Comparison of the HSI and WHAG Habitat Evaluation Procedures for Tree Squirrels

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Abstract: HSI and WHAG habitat evaluation procedures were used to determine habitat suitability indices for gray (*Sciurus carolinensis*) and fox (*S. niger*) squirrels on 6 areas in central Missouri. Results from both evaluation procedures indicated similar habitat conditions on all areas. However, Lincoln-Petersen mark-recapture estimates indicated densities of both species varied across areas. No correlations were found between suitability indices and squirrel densities for either procedure or species. WHAG indices were greater than HSI indices for the same areas with the exception of one area which had equal indices. These results suggest that conclusions regarding habitat suitability may depend more upon the assessment procedure used than habitat conditions. Our study evaluated the HSI and WHAG procedures over a narrow range of habitat conditions, but indicated both procedures should be studied more thoroughly before either can be used reliably.

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One of the more difficult challenges to resource managers is the objective evaluation of habitat suitability. To aid in this task, several types of habitat assessment procedures have been developed. Perhaps most widely used is the habitat suitability index (HSI) procedure developed by the U.S. Fish and Wildlife Service (Schamberger et al. 1982). Another assessment procedure used in Missouri is the wildlife habitat appraisal guide (WHAG) (Urich et al. 1984). Both the HSI and WHAG procedures are based on the assumption that wildlife habitat can be described mathematically (Schamberger and Farmer 1978, Urich et al. 1984). These procedures are species-specific and give a relative index rating (0.0–1.0) according to how suitable an area is for a particular species (Ellis et al. 1979, Seitz et al. 1982, Thomas 1982, Urich et al. 1984). An underlying assumption of both procedures is that there is a direct, positive relationship between habitat suitability and the capability of the area to support a population of a given species.

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Although habitat evaluation procedures are used widely, most have yet to be evaluated with empirical data. We had the opportunity to evaluate the HSI and WHAG habitat assessment procedures for fox and gray squirrels on 6 areas in central Missouri where tree squirrel population densities had been estimated as part of a separate study. Specifically, we studied the relationships between the HSI and WHAG suitability indices, as well as between the suitability indices and squirrel density estimates.

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Methods

Population estimates and habitat conditions were determined for 6 study areas in the oak (*Quercus spp.*) and hickory (*Carya spp.*) hardwood forest in central Missouri during 1987–89. Two of the areas were located on the University of Missouri's Thomas S. Baskett Wildlife Research and Education Center (TSBC). Four areas were located on the Missouri Department of Conservation's Rudolf Bennitt Wildlife Area (RBWA).

The TSBC is a 900-ha research center located 5 km east of Ashland, Missouri, in southern Boone County. It lies in the river hills physiographic region which is characterized by deep hollows, narrow ridges and steep slopes (Krusekopf 1962). Elevation ranges from 170–244 m.

We identified 5 cover types on the TSBC study areas. Old-fields in early- to mid-successional development made up 5.6% of the areas. Hardwood regeneration stands <15-cm dbh made up 5.8% of the areas and were characterized by dense stands of oak and hickory stems as well as sugar maple (*Acer saccharum*), slippery elm (*Ulmus rubra*), ash (*Fraxinus spp.*), dogwood (*Cornus spp.*), American hornbeam (*Carpinus caroliniana*), and downy serviceberry (*Amelanchier arborea*). Shortleaf pine (*Pinus echinata*) sawtimber stands comprised 4.5% of the areas. Stands of mixed cedar-hardwood poletimber accounted for 17% of the study areas and consisted primarily of eastern red cedar (*Juniperus virginiana*), oaks, dogwood, sassafras (*Sassafras albidum*), and common persimmon (*Diospyros virginiana*). The major cover type was deciduous forest ≥15-cm dbh (67%). Oaks and hickories dominated this cover type, with slippery elm, black walnut (*Juglans nigra*), and American sycamore (*Platanus occidentalis*) prevalent in drainages. The understory ranged from open to dense and consisted of sugar maple, dogwood, American hornbeam, American hophornbeam (*Ostrya virginana*), downy serviceberry, and elms.

The RBWA is a 1,362-ha wildlife area located at the intersection of Boone, Howard, and Randolph counties, Missouri. The RBWA lies on the western border of the level prairie physiographic region (Krusekopf 1962). Elevation ranges from 229 to 259 m.

Three cover types were present on the RBWA. Deciduous forest of oak and hickory trees ≥15-cm dbh was the most common, comprising 86.5% of the study areas. The understory in the deciduous forest often was open, although patches of medium to dense understory were scattered throughout. The primary understory species were hickory, American hophornbeam, sugar maple, slippery elm, dogwood, and downy serviceberry. Hardwood regeneration stands <15-cm dbh made up 9.5% of the study areas. In addition to oak and hickory, these stands contained dogwood, ash, cherry (*Prunus spp.*), American hophornbeam, and downy serviceberry. Old-fields in early- to mid-successional development made up 4% of the study areas.

Population Estimation

On each study area, wooden box traps (Mosby 1955) were placed in a 15 × 15 grid with an inter-trap distance of 50 m. Traps were baited with black walnuts. All 225 traps were checked daily and captured squirrels were ear-tagged with numbered, No. 1 monel ear tags. Traps remained open until marked squirrels made up >70% of the daily captures. This required a trapping duration of 10 to 17 days.

Recapture samples were obtained using firearms. Each area was hunted daily for ≤14 days, beginning the morning after livetrapping was completed. Typical hunting procedures such as stalking and still-hunting were used in the mornings and evenings. During the middle of the day (1000 to 1500 hours) squirrels rarely were active, so other methods were employed to expose squirrels to harvest. These methods included flushing squirrels from nests using an extendable aluminum pole, and lowering smoke bombs into tree cavities.

Population estimates were calculated using Chapman's modification of the Lincoln-Petersen estimator (Chapman 1951). Density estimates were calculated by dividing the population estimate by the grid area (700 × 700 m) plus the area of a boundary strip around the grid. The width of this strip was estimated using program CAPTURE (Otis et al. 1978) and averaged 97 m across study areas. The average size of the combined grid and boundary strip area was 79.2 ha.

Habitat Assessment

Each trap location on an area was assigned a unique plot number, and habitat information was collected at 30 randomly selected plots. The number of plots sampled within each cover type was proportional to the cover type's occurrence. Habitat data were collected from within a 0.04-ha circular plot and along 2 perpendicular 30-m line transects which intersected at the plot center (Hays et al. 1981; Allen 1982, 1987).

Data recorded within the circular plot included dbh, species of overstory trees, and number of visible den cavities. Along the line transects, overstory and understory canopy closures were measured using the line intercept and vertical rod methods

(Hays et al. 1981). Distance measurements and the percent occurrence of adjacent habitats were made from aerial photographs.

HSI models for each species contained 5 variables, with 2 variables common to both models (Table 1). Mean values for each variable within a cover type were determined and used in all calculations. Suitability indices for each variable were calculated for each cover type. The overall suitability index for a habitat variable was the average value of that variable across cover types, weighted by the percent occurrence of each cover type. These overall suitability indices then were combined into 2 life requisite values (Allen 1982, 1987). One value represented the suitability of available winter food resources; the other represented the suitability of available cover/reproduction resources. The lesser of these 2 life requisite values was considered to be the overall habitat suitability index of the study area.

The WHAG procedure for gray and fox squirrels contained 11 variables. However, during sampling, no information was collected for the variable pertaining to the amount of vegetative cover <1.5 m in height. Therefore, this variable was omitted when indices were calculated. In the WHAG procedure, numeric scores of 1–5 or 1–10 were assigned to each variable depending upon existing habitat conditions (Table 2). The higher scores were associated with variables that were believed to contribute more to squirrel habitat suitability. The maximum possible score for the woodland size variable differed between the gray and fox squirrel models, reflecting the different habitat preferences of the 2 species (Table 2). The numeric scores were summed and divided by the total possible score to yield an overall habitat index. If several cover types occurred on a study area, the overall habitat index was the average of all individual indices, weighted by the percent occurrence of each cover type.

The HSI procedures are applicable to deciduous forest, deciduous tree savanna, and deciduous forested wetland cover types (Allen 1982, 1987). Therefore, data from only the deciduous forest and mixed hardwood-cedar habitats were used to develop suitability indices. These 2 cover types made up ≥84% of each study area and represented the primary squirrel habitat on each area.

Table 1. Description of variables in the habitat suitability index (HSI) procedures used to evaluate habitats for fox and gray squirrels on six areas in central Missouri.

Variable	Species
Proportion of total canopy made up of mast producing trees ≥25cm dbh (%)	G[a]
Number of different mast producing tree species per plot	G
Canopy closure of trees ≥5m in height (%)	B
Average dbh of overstory trees (cm)	B
Canopy closure of hard mast producing trees >25-cm dbh	F
Linear distance to grain (m)	F
Crown cover of vegetation <5m in height	F

[a]G = gray squirrel, F = fox squirrel, B = both.

Table 2. Description of variables in the Wildlife Habitat Appraisal Guides (WHAG) used to evaluate habitats for fox and gray squirrels on 6 areas in central Missouri.

Variable	Gray[a]	Fox
Tree dbh size class (cm) and canopy cover (%)	10	10
Tree species diversity	10	10
Proportion of area in forest openings (%)	5	5
Number of species of food plants	5	5
Grazing pressure	10	10
Number of tree cavities per ha	10	10
Woodland size (% of stand within 200 m of any other habitat)	10	5
Extent of forest habitat (% of area within 3.2 km radius in forest habitat)	10	10
Average tree dbh (cm)	10	10
Distance to cropfield (m)	5	5

[a]Values listed beneath each squirrel species indicate maximum possible score for that variable.

We used *t*-tests to determine if mean density estimates differed between squirrel species. We also used *t*-tests to determine if mean suitability indices differed between procedures for the same squirrel species. We used Pearson's correlation analysis to examine the relationship between the HSI and WHAG indices for each species. We also used Pearson's correlation analysis to examine the relationship between HSI and WHAG indices and population density estimates for each species.

Results

Habitat conditions were similar across areas based on the variables used in both the HSI and WHAG procedures. Total canopy cover ranged from 84% to 92% and most ($\bar{x}$ = 96%) of this canopy cover was made up of hard-mast-producing species. Across study areas, average tree dbh ranged from 23 to 29 cm, and shrub canopy cover ranged from 55% to 77%. An average of 3 different species of hard-mast-producing trees occurred within each plot. All areas were part of a larger, more extensive woodland. Woodlands comprised >50% of the acreage within a 3.3-km radius of each study area. No areas were within 600 m of agricultural crop fields.

Gray squirrels were more abundant than fox squirrels on all areas (Table 3) and the overall mean gray squirrel density (1.36/ha) was greater than the overall mean fox squirrel density (0.50/ha) ($t = -3.60, P = 0.005$). Density estimates were more variable for gray squirrels than for fox squirrels. The 2 areas that had the highest gray squirrel densities also had the highest fox squirrel densities.

Individual WHAG indices for both species were greater or equal to the corresponding HSI indices on all areas (Table 4). The mean WHAG index for fox squirrels (0.68) was greater than the mean HSI index for fox squirrels (0.45) ($t = -5.61$, $P = 0.0002$). Further, the mean WHAG index for gray squirrels (0.74) was greater than the mean HSI index for gray squirrels (0.59) ($t = -3.67, P = 0.01$). The HSI index for gray squirrels was greater than the HSI index for fox squirrels on 5 of 6

Table 3. Number of tagged and recaptured fox (F) and gray (G) squirrels trapped on six areas in central Missouri during two winter field seasons and used to calculate density estimates using Chapman's modification of the Lincoln-Petersen technique.

Study Area[a]	1987–88 Tagged G	Tagged F	Recaptured G	Recaptured F	Estimated (*N*/ha) G	Estimated (*N*/ha) F	1988–89 Tagged G	Tagged F	Recaptured G	Recaptured F	Estimated (*N*/ha) G	Estimated (*N*/ha) F
RBWA-1	49	27	10(4)[b]	12(10)	1.38	0.41	40	9	12(7)	15(6)	0.83	0.25
RBWA-2	26	15	10(2)	3(1)	1.24	0.39	38	15	16(5)	7(2)	1.35	0.53
RBWA-3	—[c]	—	—	—	—	—	44	12	11(6)	7(2)	0.95	0.54
RBWA-4	35	23	5(3)	1(0)	0.46	0.42	44	12	29(16)	3(0)	0.94	0.43
TSBC-1	—	—	—	—	—	—	52	14	31(9)	9(2)	2.05	0.58
TSBC-2	41	29	30(7)	6(3)	2.04	0.65	46	11	35(9)	13(2)	2.12	0.63

[a]Average total sample area was 79.2 ha.
[b]Number in parenthesis is the number of marked individuals in the recapture sample.
[c]Sample size insufficient to develop estimate.

Table 4. Mean ($\bar{x}$) ± standard deviation (SD) of density estimates for 2 field seasons and associated Habitat Suitability Index (HSI) and Wildlife Habitat Appraisal Guideline (WHAG) indexes for gray and fox squirrels on 6 areas in central Missouri.

Area	$\bar{x}$ ± SD Gray	$\bar{x}$ ± SD Fox	Gray HSI	Gray WHAG	Fox HSI	Fox WHAG
RBWA-1	1.10 ± 0.39	0.33 ± 0.11	0.67	0.74	0.49	0.69
RBWA-2	1.29 ± 0.08	0.46 ± 0.10	0.42	0.76	0.56	0.56
RBWA-3	0.95[a]	0.54[a]	0.64	0.71	0.43	0.74
RBWA-4	0.70 ± 0.34	0.42 ± 0.01	0.61	0.78	0.44	0.76
TSBC-1	2.05[a]	0.58[a]	0.66	0.69	0.49	0.71
TSBC-2	2.08 ± 0.06	0.64 ± 0.01	0.53	0.78	0.37	0.64

[a]Sample size insufficient to develop estimate during the 1987–88 field season.

areas, whereas the WHAG index for gray squirrels was greater than the WHAG index for fox squirrels on 4 of 6 areas.

We found no correlations between HSI indices and gray and fox squirrel density estimates ($P = 0.80$ and $P = 0.16$, respectively); nor between WHAG indices and gray and fox squirrel density estimates ($P = 0.71$ and $P = 0.86$, respectively). Further, we found no correlations between HSI and WHAG indices for fox squirrels ($P = 0.39$) or gray squirrels ($P = 0.25$).

Discussion

Based on the variables used in the HSI and WHAG procedures, our study areas were similar. However, squirrel densities varied across areas, especially for gray squirrels. The variability in squirrel densities may have been due to small sample sizes of marked squirrels. Marking and especially recapturing squirrels during the winter season were difficult and resulted in small sample sizes for calculating population estimates. The small sample sizes may have affected the accuracy and precision of the population estimates.

Squirrel densities on our areas were low compared to values reported from other studies (Nixon et al. 1967, 1974; Whitehead 1976, Don 1984). This may be because our estimates represented winter densities, whereas other reported estimates represented spring, summer, or autumn abundance.

If habitat differences influenced the observed variation in population estimates, these differences were not apparent based on the HSI or WHAG indices. There was no detectable trend for areas with the highest estimated squirrel densities to have the highest suitability indices. The inability of either procedure to detect differences between areas may suggest that the relationships between specific variables and habitat suitability represented in the procedures were incorrect, or that other habitat variables should be added or substituted for existing variables.

Another possibility is that factors other than habitat influenced the variation in squirrel densities. The 4 areas on the RBWA were open to squirrel hunting during this study, whereas the 2 TSBC areas were not. However, Nixon et al. (1975) studied the variation in gray squirrel abundance over a 10-year period on an area that was hunted and determined that hard mast production had the greatest influence on squirrel abundance. We did not measure the number of squirrels harvested on the RBWA areas, but we believe hunting pressure was light and harvest probably had a negligible influence on density estimates.

Both the HSI and WHAG procedures were based on the same index rating scale. However, the WHAG procedure consistently indicated habitat suitability was average to excellent (index $\geq$0.50), whereas HSI indices were lower, especially for fox squirrels. Thus, conclusions regarding the suitability of squirrel habitat differed depending upon the evaluation procedure used rather than habitat conditions.

Our study was limited in that we evaluated these procedures over a narrow range of habitat conditions. However, based on our findings, a more thorough study of these 2 procedures is needed before either can be used reliably.

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