A Method to Create Simplified Versions of Existing Habitat Suitability Index (HSI) Models

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ABSTRACT / The habitat evaluation procedures (HEP), developed by the US Fish and Wildlife Service, are widely used in the United States to determine the impacts of major construction projects on fish and wildlife habitats. HEP relies heavily on habitat suitability index (HSI) models that use measurements of important habitat characteristics to rate habitat quality for a species on a scale of 0 (unsuitable) to 1.0 (optimal). This report describes a method to simplify existing HSI models to reduce the time and expense involved in sampling habitat variables. Simplified models for three species produced HSI values within 0.2 of those predicted by the original models 90% of the time. Simplified models are particularly useful for rapid habitat inventories and evaluations, wildlife management, and impact assessments in extensive areas or with limited time and personnel.

The National Environmental Policy Act of 1969 mandated environmental impact studies of large, federally funded construction projects, and produced a need for objective methods to determine impacts on valuable environmental resources. The US Fish and Wildlife Service (FWS), in cooperation with the US Army Corps of Engineers and other federal agencies, responded by developing the habitat evaluation procedures (HEP) (US Fish and Wildlife Service 1980 and 1981), an accounting system for determining the quality and quantity of habitat for fish and wildlife.

HEP is based on habitat suitability index (HSI) models that quantitatively describe the habitat requirements of a species or group of species. HSI models use measurements of appropriate variables to rate the habitat on a scale of 0 (unsuitable) to 1.0 (optimal). Models for more than 100 species of birds, mammals, reptiles, amphibians, fish, and shellfish have been published by the FWS and additional models are available from other federal and state agencies (Roberts and others 1987).

Much of the time and effort involved in applications of HEP is spent sampling habitat variables specified in the models for each evaluation species. A typical application involves several species, and individual HSI models contain 2–20 variables (Wakeley and O'Neil 1988). This report describes a procedure for simplifying HSI models to reduce sampling effort. The simplified models produce HSI scores within 0.2 of those produced by the original models 90% of the time. This level of accuracy is sufficient for many applications, including rapid habitat inventories and evaluations, wildlife-management planning, and simple damage assessments.

KEY WORDS: Habitat evaluation procedures; Habitat quality; Habitat suitability index models; Impact assessment; Wildlife management

Procedure

Most HSI models are composed of variables that are measured on continuous scales; examples include percent ground cover, average diameter of overstory trees, and velocity of stream current. Each variable is converted with curves provided in the model into a suitability index (SI) that also is continuous, ranging from 0 to 1.0. SI values for each variable are then combined into an overall HSI. One way to simplify existing HSI models is to convert model curves from continuous to discrete forms.

Discrete versions of HSI models were herein developed by reducing the suitability index for each variable to only three categories: *zero* (SI $=$ 0); *low* ($0 < \text{SI} < 0.5$); and *high* ($\text{SI} \geq 0.5$). This effectively divides the habitat variables themselves into categories corresponding with the three levels of suitability; break points between levels are determined by examining the original curves. In Figure 1, for example, values of the variable between 0% and 20% have zero suitability, those between 20% and 60% have low suitability, and those 60% or more have high suitability. The procedure is repeated for all variables whose suitability curves are continuous; variables that are already categorical, such as successional stage or substrate type, need not be altered.

After the suitability ratings for each variable on a site have been determined in the field, a standard numeric SI score is assigned to each rating. For suitability ratings of zero, low, and high as described above, numeric scores of 0, 0.2, and 0.9 are recommended. An HSI is then calculated in the usual way, by combining SI values using the equation specified in the model.

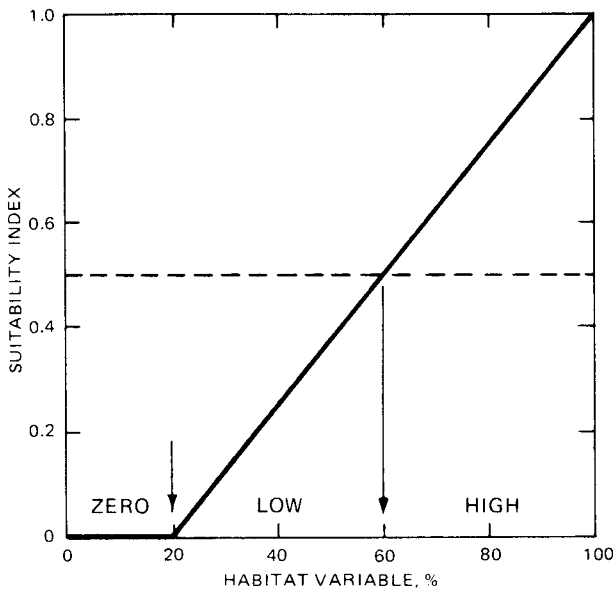

Figure 1. Hypothetical continuous suitability index curve showing the method used to convert it to a discrete version. The habitat variable is scored in three categories: *zero* where SI = 0, *low* where $0 < SI < 0.5$, and *high* where $SI \geq 0.5$.

Table 1. Discrete version of the red-backed vole HSI model.

Variable	Score[a]	Definition
V1	0	Average dbh of overstory trees is 0 cm.
	L	Average dbh of overstory trees is >0 cm but <15 cm.
	H	Average dbh of overstory trees is ≥15 cm.
V2	0	Percent ground surface covered by downfall is 0%.
	L	Percent ground surface covered by downfall is >0% but <10%.
	H	Percent ground surface covered by downfall is ≥10%.
V3	0	Percent grass canopy cover is ≥80%.
	L	Percent grass canopy cover is >45% but <80%.
	H	Percent grass canopy cover is ≤45%.
V4	L	Percent canopy closure of evergreens is ≤33%.
	H	Percent canopy closure of evergreens is >33%.

[a] Suitability scores are 0 for "zero," L for "low," and H for "high."

Example: The Red-Backed Vole

The HSI model for the southern red-backed vole (*Clethrionomys gapperi*) in the western part of its range (Allen 1983) contains four habitat variables, each described by a continuous suitability curve (Figure 2). The following equation is used to calculate an overall HSI value:

$$HSI = (SI1 \times SI2 \times SI3)^{1/3} \times SI4 \quad (1)$$

A discrete version of the model was produced by examining each variable's suitability curve and defining intervals within which the suitability index was either zero (SI = 0), low ($0 < SI < 0.5$), or high ($SI \geq 0.5$). The resulting model is shown in Table 1. The HSI is calculated as in equation 1 by substituting numeric values of 0, 0.2, and 0.9 for suitability ratings of 0, L, and H, respectively.

Testing Simplified Models

Discrete versions of the red-backed vole HSI model and two additional models [American woodcock (*Scolopax minor*), Cade 1985; red-spotted newt (*Notophthalmus viridescens viridescens*), Sousa 1985] were tested by comparing their results to those of the original models. The woodcock model as applied to forested cover types contained four variables: (a) soil drainage/textural class, (b) percent canopy cover of vegetation and downfall ≤30 cm above the ground, (c) percent herbaceous and shrub canopy cover >0.5 m tall, and (d) stem density of trees. The model for the newt's terrestrial stage contained six variables: (a) percent tree canopy closure, (b) percent of trees that are deciduous species, (c) percent of trees ≤19.1 cm dbh, (d) percent herbaceous canopy cover, (e) distance to permanent water, and (f) percent of area covered by standing water during average April-to-September conditions.

Data for 1000 hypothetical field sites were produced by generating uniform random numbers within the appropriate range for each habitat variable in the three models. HSI values for each site were calculated with both the original and simplified models. Random numbers and statistical analyses were produced with SYSTAT software (SYSTAT, Inc., Evanston, Illinois, USA) on a microcomputer.

For the red-backed vole model, the difference between HSI values produced by the original and discrete versions (simplified HSI minus original HSI) ranged from −0.298 to 0.451 and averaged 0.007 (Table 2). Because the distribution of differences was significantly skewed ($P < 0.01$), a confidence interval was determined by truncating the tails of the distribution. Thus, for 90% of the sites, the discrete model produced an HSI value within 0.200 of that produced by the original model (Table 2). The correlation between the original and modified HSI values was $r = 0.929$.

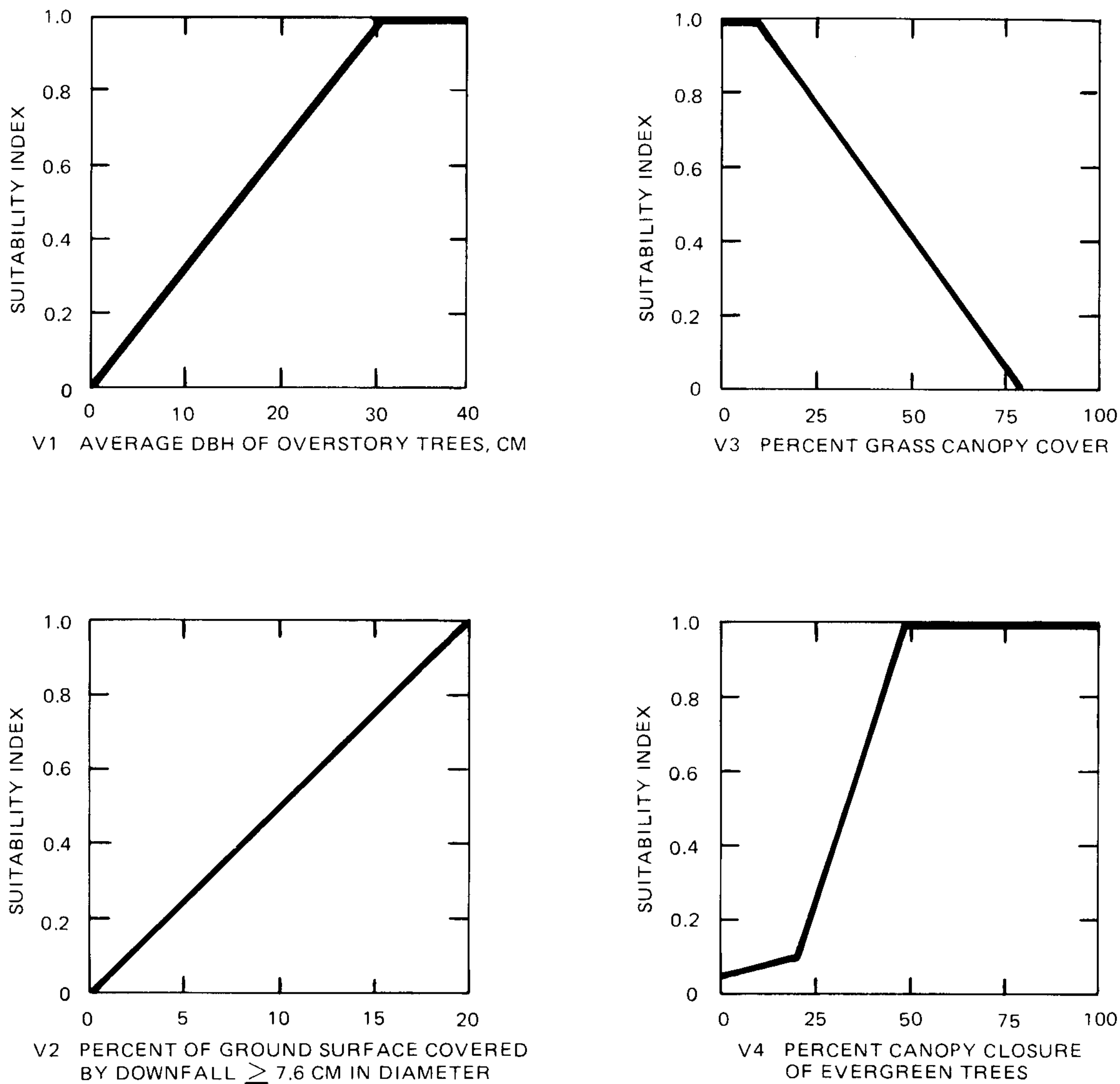

Figure 2. Suitability index curves contained in the HSI model for the southern red-backed vole (Allen 1983).

Simplified models for the woodcock and newt performed similarly. Confidence limits on the difference between HSI values produced by the simplified and original models ranged from −0.100 to 0.140 for the woodcock and from −0.078 to 0.135 for the newt (Table 2).

To determine the best numeric scores to assign to habitat suitability ratings produced by a discrete model, various scores were tried in each of the three models. For habitats of "low" suitability, numeric scores of 0.1, 0.2, 0.3, and 0.4 were tested. Scores of 0.8, 0.9, and 1.0 were tried for suitability ratings of "high". The values used in the examples above (0.2 for "low", 0.9 for "high") produced the best agreement between HSIs predicted by the discrete and original versions of the models.

Many HSI models are very sensitive to zero values for the suitability indices. Models with equations that contain products and geometric means return HSIs of zero whenever any one of the component SI values is zero. Therefore, it is important in developing a discrete HSI model that unsuitable values for any variable be given a numeric score of 0.

Discussion

The advantage of HSI models with discrete variables is that they require much less sampling effort than the original models. It is not necessary to estimate the value of each habitat variable, only to determine

Table 2. Comparison of HSI values produced with original and modified models for three species.

	Species		
	Red-backed vole	American woodcock	Red-spotted newt
Number of variables	4	4	6
Sample size	1000	1000	1000
Difference between HSI values (modified HSI − original HSI)			
Mean	0.007	−0.012	0.013
Range	−0.298–0.451	−0.393–0.400	−0.275–0.441
Standard deviation	0.111	0.083	0.069
Skewness	0.289[a]	1.299[a]	1.810[a]
90% confidence interval	−0.190–0.200	−0.100–0.140	−0.078–0.135
Correlation coefficient (r)	0.929	0.964	0.865

[a] $P < 0.01$.

into which category it falls. Detailed field measurements are therefore unnecessary, except to resolve borderline cases. Visual estimates of habitat variables are sufficient whenever the value of a variable clearly falls within a particular category.

Simplified models are advantageous only when they reduce sampling effort. If it is not possible to estimate a variable visually (for instance, dissolved oxygen) it will not help much to simplify its suitability curve. However, a single model can contain both discrete and continuous suitability functions for different variables.

A modified model will mimic the original model even more closely if more than three suitability levels are used. For example, a four-level version of the vole model with suitability categories of zero (SI = 0), low ($0 < SI < 0.33$), medium ($0.33 \leq SI < 0.67$), and high ($SI \geq 0.67$), and arbitrarily assigned suitability scores of 0, 0.2, 0.5, and 0.9, respectively, produced HSI values that differed from those of the original model by an average of 0.002 with a 90% confidence interval between −0.133 and 0.137 (range −0.200 to 0.254). Although the performance of this modified model was better than that of the three-level version presented earlier, it may be more difficult and time-consuming to use because of the increased number of borderline cases requiring additional sampling to resolve.

The question of how close is close enough for agreement between the simplified and original model must be decided by the user in light of his or her objectives and the consequences of error. Table 2 indicates that, in a small percentage of cases, differences can be quite large. Therefore, simplified models are not recommended for applications involving particularly valuable resources, such as management of rare species, or for determining mitigation needs on large construction projects.

Simplified models are most useful when a rapid habitat evaluation is desired. They can provide guidance in planning wildlife-management activities, and can serve as the basis for habitat inventories or monitoring programs, whenever a low-resolution result will do. Furthermore, simplified models can be used in extensive study areas where the amount of sampling required with the original models would be prohibitive. In environmental impact assessments, simplified models may be appropriate: (a) when there are limited personnel, time, or funds; (b) when anticipated impacts are minimal; or (c) when the resources involved are ubiquitous or of low priority (Wakeley and O'Neil 1988).

To evaluate the performance of simplified HSI models, their output was compared with that of the original models. This approach, however, is not equivalent to a test of a model's accuracy in predicting the quality of habitat for a species. A model can be tested by comparing its output to a standard that is thought to reflect habitat quality in the area where it is to be used. Potential standards of comparison include long-term population sizes, measurements of habitat use by individual animals, and reproductive rates or other indicators of animal well-being (Schamberger and O'Neil 1986). If the original model has been tested and found to be accurate, further testing of a simplified version may be unnecessary. However, discrete versions of untested originals should be tested before they are used to guide important land-use decisions.

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