REFERENCE COPY
Do Not Remove from the Library
U. S. Fish and Wildlife Service
National Wetlands Research Center
700 Cajun Dome Boulevard

BIOLOGICAL REPORT 82(10.146)
SEPTEMBER 1987

HABITAT SUITABILITY INDEX MODELS: HAIRY WOODPECKER

SK
361
.U54
no.82-
10.146

Fish and Wildlife Service

U.S. Department of the Interior

MODEL EVALUATION FORM

Habitat models are designed for a wide variety of planning applications where habitat information is an important consideration in the decision process. However, it is impossible to develop a model that performs equally well in all situations. Assistance from users and researchers is an important part of the model improvement process. Each model is published individually to facilitate updating and reprinting as new information becomes available. User feedback on model performance will assist in improving habitat models for future applications. Please complete this form following application or review of the model. Feel free to include additional information that may be of use to either a model developer or model user. We also would appreciate information on model testing, modification, and application, as well as copies of modified models or test results. Please return this form to:

Habitat Evaluation Procedures Group
U.S. Fish and Wildlife Service
2627 Redwing Road, Creekside One
Fort Collins, CO 80526-2899

Thank you for your assistance.

Species _____ Geographic Location _____

Habitat or Cover Type(s) _____

Type of Application: Impact Analysis ____ Management Action Analysis _____
Baseline _____ Other _____

Variables Measured or Evaluated _____
_____
_____
_____

Was the species information useful and accurate? Yes ____ No ____

If not, what corrections or improvements are needed?_____
_____
_____
_____

Were the variables and curves clearly defined and useful? Yes ____ No ____

If not, how were or could they be improved? _____

_____

_____

_____

Were the techniques suggested for collection of field data:

Appropriate? Yes ____ No ____

Clearly defined? Yes ____ No ____

Easily applied? Yes ____ No ____

If not, what other data collection techniques are needed? _____

_____

_____

_____

Were the model equations logical? Yes ____ No ____

Appropriate? Yes ____ No ____

How were or could they be improved? _____

_____

_____

_____

Other suggestions for modification or improvement (attach curves, equations, graphs, or other appropriate information) _____

_____

_____

_____

Additional references or information that should be included in the model:

_____

_____

_____

_____

_____

Model Evaluator or Reviewer _____ Date _____

Agency _____

Address _____

_____

_____

Telephone Number Comm: _____ FTS _____

Biological Report 82(10.146)
September 1987

HABITAT SUITABILITY INDEX MODELS: HAIRY WOODPECKER

by

Patrick J. Sousa
U.S. Fish and Wildlife Service
National Ecology Center
Creekside One Building
2627 Redwing Road
Fort Collins, CO 80526-2899

U.S. Department of the Interior
Fish and Wildlife Service
Research and Development
Washington, DC 20240

Suggested citation:

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

PREFACE

This document is part of the Habitat Suitability Index (HSI) model series [Biological Report 82(10)], which provides habitat information useful for impact assessment and habitat management. Several types of habitat information are provided. The Habitat Use Information section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. This information provides the foundation for the HSI model and may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

The HSI Model section documents the habitat model and includes information pertinent to its application. The model synthesizes the habitat use information into a framework appropriate for field application and is scaled to produce an index value between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). The HSI Model section includes information about the geographic range and seasonal application of the model, its current verification status, and a list of the model variables with recommended measurement techniques for each variable.

The model is a formalized synthesis of biological and habitat information published in the scientific literature and may include unpublished information reflecting the opinions of identified experts. Habitat information about wildlife species frequently is represented by scattered data sets collected during different seasons and years and from different sites throughout the range of a species. The model presents this broad data base in a formal, logical, and simplified manner. The assumptions necessary for organizing and synthesizing the species-habitat information into the model are discussed. The model should be regarded as a hypothesis of species-habitat relationships and not as a statement of proven cause and effect relationships. The model may have merit in planning wildlife habitat research studies about a species, as well as in providing an estimate of the relative suitability of habitat for that species. User feedback concerning model improvements and other suggestions that may increase the utility and effectiveness of this habitat-based approach to fish and wildlife planning are encouraged. Please send suggestions to:

Resource Evaluation and Modeling Section
U.S. Fish and Wildlife Service
National Ecology Center
2627 Redwing Road
Ft. Collins, CO 80526-2899

CONTENTS

	Page
PREFACE	iii
ACKNOWLEDGMENTS	vi
HABITAT USE INFORMATION	1
General	1
Food	1
Water	2
Cover	2
Reproduction	2
Interspersion and Composition	5
Special Considerations	6
HABITAT SUITABILITY INDEX (HSI) MODEL	6
Model Applicability	6
Model Description	7
Application of the Model	12
SOURCES OF OTHER MODELS	15
REFERENCES	15

ACKNOWLEDGMENTS

A field validation of an earlier version of the HSI model for the hairy woodpecker was conducted under the direction of Ms. L. Jean O'Neil, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS. The field validation was based on habitat evaluation by the following individuals:

Dr. F.J. Alsop, III, East Tennessee State University, Johnson City

Dr. C.E. Bock, University of Colorado, Boulder

Dr. R.N. Conner, U.S. Forest Service, Nacogdoches, TX

Dr. J.A. Jackson, Box Z, Mississippi State, MS

Dr. F.C. James, Florida State University, Tallahassee

Dr. B.J. Schardien Jackson, Mississippi State, MS

Mr. J. Teaford and Dr. T. Roberts, Waterways Experiment Station, and Dr. J. Wakeley, Pennsylvania State University, assisted in the study design, data collection, data analysis, and model modification. The field validation resulted in several improvements in the model. The efforts of all of those involved in the field validation are very much appreciated.

Earlier drafts of the model were reviewed by Dr. R.N. Conner and Dr. C.E. Bock. Their review comments led to significant improvements in the model and are appreciated.

Word processing of this document was provided by C. Gulzow, D. Ibarra, P. Gillis, and E. Barstow. The cover was illustrated by J. Shoemaker.

HAIRY WOODPECKER (*Picoides villosus*)

HABITAT USE INFORMATION

General

The hairy woodpecker (*Picoides villosus*) breeds and winters throughout most of North America (American Ornithologists' Union 1983). The species is a primary cavity nester in "deciduous or coniferous forest, well-wooded towns and parks, and open situations with scattered trees ..." (American Ornithologists' Union 1983:391).

Food

Animal matter, such as beetle larvae (Coleoptera), ants (Hymenoptera), caterpillars (Lepidoptera), and adult beetles, accounted for 78% of the hairy woodpecker's annual diet, based on 382 stomachs collected throughout North America (Beal 1911). The diet is supplemented by fruit and mast (Beal 1911; Hardin and Evans 1977). Hairy woodpeckers forage extensively for seeds in winter (Jackman 1975); in Colorado, they foraged extensively during the non-reproductive season on the seeds of ponderosa pine (*Pinus ponderosa*) (Stallcup 1966). Hairy woodpeckers may concentrate in areas of insect outbreaks in response to the increased food source (Koplin 1967; Massey and Wygant 1973). The hairy woodpecker was considered to be a primary predator of the Southern pine beetle (*Dendroctonus frontalis*) in east Texas (Kroll and Fleet 1979).

Hairy woodpeckers are considered opportunistic foragers (Raphael and White 1984); they forage on a variety of substrates, including tree trunks, stumps, exposed roots (Lawrence 1966), snags, downed logs, the ground (Mannan et al. 1980), and logging debris in recent clearcuts (Conner and Crawford 1974). In California, hairy woodpeckers foraged on snags 51% of the time and on live trees 47% of the time (Raphael and White 1984). During winter, hairy woodpeckers in Virginia foraged most often on dead trees or dead parts of live trees (Conner 1980). Hairy woodpeckers in New York exhibited a sexual difference in the selection of winter foraging sites; males foraged on dead trees significantly more often than females, and females foraged significantly more often on live trees (Kisiel 1972). Both sexes used a variety of tree species for foraging sites. A variety of tree species was also used for foraging by hairy woodpeckers in Sierra Nevada forests (Raphael and White 1984). Snags used for foraging in Douglas-fir (*Pseudotsuga menziesii*) forests in Oregon averaged 61 cm dbh and ranged from 13 to 173 cm dbh (Mannan 1977). The average foraging height of hairy woodpeckers in Iowa was 8.8±1.55 m, and the average diameter of limbs used for foraging was 6.52±1.04 cm (Gamboa and Brown 1976). Hairy woodpeckers in New York typically foraged on limbs 5 to 10 cm in diameter (Kisiel 1972).

Hairy woodpeckers in southwestern Virginia foraged in "... habitats with relatively dense vegetation near the ground" (Conner 1980:121) in comparison to foraging habitat selected by other species of woodpeckers, especially the downy woodpecker (P. pubescens).

Water

No specific information on water requirements of the hairy woodpecker was found in the literature.

Cover

Hairy woodpeckers inhabit a wide variety of forest cover types. For example, they inhabit Douglas-fir forests (Mannan et al. 1980), ponderosa pine forests (Diem and Zeveloff 1980), pinyon-juniper (Pinus edulis - Juniperus spp.) woodlands (Balda and Masters 1980), eastern deciduous forests (Conner et al. 1975), and riparian communities (Stauffer and Best 1980). Winter population densities of hairy woodpeckers in Illinois were positively correlated with the number of trees >56 cm dbh and with a diversity of genera and species of large trees (Graber et al. 1977). Hairy woodpeckers in Oregon use the shrub/sapling (8 to 15 yr) and second-growth (16 to 40 yr) stages of Douglas-fir forests, but they do not nest in these younger stages (Meslow and Wight 1975). Jackman (1975) stated that hairy woodpeckers inhabit second-growth, partially thinned, and other altered forest types; however, hairy woodpeckers were reported more frequently (95% of 40 breeding bird censuses) in mature undisturbed habitats in the northern hardwoods region than in disturbed and successional habitats (43% of 30 censuses) (Noon et al. 1979).

Hairy woodpeckers use tree cavities for roosting and winter cover, as well as for nesting and rearing young (Thomas et al. 1979), and they will excavate new cavities in the fall to be used for roosting (Jackman 1975).

Reproduction

The hairy woodpecker is a primary cavity nester that is able to adapt to a wide variety of habitats (Kilham 1968). In the Pacific Northwest, hairy woodpeckers require standing dead trees and live trees with rotted heartwood (Jackman 1975). Similarly, hairy woodpeckers in Virginia exhibited a definite preference for trees with heartrot (Conner et al. 1975; Conner et al. 1976). Thomas et al. (1979), however, listed the hairy woodpecker as a species that usually excavates in sound wood. Runde and Capen (1987) found that the amount of sound wood varied widely (based on a visual estimate) in live trees used for nesting by hairy woodpeckers; 11 of 21 nests were in live trees. A possible exception to the apparently general use of live or dead trees for nest sites is that hairy woodpeckers do not nest in Engelmann spruce (Picea engelmannii) forests in the Pacific Northwest (Jackman 1975). Haapanen (1965 cited by Smith 1980:264) found that "of all the woodpeckers found in spruce-fir forests, apparently only the Northern 3-toed Woodpecker [Picoides tridactylus] is capable of making holes in the dense wood of living spruce trees." R.N. Conner (U.S. Forest Service, Nacogdoches, TX; letter dated February 19, 1986) suggests, however, that Engelmann spruce and other North American spruces

are relatively soft-wooded trees (compared to oaks) that can be easily excavated by some species of woodpeckers. He suggests that the lack of use may be due to the absence of heartwood decay or to resin produced by spruce rather than to the density of the spruce wood. Whatever the reason for the observed lack of use, Conner believes that insufficient data exist to categorically classify live spruces as unsuitable for excavation by hairy woodpeckers.

Preferred nesting areas of hairy woodpeckers in east Tennessee were characterized by a large number of trees >23 cm dbh and associated high canopy biomass (Anderson and Shugart 1974). Hairy woodpeckers in Virginia apparently preferred areas with high stem density, but nested in areas with a wide range of basal areas, canopy heights, stem densities, and distances from cleared areas (Conner and Adkisson 1977). In northwestern Washington, hairy woodpecker nests were found in a variety of successional stages, though most were in, or at the edge of, old-growth forests (Zarnowitz and Manuwal 1985). Hairy woodpeckers in Washington are found in open rather than dense stands of timber (Larrison and Sonnenberg 1968), and in California's Sierra Nevada they prefer forests of low to moderate canopy closure (<70%) (Verner 1980). Both understocked and fully stocked stands in Virginia were suitable nesting areas as long as decayed trees were present (Conner et al. 1975). Hairy woodpeckers have even been reported nesting in the grass-forb stage of mixed coniferous forest regeneration by using stumps <1.5 m tall (Verner 1980).

Hairy woodpeckers require trees with a minimum dbh of 25 cm and a minimum height of 4.6 m for nesting (Thomas et al. 1979). Raphael and White (1984:24) found that "...diameter was the tree characteristic most closely correlated with nesting use" for 17 cavity-nesting birds. Conner and Adkisson (1976) found that canopy height had a greater influence on distinguishing between "possible nesting habitat" and "not nesting habitat" than did either basal area or stem density. In Vermont, no significant difference in mean tree height was detected between nest trees and adjacent non-nest trees (Runde and Capen 1987). Diameter at breast height (dbh) and diameter at nest height (dnh) were significantly greater for nest trees than non-nest trees ($\bar{x}$ dbh:27.1±1.3 cm vs. 23.9±0.7 cm, $P<0.05$; $\bar{x}$ dnh:22.4±1.1 cm vs. 13.2±9.6 cm, $P<0.01$). The probable optimum diameter range for hairy woodpecker nest trees is 25 to 35 cm dbh, and the probable optimum height range for nest trees is 6 to 12 m (Evans and Conner 1979). In Douglas-fir forests, however, hairy woodpeckers nest in older second-growth (41 to 120 yr) and mature (120+ yr) forests (Meslow and Wight 1975); these age classes are presumably taller than the optimum range suggested by Evans and Conner (1979). The average height of eight trees used for nesting in a Colorado aspen forest was 18 m, and ranged from about 11 to 21.3 m (Scott et al. 1980). Ten trees used for nesting in Virginia averaged 13.0 m tall and ranged from 4 to 26.5 m (Conner et al. 1975). The diameter of the tree at the cavity level in these 10 trees averaged 25.2 cm and ranged from 20 to 46 cm. In California, 19 nest trees averaged 13.7 m tall with an average diameter at the cavity level of 36.3±2.09 cm (Raphael and White 1984). Table 1 summarizes tree condition, nest heights, and nest tree diameter from several studies.

Table 1. Characteristics of nest sites selected by hairy woodpeckers in several study areas.

Source	Number of nests (n)	Tree condition Dead	Tree condition Live	Average nest height (range)	Average nest tree dbh (range)
Lawrence (1966) (NH)	11 (n=7 for dbh)	1	10	10.5 m (4.5-14 m) 34.9 ft (15-45 ft)	28 cm (25.4-34.8 cm) 11.1 inches (10-13.7 inches)
Conner et al. (1975) (VA)	10	5	5[a]	8.8 m (2.4-19.8 m) 28.9 ft (7.9-65 ft)	40.6 cm (20-64 cm) 16 inches (7.9-25.2 inches)
Jackman (1975) (OR)	33	?	?	7.6 m (5-10 m) 24.9 ft (16.4-32.8 ft)	?
Graber et al. (1977) (IL)	17	6	11[b]	4.6-10.7 m 15-35 ft	?
Mannan (1977) (OR)	7	?	?	18.2 m (7.9-41.8 m) 59.4 ft (25.9-137.1 ft)	92 cm (48-172 cm) 36.2 inches (18.9-67.8 inches)
Scott et al. (1980) (CO)	8	2	6	10 m (6.7-15.2 m) 33 ft (22-50 ft)	38 cm (25.4-58.4 cm) 15 inches (10-23 inches)
Raphael and White (1984) (CA)	19	16	3[c]	4.9±0.69 m 16.1±2.26 ft	43.8 cm 17.2 inches
Zarnowitz and Manuwal (1985) (WA)	16	16[d]	-	13±12 m 42.6±39.4 ft	41±13 cm 16.1±5.1 inches
Runde and Capen (1987) (VT)	21	10	11[e]	17.5±1.2 m 57.4±3.9 ft	27.1±1.3 cm 10.7±0.5 inches

[a]Four of the five nests in live trees were located in dead portions of the trees; the fifth was located in a totally live oak tree with a decayed heartwood (Conner, unpubl.).

[b]About one-half of these nests were located in dead portions of the trees.

[c]Located in dead portions of live trees.

[d]All nests located in broken-top trees.

[e]All 11 cavities were drilled through live wood.

Hairy woodpeckers will excavate in both hard and soft snags (Evans and Conner 1979); however, hairy woodpecker breeding densities were significantly positively correlated ($P \leq 0.01$) with soft snags in Iowa riparian forests (Stauffer and Best 1980). The hairy woodpecker was categorized as a soft snag excavator in Sierra Nevada forests (Raphael and White 1984). Evans and Conner (1979) estimated that 200 snags were necessary in order to support the maximum population of hairy woodpeckers on 40 ha of forest. Their estimate was based on a minimum annual need of four cavities per pair, and an assumption that only 10% of the available snags would be suitable for use. Snag density requirements decreased in direct proportion to the percentage of maximum population desired; e.g., 160 snags are required to support 80% of the maximum population, and 100 snags would support 50% of the maximum population. A similar estimate for the Blue Mountains of Oregon and Washington was that 180 snags/40 ha are necessary to support maximum populations of hairy woodpeckers (Thomas et al. 1979). Raphael and White (1984) distinguished between hard and soft snags in estimating the density of snags required to support the maximum density of hairy woodpeckers. They assumed a maximum density of 16 pairs/40 ha, an annual rate of excavation of 4 cavities/pair, and a reserve of 3 suitable cavities per pair to arrive at an estimate of 192 suitable snags/40 ha to support the maximum density. They further estimated that 4 hard snags are required to produce 1 soft snag, resulting in an estimate of 768 "hard snag equivalents" (Raphael and White 1984:56) per 40 ha. Although low numbers of snags can, in theory, support low-density woodpecker populations, enough snags to support 40% of the maximum population was assumed to be the minimum that will support a self-sustaining population of hairy woodpeckers in the Pacific Northwest (Bull 1978).

Interspersion and Composition

Territory size in a mature bottomland forest in Illinois averaged 1.1 ha and ranged from 0.6 to 1.5 ha (Calef 1953 cited by Graber et al. 1977). Reported territory size of hairy woodpeckers in the Blue Mountains of Washington and Oregon averaged 2.4 to 3.6 ha (Thomas et al. 1979). Evans and Conner (1979), however, reported an average territory size of 8 ha based on available literature, whereas territories reported for two hairy woodpeckers in Kansas were 9 and 15 ha (Fitch 1958). Home range and territory size are strongly influenced by habitat quality and, therefore, can be quite variable (Conner, unpubl.).

In a study of bird use of various sized forested habitats in New Jersey, hairy woodpeckers did not occur in areas of <2 ha (Galli et al. 1976). A minimum width of riparian forest necessary to support breeding populations of hairy woodpeckers in Iowa was 40 m (Stauffer and Best 1980). Robbins (1979) compared frequency of occurrence of hairy woodpeckers at Breeding Bird Survey stops in Maryland to the amount of contiguous forested area. The greatest decrease in frequency of occurrence was recorded at 4 ha of contiguous forested habitat, and Robbins (1979) proposed this value as a preliminary estimate of the minimum area necessary to support a viable breeding population of hairy woodpeckers. Conner (unpubl.), however, believes that 4 ha may represent the minimal area that hairy woodpeckers will use, but that such a small area could not support a viable breeding population, which he considers to be a minimum

of 250 pairs. He suggested a minimum habitat area of 12 ha to support several breeding pairs of hairy woodpeckers (R.N. Conner, U.S. Forest Service, Nacogdoches, TX; letter dated December 1, 1981).

Although the hairy woodpecker is considered a resident species throughout its range, altitudinal migrations between mountainous areas and lower elevations do occur (Bailey and Niedrach 1965).

Special Considerations

The hairy woodpecker has been classed as a "tolerant species" to habitat alteration in Iowa (Stauffer and Best 1980), but also has been suggested as a sensitive environmental indicator of the ponderosa pine community (Diem and Zeveloff 1980).

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. This model was developed for application within forested habitat throughout the entire range of the hairy woodpecker. Use of the model differs, however, between forests in the eastern United States and the western United States. The differences in application are described in the model.

Season. This model was developed to evaluate the year-round habitat of the hairy woodpecker.

Cover types. This model was developed to evaluate habitat in the following forested cover types: Deciduous Forest (DF), Evergreen Forest (EF), Deciduous Forested Wetland (DFW), and Evergreen Forested Wetland (EFW) (terminology follows U.S. Fish and Wildlife Service 1981).

Minimum habitat area. A minimum of 4 ha of forested habitat has been estimated to be necessary to support a viable breeding population of hairy woodpeckers (Robbins 1979), although Conner (unpubl.) believes that such a small area may represent the minimum needed to support one pair rather than a viable breeding population. Conner (unpubl.) suggested 12 ha as a reasonable estimate of the area needed to support several pairs of hairy woodpeckers. Additionally, forested riparian zones should be at least 40 m wide to be considered as potential breeding habitat for hairy woodpeckers (Stauffer and Best 1980).

Verification level. An earlier draft of the HSI model for the hairy woodpecker was used in a field evaluation of model outputs compared to expert opinion (O'Neil et al. 1988). The following species experts participated in the field evaluation:

Dr. F.J. Alsop, III, East Tennessee State University, Johnson City

Dr. C.E. Bock, University of Colorado, Boulder

Dr. R.N. Conner, U.S. Forest Service, Nacogdoches, TX

Dr. J.A. Jackson, Box Z, Mississippi State, MS

Dr. F.C. James, Florida State University, Tallahassee

Dr. B.J. Schardien Jackson, Mississippi State, MS

Initial results indicated that outputs from the earlier model were poorly correlated ($r=0.07$, $P>0.50$) with habitat ratings by experts for 40 sites in eastern Tennessee (O'Neil et al. 1988). Important habitat criteria identified by the experts were used to modify the model in an attempt to more closely mimic the procedures used by experts to rate habitats. The major changes to the model as a result of the field evaluation were (1) optimum suitability for the average diameter of overstory trees was changed from 25 to 38 cm; (2) snags were assigned greater importance than live trees for nesting; (3) the variable "percent canopy cover of pines" was added to reflect a strong negative correlation ($r=-0.91$, $P<0.001$) between this variable and habitat ratings by species authorities; (4) the mathematical function used to calculate the cover suitability index was changed from a geometric mean to a multiplicative function; and (5) the suitability relationship for tree canopy closure was changed from a preference for moderate canopy closure to a preference for dense forest canopy. Correlation of outputs from the modified model to habitat ratings by species authorities improved considerably ($r=0.82$, $P<0.001$) (O'Neil et al. 1988).

All of the changes to the model as a result of the field evaluation were based on input from species experts and reflect hairy woodpecker ecology in forests in the eastern United States. The variable "percent canopy cover of pines" is not recommended as an appropriate variable in western forests; use of the model in western vs. eastern forests is described below. The current model is the direct result of the field evaluation; it has not been field tested.

Model Description

Overview. The hairy woodpecker can satisfy all of its habitat requirements within any one of the forested cover types listed above. Reproductive and cover needs are evaluated in this model. Although sufficient food is an obvious life requisite of the hairy woodpecker, I assume in this model that food will never be more limiting than cover and reproductive requirements and that water is not a limiting factor.

The following sections identify important habitat variables, describe suitability levels of the variables, and describe the relationships between variables.

Reproduction component. The hairy woodpecker is able to adapt to a variety of habitats, but suitable reproductive habitats must (1) be dominated by trees of sufficient size and decay for nesting, (2) have adequate snag densities, or (3) have some combination of the two.

The number of snags ≥25.4 cm dbh necessary to support maximum densities of hairy woodpeckers has been estimated to range from 180/40 ha (Thomas et al. 1979) to 200/40 ha (Evans and Conner 1979), or 4.5 to 5 snags/ha; a snag density of 5/ha is assumed to represent optimal conditions for reproduction (Figure 1a). This estimate refers specifically to nesting and roosting requirements and may not adequately satisfy foraging needs (Conner, unpubl.). Potential population density is assumed to decrease proportionally with a decrease in snag density. Although I assume in this model that low snag densities will support low woodpecker densities, Bull (1978) assumed that snag densities <40% of those needed for maximum population density would not support a self-sustaining population.

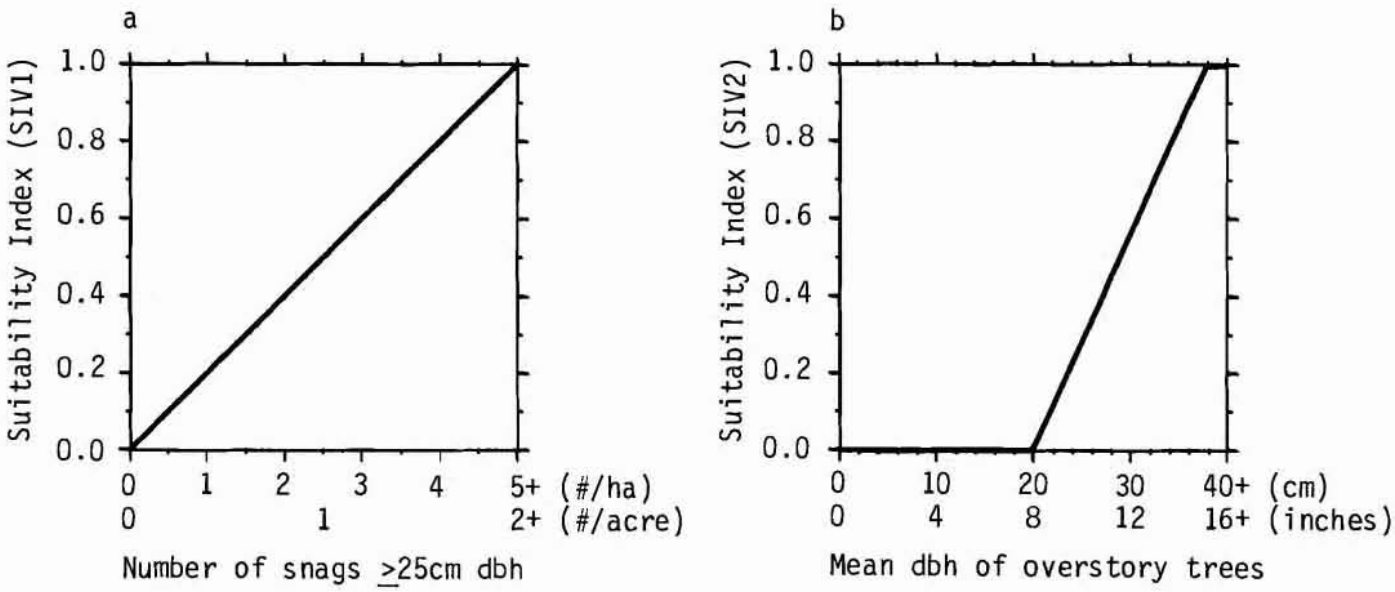

Figure 1. Relationships between variables used to evaluate reproductive habitat for the hairy woodpecker and suitability levels for the variables.

Hairy woodpeckers can excavate cavities in live trees provided that heartrot is present, and thus may inhabit a forested area even in the absence of snags. Runde and Capen (1987) believed that trees >30 cm dbh would be most useful to hairy woodpeckers, downy woodpeckers, and yellow-bellied sapsuckers (Syphrapicus varius). For this model, I assume that if the average dbh of overstory trees is ≥38 cm, then trees will be of optimum size for nesting. I assume that an adequate number of available (i.e., with heartrot) live trees will be present if the average dbh of overstory trees is ≥38 cm. There is little evidence correlating tree diameter and presence of heartrot, but the alternative is to physically examine trees for heartrot; this level of detail is presumed to be too great for the typical application of this model. Use of the average dbh of overstory trees does not consider the absolute number of available live trees. I assume that if an area meets the minimum requirements to be classified as a forest and is >4 ha, then the total number of trees available for potential nesting will be optimal. Assuming that adequate numbers of trees are present, the size and condition of the trees will determine whether the nesting potential will be low or high. The minimum reported dbh of a tree used for nesting by hairy woodpeckers is 20.1 cm (Conner et al. 1975). Thus, I assume that optimal conditions for this variable exist when the average dbh of overstory trees is ≥38 cm, and that conditions are unsuitable when the average dbh of overstory trees is ≤20 cm (Figure 1b). The values defining optimum and suitable levels of this variable are based on results of the field test mentioned earlier.

Overall nesting suitability is a function of the availability of snags or live trees. In the field test, experts consistently rated habitats without snags lower than habitats with snags (O'Neil et al. 1988), presumably because hairy woodpeckers cannot excavate in undecayed trees and prefer to forage on dead snags (Conner, unpubl.). Habitat suitability ratings in habitats without snags that were otherwise suitable were generally between 0.7 and 0.8 (on a 0-1 scale). I assume, therefore, that habitats without snags (i.e., all potential nest sites are in live trees) will have a maximum suitability rating of 0.75. An overall suitability index for nesting (SIN), based on the relationships described above, can be determined with Equation 1.

$$SIN = SIV1 + (0.75 \times SIV2) \qquad (1)$$

[Note: If the value resulting from Equation 1 exceeds 1.0, it should be set to 1.0.]

Cover component. Besides having sufficient potential nest sites, at least three other habitat factors affect the overall suitability of a habitat for hairy woodpeckers. These three factors are the seral stage of a forest stand, the degree of canopy cover of the forest, and the proportion of pines in the canopy. These variables are assumed to influence food availability, foraging, nesting suitability, and cover, but are aggregated into a cover component in this model. Because these factors affect overall habitat suitability, they will be used in this model as modifiers of the reproductive value.

A measure of the seral stage of a forest is the average diameter of the overstory trees. Hairy woodpeckers may inhabit young forests, but at lower densities than in older forests. Because they do inhabit forests in a variety of seral stages, however, this habitat variable should not be strictly limiting. I assume in this model that the optimal seral stage exists when the average dbh of overstory trees is >25 cm (Figure 2a). When the average dbh of overstory trees is <15 cm, suitability is assumed to be one-half of optimum, i.e., a suitability index of 0.5.

The literature suggests that hairy woodpeckers apparently prefer forests of moderate canopy cover. Habitat ratings by species experts in the field test, however, tended to be higher in forest stands with a dense canopy, except that closed canopy stands were generally rated lower than stands with <100% canopy cover (O'Neil et al. 1988). I assume that optimal conditions for this variable occur at 85% to 90% (Figure 2b) with complete canopy cover representing less than optimal habitat. I further assume that canopy cover <15% will provide unsuitable habitat conditions. Since the definition of a forest is a cover type with at least 25% tree canopy cover, any forest will have canopy conditions of some positive suitability level for hairy woodpeckers.

Hairy woodpeckers inhabit a variety of deciduous, coniferous, and mixed deciduous-coniferous habitats. Habitat ratings by experts were negatively correlated ($r=-0.91$, $P<0.001$) with the percent canopy closure of pines; sites completely dominated by pines received relatively low habitat ratings (O'Neil et al. 1988). I assume in this model that an increase in the canopy cover of pines in a stand will generally reflect a decrease in habitat suitability for the hairy woodpecker, although a small amount of pines (≤10% canopy cover) is assumed to contribute to the diversity of cover and prey (Figure 2c). Sites completely dominated by pines are assumed to have a suitability index for this variable of 0.2. The apparent influence of pines on hairy woodpecker habitat suitability described above probably does not apply in western coniferous forests (C.E. Bock, Environmental, Population and Organismic Biology, University of Colorado, Boulder; letter dated February 24, 1986). I recommend that the variable "percent canopy cover of pines" be deleted from the model for application in western coniferous forests. It is unclear whether a similar negative relationship exists between other species of conifers in eastern forests and perceived habitat suitability for the hairy woodpecker.

Results from the field test of the earlier model indicated that the product of the suitability indices (Equation 2) for the cover component variables most closely reflected habitat ratings by species experts (O'Neil et al. 1988).

$$SIC = SIV3 \times SIV4 \times SIV5 \qquad (2)$$

As long as an area is classified as a forested type, all of the variables in Equation 2 will be greater than zero, and the index value for the cover component will likewise be greater than zero.

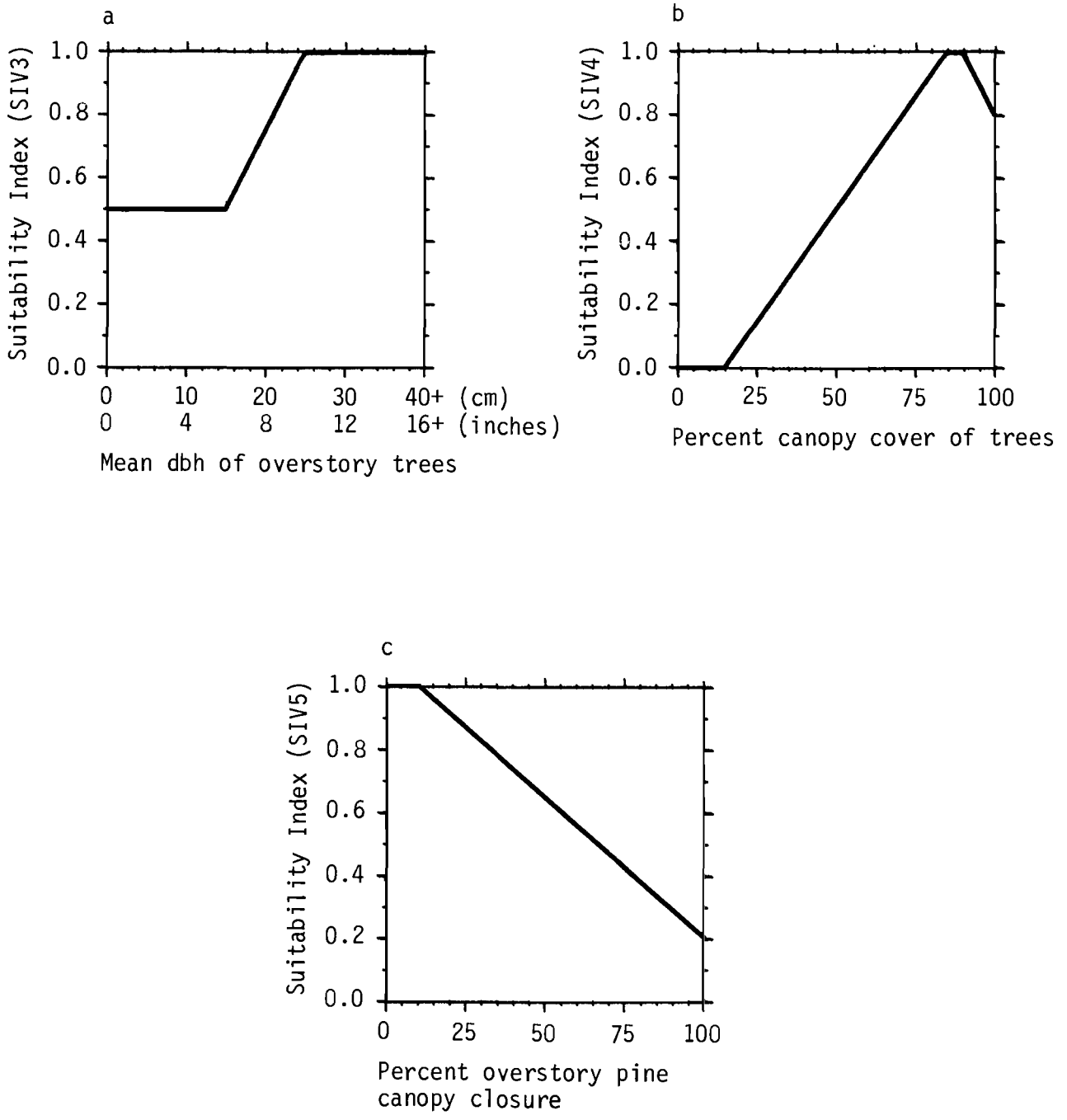

Figure 2. Relationships between variables used to evaluate cover for the hairy woodpecker and suitability levels for the variables.

HSI determination. The suitability index for the cover component is assumed to directly modify the suitability index for the reproduction component (Equation 3) to yield an overall HSI value for the hairy woodpecker in the habitat being evaluated. At optimal cover component conditions (i.e., SIC=1.0), the reproduction component will determine the habitat suitability index. If cover conditions are anything less than optimum, then the reproduction value will be reduced based on the quality of the cover conditions.

$$HSI = SIN \times SIC, \text{ or}$$

$$HSI = [SIV1 + (0.75 \times SIV2)] \times (SIV3 \times SIV4 \times SIV5) \quad (3)$$

[Note: In instances where SIN >1.0, it should be set equal to 1.0 prior to using Equation 3.]

Application of the Model

Summary of model variables. Several habitat variables are used in this model to evaluate habitat suitability for the hairy woodpecker. The relationships between habitat variables, life requisites, cover types, and an HSI are summarized in Figure 3. The definitions and suggested measurement techniques (Hays et al. 1981) for the variables used in this model are listed in Figure 4.

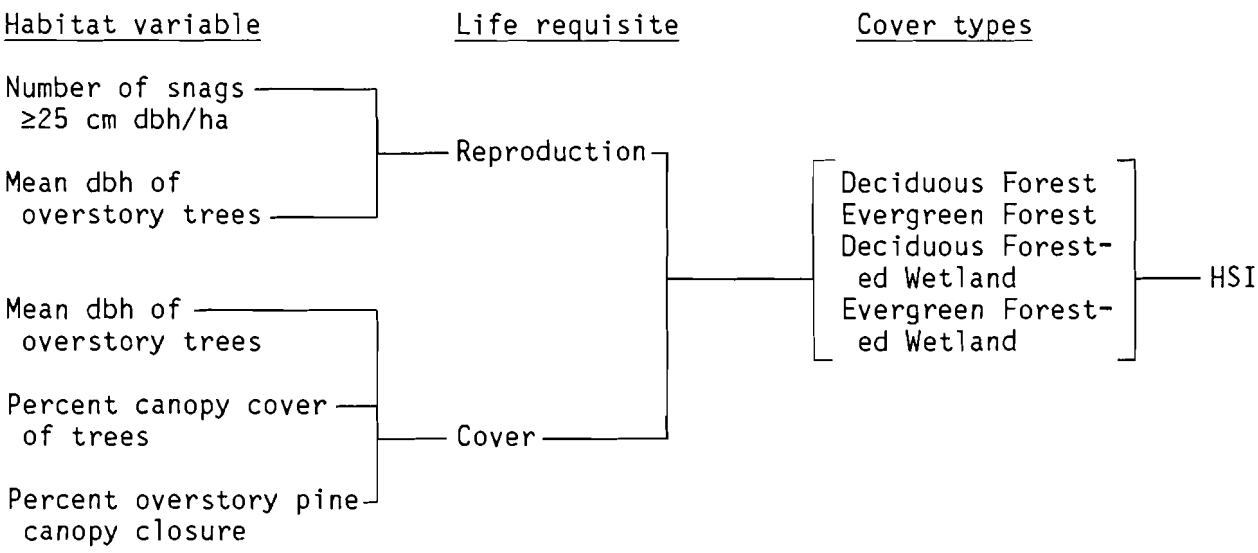

Figure 3. Relationships of habitat variables, life requisites, and cover types to the HSI for the hairy woodpecker.

Variable (definition)	Cover types	Suggested technique
Number of snags ≥25 cm dbh per ha [actual or estimated number of standing dead trees ≥25 cm dbh and ≥1.8 m tall. Trees in which ≥50% of the branches have fallen, or are present but no longer bear foliage, are to be considered snags].	DF,EF,DFW, EFW	Quadrat, remote sensing
Mean dbh of overstory trees [the mean diameter at breast height (1.4 m) above the ground of those trees that are ≥80% of the height of the tallest tree in the stand].	DF,EF,DFW, EFW	Diameter tape
Percent canopy cover of trees [the percent of the ground surface that is shaded by a vertical projection of all woody vegetation >6.0 m tall].	DF,EF,DFW, EFW	Line intercept, remote sensing
Percent overstory pine canopy closure [the percent of the ground surface that is shaded by a vertical projection of all pines (*Pinus* spp.) >6.0 m tall and ≥80% of the height of the tallest tree in the stand; recommended for use in eastern U.S. forests only (see text for explanation)].	DF,EF,DFW, EFW	Line intercept, remote sensing

Figure 4. Definitions of variables and suggested measuring techniques.

Model assumptions. A number of assumptions were made in the development of this HSI model.

1. The criteria identified for evaluation of hairy woodpecker habitat are generally assumed to be appropriate throughout the range of the species. Many of the variables and variable relationships identified in the model resulted from a field test of an earlier HSI model in eastern Tennessee. As a result, the model is probably best suited for application in the southeastern United States. No information is available to indicate the model's applicability to other parts of the United States, except there is adequate information that the presumed negative influence of pines does not apply to western U.S. forests (see number 7 below).

2. Nest sites can be provided by a combination of snags and live trees, but live trees in the absence of snags cannot provide optimal nesting habitat.

3. A measure of the average diameter at breast height of overstory trees is assumed to be an adequate estimator of the suitability of live trees for nesting. An adequate number of trees in suitable condition (i.e., with decayed heartwood) is assumed to be present as long as the cover type is classified as a forest (i.e., has ≥25% canopy cover) and tree diameter is suitable.

4. All tree species are assumed to be available for excavation by hairy woodpeckers. It is possible that some species may not typically have decayed heartwood and, therefore, will be unsuitable for excavation. It is also possible that some tree species will be unsuitable for excavation because of resins or the density of the wood. Little definitive evidence is available, however, to determine whether some tree species are absolutely unsuitable for excavation by hairy woodpeckers.

5. Hairy woodpeckers can inhabit a variety of forested habitats, but potential nesting in live trees will only be provided by older forest stands with large trees.

6. Hairy woodpeckers prefer forest stands with a dense canopy. This assumption may be valid in the southeastern United States but may be invalid in the western United States, where the forest canopy is generally less dense than in the east. The relationships described for percent canopy cover of trees and habitat suitability (Figure 2b) may need to be redefined for use in western forest habitat if the standard of comparison in such applications is intended to be the best regional habitat. Use of the model without modification will yield outputs based on a standard of comparison developed in the southeastern United States.

7. The presence of pines above a minimal level (10%) is considered to be a negative factor in habitat suitability for the hairy woodpecker in this model (Figure 2c). Pine and other coniferous forests in the western United States, however, are regularly used by hairy woodpeckers. I recommend that this variable be eliminated for application in western coniferous forests.

8. The hairy woodpecker breeds and winters throughout most of North America. I assume in this model that the year-round suitability of a habitat is a function of the habitat suitability during both the reproductive and nonreproductive seasons. Model users who wish to evaluate either of the seasons rather than both can simply use the appropriate portion of this model. Users should be aware that model outputs in such instances will refer only to a portion of the year-round needs of the hairy woodpecker.

SOURCES OF OTHER MODELS

Conner and Adkisson (1976) developed a model to distinguish between "possible nesing habitat" and "not nesting habitat" for the hairy woodpecker in oak-hickory forests of southwestern Virginia. Three variables were included in the model: basal area (m^2/ha), canopy height to crown cover (m), and stem density (number/ha). The model includes coefficients for the three variables, an aggregation function, and a linear decision scale. The model was applied to two groups, the first consisting of stands containing hairy woodpecker nests, and the second consisting of six random plots in each of five habitat types; results of the analysis were significant (P=0.02).

REFERENCES

American Ornithologists' Union. 1983. Check-list of North American birds. 6th ed. American Ornithologists' Union. Washington, DC. 877 pp.

Anderson, S.H., and H.H. Shugart, Jr. 1974. Habitat selection of breeding birds in an east Tennessee deciduous forest. Ecology 55(4):828-837.

Bailey, A.M., and R.J. Niedrach. 1965. Birds of Colorado. 2 Vols. Denver Mus. Nat. Hist., Denver, CO. 895 pp.

Balda, R.P., and N. Masters. 1980. Avian communities in the pinyon-juniper woodland. Pages 146-169 in R.M. DeGraaf and N.G. Tilghman, compilers. Management of western forests and grasslands for nongame birds. U.S. For. Serv. Gen. Tech. Rep. INT-86.

Beal, F.E.L. 1911. Food of the woodpeckers of the United States. U.S. Dept. Agric. Biol. Surv. Bull. 37. 64 pp.

Bull, E.L. 1978. Specialized habitat requirements of birds: snag management, old growth, and riparian habitat. Pages 74-82 in R.M. DeGraaf, tech. coord. Proceedings of the workshop on nongame bird habitat management in the coniferous forests of the western United States. U.S. For. Serv. Gen. Tech. Rep. PNW-64.

Calef, R.T. 1953. Ecological analysis of the flora and vertebrate fauna of Funks Forest National Area, McClean Co., Ill. M.S. Thesis. University of Illinois. 85 pp. [Cited by Graber et al. (1977).]

Conner, R.N. 1980. Foraging habitats of woodpeckers in southwestern Virginia. J. Field Ornith. 51(2):119-127.

Conner, R.N., and C.S. Adkisson. 1976. Discriminant function analysis: a possible aid in determining the impact of forest management on woodpecker nesting habitat. Forest Sci. 22(2):122-127.

Conner, R.N., and C.S. Adkisson. 1977. Principal component analysis of woodpecker nesting habitat. Wilson Bull. 89(1):122-129.

Conner, R.N., and H.S. Crawford. 1974. Woodpecker foraging in Appalachian clearcuts. J. For. 72:564-566.

Conner, R.N., 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(1):144-150.

Conner, R.N., O.K. Miller, Jr., and C.S. Adkisson. 1976. Woodpecker dependence on trees infected by fungal heart rots. Wilson Bull. 88(4):575-581.

Diem, K.L., and S.I. Zeveloff. 1980. Ponderosa pine bird communities. Pages 170-197 in R.M. DeGraaf and N.G. Tilghman, compilers. Management of western forests and grasslands for nongame birds. U.S. For. Serv. Gen. Tech. Rep. INT-86.

Evans, K.E., and R.N. Conner. 1979. Snag management. Pages 214-225 in R.M. DeGraaf and K.E. Evans, compilers. Management of northcentral and northeastern forests for nongame birds. U.S. For. Serv. Gen. Tech. Rep. NC-51.

Fitch, H.S. 1958. Home ranges, territories, and seasonal movements of vertebrates of the Natural History Reservation. Univ. Kansas Publ. Mus. Nat. Hist. 11(3):63-326.

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(2):356-364.

Gamboa, G.J., and K.M. Brown. 1976. Comparative foraging behavior of six sympatric woodpecker species. Proc. Iowa Acad. Sci. 82:179-181.

Graber, J.W., R.R. Graber, and E.L. Kirk. 1977. Illinois birds: Picidae. Illinois Nat. Hist. Surv. Biol. Notes 102. 73 pp.

Haapanen, A. 1965. Bird fauna of the Finnish forests in relation to forest succession. I. Ann. Zool. Fenn. 2:154-196. [Cited by Smith (1980).]

Hardin, K.I., and K.E. Evans. 1977. Cavity nesting bird habitat in the oak-hickory forest ... a review. U.S. For. Serv. Gen. Tech. Rep. NC-30. 23 pp.

Hays, R.L., C. Summers, and W. Seitz. 1981. Estimating wildlife habitat variables. U.S. Fish Wildl. Serv. FWS/OBS-81/47. 111 pp.

Jackman, S.M. 1975. Woodpeckers of the Pacific Northwest: their characteristics and their role in the forests. M.S. Thesis. Oregon State University, Corvallis. 147 pp.

Kilham, L. 1968. Reproductive behavior of hairy woodpeckers. II. Nesting and habitat. Wilson Bull. 80(3):286-305.

Kisiel, D.S. 1972. Foraging behavior of Dendrocopus villosus and D. pubescens in eastern New York state. Condor 74(4):393-398.

Koplin, J.R. 1967. Predatory and energetic relations of woodpeckers to the Engelmann spruce beetle. Ph.D. Dissertation. Colorado State University, Ft. Collins. 187 pp.

Kroll, J.C., and R.R. Fleet. 1979. Impact of woodpecker predation on overwintering within-tree populations of the Southern pine beetle (Dendroctonus frontalis). Pages 269-281 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, New York.

Larrison, E.J., and K.G. Sonnenberg. 1968. Washington birds: their location and identification. Seattle Audubon Society, Seattle. 258 pp.

Lawrence, L. DeK. 1966. A comparative life-history study of four species of woodpeckers. Ornithol. Monogr. No. 5, American Ornithologists' Union. 156 pp.

Mannan, R.W. 1977. Use of snags by birds, Douglas-fir region, western Oregon. M.S. Thesis. Oregon State University, Corvallis. 114 pp.

Mannan, R.W., E.C. Meslow, and H.M. Wight. 1980. Use of snags by birds in Douglas-fir forests, western Oregon. J. Wildl. Manage. 44(4):787-797.

Massey, C.L., and N.D. Wygant. 1973. Woodpeckers: most important predators of the spruce beetle. Colorado Field Ornithol. 16:4-8.

Meslow, E.C., and H.M. Wight. 1975. Avifauna and succession in Douglas-fir forests of the Pacific Northwest. Pages 266-271 in D.R. Smith, tech. coord. Management of forest and range habitats for nongame birds. U.S. For. Serv. Gen. Tech. Rep. WO-1.

Noon, B.R., V.P. Bingham, and J.P. Noon. 1979. The effects of changes in habitat on northern hardwood forest bird communities. Pages 33-48 in R.M. DeGraaf and K.E. Evans, compilers. Management of northcentral and northeastern forests for nongame birds. U.S. For. Serv. Gen. Tech. Rep. NC-51.

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):In press.

Raphael, M.G., and M. White. 1984. Use of snags by cavity-nesting birds in the Sierra Nevada. Wildl. Mónogr. 86. 66 pp.

Robbins, C.S. 1979. Effects of forest fragmentation on bird populations. Pages 199-212 in R.M. DeGraaf and K.E. Evans, compilers. Management of northcentral and northeastern forests for nongame birds. U.S. For. Serv. Gen. Tech. Rep. NC-51.

Runde, D.E., and D.E. Capen. 1987. Characteristics of northern hardwood trees used by cavity-nesting birds. J. Wildl. Manage. 51(1):217-223.

Scott, V.E., J.A. Whelan, and P.L. Svoboda. 1980. Cavity-nesting birds and forest management. Pages 311-324 in R.M. DeGraaf and N.G. Tilghman, compilers. Management of western forests and grasslands for nongame birds. U.S. For. Serv. Gen. Tech. Rep. INT-86.

Smith, K.G. 1980. Nongame birds of the Rocky Mountain spruce-fir forests and their management. Pages 258-279 in R.M. DeGraaf and N.G. Tilghman, compilers. Management of western forests and grasslands for nongame birds. U.S. For. Serv. Gen. Tech. Rep. INT-86.

Stallcup, P.L. 1966. Spatio-temporal relationships of nuthatches and woodpeckers in northern Colorado. Ph.D. Dissertation. Colorado State University, Ft. Collins. 111 pp.

Stauffer, D.F., and L.B. Best. 1980. Habitat selection by birds of riparian communities: evaluating effects of habitat alterations. J. Wildl. Manage. 44(1):1-15.

Thomas, J.W., R.G. Anderson, C. Maser, and E.L. Bull. 1979. Snags. Pages 60-77 in J.W. Thomas, tech. ed. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. U.S. For. Serv. Agric. Handb. 553.

U.S. Fish and Wildlife Service. 1981. Standards for the development of Habitat Suitability Index models. 103 ESM. U.S. Fish Wildl. Serv., Div. Ecol. Serv. n.p.

Verner, J. 1980. Bird communities of mixed-conifer forests of the Sierra Nevada. Pages 198-223 in R.M. DeGraaf and N.G. Tilghman, compilers. Management of western forests and grasslands for nongame birds. U.S. For. Serv. Gen. Tech. Rep. INT-86.

Zarnowitz, J.E., and D.A. Manuwal. 1985. The effects of forest management on cavity-nesting birds in northwestern Washington. J. Wildl. Manage. 49(1):255-263.

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. Biological Report 82(10.146)	2.	3. Recipient's Accession No.

4. Title and Subtitle

Habitat Suitability Index Models: Hairy Woodpecker

5. Report Date September 1987

6.

7. Author(s)

P. J. Sousa

8. Performing Organization Rept. No.

9. Performing Organization Name and Address

National Ecology Research Center
U.S. Fish and Wildlife Service
Drake Creekside One Bldg.
2627 Redwing Rd.
Fort Collins, CO 80526-2899

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.

(C)

(G)

12. Sponsoring Organization Name and Address

National Ecology Research Center
Research and Development
Fish and Wildlife Service
Department of the Interior
Washington, DC 20240

13. Type of Report & Period Covered

14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

A review and synthesis of existing information were used to develop a Habitat Suitability Index (HSI) model for the hairy woodpecker (*Picoides villosus*). The model consolidates habitat use information into a framework appropriate for field application, and is scaled to produce an index between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). HSI models are designed to be used with Habitat Evaluation Procedures previously developed by the U.S. Fish and Wildlife Service.

17. Document Analysis a. Descriptors

Birds
Wildlife
Habitability
Mathematical models

b. Identifiers/Open-Ended Terms

Hairy woodpecker
Picoides villosus
Habitat suitability

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Release unlimited	Unclassified	19
	20. Security Class (This Page) Unclassified	22. Price

(See ANSI-Z39.18) See Instructions on Reverse OPTIONAL FORM 272 (4-77) (Formerly NTIS-35) Department of Commerce

☆ U.S. GOVERNMENT PRINTING OFFICE: 1988—574-162/85,052 REGION NO. 8

Take Pride in America

Preserve Our Natural Resources

DEPARTMENT OF THE INTERIOR

U.S. FISH AND WILDLIFE SERVICE

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.