BIOLOGICAL REPORT 82(10.143)
SEPTEMBER 1987

HABITAT SUITABILITY INDEX MODELS: BARRED OWL

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? ________________________________

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____

____

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? ________________________________

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____

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

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

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Model Evaluator or Reviewer ______________________ Date ____________

Agency ____

Address ____

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____

Telephone Number Comm: ______________________ FTS ____________

Biological Report 82(10.143)
September 1987

HABITAT SUITABILITY INDEX MODELS: BARRED OWL

by

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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
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ACKNOWLEDGMENTS

This HSI model was initiated in two modeling workshops hosted by the U.S. Fish and Wildlife Services' Gloucester Point, VA, and Lafayette, LA, Field Offices of the Division of Ecological Services. Participants in the Virginia workshop included: Karen Mayne and Gary Fraser, Division of Ecological Services, Gloucester Point, VA; Deborah Rudis, Susanne Nair, and Charlie Rewa, Division of Ecological Services, Annapolis, MD; Bob Hume and Doug Davis, U.S. Army Corps of Engineers, Norfolk, VA; John Badin, U.S. Army Corps of Engineers, Wilmington, NC; and Charlie Rhodes, U.S. Environmental Protection Agency, Philadelphia, PA. Participants in the Lafayette workshop included the following Division of Ecological Services biologists: Robert Strader, Lafayette, LA; Danny Dunn, Daphne, AL; Robert Willis, Cookeville, TN; and Robert Barkley, Steve Forsythe, and Charles McCabe, Vicksburg, MS. Brian Cade, Patrick Sousa, and the author, U.S. Fish and Wildlife Service, Fort Collins, CO, served as facilitators of the workshops.

Subsequent to the workshops, reviews of the draft model were provided by Robert Barkley, Steve Forsythe, Charles McCabe, Robert Strader, and Robert Willis. The time and contributions of these individuals are sincerely appreciated.

The revised draft was reviewed by Dr. Mark R. Fuller, U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, Laurel, MD; Mr. Tom Hamer, U.S. Forest Service, Sedro Woolley, WA; and Dr. Jerome A. Jackson, Mississippi State University, Mississippi State. The additional information provided, as well as the time and willingness of these individuals to contribute to the improvement and completion of this model, is gratefully acknowledged.

The cover of this document was illustrated by Jennifer Shoemaker. Word processing was provided by Dora Ibarra. Kay Lindgren assisted with literature searches and information acquisition.

BARRED OWL (_Strix varia_)

HABITAT USE INFORMATION

General

The barred owl (_Strix varia_) is widely distributed throughout North America, ranging from the east coast to western Canadian Provinces (American Ornithologists' Union 1983). The species has recently expanded its range into extreme western Canada and the northwest United States (Fyfe 1976; Taylor and Forsman 1976; Boxall and Stepney 1982; Marks et al. 1984). In the midwestern and eastern portions of North America the species is associated primarily with mixed woodland, boreal forest, mixed transitional forest, and deciduous forest (Boxall and Stepney 1982). For successful inhabitation the species requires an expansive forested area that contains large mature and decadent trees that provide cavities suitable for security and reproduction.

Food

The diet of the barred owl is governed by availability of prey. The species is primarily nocturnal (Taylor and Forsman 1976), although diurnal foraging and activity is not uncommon (Caldwell 1972; Fuller 1979). Small mammals are the primary component of the barred owls' diet (Wilson 1938; Earhart and Johnson 1970; Holgersen 1974; Hanebrink et al. 1979). Meadow voles (_Microtus pennsylvanicus_), short-tailed shrews (_Blarina brevicauda_), and white-footed mice (_Peromyscus leucopus_) composed the bulk of the barred owls' prey in Ohio (Dexter 1978). Small mammals accounted for 65.9% of the prey items recorded in Maryland (Devereux and Mosher 1984). Rats, mice (Cricetidae), and shrews (Soricidae) composed 81.5% of the mammalian prey. Meadow and montane voles (_M. montanus_) composed 96.3% of the total winter food of barred owls in Montana (Marks et al. 1984).

Fish, amphibians, reptiles, birds, and invertebrates generally account for a smaller portion of the barred owls' diet (Earhart and Johnson 1970). Birds and arthropods accounted for 14.6% and 19.5%, respectively, of the total number of prey items consumed by barred owls in Maryland (Devereux and Mosher 1984). Investigations in Mississippi, however, suggest that invertebrates, primarily crayfish, exceed small mammals in importance in the barred owls' diet (J.A. Jackson, Department of Biological Sciences, Mississippi State University, Mississippi State; letter dated June 23, 1987).

Water

Information pertaining to dietary water requirements of barred owls was not located in the literature.

Much of the earlier literature pertaining to barred owl ecology (Carter 1925; Errington and McDonald 1937; Bent 1938; Applegate 1975; Soucy 1976) concluded or implied that barred owls prefer to establish nests in close association with water or within forested wetland cover types. More recent and exhaustive investigations tend to disprove the conclusion that the species prefers to nest in close proximity to water. Devereux and Mosher (1984) did not record differences in the distance to water from nest sites and random sample plots in Maryland. Furthermore, radiotelemetry investigations (Nicholls and Warner 1972; Fuller 1979) have shown that barred owls consistently used suitable upland forest cover types more frequently than forested wetlands and lowlands. Devereux and Mosher (1984) concluded that the relationship between barred owls and forested wetland cover types was a result of the vegetation associated with these cover types rather than an attraction for the water itself. Forested wetlands are often inaccessible or too wet for timber harvesting. As a result, these sites often contain remnant stands of mature and old-growth forest. The large size classes and decadent nature of these forests provide ideal cover and nest cavities, thereby attracting and supporting barred owl populations.

Fifty-five percent of barred owl observations in the Pacific Northwest have been reported near a wetland cover type (T. Hamer, U.S. Forest Service, Sedro Woolley, WA; unpubl.). The apparent relationship between barred owls and wetlands may stem from past forest management in the region (Hamer, pers. comm.). In the Pacific Northwest, low elevation forests historically have been those initially subjected to timber harvest and management. Low elevation areas in this region contain a greater abundance and distribution of wetlands than do tracts of higher elevation and steeper topography. Older seral vegetation stages now occur in these areas, resulting in mixed coniferous and deciduous stands that provide suitable barred owl habitat, frequently in relatively close proximity to wetlands.

Cover

The survival of the barred owl depends on the availability of suitable food and forested areas that provide adequate conditions for perching, courtship, and reproduction (Nicholls and Warner 1972; Elody and Sloan 1985). Barred owls appear to prefer older stands, but earlier stages of forest succession will be used if a suitable number of large diameter trees or snags is present (Hamer, pers. comm.). Although barred owls occasionally may be found in small woodlots, they are much more likely to inhabit extensive tracts of forest (Jackson, unpubl.). The barred owl is most frequently associated with densely forested woodlands and deciduous and mixed deciduous/coniferous forests (American Ornithologists' Union 1983); however, barred owls are not restricted to specific floristic associations in their foraging activities (Fuller 1979). Deciduous woodlands, specifically riparian and lowland areas, were the most frequently recorded forest types for barred owl nesting throughout North America (Apfelbaum and Seelbach 1983). Establishment of nests in pure coniferous cover types has not been recorded in the midwest and has been recorded only infrequently elsewhere in North America.

Definite preferences for specific cover types were exhibited by barred owls in Minnesota (Nicholls and Warner 1972). Cover types in order of preference were (1) oak (*Quercus* spp.) woodland, (2) mixed deciduous/coniferous woodland, (3) white cedar (*Thuja occidentalis*) swamps, (4) oak savanna, (5) alder (*Alnus* spp.) swamps, (6) marshes, and (7) old fields. Oak woodland and mixed deciduous/coniferous cover types contained trees that provided perch sites and cavities and cover for prey species. The first four cover types were normally free of dense understory vegetation, that might have facilitated foraging through increased visibility and reduced obstructions to flight. McGarigal and Fraser (1984) also found barred owls in forested cover types that were relatively free of understory vegetation and other obstructions that would impede the owls mobility and foraging success. Nest sites in Maryland were located significantly closer to forest openings than were random sites in cover types with well developed understory vegetation (Devereux and Mosher 1984). Nicholls and Warner (1972) attributed the barred owls' preference for upland woodlands to drier conditions on the forest floor, as compared to wetter lowland sites, and the likelihood that prey were easier to hear and locate under dry conditions. Lower use of white cedar swamps by barred owls was attributed to an absence of suitable nest sites, lower prey availability, and less than ideal hunting conditions (e.g., muffled noise due to wet substrate and dense understory). The relatively open oak savanna cover type received lower use by barred owls. Although prey were believed to be abundant in this cover type, the trees present were smaller in height and diameter than those within the oak and mixed woodlands, resulting in a lack of suitable cavities and decadent trees. The barred owls' low use of alder swamps was attributed to extremely dense tree canopy cover that could inhibit the owls' mobility and foraging success. Suitable cavities and nest trees were absent in this cover type. Marshes and open fields did not contain suitable trees for perch sites or cover. Although prey were abundant in the old field cover type, they were not accessible. No seasonal differences in preference for these cover types, nor major differences in the intensity of cover type use between sexes, were recorded.

Most observations of barred owls in Alberta have been reported in mixed woodland, boreal forest, and montane forest (Boxall and Stepney 1982). The relative absence of barred owl observations in Alberta's aspen (*Populus* spp.) parkland was attributed to the absence of large, mature trees and the consequent lack of suitable cavities. The majority of barred owl observations in British Columbia have occurred in the Columbia Forest Biotic Area in which western hemlock (*Tsuga heterophylla*) and western redcedar (*Thuja plicata*) are the major climax species (Grant 1966).

Establishment of mixed deciduous and coniferous stands subsequent to clearcutting in the Pacific Northwest has enhanced habitat conditions for barred owls (Hamer, pers. comm.). Release of understory and invasion by pioneer species [e.g., alder, vine maple (*Acer circinatum*), and bigleaf maple (*A. macrophyllum*)], combined with the breaking up of large tracts of purely coniferous forest, have provided suitable habitat and may be a key reason behind the barred owls' range expansion in the Pacific Northwest in recent decades. Analysis of four decades of barred owl detections (collected specimens, calls, and visual sightings) in the Pacific Northwest provide the following examples of where the species occurs in this region (Hamer, unpubl.).

Eighty-three percent of observations (n=140) were at sites <1,067 m in elevation (range: sea level to 1,981 m). Although barred owls were observed in a wide variety of stand types, the common characteristic was the presence of large, mature or old-growth trees required for cover and nesting. Sixty-two percent of observations occurred in coniferous associations, 17% in mixed coniferous/deciduous and 6% in deciduous cover types. The remaining observations (15%) were recorded in city/urban and roadside vegetation. Analysis of successional stage showed the following relationship to barred owl observations: old-growth, 53%; mature, 23%; medium-sized sawtimber, 10%; pole-sapling, 12%; and mixed old-growth/pole sapling, 1%. No observations were recorded in scrub/shrub or grass-forb cover types.

Reproduction

Barred owls often nest in interior portions of expansive, mature woodland (Dunstan and Sample 1972; Elody 1983). Primary barred owl reproductive habitat in the southeastern United States was described as forested wetlands and bottomland hardwoods in the Piedmont and Coastal Plain, and wooded stream courses and stands of spruce (*Picea* spp.), fir (*Abies* spp.), or hemlock (*Tsuga* spp.) in mountainous regions (Hamel et al. 1982). Stands composed of sapling to pole-sized trees were described as marginal reproductive habitat in southern mixed mesic hardwoods. Sawtimber-sized trees (≥51 cm dbh) were thought to be indicative of potentially optimum reproductive habitat, as few nests are established in stands of immature trees or in relatively small woodlots. All barred owl nests located in Maryland were situated in stands of old-growth timber (Devereux and Mosher 1982). Within these stands there were significantly more trees >50 cm dbh than in random sites, (45/ha compared to 5/ha in random sites). Old-growth stands in Virginia that were inhabited by barred owls appeared to have lower stem densities and more subcanopy flying space than did younger stands (McGarigal and Fraser 1984). Barred owl reproductive habitat in Washington was described as dense, >80 years-old, second-growth, mixed hardwood-conifer forest (Leder and Walters 1980).

Summarizing nest site data from across North America, Apfelbaum and Seelbach (1983) reported that elm (*Ulmus* spp.) and beech (*Fagus* spp.) were the most frequently used nest trees. Unidentified oaks, hickories (*Carya* spp.), yellow birch (*Betula alleghaniensis*), sycamore (*Platanus occidentalis*), and aspen also were used occasionally for nesting in midwestern North America.

The typical barred owl nest tree is tall, decadent, and has a suitable cavity or nest site ≥7.6 m above the ground (Dunstan and Sample 1972). Nests are most frequently established in cavities in large living or dead trees (Apfelbaum and Seelbach 1983). The majority of nest sites observed in Mississippi have been in cavities in living trees (Jackson, unpubl.). Living trees are believed to provide superior nest sites to those of snags due to the additional cover provided by foliage. Cavities in large trees composed 80.8% of the nest sites located in Michigan (Elody 1983). Nests also have been recorded in the tops of broken snags (LeDuc 1970; Devereux and Mosher 1982) and in unoccupied hawk nests (Eckert 1974; Apfelbaum and Seelbach 1983). Devereux and Mosher (1984) postulated that barred owls fledged from hawk nests may become inprinted on this type of nest and may subsequently nest in suitable abandoned nests regardless of cavity availability.

Recommended dbh for cavity trees suitable for barred owl nesting is ≥50.8 cm (Evans and Conner 1979; Hamel et al. 1982). The average height of nests in Michigan was 9.1 m (range: 1.5 to 30.4 m) (Apfelbaum and Seelbach 1983). Cavities used for nesting in Maryland averaged 3 m higher than randomly sampled cavities (Devereux and Mosher 1984). Cavities >9 m above the ground may be preferred. Carmichael and Guynn (1983) estimated that the minimum number of snags/ha required to support various population levels of barred owls were as follows: 100% of potential population = 0.1 snag/ha, 60% of potential population = 0.05 snag/ha, and 20% of potential population = 0.02 snag/ha.

Interspersion and Composition

Barred owls frequently traveled between separate woodlots within their home range in Minnesota (Nicholls and Warner 1972). Fuller (1979) reported that barred owls frequently occurred along field/forest edge and that the species will forage within several cover types if perch sites are available. Cover types that typically receive little use by barred owls (e.g., marshes, old fields) might be important in that they generally support high production of prey species and can serve as source areas for prey immigration into cover types more heavily used by barred owls.

The average home range for barred owls in Minnesota was 228.6 ha (range = 86.1 to 369.0 ha) (Nicholls and Warner 1972). Differences between home range sizes of barred owls appeared to be associated with breeding status and season or age (Fuller 1979). The average cumulative home range, based on minimum area, for breeding females in Fuller's Minnesota study was 507.8 ha. Average home range size for barred owls in Michigan's upper peninsula was 282 ha (Elody and Sloan 1985). The area used decreased to an average of 118 ha during the summer months.

Special Considerations

Barred owls will successfully use artifical structures for nesting (Johnson 1980). Johnson and Follen (1984) provided guidance for the construction of nest boxes suitable for barred owls. Devereux and Mosher (1984) concluded that intensive forest management, where stands are harvested at <80 years, may cause a decline in the number of nesting barred owls due to the loss of suitable cover (i.e., old-growth) and nest sites. Retention of a few mature trees might maintain the owls' cover requirements. The preservation of older maple and yellow birch may prevent declines in barred owl populations in intensively managed forest stands in Michigan (Apfelbaum and Seelbach 1983).

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. This HSI model has been developed for application throughout the barred owls' range (Figure 1).

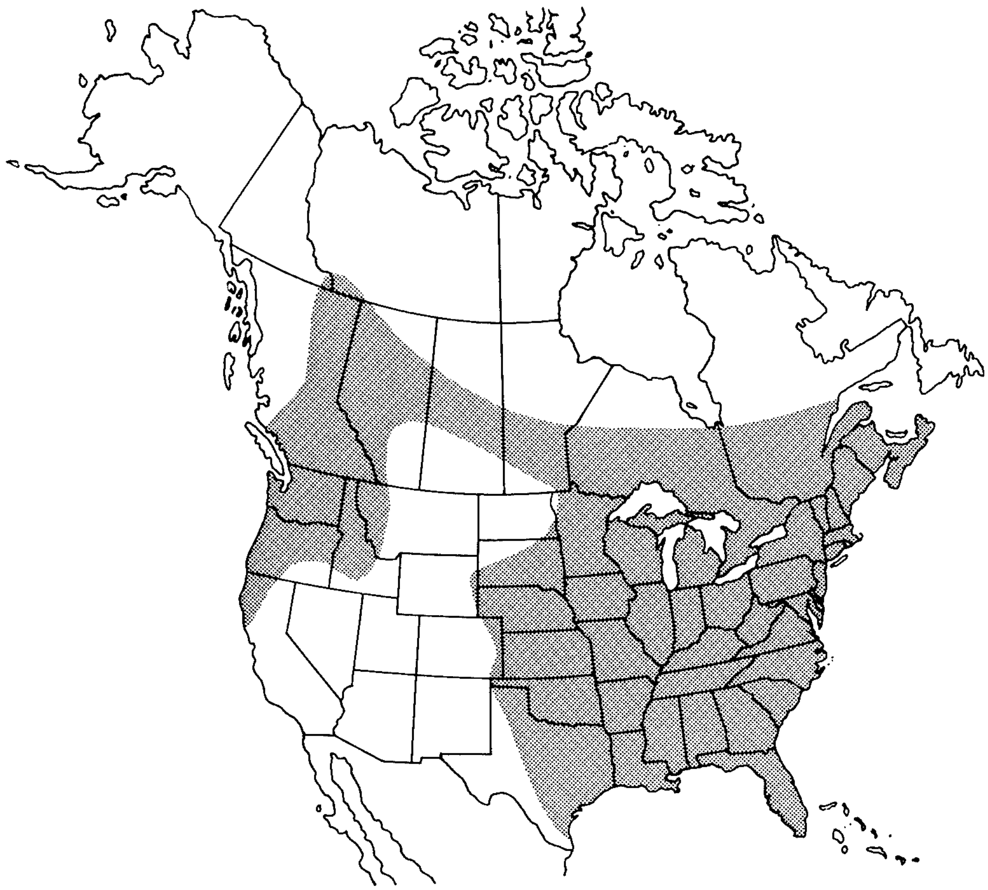

Figure 1. Approximate distribution of the barred owl [modified from Eckert (1974) and Hamer (unpubl.)].

This model has been formulated chiefly from data and information obtained in the midwestern and eastern portions of the barred owls' range. The majority of these investigations have been conducted in deciduous and mixed coniferous/deciduous forests. The size range used to define trees of suitable size to contain cavities for barred owl use has been extrapolated from these data. Because barred owls inhabit a wide variety of forest associations throughout North America, users of this model should modify the tree size constraints presented in the model to more accurately reflect mature tree size and cavity occurrence according to regional or habitat specific data.

Season. This model has been developed to evaluate reproductive habitat quality for the barred owl.

Cover types. This model was developed for application in the following cover types (terminology follows that of U.S. Fish and Wildlife Service 1981): Deciduous Forest (DF), Evergreen Forest (EF), and Palustrine, Forested Wetlands (PFO) (wetland terminology follows that of Cowardin et al. 1979).

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous habitat required before an area will be occupied by a species. Specific information on the minimum habitat area required by the barred owl was not located in the literature. The species is restricted to forested cover types for shelter and reproductive purposes; however, many cover types are used for foraging if suitable perch sites are available. Therefore, minimum area of contiguous habitat (e.g., home range) does not directly relate to minimum size of forested habitat required for nest establishment. The literature alludes to the barred owls' preference for expansive woodlands for reproductive habitat. Barred owls probably do not do well in areas with only tens of hectares of forest, whereas they probably thrive in forests of hundreds to thousands of hectares (M.R. Fuller, Patuxent Wildlife Research Center, U.S. Fish and Wildlife Service, Laurel, MD; letter dated September 18, 1987). The minimum size of contiguous forest cover required for acceptable reproductive habitat is unknown.

Verification level. This HSI model provides information useful for impact assessment and habitat management. The model is a hypothesis of species-habitat relationships and does not reflect proven cause and effect relationships. Previous drafts of this model were reviewed by Dr. M.R. Fuller, U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, Laurel, MD; Mr. T. Hamer, U.S. Forest Service, Mt. Baker Ranger District, Sedro Woolley, WA; and Dr. J.A. Jackson, Mississippi State University, Mississippi State, MS. Modifications and additional information provided as a result of these reviews have been incorporated into the model. Model output has not been evaluated against measures of barred owl habitat use or population density.

Model Description

Overview. Based on available literature, the most critical component of barred owl habitat appears to be availability of trees of sufficient size to provide cavities that are required for nesting. This model is based on the assumption that reproductive habitat is the most limiting characteristic of year-round barred owl habitat. If trees of sufficient size and numbers are present to ensure the availability of potential nest sites, then the cover and roosting requirements of the species also are assumed to be provided.

The availability and distribution of water does not appear to be a potentially limiting component of barred owl habitat, therefore these factors are not addressed in this HSI model. Several investigations of barred owl habitat relationships have shown the owls' use of forest stands that contain relatively open understories. It has been suggested that dense mid and understory vegetation inhibits the barred owls' ability to fly and effectively forage. This model is based on the assumption that mid and understory vegetative density has less influence in the definition of habitat quality for barred owls than do the characteristics of a forest stand that provide reproductive habitat (e.g., availability of cavities and the size and canopy density of overstory trees). It is assumed that barred owls will locate suitable foraging sites regardless of understory density at a specific location or within an individual stand. Therefore, the density and abundance of mid and understory vegetation is not addressed in this model.

This model will produce index values that are assumed to be proportional to a forest stand's ability to provide suitable reproductive habitat for barred owls. Stands that receive a 0.0 value are assumed to be indicative of unsuitable reproductive habitat due to small size class trees dominating the stand, an absence of suitable cavities, or relative sparseness. The potential of a stand for providing suitable reproductive habitat is assumed to correspond to increasing HSI values. When applied to areas larger than individual stands (e.g., management units, drainages), higher HSI values are assumed to correspond to greater overall reproductive habitat quality and a higher density of breeding pairs than can be expected in an equally sized area with a lower HSI value.

The following sections provide documentation of the logic and assumptions used to translate habitat information for the barred owl into the variables and equation used in the HSI model. Specifically, these sections cover (1) identification of variables, (2) definition and justification of the suitability levels of each variable, and (3) description of the assumed relationships between variables.

Reproduction component. High quality reproductive habitat for barred owls requires the presence of large size class, mature to old-growth, forest stands to provide nest cavities. Nests can be established in cavities within the boles of living or dead trees. Barred owls require relatively large cavities, therefore, large diameter trees have the greatest likelihood of containing cavities of sufficient size for use by the species. A precise count of the number of suitable tree cavities existing in a stand, or given area, would provide a more accurate indication of reproductive habitat quality for barred owls than would a surrogate measure of a stand's structural composition. This model, however, is based on the assumption that users will typically not have the time or resources to conduct intensive surveys to locate and count the number of cavities in a stand. Therefore, the reproductive component of this model is based on the assumption that the probability of the existence of suitable tree cavities in a stand will increase as the stand approaches maturity.

Several references in the preceding narrative have emphasized the number of snags per area required to support various population levels of barred owls. Barred owls will, however, nest in cavities within both living trees and snags. There also is some indication that cavities within living trees may provide nest sites superior to those in snags. This model is based on the assumption that dbh is the primary indicator of potential nest site quality. No distinction is made between the potential quality of living trees or snags as nest sites for barred owls.

Trees ≥51 cm dbh are believed to be of sufficient size to contain cavities of adequate dimensions for use by barred owls; however, most trees in this size class will not contain a suitable cavity. Therefore, it is assumed that as the number of trees (either living or snags) ≥51 cm dbh increases, the probability of the existence of suitable cavities also will increase. It is assumed that ≥2 trees/0.4 ha that are ≥51 cm dbh represents a sufficient number of trees to meet the nesting requirements of the barred owl (Figure 2). Stands that contain <2 trees/0.4 ha in this size class are assumed to be indicative of lower reproductive habitat quality due to the decreased probability of suitable cavities. The complete absence of trees ≥51 cm is assumed to reflect stands with minimum potential, but not totally unsuitable reproductive habitat, since barred owls may nest within trees of slightly smaller diameter, or abandoned nests of other raptors.

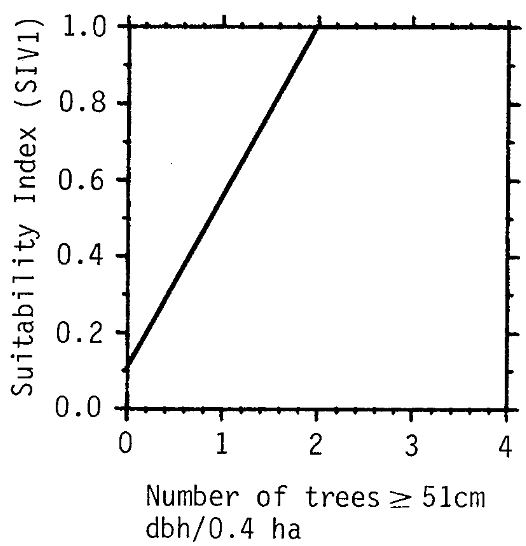

Figure 2. The relationship between the number of trees ≥51 cm dbh/0.4 ha and reproductive habitat quality for barred owls.

Reproductive habitat conditions are assumed to be enhanced as forest stands approach maturity and decadence. The characteristics of senescent stands are typically: a larger mean dbh of trees that compose the dominant overstory, decreased growth rates, and a heightened susceptibility to damage as a consequence of climatic extremes or insect or fungal infestations, resulting in a greater distribution and abundance of dying and dead trees than can be expected in younger, more vigorous stands (Spurr and Barnes 1980). A mean dbh of overstory trees of ≥51 cm is assumed to be indicative of a mature to old-growth forest stand. It can be assumed that the existence of suitable nest cavities will be greater in such stands. More importantly, a mean dbh of overstory trees ≥51 cm is assumed to be representative of mature forest stands that appear to be preferred by barred owls as reproductive habitat. Reproductive habitat quality for the barred owl is assumed to decline in response to a decrease in the mean dbh of trees composing the dominant overstory (Figure 3). Stands dominated by pole sized trees (12 to 22 cm for conifers, 12 to 28 cm for hardwoods) are assumed to have marginal value as reproductive habitat for the species due to the immature nature of the stand. Totally unsuitable reproductive habitat is assumed to be present when stands are dominated by sapling sized trees (dbh <12 cm).

Barred owls have been reported to prefer dense stands as reproductive habitat. Therefore, the density of the forest canopy is assumed to have a major influence on a stand's potential to provide suitable reproductive habitat. This model is based on the assumption that a stand will provide poor to unsuitable reproductive habitat, regardless of the presence of trees ≥51 cm, if the overall canopy closure of overstory trees is low. Optimum reproductive habitat is assumed to be present when overstory tree canopy cover is ≥60% (Figure 4). Overstory tree canopy closure <60% is assumed to be indicative of less suitable reproductive habitat due to the more open nature of the stand. Unsuitable reproductive habitat is assumed to exist when overstory tree canopy is ≤20% regardless of the size class of trees that compose the overstory.

HSI determination. The calculation of an HSI for the barred owl considers only the life requisite value calculated for reproductive habitat. Therefore, the HSI for the barred owl is equal to the reproduction suitability index (SIR) presented below.

$$HSI = SIR = (SIV1 \times SIV2)^{1/2} \times SIV3$$

The reproduction suitability index is based on the following suppositions. Barred owl reproductive habitat quality is assumed to be a function of the number of trees ≥51 cm dbh/0.4 ha (SIV1), the mean dbh of overstory trees (SIV2), and the canopy cover of overstory trees (SIV3). SIV1 and SIV2 are assumed to be equal and compensatory in defining reproductive habitat quality. Stands with at least two 51 cm dbh trees/0.4 ha and having a mean overstory tree dbh ≥51 cm represent ideal conditions. Stands with ≥2 51-cm dbh trees/ 0.4 ha but having a mean dbh of overstory trees <51 cm are assumed to be indicative of lower reproductive habitat quality as a result of the smaller diameter of overstory trees. SIV3 is assumed to directly modify the value calculated for SIV1 and SIV2. As a result of the barred owls' preference for selecting "dense" stands for establishment of nests, stands composed of large diameter overstory trees will be of lower value as barred owl reproductive habitat if the stand is relatively open, <60% canopy cover of overstory trees. Unsuitable reproductive habitat is assumed to be present when the canopy cover

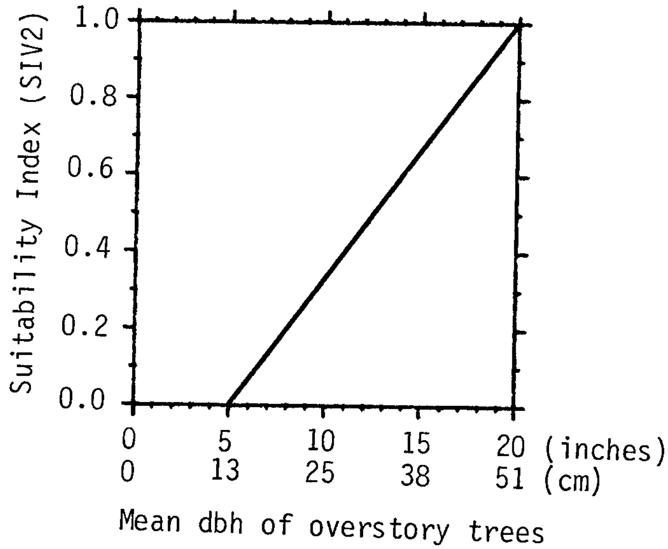

Figure 3. The relationship between mean dbh of overstory trees and reproductive habitat quality for barred owls.

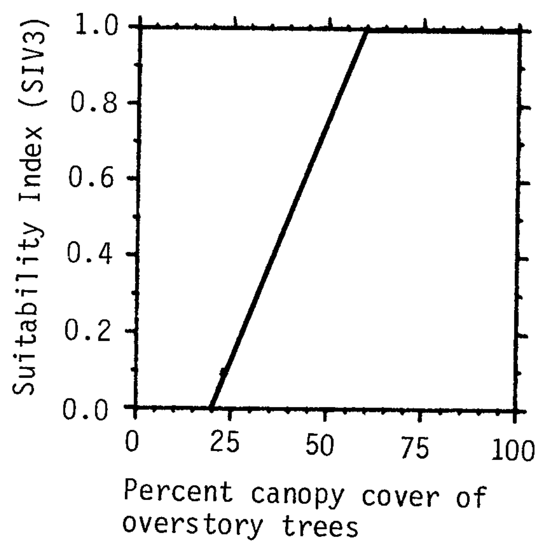

Figure 4. The relationship between percent canopy cover of overstory trees and reproductive habitat quality for barred owls.

of overstory trees is ≤20% regardless of overstory tree size. In summary, optimum reproductive habitat for barred owls can be characterized as a forest stand that has ≥2 51-cm dbh trees/0.4 ha, a mean overstory tree dbh of ≥51 cm, and an overstory canopy cover ≥60%.

Application of the Model

This model may be used to determine the HSI values for individual forest stands or for a number of forest stands that make up the total evaluation area. In situations where two or more stands are evaluated, an overall weighted HSI (weighted by area) can be determined by performing the following steps:

1. Stratify the evaluation area into forest or stand types.

2. Determine the area of each stand and the total area of the evaluation area.

3. Determine an HSI value for each stand in the evaluation area.

4. Multiply the area of each stand by its respective HSI value.

5. Add all products calculated in step 4 and divide the sum by the total area of all stands evaluated to obtain the weighted HSI value.

The steps outlined above are expressed by the following equation:

$$\text{Overall HSI (weighted by area)} = \frac{\sum_{i=1}^{n} HSI_i \, A_i}{\sum A_i}$$

where n = number of stands

HSI_i = HSI of stand i

A_i = area of stand i

Summary of model variables. Three habitat variables are used in this model to evaluate barred owl reproductive habitat quality. The relationship between habitat variables, cover types, life requisite value, and HSI are summarized in Figure 5. Definitions and suggested measurement techniques (Hays et al. 1981) for the variables used in the barred owl HSI model are provided in Figure 6.

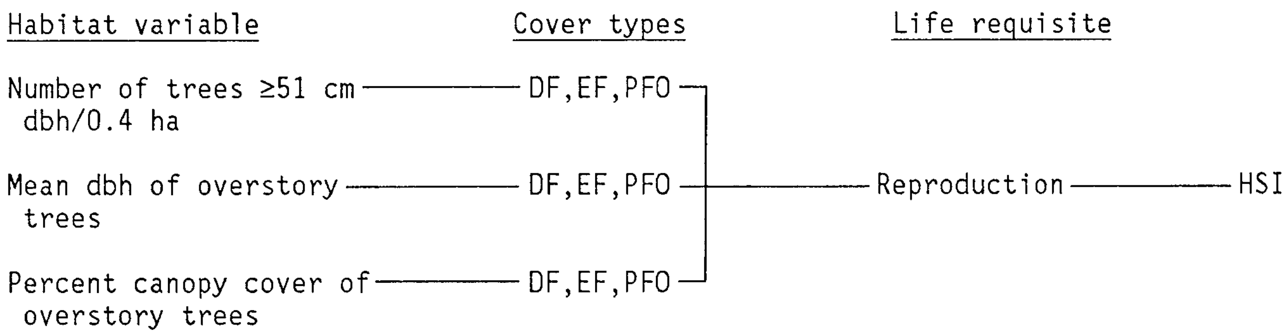

Figure 5. Relationships of habitat variables, cover types, and life requisite values in the barred owl HSI model.

Variable (definition)	Cover types	Suggested technique
Number of trees ≥51 cm dbh/0.4 ha [number of trees, either living or snags, ≥51 cm (20 inches) diameter at breast height (1.4 m or 4.5 ft)/acre].	DF,EF,PFO	line intercept, quadrat, circular plot, remote sensing
Mean dbh of overstory trees [the mean diameter at breast height (1.4 m or 4.5 ft) of trees that are ≥80% of the height of the tallest tree in the stand].	DF,EF,PFO	line intercept, quadrat, circular plot, dbh tape
Percent canopy cover of overstory trees (the percent of the ground surface that is shaded by a vertical projection of the canopies of all trees that are ≥80% of the height of the tallest tree in the stand).	DF,EF,PFO	line intercept, quadrat, circular plot, remote sensing

Figure 6. Definitions of variables and suggested measurement techniques.

Model assumptions. The barred owl habitat model is based on the following assumptions.

1. The availability and quality of reproductive habitat is assumed to be the most limiting component of year-round barred owl habitat.

2. The probability of sufficient numbers of cavities suitable for barred owl use is assumed to be greater in mature and old-growth stands than in younger stands. Therefore, reproductive habitat quality is assumed to increase as forest stands approach maturity and decadence.

3. Trees with a dbh ≥51 cm are assumed to be of adequate size to contain cavities of dimensions suitable for barred owl use.

4. Densely forested stands, as reflected by percent canopy cover of overstory trees, are assumed to provide reproductive habitat of higher quality than less dense stands, regardless of the abundance of trees ≥51 cm dbh.

5. Based on measures of size and density of overstory trees and trees ≥51 cm, upland forests and forested wetlands are assumed to have equal potential as barred owl habitat. The availability and distribution of water is assumed to have no direct influence on the quality of reproductive habitat for the species.

6. Evergreen, deciduous, and stands of mixed composition are assumed to have equal potential as barred owl reproductive habitat.

7. Provided that they are ≥51 cm dbh, living trees and snags are assumed to have equal values as potential nest sites for barred owls.

8. Although barred owls have been reported to use abandoned raptor nests, the presence or absence of raptor nests is assumed to be inconsequential in the definition of barred owl reproductive habitat quality. It is assumed that the presence of raptor nests will not insure their use by barred owls and that the structural characteristics of a forest stand far outweigh the presence of raptor nests in the definition of reproductive habitat quality for barred owls.

SOURCES OF OTHER MODELS

No other models for the evaluation of barred owl habitat were located in the literature.

The barred owl and spotted owl (*Strix occidentalis*) are closely related and are considered by some authors to represent a superspecies (American Ornithologists' Union 1983). Laymon et al. (1985) developed a Habitat Suitability Index (HSI) model for evaluation of spotted owl habitat. The model is applicable to the Sierran Forest Province (as defined by Bailey 1978) and the Pacific Forest Province. The model is intended to evaluate year-round habitat quality based on the evaluation of average dbh of overstory trees, percent tree canopy closure, and tree canopy diversity.

Since this barred owl model has been formulated based on data gathered chiefly in the midwest and eastern portions of the species range, users in the Pacific Northwest may find it useful to compare the two models. The major difference in the models is that overstory trees with a dbh ≥90 cm are defined as optimum in the spotted owl model rather than ≥51 cm as defined in this model. In addition, a variable is included in the spotted owl model that is used to evaluate the structural composition of forest stands.

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A review and synthesis of existing information were used to develop a Habitat Suitability Index (HSI) model for the barred owl (*Strix varia*). 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 U.S. Fish and Wildlife Service.

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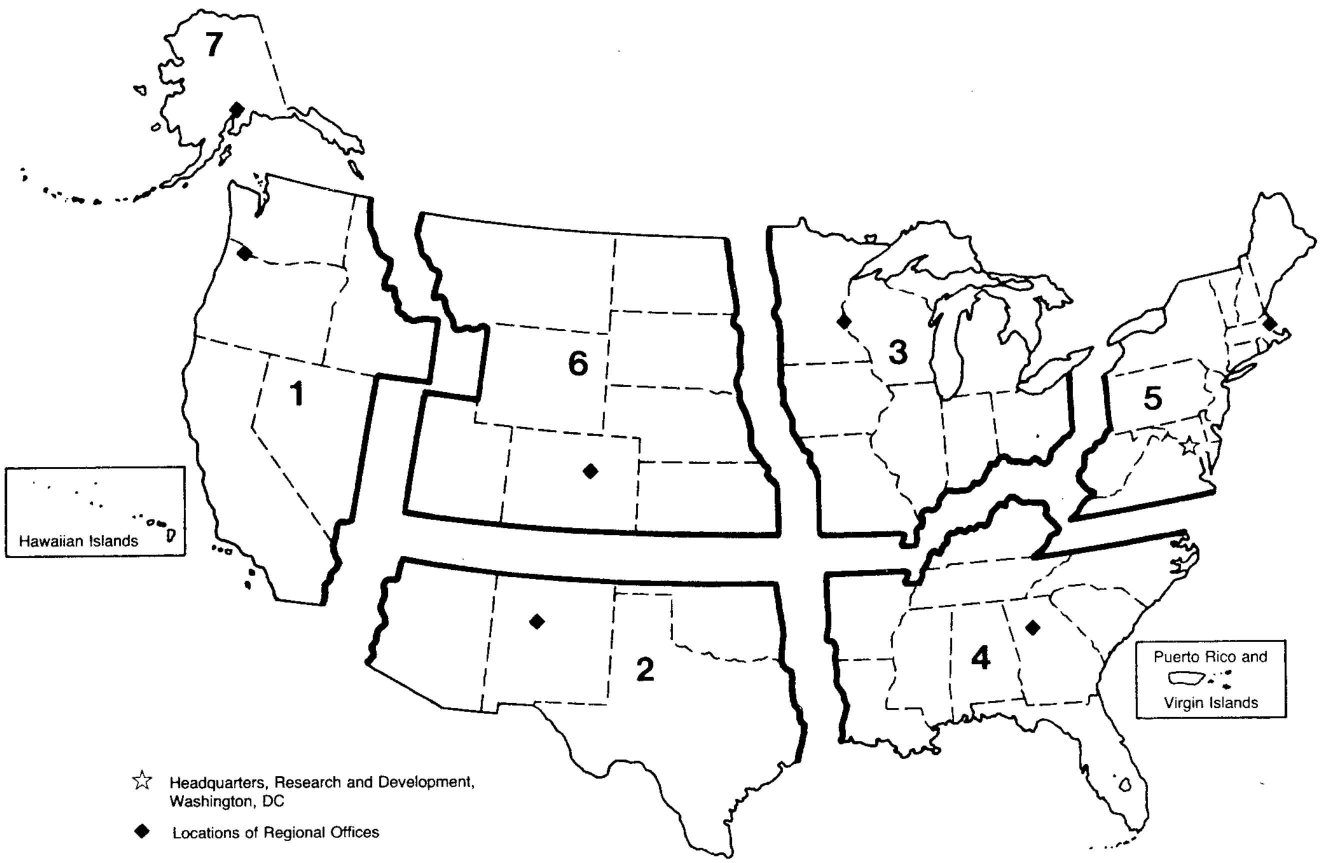

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