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HABITAT SUITABILITY INDEX MODELS: SPOTTED OWL

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HABITAT SUITABILITY INDEX MODELS: SPOTTED OWL

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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is a formalized synthesis of biological and habitat information published in the scientific literature and may include unpublished information reflecting the opinions of identified experts.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:

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SPOTTED OWL (*Strix occidentalis*)

HABITAT USE INFORMATION

General

The spotted owl (*Strix occidentalis*) inhabits dense coniferous forests and wooded ravines in western North America from southwestern British Columbia to central Mexico (American Ornithologists' Union 1983). It nests in tree cavities, old nests of woodrats (*Neotoma* spp.) and hawks (*Accipiter* spp.), deformed branches, witches-broom clumps, or in crevices in cliffs, and feeds on a variety of animal life associated with dense wooded habitats. Spotted owls are territorial during their breeding season, and may occupy the same area for life (Bent 1938; Gould 1974; Miller 1974; Forsman 1980, 1981).

Coniferous habitats occupied by spotted owls are characterized by large trees, a structurally and floristically diverse tree canopy of moderate to dense closure, decadence in the stand, and proximity to water courses (Gould 1977; Forsman et al. 1984). Woodland habitats in Arizona and southern California are dominated by evergreen oaks (*Quercus* spp.) and pines (*Pinus* spp.) and located near water and steep-walled canyons (Bent 1938; C. W. Barrows, 42101 Wilderness Road, Branscomb, CA; pers. comm.).

The spotted owl is a major issue in forest management in the western United States. The U.S. Forest Service has selected the owl as a Management Indicator Species for old growth coniferous forests and has developed specific plans for maintaining viable populations throughout its geographic range. This decision has not been without controversy, because there are significant economic tradeoffs involved with preserving habitat for spotted owls. Research and environmental assessments on the owl were ongoing at the time this habitat model went to press; hence, new information is anticipated annually for evaluating and managing spotted owl habitats.

Food

Spotted owls feed on a variety of prey including flying squirrels (*Glaucomys* spp.), woodrats, deer mice (*Peromyscus* spp.), voles (*Microtus* spp.), snowshoe hares (*Lepus americanus*), small birds, amphibians, and insects (Marshall 1942; Forsman 1976, 1980, 1981; Kertell 1977; Barrows 1980). They forage primarily at night, sitting on elevated perches and diving at prey on tree trunks, limbs, or the ground (Forsman 1976, 1980, 1981; Barrows 1980). Prey items selected and foraging strategy indicate that spotted owls spend a considerable amount of time foraging in forest foliage (Jackman and Scott 1975). Forsman (1976) found that mammals constitute > 90% of the diet of spotted owls in Oregon. Flying squirrels were the principal prey in moist temperate forests, whereas woodrats were predominant in the diet in drier mixed conifer habitats. Barrows (1980) found woodrats to be the most important prey item in both the North Coast and the Peninsular Ranges of California. Mammals also were predominant in spotted owl diets in British Columbia (Smith 1963). However, pellet samples may grossly underestimate the percent of insects in the diet, because pellets with insects do not fall to the ground intact (S. A. Laymon, Department of Forestry and Resource Management, University of Caliornia, Berkeley; unpubl.).

Spotted owls selectively prey on larger arboreal and semiarboreal flying squirrels and woodrats (Forsman 1976; Barrows 1980). Use of terrestrial mammals appeared to increase at higher elevations in Oregon where deeper snowpack and sparse herbaceous cover tended to increase terrestrial prey vulnerability (Forsman 1976). Diet varied by season, with juvenile snowshoe hares fed on in spring, arboreal mammals in winter (Forsman 1976), and insects during summer months (Marshall 1942). Nesting attempts and fledgling success, key parameters in population dynamics, may be linked to the abundance of prey (Forsman 1976; Barrows 1980).

Marshall (1942) estimated foraging areas in California to be 520 ha. Telemetry work by Forsman et al. (1984) indicated that individual home ranges, and presumably foraging areas, were 549 to 3,380 ha in Oregon. Average home range size was larger in areas where most of the old-growth forests were harvested. Gutierrez et al. (1983) observed home ranges of 331 to 1,656 ha ($\bar{x}$ = 1,004 ha) in northern California. The amount of old growth forest within known home ranges varied from 331 to 1,286 ha, and averaged 888 ha in the Cascades and 556 ha in the Coast Range mountains (Carey 1985). The mean area of old growth within home ranges in Oregon was 1,012 ha (Forsman et al. 1985). A pair of owls used a minimum of 408 ha of old-growth forest (Forsman 1980, 1981).

Several authors suggest that old-growth forest contributes to the foraging success of spotted owls (Gould 1977; Forsman et al. 1984). They hypothesize that the fallen dead trees found in an old-growth stand provide for a greater abundance of vulnerable prey than a younger, or intensively managed, stand.

Water

It is not known whether spotted owls require free water. Spotted owls have been observed drinking water from small springs and streams, and bathing in shallow pools (Forsman 1976; Barrows and Barrows 1978). Fifteen of 18 nests found by Forsman (1976) were within 400 m of small perennial streams or springs; the farthest nest was 1,420 m from water. Gould (1977) noted that 98% of all spotted owl observations made in California were within 600 m of water. E. D. Forsman (Oregon Cooperative Wildlife Research Unit, Corvallis; pers. comm.) and Laymon (unpubl.) suggest that the habitat used by spotted owls tends to occur near water, though water itself has not been proven to be a key habitat variable.

Cover

Dense multilayered forests and woodlands are used for daytime roosts throughout the year in most areas (Barrows and Barrows 1978; Forsman et al. 1984). Roost site selection varies seasonally, probably as a function of thermal patterns and vegetation structure. Summer roost sites in California were typically on northwest to northeast aspects, on slopes over 35%, and in stands with a tall (65 m), irregular conifer canopy and a dense conifer and hardwood subcanopy (Barrows and Barrows 1978). Slope does not appear to be a controlling factor in roost site selection (Forsman, pers. comm.); owls in rugged terrain will roost in trees on slopes, but may not necessarily select slopes. Summer roost sites are located 1 to 5 m above the ground in subcanopy trees near the bottom of slopes or draws, whereas winter roost sites are 15 to 45 m above the ground in overstory trees (Forsman 1976, 1980, 1981). The selection of dense, multilayered, and often north-facing sites for summer roosts is most pronounced in areas where the mean ambient temperature reaches 29° C (Barrows 1981). This behavior compensates for the species' inefficiency in dissipating body heat. Winter roost sites are located farther upslope than summer roost sites to avoid "cold air sinks". Canopy closure at roost sites ranged from 50 to 90% and was greater during hot weather (Forsman 1976; Barrows and Barrows 1978; Barrows 1981).

Reproduction

Spotted owls nest in tree cavities, nest platforms built by other animals, platforms created from debris trapped by dwarf mistletoe (*Arceuthobium* spp.), and potholes on cliffs (Bent 1938). In forests, nest stands typically are characterized by large trees > 76 cm diameter at breast height (dbh), with a dense (50 to 90%) canopy closure (Forsman 1976, 1980, 1981; Gould 1977; Barrows and Barrows 1978). A subcanopy or understory often increases the total closure of these sites to 100% (Laymon, unpubl.). Nest stands have a high incidence of disease and tree damage, e.g., fungal and dwarf mistletoe infections, broken top trees, and snags (Forsman et al. 1984). Forsman (1976) found 13 of 18 nests in cavities 30.5 to 61.0 m above the ground in large trees 114 to 203 cm dbh. Three nests were on limbs deformed by dwarf mistletoe and two were on abandoned platform nests of other birds. Trees with cavity nests were 220 to 380 years old, whereas trees with other kinds of nests were younger (Forsman 1976). Ligon (1926) observed nests on cliff ledges and potholes in the southwest.

Forsman (pers. comm.) measured 47 nest sites for slope and aspect and did not detect any preference for north aspects or for slopes > 25%. Nests are associated with large old-growth stands. Fifteen of the 18 nests in Forsman's (1976) study were more than 180 m from the nearest forest opening. Marcot and Gardetto (1980) suggested that a minimum area of 81 ha is required for a nest stand, whereas Forsman (1976) considered 121.5 ha to be the minimum required. Two nests from which juveniles successfully fledged were found in stands of old-growth forest < 50 ha in extent on the Klamath National Forest in northern California (Laymon, unpubl.). A successful nest stand found on the Blodgett Experimental Forest in the central Sierra Nevada was surrounded by an old-growth stand of only 25 ha (Laymon, unpubl.). These examples indicate that forest stands < 120 ha may be adequate for nesting.

Many authors noted that nest stands are in old-growth forests (Bent 1938; Forsman et al. 1984; Carey 1985). In Oregon, 95% of 123 spotted owl pairs were located in old-growth forests (Forsman 1976), and a similar percentage was found on the Klamath National Forest (Laymon 1982). In the Sierra Nevada range in California, some owls have been found in forest stands < 100 years old (H. Salwasser, USDA Forest Service, Washington, DC; unpubl.). It is not known whether the owls using these younger forest stands nested. These stands contained large trees with a moderately dense canopy closure and were decadent, similar to stand conditions found in old-growth forests. One reason for this similarity is that much of the Sierra Nevada range was "high-graded" when it was logged in the late 1800's. Only the large, sound trees of high commercial value were removed, giving the stands a head start towards old-growth characteristics compared to clear cut stands. Considerable doubt remains about whether spotted owls can be maintained in second-growth forest intensively managed on a short rotation for timber production (Laymon, unpubl.).

An understory vegetation layer appears to be important for nesting habitat (Forsman et al. 1984; Laymon, unpubl.). Young spotted owls leave the nest before they can fly and use small trees and shrubs for perching (Forsman 1976).

Interspersion and Composition

The home range of a spotted owl can include areas 6.4 to 8.0 km from the nest site (Forsman 1980, 1981), especially in years when the owls do not nest. However, the majority of foraging occurs within a 3.2 km radius of the nest site. These data indicate that an average home range area could approach 3,220 ha if an owl used all sites within the 3.2 km radius. Forsman's telemetry work, however, shows that the average home range for 14 birds was 1,713 ha (Forsman et al. 1984). The average home range for pairs was 2,144 ha with a range from 1,149 to 4,225 ha. The Spotted Owl Management Task Group (U.S. Forest Service 1981) recommended a management area of 405 ha/pair including at least one contiguous 121.5-ha stand of old-growth forest and an additional 283.5 ha of late successional to old-growth forest within a 2.4 km radius of the nest site. This is a total area of 1,810 ha, 22% of which is suitable habitat for the owls. Since average home ranges are > 1,810 ha, and Forsman's data (1980, 1981) indicate that for 14 birds the average area of old-growth forest within the home range was 685 ha with a range from 300 to 1,186 ha, these management guidelines represent the lower range of habitat needs for the spotted owl. All radio-tagged pairs studied by Forsman et al. (1984) had more than 396 ha of old-growth forest within their home ranges. An increasing proportion of late successional to old-growth forest within home ranges of spotted owls increases habitat suitability (Laymon, unpubl.).

Spotted owls can, but rarely do, forage in mid-successional forest stands (Forsman et al. 1984). They require a relatively large area comprised of large trees providing moderate to dense canopy closure, a well developed subcanopy or understory, and decadent trees in the stands. Forsman et al. (1977) cited densities of 0.36 spotted owl pairs/linear km in 20 to 80-year-old second-growth forest. Owls found in second growth areas appeared to be non-breeding birds and were located in association with remnant old-growth trees. The mean nearest-neighbor distances between pairs was 2.8 km (n = 65, range = 1.6 to 6.4 km) (Forsman et al. 1984). However, the minimum distance between two active nests was 1.9 km.

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. This HSI model applies to the cover types listed below within the breeding range of spotted owls in the Sierran Forest Province (M261) of Bailey (1978). It probably will be applicable in the Pacific Forest Province (M241) (Fig. 1).

Season. The model was developed to evaluate quality of habitat for spotted owls throughout the year, but the data used to derive the model were primarily from spring, summer, and fall. Application to winter habitat should be made with caution, as little is known about the species during that season.

Cover types. This model was developed for application in Evergreen Forest (EF) (U.S. Fish and Wildlife Service 1981). In the Sierran Forest Province this includes mixed conifer, Douglas-fir (*Pseudotsuga menziesii*), and redwood (*Sequoia sempervirens*) as primary forest types. Also included are red fir (*Abies magnifica*) and white fir (*A. concolor*) as secondary forest types (Bailey 1978).

Minimum habitat area. The amount and quality of suitable habitat required to maintain a pair of spotted owls over several generations is unknown. Habitat value for spotted owls should be highest when all stands in a 1,963 ha area around the nest site have high suitability values for reproduction and, therefore, feeding and roosting. This would be the area of a 2.5 km radius circle entirely composed of old-growth forest. Under these conditions, the density of owls should be limited by territorial behavior, and territories and home ranges should be the smallest possible while still maintaining minimum spacing between owl pairs. It is not known how great a decrease in the proportion of old-growth within a 2.5 km radius area could occur and still maintain owls at densities limited by social interactions rather than habitat. Conceivably, as the proportion of high quality forest stands in an area declines, the owls should expand their territories and home ranges in relation to availability of food resources. Territory and home range expansion would require more energy expenditure by the owls. When home ranges become so large that energy intake by the owls balances energy spent obtaining prey and maintaining homeothermy, reproduction would cease. This maximum area is unknown, but would represent the threshold for maintaining a viable pair of owls. Many biologists and scientists use the mean area of old-growth within home ranges studied to date (1,000 ha) as a measure of optimum habitat quality within a 2.5 km average foraging radius.

Verification level. The model has been reviewed by Cameron Barrows, Eric Forsman, and Bruce Marcot. Their comments and suggested improvements were incorporated. The model has been tested on the El Dorado National Forest using known population and habitat data, additional field survey work, and radio telemetry locations (see Laymon and Barrett 1982 for test methods). Results of the model test showed significantly higher ($P < 0.05$) HSI values (42% higher) for the 97 ha surrounding known owl locations compared to random locations ($\Delta X = 0.22$, $n = 70$). The frequency of owls present was positively correlated ($r = 0.61$, $P < 0.001$) with the HSI score for the sites using owl responses to imitation calls in a stratified random sample of sites.

Figure 1. Approximate geographic area of applicability for the spotted owl HSI model (cross-hatching) compared to the estimated total range (Forsman et al. 1984). Distribution of the spotted owl in Colorado is not well documented.

Frequency of habitat use by radio-tagged owls and HSI scores were not correlated within home ranges. The relationship between use and availability of habitat within home range was dependent on grid cell resolution; a 16-ha cell resolution showed no relationship, whereas a 4-ha resolution showed good predictive power with high HSI values (> 0.7), but no relationship at moderate to low values (< 0.7). The model appears to be useful for predicting where owls will be found in a large geographic area, e.g., ≥ 1,000 ha watershed. It has low power for predicting which sites will be used for foraging within an owl's home range.

Model Description

Overview. The spotted owl can satisfy all of its habitat requirements within any one of the above primary cover types. In this model it is assumed that requirements for reproduction, feeding, and roosting are met by the same habitat parameters: large trees, moderate to dense canopy closure, multilayered canopy, and decadent trees (snags) in forest stands. Summer roosts would require the highest habitat values, whereas foraging sites would require the lowest. These life requisites are included in the reproduction component. Water is not considered to be a limiting factor for spotted owls.

Reproduction component. Habitat suitability for reproduction is assumed to be optimum when average canopy tree size is > 91 cm dbh, canopy closure is 70 to 100%, and the stand is multilayered (i.e., ≥ 3 size classes of trees are present). Understory trees and abundance of decadent trees in the stand are also necessary. The model assumes that these latter two conditions will be fulfilled if the previous three characteristics are present. This is a reasonable assumption because stands become multilayered during the aging process that is accompanied by an increase in decadent trees and the development of shrub and understory layers. Intermediate habitat suitability occurs when the average canopy tree is 61 to 91 cm dbh, canopy closure is between 40 and 70%, and 2 size classes of trees are present. Low habitat suitability occurs when the average canopy tree is 30 to 61 cm dbh, canopy closure is 20 to 40%, and 1 size class of tree dominates the stand. Stands with an average canopy tree < 30 cm dbh or < 20% canopy closure are considered to be unsuitable. Stands with high canopy closure but with an average canopy tree < 30 cm dbh, or with large average dbh but < 20% canopy closure would also be unsuitable. Suitability curves are illustrated in Figure 2.

HSI determination. It is assumed that the habitat variables are partially compensatory, and that 0.0 values for any variable would result in the stand being unsuitable. The habitat suitability of a stand is estimated by its reproductive suitability index (SIR). The model form tested by Laymon and Barrett (1982) was:

$$SIR = (SIV1 \times SIV2 \times SIV3)^{1/3} \quad (1)$$

Subsequent analysis of the equation indicated that a slightly different structure may more accurately reflect the importance of tree dbh in assessing stand value. That structure is:

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

Users of this model are encouraged to work with local data to determine the best method for integrating the three habitat variables.

A particular assessment area may be comprised of many stands that differ for one or more of the habitat variables. An HSI for an assessment area can be calculated with Equation 3.

$$HSI = \frac{\sum_{i=1}^{n} (A_i SIR_i)}{\text{Total area}} \quad (3)$$

where n = the number of distinct stands

A_i = the area of stand type i

SIR_i = the reproductive suitability index of stand type i defined by Equation 1 or 2

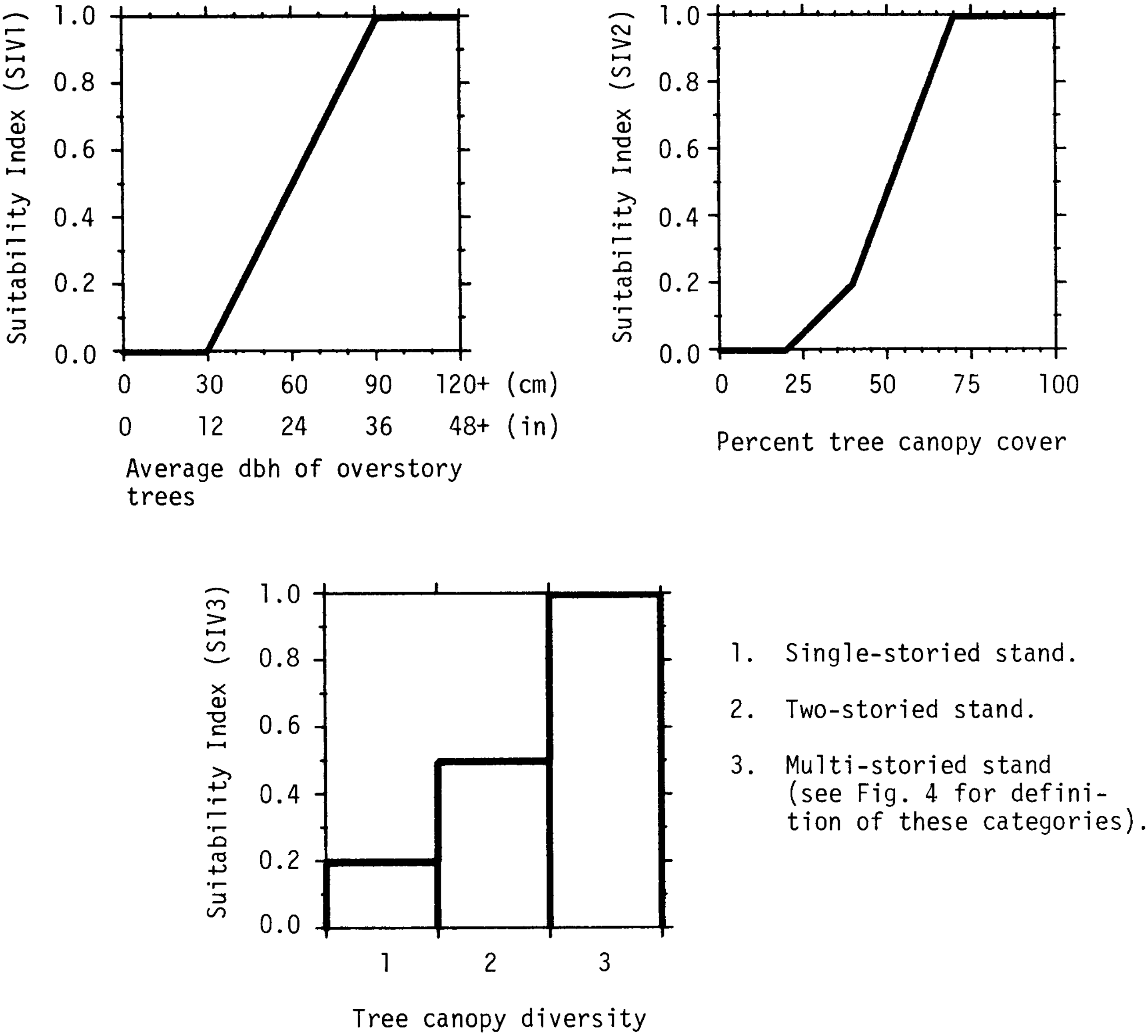

Figure 2. The relationships between habitat variables used to evaluate spotted owl reproductive habitat and suitability indices for the variables.

Empirical data suggest that a pair of owls uses an average of about 1,000 ha of old-growth within their home range. Assuming that 1,000 ha would, on the average, successfully support a breeding pair, then 1,000 habitat units (HSI x usable area) within an average 1,963-ha home range would constitute maximum habitat suitability for spotted owls. If the habitat units exceed 1,000 within a 1,963-ha home range area, then it is assumed that owl density will be limited by social and behavioral factors.

Application of the Model

Summary of model variables. The model is designed to accept some estimates from aerial photos, and can be used with forest inventory data that have been obtained from aerial photo interpretation. Accuracy of results should increase with accurate ground truthing of data estimated with photo interpretation.

The relationships between habitat variables, spotted owl life requisites, cover types, and overall habitat suitability are shown in Figure 3.

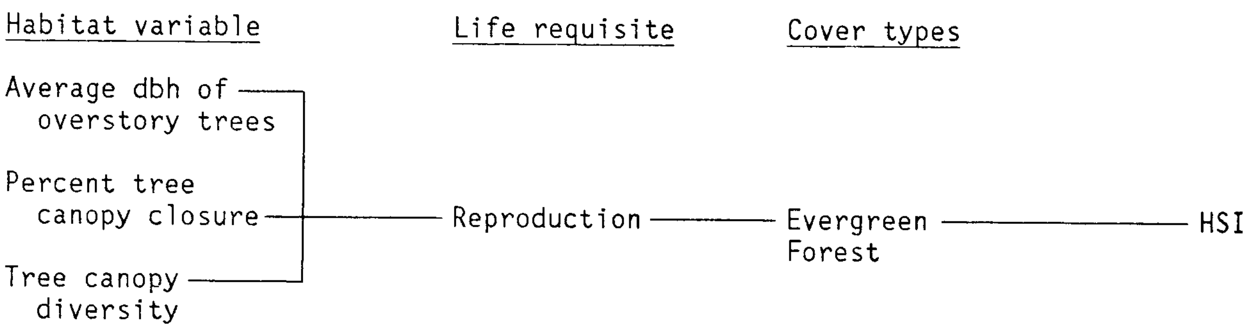

Figure 3. Relationships between habitat variables, life requisites, and an HSI value in the spotted owl HSI model.

Definitions of habitat variables and suggested field measurement techniques are provided in Figure 4. In order to obtain an HSI using this model, field data for habitat conditions must be measured or estimated and mean habitat characteristics entered into the appropriate suitability curves.

Model assumptions. In addition to the assumptions previously mentioned, this model assumes that past management (e.g., salvage logging or stand thinning) has not negated the assumption that presence of snags and fallen trees is correlated with tree diameter and structural layering.

Variable (definition)	Cover types	Suggested technique
Average dbh of overstory trees [the average diameter at breast height (1.4 m/4.5 ft) above the ground of those trees that are ≥ 80 percent of the height of the tallest trees in the stand].	EF	Estimate dbh from aerial photos using conversion factors based on tree height and crown diameters.
Percent tree canopy closure [the percent of the ground surface that is shaded by a vertical projection of the canopies of all woody vegetation taller than 5.0 m (16.5 ft)].	EF	Estimate from aerial photos.
Tree canopy diversity (an evaluation of the vertical structural diversity within a forest stand classed as one of the following: 1. Single-storied stand Stand canopy is comprised of dominant and codominant trees that are generally of the same age and size class. Canopies of trees are within the same height stratum, or are overlapping. Understory trees comprise < 10% canopy closure.	EF	Infer by dbh and canopy closure classes based on samples from field measurements.

Figure 4. Definitions of variables and suggested measurement techniques.

Variable (definition)	Cover types	Suggested technique
2. Two-storied stand Stand canopy is stratified into two distinct layers: overstory and understory. The understory is clearly developed, having > 10% canopy closure of trees with their crowns entirely below the dominant canopy strata.		
3. Multi-storied stand Stand canopy is comprised of the crowns of trees in various age and size classes. Shrubs, trees of intermediate height, dominant and codominant trees all occur in the stand.).		

Figure 4. (concluded)

Further research to refine this model should examine the assumptions addressing: (1) quality and quantity of habitat within home ranges, i.e. Equation 3; (2) slope and its relationship to each variable; and (3) the amount of high quality habitat required within a home range to sustain reproductive success.

SOURCES OF OTHER MODELS

Several models for predicting the value of single stands as spotted owl habitat have been proposed (Verner and Boss 1980; Hurley et al. 1981; Shimamoto and Airola 1981; Brown 1985; Forsman et al. 1985). However, to our knowledge, this is the only spotted owl habitat model that has been developed and tested to assess the suitability of an aggregate of stands within an area large enough to serve as the home range for a pair of spotted owls.

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16. Abstract (Limit: 200 words)

A review and synthesis of existing information were used to develop a Habitat Suitability Index (HSI) model for the spotted owl (*Strix occidentalis*). 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.

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b. Identifiers/Open-Ended Terms

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Strix occidentalis
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