BIOLOGICAL REPORT 82(10.135)
JULY 1987 REVISED

# HABITAT SUITABILITY INDEX MODELS: GRAY SQUIRREL







.nd Wildlife Service

)epartment of the Interior

# MODEL EVALUATION FORM

Habitat models are designed for a wide variety of planning applications where habitat information is an important consideration in the decision process. However, it is impossible to develop a model that performs equally well in all situations. Assistance from users and researchers is an important part of the model improvement process. Each model is published individually to facilitate updating and reprinting as new information becomes available. User feedback on model performance will assist in improving habitat models for future applications. Please complete this form following application or review of the model. Feel free to include additional information that may be of use to either a model developer or model user. We also would appreciate information on model testing, modification, and application, as well as copies of modified models or test results. Please return this form to:

Habitat Evaluation Procedures Group
U.S. Fish and Wildlife Service
2627 Redwing Road, Creekside One
Fort Collins, CO 80526-2899

Thank you for your assistance.

Species ______________ Geographic Location ______________________________

Habitat or Cover Type(s) ______________________________

Type of Application: Impact Analysis ____ Management Action Analysis ____
Baseline ____ Other ______________________________

Variables Measured or Evaluated ______________________________

______________________________

______________________________

______________________________

Was the species information useful and accurate? Yes ____ No ____

If not, what corrections or improvements are needed? ______________________________

______________________________

______________________________

______________________________

Were the variables and curves clearly defined and useful? Yes ____ No ____

If not, how were or could they be improved? ______________________________

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Were the techniques suggested for collection of field data:

Appropriate? Yes ____ No ____

Clearly defined? Yes ____ No ____

Easily applied? Yes ____ No ____

If not, what other data collection techniques are needed? ______________

______________________________________________________________________________

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Were the model equations logical? Yes ____ No ____

Appropriate? Yes ____ No ____

How were or could they be improved? ______________________________________

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Other suggestions for modification or improvement (attach curves, equations, graphs, or other appropriate information) ______________________

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Additional references or information that should be included in the model:

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Model Evaluator or Reviewer ______________________ Date ______________

Agency ______________________________________________________________________

Address _____________________________________________________________________

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Telephone Number Comm: ______________________ FTS ______________________

Biological Report 82(10.135)
July 1987 Revised

# HABITAT SUITABILITY INDEX MODELS: GRAY SQUIRREL

by

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## PREFACE

This document is part of the Habitat Suitability Index (HSI) Model Series [Biological Report 82(10)], which provides habitat information useful for impact assessment and habitat management. Several types of habitat information are provided. The Habitat Use Information section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. This information provides the foundation for the HSI model and may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

The following HSI model is a revision of the gray squirrel model published in 1982 (FWS/OBS-82/10.19). The variable percent shrub crown cover has been eliminated from the determination of a cover/reproduction value based in part on the findings of recent research (Brown and Batzli 1984) and the assumption that under most circumstances winter food and den site availability are the most limiting characteristics of gray squirrel habitat.

The HSI Model section documents the habitat model and includes information pertinent to its application. The model synthesizes the habitat use information into a framework appropriate for field application and is scaled to produce an index value between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). The HSI Model section includes information about the geographic range and seasonal application of the model, its current verification status, and a list of the model variables with recommended measurement techniques for each variable.

The model is a formalized synthesis of biological and habitat information published in the scientific literature and may include unpublished information reflecting the opinions of identified experts. Habitat information about wildlife species frequently is represented by scattered data sets collected during different seasons and years and from different sites throughout the range of a species. The model presents this broad data base in a formal, logical, and simplified manner. The assumptions necessary for organizing and synthesizing the species-habitat information into the model are discussed. The model should be regarded as a hypothesis of species-habitat relationships and not as a statement of proven cause and effect relationships. The model may have merit in planning wildlife habitat research studies about a species, as well as in providing an estimate of the relative suitability of habitat for that species. User feedback concerning model improvements and other suggestions that may increase the utility and effectiveness of this habitat-based approach to fish and wildlife planning are encouraged. Please send suggestions to:

National Ecology Center
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ACKNOWLEDGMENTS

Appreciation is sincerely extended to F.S. Barkalow and C.M. Nixon for their reviews of earlier drafts of this HSI model. The cover of this document was illustrated by Jennifer Shoemaker. Word processing was provided by Dora Ibarra and Patricia Gillis.

GRAY SQUIRREL (*Sciurus carolinensis*)

## HABITAT USE INFORMATION

### General

The gray squirrel (*Sciurus carolinensis*) inhabits deciduous and mixed deciduous-coniferous forests (Uhlig 1955; Golley 1962). Although they may occur in a variety of forested habitats, large, densely forested areas are preferred (Taylor 1974).

### Food

Tree seed, or mast, is the most important food of gray squirrels (Gurnell 1983). Fruits, floral parts, buds, bark, roots, fungi, and animal matter are seasonally important foods. The annual diet of the gray squirrel in Missouri included 97 plant and 47 animal foods (Korschgen 1981). Eighteen of the plant items contributed 86.8% of the total food volume. Mast was the principal food consumed during winter. Hickory (*Carya* spp.), pecan (*C. illinoensis*), black walnut (*Juglans nigra*), and red mulberry (*Morus rubra*) were used to a much greater extent than indicated by their percentage of the forest composition. Hickory mast was selected most often by squirrels in Ohio (Nixon et al. 1968).

Availability of mast is highly correlated with adult and juvenile gray squirrel survival (Heaney 1984). Mast is generally high in digestible energy and provides an energy-rich diet during the critical fall and winter period (Gurnell 1983; Reynolds 1985). Availability of mast has a direct influence on the length of the gray squirrel's breeding season, the number of adults and juveniles that produce litters, the number of adults that produce more than one litter, and litter size (Gurnell 1983). Decreased availability or failure of mast crops results in increased emigration and intensified social stress due to competition for limited resources (Nixon and McClain 1969). Survival of summer-born squirrels was drastically reduced when the mast crop fell below 145.7 kg of sound seed per hectare due to increased competition for mast from older, dominant squirrels and other wildlife species (Nixon et al. 1975). Mast production >168 kg/ha was believed to be necessary to sustain reasonably high squirrel densities. Approximately 8.5 $m^2$ of basal area of trees in seed producing size [≥25.4 cm diameter at breast height (dbh)] was believed sufficient to produce this amount of seed.

The density and species composition of trees of mast-bearing age has a major influence on long-term squirrel densities (Gurnell 1983). An increased diversity of mast producing trees will result in a more stable food supply due to the fact that mast failures typically do not occur concurrently in all species. Nixon et al. (1975) recommended that a variety of mast producing tree species should be present over a range of sites to minimize the effect of mast crop failure on squirrel populations. Because time of flowering, (therefore susceptibility to frost) varies between species, weather is less likely to have a major impact on seed production in a stand or forest that contains several species of mast producing trees (Spurr and Barnes 1980). The amount of mast produced by trees varies by species, age or vigor of individual trees, and site conditions. Large, dominant trees with exposed, sunlit crowns are the primary seed producers. Smaller trees with shaded, overtopped crowns will produce few, if any, seeds.

Water

Eastern gray squirrels can satisfy water needs from free water or succulent plant materials (U.S. Forest Service 1971; Flyger and Gates 1982). Pregnant and lactating females, however, often use free water (F.S. Barkalow, Jr., Department of Zoology and Forestry, North Carolina State University; letter dated October 10, 1981). Therefore, surface water should be available within the normal home range.

Cover

Gray squirrels are primarily associated with extensive, mature hardwood forests that provide an abundance of potential den sites (tree cavities) and contain dense understory vegetation (Flyger and Gates 1982). Optimum gray squirrel habitat in Illinois was characterized as a closed canopy forest with a well developed understory (Nixon et al. 1978). The squirrels were most often associated with extensive, ungrazed forests with a predominance of trees in the sawtimber size class (dbh ≥22.8 cm). Important tree species were sugar maple (Acer saccharum), white oak (Quercus alba), elm (Ulmus spp.), and black oak (Q. velutina). These species indicate climax, or near climax, conditions on upland sites in Illinois. Gray squirrels were absent from forests in early successional stages containing tree species such as osage orange (Maclura pomifera), shagbark hickory (C. ovata), common hackberry (Celtis occidentalis), and hawthorn (Crataegus spp.).

Tree cavities are almost always used by gray squirrels for rearing their winter litters (Barkalow, unpubl.). Although leaf nests are often used by fox squirrels (S. niger), they are seldom used by gray squirrels (C.M. Nixon, Illinois Institute of Natural Resources, letter dated October 2, 1981). The most critical need for dens is for rearing litters and winter shelter (Nixon et al. 1968). At least one den per 0.8 ha was recommended to provide enough winter shelter for gray squirrels (Sanderson 1975). Two to five den trees per 0.4 ha is optimum (Brown and Yeager 1945; U.S. Forest Service 1971). Forest stands occupied by gray squirrels in Illinois never average <6 cavities/ha (Nixon et al. 1978). The average number of cavities was twice the number available in stands that were not occupied by gray squirrels.

Ash (*Fraxinus* spp.), elm, oak, hickory, beech (*Fagus* spp.), baldcypress (*Taxodium distichum*), sycamore (*Platanus occidentalis*), sassafras (*Sassafras albidum*), and basswood (*Tilia* spp.) are most often used as den trees by gray squirrels in the eastern United States (Goodrum 1938; Nixon et al. 1968). Blackgum tupelo (*Nyssa sylvatica*), beech, and maple (*Acer* spp.) produced most of the cavities suitable for gray squirrels in Georgia, although oaks, which are more common, may be the most important trees in terms of providing shelter (Golley 1962). Sassafras, elm, beech, and sugar maple in Illinois contained more cavities than expected based on their relative abundance (Nixon et al. 1980). White oak and black walnut contained significantly fewer cavities than expected.

Gray squirrels in West Virginia usually denned in live trees with a dbh of at least 40.0 cm (Sanderson et al. 1975). Eighty-eight percent of gray squirrel dens in eastern Texas were in trees with a dbh of at least 30.5 cm (Baker 1944).

Gray squirrel abundance in unmanaged, low quality forests in Tennessee was influenced more by the availability of hard mast than by the density and availability of suitable den trees (i.e., those containing suitable cavities) (Huntley 1983). The availability of suitable den sites appeared to have little impact on large fluctuations in gray squirrel density. The author concluded that limited production of hard mast constrained gray squirrel production and that management actions that would increase mast production would increase the squirrel population.

Even-aged stands of hardwoods less than 30 to 40 years old do not produce sufficient mast or cavities to support gray squirrel populations (U.S. Forest Service 1971). Hardwood stands more than 60 years old are potentially optimum gray squirrel habitat.

Several authors have reported that gray squirrels prefer forests with a well-developed understory (Madson 1964; Taylor 1974; Nixon et al. 1978; Flyger and Gates 1982). Forests in Illinois that contained gray squirrels had a mean percentage of woody canopy below 1.5 m in height of 52.9%, whereas forests devoid of gray squirrels had 34.2% woody cover in this height class (Nixon et al. 1978). In midstory (1.5 - 9.0 m), the percentage of woody cover was 83.5% where gray squirrels were absent and 90.4% in forests containing the species. Brown and Batzli (1984) concluded that the density of understory trees was not important in determination of gray squirrel distribution and that the relationship between the presence of the species and understory cover may be correlated with forest size. The authors speculated that small forested areas, characteristically unsuitable gray squirrel habitat, are more likely to be subject to grazing that eliminates understory cover. Conversely, large tracts of forest cover generally receive less grazing pressure and typically have well developed understory cover. Therefore, the size of the forested area may have an important influence on gray squirrel distribution and the presence of understory cover may be correlated with the size of the contiguous forested cover type. Brown and Batzli (1984) were of the opinion that encouragement of undergrowth in forested stands with the intention of maintaining or enhancing gray squirrel populations may be less beneficial than management techniques that maintain larger patches of forest.

## Reproduction

The reproductive requirements of the gray squirrel are assumed to be synonymous with the cover requirements described above.

## Interspersion

The proportion of forest cover in an area may be the most important factor influencing gray squirrel distribution (Brown and Batzli 1984). Nixon et al. (1978) concluded that landscapes in northern and central Illinois must be ≥20% forested in order to support at least a minimal gray squirrel population.

Factors that influence the size of a gray squirrel's home range include availability of food, population density, habitat quality, sex, and age (Cordes and Barkalow 1972; Flyger and Gates 1982). Males generally have larger home ranges than do females, and their home range often overlaps with those of other adult squirrels (Bakken 1959; Cordes and Barkalow 1972; Doebel and McGinnes 1974). Breeding females defend their territory against other female gray squirrels (Nixon et al. 1975) and are more sedentary than are adult males and subadults (Nixon et al. 1980). Therefore, they are more susceptible to changes in habitat conditions that influence availability of denning sites and food.

The average annual home range for adult gray squirrels in North Carolina was 0.72 ha (Cordes and Barkalow 1972). Home range size for subadults and juveniles averaged 1.09 ha and 1.01 ha, respectively. Overall population density was <3 squirrels/0.4 ha. The average home range for gray squirrels in Virginia was <6 ha (Doebel 1967). The home range for adult male and female gray squirrels was 0.8 ha and 0.5 ha in Maryland (Flyger 1960). Larger home ranges can be expected to be associated with low quality habitats, whereas smaller home ranges correspond with higher population densities (Flyger and Gates 1982).

## Special Considerations

The ranges of fox and gray squirrels overlap through most of the eastern United States (Bakken 1952, cited by Taylor 1974). Coexistence of the two species occurs mostly in the western and northern portions of the ranges of both species. Although the two species may inhabit the same general area, they tend to concentrate in slightly different habitats. Gray squirrels prefer large dense stands of hardwoods with a dense understory, whereas fox squirrels generally prefer open woodland habitats with little understory vegetation (Taylor 1974). Gray squirrels are generally more abundant in extensive, mature forest stands, whereas fox squirrels are more common in small woodlots, fencerows, and less dense forest stands (Flyger and Gates 1982). Gray squirrels in Texas were more common in poorly drained lowland areas, while fox squirrels were more frequent in upland and well drained bottomland habitats (Goodrum 1938). Differences in habitat preference and foraging behavior are reflected in the foods eaten. Fox squirrels in Missouri commonly inhabit open forests, forest edges, woodlots, and fencerows where oak-hickory mast (52.2% of the annual diet) is supplemented with corn and other foods associated with these habitats (Korschgen 1981). Gray squirrels occupy dense forests with nearly closed canopies and abundant ground cover, and rely more on oak-hickory mast (73.3% of the annual diet).

## HABITAT SUITABILITY INDEX (HSI) MODEL

### Model Applicability

Geographic area. This HSI model has been developed for application throughout the range of the gray squirrel (Figure 1).

Season. This HSI model was developed to evaluate the potential quality of year-round habitat for the gray squirrel.

Cover types. This model was developed to evaluate the quality of gray squirrel habitat in the following cover types (terminology follows that of U.S. Fish and Wildlife Service 1981 and Cowardin et al. 1979): Deciduous Forest (DF) and Palustrine Forested Wetland (PFO).

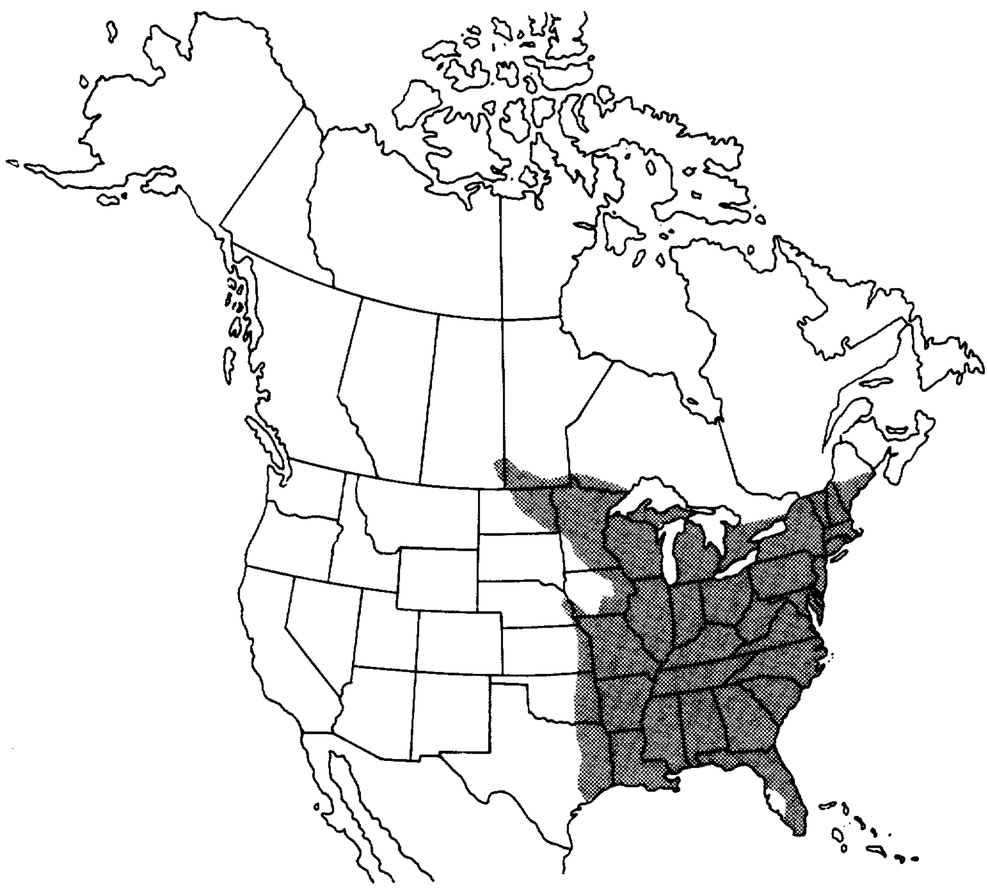

Figure 1. Approximate distribution of the gray squirrel in North America (adapted from Flyger and Gates 1982).

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous habitat that is required before an area will be occupied by a species. Information pertaining to the minimum habitat area for gray squirrels was not located in the literature. The mean minimum home range for the gray squirrel is at least 0.49 ha. For the purposes of this model, it is assumed that an area of <0.4 ha is unsuitable, and the HSI will equal 0.

Verification level. This HSI model provides habitat information useful for impact assessment and habitat management. The model is a hypothesis of species-habitat relationships and does not reflect proven cause and effect relationships. Earlier drafts of this model were reviewed by F.S. Barkalow, North Carolina State University, and C.M. Nixon, Illinois Institute of Natural Resources. Improvements suggested by these reviewers were incorporated into the model.

## Model Description

Overview. All habitat requirements of the gray squirrel potentially can be satisfied within deciduous forests and deciduous forested wetlands. This model is based on the assumption that the availability of suitable winter food (hard mast) and den sites provided by tree cavities are the most limiting components of year-round gray squirrel habitat. Foods utilized by gray squirrels during spring and summer are variable and, due to their diversity and relative abundance, are assumed to be less limiting than is the availability of hard mast. The cover and reproductive habitat requirements are assumed to be synonymous in that tree cavities provide sites for parturition and litter rearing as well as shelter throughout the year.

The availability and distribution of surface water is assumed to be less limiting in the definition of habitat quality for gray squirrels than are winter food and cover/reproduction requirements. Therefore, the presence of surface water is not addressed in this model.

Gray squirrels have been reported to prefer forests with well developed understory vegetation. This model, however, is based on the assumption that the density of understory vegetation is of less importance in the definition of habitat quality for gray squirrels than are the availability of winter food and cover/reproduction habitat requirements. It is assumed that if suitable winter food and den sites are available then the evaluation area will be suitable habitat for gray squirrels regardless of understory density. Therefore, understory vegetation is not addressed in this model.

Index values derived through the application of this model are assumed to be indicative of the relative abundance of gray squirrels that can be supported within the evaluation area on a long-term basis. Areas with low HSI values are assumed to be unsuitable-to-poor habitat as a result of inadequate den sites or insufficient availability of winter food and are assumed to support few gray squirrels on a long-term basis. The potential for an area to support greater numbers of gray squirrels is assumed to correspond to increasing HSI values.

The following sections provide documentation of the logic and assumptions used to translate habitat information for the gray squirrel to the variables and equations used in the HSI model. Specifically, these sections identify important habitat variables, define and justify the suitability levels of each variable, and describe assumed relationships between variables and life requisites.

Winter food component. The availability of a winter food source, e.g., hard mast, for gray squirrels is assumed to be a function of the abundance and diversity of mast producing trees and the total canopy closure of the stand. Cover types that do not produce hard mast are assumed to be representative of marginal year-round gray squirrel habitat due to the absence of high quality winter food. For the purposes of this model, the availability of hard mast is assumed to be a function of the canopy cover of hard mast trees that are ≥25 cm dbh, the number of hard mast producing tree species, and percent tree canopy cover (Figure 2).

Figure 2a illustrates the assumed relationships between the proportion of the total tree canopy cover that is hard mast producing trees >25 cm dbh and the quality of winter food for the gray squirrel. Maximum availability of hard mast is assumed to occur when the forest canopy is totally composed of trees that produce hard mast. The size constraint, 25 cm, has been incorporated into the measure of canopy closure of hard mast trees with the assumption that trees ≥25 cm dbh represent mature trees that produce seed crops. Depending on site conditions, however, trees in smaller or larger size classes may be the primary seed producers in a stand. Users of this model may wish to modify the size constraint in Figure 2a based on regional knowledge or data, to more accurately reflect local conditions.

Forest stands composed of several species of trees that produce hard mast are assumed to have greater potential for providing consistent and dependable winter food for gray squirrels. Because the time of flowering varies by species, adverse weather that eliminates flower/seed production is less likely to result in total failure in stands composed of several species than in monotypic stands or stands with minimum diversity of hard mast producing species. Figure 2b displays the assumed relationship between the number of species of trees that produce hard mast and winter food quality for gray squirrels. Stands containing ≥4 species of hard mast producing trees are assumed to represent maximum dependability of mast production and optimum conditions in terms of winter food quality for gray squirrels. As the number of hard mast producing species present decreases the probability of the production of consistent mast crops is assumed to decrease. A minimal value has been assigned to stands devoid of mast producing trees with the assumption that other foods may be available to support gray squirrels through the winter. This may be particularly true in areas of relatively low elevation or latitude with comparatively long growing seasons.

The total percent tree canopy cover is assumed to influence mast production and the availability of winter food for gray squirrels. Large, dominant trees with well exposed sunlit crowns are the primary seed producers in forest stands (Spurr and Barnes 1980). Conversely, overtopped, shaded, and

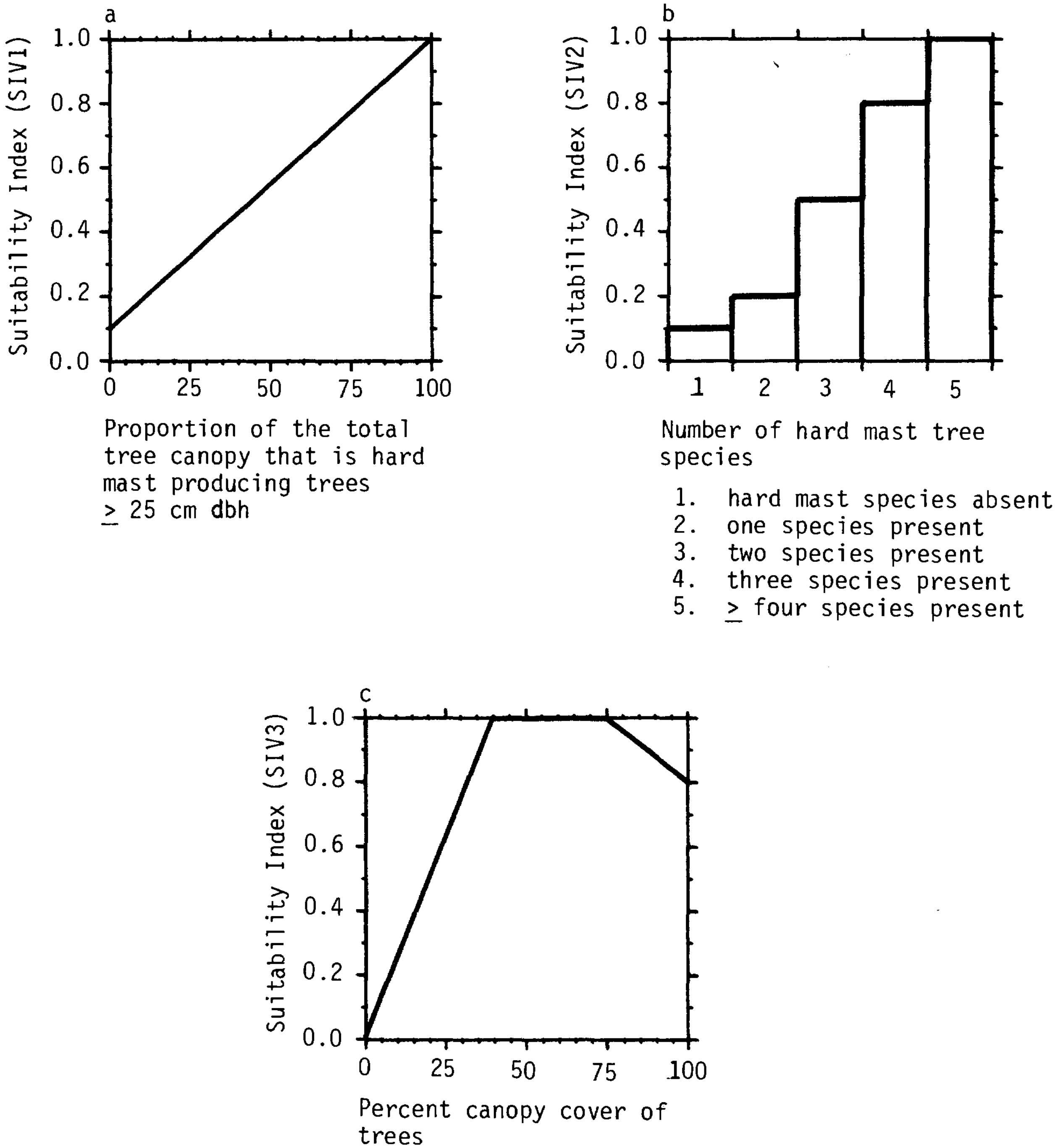


Figure 2. Relationships between percent canopy cover of hard mast trees ≥25 cm dbh, the number of hard mast tree species, and percent canopy cover of trees to winter food habitat quality for the gray squirrel.

suppressed trees generally produce minimal seed crops. This model is based on the assumption that forest stands that range from 40% to 75% canopy cover are representative of stands where maximum seed production can be expected to occur, resulting in assumed optimum winter food conditions for gray squirrels (Figure 2c). Stands with >75% tree canopy cover are assumed to represent decreased potential for maximum seed production due to the closed nature of the canopy. It is assumed, however, that significant seed production will occur in the crowns of dominant and codominant trees, resulting in only slightly less than ideal availability of winter food. Forest stands with <40% canopy cover of trees are assumed to represent less suitable availability of winter food due to the open nature of the stand.

The values obtained from the curves in Figure 2 are combined in equation 1 to calculate the winter food index (SIWF) for the gray squirrel.

$$SIWF = (SIV1 \times SIV2)^{1/2} \times SIV3 \quad (1)$$

Equation 1 is based on the following assumptions. The index values for proportion of the total tree canopy cover that is hard mast producing species ≥25 cm dbh (SIV1) and number of hard mast tree species (SIV2) are assumed to have equal value in the definition of gray squirrel winter food quality. The variables are assumed to be compensatory in that a low value for one variable will be offset by a higher value for the remaining variable. Optimum conditions are assumed to occur when a stand is totally composed of ≥4 species of hard mast producing trees. Winter food index values of <1.0 will be obtained if <4 species of hard mast trees are present or if <100% of the stand is composed of these species. The index value for percent canopy cover of trees (SIV3) is assumed to directly modify the value calculated for SIV1 and SIV2. When percent canopy cover of trees is <40%, a winter food index value of <1.0 will be obtained regardless of the proportion of the canopy composed of hard mast trees or the number of mast producing species that are present. Optimum winter food availability (SIWF=1.0) is assumed to occur when tree canopy cover ranges from 40% to 75%, and the stand is totally composed of ≥4 species of hard mast producing trees.

Cover/reproduction component. Densely forested stands dominated by comparatively large, mature to overmature trees are assumed to represent conditions that are suitable for the development of tree cavities, which are required to meet the gray squirrel's cover and reproductive habitat requirements. Cover quality is assumed to be a function of the percent canopy cover of trees and the mean dbh of overstory trees (Figure 3).

Gray squirrels are primarily associated with densely forested cover types. Optimum conditions in terms of stand density are assumed to occur when tree canopy cover ranges from 40% to 100% (Figure 3a). Forested cover types with <40% canopy cover of trees are assumed to be too open to provide suitable conditions for the species and are assumed to be indicative of lower cover/reproductive habitat quality.

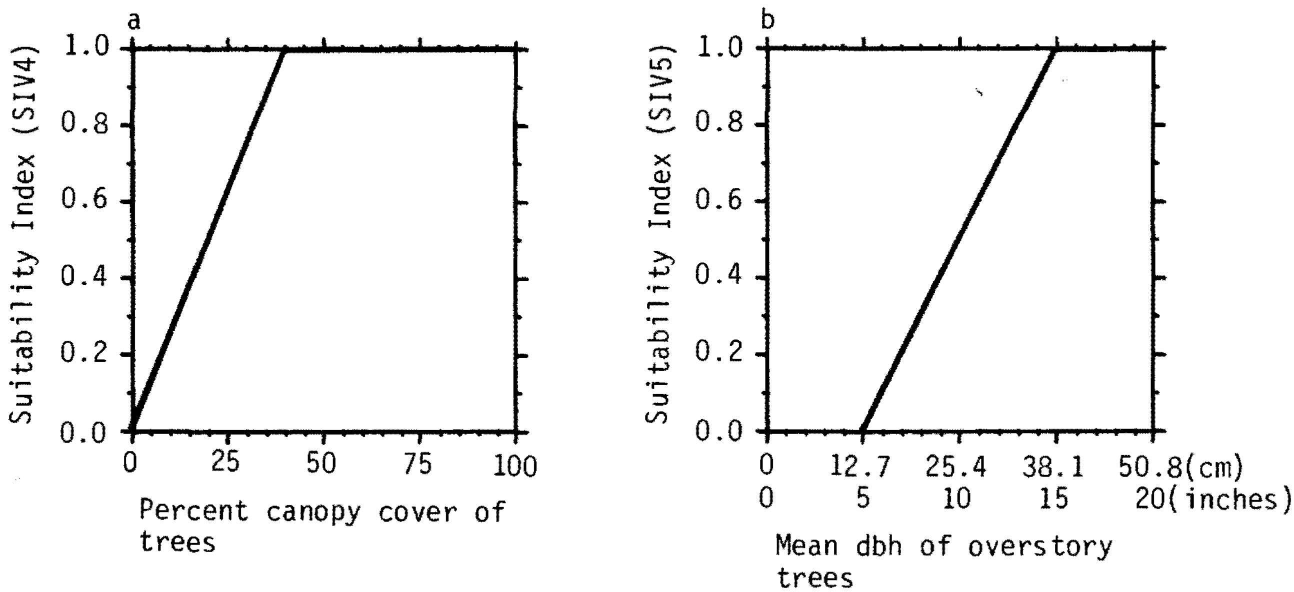


Figure 3. Relationships between canopy cover of trees and mean dbh of overstory trees to gray squirrel cover/reproduction habitat quality.

Gray squirrels are believed to be almost entirely dependent on tree cavities for cover and litter rearing. Forest stands with overstories dominated by mature to overmature trees are assumed to provide conditions suitable for the formation of tree cavities. Nixon et al. (1978) recommended that a minimum of six tree cavities per hectare be maintained to meet the gray squirrel's denning requirements. Admittedly, precise counts of the number of tree cavities existing in a stand, or given area, would provide a more accurate indication of cover/reproduction quality than does a generalized characterization of a stand's structural composition. This model, however, is based on the assumption that users will typically not have the time or resources to conduct intensive surveys to locate and count the number of tree cavities in a stand. It is possible that counting the number of cavities may result in an underestimation of those actually present. Conversely, all cavities located may not be suitable for gray squirrel use, resulting in a possible overestimation of cover/reproduction habitat quality.

The cover/reproduction component of this model is based on the assumption that the probability of the existence of tree cavities in a stand will increase as the stand approaches maturity. Large mature trees are assumed to have a greater likelihood of containing cavities suitable for gray squirrel use than do young or small trees. Similarly, as the number of large, mature trees increases in a stand, it is assumed that the number of tree cavities also will increase. Forested cover types with overstories dominated by mature to overmature trees are assumed to provide an adequate number and density of cavities to meet gray squirrel cover requirements. For the purposes of this model, a stand composed of dominant trees with a mean dbh ≥38.1 cm is assumed to represent optimum cover/reproduction conditions for the species (Figure 3b). Stands comprised of overstory trees with a mean dbh <38.1 cm are assumed to be indicative of younger-aged stands, a lower abundance of cavities, and therefore less than ideal cover conditions for gray squirrels. Forest stands dominated by trees with a mean dbh of <12.7 cm are assumed to be indicative of stands of insufficient maturity to meet gray squirrel cover requirements.

The values obtained from the curves in Figure 3 are combined in equation 2 to calculate the cover/reproduction index (SICR) for the gray squirrel.

$$SICR = (SIV4 \times SIV5)^{1/2} \qquad (2)$$

Equation 2 is based on the following assumptions. The index values derived from Figure 3 are assumed to have equal value in determination of the cover/reproduction index. Percent canopy cover of trees (SIV4) and the mean dbh of overstory trees (SIV5) are assumed to be compensatory. A low value for one variable will be offset by a higher value for the other. Optimum value for cover/reproduction will be obtained when percent canopy cover of trees is ≥40% and the mean dbh of overstory trees is ≥38.1 cm. In stands where tree canopy cover is <40% or the mean dbh of overstory trees is <38.1 cm, a SICR of <1.0 will be obtained.

<u>HSI determination</u>. The calculation of an HSI for the gray squirrel considers life requisite values for winter food (SIWF) and cover/reproduction (SICR). These life requisite values are assumed to be equal in their importance in the definition of gray squirrel habitat quality. Therefore, the HSI value is equal to the lowest value calculated for either life requisite.

This model may be used to determine HSI values for individual forest stands or for a number of stands that make up the total forest cover type being evaluated. Stands are an aggregation of trees, occupying a specific area that are sufficiently uniform in composition, age, size, or condition as to be distinguishable from the growth on adjoining sites. Therefore, HSI values may be quite different between adjacent stands. In situations where two or more stands are present, an overall weighted HSI (weighted by area) can be determined by performing the following steps.

1. Stratify the forested area into individual stands.

2. Determine the area of each stand and the total area of the forest cover type.

3. Determine an HSI value for each stand using equations 1 and 2.

4. Multiply the area of each stand by its respective HSI value.

5. Add all products calculated in step 4 and divide the sum by the total area of all stands to obtain a weighted HSI value.

The steps outlined above are expressed by the following equation:

$$\sum_{i=1}^{n} \frac{HSI_i A_i}{A_i}$$

where $n$ = number of stands

$HSI_i$ = HSI of stand i

$A_i$ = area of stand i

## Application of the Model

Summary of model variables. The relationships between habitat variables, cover types, life requisites, and HSI are summarized in Figure 4. Definitions for the variables used in the gray squirrel model and suggested measurement techniques are provided in Figure 5 (Hays et al. 1981).

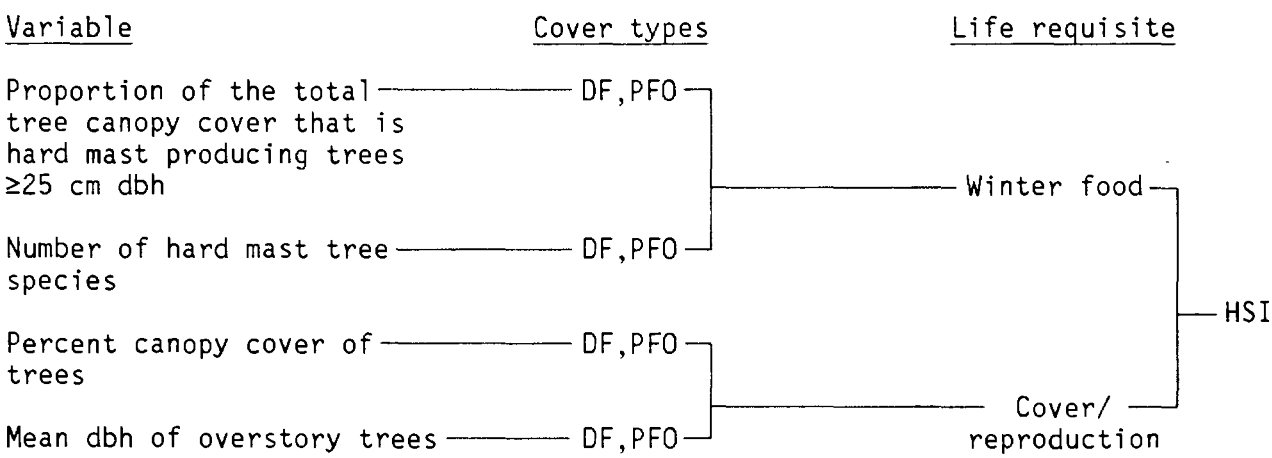


Figure 4. Relationships of habitat variables, cover types, life requisites, and HSI in the gray squirrel HSI model.

| Variable (definition) | Cover types | Suggested technique |
|---|---|---|
| Proportion of the total tree canopy that is hard mast producing trees ≥25 cm dbh [the canopy cover of hard mast producing trees (e.g., oak) that are >25 cm (10 inches) dbh divided by the total canopy cover of all trees]. | DF,PFO | Transect, quadrat |
| Number of hard mast tree species (the number of tree species present in the stand or sample site that produce hard mast). | DF,PFO | Transect, quadrat, tally |
| Percent canopy cover of trees [the percent of the ground surface that is shaded by a vertical projection of the canopies of all woody vegetation >6.0 m (20 ft) tall]. | DF,PFO | Transect, line intercept, quadrat, remote sensing |
| Mean dbh of overstory trees [the mean diameter at breast height (1.4 m; 4.5 ft) of those trees that are ≥80% of the height of the tallest tree in the stand]. | DF,PFO | Cruise for tallest tree, sample with optical range finder and Biltmore stick on strip quadrat |

Figure 5. Definitions of variables and suggested measurement techniques.

Model assumptions. The gray squirrel model has been constructed based on the following major assumptions.

1. Winter food and den sites (specifically tree cavities) are assumed to be the most limiting characteristics of habitat quality for gray squirrels.

2. The availability of winter food is assumed to be directly related to the abundance of hard mast producing trees of seed bearing size and the diversity of these species within an individual stand.

3. The size of the dominant trees in a stand is assumed to provide a surrogate measure of the potential existence of tree cavities. The presence of tree cavities is assumed to be greater in mature to overmature stands than in young and intermediate age class stands.

## SOURCES OF OTHER MODELS

No other habitat models for the gray squirrel were located in the literature.

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16. Abstract (Limit: 200 words)

A review and synthesis of existing information were used to develop a Habitat Suitability Index (HSI) model for the gray squirrel (*Sciurus carolinensis*). The model consolidates habitat use information into a framework appropriate for field application, and is scaled to produce an index between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). HSI models are designed to be used with Habitat Evaluation Procedures previously developed by U.S. Fish and Wildlife Service.

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