A TEST OF THE HABITAT SUITABILITY MODEL FOR MERRIAM'S WILD TURKEYS

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Abstract: An important research area regarding the wild turkey *(Meleagris gallopavo)* is development of sound habitat models. Habitat models provide standardized methods to quantify wild turkey habitat and stimulate new research hypotheses. Habitat suitability index (HSI) models show species-habitat relationships on a scale of O-l, with 1 being optimum. A proposed HSI model for Merriam's turkeys *(M. g. merriami)* was applied to data we collected at Merriam's turkey locations and random sites in the Black Hills, South Dakota. We tested this model, assuming that if all available habitats were suitable for turkeys, HSIs of random sites should not exceed those of turkey locations. Several variables and one component of the proposed model had higher HSIs from random sites than from turkey locations. The overall HSI from the Lindzey-Suchy (L-S) model suggested low habitat suitability for an area with an abundant and productive turkey population. We propose a revised HSI model that contains winter and summer brood components. Optimum values for some variables of our model are similar to those from other subspecies of wild turkeys.

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Key words: habitat suitability, Merriam's turkey, models, model testing.

Modeling wild turkey habitat is a procedure to quantify and synthesize habitat relationships. (*L. Flake*)

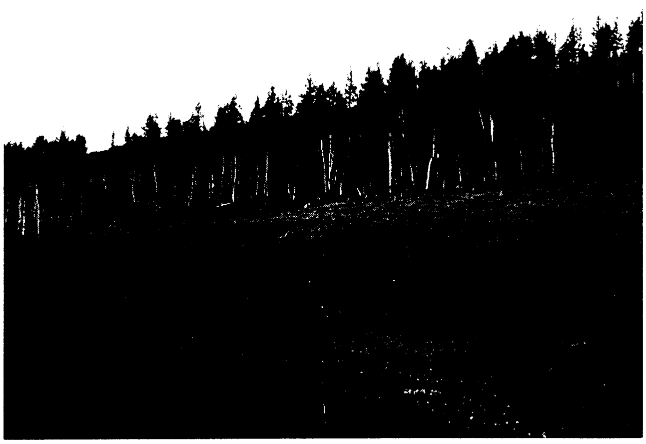
There is great need for a generalized theory of turkey habitat selection and the development of models that direct management and evaluate landscapes for wild turkeys (Healy 1990). Habitat models provide biologists with tools to examine wildlife habitat requirements and habitat quality. Economically and socially important management decisions affecting wildlife and wildlife habitats are often based on models (Schamberger and O'Neil 1986; O'Neil et al. 1988). Habitat models also provide hypotheses of species-habitat interactions. Research to test these hypotheses and assess mechanisms of habitat selection processes are by-products of habitat models. However, wildlife habitat models have shortcomings (e.g., Van Horne 1983).

Habitat suitability index (HSI) models provide a numerical index of habitat quality for species (Schamberger et al. 1982). These models are based on the Fretwell and Lucas (1969) model of habitat selection and assume a positive relationship between carrying capacity and HSI (Schamberger et al. 1982).

A habitat model for eastern turkeys *(M. g. silvestris)* has been developed (Schroeder 1985), but no habitat suitability models have been published for Merriam's turkeys. An unpublished HSI model for Merriam's turkeys was proposed by F. G. Lindzey and W. J. Suchy (U.S. Fish and Wildl. Serv.,

Previously a Habitat Suitability Index Model was devised for the Merriam's turkey. (C. Sieg)

This model was applied to data collected at turkey locations and random sites in the Black Hills. South Dakota. (L. Flake)



A revised Habitat Suitability Index Model that contains winter and summer-brood components is proposed. (L. Flake)

Western Energy and Land Use Team, Fort Collins, CO; unpubl. rep. 1986). The L-S model was developed from literature and has not been tested. Our objective was to test the L-S model and present a revised HSI model based on our research on Merriam's turkeys in the Black Hills, South Dakota.

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METHODS

HSIs represent the relative suitability of habitats (0 is unsuitable and 1 is optimal) (Schamberger et al. 1982) to support Merriam's turkeys. We used the terminology from the L-S model because it also occurs in other HSI models. HSIs are computed for model components (HSI_c) of hypothesized mathematical aggregations for key habitat variables that supply life requisites of the species (U.S. Fish and Wildl. Serv. 1980; Schamberger et al. 1982). Hypothesized HSI_cs for the L-S model are represented by equations 1.1 to 1.3 (Fig. 1). Hypothesized suitability between key habitat variables (HSI_v) that are components of the L-S model is displayed graphically and mathematically (SIV1 to SIV9, Fig. 2). HSI for an area (HSI_a) is the hypothesized carrying capacity of the species. HSI_a of the L-S model is the lowest of the HSI_cs. Table 1 includes a list of abbreviations and definitions used to discuss HSI models in this paper.

We conducted research to determine habitats selected bv Merriam's turkeys from March 1986 to January 1989. Forty-four turkeys (36 females and 8 males) were trapped and fitted with backpack radio transmitters weighing approximately 108 g. The study area boundary was determined by movements of birds (Porter and Church 1987) during the first 2 years of our study. We attempted to obtain one precise location each week for each radio-marked bird that remained in the study area. We

L-S model equations

1.1 Winter food component

$$SIWF = \frac{3\,(SIV1 \times SIV4) + (SIV2 \times SIV3 \times SIV4)}{4}$$

1.2 Cover roost component

$$SICR = (SIV5 \times SIV6)^{1/2} \times SIV7$$

1.3 Brood habitat component

$$SIBH = \frac{SIV8 + \frac{SIV5 + SIV9}{2}}{2}$$

Figure 1. Mathematical relationships among variables to estimate habitat suitability for components of the Lindzey-Suchy (L-S) model. See Table 1 for acronym definitions.

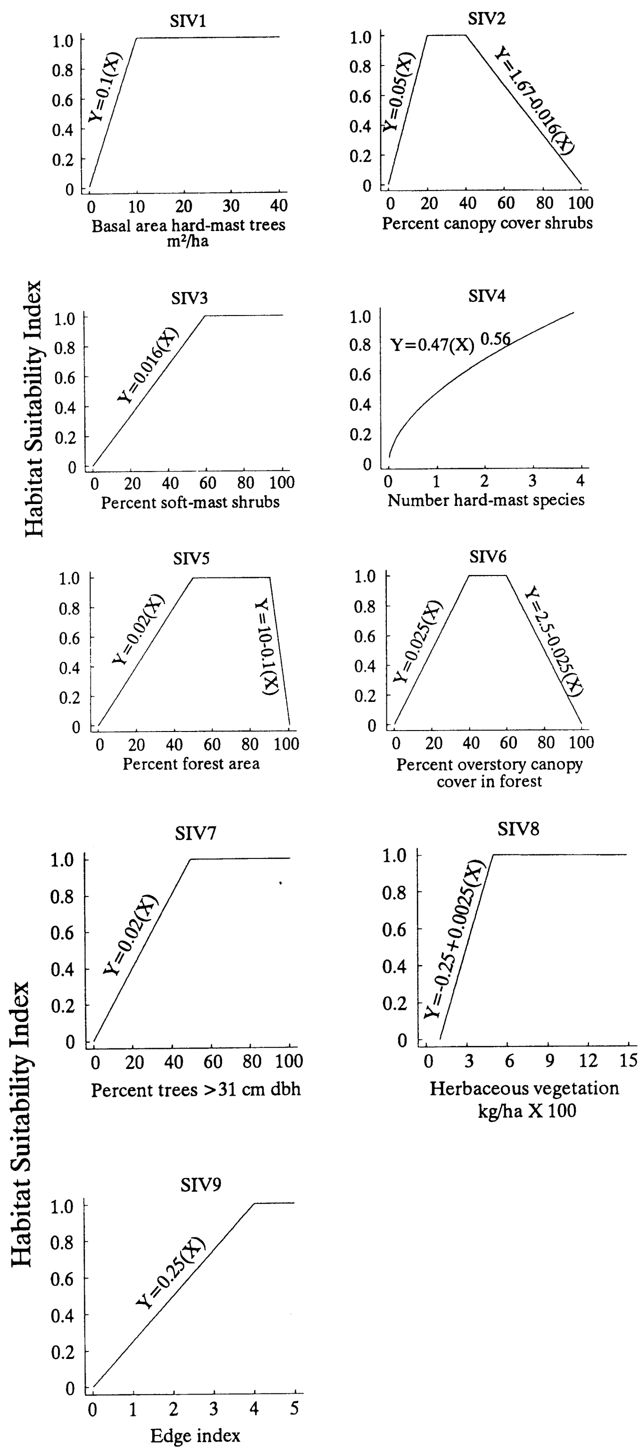

Figure 2. Graphical and mathematical relationships between habitat suitability and variables in the Habitat Suitability Index model proposed by Lindzey and Suchy for Merriam's turkeys.

purposely spread these locations among three time periods (sunrise to 1000, 1001 to 1400, and 1401 to sunset) for each bird. Precise locations were made by visual observation of birds or by close-range (<100 m) determination of the bird's location with handheld telemetry equipment.

Table 1. Acronyms and definitions used in the evaluation of the habitat suitability index (HSI) model for Merriam's turkeys proposed by Lindzey and Suchy and a proposed revised HSI model.

Acronym	Definition
dbh	Diameter at breast height (~1.4 m)
BA	Basal area (m^2/ha)
VOR	Visual obstruction reading
OCC	Overstory canopy cover (%)
HSI	Habitat suitability index
HSI_c	HSI for components of the model
HSI_v	HSI for variables of each component
HSI_a	HSI from application of the model for an area
L-S Model	HSI model for Merriam's turkeys proposed by Lindzey and Suchy
SIWF	Suitability index for winter food component
SICR	Suitability index for cover-roost component
SIBH	Suitability index for brood habitat component
SIV1	Basal area (m^2/ha) of hard-mast-producing trees
SIV2	Percent canopy cover shrubs
SIV3	Percent of shrubs that produce soft mast
SIV4	Number of tree and shrub species that produce hard mast
SIV5	Percent of area with forest cover
SIV6	Percent overstory canopy cover in forest
SIV7	Percent of trees >31 cm dbh
SIV8	Estimated weight (kg/ha) of herbaceous vegetation
SIV9	Edge index for meadows
Revised Model	Revised HSI model for Merriam's turkeys
SIWC	Suitability index for winter component
SISBC	Suitability index for summer brood component
SIV1	Basal area (m^2/ha) of hard-mast-producing trees
SIV2	Number of tree and shrub species that produce hard mast
SIV3	Percent of area with forest cover
SIV4	Percent overstory canopy cover in forest
SIV5	Percent of trees suitable for roosting
SIV6	Estimated weight (kg/ha) of herbaceous vegetation
SIV7	Edge index for meadows

We measured habitat characteristics at 114 locations of brood hens from June to September and 245 locations of adult turkeys throughout the year. These measurements were usually collected within 1 week of the location date. We also measured habitat characteristics at 240 random sites from July to August of 1987 and 1988. Random sites are not intended to contrast used and unused sites but serve as a measure of availability. We pooled habitat data for male and female birds because microhabitat characteristics between sexes were similar (Rumble and Anderson 1996).

We averaged appropriate subsets of the data collected from turkey locations and random sites to determine HSI_vs of the L-S model. Percentage of forest area (SIV5, Fig. 2) and edge index (SIV9, Fig. 2) of the L-S model were landscape measurements, and HSI_vs for these variables are the same for turkey locations and random sites. We assumed that if all habitat were suitable for turkeys, HSIs from random sites could not exceed HSIs from turkey locations if the model reflected habitat suitability for turkeys. All habitats were not suitable for turkeys. Thus, except HSI_v for landscape variables, HSIs from turkey locations should exceed HSIs from random sites. This was the basis for our qualitative test of the L-S model.

Winter Food Component

Suitability index for the winter food (SIWF) component of the L-S model included four variables and was estimated from the mathematical relationships among variables in equation 1.1 (Fig. 1). We measured bur oak *(Quercus macrocarpa)* and ponderosa pine *(Pinus ponderosa)* basal area at three points per site using a 10-factor prism (see Rumble and Anderson [1996] for greater detail in sampling protocol). Because birds consumed mostly hard mast during winter, we used data from November to March to estimate HSI_v for mast-tree basal area from turkey locations (SIV1, Fig. 2). Percent canopy cover (Daubenmire 1959) of shrubs (SIV2, Fig. 2) was estimated from 30 0.10-m^2 quadrats along a 60-m transect at turkey locations and random sites. We summed percent canopy cover for all shrub species and divided it into the summed percent canopy cover of soft-mast-producing shrub species to estimate HSI_v for percent soft-mast shrubs (SIV3, Fig. 2). Hard-mast-producing shrubs and trees were included in tallies to estimate HSI_v for number of hard-mast species (SIV4, Fig. 2). Hard-mast species included ponderosa pine, bur oak, beaked hazelnut *(Corylus cornuta),* and kinnikinnick *(Arctostaphylos uva-ursi).* Tallies of hard-mast species at turkey locations were made from locations occurring between November and March, as discussed for hard-mast basal area. Although some researchers consider kinnikinnick seeds soft mast, we tallied them as hard mast because they have a hard seed that is persistent through the winter. The L-S model depicted a discrete integer relationship between HSI_v and number of hard-mast species. Because number of hard-mast species was averaged for turkey locations and random sites, we needed to interpolate decimal values for HSI_v. Therefore, we developed a nonlinear regression estimating HSI_v for number of hard-mast species in the L-S model.

Cover-Roost Component

Suitability index for the cover-roost component (SICR) of the L-S model included three variables and was estimated from the mathematical relationships in equation 1.2 (Fig. 1). Percent forest area (SIV5, Fig. 2) was digitized from 1:24,000 maps that were constructed from 1:24,000 aerial photographs. We did not include aspen-birch *(Populus tremuloides–Betula papyrifera)* in the variable percent forest area because this vegetation type does not have mast-producing species, birds were rarely observed in it, and birds never roosted in aspen or birch. Percent overstory canopy cover (SIV6, Fig. 2) was measured at three points per site using a spherical densiometer (Lemmon 1956; Griffing 1985) and was greater at winter turkey locations than at summer locations (Rumble and Anderson 1996). Because this variable depicts cover requirements in the L-S model, we used overstory measurements from winter turkey locations to estimate HSI_v for percent overstory canopy cover. HSI_v for roost tree abundance was calculated as the percent of trees >31 cm dbh (SIV7, Fig. 2) at roosts (Rumble 1992) and at random sites.

Brood Habitat Component

Suitability index for the brood habitat (SIBH) component of the L-S model included three variables and was estimated from the mathematical relationships in equation 1.3 (Fig. 1). We measured height of visual obstruction (VOR) on a pole (Robel et al. 1970) at hen-poult locations. Herbaceous vegetation was then calculated from VORs using the following equation:

$$\text{Herbaceous vegetation (g/m}^2) = 125 \times \ln(\text{VOR [cm]}) - 114.9.$$

We estimated herbaceous vegetation for random sites in habitats that provided foraging habitat for poults. These included meadows, ponderosa pine with ≤40% overstory canopy cover, and aspen-birch with ≤70% overstory canopy cover. Ponderosa pine with >40% overstory canopy cover and aspen-birch with >70% overstory canopy cover did not provide foraging habitat for poults feeding on invertebrates. We used several methods to estimate herbaceous vegetation for random sites. In meadows, we used VORs and the equation above to estimate herbaceous vegetation. For ponderosa pine with <40% overstory canopy cover, we calculated tree basal area at the midpoint of 20% overstory canopy cover (Bennett 1984):

$$\text{Basal area (m}^2\text{/ha)} = \frac{(\text{OCC} + 1.94)}{2.22},$$

where OCC equals overstory canopy cover (%).

We then estimated herbaceous vegetation beneath these stands using equations from Uresk and Severson (1989):

$$\text{Grasses (g/m}^2) = e^{6.68 - 0.134\text{BA}}$$

and

$$\text{Forbs (g/m}^2) = e^{5.48 - 0.12\text{BA}},$$

here BA equals basal area (m^2/ha).

Herbaceous vegetation in aspen-birch with ≤70% overstory canopy cover was estimated from clipped plants, which were air dried and weighed, from three 0.5-m^2 plots at each of six sites during June 1987. Total herbaceous vegetation for random sites was a weighted calculation based on proportional area of habitats that we considered potential brood habitat.

Edge index (SIV9, Fig. 2) in the L-S model was not clearly defined. We selected the shoreline development index (Lind 1974; Patton 1975) as the edge index. Merriam's turkey poults usually feed along forest-meadow edges (Day et al. 1991; Gobeille 1992; Rumble and Anderson 1993). Because edge index was included in the brood-habitat component, we assumed that it was to be applied to meadows. The perimeter and area of meadows were digitized from the 1:24,000 maps of the study area. HSI_v for edge index was the same for turkey locations and random sites.

RESULTS

Evaluation of L-S Model and Proposed Revisions

Table 2. Values for components of the Merriam's turkey habitat suitability index (HSI) model proposed by Lindzey and Suchy for turkey locations and random sites in the Black Hills, South Dakota.

	Turkey locations		Random sites	
Model component	x	HSI	x	HSI
Winter food				
Basal area mast trees (m^2/ha)	25.5	1.00	20.1	1.00
Shrub cover (%)	6.1	0.3 1	14.9	0.75
Soft-mast shrubs (%)	75.0	1.00	67.0	1 .00
Number hard-mast species	1.3	0.54	1.2	0.52
HSI_c winter food		0.43		0.5 1
Roost cover				
Forest area (%)	81.4	1.00	81.4	1.00
Overstory canopy cover (%)	49.0	1.00	47.3	1.00
Trees >31 cm dbh (%)[a]	12.5	0.25	2.4	0.05
HSI_c roost cover		0.25		0.05
Brood habitat				
Herbaceous vegetation (kg/ha)	202.6	1.00	101.9	1.00
Edge index	2.54	0.63	2.54	0.63
HSI_c brood habitat		0.91		0.91

[a] Turkey location data from year-round roost sites.

Winter Food Component. HSI_c for the winter food component at turkey locations was lower than at random sites (Table 2). Low shrub cover resulted in lower HSI_c at turkey locations compared with random sites. HSI_c for winter food did not reflect patterns of habitat selection by Merriam's turkeys in the Black Hills. Shrubs and soft-mast shrubs were not important to turkeys in the Black Hills; birds consumed soft mast only during summer (Rumble 1990). Scott and Boeker (1973, 1975) suggested that soft mast and shrubs were important food sources for Merriam's turkeys. The emphasis on soft mast and shrubs in the L-S model resulted from interpreting juniper *(Juniperus* spp.) as a soft-mast shrub (Scott and Boeker 1977). Juniper berries usually occur on trees (>3 cm dbh) and are available throughout the winter. Other soft-mast species such as raspberry *(Rubus* spp.), hawthorn *(Crateagus* spp.), and snowberry *(Symphoricarpos* spp.) are not available during winter. Merriam's turkeys in the Southwest use pinyon pine (*P. edulis)*-juniper during periods of deep snow or low availability of hard mast (Scott and Boeker 1977). Shrubs were a minor component of winter turkey habitat in the Black Hills comprising <10% canopy cover at >90% of radio-marked turkey locations. In the Black Hills, ponderosa pine seeds are the preferred winter food; in the absence of pine seeds, birds consumed kinnikinnick seeds, grass leaves, and grass seeds (Rumble 1990). Because neither shrubs nor soft mast were selected by wintering birds, these variables are excluded from our revised model (Table 3, Fig. 3).

Table 3. Values for components of the revised Merriam's turkey habitat suitability index (HSI) model for turkey locations and random sites in the Black Hills, South Dakota.

	Turkey locations		Random sites	
Model component	x	HSI	x	HSI
Winter habitat				
Basal area mast trees (m^2/ha)	25.5	1.00	20.1	1 .00
Number hard-mast species	1.3	0.54	1.2	0.52
Forest area (%)	81.4	0.74	81.4	0.74
Overstory canopy cover (%)	49.0	0.98	47.3	0.95
Suitable roost trees (%)[a]	23.0	1 .00	6.9	0.92
HSI_c winter habitat		0.66		0.64
Summer brood habitat				
Herbaceous vegetation (kg/ha)	202.6	1 .00	101.9	0.91
Forest area (%)	81.4	0.74	81.4	0.74
Edge index	2.3	0.59	2.3	0.59
Suitable roost trees (%)[b]	15.0	1.00	6.9	0.92
HSI_c summer brood habitat		0.89		0.83

[a] Trees >25 cm dbh from turkey year-round roost sites.
[b] Trees >25 cm from June to August in hen-poult locations.

The L-S model suggested that optimal habitat suitability for hard-mast tree basal area exceeded 10 m^2/ha. Ponderosa pine is the dominant mast-producing species in the Black Hills, and pine seed production increases asymptotically with basal area. Maximum pine seed availability occurs in stands 223 m^2/ha basal area (Rumble 1990). Following high pine seed production, wintering birds selected ponderosa pine stands exceeding 28 m^2/ha basal area, whereas in winters following failure of the ponderosa pine seed crop, birds selected habitats averaging 10 m^2/ha basal area. Optimum HSI_v for hard-mast tree basal area occurred between 21 and 32 m^2/ha (SIV1, Fig. 3).

Hard-mast seed crops are infrequent throughout the western United States (Olson 1974; Oliver and Ryker 1990). Greater diversity in hard-mast species increases the probability of mast availability to turkeys (Scott and Boeker 1973). Thus, HSI_v increases with the number of hard-mast species. The habitat suitability model for eastern turkeys (Schroeder 1985) also includes a variable for hard-mast species. Most current ranges occupied by Merriam's turkeys support two to three hard-mast species, and kinnikinnick should be considered hard mast. The number of hard-mast species should account for the periodicity of mast crops. Species that produce mast crops in 4 out of 5 years should be recorded as 4/5 versus 1 hard-mast species. Prior to inclusion in tallies of hard-mast species, each species tallied should constitute > 10% of the stand basal area. The relationships between HSI_v and number of hard-mast species in the L-S model are recommended in our model (SIV2, Fig. 3).

The L-S model suggested that forest area between 50 and 90% was optimal for Merriam's turkeys. Optimal habitat for eastern turkeys in Missouri had 25 to 40% open or semiopen areas (Kurzejeski and Lewis 1985). It is generally recognized that turkey habitats in Missouri are more productive than those for Merriam's turkeys, so there is no reason to assume that

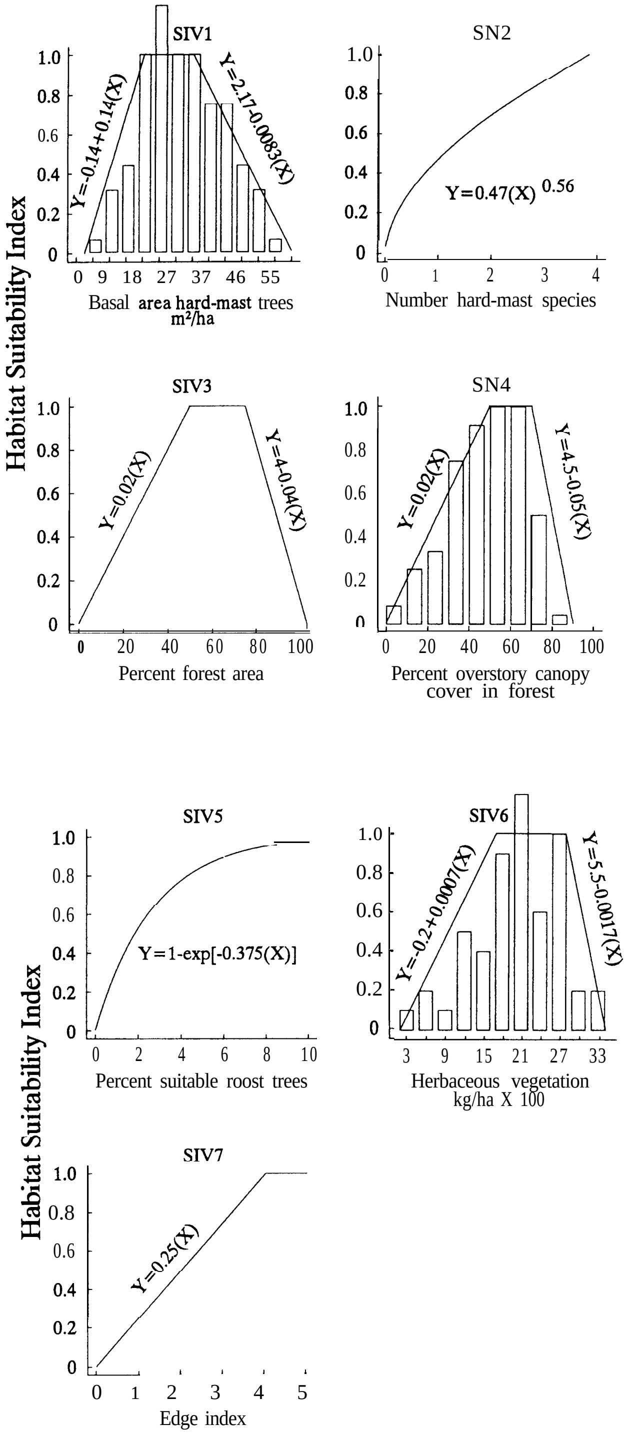

Figure 3. Graphical and mathematical relationships between habitat suitability and variables of a proposed Habitat Suitability Index model for evaluating Merriam's wild turkey habitat. Plotted histograms represent data from this study.

optimal habitats of Merriam's turkeys should contain fewer openings. HSI, in our revised model declines when forest area exceeds 75% (SIV3, Fig. 3).

The L-S model suggested an optimal habitat of 40 to 60% for overstory canopy cover in the forest. Our data showed optimal habitat to be between 50 and 70% overstory canopy cover (SIV4, Fig. 3).

Cover-Roost Component. The cover-roost component of the L-S model suggested poor habitat suitability for turkeys in the Black Hills. Yet the Black Hills area has excellent Merriam's turkey population densities (Kennamer et al. 1992) that are more productive than other populations (Rumble and Hodorff 1993). Inadequate abundance of trees >31 cm dbh limited the cover-roost and area HSIs in the L-S model. Lack of roost sites or trees can limit the distribution of Merriam's turkeys (Bryant and Nish 1975; Scott and Boeker 1975). Roost trees for Merriam's turkeys may be large, overmature ponderosa pine >40 cm dbh (Hoffman 1968; Scott and Boeker 1969; Phillips 1980; Mackey 1984). Turkeys in the Black Hills roosted in smaller-diameter trees, and there is no evidence suggesting that diameter is the mechanism for selection of roost trees (Rumble 1992). Trees selected for roosting by Merriam's turkeys had horizontal branches spaced at l-m intervals (Rumble 1992). In some portions of Merriam's turkey range, these characteristics occur only in large old trees. This variable should be percentage of trees suitable for roosting, and the criteria for trees suitable for roosts should be determined for the area of application. In the Black Hills, Merriam's turkeys roost in trees >25 cm dbh. If we used percentage of trees suitable as roosts (>25 cm dbh), HSI, for cover-roosting increased from 0.25 to 0.46 at turkey roosts and from 0.05 to 0.14 at random sites.

The L-S model shows optimal roost habitat when 250% of the trees are suitable as roost trees-much greater than are necessary. Only 23% of trees at roost sites in our study were suitable as roosts (>25 cm dbh). Birds rarely selected the same trees or sites for roosting on consecutive nights (except during winter), suggesting that roost trees or sites were abundant. Phillips (1980) recommended two roost sites <1.6 ha in size per section for general roost requirements; four roost sites per section were required in areas of high concentrations of turkeys. Based on Phillips's recommendations, Merriam's turkeys require <6.5 ha of roost site per section (<1% of the area). In the revised model, a nonlinear relationship between suitable roost trees and habitat suitability requires fewer roost trees (SIV5, Fig. 3).

Location of roost sites may be equally important as percentage of trees suitable for roosting. Merriam's turkeys often roost on eastern slopes, on upper portions of slopes, in multistory or unharvested stands >1 8 m^2/ha basal area, and near clearings, water, or food (Phillips 1980; Mackey 1984; Rumble 1992).

Brood Habitat Component. The brood habitat component of the L-S model showed excellent habitat suitability for poults. Poults require invertebrates for growth and development (Robbins 1983; Hurst and Poe 1985), and invertebrates are positively correlated with the amount of herbaceous vegetation (Healy 1985; Rumble 1990). Herbaceous vegetation also provides cover for poults if it is sufficiently tall. The L-S model showed an HSI, of 1.0 for both poult locations and random estimates of herbaceous vegetation. Yet herbaceous vegetation at random sites was less than half as tall as that at hen-poult locations. When the dietary protein requirement of poults was high (<7 weeks of age; Robbins 1983), poults rarely used forests except for loafing (M. Rumble, pers. observ.). Optimal herbaceous vegetation in the L-S model occurred at 2500 kg/ha. Our data suggested that 1,700 to 3,000 kg/ha of herbaceous vegetation was optimal for poults (SIV6, Fig. 3); 80% of feeding sites of young poults had >1,260 kg/ha of herbaceous vegetation. Eastern turkey poults did not receive adequate food with 400 kg/ha of herbaceous vegetation, and >3,000 kg/ha impeded their movement (Healy 1985).

Edge index was the limiting variable for the brood habitat component in the L-S model. Meadows selected by hens with poults were often connected, and estimates of edge indices for individual locations of hens with poults were not practical. Except for selection of forest-meadow edges by hens with poults, Merriam's turkeys rarely selected edges of other habitats. Because we do not have a better estimate for HSI, and edge index, we used the relationship from the L-S model (SIV7, Fig. 3). Other methods for estimating edge relationships were proposed for eastern turkeys (Donavan et al. 1987).

Revised HSI model equations

4.1 Winter component

$$SIWC = \frac{2\,(SIV1 \times SIV2) + (SIV3 \times SIV4 \times SIV5)^{1/3}}{3}$$

4.2 Summer brood component

$$SISBC = \frac{SIV6 + (SIV3 \times SIV7)^{1/2} + SIV5}{3}$$

Figure 4. Mathematical relationships among variables to estimate habitat suitability for components of a revised proposed Habitat Suitability Index model for Merriam's turkeys. See Table 1 for acronym definitions.

Revised Model

The key habitat components of Merriam's turkeys in our research area were brood and winter habitats. The HSI model we propose has two components: summer brood and winter. Because of similar characteristics, roost habitat for Merriam's turkeys can be managed like winter habitat (Rumble 1992). Mathematical relationships among variables to estimate HSI, s were modified from those in the L-S model (Fig. 4). Suitability index for the winter component (SIWC) and the relationships among variables are depicted by equation 4.1 (Fig. 4). Suitability index for the summer brood component (SISBC) and relationships among variables are depicted by equation 4.2. If summer and winter ranges overlap, the estimated HSI, should be the lower of the HSI_cs. If summer and winter ranges are separated, consideration must be given to population boundaries and relative area of each component.

HSI_cs for winter in our revised model were 0.66 and 0.64 for turkey locations and random sites, respectively (Table 3). Except for number of hard-mast species, variables in the winter component were abundant on our study area. The winter HSI, was limited by the lack of diversity and consistency in hard-mast production. Habitat selection patterns of Merriam's turkeys and diets during winters of pine seed crop failure (Rumble and Anderson 1996) support this conclusion. Although pine mast production is more consistent in the Black Hills than in other regions in the western United States (Boldt and Van Desen 1974), alternative natural foods were limited to kinnikinnick, grasses, and grass seeds.

The summer brood HSI_cs of our revised model were 0.89 for turkey locations and 0.83 for random sites. Data for the HSI, for suitable roost trees were from hen-poult locations from June to August. Hens with poults are more likely to select a nearby tree for roosting than to go to an area typical of roosts during the remainder of the year. Lower HSI, at random sites than at hen-poult locations resulted from lower estimates of herbaceous vegetation. Greater interspersion of openings had the greatest potential for increasing the HSI, of the summer brood component of our model. More irregularity along edges of meadows or openings would have increased the summer-brood HSI,. HSI_vs for herbaceous vegetation were close to optimal.

DISCUSSION

The L-S model did not accurately reflect the habitat suitability for Merriam's turkeys in the Black Hills. It overemphasized soft mast and shrubs in winter habitats and trees >31 cm dbh for roosts and underestimated herbaceous vegetation requirements for poults. The model also performed poorly for assessing the general suitability of the Black Hills as turkey habitat. Typical applications of HSI models are made from random samples. Thus, the L-S model resulted in an HSI, of 0.05 for an area with an abundant and productive turkey population (Kennamer et al. 1992; Rumble and Hodorff 1993). The L-S model also resulted in several HSI_vs from random sites that were equal to those from turkey locations. Under normal circumstances, this should be a rare occurrence.

Models depicting the habitat requirements for a species undergo continuous revision and modification (Schamberger et al. 1982). Our revised model depicts habitat suitability for Merriam's turkeys in ponderosa pine forests in the Northern Great Plains and Rocky Mountains. It should serve as a stimulus for further research to define the habitat requirements of Merriam's turkeys. Our revised HSI model depicts natural habitats for all components.

Winter appears to limit Merriam's turkey populations in the Black Hills. During periods of deep snow or pine mast failure, birds must find artificial food sources or consume less preferred natural foods. Average ambient temperatures during winter are near the thermoneutral temperature of turkeys (Oberlag 1985). In the Black Hills, there is little potential for birds to migrate to lower elevations and milder climate. Our revised model directs attention to maintaining ponderosa pine stands with approximately 25 m^2/ha basal area as winter habitat. Summer brood habitat in the Black Hills can be increased by creating openings, but there will be less herbaceous vegetation in them than in natural meadows (Hamm 1973). Management of herbaceous vegetation is important to maintain a high summer brood HSI_c. Livestock grazing independently or coupled with drought can reduce herbaceous vegetation. Low poult-hen ratios occur during drought periods (R. W. Hauk, Game Rep. No. 90- 18, S.D. Game, Fish, and Parks, Pierre).

Our research, review of literature, and development of this model led us to conclude that "good turkey habitat" has some elements common to all subspecies of wild turkeys. Our estimates of herbaceous vegetation requirements for poults are similar to those for eastern turkeys. The number of hard-mast species and the percentage of forest area are also variables in the HSI model of eastern turkeys (Schroeder 1985). Merriam's turkeys may not have evolved in arid forests of the Southwest (Rea 1980; McKusick 1986), so it is not surprising that there are similarities between their habitat requirements and those of other subspecies (e.g., Schroeder 1985).

LITERATURE CITED

Bennett, D. L. 1984. Grazing potential of major soils within the Black Hills of South Dakota. M.S. thesis, South Dakota State Univ. Brookings. 199pp.

Boldt, C. E., and J. L. Van Duesen. 1974. Silviculture of ponderosa pine in the Black Hills: the status of our knowledge. USDA For. Serv., Res. Pap. RM- 124. 45pp.

Bryant, F. C., and D. Nish. 1975. Habitat use by Merriam's turkey in southwestern Utah. Proc. Natl. Wild Turkey Symp. 3:6-13.

Daubenmire, R. D. 1959. A canopy-coverage method of vegetational analysis. Northwest Sci. 33:43-64.

Day, K. S., L. D. Flake, and W. L. Tucker. 199 1. Movements and habitat use by wild turkey hens with broods in a grassland-woodland mosaic in the northern plains. Prairie Nat. 23:73-83.

Donavan, M. L., D. L. Rabe, and C. E. Olson, Jr. 1987. Use of geographic information systems to develop habitat suitability models. Wildl. Soc. Bull. 15:574-579.

Fretwell, S. D., and H. L. Lucas, Jr. 1969. On territorial behavior and other factors influencing habitat distribution in birds. I. Theoretical development. Acta Biotheor. 19: 16-36.

Gobeille, J. E. 1992. The effect of fire on Merriam's turkey brood habitat in southeastern Montana. M.S. thesis, Montana State Univ., Bozeman. 6 lpp.

Griffing, J. P. 1985. The spherical densiometer revisited. Southwest Habitater, vol. 6, no. 12, USDA For. Serv., Reg. 3. Albuquerque, NM. 2pp.

Hamm, D. C. 1973. Evaluation of cattle use of a deer winter range in the Black Hills. M.S. thesis, South Dakota State Univ., Brookings. 69pp.

Healy, W. M. 1985. Turkey poult feeding activity, invertebrate abundance, and vegetation structure. J. Wildl. Manage. 49:466-472.

——— 1990. Symposium summary: looking toward 2000. Proc. Natl. Wild Turkey Symp. 6:224-228.

Hoffman, D. M. 1968. Roosting sites and habits of Merriam's turkeys in Colorado. J. Wildl. Manage. 32:859-866.

Hurst, G. A., and W. E. Poe. 1985. Amino acid levels and patterns in wild turkey poults and their food items in Mississippi. Proc. Natl. Wild Turkey Symp. 5: 133-143.

Kennamer, M. C., R. Brenneman, and J. E. Kennamer. 1992. Guide to the American wild turkey. Natl. Wild Turkey Fed., Edgefield, SC. 158pp.

Kurzejeski, E. W., and J. B. Lewis. 1985. Application of PATREC modeling to wild turkey management in Missouri. Proc. Natl. Wild Turkey Symp. 5:269-283.

Lemmon, P. E. 1956. A spherical densiometer for estimating forest overstory density. For. Sci. 2:3 14-320.

Lind, 0. T. 1974. Handbook of common methods in limnology. C. V. Mosby, St. Louis, MO. 154pp.

Mackey, D. L. 1984. Roosting habitat of Merriam's turkeys in south-central Washington. J. Wildl. Manage. 48: 1377-1382.

McKusick, C. R. 1986. Southwest Indian turkeys-prehistory and comparative osteology. Southwest Bird Lab., Globe, AZ. 56pp.

Oberlag, D. F. 1985. The influence of season and temperature on metabolism of eastern wild turkeys in New Hampshire. M.S. thesis, Univ. New Hampshire, Durham. 57pp.

Oliver, W. W., and R. A. Ryker. 1990. *Pinus ponderosa*. Pages 413-424 *in* R. M. Burns and B. H. Honkala, tech. coords. Silvics of North America: Vol. 1. Conifers. USDA For. Serv. Agric. Handb. No. 654, Washington, D.C.

Olson, D. F., Jr. 1974. *Quercus* L. Oak. Pages 692-703 *in C. S.* Schopmeyer, tech. coord. Seeds of woody plants in the United States. USDA For. Serv., Agric. Handb. No. 450, Washington, DC.

0' Neil, L. J., T. H. Roberts, J. S. Wakeley, and J. W. Teaford. 1988. A procedure to modify habitat suitability index models. Wildl. Soc. Bull. 15:33-36.

Patton, D. R. 1975. A diversity index for quantifying habitat "edge." Wildl. Soc. Bull. 3: 171-173.

Phillips, F. 1980. A basic guide to roost site management for Merriam's turkeys. Wildl. Dig. Abstr. No. 12., Ariz. Game Fish Dep., Phoenix. 6pp.

Porter, W. F., and K. E. Church. 1987. Effects of environmental pattern on habitat preference analysis. J. Wildl. Manage. 5 l-685.

Rea, A. M. 1980. Late Pleistocene and Holocene turkeys in the Southwest. Pages 210-223 *in K.* E. Cambell Jr., ed. Papers in avian paleontology. Nat. Hist. Mus. Los Angeles Co., No. 330.

Robbins, C. T. 1983. Wildlife feeding and nutrition. Academic Press, New York, NY. 343pp.

Robel, R. J., J. N. Briggs, A. D. Dayton, and L. C. Hurlbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. J. Range Manage. 23:295-297

Rumble, M. A. 1990. Ecology of Merriam's turkeys *(Meleagris gallopavo merriami)* in the Black Hills, South Dakota. Ph.D. thesis, Univ. Wyoming, Laramie. 169pp.

———. 1992. Roosting habitat of Merriam's turkeys in the Black Hills, South Dakota. J. Wildl. Manage. 56: 750-759.

Rumble, M. A., and S. H. Anderson. 1993. Habitat selection of Merriam's turkey *(Meleagris gallopavo merriami)* hens with poults in the Black Hills, South Dakota. Great Basin Nat. 53:131-136.

———. 1996. Microhabitats of Merriam's turkeys in the Black Hills, South Dakota. Ecol. Appl. 6:326-334.

Rumble, M. A., and R. A. Hodorff. 1993. Nesting ecology of Merriam's turkeys in the Black Hills, South Dakota. J. Wildl. Manage. 57:789-801.

Schamberger, M., A. H. Farmer, and J. W. Terrell. 1982. Habitat suitability index model: introduction. USDI Fish and Wildl. Serv. FWS/OBS-82/10. 2pp.

Schamberger, M., and L. J. O'Neil. 1986. Concepts and constraints of habitat-model testing. Pages 5-10 *in* J. Verner, M. L. Morrison, and C. J. Ralph, eds. Wildlife 2000: modeling habitat relationships of terrestrial vertebrates. Univ. Wisconsin Press, Madison. 470pp.

Schroeder, R. L. 1985. Habitat suitability index models: eastern wild turkey. USDI Fish and Wildl. Serv. Biol. Rep. 82(10.106), Washington, DC. 33pp.

Scott, V. E., and E. L. Boeker. 1969. Roost tree characteristics for Merriam's turkey. J. Wildl. Manage. 33: 121-124.

———. 1973. Seasonal food habits of Merriam's turkeys on the Fort Apache Indian Reservation. Pages 15 1-157 *in G. C.* Sanderson and H. C. Schultz, eds. Wild turkey management: current problems and programs. The Mo. Chap, The Wildl. Soc., and Univ. Missouri Press, Columbia.

———. 1975. Ecology of Merriam's wild turkey on the Fort Apache Indian Reservation. Proc. Natl. Wild Turkey Symp. 3: 141-158.

———. 1977. Responses of Merriam's turkey to pinyon-juniper control. J. Range Manage. 30:220-223/

Uresk, D. W., and K. E. Severson. 1989. Understory-overstory relationships in ponderosa pine forests, Black Hills, South Dakota. J. Range Manage. 42:203-208/

U.S. Fish and Wildlife Service. 1980. Habitat as a basis for environmental assessment. USDI Fish and Wildl. Serv., Div. Ecol. Serv., ESM 101, Washington, DC.

Van Horne, B. 1983. Density as a misleading factor of habitat quality. J. Wildl. Manage. 47:893-901.