A Test Of Habitat Suitability Index Models For Five Bird Species

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Abstract: Habitat Suitability Index (HSI) models for 5 bird species were tested with spatially-referenced habitat and frequency of use data using a computerized grid-cell mapping system (SYMAP) and the Statistical Analysis System (SAS). According to our spatial approach for testing, pine (*Dendroica pinus*) and prairie warbler (*D. discolor*) models performed well—better than those for eastern bluebirds (*Sialia sialis*) or red-cockaded (*Picoides borealis*) and pileated woodpeckers (*Dryocopus pileatus*); however, the poor performance of the latter models was probably due more to the testing paradigm and/or to a low number of observed birds than to the models themselves. Models should be tested at scales commensurate with home ranges over an appropriate range of habitat suitability.

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Use of quantitative methods to evaluate consequences of management alternatives or impacts associated with changes in land use is essential in light of current legislation and regulations (e.g., Fish and Wildlife Coordination Act of 1934, National Environmental Policy Act of 1969, and National Forest Management Act of 1976). Integral to quantitative methods of habitat evaluation are species-habitat relationship models, many of which have been developed by biologists in various agencies (e.g., U.S. Army Corps of Engineers 1980; U.S. Department of Interior, Fish and Wildlife Service 1980). Although these models can be constructed, validating their performance is an essential prerequisite to successful application. Objectives of this study were to take existing species-habitat models, apply them within time and manpower constraints typical of many evaluation efforts, and test their performance.

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Methods

A 572-ha study site was selected on the Croatan National Forest in the Coastal Plain of eastern North Carolina. The site contained a diversity of habitat types including bottomland hardwoods, mixed pine-hardwoods, shrub swamps, and southern yellow pine stands (*Pinus taeda, P. palustris, P. serotina*). Pine types comprised age classes from clearcuts to mature stands with dense to open understories, snags, and remnant old-age pines. Roads bordered all but the north side of the study area, facilitating establishment of the sampling grid.

Species-Habitat Models

Most species-habitat relationships models use key habitat variables that quantify the capability of land areas to meet the life requisites of wildlife species. Life requisites include food, cover, water, and if necessary, special habitat components for reproduction or other activities (U.S. Dep. Int., Fish and Wildl. Serv. 1980). Habitat variables often are ranked on a 0.0 to 1.0 dimensionless scale and combined in functions to estimate a Suitability Index (SI) for each life requisite. SIs for a species can be combined in a Habitat Suitability Index (HSI) function to estimate habitat quality. Values near 1.0 represent excellent habitat quality and those near 0.0 represent poor habitat.

Five bird species (prairie warbler, pine warbler, eastern bluebird, red-cockaded woodpecker, and pileated woodpecker) were selected for model testing because they represent species of concern for the U.S. Department of Agriculture, Forest Service (FS), they use a variety of habitat types, and species-habitat models were available from the U.S. Department of the Interior, Fish and Wildlife Service (FWS) or the FS (Sheffield 1981; Schroeder 1982, 1983). Each model was reviewed and, when necessary, adapted slightly to conditions on the study area. Modifications were based on Habitat Evaluation Procedures (HEP) guidelines (U.S. Dep. Int., Fish and Wildl. Serv. 1980), published literature, and personal communication with species "experts."

Field Data Collection

Habitat and census data were recorded on 67 of 81 points at the intersections of 305-m grid lines transecting the study area. Inaccessible points due to impenetrably dense vegetation were not sampled. Habitat data were collected from 17–23 March 1983, by field technicians trained together for 1 day to reduce observer variability. At each sample point 0.04-ha circular plots were installed to estimate average dbh, percent cover, and downed logs per 0.04 ha. Percent cover for herbaceous vegetation, shrubs, and canopy trees and the percent of snags with broken tops were measured at plot center to the nearest 25%—a precision commensurate with the SI graphs used in the HSI models. Tree canopy covers for pine and hardwood were estimated separately. Basal area was estimated using a 10 BAF prism. Forest type and stand age were determined using FS Continuous Inventory of Stand Condition (CISC) data. The distance to openings >0.4 ha was measured from U.S. Geological Survey quadrangle maps.

Variable-radius, circular plots (Anderson and Pospahala 1970, Reynolds et al. 1980) were used to estimate the density of large trees or snags. A sighting function was developed to represent the probability of observing a tree or snag at a given distance from plot center. A sharp decrease in sighting probability defined the effective sighting distance, and the area under the curve of the sighting function was used to estimate the proportion of trees or snags missed.

Bird census data were taken twice at each sample point by recording the number of birds by species heard calling at any distance during a 5-minute period between 0600 and 1030 EST on 17–23 March and 6–18 April 1983. The survey probably recorded both breeding and transient individuals. Sampling intensity and timing was designed to measure relative abundance and to mimic application of these models within reasonable operational constraints of wildlife agencies. It was assumed that birds of a given species could be heard up to the same maximum distance regardless of habitat type. To avoid counting the same individual more than once, only birds heard in different directions or at different distances were recorded. Relative frequency (birds/sample point) by species was estimated by the average number of birds heard at each sample point. Occurrence was defined as the presence of a species (i.e., relative frequency >0.0) at a given grid cell.

Data Analysis

The SAS statistical package (SAS Institute, Cary, N.C.) and the SYMAP grid-cell mapping system (Dougenik and Sheehan 1979) were used to solve species-habitat functions and to display maps of habitat suitability, respectively (Adams 1980, Lancia et al. 1982). Each input package contained a coordinate description of the study area, the coordinates of each sample point location, values for every habitat variable at each sample point, and the program options desired. SYMAP was used to produce contour and proximal maps from the georeferenced data. Proximal maps were used to display the distribution of forest type and stand age, and contour maps were used to show the distribution of habitat variables, habitat suitability, and census data. All maps were based on interpolated data from the 67 sample plots yielding 5,200 grid cells of about 0.11 ha each. The intent of the interpolation was to retain spatially-related information in the data set. It was recognized that this procedure greatly inflates sample sizes and affects the statistical significance of the tests. Output files from SYMAP contained the interpolated values of all grid cells for statistical analysis with SAS. Grid-cell census data and grid-cell habitat suitability data were merged using SAS to test model performance.

The objective of model testing is to determine the relationship of predicted habitat suitability and some measure of actual use of habitat. Ideally, this relationship should be linear and scaled from 0.0 to 1.0, or at least rank ordered from poor to best quality. At the preliminary steps of model development, the least presumptuous test of model performance should be applied first. As modeling becomes more sophisticated, more stringent tests may be appropriate.

A chi-square contingency table analysis for model testing requires only independence among sample units and, therefore, can be an appropriate first test. HSI and relative frequency of use data were separated into quartile groups, i.e., groups determined by dividing the range of observations into 4 equal portions of the total number of observations. A 4 x 4 contingency table then was used to compare respective percentile groups of HSI values and relative frequency. All 5,200 grid cells were used in the contingency table analysis, even though this is likely to result in an inflated chi-square value, in a crude attempt to reflect the spatial arrangement of the sample locations. If a model is 100% accurate, all data should fall along 1 diagonal. Deviations from the diagonal due to low HSI-high use or high HSI-low use represent model failure. Errors of the former appear more serious than the latter. If the habitat is not fully saturated, errors of high HSI-low use may not be relevant to making timely decisions about habitat management. A model may perform adequately for making management decisions if a reasonably small proportion, say 10–20%, of the grid cells fall in the zone of low HSI-high use. Also, *P* values were included without reference to statistical significance so that model users could evaluate for themselves the significance level appropriate for their particular application.

Percent frequency of occurrence of a particular species was determined for each quartile of HSI values (i.e., the percent of grid cells in a given HSI quartile in which a particular species was present) and converted to a density estimate. The frequency-density conversion (Caughley 1977:20) fits a Poisson distribution and assumes all individuals have an equal probability of occurring at each sample point and are equally observable. Clumped distributions lead to underestimates of density with the negative bias increasing at higher densities. Thus, in most cases the conversion provides an underestimate of density.

To evaluate model performance, means of the HSI quartiles were plotted against corresponding density estimates derived from the frequency-density conversions. If the models performed as expected, the relationship should be positive and possibly be linear passing through the origin of the graph.

Results

Habitat

The southern pine type covered approximately 66% of the area, followed by pine-hardwood (13%), longleaf pine-hardwood (7%), and longleaf pine (6%). Four remaining types occupied 8% of the area. Ninety-five percent of the study site was in the 30- to 70-year-old age class. Dominant and codominant canopy trees averaged 33-cm dbh. Basal area for the study site was about 17.5 m^2/ha. Average snag dbh was 15 cm.

Herbaceous vegetation occurred on 49% of the sample plots. Shrubs were dense and prevalent; 75–100% shrub canopy cover characterized about 73% of the sample locations. Tree understory canopies <9 m were relatively sparse as 48% of the plots had no understory cover and 21% had <25%. Tree canopy cover >9 m was better developed with 22% and 36% of the sample plots having 50–75% and 75–100% cover, respectively.

Large pine (>35-cm dbh) and hardwood (>40-cm dbh) densities ranged up to 30/ha, but only 11 sample plots had more than 3 large trees per ha. The density of snags ranged from 0/ha to 68/ha. Only 18% of the plots contained one large snag (>40-cm dbh). The number of downed logs >2.8 cm in diameter ranged up to 28/ha; 37% of the sample plots had up to 3 logs and 54% had none. Distance to openings >0.4 ha was >122 m for 88% of the sample plots.

Habitat Suitability Indices

HSIs for all species ranged form 0.00 to 0.91 with means between 0.10 and 0.49 (Table 1). For the bluebird and pileated woodpecker, both HEP (minimum of geometric SIs) and arithmetic models were evaluted, and the latter yielded higher average and maximum values. The study area was best for pine warblers both in terms of mean HSI and the proportion of the area in good and excellent habitat categories. HSIs for bluebirds and pileated woodpeckers (HEP models) were lowest of the species evaluated.

Bird Census

Pine and prairie warblers were heard most frequently, bluebirds and red-cockaded woodpeckers least frequently, and pileated woodpeckers were intermediate (Table 2).

Model Validation

Prairie Warbler.—The relationship between HSI and density for the prairie warbler was nearly linear ($r^2 = 0.93$, $P = 0.035$) and nearly passed through the

Table 1. Habitat suitability indices and percent of the study area in 5 habitat suitability classes for 5 bird species, Croatan National Forest, 1983.

	HSI		Percent of the Area[a]				
Species	Range	Mean (SD)	Exc	Gd	Fr	Pr	No
Prairie warbler	0.00–0.88	0.35 (0.26)	3	22	36	11	28
Pine warbler	0.00–0.88	0.49 (0.18)	4	48	38	3	7
Eastern bluebird							
HEP	0.00–0.75	0.20 (0.10)	0	1	3	4	92
Arithmetic	0.14–0.91	0.33 (0.10)	2	2	81	15	0
Red-cockaded woodpecker	0.00–0.85	0.30 (0.22)	1	14	59	0	26
Pileated woodpecker							
HEP	0.00–0.76	0.10 (0.19)	1	6	12	16	65
Arithmetic	0.00–0.88	0.28 (0.24)	5	10	39	23	23

[a] Exc = excellent (HSI = 0.76–1.00); Gd = good (HSI = 0.51–0.75); Fr = fair (HSI = 0.26–0.50); Pr = poor (HSI > 0.0–0.25); No = none (HSI = 0.0). Percentages based on 5,200 grid cells.

Table 2. Number of birds heard during 2 spring surveys at 67 sample points, Croatan National Forest, 1983.

Species	Number of Birds Heard	
	Mean (SD)/Point	Percent of Points
Prairie warbler	0.71 (0.71)	64
Pine warbler	1.31 (0.97)	88
Eastern bluebird	0.13 (0.25)	22
Red-cockaded woodpecker	0.07 (0.21)	10
Pileated woodpecker	0.48 (0.54)	58

origin. A relatively large (in relation to those calculated below) and significant chi-square value ($\chi^2 = 290.41$, df = 9, $P < 0.005$) substantiated this relationship. Most of the cells (60%) fell in the zone of near agreement and only 8% fell in the zone of low HSI-high use. Inspection of the HSI and census maps revealed an anomaly at the northern edge of the study area where HSIs were low and many birds were heard. Although it was not done, an advantage of spatially displaying that data is that these discrepancies could be located and re-evaluated.

Pine Warbler.—The HSI-density plot for pine warblers was similar to the plot for prairie warblers ($r^2 = 0.87$, $P = 0.067$). The chi-square analysis was also similar ($\chi^2 = 83.6$, df = 9, $P < 0.005$) although a slightly larger proportion of the cells fell in the zone of near agreement (74%) and less in the zone of low HSI-high use (7%).

Bluebird.—Two models were evaluated: an HEP minimum of geometric SI functions (for food, cover, reproduction, and interspersion) and an arithmetic mean of geometric SI functions. The minimum model yielded zeros for most of the study area because interspersion SI, a measure of the distance to openings >0.4 ha, was almost always zero, hence the minimum SI for most cells was zero. The arithmetic model averaged interspersion with other life requisites resulting in a reduced number of zero cells. However, which is more accurate biologically remains to be answered.

The density-HSI plot revealed no apparent relationship between HSIs and density. Relative frequencies were less than 0.13 birds/point, and the range of HSI-quartile means was 0.0 to 0.14 and 0.25 to 0.44 for the minimum and arithmetic models, respectively. Thus, the range of values was too narrow for a reasonable test of the models. Contingency table analysis was not considered meaningful because of too few nonzero data.

Red-cockaded Woodpecker.—Because of a small number of nonzero HSI values and relative frequencies, the density-HSI plot and contingency table tests were not considered appropriate, and model performance was evaluated subjectively by inspecting HSI and census maps. Foraging and reproduction SI components of the HSI were treated separately. Observations of birds were compared with predicted foraging habitat and colony site locations with predicted reproduction habitat. Birds were observed only in areas predicted to be excellent foraging habitat; no birds were observed in poor quality foraging habitat. Evaluation of the reproduction SI revealed no predicted reproduction habitat where 2 colonies were located.

Pileated Woodpecker.—The HSI-density plot for both the HEP and arithmetic models indicated no relationship between the variables, in fact the highest HSI quartile had the lowest relative frequency. The contingency table analysis was similar with a comparatively low, in relation to the values above, chi-square ($\chi^2 = 50.6$, df = 9, $P < 0.005$). Only 49.2% of the grid cells fell in the zone of near agreement. Although only 10.7% of the cells fell in the zone of low HSI-high use, this was probably an artifact of a low number of bird observations.

Discussion

Using this approach to model testing, the prairie and pine warbler models performed best of the 5 models. Apparently, models can be developed and refined to a sophistication required for management decisions for species that are abundant, have relatively small home ranges (territories), and have easily identified and specific habitat requirements. For less common species or species with large home ranges, other approaches to model testing such as intensity of use (Lancia et al. 1982) may be warranted. The bluebird models could not be tested adequately because the range of HSI values was too narrow and the population of birds too sparse. Other areas with a wider array of habitat conditions and population densities would be necessary to test the models. The rarity of red-cockaded woodpeckers also prohibited adequate model testing; however, observations of foraging birds suggested that major factors comprising foraging habitat were identified. The failure to identify potential reproduction habitat where colony sites were located probably indicated that the 305-m sampling grid was too large to reliably locate colony sites. Harlow et al. (1983) found that 460 m represented the extreme distance between 2 cavity trees in 90% of 30 colonies that they studied. Finally, the pileated woodpecker model probably did not work well because habitat conditions and woodpecker populations were investigated on incommensurable scales for correlation. The sample grid was small relative to woodpecker territories and to the volume of their vocalizations such that birds were heard from locations bearing no relation to habitat conditions at sample plots. Recording birds heard within a fixed distance commensurate with the scale of the habitat data should alleviate this problem.

Geometric means were commonly used and, in most cases, yielded plausible results. However, if zeros were present in a geometric function because of an inability to detect rare habitat features like snags rather than a true absence, then an arithmetic mean function may provide more reasonable results. For example, based on our sighting functions as many as 58% of the snags present were not recorded in our samples. Therefore, some snags may have been present when we recorded none. In these cases the geometric mean would weight the absence of snags too heavily.

In conclusion, we must stress that these tests are only a crude initial attempt to evaluate HSI models, and our results are as dependent on the appropriateness of the tests as the quality of the models themselves. Further work developing meaningful test paradigms and improving models with feedback from test results is essential.

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