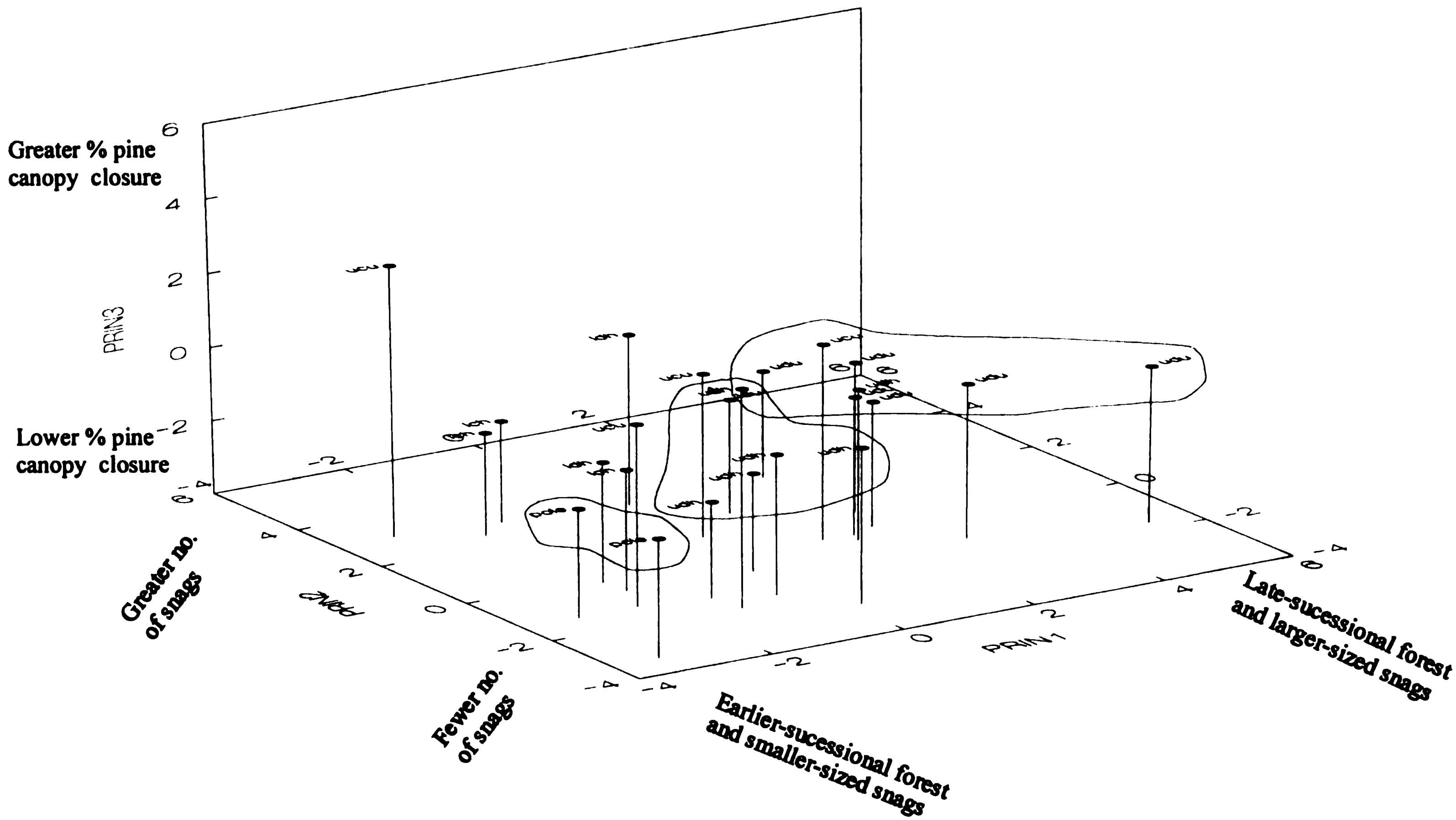


Figure 6. Mean principal component (PRIN) values of the first 3 principal components on twenty-four 70 ha study areas dominated by 6 general cover types. **ldh**=previously harvested mature lowland deciduous forest, **udh**=previously harvested mature upland deciduous forest, **udu**=unharvested late-successional upland deciduous forest found in the Huron Mountain Club, **lch**=previously harvested mature lowland coniferous forest, **uch**=previously harvested mature upland coniferous forest, **pole**=pole-timber sized upland deciduous forest. Bands encircling the forest types pole, udh and udu show differences in forest structure and composition based on the pileated, hairy, and downy woodpeckers and the black-capped chickadee HSI models variables.

could be characterized by large snags (PRIN1), and intermediate to many snags (PRIN2). Lowland conifer study areas were characterized as having many small snags (PRIN1-2), and little in the way of pine canopy cover. Four of the upland conifer sites tended to be characterized as having intermediate sized snags (PRIN1), low to moderate numbers of snags (PRIN2) and relatively greater percentage of pine canopy cover (PRIN3). However, 1 study area dominated by jack pine was best characterized as having greater numbers of snags but relatively small in size, (PRIN1-2), and a large percentage of pine canopy cover. Lowland deciduous sites had intermediate numbers and sized snags (PRIN1-2), but loadings were noticeably different in terms of the amount of pine cover found within these sites (PRIN3). Study areas associated with late-successional forest types, regardless of cover type, exhibited higher HSI scores for the pileated and hairy woodpeckers (Figures 7-8). Higher scores indicate that the structural and compositional habitat attributes, associated with mature to late-successional forests, are providing good to optimal habitat quality for the 2 aforementioned cavity-nesters.

Relative bird abundance indices

Census data for 1993 and 1994 were not pooled for testing models. Population indices were obtained using the maximum number of individual species censused during any 1 of the 3 census periods conducted on each study area. The abundance index used for the black-capped chickadee ranged from 1-7 birds in 1993 and 1-9 chickadees in 1994; downy woodpecker numbers ranged from 0-2 birds in both 1993 and 1994; hiary woodpecker numbers ranged from 1-6 birds in 1993 and 0-4 birds in 1994; and pileated woodpeckers censused across all study areas ranged from 0-2 birds in 1993 and 0-3 birds in 1994.

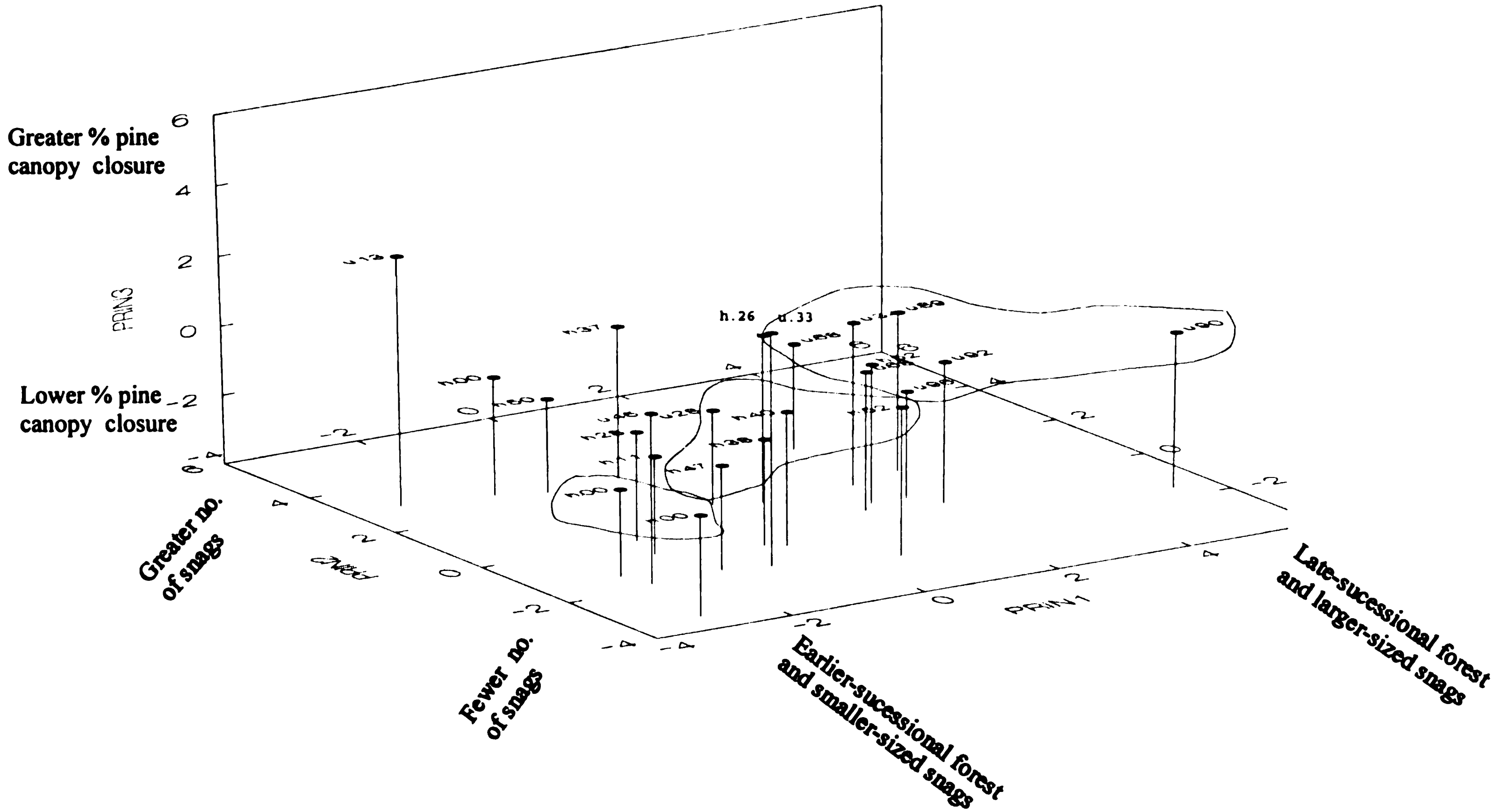


Figure 7. Mean-weighted HSI values for the pileated woodpecker plotted against the mean principal component (PRIN) values of the first 3 principal components on twenty-four 70 ha study areas dominated by 6 general cover types. The **u**=unharvested forest types found within the Huron Mountain Club and **h**=previously harvested mature forest types typically found within the Hiawatha National Forest. HSI values are indicated to the right of each letter. Bands encircling areas on the graph indicate differences in habitat quality for the pileated woodpecker. The encircled area in the lower left of the graph are pole-timber sized upland deciduous forested areas and provide no pileated woodpecker habitat (HSI=0.0). The encircled areas in the middle and right of the graph are previously harvested and unharvested upland deciduous stands, respectfully. The upper right hand of the graph have higher calculated HSI scores.

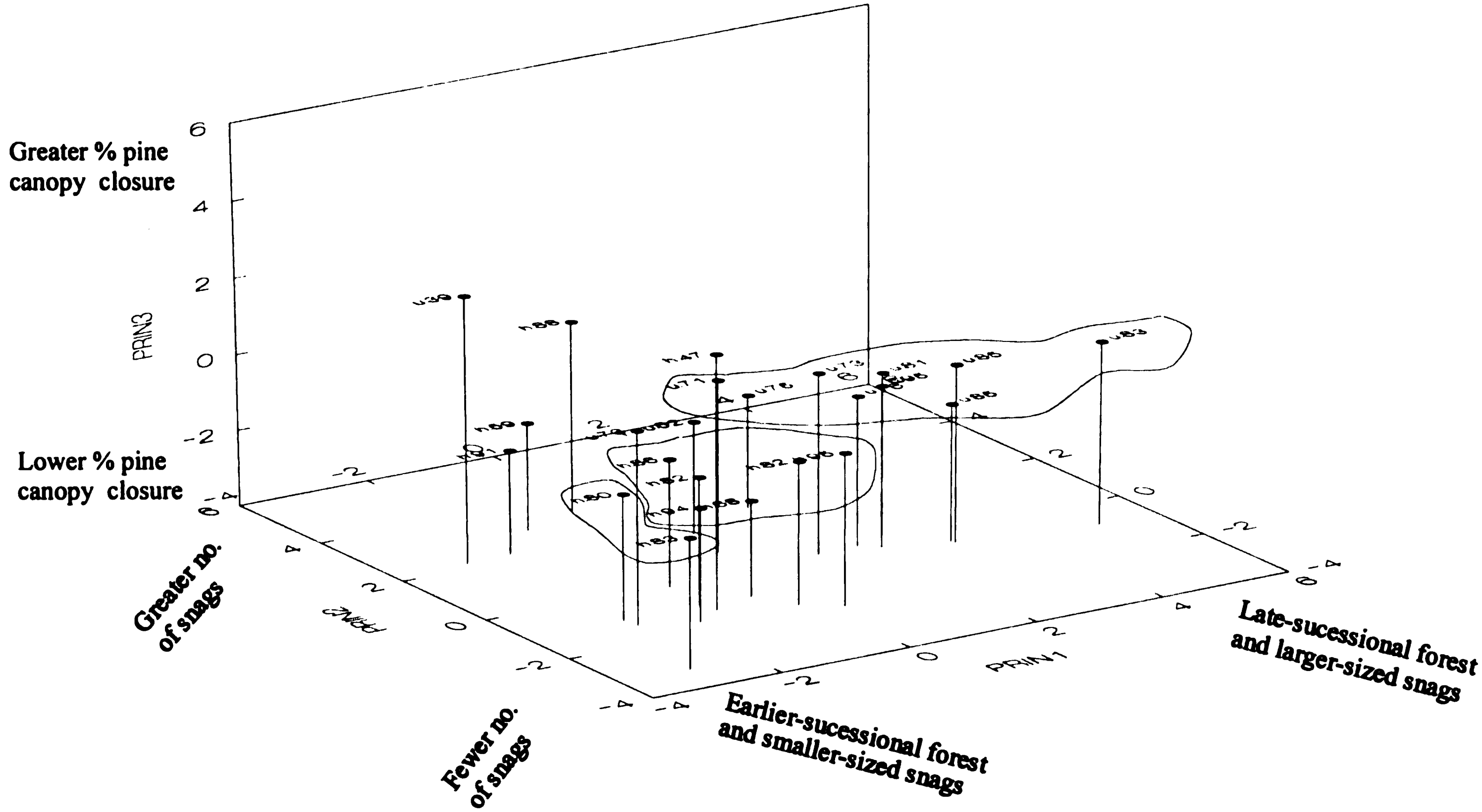


Figure 8. Mean-weighted HSI values for the hairy woodpecker plotted against the mean principal component (PRIN) values of the first 3 principal components on twenty-four 70 ha study areas dominated by 6 general cover types. The **u**=unharvested forest types found within the Huron Mountain Club and **h**=previously harvested mature forest types typically found within the Hiawatha National Forest. Calculated HSI values for each study area are indicated to the right of each letter. Bands encircling areas on the graph indicate that although there are structural and compositional differences within each forest type, habitat quality for the hairy woodpecker is provided regardless of cover type. The encircled area in the lower left of the graph are pole-timber sized upland deciduous forested areas and provides good hairy woodpecker habitat (HSI=0.80+). The other encircled areas are previously harvested and unharvested upland deciduous stands and have similar calculated HSI values.

Habitat model scale

HSI values were calculated for each 70 ha study area and subsequently compared to the maximum number of birds censused on all sample points within a single census period. It should be noted that all HSI scores were calculated using all 16 cover types listed in Appendix C and reflected all vegetation types found within study areas. Home range sized spatial scales ranging from 2-12 ha were centered over each vegetative sampling point (n=73) for the hairy woodpecker, downy woodpecker and black-capped chickadee. Based on the relatively large tracts of forest types and the distribution of compositional and structural attributes throughout all study areas, the influence of spatial scale (e.g. home ranges of each species) was somewhat ambiguous (Figures 9-11).

The appropriate spatial scale of assessment for the black-capped chickadee, downy woodpecker and hairy woodpecker generally corresponded to each species home range. The black-capped chickadee model discriminated habitat across a broad range of spatial scales (Figure 9), however, 10 ha was the scale at which a full range of habitat quality (e.g. HSI classes) was distinguished. The downy model also discriminated habitat across a range of spatial scales but, spatial scales of 2 to 4 ha encompassed the broadest range of HSI classes (Figure 10). The hairy woodpecker model seemed to discriminate habitats equally from a 2 to 12 ha spatial scale (Figure 11).

Generally, the ability to discriminate habitats of different quality decreased to 3 or 4 HSI classes at larger spatial scales (e.g. 70 ha). This is primarily due to the effects of the area-weighting procedure used in HSI calculations (U.S.D.I. Fish and Wildlife Service 1981). HSI models are extremely sensitive to spatial scale, especially in

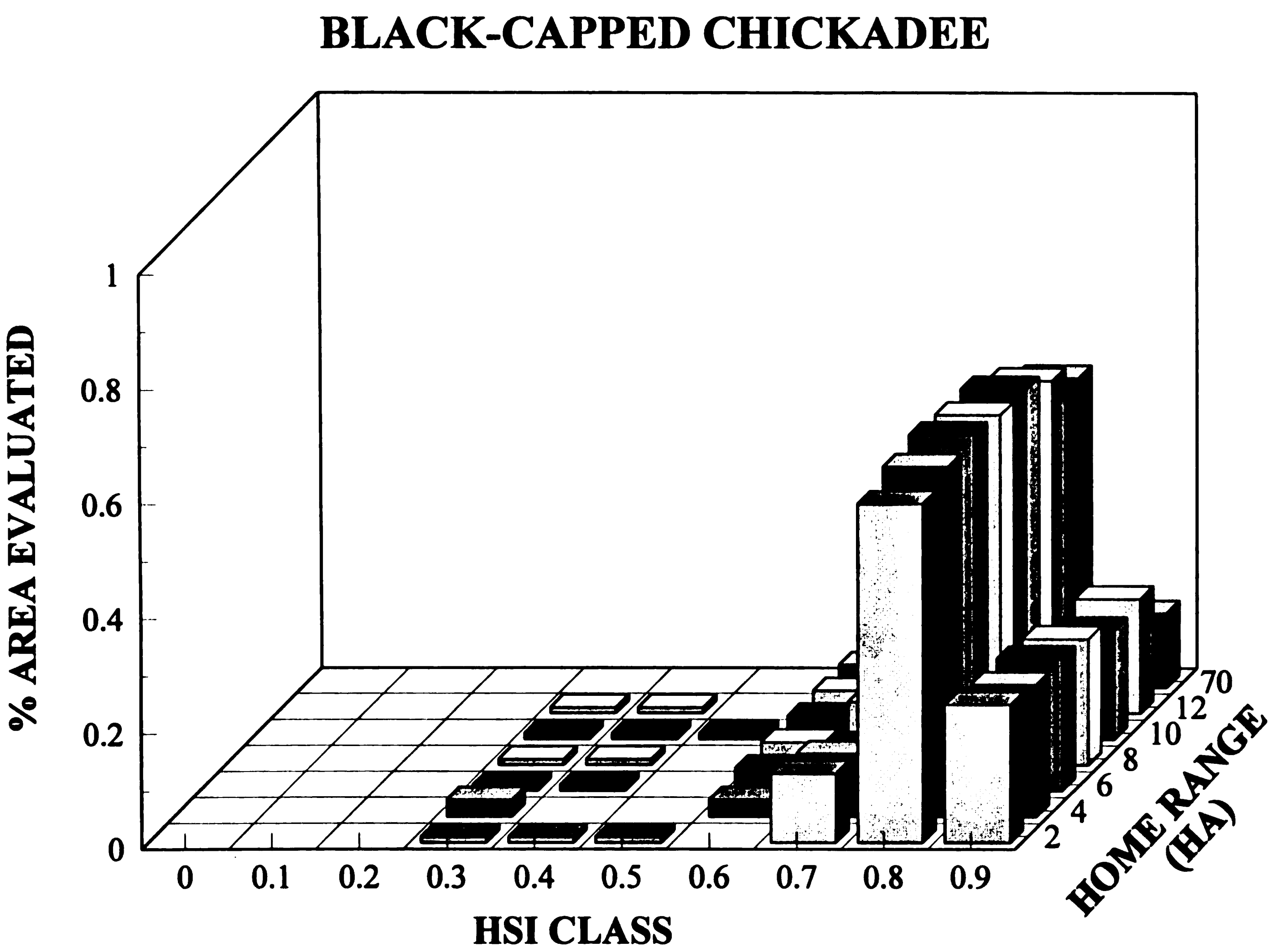


Figure 9. The influence of spatial scale on HSI model (Schroeder 1982c) output for the black-capped chickadee.

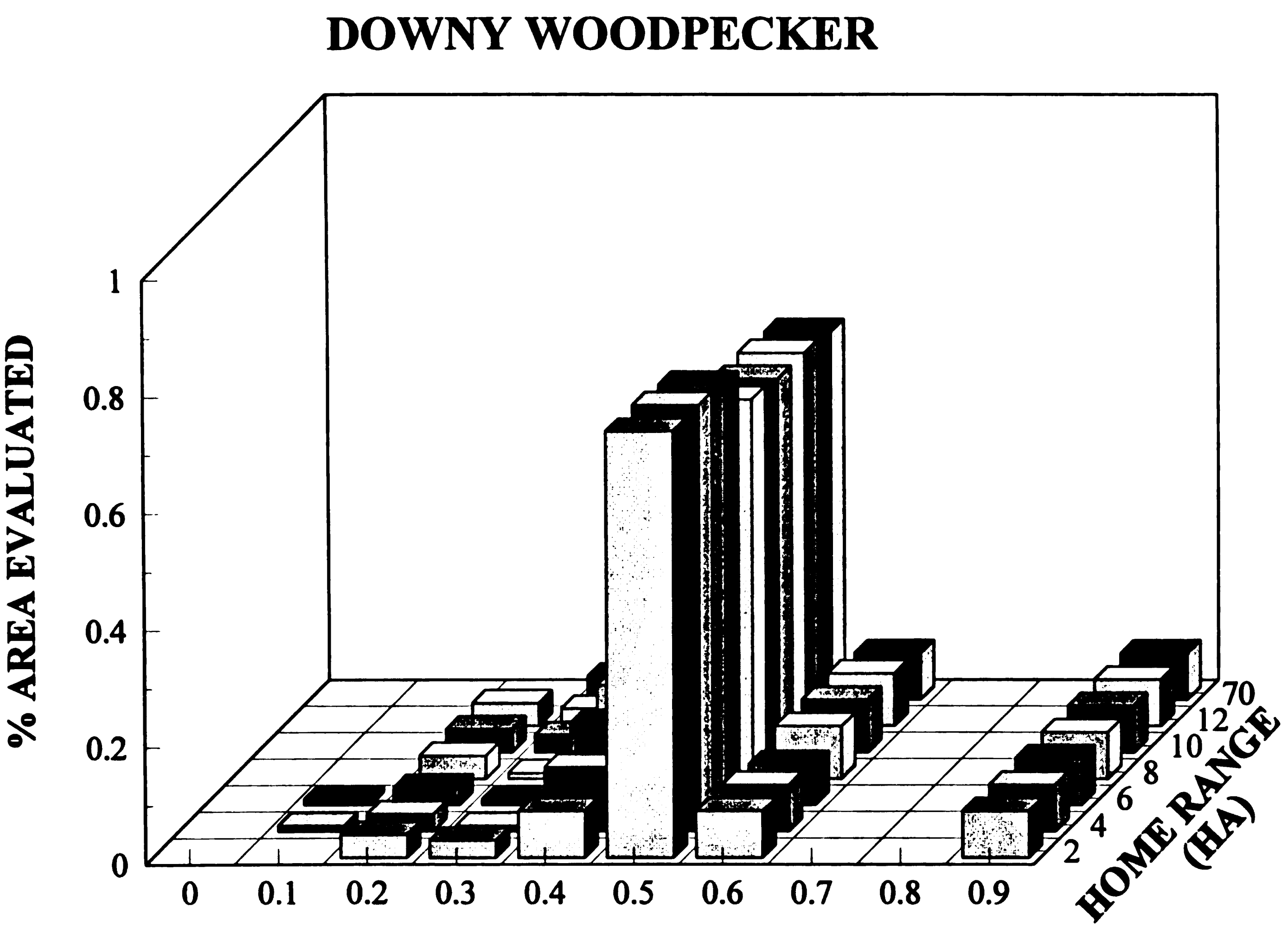


Figure 10. The influence of spatial scale on HSI model (Schroeder 1982b) output for the downy woodpecker.

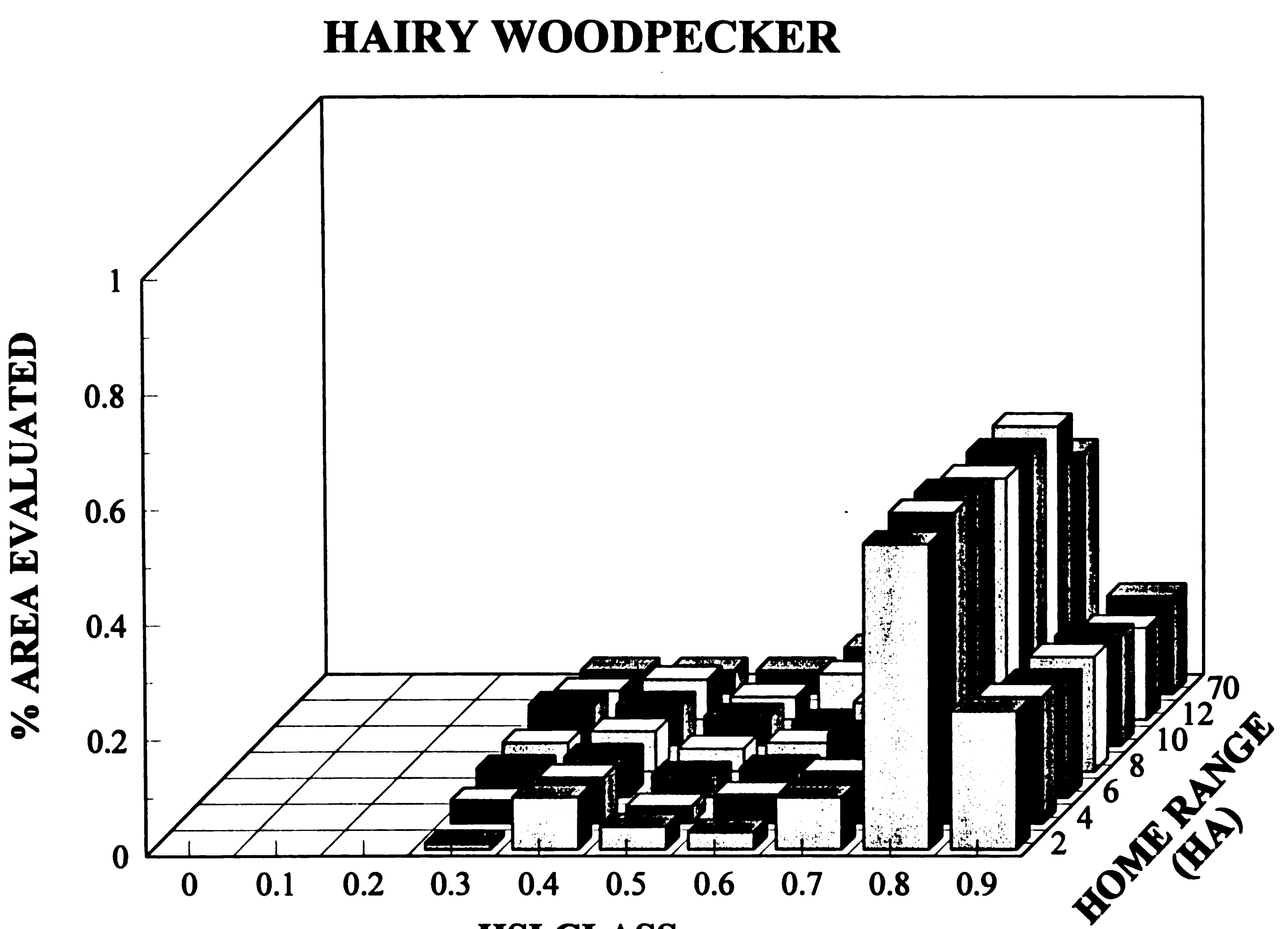


Figure 11. The influence of spatial scale on HSI model (Sousa 1987) output for the hairy woodpecker.

heterogeneous environments (Van Horne and Wiens 1991). The majority of the study areas provided relatively consistent habitat quality values (e.g. good to optimal) across a broad range of spatial scales for each species. These results may be due to relatively large, uniform, and contiguous tracts of forest lands within and around each study area. The influence of scale on model output is related to the habitat configuration surrounding each point, explaining why some points (for individual models) exhibit large changes in HSI values, whereas others remain relatively constant (Roloff 1994). Although, smaller spatial scales generally corresponded to the home ranges of each of the aforementioned species, the majority of the study areas provided habitat quality associated with the 3 or 4 HSI classes that were consistent across the range of spatial scales (e.g. 2 to 70 ha). Because of this lack of large differences in habitat quality among spatial scales, all models were validated based on 70 ha areas.

Habitat suitability indices

HSI's for all species ranged from 0.00 to 1.00 with means between 0.41 and 0.82 (Table 5). All HMC study areas (n=11) provided optimal (0.76-1.00) and good (0.51-.75) HSI values for all primary cavity-nesting bird species, with HNF sites (n=13) provided poor (0.0-0.25) to optimal being intermediate in terms calculated HSI values. The range of HSI values calculated for the pileated woodpecker ranged from 0.0 to 0.96. Cover types providing optimal habitat quality for the pileated woodpecker were the unharvested upland deciduous forests (n=6) found in the HMC and 2 previously harvested upland deciduous forest types found in the HNF. Marginal sites included 3 previously harvested upland deciduous, 3 lowland deciduous forest types, and 4 upland conifer forest types.

Table 5. Habitat Suitability Indices and general classification of all twenty-four 70 ha study areas delineated into 4 habitat suitability classes for 4 cavity-nesting bird species.

Species	HSI Values		Classification of Study Areas[a]			
	Range	$\bar{X}$ (SD)	Optimal	Good	Marginal	Poor
pileated woodpecker	0.00-0.96	0.41 (0.55)	4	4	10	6
hairy woodpecker	0.39-0.95	0.77 (0.38)	15	7	2	0
downy woodpecker	0.36-1.00	0.54 (0.38)	2	6	16	0
black-capped chickadee	0.65-0.97	0.82 (0.27)	21	3	0	0

[a] Optimal (HSI=0.76-1.00); Good (HSI=0.51-0.75); Marginal (HSI=0.26-0.50); and Poor (HSI=0.00-0.25).

Areas providing poor habitat quality for the pileated woodpecker included 2 areas dominated by upland deciduous pole timber, 3 lowland coniferous forest types and 1 upland coniferous forest type.

The range of HSI values calculated for the hairy woodpecker model ranged from 0.39 to 0.95. Twenty-two of the 24 study areas provided optimal to good habitat quality for the hairy woodpecker (Table 5). Two study areas dominated by upland coniferous forest provided marginal habitat for the hairy woodpecker. Study areas found in both the HMC and HNF seemed to be providing good to optimal habitat quality for hairies.

The downy woodpecker model calculated HSI values ranging from 0.36 to 1.00. Two upland deciduous pole timber sites provided the only areas where HSI values were deemed optimal. Six study areas provided good quality habitat for the downy, however, these calculated values ranged from 0.50 to 0.60 and were just slightly better than sites with marginal habitat quality values.

The range of HSI values calculated for the black-capped chickadee had a rather tight range, 0.65 to 0.97. Twenty-one of the 24 study areas provided optimal habitat quality based on the models variables (Table 5). The 3 sites that provided good quality habitat for chickadees were in the 0.65 to 0.75 range and, therefore, were on the high end of the classification of "good" habitat quality.

HSI-bird abundance associations

Logistic regression was performed using SAS (SAS Institute 1985) for the pileated woodpecker model. Logistic regression analysis was used to investigate the relationship between bird abundance data, referred to as either presence or absence, and the 5 habitat variables described in the model (Figure 5). For 1993 and 1994, the model remained significant (p <0.05) when 3 of the 5 variables were included in the analysis. The 3 variables ranked by decreasing Chi-square (X^2) values and probabilities were as follows for both years: percent canopy closure, trees >51 cm dbh, and average dbh of snags > 38 cm. The model significance levels for 1993 and 1994 were (p <0.0301) and (p <0.0437), respectfully. Using only the above variables in the analysis, the model correctly classified each study area by presence or absence 75% of the time. However, even though the overall model was significant using 3 variables, the individual model variables did not remain significant. This analysis was used on only the pileated woodpecker model because the black-capped chickadee, hairy and downy woodpecker models did not provide as great a range of habitat quality values. Therefore, since the pileated model did not remain significant, Spearman rank correlations in conjunction with Kruskal-Wallis 1-one way ANOVA, Mann-Whitney U tests, and ranked ANOVA's were used to determine if model output corresponded to census data.

Spearman rank correlation tests (Siegel 1956) were performed for 1993 and 1994 and produced variable results. Probability was 2-tailed and tested if the correlation coefficient differed from zero. Although correlations of all models were consistent across years, only the pileated woodpecker ($P \leq 0.001$) and the hairy ($P \leq 0.10$) woodpecker models exhibited significant correlation coefficients (Table 6). The downy woodpecker and black-capped chickadee models exhibited either non-significant correlations or inverse correlation coefficients.

Table 6. Spearman rank correlation coefficients and associated probabilities for tests between bird abundance indices, individual model variables, and habitat suitability indices (HSI's), calculated for all 70 ha study areas in 1993 (n=20) and 1994 (n=24).

	1993		1994	
Bird Species / Model Variables	r_s[a]	P	r_s	P
Pileated Woodpecker				
SIV1- percent canopy closure	0.20	n.s.[b]	0.09	n.s.
SIV2- No. Trees > 51 cm dbh / 0.4 ha	0.60	0.01*	0.58	0.01*
SIV3- No. of tree stumps and logs / 0.4 ha	0.18	n.s.	0.06	n.s.
SIV4- No. snags > 38 cm dbh / 0.4 ha	0.28	n.s.	0.15	n.s.
SIV5- mean dbh of snags > 38 cm dbh / 0.4 ha	0.46	0.05*	0.50	0.02*
70 ha study areas for the pileated woodpecker model	0.69	0.001*	0.64	0.01*
Hairy Woodpeckcer				
SIV1- No. snags >25 cm dbh / 0.4 ha	0.10	n.s.	-0.03	n.s.
SIV2- mean dbh of overstory trees[c]	-0.02	n.s.	-0.29	n.s.
SIV3- mean dbh of overstory trees	0.07	n.s.	-0.05	n.s.
SIV4- percent pine canopy closure	0.13	n.s.	0.48	0.02*
SIV5- percent canopy cover	0.57	0.01*	0.48	0.02*
70 ha study areas for the hairy woodpecker model	0.31	0.10*	0.32	0.10*
Downy Woodpecker				
SIV1- basal area (m^2 / ha)	0.16	n.s.	0.15	n.s.
SIV2- No. snags>15 cm dbh / 0.4 ha	-0.23	n.s.	-0.11	n.s.
70 ha study areas for the downy woodpecker model	0.14	n.s.	0.10	n.s.
Black-capped Chickadee				
SIV1- percent canopy closure	-0.08	n.s	-0.20	n.s.
SIV2- height of overstory trees	0.10	n.s.	-0.04	n.s.
SIV4- No. snags 10-25 cm dbh / 0.4 ha	0.12	n.s.	0.02	n.s.
70 ha study areas for the black-capped chickadee model	0.00	n.s.	-0.17	n.s.

[a] r_s = Spearman rank correlation coeffient, P = 2-tailed probability and tested if the correlation coefficient differed from zero (Siegel 1956).

*Significant correlations ($P \leq 0.10$).

[b] Not significant ($P > 0.10$).

[c] SIV2 and SIV3 are calculated differently in the hairy woodpecker model (Schoeder 1982b).

The Mann-Whitney U test, Kruskal-Wallis 1-way ANOVA and ranked ANOVA's in conjunction with Tukey multiple comparisons were performed using calculated HSI values and bird abundance to determine if bird models could predict whether a species would be present or not across study areas. Results indicate that the pileated woodpecker model can discriminate between areas where birds were censused and those areas where no birds were observed (Kruskal-Wallis, Tukey multiple comparisons $p=0.024$) (Table 7). In addition, the pileated model showed significant differences in 1994 between HSI scores on sites where 1 bird was censused and sites that 2 or more birds were recorded (ranked ANOVA, Tukey multiple comparison $p=0.006$). However, the hairy model did not show significant differences between HSI scores and bird abundance for 1993 or 1994.

Spearman correlations were also performed between each of the individual model variables and bird abundance to examine which variables may be influencing model output. Several significant correlations indicate an association between individual model variables and bird abundance (Table 6). The pileated woodpecker model variables exhibiting significant correlations included number of trees > 51 cm dbh ($r_s=0.60$, $P<0.01$) in 1993 and $r_s=0.58$, $P<0.01$) in 1994; mean dbh of snags > 38 cm dbh ($r_s=0.46$, $P<0.05$) in 1993 and ($r_s=0.50$, $P<0.02$). Significantly correlated variables in the hairy woodpecker model included number of snags 10-25 cm ($r_s=0.57$, $P<0.01$) in 1993 and ($r_s=0.48$, $P<0.02$) in 1994 and percent pine canopy closure ($r_s=0.48$, $P<0.02$) in 1994.

There were no significant associations between the habitat variables and bird abundance for the downy woodpecker or black-capped chickadee models. However, both

Table 7. Descriptive statistics showing differences in HSI values grouped by bird absence, bird presence, and 2 or more birds present for the pileated and hairy woodpecker. Twenty 70 ha study areas were censused in 1993 and twenty-four 70 ha study areas were censused in 1994.

	Year 1993			Year 1994		
Bird Species	Absent	Present	2+ Present	Absent	Present	2+Present
Pileated woodpecker						
Mean	0.25A[a]	0.60B	0.94BC	0.26A	0.57A	0.81B
Standard. error	0.052	0.088	0.028	0.064	0.085	0.071
Range	0.0-0.47	0.11-0.96	0.92-0.96	0.0-0.68	0.11-0.96	0.52-0.96
No. of study areas	9	11	2	12	6	6
Hairy woodpecker						
Mean	0.67A	0.78A	n.s.[b]	0.76A	0.77A	n.s
Standard error	0.045	0.037	n.s	0.037	0.032	n.s
Range	0.62-0.71	0.39-0.95	n.s	0.71-0.83	0.39-0.95	n.s
No. of study areas	2	18	n.s	3	21	n.s

[a] Significantly different HSI scores among bird abundance classifications (Kruskal-Wallis, $p < 0.007$). Means within the same row and year having the same letter are not significantly different ($P \leq 0.10$, ranked ANOVA, Tukey multiple comparisons) (Conover and Iman 1981).

[b] Mann-Whitney U tests did not show a significant difference ($P \leq 0.10$) between those study areas where birds were present and those areas where no birds were recorded.

the downy woodpecker and black-capped chickadee models were tested in a rather narrow range of habitat conditions and therefore, probably not testing the full range of the models applicability.

Structural attributes, such as numbers of trees > 51 cm dbh and mean dbh of snags > 38 cm, were key habitat components that were significantly correlated with the pileated woodpecker numbers, whereas, compositional attributes such as percent pine canopy and percent canopy cover seemed to be important habitat components for the hairy woodpecker (Table 6). Individual habitat attributes that were significantly correlated to bird abundance indicate that those habitat components are essential in meeting the life requisites of the pileated and hairy woodpeckers.

With the exception of the black-capped chickadee (Figures 12-13), the HSI models evaluated across the 24 study areas exhibited positive associations with bird abundance in 1993 and 1994 (Figures 14-19). The HSI values for the black-capped chickadee model ranged from (0.65-0.97) indicating "good" quality habitat across all sites and chickadees were censused on each of the study areas. However, the narrow range of HSI values may indicate a broader range of habitat conditions need to be sampled to adequately validate the model.

There was a range of HSI values (0.36-1.00) calculated for the downy woodpecker model, however, this model may have performed poorly because the majority (67%) of the study areas had marginal HSI values (e.g. 0.26 to 0.50) in connection with few numbers of censused individuals (Figures 14-15). The hairy (Figures 16-17) and pileated woodpecker (Figures 18-19) models performed the best with habitat suitability's ranging from 0.39-0.95 and 0.00-0.96, respectfully.

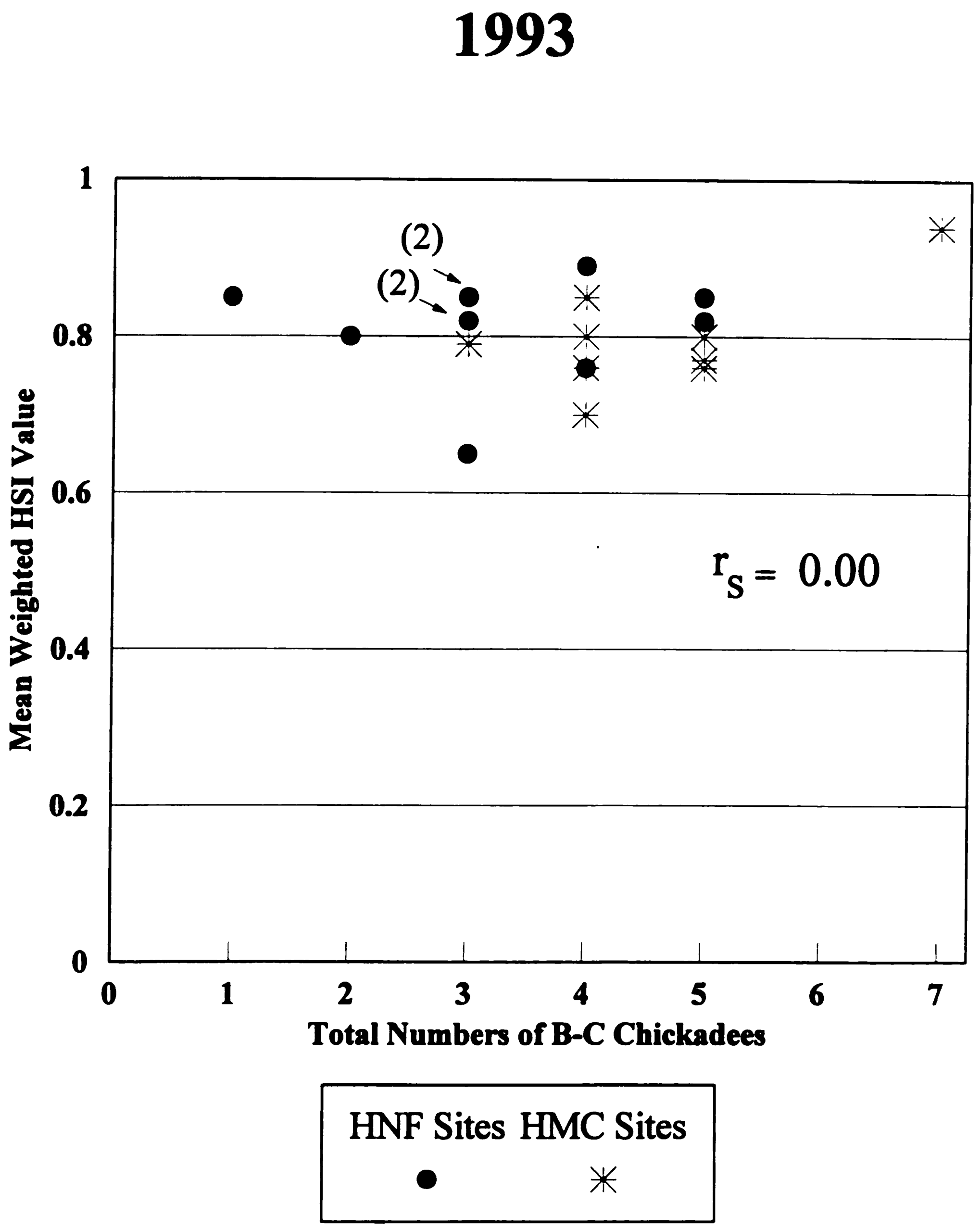


Figure 12. Habitat suitability values and maximum numbers of black-capped chickadees censused during any single period across twenty 70 ha study areas. Sites indicated are the Huron Mountain Club (HMC) and Hiawatha National Forest (HNF) located in the Upper Peninsula of Michigan, 1993.

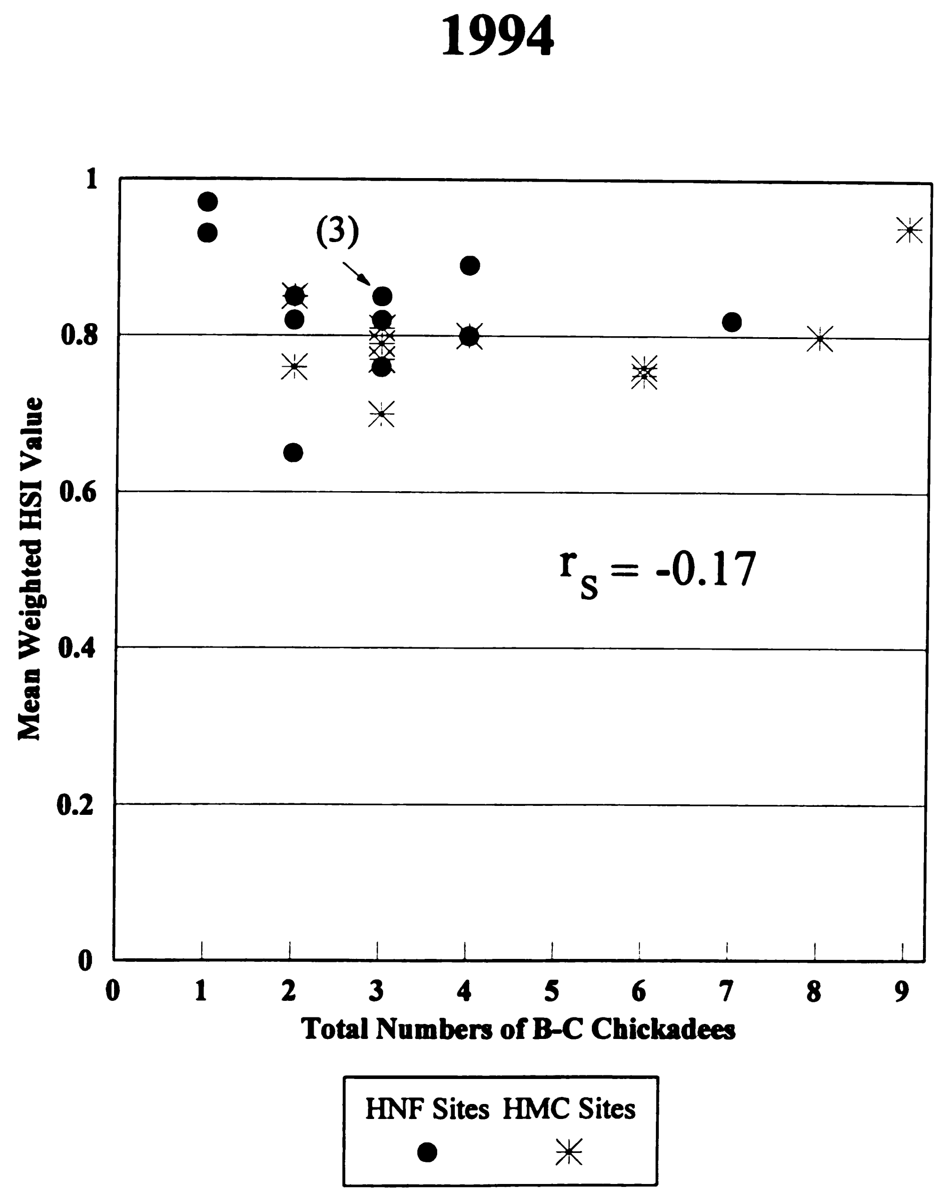


Figure 13. Habitat suitability values and maximum numbers of black-capped chickadees censused during any single period across twenty-four 70 ha study areas. Sites indicated are the Huron Mountain Club (HMC) and Hiawatha National Forest (HNF) located in the Upper Peninsula of Michigan, 1994.

1993

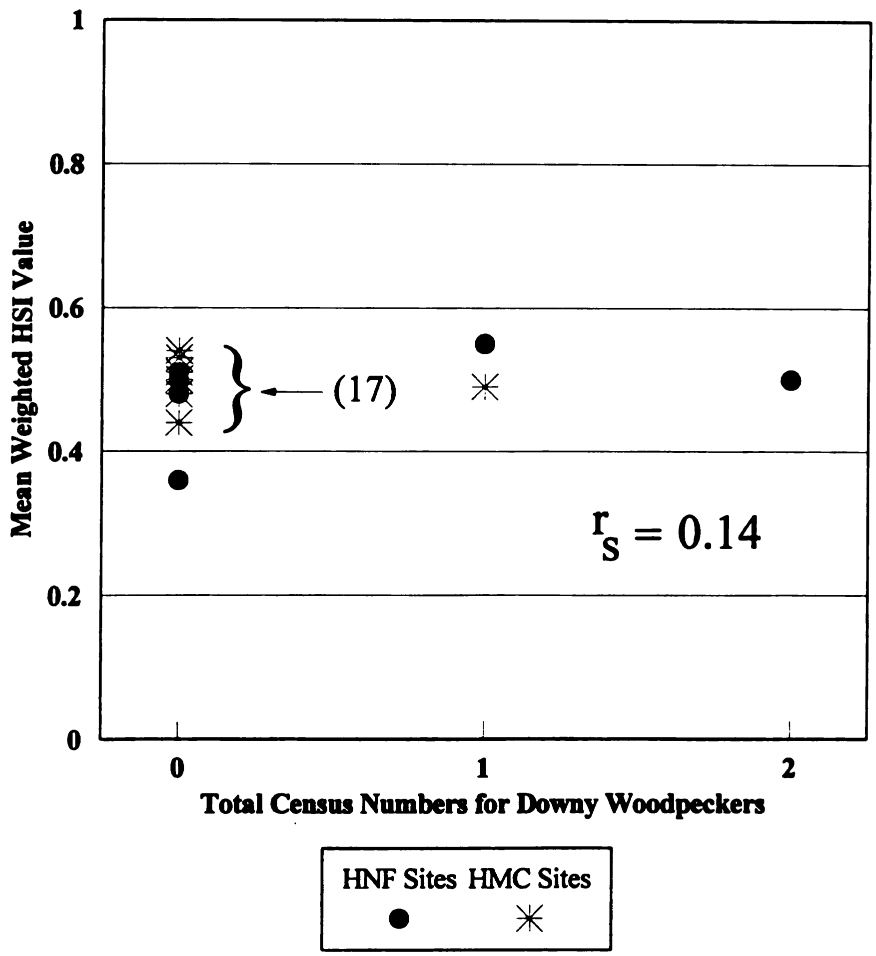


Figure 14. Habitat suitability values and maximum numbers of downy woodpeckers censused during any single period across twenty 70 ha study areas. Sites indicated are the Huron Mountain Club (HMC) and Hiawatha National Forest (HNF) located in the Upper Peninsula of Michigan, 1993.

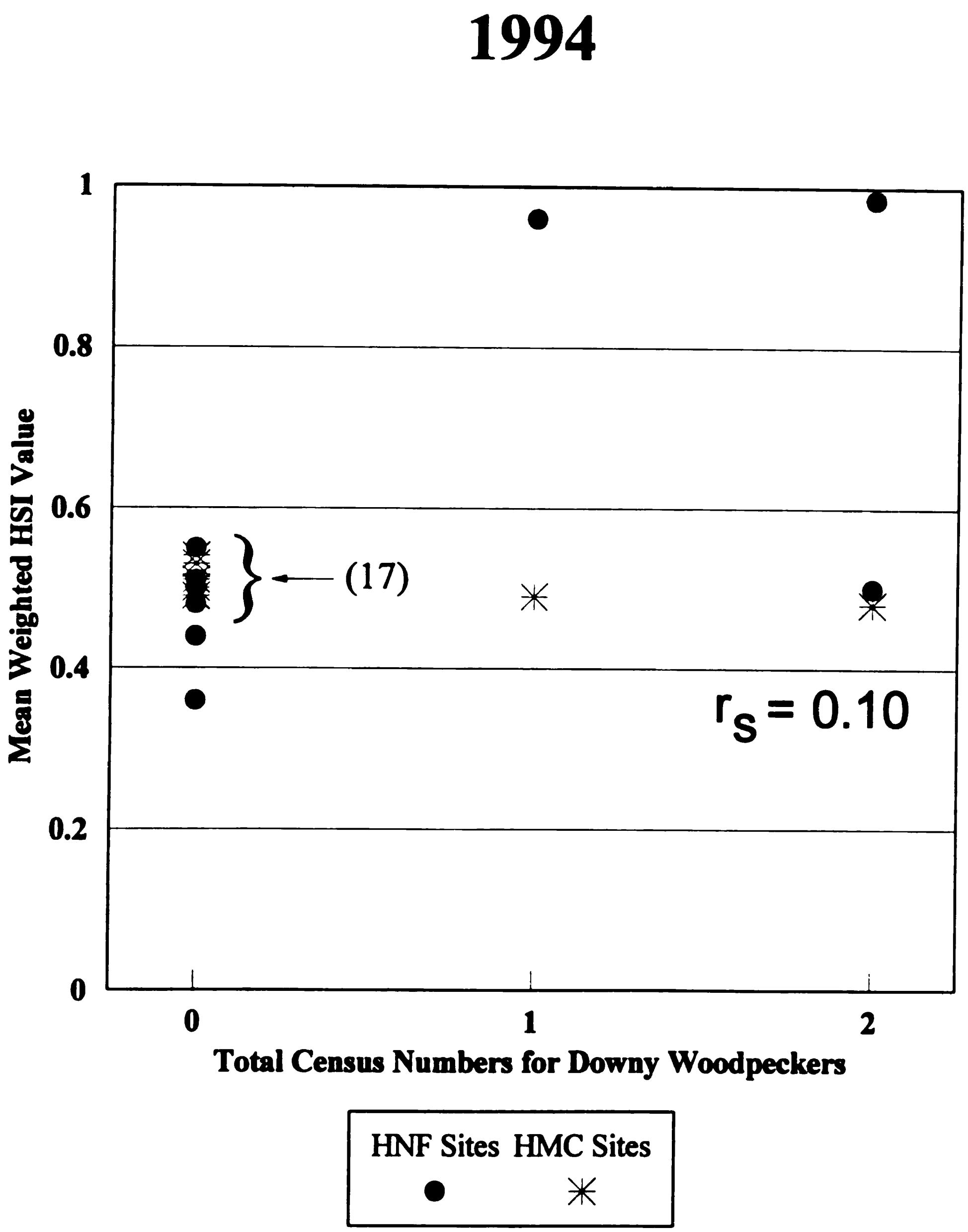


Figure 15. Habitat suitability values and maximum numbers of downy woodpeckers censused during any single period across twenty-four 70 ha study areas. Sites indicated are the Huron Mountain Club (HMC) and Hiawatha National Forest (HNF) located in the Upper Peninsula of Michigan, 1994.

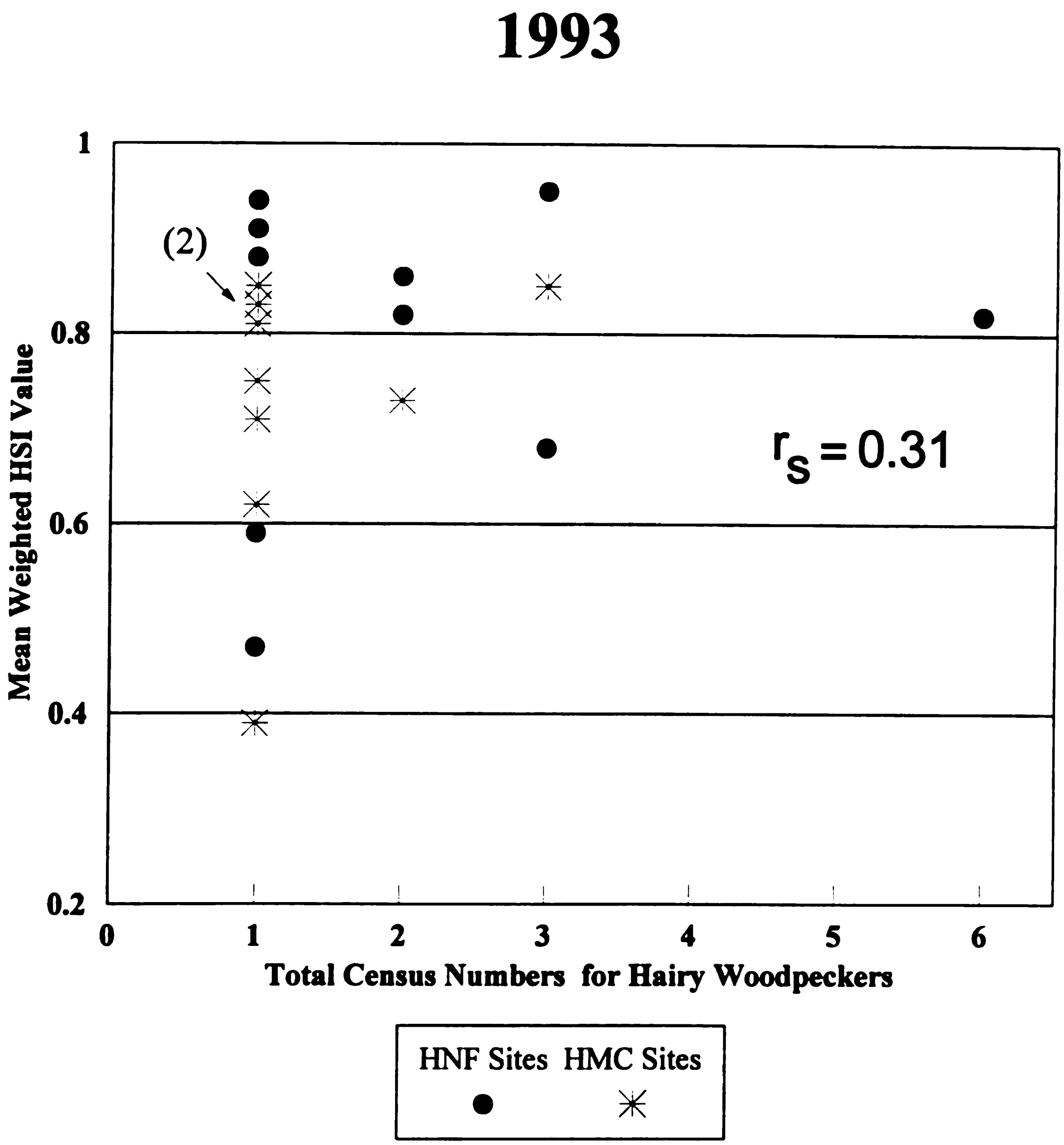


Figure 16. Habitat suitability values and maximum numbers of hairy woodpeckers censused during any single period across twenty 70 ha study areas. Sites indicated are the Huron Mountain Club (HMC) and Hiawatha National Forest (HNF) located in the Upper Peninsula of Michigan, 1993.

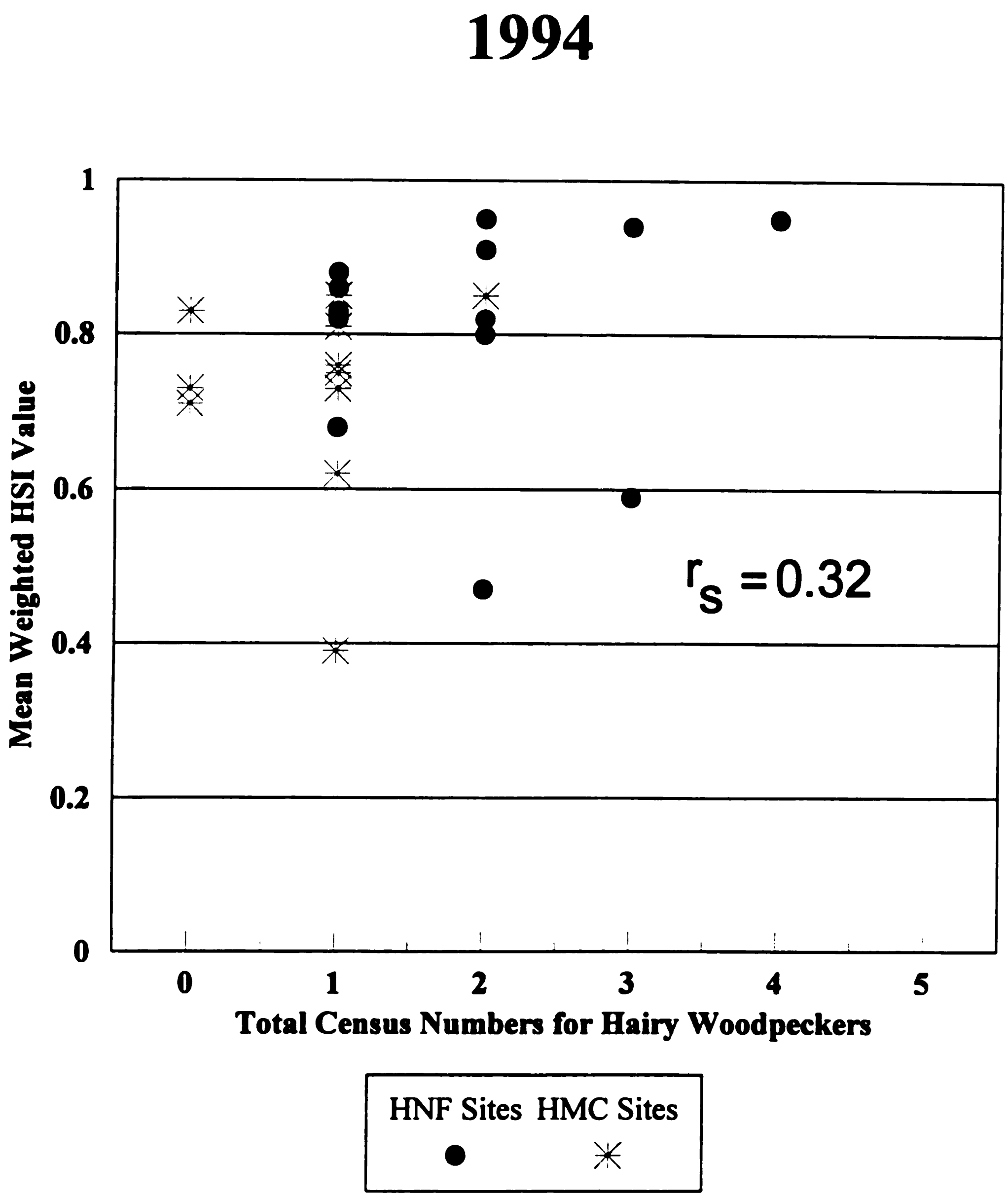


Figure 17. Habitat suitability values and maximum numbers of hairy woodpeckers censused during any single period across twenty-four 70 ha study areas. Sites indicated are the Huron Mountain Club (HMC) and Hiawatha National Forest (HNF) located in the Upper Peninsula of Michigan, 1994.

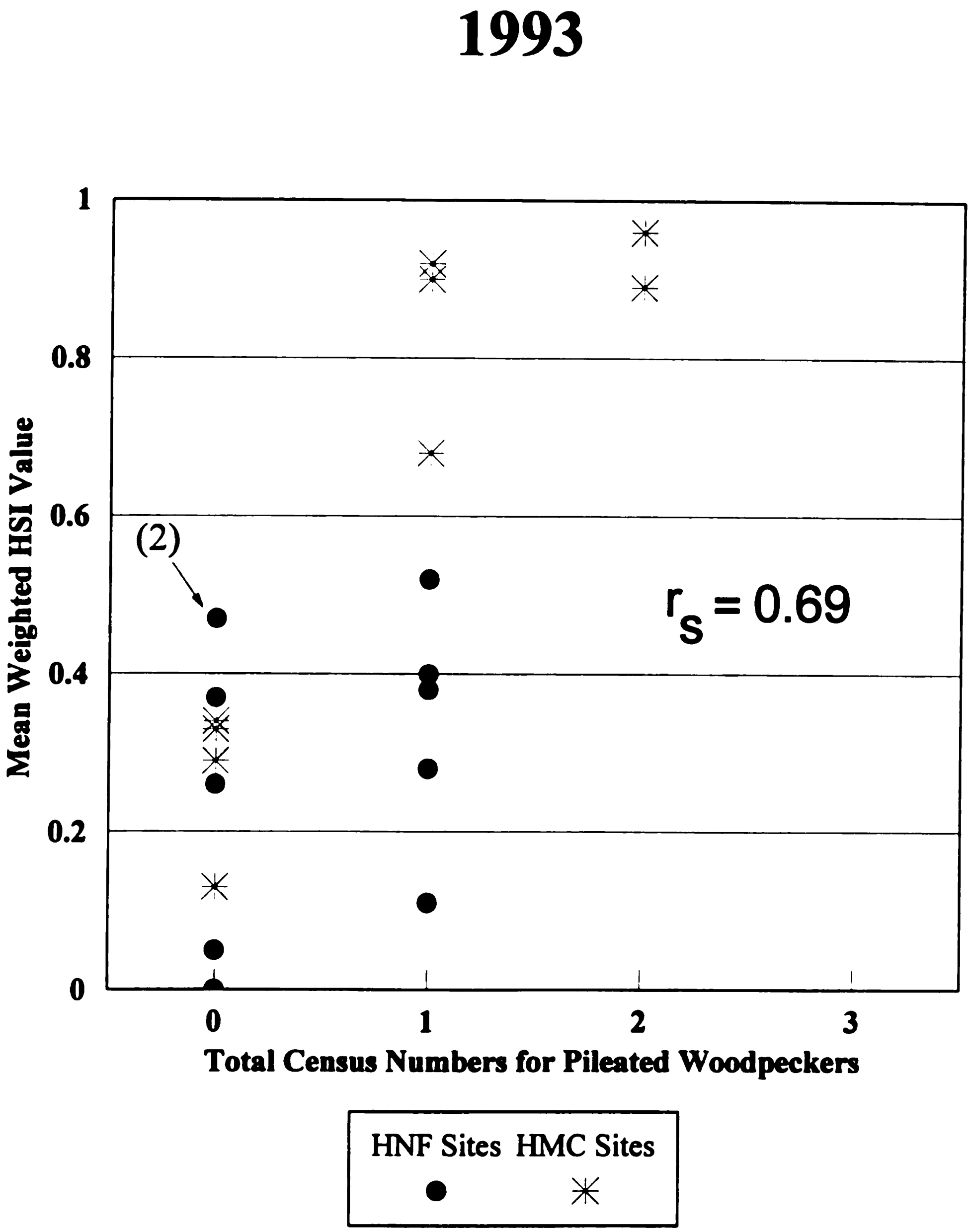


Figure 18. Habitat suitability values and maximum numbers of pileated woodpeckers censused during any single period across twenty 70 ha study areas. Sites indicated are the Huron Mountain Club (HMC) and Hiawatha National Forest (HNF) located in the Upper Peninsula of Michigan, 1993.

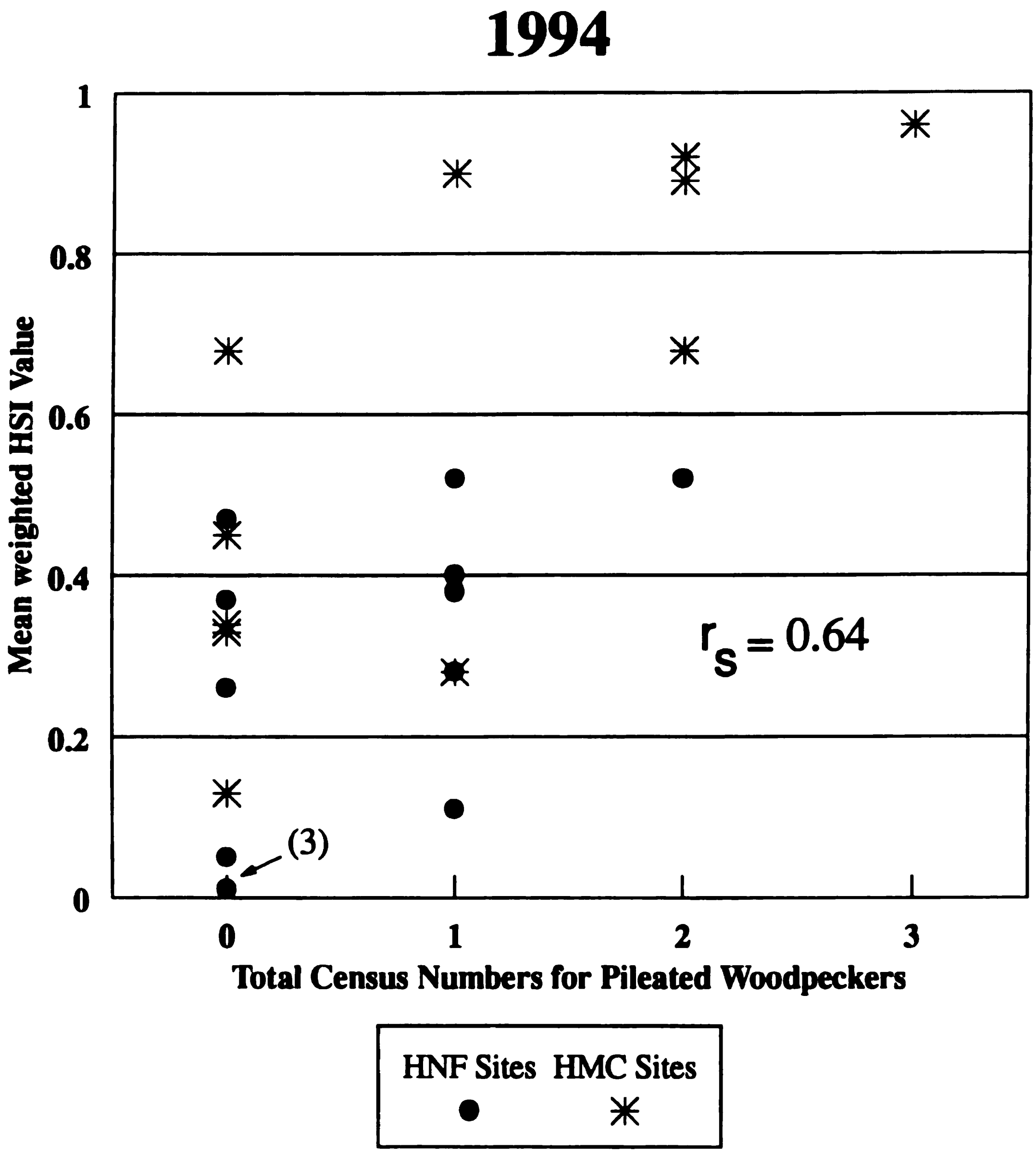


Figure 19. Habitat suitability values and maximum numbers of pileated woodpeckers censused during any single period across twenty-four 70 ha study areas. Sites indicated are the Huron Mountain Club (HMC) and Hiawatha National Forest (HNF) located in the Upper Peninsula of Michigan, 1994.

DISCUSSION

Habitat attributes associated with the dominate forest types and bird abundance

Results from this study suggest that late-successional forest types associated with the HMC provided the best overall habitat quality for the pileated woodpecker and good to optimal habitat quality for the hairy woodpecker across years (Figures 16-19). The previously harvested mature forest types evaluated in the HNF, however, provided relatively marginal habitat quality (HSI scores between 0.0-0.52) for the pileated woodpecker and good to optimal habitat quality for the hairy woodpecker (HSI scores between 0.47-0.95) across years (Figures 18-19).

Pileated woodpecker model

The pileated woodpecker inhabits both coniferous and deciduous forests, but selects areas containing mature, dense, productive stands (Bock and Lepthien 1975). Study areas dominated by unharvested upland deciduous forest types at the HMC had significantly greater numbers of large trees (> 51 cm dbh) and snags (>38 cm dbh), with 26.6 trees / 0.4 ha and 5.3 snags / 0.4 ha, respectfully, than all other forest cover types except lowland deciduous forest sites (Table 4). These variables also correlated well to bird abundance values for 1993 and 1994 (Table 6), suggesting that habitat requirements of the pileated woodpecker are being met within those study areas dominated by late-successional forest. Study areas dominated by previously harvested mature upland and lowland deciduous, upland deciduous pole-timber, and upland and lowland coniferous forest types had relatively fewer numbers of large trees and snags. The aforementioned study areas were primarily found within the HNF where HSI values ranged from poor

(0.00-0.25) on the pole-timber and upland conifer sites to marginal (0.26-50) on lowland conifer sites. Two sites dominated by lowland deciduous forest provided good quality habitat with HSI values of 0.52.

Significant differences were observed between HSI scores on study areas where pileated woodpeckers were not recorded and areas where they were observed (Table 7). Furthermore, 1994 HSI scores for areas where 1 bird was recorded and sites where 2 or more birds were recorded was significantly different (ranked ANOVA, Tukey's multiple comparisons $p < 0.006$). These data indicate that the pileated woodpecker model can discern between areas where birds are most likely going to be found and areas that do not provide habitat needs. Moreover, it shows that areas with higher calculated HSI scores will generally have higher numbers of birds present. One can only speculate on the HSI value cutoff, however, data from this study indicate that pileated woodpeckers were most abundant in forest types with relatively large trees, large snags, and a dense canopy. Of the 6 dominate cover types (Table 4) measured across all 24 study areas, the unharvested upland deciduous forest types associated with the HMC provided the best habitat quality for pileated woodpeckers.

Making assumptions are inherent in any model building process. Bull (1975) stated that critical components of pileated woodpecker habitat include large snags, large trees, diseased trees, dense forest stands, and high snag densities. Major assumptions for the pileated model (Schroeder 1982a) include: (1) birds will be most abundant in forested areas with large diameter trees (30+ trees / 0.4 ha), (2) optimal habitats should have >75% canopy closure, (3) habitats with <3 large trees / 0.4 ha will have no suitability, and

(4) stumps and logs are important foraging bases but will carry less influence in areas that have dense canopies and large trees.

Results from this study indicate that relatively more birds were observed on areas that had greater numbers of large trees which ranged from 0.90 to 26.6 / 0.4 ha for upland deciduous pole timber to unharvested upland deciduous forests, respectfully. Study areas dominated by lowland deciduous and upland deciduous pole timber forests had an average of 3 or less large trees / 0.4 ha (Table 4), and HSI scores calculated for these sites ranged from 0.0 to 0.11, indicating poor quality habitat. Significant correlations (r_s=0.60, p=0.005 and r_s=0.58, p=0.005) for 1993 and 1994, respectfully, were found between numbers of large trees (e.g. trees > 51 cm) and bird abundance values. Similar correlations occurred for the average dbh of snags >38 cm variable and bird abundance (Table 6).

Dominate vegetation types found on all study areas (Table 4) contained percent canopy closures that were consistently > 75% on all study areas. No significant correlations occurred between percent canopy and bird abundance (Table 6), however, this may have occurred due to a relatively tight range of habitat conditions for this variable. The amount of dead and down woody material (e.g. stumps and logs) did not correlate with bird abundance for 1993 or 1994. Unharvested upland deciduous sites found in the HMC made up 25% of all study areas.These areas were characterized by having greater numbers of large trees, large snags and dense canopies overall, however, all dominant cover types provided large amounts of dead and down woody material. Censusing pileated woodpeckers on areas that HSI scores were classified as poor to marginal may indicate that although there may not be sufficient numbers of large trees etc., pileated's are using these areas for foraging.

Hairy woodpecker model

Both the HNF and HMC sites seem to be providing good quality habitat for hairy woodpeckers. Relatively high HSI scores were associated with previously harvested upland, lowland, and pole-timber deciduous and lowland conifer sites found within the HNF. These areas were characterized by having similar overstory tree dbh, low amounts of percent pine canopy cover, and a relatively more open canopy than the unharvested sites found at the HMC (Figure 8). Optimal canopy conditions for the hairy woodpecker occurs between 85-90% with complete canopy being less than optimal (O'Neil et al. 1988). Although HSI scores were still good to optimal within the unharvested upland deciduous sites, they had on average, relatively lower scores than areas found in the HNF. Again, this may be attributed to the more dense canopy cover, however, there was a significant positive correlation between bird numbers and the canopy closure variable for both years (Table 6). The number of snags >25 cm dbh were not limiting on any of the habitat cover type classes (Table 4); all study areas had at least 2.2 snags > 25 cm dbh / 0.4 ha. According to the hairy woodpecker model, optimal habitat quality for number of snags > 25 cm dbh / 0.4 ha is provided by areas with 2 or more snags / 0.4 ha.

O'Neil et al. (1988) found that habitat scores for percent pine canopy closure were negatively correlated with hairy woodpecker numbers, and sites completely dominated by pines received relatively lower habitat scores. Study areas dominated by upland coniferous forests (*Pinus spp.*) had a lower mean HSI score ($\overline{X}$ = 0.61, n=5) than sites dominated by other forest cover types. However, a significant positive correlation (r_s=0.48, p=0.01) was exhibited between the percent pine canopy variable and bird abundance for 1994.

Although the model could not distinguish between areas of bird presence and absence (Table 7), the overall model HSI scores was significantly correlated to bird abundance with r_s = 0.31 and r_s = 0.32 for 1993 and 1994, respectfully. A rather tight range of habitat conditions measured, relatively small sample size, and few areas where birds were not found may be reasons for the models inability to discern between areas where birds were present and those areas where no birds were observed.

Black-capped chickadee and downy woodpecker models

The black-capped chickadee and downy woodpecker models performed poorly overall. All study areas seemed to provide good to optimal habitat conditions for the black-capped chickadee (Table 5), although, correlations between model variable HSI values and bird abundance for both years were not significant (Figures 12-13). Again, this may be due in part to the rather narrow range of habitat conditions in which this model was evaluated. For example, 88% of the 24 study areas were classified as optimal habitat quality and chickadees were recorded across all study areas.

The downy woodpecker model consistently predicted poor to marginal habitat quality across all but a few study areas for 1993 and 1994 (Figures 14-15). No significant correlations occurred between the downy model variables and bird abundance (Table 6).

The poor performance of this model may be attributed to a combination of factors and will be discussed later.

Describing habitat conditions using principal components analysis

Results obtained from PCA suggest that habitat quality for 4 cavity-nesting bird species may be described by certain compositional and structural components associated with each of the 6 general cover type classifications. Study areas located in the Upper Peninsula can be described as a gradient from younger pole-timber aged deciduous sites to older late-successional deciduous sites. Results from PCA aid in determining the vegetative variables most important in describing potential habitat quality for cavity-nesting birds. For example, the early or second growth forested sites found within the HNF, were characterized by having smaller tree dbh's and smaller snag dbh's, which provided an HSI value of 0.0 for pileated woodpeckers (Figure 7). These same forest cover types, however, provided good to optimal habitat quality for black-capped chickadees, hairy and downy woodpeckers.

The HMC study areas provided a greater range of habitat conditions than HNF study areas in terms of snag conditions (Figure 6). HNF sites tended to have both intermediate snag numbers and small to intermediate sized snags, whereas, HMC sites were characterized as having few areas of small to intermediate sized snags and the greatest number of areas with large snags at high densities. Figures 7 and 8 show the range of available habitat conditions in the HMC provided good to optimal habitat quality for the pileated and hairy woodpecker, while only 3 of the 13 HNF sites provided good quality habitat conditions for the pileated woodpecker. Study areas in the HNF, regardless of cover type, provided a good range of habitat conditions for the hairy woodpecker (Figure 8).

As forest succession moves to a mature tree stage forest and ultimately into a late-successional stage forest, structural and compositional components which are thought to be important habitat attributes for pileated woodpeckers and other cavity-nesting species will be provided. However, the habitat attributes associated with late-successional forest stages may not provide optimal habitat quality for species such as the downy woodpecker, which may be more associated with earlier successional stages and habitats with more open canopies.

Habitat model validation

Habitat model validation is difficult because there are no consistent standards relating to habitat quality and because the models are founded on concepts (e.g. limiting factors, carrying capacity) often viewed with ambiguity (Schamberger and O'Neil 1986). The approach of HSI models is generally valid in that habitat quality is likely to exhibit thresholds below which habitat becomes unsuitable and above which further changes make little difference in quality (Van Horne and Wiens 1991, and Williamson and Lawton 1991). Habitat models have the potential to adequately reflect suitable habitat conditions needed to satisfy the life requisites of a particular species, however, habitat is only 1 variable that may dictate species presence and abundance. A species relative abundance may be influenced by other factors, including range of habitat conditions sampled, home range or territory size, interactions with other species, breeding success, and mortality factors (Best and Stauffer 1986).

The geographic scale at which habitat models are applied should reflect the size of the animals home range, the degree of habitat specialization by the animal, the heterogeneity of the habitat, and the intended use of the model (Flather and Hoekstra 1985, Lanica and Adams 1985, Laymon and Barrett 1986, and Roloff 1994). For this study, relatively large tracts of different forest types were selected based on cover types thought to be representative of the Upper Peninsula, therefore, the range of habitat conditions across all study areas may not be all encompassing in terms of the geographic scale in which these models were tested. Home range sized assessment areas for species other than the pileated woodpecker (e.g. spatial scales ranging from 2-12 ha) were consistent and did not dramatically influence HSI values when using smaller evaluation areas (Figures 9-11). Therefore, all species models were evaluated on a 70 ha spatial scale. The hairy and black-capped chickadee models consistently predicted relatively good to optimal habitat quality and the downy woodpecker model consistently calculated relatively marginal habitat quality across all study areas, regardless of spatial scale.

The low correlation coefficients associated with the black-capped chickadee and downy woodpecker models in this study may be attributed to a variety of factors. Although vegetation sampling error was minimized, there is error inherent in sampling vegetation which is associated with the variability of vegetation structure. There is also error associated with the conversion of vegetation structures into indices of habitat suitability and is compounded when these habitat components are mathematically combined. Forest stand size within each study area influences HSI output due to weighting. The rather narrow range of habitat conditions across study areas may not be adequately assessing suitable habitat for these models and therefore, may need to be tested on a broader range of habitat conditions. Finally, the model variables measured for the black-capped chickadee and downy woodpecker may not reflect habitat conditions perceived to be important for these species in Michigan's Upper Peninsula.

Efforts to determine meaningful wildlife-habitat relationships involve sorting through potentially important variables and identifying those that best predict habitat use (Best and Stauffer 1986). Although the black-capped chickadee and downy woodpecker are somewhat specialized in habitat use for nesting, they may be considered more of habitat generalists than either the pileated or hairy woodpecker in terms of foraging behavior. Chickadees are insectivorous gleaners and forage from the ground to the tree tops in a variety of vegetation types (Brewer 1961, Sturman 1968). Downy woodpeckers forage by boring, gleaning bark, and infrequently, by flycatching (Jackson 1970). Variables used to identify these species life history requisites (food, cover) may be less well defined than the pileated and hairy woodpecker, and therefore, a generalist species measured responses to perceived habitat may be difficult to depict.

Maurer (1966) stated that the primary reason for using animal abundance to assess habitat quality is that all members of a population have the same limiting habitat components. Although individual variation in habitat selection occurs, the average habitat selection pattern will be consistent with their limiting needs, but caution should be exercised when using animal abundance to assess habitat quality. Researchers are in general agreement that better estimates of habitat quality are obtained through direct measures of population fitness (e.g. fecundity and survival) (Van Horne 1983, Van Horne and Wiens 1991, Martin and Nur 1992, and Noon 1992). Obtaining data on population demographics is currently an impractical way to assess habitat conditions, chiefly due to the time and cost involved. Therefore, until more efficient population assessment techniques are developed, relative animal abundance indices will continue to be used in conjunction with other assessment tools, as indicators of habitat quality.

Considering the potential cumulative effects of the error associated with HSI validation, the consistent performance of the pileated and hairy woodpecker HSI models in this study are promising. The significance of the correlations indicate that the pileated and hairy woodpecker models (Table 6) have good potential as evaluation tools for forest planning or habitat mitigation assessments in Michigan's Upper Peninsula. Because the black-capped chickadee model exhibited low correlation coefficients and was tested in perhaps a relatively narrow range of habitat conditions, it should be evaluated on a broader range of habitat conditions that include younger successional stage forests and areas with more open canopies before being rejected as a reliable habitat assessment tool. Although all 24 study areas provided good habitat quality, and relatively good numbers of chickadees were recorded across each general cover type, correlations between HSI values and bird abundance were poor. For example, the black-capped chickadee model predicted optimal HSI values for the 2 pole-timber sites, but only 1 chickadee was recorded for each site (Figure 13). Lowland coniferous sites had significantly greater numbers of snags (10-25 cm dbh) than all other sites but this variable was not limiting on any of the study areas. Optimal quality chickadee habitat is described in the model as areas with 50-75% canopy closure. In this study, only pole-timber and upland conifer sites provided close to this type of habitat condition (Table 4).

The poor performance of the downy woodpecker model may be attributed to a tight range of habitat conditions in conjunction with very few birds censused across all 24 study areas. For this study, when the 16 different cover types used to calculate HSI scores were pooled, 6 dominant cover types resulted and percent canopy cover ranged from 78.2-99.6%, therefore, the downy model should also be assessed in a broader range of habitat conditions that include forests in younger successional stages and habitats with more open canopies.

The black-capped chickadee and the downy woodpecker models are also more simplistic than the pileated or hairy woodpecker, in terms of number of variables used to assess habitat quality. Three variables are used to assess habitat conditions needed for the black-capped chickadee and 2 variables are used in the downy woodpecker model. Using relatively few variables to assess habitat quality may be too coarse to determine existing wildlife-habitat relationships (Best and Stauffer 1986), especially for species that may be considered a generalist. For example, snag densities ranging from 10-25 cm dbh encompass variables in black-capped chickadee and the downy woodpecker models and are based on the number of all standing snags taller than 1.8 m; but for these species, the hardness or softness of a snag may influence how easily snags can be for excavating nest holes (Best and Stauffer 1986) and, therefore, may be an important additional habitat attribute to consider.

These models were field tested in the Upper Peninsula of Michigan. Managers must realize that models should be validated in the geographic region in which the model is to be applied. Habitat model variables developed and used in other regions of the country may not include habitat components important to species in another region. Laymon and Barrett (1986) stated that implementing untested models is not credible and therefore, of little use. Given the current need for rapid assessment tools in forest planning and habitat modification, an untested model used with a good deal of caution may be better than no assessment at all. With additional validations in other regions of these species ranges, resource managers can help build more comprehensive models that will enhance the accuracy and reliability of models to describe habitat conditions needed by these species.

CONCLUSIONS

The pileated and hairy woodpecker models evaluated in this study have good potential as evaluation tools for forest management planning efforts in the Upper Peninsula of Michigan. Both of the above models accurately described habitat conditions needed by the pileated and hairy woodpeckers on 70 ha sized areas. Wildlife habitat models that are validated and can predict a species occurrence in relation to environmental conditions is the critical link in monitoring impacts of land management practices on wildlife. Results indicate that the pileated model could discern between areas where birds were most likely to occur and areas that provided little or no habitat needs.

Habitat attributes associated with the dominate forest types across study areas provided a range of habitat conditions for the pileated and hairy woodpeckers. Relatively more pileated woodpeckers were observed in areas dominated by large trees, large snags, dense canopies found in the late-successional forest stages. The unharvested/late-successional forest types found at the HMC provided optimal habitat quality for the pileated woodpecker and optimal to good habitat quality for hairy woodpeckers. Previously harvested mature forest types provided poor to marginal habitat quality for pileated woodpeckers with the exception of 2 sites that provided good habitat quality, however, these sites provided good to optimal habitat quality for hairies.

The downy woodpecker and the black-capped chickadee models were field tested in perhaps only a portion of the habitat conditions in which these models are expected to portray. Habitat conditions in this study ranged from pole timber to late-successional upland deciduous forest types. However, the habitat attributes associated with later successional forest stages may not provide optimal habitat quality for species such as the downy woodpecker, which may be more associated with earlier successional forest stages and habitats with more open canopies.

The geographic scale at which habitat models are applied should reflect the size of an animals home range, degree of habitat specialization by an animal, heterogeneity of the habitat, and the intended use of the model (Flather and Hoekstra 1985, Lanica and Adams 1985, Laymon and Barrett 1986, and Roloff 1994). Given the systematic approach in locating relatively large tracts of forest which represent the different forest types in the Upper Peninsula, home range sized assessment areas for species other than the pileated woodpecker did not influence HSI values at smaller evaluation areas, therefore, all species were evaluated on a 70 ha spatial scale. Habitats that correlated significantly with pileated and hairy woodpecker numbers were areas that were dominated by unharvested/late-successional and previously harvested mature forests.

Most managers are willing to accept a limited degree of error, and past experiences suggest that the error inherent in HSI validity and land-use conversion functions are usually tolerable for strategic decision making (Lancia et al. 1986). Wildlife modeling is an evolving process and therefore, further work developing meaningful ways to evaluate habitat models is essential. With the acquisition of new data (e.g. validation studies) and modification, the performance of HSI models should continue to improve.

MANAGEMENT IMPLICATIONS

There is an immediate need for rapid assessment tools in forest planning and habitat mitigation. Natural resource managers have to understand that HSI models will capture only a portion (typically half or less) of the variation in population estimates (Morrison et al. 1992). The standards of science are not applied to planning decisions that merely require decisions be made, using the best available information (Schamberger and O'Neal 1986). Science and planning are two separate realms (Romesburg 1981). Therefore, habitat suitability models may provide a link to integrating the concepts and rigor of science into the realm of resource planning. Resource managers must realize that habitat is not the only factor that determines animal presence or abundance, and the vast majority of habitat models include only a few of the factors that determine population levels (Schamberger and O'Neal 1986).

Four cavity-nesting bird HSI models were field tested in the Upper Peninsula of Michigan. Results of this study suggest that pileated and hairy woodpecker HSI models accurately describe habitat conditions used by each species and have good potential as evaluation tools for forest management planning efforts in the Upper Peninsula of Michigan. The downy woodpecker and black-capped chickadee models should to be evaluated in a broader range of habitat conditions than those evaluated in this study before rejecting their reliability as a habitat assessment tool. Specifically, additional assessment areas should include earlier forest successional stages with basal areas ranging from 0.0 to 16.0 m^2 / ha and percent canopy closures between 0 to 75%.

Although pileated woodpeckers will use immature forest habitat (Mellen 1987), they more frequently use older, mature, dense canopied forest (Conner et al. 1975, McClelland 1979, Conner 1980, Mannan 1984, Bull 1987, Mellen 1987, and Renken and Wiggers 1989). During this study, relatively more pileated woodpeckers were observed in areas dominated by late-successional stage forests. Habitat components appearing to best describe habitat suitability for the pileated included: number of live trees >51 cm dbh (> 26 / 0.4 ha), and number of snags ≥38 cm dbh (≥ 5 snags / 0.4 ha). Relatively greater numbers of hairy woodpeckers were found on sites with canopy closure ranging from 78 to 92%. Bull et al. (1980) stated that unmanaged mature forest stands usually have adequate numbers of snags for resident woodpeckers. In general, the previously harvested mature forest types, regardless of cover type, provided poor to marginal habitat quality for pileated woodpeckers, however, these sites provided good to optimal habitat quality for hairies.

When developing forest management plans, resource managers are encouraged to provide the necessary habitat attributes required by cavity nesting species. Allowing some areas to develop into older seral stages of forest succession will enhance habitat quality for all cavity nesting birds, as well as other forest species in the Upper Peninsula. All cavity nesting species would benefit by leaving their desired sizes and densities of dead snags and trees with heart rot standing during regeneration cuts and subsequent thinnings. Snags numbers could be increased by killing trees, leaving snags during selective cuts, or by perpetuating early successional tree species such as yellow birch, which become snags at a faster rate than more long lived tree species. Conner (1980) suggested a cutting rotation in eastern forests of 80-100 years would probably provide adequate foraging habitat, but that a longer rotation may be needed for nesting habitat. Areas typically associated with late-successional stage forests are best suited for providing good quality habitat for the pileated woodpecker. However, the hairy woodpecker model predicted relatively good quality habitat, regardless of cover type, and can be maintained in good numbers within mature forest types characteristic of the Upper Peninsula of Michigan.

Wildlife-habitat models vary in complexity and appear to produce results of questionable reliability, perhaps primarily as a result of a lack of field validation (Mayer 1986). Managers must realize that models should be validated in the geographic region in which the model is to be applied. Habitat model variables developed and used in other regions of the country may not include habitat components important to species in another region. Use of untested habitat models in assessing impacts of management practices on habitat quality is dangerous, however, if used by experienced biologists, an untested habitat model may be better than no assessment at all.

Validated HSI models are valuable because they provide repeatable assessment procedures and indices of particular environmental characteristics that can be compared between alternative management plans. Wildlife habitat models that are validated and can predict a species occurrence in relation to environmental conditions is the critical link in monitoring impacts of land management practices on wildlife.

LITERATURE CITED

Albert, D.A., S.R. Denton, and B.V. Barnes. 1986. Regional landscape ecosystems of Michigan. School of Natural Resources, Univ. Mich., Ann Arbor. 32pp.

Barrett, R.H., and H. Salwasser. 1982. Adaptive management of timber and wildlife habitat using DYNAST and wildlife habitat relationship models. Proc. Annual Conf. Western Assoc. Fish Wildl. Agencies 62: 350-365.

Bart, J., D.R. Petit, and G. Linscombe. 1984. Field evaluation of two models developed following the Habitat Evaluation Procedures. Trans. N. Amer. Wildl. Nat. Resour. Conf. 49:489-499.

Best, L.B., and D.F. Stauffer. 1986. Factors confounding evaluation of bird-habitat relationships. Pages 209-216 in J. Verner, M.L. Morrison, and C.J. Ralph, eds. Wildlife 2000. Univ. Wisconsin Press, Madison.

Blake, J.G., and J.R. Karr. 1984. Species composition of bird communities and the conservation benefit of large versus small forests. Biol. Conserv. 30:173-187.

Bock, C.E., and L.W. Lepthien. 1975. A Christmas count analysis of woodpecker abundance in the United States. Wilson Bull. 87: 355-366.

Bond, R.R. 1957. Ecological distribution of breeding birds in upland forests of southern Wisconsin. Ecol. Monogr. 27:351-384.

Brower, J.E., and J.H. Zar. 1984. Field and laboratory methods for general ecology. William C. Brown Publ., Dubuque, Iowa.

Bull, E.L. 1987. Ecology of the pileated woodpecker in northeastern Oregon. J. Wildl. Manage. 51:472-481.

_____, A.D. Twombly, and T.G. Quigley. 1980. Perpetuating snags in managed conifer forests of the Blue Mountains, Oregon. Pages 325-336 in R.M. DeGraaf and N.G.Tilgham, compilers. Management of western forests and grasslands for nongame birds. U.S. Dept. Agric., For. Serv. Gen. Tech. Rep. INT-86. 525pp.

_____. 1975. Habitat utilization of the pileated woodpecker. Blue Mountains, Oregon. M.S. Thesis, Oregon State Univ., Corvallis. 58pp.

Canfield, R.H. 1941. Application of the line intercept method in sampling range vegetation. J. For. 39:388-394.

Capen, D.E., J.W. Fenwick, D.B. Inkley, and A.C. Boynton. 1986. Multivariate models of songbird habitat in New England forests. Pages 171-175 in J. Verner, M.L. Morrsion, and C.J. Ralph, eds. Wildlife 2000. Univ. Wisconsin Press, Madison.

Clark, J.D., and J.C. Lewis. 1983. A validity test of a habitat suitability index model for clapper rail. Proc. Annu. Conf. Southeast. Assoc. Fish Wildl. Agencies 37:95-102.

Cole, C.A., and R.L. Smith. 1983. Habitat suitability indices for monitoring wildlife populations. Trans. N. Amer. Wildl. Nat. Resour. Conf. 48:367-375.

Conner, R.N. 1980. Foraging habitats of woodpeckers in southwestern Virginia. J. Field Ornithol. 51: 119-127.

_____, R.G. Hooper, H.S. Crawford, and H.S. Mosby. 1975. Woodpecker nesting habitat in cut and uncut woodlands in Virginia. J. Wildl. Manage. 39:144-150.

Conover, W.J., and R.L. Iman. 1981. Rank transformations as a bridge between parametric and nonparametric statistics. The Amer. Statist. 35:124-133.

Cook, J.G., and L.L. Irwin. 1985. Validation and modification of a habitat suitability model for pronghorns. Wildl. Soc. Bull. 13:440-448.

Davis, L.S. 1980. Strategy for building a location-specific multipurpose information system for wildlife management. J. For. 78: 402-408.

Dedon, M.F., S.A. Laymon, and R.H. Barrett. 1986. Evaluating models of wildlife-habitat relationships of birds in black oak and mixed-conifer habitats. Pages 115-119 in J. Verner, M.L. Morrison, and C.J. Ralph, eds. Wildlife 2000. Univ. Wisconsin Press, Madison.

Evans, D.E., and R.N. Conner. 1979. Snag management. Pages 215-225 in R.M. DeGraaf, tech. coord. Management of north central and northeastern forests for nongame birds. U.S. Dept. Agric., For. Serv. Gen. Tech. Rep. NC-51.

Farmer, A.H., M.J. Armbruster, J.W. Terrell, and R.L. Schroeder. 1982. Habitat models for land-use planning: assumptions and strategies for development. Trans. N. Amer. Wildl. Nat. Resour. Conf. 47:47-56.

Flather, C.H., and T.W. Hoekstra. 1985. Evaluating population-habitat models using ecological theory. Wildl. Soc. Bull. 13:121-130.

_____, _____, D.E. Chalk, N.D. Cost, and V.A. Rudis. 1989. Recent historical and projected regional trends of white-tailed deer and wild turkey in the southern United States. U.S. For. Serv. Gen. Tech. Rep. RM-172. 22pp.

Freese, F. 1978. Elementary forest sampling. U.S. Dep. Agic. For. Serv. Handb. No. 232. 91pp.

Galli, A.E., C.F. Leck, and T.T. Forman. 1976. Avian distribution patterns in forest islands of different sizes in central New Jersey. Auk 93: 356-364.

Hammill, J.H., and R.J. Moran. 1986. A habitat model for ruffed grouse in Michigan. Pages 15-18 in J. Verner, M.L. Morrison, and C.J. Ralph, eds. Wildlife 2000. Univ. Wisconsin Press, Madison.

Hurley, J.F., H. Salwasser, and K. Shimamoto. 1982. Fish and Wildlife habitat capability models and special habitat criteria. Cal-Neva Wildl. Trans. 1982:40-48.

Jackson, Donald A. 1993. Stopping rules in principal components analysis: A comparison of heuristical and statistical approaches. Ecology 74: pp. 2204-2214.

Jackson, J.A. 1970. Quantitative study of the foraging ecology of downy woodpeckers. Ecology 51: 318-323.

Jarvinen, O. and R.A. Vaisanen. 1979. Changes in bird populations as criteria of environmental changes. Holarct. Ecol.: 75-80.

Johnson, R.G., and S.A. Temple. 1986. Assessing habitat quality for birds nesting in fragmented tallgrass prairies. Pages 245-249 in J. Verner, M.L. Morrison, and C.J. Ralph, eds. Wildlife 2000. Univ. Wisconsin Press, Madison.

Kilham, L. 1976. Winter foraging and associated behavior of pileated woodpeckers in Georgia and Florida. Auk 93:15-24.

Lancia, R.A., S.D. Miller, D.A. Adams, and D.W. Hazel. 1982. Validating habitat quality assessment: an example. Trans. N. Amer. Wildl. Nat. Resour. Conf. 47:96-110.

_____, D.A. Adams, 1985. A test of habitat suitability index models for five bird species. Proc. Annu. Conf. Southeast Fish and Wildl. Agencies. 39:412-419.

_____., D.A. Adams, and E.M. Lunk. 1986. Temporal and spatial aspects of species-habitat models. Pages 65-69 in J. Verner, M.L. Morrison, and C.J. Ralph, eds. Wildlife 2000. Univ. Wisconsin Press, Madison.

Larson, D.L., and C.E. Bock. 1986. Determining avian habitat preference by bird-centered vegetation sampling. Pages 37-43 in J. Verner, M.L. Morrison, and C.J. Ralph, eds. Wildlife 2000. Univ. Wisconsin Press, Madison.

Latka, D.C., and J.W. Yahnke. 1986. Simulating the roosting habitat of sandhill cranes and validating suitability-of-use indices. Pages 19-22 in J. Verner, M.L. Morrison, and C.J. Ralph, eds. Wildlife 2000. Univ. Wisconsin Press, Madison.

Laymon, S.A., and R.H. Barrett. 1986. Developing and testing habitat-capability models: pitfalls and recommendations. Pages 87-91 in J. Verner, M.L. Morrison, and C.J. Ralph, eds. Wildlife 2000. Univ. Wisconsin Press, Madison.

_____, and J.A. Reid. 1986. Effects of grid-cell size on tests of a spotted owl model. Pages 93-96 in J. Verner, M.L. Morrison, and C.J. Ralph, eds. Wildlife 2000. Univ. Wisconsin Press, Madison

Mannan, R.W. 1984. Summer area requirements of pileated woodpeckers in western Oregon. Wildl. Soc. Bull. 12:265-268.

_____, M.L. Morrison, and C.E. Meslow. 1984. Comment: the use of guilds in forest bird management. Wildl. Soc. Bull. 12: 426-430.

_____, and E.C. Meslow. 1984. Bird populations and vegetation characteristics in managed and old-growth forests, northeastern Oregon. J. Wildl. Manage. 48: 219-228.

Marcot, B.G., M.G. Raphael, and K.H. Berry. 1983. Monitoring wildlife habitat and validation of wildlife-habitat relationships models. Trans. North Am. Wildl. Nat. Resour. Conf. 48: 315-329.

Martin, T.E., and N. Nur. 1992. Population dynamics and their implications for vulnerability of species. Nation. Training Wkshp., Status and Manage. Neotropical Migratory Birds, Executive Summ. Sept. 21-25, Este Park Center, Colo. pp.9-10.

Maurer, B.A. 1986. Predicting habitat quality for grassland birds using density-habitat correlations. J. Wildl. Manage. 50:556-566.

May, R.H. 1977. Thresholds and breakpoints in ecosystems with a multiplicity of stable states. Nature 269:471-477.

McClelland, B.R. 1979. The pileated woodpecker in forests of northern Rocky Mountains. Pages 283-299 in J.G. Dickson, R.N. Conner, R.R. Fleet, J.C. Kroll, and J.A. Jackson, eds. The role of insectivorous birds in forest ecosystems. Academic Press, N.Y. 381pp.

Meents, J.K., J. Rice, B.W. Anderson, and R.D. Ohmart. 1983. Nonlinear relationships between birds and vegetation. Ecology 64: 1022-1027.

Mellen, T.K. 1987. Home range and habitat use of pileated woodpeckers, western Oregon. M.S. Thesis, Oregon State Univ., Corvallis.

Morin, P.J. 1981. Predatory salamanders reverse the outcome of competition among three species of anuran tadpoles. Science 212: 1284-1286.

Morrison, M.L., B.G. Marcot, and R.W. Mannan. 1992. Wildlife-habitat relationships: concepts and applications. Univ. Wisconsin Press, Madison. 470pp.

Nelson, M.E., and L.D. Mech. 1981. Deer social organization and wolf predation in northeastern Minnesota. Wildl. Monogr. 77. 53pp.

Nelson, R.D., and H. Salwasser. 1982. The Forest Service wildlife and fish habitat relationship program. Trans. of the North Am. Wildl. and Nat. Res. Conf. 47: 174-183.

Noon, B. 1992. Thought of improving the biological value of bird-habitat models. Nation.Training Wkshp., Status and Manage. of Neotropical Migratory Birds, Executive Summaries. Sept. 21-25, Este Park Center, CO. 40pp.

O'Neil, L.J., T.H. Roberts, J.S. wakeley, and J.W. Teaford. 1988. A procedure to modify habitat suitability index models. Wildl. Soc. Bull. 16(4): 33-36.

Patterson, J.H. 1976. The role of environmental heterogeneity in the regulation of duck populations. J. Wildl. Manage. 40:22-32.

Raphael, M.G. and B.G. Marcot. 1986. Validation of wildlife-habitat relationships model: vertebrates in a Douglas fir sere. Pages 129-138 in J. Verner, M.L. Morrison, and C.J. Ralph, eds. Wildlife 2000. Univ. Wisconsin Press, Madison

Renken R.B., and E.P. Wiggers. 1989. Forest characteristics related to pileated woodpecker territory size in Missouri. Condor 91: 642-652.

Robbins, C.S. 1981. Bird activity levels related to weather. Stud. in Avian Biol. No. 6: 301-310.

Robel, R.J., L.B. Fox, and K.E. Kemp. 1993. Relationship between habitat suitability index values and ground counts of beaver colonies in Kansas. Wildl. Soc. Bull. 21:415-421.

Roloff, G.J. 1994. Using an ecological classification system and wildlife habitat models in forest planning. Ph.D. Dissertation. Michigan State Univ. East Lansing. 203 pp.

Romesburg, H.C. 1981. Wildlife science: Gaining reliable knowledge. J. Wildl. Manage. 45:293-331.

Root, R.B. 1967. The niche exploitation patterns of the blue-gray gnatcatcher. Ecol. Mono. 37: 317-350.

SAS Institute. 1985. SAS user's guide: statistics, version 5. SAS Institute, Inc. Cary N.C. 956pp.

Salwasser, H. 1982. California's wildlife information system and its application to resource decisions. Cal-Neva Wildl. Trans. 1982: 34-39.

Schamberger, M., and W.B. Krohn. 1982. Status of the habitat evaluation procedures. Trans. N. Amer. Fish Wildl. Conf. 1982:154-164.

_____., and L.J. O'Neill. 1986. Concepts and constraints of habitat model testing. Pages 5-10 in J. Verner, M.L. Morrison, and C.J. Ralph, eds. Wildlife 2000. Univ. Wisconsin Press, Madison

Schroeder, R.L. 1982a. Habitat suitability index models: pileated woodpecker. U.S. Dept. Inter., Fish Wildl. Serv. FWS/OBS-82/10.39. 15pp.

_____. 1982b. Habitat suitability index models: downy woodpecker. U.S. Dept. Inter., Fish Wildl. Serv. FWS/OBS-82/10.38. 10pp.

_____. 1982c. Habitat suitability index models: black-capped chickadee. U.S. Dept. Inter., Fish Wildl. Serv. FWS/OBS-82/10.37. 12pp.

Seitz, W.K., C.L. Kling, and A.H. Farmer. 1982. Habitat evaluation: a comparison of three approaches on the norhern Great Plains. Trans. N. Amer. Wildl. Nat. Resour. Conf. 47:82-95.

Seng, P.T. 1991. Evaluation of techniques for determining tree squirrel abundance and habitat suitability in central Missouri. M.S. Thesis, Univ. Missouri, Columbia. 128pp.

Severinghaus, W.D. 1981. Guild theory development as a mechanism for assessing environmental impact. Environ. Manage. 5: 187-190.

Short, H.L., and K.P. Burnham. 1982. Technique for structuring wildlife guilds to evaluate impacts on wildlife communities. Special Scientific Report--Wildl. Rep. 244.

Siegel, S. 1956. Nonparametric statistics for the behavioral sciences. McGraw-Hill Book Co., New York. 312pp.

Simpson, T.B., P.E. Stuart, and B.V. Barnes. 1990. Landscape ecosystems and cover types of the reserve area and adjacent lands of the huron mountain club. Occasional Papers of the Huron Mountain Wildlife Foundation. No. 4. 128pp.

Skirvin, A.A. 1981. Effect of time of day and time of season on the number of observations and density estimates of breeding birds. Stud. in Avian Biol. 6: 271-274.

Soo Line Railroad Company. 1964. Upper Michigan forest resources. Forest Products Development Dept., Minneapolis, Minn. 30pp.

Sousa, P.J. 1987. Habitat suitability index models: hairy woodpecker. U.S. Dept. Inter., Fish Wildl. Serv. Biol. Rep. 82(10.146). 19pp.

Stauffer, D.F., and L.B. Best. 1986. Effects of habitat type and sample size on habitat suitability index models. Pages 71-77 in J. Verner, M.L. Morrison, and C.J. Ralph, eds. Wildlife 2000. Univ. Wisconsin Press, Madison

Systat, Inc. 1992. Systat for Windows: Statistics, Version 5 Edition. Evanston, Ill. 750 pp.

Szaro, R.C. 1986. Guild management: an evaluation of avian guilds as a predictive tool. Environmental Manage. 10:681-688.

Tanner, J.T. 1952. Black-capped and Carolina chickadees in the southern Appalachian mountains. Auk 69: 407-424.

Thomas, J.W. (ed.). 1979. Wildlife habitats in managed forests: The Blue Mountains of Oregon and Washington. U.S. Dept. Agric., For. Serv. Hanb. 553. Washington D.C. 512pp.

U.S. Department of Agriculture, Forest Service. 1973. Wildlife management guide for the National Forests in Missouri. Mark Twain Natl. For., Rolla, Missouri.

U.S. Department of Commerce. 1991. Climatological data annual summary Michigan. (106) No. 13. Natl. Oceanic Atmos. Adm. 34pp.

U.S.D.I. Fish and Wildlife Service. 1981. Standards for the development of Habitat Suitability Index models. Release No. 1-81, 103 ESM. U.S. Fish Wildl. Serv., Div. Ecol. Serv. n.p.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. J. Wildl. Manage. 47: 893-901.

_____, and J.A. Wiens. 1991. Forest bird habitat suitability models and the development of general habitat models. USDI Fish Wildl. Serv. Res. 8. 31pp.

Verner, J. 1984. The guild concept as applied to management of bird populations. Environ. Manage. 8: 1-13.

_____, M.L. Morrison, and C.J. Ralph. 1986. Wildlife 2000: Modeling habitat relationships of terrestrial vertebrates. Univ. Wisconsin Press, Madison. 470pp.

Westover, A.J. 1971. The use of a hemlock-hardwood winter yard by white-tailed deer in northern Michigan. Occasional Papers of the Huron Mountain Wildlife Foundation. No. 4. 59pp.

Wiens, J.A. 1986. Spatial and temporal variation in studies of shrubsteppe birds. Pages 154-172 in J. Diamond, and T.J. Case, eds. Community Ecology. Harper & Row, Publ. New York.

Williamson, M.H., and J.H. Lawton. 1991. Fractal geometry of ecological habitats. Pages 69-86 in S.S. Bell, E.D. McCoy, and H.R. Mushinsky, eds. Habitat structure: The physical arrangement of objects in space. Chapman and Hall, New York.

APPENDICES

Appendix A. Summary of percent area of cover types found within all twenty-four 70 ha study areas sampled in 1993 and 1994. Major forest cover types are UCF-Upland Coniferous Forest, LCF-Lowland Coniferous Forest, LDF-Lowland Deciduous Forest, and UDF-Upland Deciduous Forest delineated by forest successional stage.

	Forested Cover Types (%)[a]									
Study Areas	UCF Mature	LCF Mature	LCF Late Successional	UDF Pole Timber	UDF Mature	UDF Late Successional	LDF Mature	LDF Late Successional	Open Land	Misc. cover types[b]
1	<1.0	11.4		<1.0	15.0		70.0		4.0	
2					100.0					
3	87.4			5.9					5.8	
4		63.8			2.2		30.4		3.6	
5		57.7		14.4					<1.0	27.2
6	95.9		< 1.0							4.1
7	3.6		1.0			94.1				<1.0
8	2.1		< 1.0		14.2	79.1				<1.0
9	8.5					87.6		1.4	1.0	1.5
10	65.2					24.0	2.4			8.5
11	2.3					79.4	< 1.0	6.6		9.0
12	58.8		<1.0			26.0	5.7	<1.0		6.3
13	28.0		<1.0			4.3	<1.0	44.2		22.4
14					100.0					
15		4.9			83.0		12.3			
16				11.1	77.1				10.4	1.3
17	1.9	85.5			7.6				2.8	2.2
18		< 1.0			72.1				5.8	22.0
19		13.9					86.0			<1.0
20	19.1				<1.0	56.9	8.8	3.1		5.0
21	16.6				13.5	44.8	<1.0	5.3	1.1	7.4

Appendix A (cont'd).

	Forested Cover Types (%)[a]									
Study Areas	UCF Mature	LCF Mature	LCF Late Successional	UDF Pole Timber	UDF Mature	UDF Late Successional	LDF Mature	LDF Late Successional	Open Land	Misc. cover types[b]
22	47.7					38.9	3.7	<1.0		8.1
23				99.7					<1.0	
24				95.7					4.3	
Mean (%)	18.9	9.9	<1.0	9.5	20.2	22.3	9.1	1.85	1.6	5.2
SE (%)	6.2	4.8	<1.0	5.6	7.2	6.8	4.6	1.2	.6	1.6

[a] Forested cover types are delineated into 10 general cover types. Cover type descriptions can be found in Appendix C.
[b] Miscellaneous cover types have <1% coverage or found on only 2 or fewer study areas.

Appendix B. Common and scientific names by family of birds censused on or near proximity to twenty-four 70 ha study areas located in the Huron Mountain Club and the Hiawatha National Forest in the Upper Peninsula of Michigan during 1993 and 1994.

Species	***(Scientific name)***	**Censused**	**On / off areas**[a]
Gaviidae:			
Common Loon	*(Gavia immer)*	HMC[b]	off
Podicipedidae:			
Horned Grebe	*(Podiceps auritus)*	HMC	off
Pied-billed Grebe	*(Podilymbus podiceps)*	HMC	off
Phalacrocoracidae:			
Double-crested Cormorant	*(Phalacrocorax auritus)*	HMC	off
Ardeidae:			
American Bittern	*(Botaurus lentiginosus)*	HMC	off
Great Blue Heron	*(Ardea herodias)*	BOTH[c]	on HNF[d]
Green Heron	*(Butorides striatus)*	HMC	off
Gruidae:			
Sandhill Crane	*(Grus canadensis)*	BOTH	on HNF
Anatidae:			
Canada Goose	*(Branta canadensis)*	HMC	off
Mallard	*(Anas platyrhynchos)*	HMC	off
Green-winged Teal	*(Anas crecca)*	HMC	off
Northern Shoveler	*(Anas clypeata)*	HMC	off
American Widgeon	*(Anas americana)*	HMC	off
Wood Duck	*(Aix sponsa)*	HMC	off
Canvasback	*(aythya valisineria)*	HMC	off
Ring-necked Duck	*(Aythya collaris)*	HMC	off
Lesser Scaup	*(Aythya affinis)*	HMC	off
Common Goldeneye	*(Bucephala clangula)*	HMC	off
Bufflehead	*(Bucephala albeola)*	HMC	off
Hooded Merganser	*(Lophodytes cucullatus)*	HMC	off
Common Merganser	*(Mergus merganser)*	HMC	off
Rallidae:			
Sora	*(Porzana carloina)*	HMC	off
American Coot	*(Fulica americana)*	HMC	off
Charadriidae:			
Killdeer	*(Charadrius vociferus)*	HMC	off
Ruddy Turnstone	*(Arenaria interpres)*	HMC	off
Scolopacidae:			
American Woodcock	*(Scolopax minor)*	BOTH	on
Common Snipe	*(Gallinago gallinago)*	BOTH	on

Appendix B (cont'd).

Species	*(Scientific name)*	Censused	Off Sites
Laridae:			
Ring-billed Gull	*(Larus delawarensis)*	HMC	off
Herring Gull	*(Larus argentatus)*	HMC	off
Black Tern	*(Chlidonias niger)*	HMC	off
Cathartidae:			
Turkey Vulture	*(Cathartes aura)*	BOTH	on
Accipitridae:			
Bald Eagle	*(Haliaeetus leucocephalus)*	HMC	off
Northern Goshawk	*(Accipiter gentilis)*	HNF	on
Broad-winged Hawk	*(Buteo platypterus)*	HMC	off
Northern Harrier	*(Circus cyaneus)*	HMC	off
Cooper's Hawk	*(Accipiter cooperii)*	HMC	off
Red-tailed Hawk	*(Buteo jamaicensis)*	BOTH	off
Red-shouldered Hawk	*(Buteo lineatus)*	HMC	off
Pandionidae:			
Osprey	*(Pandion haliaetus)*	BOTH	on
Falconidae:			
American Kestrel	*(Falco sparverius)*	HMC	off
Phasianidae:			
Spruce Grouse	*(Dendragapus canadensis)*	HMC	off
Ruffed Grouse	*(Bonasa umbellus)*	BOTH	on
Columbidae:			
Mourning Dove	*(Zenaida macroura)*	HMC	off
Cuculidae:			
Yellow-billed Cuckoo	*(Coccyzus americanus)*	BOTH	on
Strigidae:			
Barred Owl	*(Strix varia)*	BOTH	on
Long-eared Owl	*(Asio otus)*	HMC	off
Caprimulgidae:			
Whip-poor-will	*(Caprimulgus vociferus)*	BOTH	on
Common Nighthawk	*(Chordeiles minor)*	BOTH	on
Chuck-will's-widow	*(Caprimulgus carolinensis)*	HMC	off
Apodidae:			
Chimney Swift	*(Chaetura pelagica)*	HMC	off
Trochiidae:			
Ruby-throated Hummingbird	*(Archilochus colubris)*	BOTH	on
Alcedinidae:			
Belted Kingfisher	*(Ceryle alcyon)*	BOTH	off

Appendix B (cont'd).

Species	*(Scientific name)*	Censused	Off Sites
Picidae:			
Hairy Woodpecker	*(Picoides villosus)*	BOTH	on
Downy Woodpecker	*(Picoides pubescens)*	BOTH	on
Red-headed Woodpecker	*(Melanerpes erythrocephalus)*	HMC	off
Black-backed Woodpecker	*(Picoides arcticus)*	BOTH	on
Yellow-bellied Sapsucker	*(Sphyrapicus varius)*	BOTH	on
Pileated Woodpecker	*(Dryocopus pileatus)*	BOTH	on
Northern Flicker	*(Colaptes auratus)*	BOTH	on
Tyrannidae:			
Eastern Kingbird	*(Tyrannus tyrannus)*	HMC	off
Great Crested Flycatcher	*(Myiarchus crinitus)*	BOTH	on
Eastern Phoebe	*(Sayornis phoebe)*	BOTH	off
Olive-sided Flycatcher	*(Contopus borealis)*	HMC	off
Yellow-bellied Flycatcher	*(Empidonax flaviventris)*	BOTH	on
Eastern Wood Pewee	*(Contopus virens)*	BOTH	on
Alder Flycatcher	*(Empidonax alnorum)*	BOTH	on
Least Flycatcher	*(Empidonax minimus)*	BOTH	on
Hirundinidae:			
Cliff Swallow	*(Hirundo pyrrhonota)*	HMC	off
Bank Swallow	*(Riparia riparia)*	HMC	off
Barn Swallow	*(Hirundo rustica)*	HMC	off
Tree Swallow	*(Tachycineta bicolor)*	BOTH	on
Corvidae:			
Gray Jay	*(Perisoreus canadensis)*	HMC	on
Blue Jay	*(Cyanocitta cristata)*	BOTH	on
Common Raven	*(Corvus corax)*	BOTH	on
American Crow	*(Corvus brachyrhynchos)*	BOTH	on
Paridae:			
Boreal Chickadee	*(Parus hudsonicus)*	HMC	on
Black-capped Chickadee	*(Parus atricapillus)*	BOTH	on
Certhiidae:			
Brown Creeper	*(Certhia americana)*	BOTH	on
Sittidae:			
White-breasted Nuthatch	*(Sitta carolinensis)*	BOTH	on
Red-breasted Nuthatch	*(Sitta canadensis)*	BOTH	on
Troglodytidae:			
House Wren	*(Troglodytes aedon)*	HMC	off
Winter Wren	*(Troglodytes troglodytes)*	BOTH	on
Marsh Wren	*(Cistothorus palustris)*	HMC	off
Carolina Wren	*(Thryothorus ludovicianus)*	BOTH	on

Appendix B (cont'd).

Species	*(Scientific name)*	Censused	Off Sites
Muscicapidae:			
Golden-crowned Kinglet	*(Regulus satrapa)*	HMC	on
Ruby-crowned Kinglet	*(Regulus calendula)*	BOTH	on
Turdidae:			
Wood Thrush	*(Hylocichla mustelina)*	BOTH	on
Veery	*(Catharus fuscescens)*	BOTH	on
Swainson's Thrush	*(Catharus ustulatus)*	BOTH	on
Hermit Thrush	*(Catharus guttatus)*	BOTH	on
American Robin	*(Turdus migratorius)*	BOTH	on
Eastern Bluebird	*(Sialia sialis)*	BOTH	off
Laniidae:			
Northern Shrike	*(Lanius excubitor)*	HMC	on
Mimidae:			
Gray Catbird	*(Dumetella carolinensis)*	HMC	off
Brown Thrasher	*(Toxostoma rufum)*	HMC	off
Bombycilliidae:			
Cedar Waxwing	*(Bombycilla cedrorum)*	BOTH	on
Sturnidae:			
European Starling	*(Sturnus vulgaris)*	HMC	off
Vireonidae:			
Red-eyed Vireo	*(Vireo olivaceus)*	BOTH	on
Solitary Vireo	*(Vireo solitarius)*	BOTH	on
Warbling Vireo	*(Vireo gilvus)*	HMC	on
Parulidae:			
Black-and-White Warbler	*(Mniotilta varia)*	BOTH	on
Nashville Warbler	*(Vermivora ruficapilla)*	BOTH	on
Northern Parula	*(Parula americana)*	BOTH	on
Cape May Warbler	*(Dendroica tigrina)*	HMC	off
Yellow Warbler	*(Dendroica petechia)*	HMC	off
Black-throated Blue Warbler	*(Dendroica caerulescens)*	BOTH	on
Yellow-rumped Warbler	*(Dendroica coronata)*	BOTH	on
Magnolia warbler	*(Dendroica magnolia)*	HMC	off
Chestnut-sided Warbler	*(Dendroica pensylvanica)*	BOTH	on
Blackburnian Warbler	*(Dendroica fusca)*	BOTH	on
Black-thoated Green Warbler	*(Dendroica virens)*	BOTH	on
Pine Warbler	*(Dendroica pinus)*	BOTH	on
Cerulean Warbler	*(Dendroica cerulea)*	HMC	on
Palm Warbler	*(Dendroica palmarum)*	HMC	off
Mourning Warbler	*(Oporornis philadelphia)*	HMC	off
Common Yellowthroat	*(Geothlypis trichas)*	BOTH	on

Appendix B (cont'd).

Species	*(Scientific name)*	Censused	Off Sites
Golden-winged Warbler	*(Vermivora chrysoptera)*	HMC	off
Canada Warbler	*(Wilsonia canadensis)*	HMC	off
American Redstart	*(Setophaga ruticilla)*	BOTH	on
Ovenbird	*(Seiurus aurocapillus)*	BOTH	on
Northern Waterthrush	*(Seiurus noveboracensis)*	HMC	on
Icteridae:			
Bobolink	*(Dolichonyx oryzivorus)*	HMC	off
Eastern Meadowlark	*(Sturnella magna)*	HMC	off
Red-winged Blackbird	*(Agelaius phoeniceus)*	BOTH	on hnf
Brown-headed Cowbird	*(Molothrus ater)*	BOTH	on hnf
Thraupidae:			
Scarlet Tanager	*(Piranga olivacea)*	BOTH	on
Fringillidae:			
Evening Grosbeak	*(Coccothraustes vespertinus)*	HNF	on
Pine Siskin	*(Carduelis pinus)*	BOTH	on
American Goldfinch	*(Carduelis tristis)*	BOTH	off
Red Crossbill	*(Loxia curvirostra)*	HMC	on
Common Redpoll	*(Carduelis flammea)*	HMC	off
Cardinalidae:			
Rose-breasted Grosbeak	*(Pheucticus ludovicianus)*	BOTH	on
Rufous-sided Towhee	*(Pipilo erythrophthalmus)*	HMC	off
Indigo Bunting	*(Passerina cyanea)*	BOTH	on
White-throated Sparrow	*(Zonotrichia albicollis)*	BOTH	on
Chipping Sparrow	*(Spizella passerina)*	HMC	off
Song Sparrow	*(Melospiza melodia)*	BOTH	on
Swamp Sparrow	*(Melospiza georgiana)*	HMC	off
Dark-eyed Junco	*(Junco hyemalis)*	BOTH	on
White-crowned Sparrow	*(Zonotrichia leucophrys)*	BOTH	on
Lapland Longspur	*(Calcarius lapponicus)*	HMC	on

[a] Indicates that birds were censused "on" 70 ha study areas or "off" but within sight or sound of the edge of any study area.

[b] Censused on the Huron Mountain Club only.

[c] Censused on the Huron Mountain Club and Hiawatha National Forest study areas.

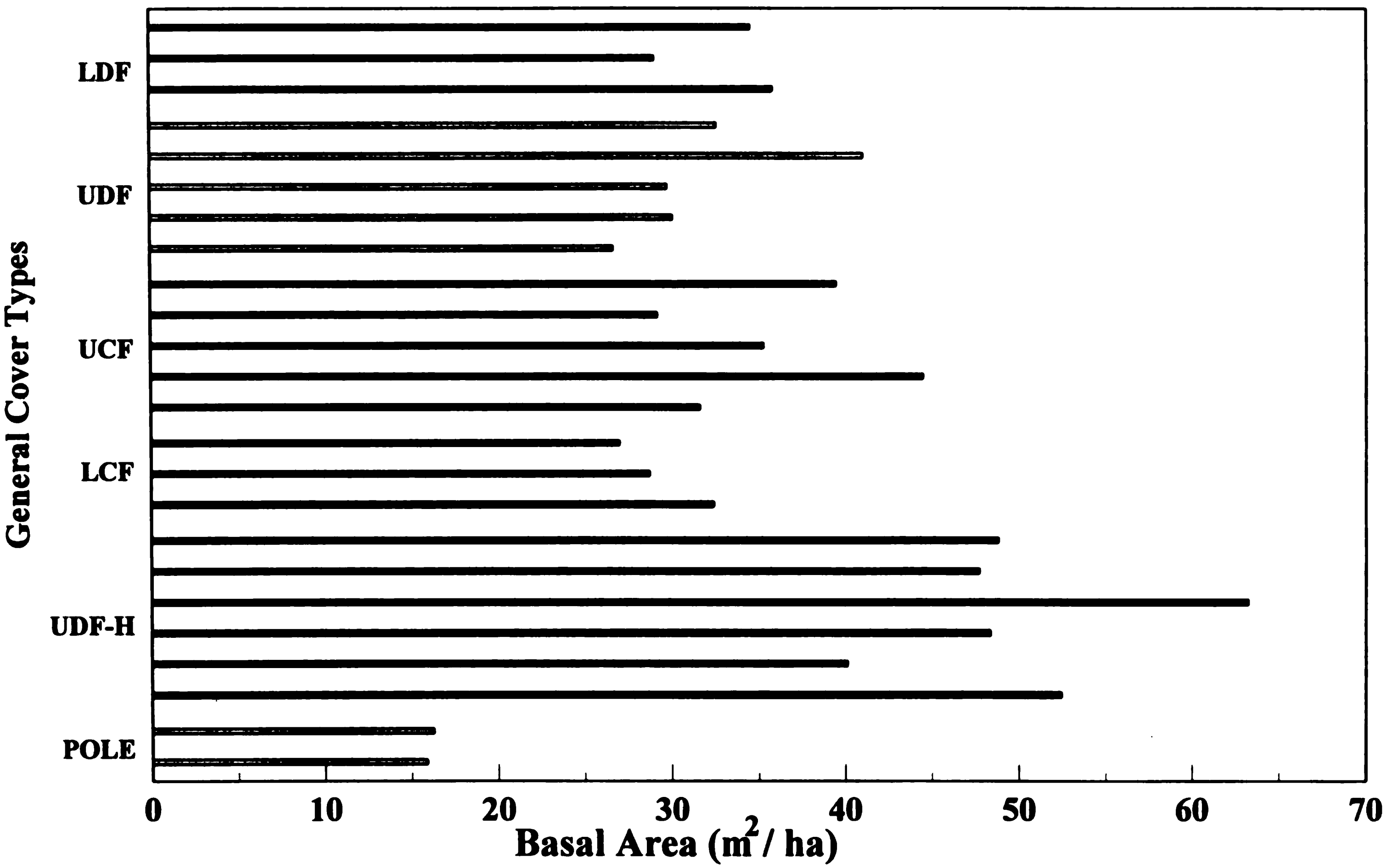
[d] Censused on the Hiawatha National Forest study areas only.

Appendix C. Summary of codes used to delineate forested cover types sampled on all twenty-four 70 ha study areas located in the Huron Mountain Club and the Hiawatha National Forest during 1993 and 1994.

Cover Type Codes	Description[a]	General Cover Type[b]
1	Jack pine-mature	Mature UCF
4	Lichen-Juniper (found on rocky outcrops with <20% tree cover)	Miscellaneous[c]
5	Pine-oak (predominately red and white pine, red oak)	Mature UCF
6	White-pine-Hemlock-Hardwood	Mature UCF
7	Birch-Hemlock-Red Maple	Mature LDF
11	Hemlock-Northern Hardwood	Late-successional UDF
17	Hemlock-Red Maple-Yellow Birch-Northern White Cedar	Mature LDF
22	Post-Clearcutting Hardwoods (predominately sugar maple, red maple, yellow and white birch)	Mature UDF
28	Conifer-Hardwood (northern white cedar, black ash, white spruce, balsam fir, and yellow birch).	Mature LCF
029	Red Pine-sawtimber size	Mature UCF
149	Northern White Cedar-sawtimber size	Mature LCF
189	Mixed Swamp Conifer (predominately balsam fir, northern white cedar, yellow birch)-sawtimber size	Mature LCF
769	Red Maple (wet site)-sawtimber size	Mature LDF
816	Sugar Maple-American Beech-Yellow Birch-poletimber size	Poletimber UDF
819	Sugar Maple-American Beech-Yellow Birch-sawtimber size	Mature UDF
849	Red Maple (dry site)-sawtimber size	Mature LDF

[a]Descriptions were taken from Simpson et al. (1990) and U.S.D.A. Forest Service, Hiawatha National Forest, MI. stand type classification.
[b]Cover types were delineated into 6 general cover types that include: UDF=upland deciduous forest, LDF=lowland deciduous forest, UCF=upland conifer forest, LCF=lowland conifer forest, late-successional UDF=late-successional upland deciduous forest, and poletimber UDF=poletimber sized upland deciduous forest.
[c]Miscellaneous cover types have <1% coverage or found on only 2 or fewer study areas.

Appendix D. Means of habitat variables (n=12) across twenty-four study areas dominated by the following cover types: LDF=mature lowland deciduous forest (n=3), UDF=previously harvested mature upland deciduous forest (n=5), UCF=upland coniferous forest (n=5), LCF=lowland coniferous forest (n=3), UDF-H=unharvested late-successional upland deciduous forest (n=6), and POLE=poletimber sized upland deciduous forest (n=2). All vegetation sampling was conducted in the Huron Mountain Club and the Hiawatha National Forest during 1993 and 1994.



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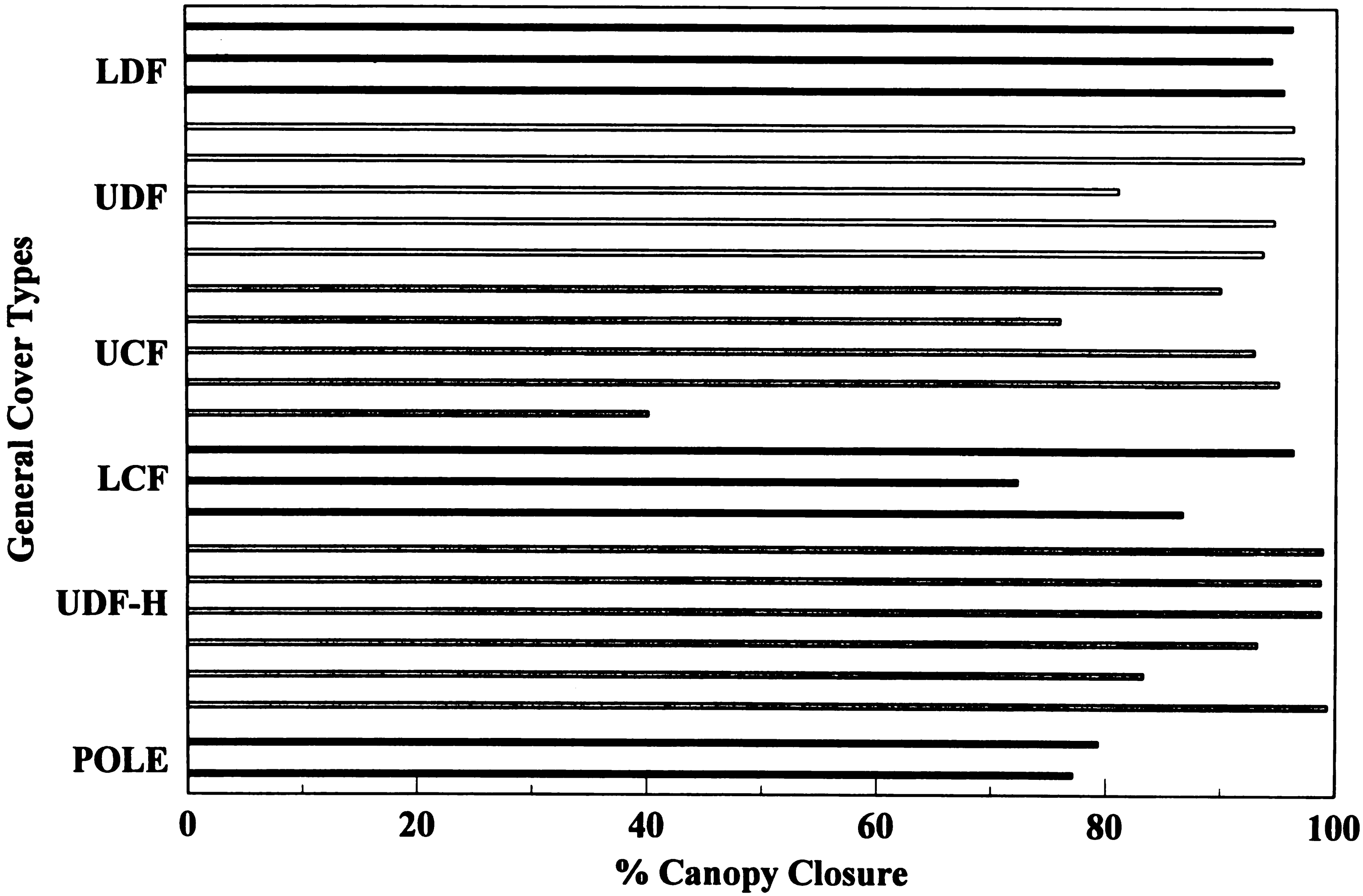

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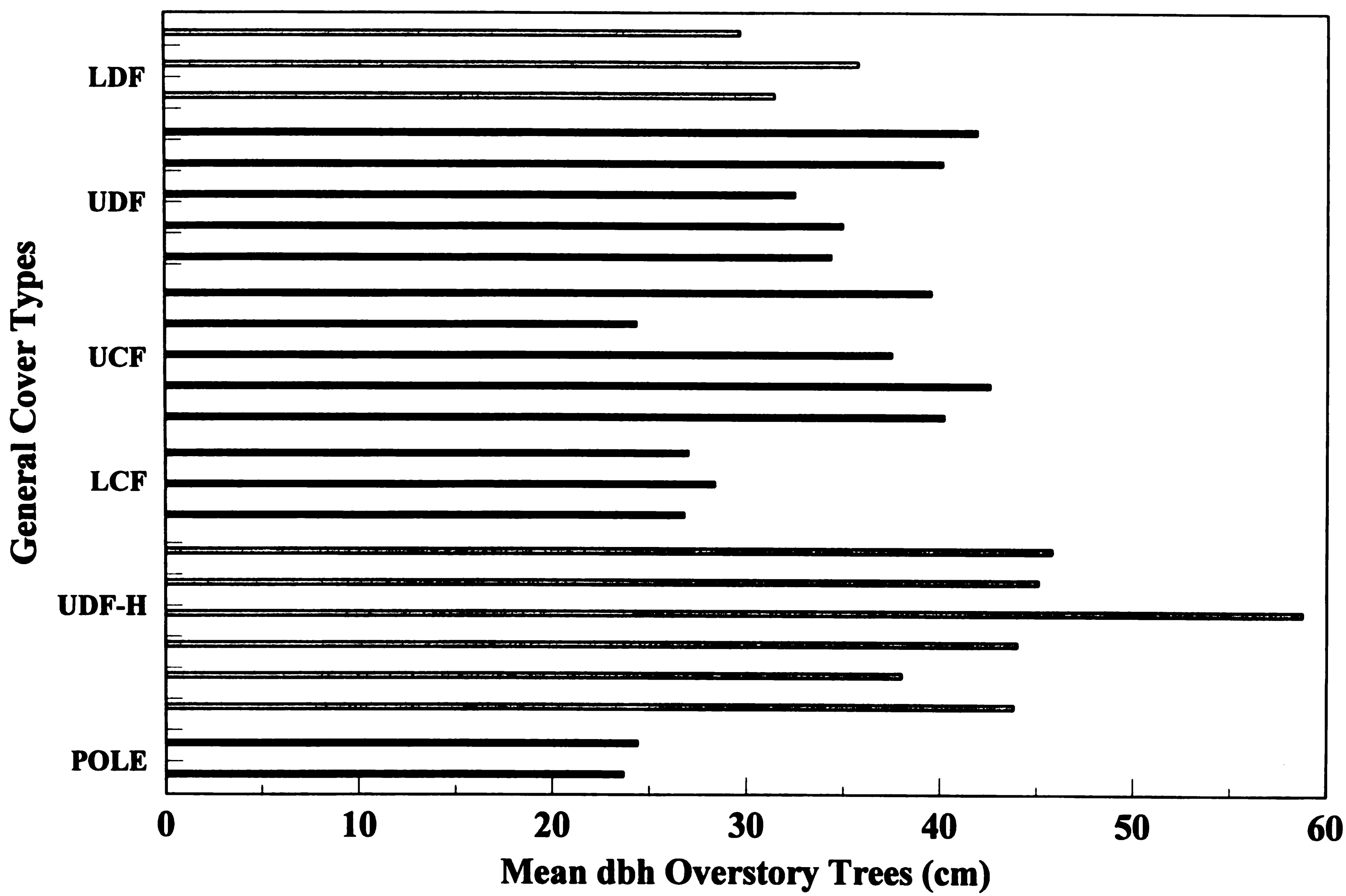

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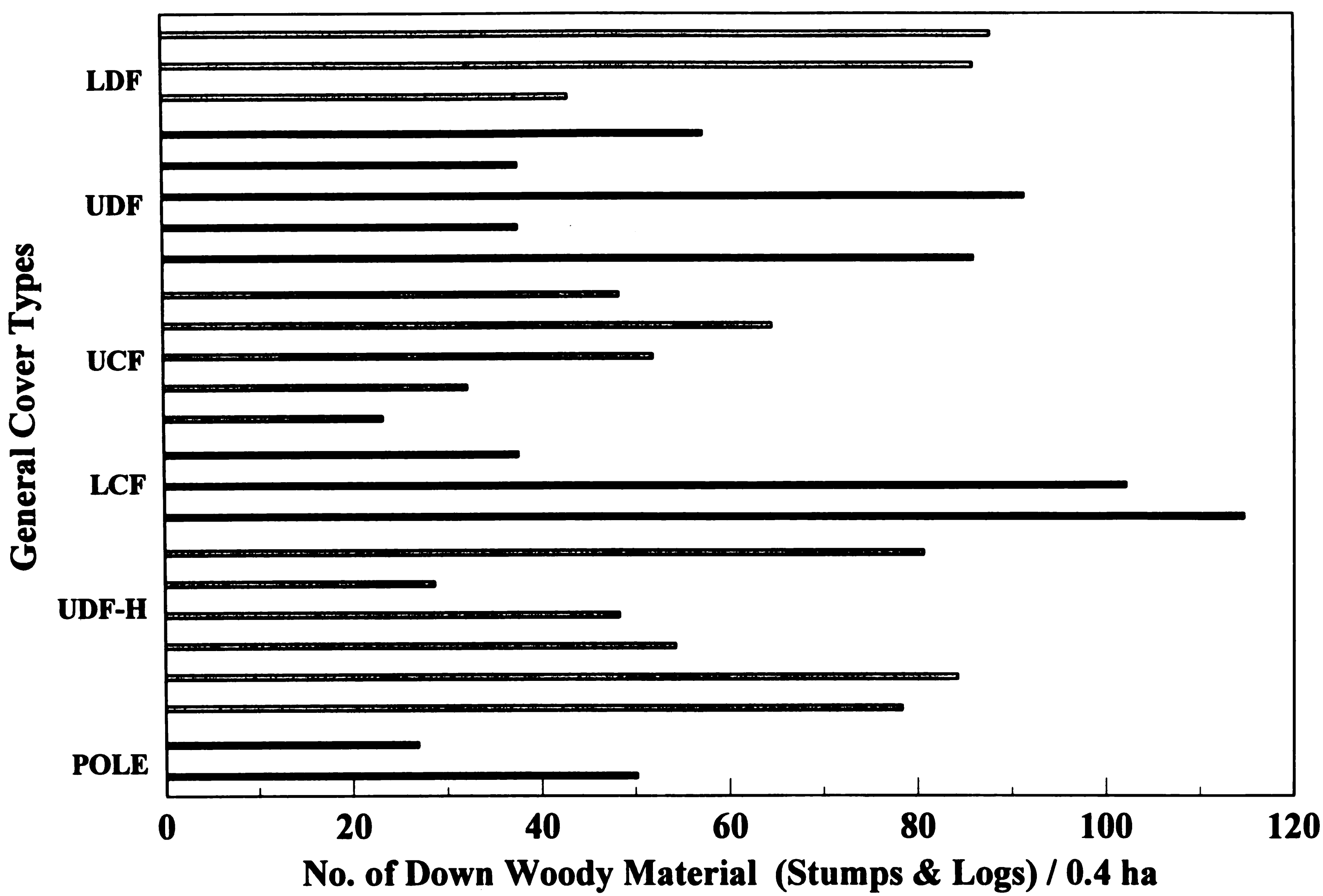

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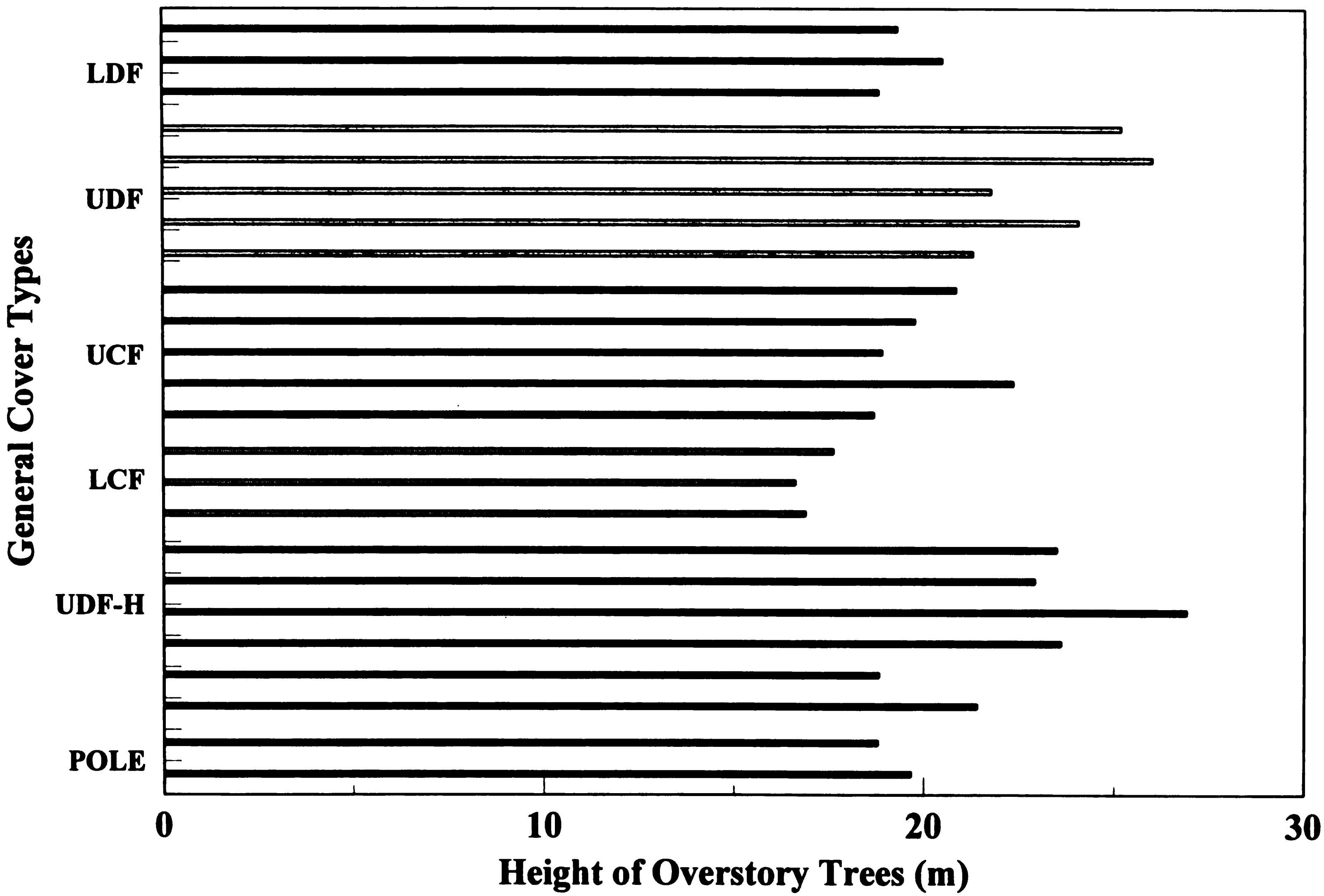

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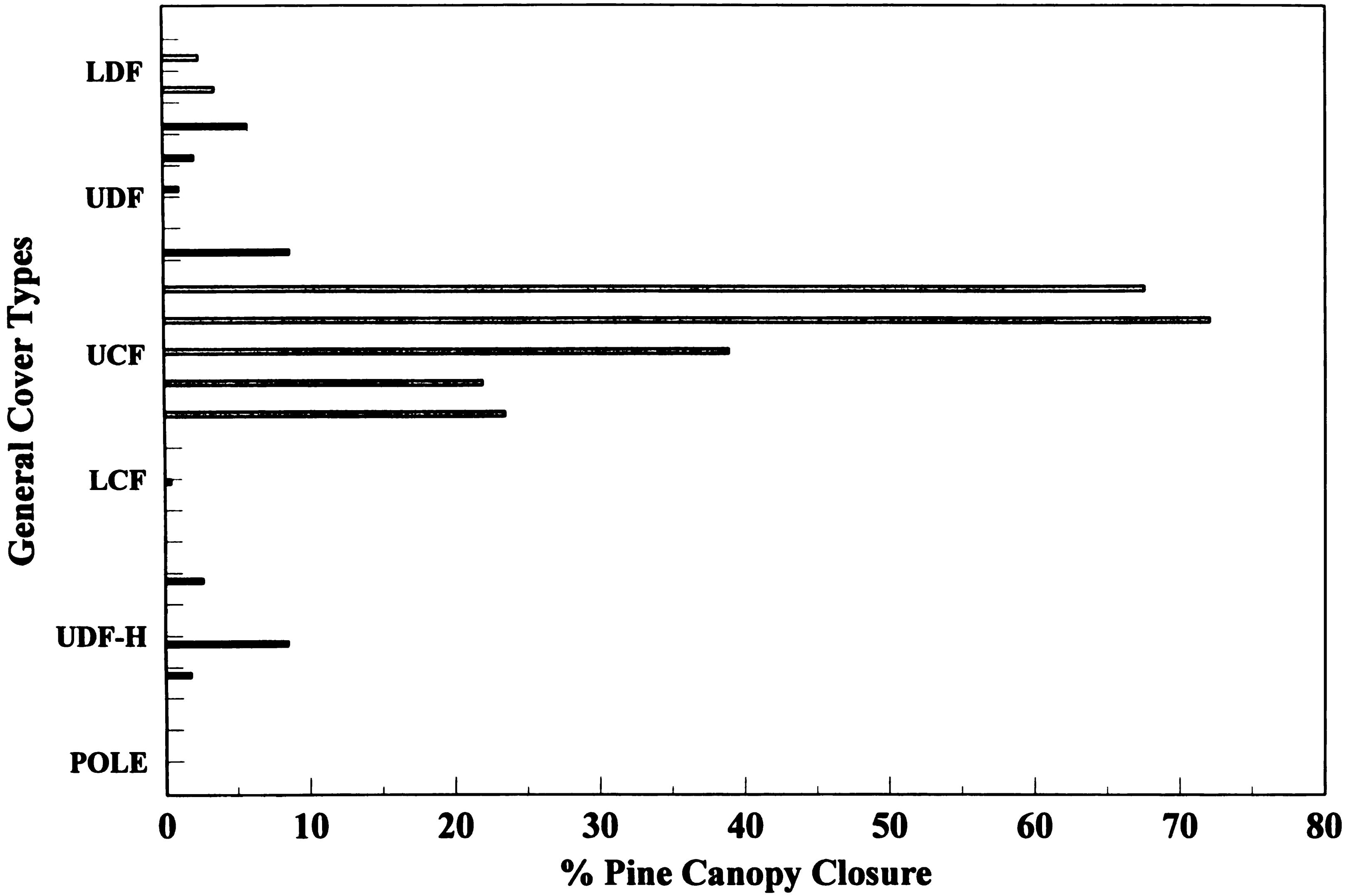

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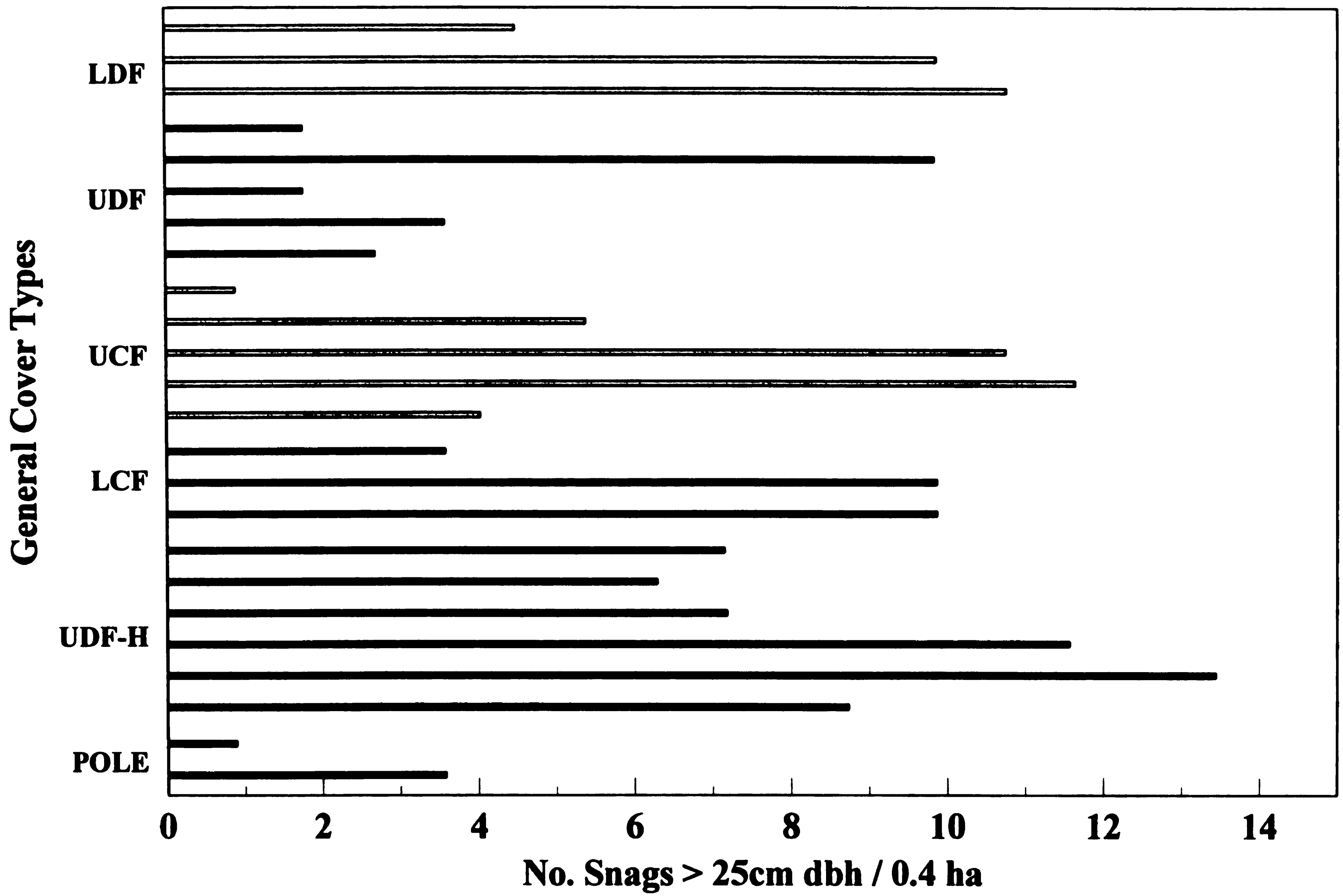

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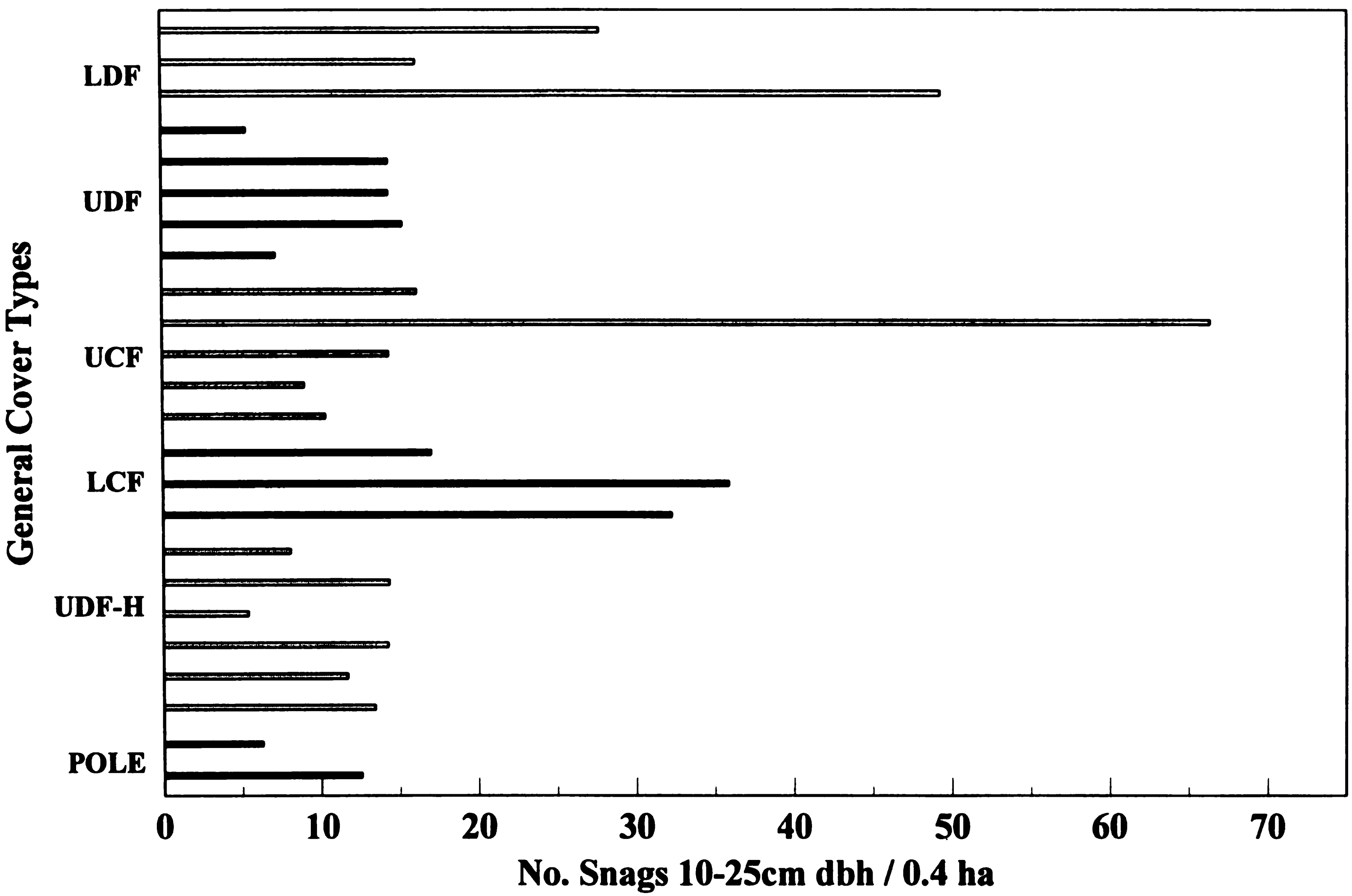

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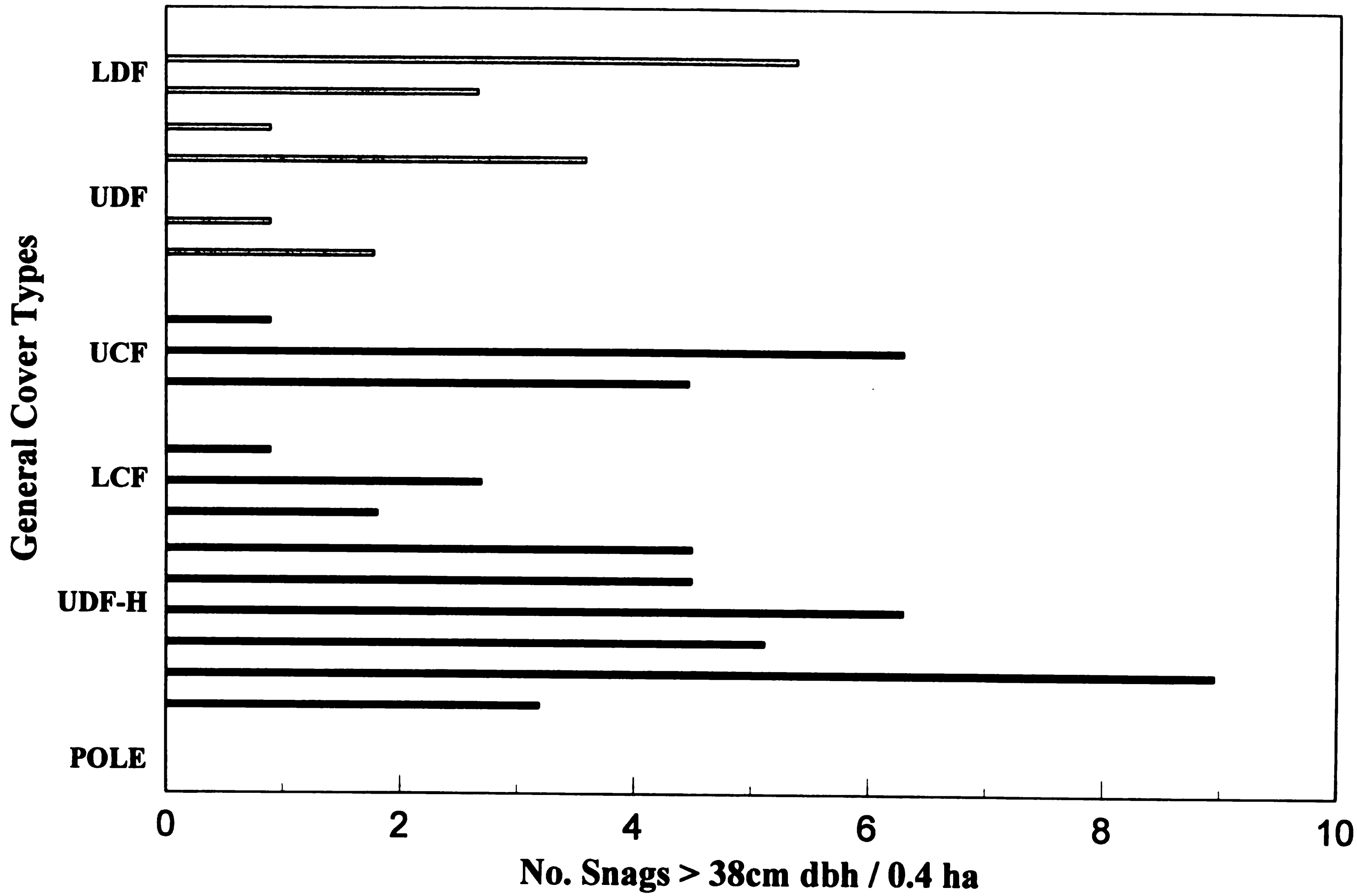

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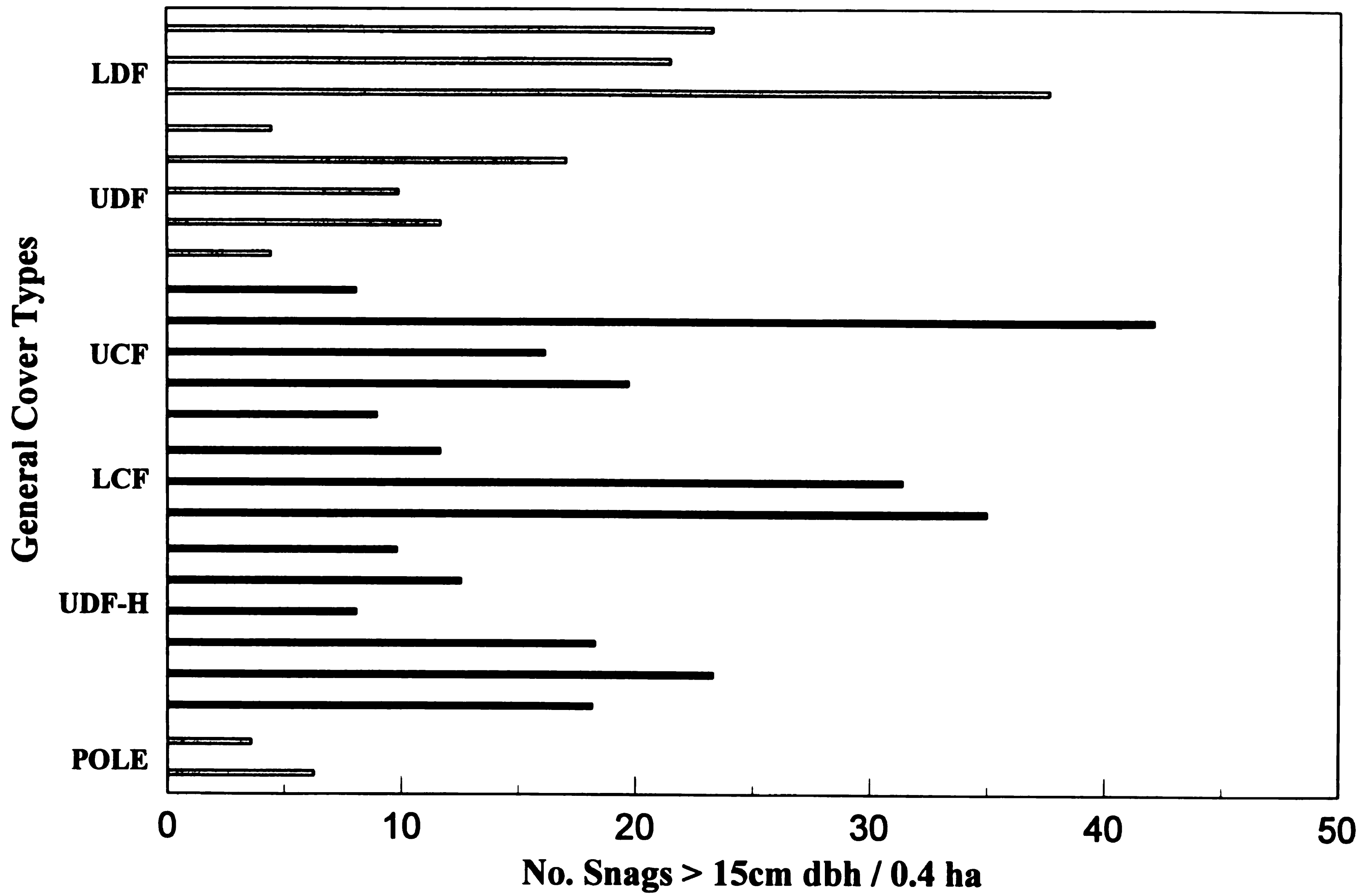
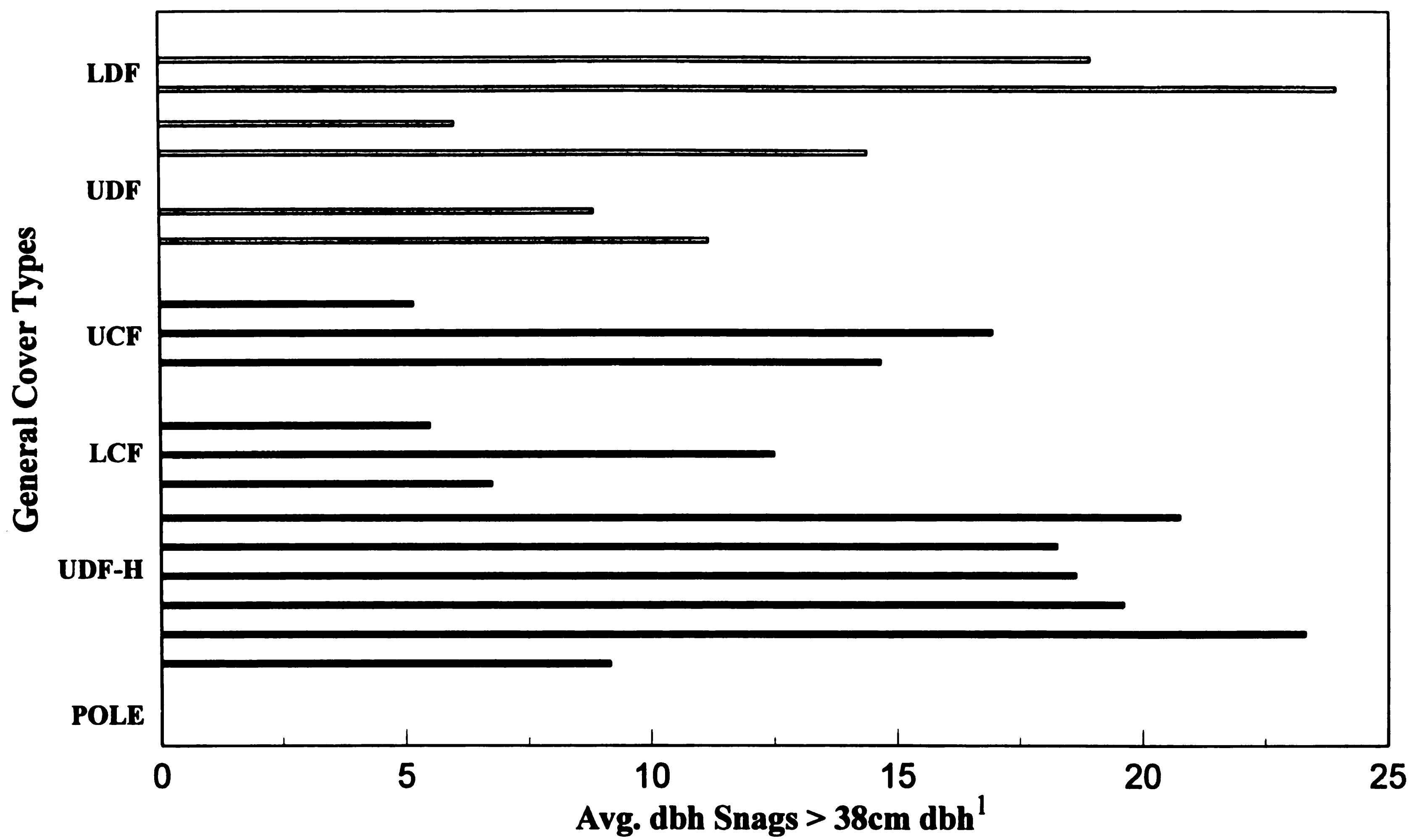
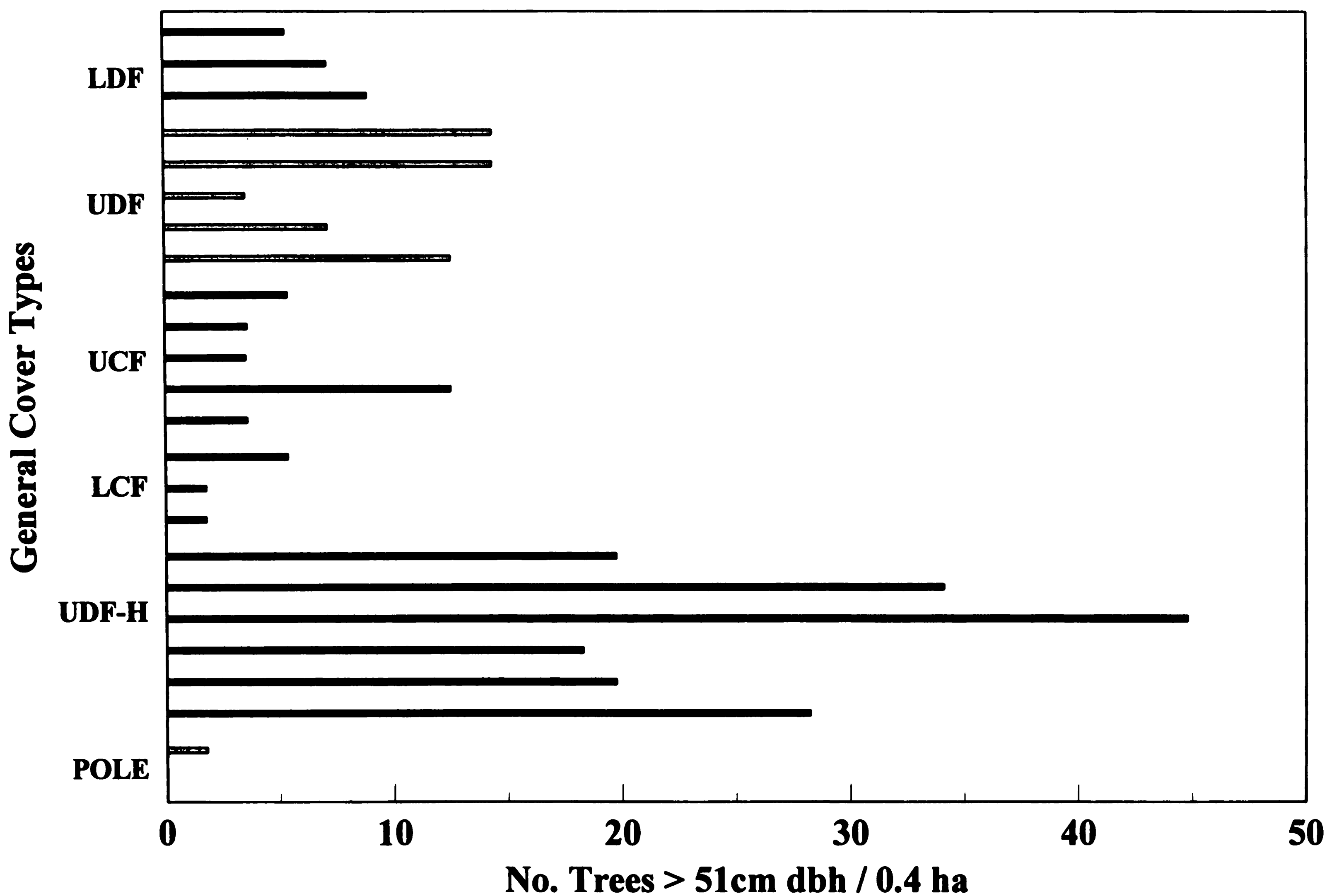


Appendix D (cont'd).



[1] Average dbh of snags > 38 cm resulted from plots where no large snags were recorded.

Appendix D (cont'd).



Appendix E. Principal components analysis eigenvalues and scores for all habitat variables found in the pileated woodpecker (Schoeder 1982a), hairy woodpecker (Sousa 1987), downy woodpecker (Schoeder 1982b) and black-capped chickadee (Schoeder 1982c) models.

The SAS System

Eigenvalues of the Correlation Matrix: Total = 12 Average = 1

	1	2	3	4
Eigenvalue	4.9169	2.9406	1.3306	0.9443
Difference	1.9762	1.6100	0.3864	0.2414
Proportion	0.4097	0.2451	0.1109	0.0787
Cumulative	0.4097	0.6548	0.7657	0.8444

	5	6	7	8
Eigenvalue	0.7028	0.5159	0.2841	0.2155
Difference	0.1869	0.2318	0.0685	0.1148
Proportion	0.0586	0.0430	0.0237	0.0180
Cumulative	0.9029	0.9459	0.9696	0.9876

	9	10	11	12
Eigenvalue	0.1008	0.0213	0.0199	0.0007
Difference	0.0795	0.0014	0.0126	0.0007
Proportion	0.0084	0.0018	0.0017	0.0006
Cumulative	0.9960	0.9977	0.9994	1.0000

3 factors will be retained by the NFACTOR criterion.

Factor Pattern

	PRIN1	PRIN2	PRIN3
CAN	0.58277	0.02570	-0.17247
TGT20	0.89208	-0.12967	0.08375
DOWN	-0.10384	0.48675	-0.49416
SNAGGT15	0.78805	0.42664	-0.08759
SNDBH15	0.76178	0.49437	-0.07474
SNAG10-	0.50823	0.75886	-0.08164
DBHOST	0.89447	-0.25330	0.20817
PINE	-0.27314	0.10057	0.84467
BA	0.87552	0.07814	0.27172
SNAGGT6	-0.14777	0.93273	0.17734
HT	0.68645	-0.47029	0.18649
SNAG410	-0.42044	0.71582	0.36453

Variance explained by each factor:

PRIN1	PRIN2	PRIN3	PRIN4
4.916864	2.940649	1.330619	0.944252