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A VERIFIED HABITAT SUITABILITY INDEX FOR THE LOUISIANA WATERTHRUSH

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Abstract.—We developed and tested a Habitat Suitability Index (HSI) for the Louisiana Waterthrush (*Seiurus motacilla*; LOWA). The model was created based on existing literature and verified using presence data within central Pennsylvania. Our LOWA HSI, based on the United States Fish and Wildlife Service (USFWS) Habitat Evaluation Procedures (HEP) format, consists of eight variables including cover, food, and nesting factors. Model variables include measures of canopy cover; shrub cover and height; ratio of deciduous to coniferous cover; herbaceous cover and height; stream order and microtopography; stream clarity and substrate, presence of overturned root masses; stream bank slope and cover type; and landscape classification. Three independent data sets were used to test our model. Two data sets (T_1 and T_2) included sites characterizing a range of habitat conditions; the third set of data (T_3) focused on good to optimal LOWA nesting habitat. Median HSI values were significantly higher on sites occupied by LOWA for T_1 (0.80 and 0.67, sites with LOWA presence and absence, respectively) and T_2 (0.76 and 0.23). HSI scores for T_1 and T_2 spanned across the 0–1 scale (0.13–1.0, and 0.04–0.89, respectively). HSI values for T_3 were not significantly higher in relation to presence or absence of LOWA (median HSI scores 0.93 and 0.88, respectively). Based on the model's performance and field observations, LOWA show a strong preference for unpolluted, headwater streams and their associated wetlands occurring in contiguous forest.

UN ÍNDICE VERIFICABLE DE ADECUACIÓN DE HABITAT PARA *SEIURUS MOTACILLA*

Sinopsis.—Desarrollamos y probamos un "Indice de Adecuación de Habitat" (HSI) para *Seiurus motacilla* (LOWA). El modelo fué creado utilizando la literatura existente y verificado utilizando los datos existentes en el centro de Pennsylvania. Nuestro HSI para LOWA, basado en el formato del "Procedimiento de Evaluación de Habitats" (HEP) del "Servicio Federal de Pesca y Vida Silvestre" (USFWS), consiste de ocho variables que incluyen covertura, alimento y anidaje como factores. Las variables del modelo incluyen medidas de cubierta y altura del dosel, razón de cubierta decidua a conifera, cobertura herbácea y su altura, orden y microtopograña de las quebradas, claridad y sustrato de las quebradas, presencia de masas de raices volcadas, pendiente de banco del rio, y clasificación del panorama. Se utilizaron tres groups independientes de datos para probar nuestro modelo. Dos grupos de datos (T_1 y T_2) incluian lugares caracterizando una variedad de condiciones de hábitat; el tercer paquete de datos tenia hábitat entre bueno y óptimo para el anidaje de LOWA. Valores medios de HSI fueron significativamente mayores en localidades ocupadas por LOWA en T_1 (0.80 y 0.67, lugares con presencia y ausencia de LOWA respectivamente) y T_1(0.76 y 0.23). Los resultados de HSI para T_1 y T_2 se extendieron a través de la escala de 0 a 1 (0.13–1.0, y 0.04–0.89, respectivamente). Los resultados de HSI para T_3 no fueron significativamente altos en relación a la presencia o ausencia de LOWA (los resultados medios de HSI son 0.93 y 0.88, respectivamente). En base a la labor del modelo y a las observaciones de campo, LOWA muestra una fuerte preferencia por quebradas principales no contaminadas y sus anegados asociados ocurrentes en los bosques contiguos.

Habitat Suitability Index (HSI) models provide an efficient and inexpensive method for determining habitat quality (Schamberger et al. 1982). HSI scores quantify the potential of a habitat for a given species, with a score between 0 and 1 depicting unsuitable to optimal structural conditions. HSI models, employed by land managers, consultants, and other natural resource professionals, are the most widely used rapid assessment protocols for wildlife habitat (Brooks 1997, Cole and Smith 1983). Common uses include estimating the quality of breeding habitat for wildlife species, simulating effects of habitat alteration, and most commonly, mitigating replacement habitat for large development projects.

Despite their widespread use, HSI models can be justified only if they provide reliable predictions of habitat quality. There are over 150 published HSI models in use, yet few have been tested (Schamberger et al. 1982). Methods of model testing include calibration, verification, and validation (Brooks 1997). After development, models may be calibrated using qualitative data. A model can be ranked on a spectrum of site conditions, ranging from unsuitable to optimal. If the model is sensitive to these conditions, then model output should span from near 0 to 1. If not, the model equation should be examined and refined, followed by recalibration. HSI models are verified by comparing model scores with quantitative presence data. This method of testing is preferred over calibration, however, it is more expensive to perform. Validation of models require testing the model against population measures such as density or reproductive success. Validated models offer the most reliable and perhaps meaningful indices, however, these are rarely completed due to high cost (Schamberber and O'Neil 1986).

The objectives of this study were to develop a HSI for the Louisiana Waterthrush (*Seiurus motacilla*), an indicator species of high quality, forest riparian habitats; and to test the model's ability to predict habitat suitability using presence data.

METHODS

Model development.—Development of the Louisiana Waterthrush (LOWA) HSI followed typical procedures (U.S. Fish and Wildl. Serv. 1980). The model, based on standard life requisites (cover, food, and nesting factors) was developed from a review of the literature. The full model, including methods for scoring habitat variables, is presented in the Appendix.

Model testing.—The completed model was tested using three independent sets of data. The initial two field tests were designed to test the original model on the full range of possible habitat conditions (T_1), and to determine if similar results would be obtained using independent observers and slightly different LOWA census methods (T_2). The third test (T_3) focused on optimal Louisiana Waterthrush habitat, testing the model's sensitivity to high-quality sites. Each test required ranking the model on a number of sites, collecting LOWA presence or absence data for each site, and comparing the model scores with the occurrence data. Within each test group, sites were grouped based on presence or absence of LOWA. Nonparametric statistics were used because the data violated assumptions of normality. One-tailed Mann-Whitney tests were used to test the hypothesis that HSI scores of occupied sites were higher than unoccupied sites (Noether 1991).

Site selection.—All sites were located within the Ridge and Valley Province or Appalachian Plateau Province (Blair, Centre, Huntingdon, and Union counties), two regions of Pennsylvania where the LOWA is found most commonly (Brauning 1992). Sites were restricted to areas containing first to third order streams, because LOWA typically depend on headwater riparian areas for feeding and nesting (Bent 1953, Eaton 1958).

To determine if the model was sensitive to surrounding disturbance levels, the first two groups of sites were selected to represent varying land cover and land use patterns (T_1 and T_2, Table 1). The extremes of undisturbed to disturbed habitat ranged from sites surrounded by forest cover ≥350 ha to sites dominated by agriculture or urbanization. A full range of HSI values were expected if the model was sensitive to landscape conditions. Because HSI models are designed to be used by many resource professionals, we included data from T_2 to explore how the model would react under similar site conditions, but with different observers ranking the model (T_2, Table 1). The third data set was designed to test the model on good to optimal nesting LOWA habitat. Preferred habitat was chosen to include sites where first to third order streams occurred within interior forest.

Louisiana Waterthrush surveys.—LOWA presence surveys for T_1 and T_2 were conducted from 12 May–27 Jun. 1994; T_3 surveys were conducted from 21 Apr.–7 Jun. 1995. A 10-min point count was conducted for LOWA on the center of each site, within 4 h of sunrise. LOWA survey areas for T_1 and T_3 were defined by 400 × 30-m rectangles aligned parallel with and centered on each stream. Observers walked a 200-m transect, conducted a 10-min point count, then continued another 200 m to the end of the 400-m site. Detection of LOWA within site boundaries using these census methods were recorded as presence of Louisiana Waterthrush. Size and shape of these sites were based on typical LOWA breeding territories (Bent 1953, Craig 1984). T_2 surveys consisted of one standard unlimited radius point count per site centered on the stream (Bibby et al. 1992, Ralph et al. 1995).

Presence of LOWA was determined by auditory or visual detection. If no individuals were detected, male LOWA vocalizations were broadcasted for 85 s using a hand-held tape player. Response of LOWA to the taped songs was noted as presence at that site. The tape was not audible beyond 200 m, reducing the possibility of attracting LOWA from adjacent sites.

Scoring of sites.—HSI models for several species are typically applied to overall site conditions rather than plots defined by set areas. Only the relevant habitat requirements outlined by the model are assessed. For each model variable, observers integrate habitat conditions for the target species over the site, and independently assign a score. If their scores differ by more than 0.3 units, that variable is reevaluated and reconciled to a lesser difference.

For our study, the HSI was ranked on sites of defined areas, within the

TABLE 1. Sample size, hypothesis, site type, and methods used for tests of the Habitat Suitability Index model developed for the Louisiana Waterthrush.

Test group	*n*	Site type	Site boundaries	LOWA survey methods	Taped male vocalizations played	HSI[a] scored by
T_1	53	range of conditions	400 × 30 m	fixed area point count and transect	yes	Team A
T_2	26	range of conditions	30-m radius	unlimited radius point count	no	Team B
T_3	17	optimal habitat	400 × 30 m	fixed area point count and transect	yes	Team A

[a] Team A: Brooks and Prosser; Team B: Gaudette and O'Connell.

TABLE 2. Median values and ranges for three data sets of LOWA presence or absence in stream habitats of Central Pennsylvania.

Test group	n	Louisiana Waterthrush Present	Louisiana Waterthrush Absent	P
T_1	53	0.80 (0.60–1.0)	0.67 (0.13–0.99)	0.009
T_2	26	0.76 (0.57–0.89)	0.23 (0.04–0.83)	0.009
T_3	17	0.93 (0.73–1.0)	0.88 (0.45–0.99)	0.142

LOWA survey dates. Habitat variables were scored for representative conditions within the site. T_1 and T_3 sites were ranked on the same 400 × 30-m rectangles where LOWA surveys were conducted. T_2 sites were ranked on 30-m radius circles centered on the LOWA census points.

The habitat model for the Louisiana Waterthrush consisted of eight variables within four categories: cover, food, nest requirements, and landscape classification (Appendix). HSI values were calculated by summing the averages of the three life requisite factors: cover, food, and nesting, dividing by three, and multiplying by the landscape variable (Variable 8). The landscape classification variable, not typically found within standard HEP models, was included to safeguard against a small patch of suitable habitat surrounded by an unsuitable matrix receiving a high HSI value. Variable 8 was weighted in the overall HSI determination equation (Appendix). Sensitivity tests were run with simulated numbers to determine the effects habitat versus landscape measures (Variables 1–7 and Variable 8, respectively) on the overall HSI score.

RESULTS

Median HSI values were higher on sites with LOWA presence for all three tests, and statistically significant for T_1 and T_2 (Table 2). Habitat scores for each test reflected the range of habitat conditions as defined in the Methods section (Table 1). T_1 and T_2 scores ranged from 0.13–1.0 and 0.04–0.89, reflecting the full range of unsuitable to optimal LOWA habitat. T_3 scores ranged from 0.45–1.0, as might be expected for study sites chosen to represent good to optimal LOWA nesting habitat. The model given in the Appendix is the final, verified model for the Louisiana Waterthrush.

Sensitivity calculations comparing habitat and landscape variables show that the effect of each was high enough to influence the other in the overall HSI score. A high combined score for Variables 1–7 may be reduced in the final equation by a low landscape score (Variable 8), and visa versa. A high score of 1 will not increase the overall HSI if the other is low.

DISCUSSION

A number of caveats must be recognized when using HSIs to make decisions about wildlife species. The first is to acknowledge that the majority of existing models have never been tested. Decisions based on information gathered from untested models should be made with caution. HSIs are designed solely to measure habitat potential, not predict population characteristics such as abundance, density, or survivorship. Such models do not consider external pressures such as competition, predation, weather, and disease (Schamberger and O'Neil 1986).

Some verified or validated avian HSIs have tested better than others (e.g., Clark and Lewis 1983, Conway and Martin 1993, Lancia and Adams 1985, Sousa 1983). Both the method and the level of testing differ among models. An optimal level of testing involves a multiple-year study comparing reproductive success with HSI values, but this is an expensive process and, therefore, may not be realistic. Although model testers commonly acknowledge that HSIs can always be improved, these types of rapid assessment indices are one of the few efficient and inexpensive methods available to natural resource managers.

Our HSI for the Louisiana Waterthrush is proficient in predicting habitat potential. This model was developed for use during the breeding season, within the Mid-Atlantic states of the U.S.A. The model is restricted for use in areas containing first to third order streams. We recommend that at least a calibration test be conducted if the model is applied to areas outside of the Mid-Atlantic region.

Although our LOWA census dates incorporated a portion of May and June, we recommend that individuals interested in calibrating the HSI conduct surveys between mid-Apr. to mid-May, depending on their geographic location. Louisiana Waterthrush, one of the earliest spring migrants, typically return to 40°N latitude within the first week of April (Bent 1953, Eaton 1958). At this time males sing vigorously until a mate is found. Frequency of male vocalization decreases substantially after pairs are formed and females begin incubation (Eaton 1958, Robinson 1995). We have found that LOWA may still be detected on their territories during this time by listening for their sharp call notes and other less obvious clues. Clearly this method is not as reliable as frequent male singing, and may be indiscernible by individuals not familiar with LOWA vocalizations.

Our census dates overlap LOWA incubation periods, and although we believe that we are familiar with Louisiana Waterthrush vocalizations, error in presence counts are possible both by missing LOWA that were present on a site, as well as recording presence of LOWA when an unmated male continuously sang throughout the summer.

The LOWA selects headwater streams and wetlands of high water quality and well developed pool and riffle complexes. LOWA prefer a landscape component composed of large blocks of interior forest where herbaceous cover is sparse and shrub cover is moderate to sparse. Fallen trees with exposed root masses and riparian banks with abundant crevices are preferred nest sites. The species was absent in highly fragmented landscapes and where sediments from agricultural and urban lands have negatively affected water quality and stream substrates. Thus, the occurrence of LOWA during the breeding season is an indicator of a habitat condition consisting of relatively pristine, headwater streams in extensive unfragmented forests. Such habitats can be readily detected using this HSI model.

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APPENDIX

Habitat Suitability Index
Louisiana Waterthrush (*Seiurus motacilla*)

Model applicability.—This model was developed for use in Pennsylvania, and the surrounding Mid-Atlantic states, of the United States of America. This model is restricted to habitat containing first to third order streams. The model is designed to be used during spring and mid-summer, the breeding season of the Louisiana Waterthrush (LOWA).

Cover types.—During the breeding season, LOWA mainly use riparian areas of headwater streams. Stream size ranges from first to third order, containing well developed riffle and pool sections as well as slower moving, backwater areas. Preferred cover consists of mixed deciduous and coniferous interior forest. Ground cover includes forbs, moss, ferns, and hummocks (Craig 1984). LOWA may also be found in river swamps and slow-moving streams (Eaton 1958).

Habitat requirements.—A typical territory includes the riparian area along a 400-m stream reach (Eaton 1958). Optimal forest area (maximum probability of occurrence) is 3000+ ha (Robbins et al. 1989), and the suggested minimum area for breeding (50% of maximum probability of occurrence) ranges between 184 ha and 250 ha (Robbins et al. 1989).

Range.—Breeding occurs in Minnesota, Ontario, and central New England, south to Georgia and Texas. LOWA winter in Mexico and the West Indies to Northern South America (Price et al. 1995). In Pennsylvania LOWA commonly breed in the Appalachian Plateau, Ridge and Valley, Pittsburgh Plateau, and Piedmont Regions (Gross 1992).

Breeding/Nesting.—Territories are established in April and May. Young are hatched and raised in Jun. and Jul. Nests are usually built in the banks of streams, or in upturned roots of fallen trees (Ehrlich et al. 1988, Harrison 1975).

Feeding.—LOWA often feed on aquatic insect larvae such as caddis flies (Trichoptera), centipedes (Chilopoda), and snails (Gastropoda). During aquatic feeding, their most frequent feeding behavior, LOWA feed upon submerged and floating organisms while walking along rocks, logs, branches and the water's edge. While ground feeding, they feed upon prey in the mud, under leaf litter, and on rocks and moss. They feed less commonly on woody plants by picking prey from foliage and stems (Craig 1985, 1987, Eaton 1958).

Below are eight habitat variables and their suitability index scores (SI). An equation for combining variable scores into the overall HSI output is included at the end of the model. Variable SI's may be interpolated if non-continuous values are offered and intermediate habitat conditions exist.

COVER

VARIABLE 1. Visual estimate of percent canopy cover within the site.

Forest cover	SI score
>80%	1.0
60–80%	0.7
40–59%	0.2
<40%	0.0

VARIABLE 2. Visual estimate of percent shrub cover within site.

	Shrub cover		
Shrub height	Dense (≥75%)	Moderate (24–74%)	Sparse (≤25%)
≥0–1.5 m	0.1	0.3	0.5
>1.5 m	0.4	1.0	0.8

VARIABLE 3. Ratio of deciduous to coniferous overstory cover[a].

Deciduous cover	SI score
0–29%	0.5
30–69%	1.0
70–100%	0.5

[a] If total forest cover (deciduous and coniferous) is <40%, then V3 = 0.

VARIABLE 4. Herbaceous cover and height.

	Herbaceous cover		
Height	Dense (≥75%)	Moderate (24–74%)	Sparse (≤25%)
>20 cm	0.0	0.3	1.0
5–20 cm	0.3	0.7	1.0
<5 cm	0.7	1.0	1.0

If habitat has more than one herbaceous type, choose the higher SI (as long as it constitutes ≥⅓ of the area being evaluated).

FOOD

VARIABLE 5. Stream order and microtopography.

Stream order and microtopography	SI
First or second order stream; well developed pool and riffle areas.	1.0
First or second order stream; steep topography, continuous rapid/ riffle or straight channel (run), flat water.	0.7
Third order stream comprised mostly of riffles and pools.	0.5
Third order stream (mostly run), or greater than 3rd order.	0.2

VARIABLE 6. Stream clarity and substrate.

	Coarse or sandy substate	Fine substrate
Clear	1.0	0.5
Turbid	0.5	0.0

NESTING

VARIABLE 7a. Presence of fallen trees (>5 cm dbh) within 50 m of stream (with appropriate root mass as defined in introductory section).

yes	1.0
no	see 7b.

note: if Variable 7a. is yes, then SI = 1; if Variable 7a. is no, then SI = Variable 7b.

VARIABLE 7b. Stream bank slope and cover type.

	Slope		
Substrate	Overhanging/ steep >60°	Moderate 30–60°	Gentle <30°
Mix of soil, roots, and rocks; forming crevices	1.0	1.0	0.7
>75% rock	0.1	0.1	0.1
>70% herbaceous material	0.1	0.1	0.1

If a section of stream bank or one side of the stream has more than one habitat type, count the higher score.

GENERAL MODIFIER

VARIABLE 8. Landscape classification.[a]

Surrounding landscape	SI
Large, interior forest (>350 ha)	1.0
Within 100 m of edge of large, interior forest, but within the forest	0.8
Shrubland/highly fragmented forest	0.5
Emergent wetland, or agricultural field, or open water	0.2
Urban	0.0

[a] Assessed for an area of 350 ha around each site, using ground reconnaissance or aerial photographs.

HSI Determination:

Cover SI = (V1 + V2 + V3 + V4)/4; Food SI = (V5 + V6)/2; Nesting SI = V7.

$$\text{HSI output} = \frac{(\text{Cover SI} + \text{Food SI} + \text{Nesting SI})}{3} \times \text{V8}$$