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Appendix A. Habitat Use Information and HSI Model for the Gray Squirrel

A.1 Introduction. HSI models should be adequately documented so that the HSI estimates can be properly interpreted. This appendix provides an example gray squirrel model with documentation as described in 103 ESM 3.4. Section A.2 below provides documentation of habitat use information, and A.3 describes the HSI model, including model assumptions and limitations. Section A.4 provides information for applying the model.

A.2 Habitat use information

- A. General. The gray squirrel (*Sciurus carolinensis*) prefers bottomland hardwood and mixed coniferous hardwood forests (Uhlig 1955; Golley 1962). The species also inhabits small woodlots, wooded fencerows, parks, and residential areas.
- B. Food requirements. Fruits, floral parts, buds, bark, roots, fungi, and animal matter are seasonally important foods for the gray squirrel (U.S. Forest Service 1971). However, the species depends heavily upon mast, particularly acorns. Late summer, fall, and winter foods consist mainly of hickory (*Carya* spp.), beech (*Fagus* spp.), and oak (*Quercus* spp.) mast; the spring and summer diet shifts to herbaceous vegetation (Nixon et al. 1968).

Nixon et al. (1975) reported that a significant relationship existed between the annual seed crop and subsequent squirrel densities on their Ohio study area. When the seed crop fell below 145.7 kg of sound seed per ha (130 lb/ac), the survival of summer-born juveniles was drastically reduced due to increased competition from older individuals and other wildlife species. To sustain reasonably high squirrel densities, it was believed that mast production should exceed 168 kg/ha (150 lb/ac). Approximately 8.5 m<sup>2</sup> (10.2 yd<sup>2</sup>) of basal area in trees of seed producing size ( $\geq$  25.4 cm (10 in) dbh) would be needed to produce this amount of seed.

Hickory mast was reported to be the first choice food for squirrels in Ohio (Nixon et al. 1968); however, a variety of mast producing species should be present over a range of sites in order to minimize the likelihood of crop failures (Nixon et al. 1975). Variable mast crops are not uncommon due to the influences of weather, yearly variance in seed production by individual trees, and the temporal difference in acorn maturation between the red and white oak groups.

- C. Water requirements. Eastern gray squirrels can satisfy water needs from free water or succulent plant materials (U.S. Forest Service 1971).

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- D. Cover requirements. Gray squirrels utilize tree cavities and temporary leaf nests for cover and litter rearing. Leaf nests are usually used for temporary summer shelter; however, they also may provide winter shelter and sites for brood-rearing (U.S. Forest Service 1971). The most critical demand for dens is for litter rearing and winter shelter (Nixon *et al.* 1968). One den per 0.8 ha (2 ac) was recommended as the minimum necessary to ensure suitable winter shelter for gray squirrels (Sanderson 1975); however, more optimum reproductive and refuge cover would be provided by 2 to 5 den trees per 0.4 ha (2 to 5/ac) (Brown and Yeager 1945; U.S. Forest Service 1971).

Ash (*Fraxinus* spp.), elms (*Ulmus* spp.), oaks, hickories, beech, cypress (*Taxodium distichum*), sycamore (*Platanus occidentalis*), sassafras (*Sassafras albidum*), and basswood (*Tilia* spp.) have been most commonly identified as potential den trees for gray squirrels in the eastern United States (Goodrum 1937; Nixon 1968). Blackgum (*Nyssa sylvatica*), beech, and maple (*Acer* spp.) were reported to be the most prolific producers of cavities suitable for gray squirrels in Georgia, although oaks, which were more common, may have been the most important trees which provided shelter (Golley 1962).

Gray squirrels in West Virginia were reported to most commonly nest in live trees which had a dbh of at least 40.0 cm (15.7 in) (Sanderson *et al.* 1975). Eighty-eight percent of gray squirrel dens recorded in eastern Texas were located in trees which were equal to or greater than 30.5 cm (12 in) dbh (Baker 1944).

The gray squirrel in eastern Texas was reported to be more numerous in forests of mixed composition than in stands providing low species diversity (Goodrum 1937). Habitats with moderate to dense brushy undergrowth will provide more valuable habitat for gray squirrels than sites with little to no understory (U.S. Forest Service 1971).

- E. Reproductive requirements. The reproductive requirements of the gray squirrel are synonymous with its cover requirements as described above.
- F. Interspersion requirements. The home range of the gray squirrel in Missouri ranged from 4 to 16 ha (10 to 40 ac) (Schwartz and Schwartz 1974). The mean minimum home range for gray squirrels in Virginia was reported as being 0.49 ha (1.2 ac) (Doebel and McGinnes 1974). Male gray squirrels generally have larger ranges than do females (Bakken 1959). The ranges of adult males often overlap with those

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of other adult males and females. In contrast, breeding females will defend their territory against other female gray squirrels (Nixon et al. 1975).

- G. Special considerations. Even-aged stands of hardwoods of less than 30 to 40 years in age do not produce sufficient mast or cavities to support gray squirrel populations (U.S. Forest Service 1971). Hardwood stands exceeding 60 years in age provide optimum gray squirrel habitat.

Livestock grazing may reduce understory vegetation utilized for cover by foraging gray squirrels (Flood et al. 1977). Croplands interspersed with forests or woodlots add to the available food supply and may supplement the diet of gray squirrels in low mast production years.

A.3 Habitat Suitability Index (HSI) model for the gray squirrel (*Sciurus carolinensis*)

A. Model applicability

- (1) Geographic area. This model is applicable to the cover types indicated below within the geographic range of the species.
- (2) Season. This model will produce HSI values for year-round habitat needs of the gray squirrel.
- (3) Cover types. The following cover types are utilized by the gray squirrel: Deciduous Forest (DF), Deciduous Forested Wetlands (DFW), and Evergreen Forest (EF)
- (4) Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous habitat that is required for a species to successfully live and reproduce. The mean minimum home range for the gray squirrel has been reported to be 0.49 ha (1.2 ac). For purposes of this model, it is assumed that a habitat of less than 0.4 ha (1 acre) will provide no suitability, and the HSI will equal zero in such areas.
- (5) Verification level. This model has been reviewed within the Habitat Evaluation Procedures Group and meets their quality standards. It has not been tested under field conditions.

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B. Model description

- (1) Graphic overview. This HSI model for the gray squirrel considers specific variables and their relationship to life requisites and the HSI, as shown in Figure A-1. Cover and reproductive needs are assumed to be the same, and it is assumed that water is not limiting.

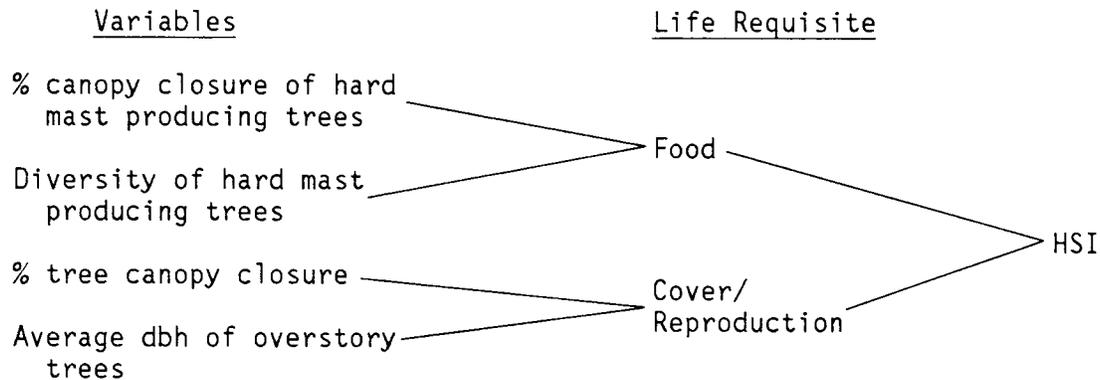


Figure A-1. Tree diagram showing relationship of habitat variables and life requisites to the HSI for the gray squirrel.

(2) Life requisite components

- a) Food. A wide variety of vegetative food is consumed by the gray squirrel during the spring and summer. The late summer, fall, and winter diet is comprised chiefly of hickory, beech, and oak mast. It is assumed that the fall and winter diet will always be more limiting than the spring and summer diet. Mixed forest stands will provide a more stable food supply than stands dominated by one mast producing species. It has been reported that to sustain reasonably high squirrel densities approximately 8.5 m<sup>2</sup> per hectare of basal area of seed producing trees ( $\geq 25.4$  cm dbh) should be present in the stand. It is assumed that greater than 75% canopy closure of hard mast producing trees exceeding 25.4 cm (10 in) dbh will be of optimal value.

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Overall food suitability is related to the density and diversity of hard mast producing trees. Habitats with a lack of hard mast trees will provide no food. Areas with low diversity will be more valuable if they have high densities, and areas with low densities will be more valuable with accompanying high diversity.

- b) Cover/Reproduction. Gray squirrels utilize temporary leaf nests and tree cavities for litter rearing and shelter. The most critical aspect of cover for this species is the availability of tree cavities. It is assumed that if large diameter trees are available, cavities will be present to provide winter and reproductive cover for the gray squirrel. Cover requirements for the gray squirrel are assumed to be optimum where the percent tree canopy closure exceeds 40%, and the average dbh of overstory trees is equal to or exceeds 30.5 cm (12 in).

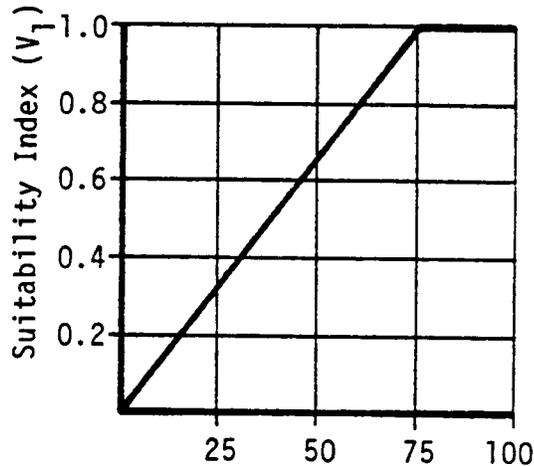
Overall cover/reproductive suitability is related to the size and density of trees. It is assumed that any size and density combination has some value to gray squirrels. It is further assumed that habitats with low tree densities will be more valuable if they have large diameters, and areas with lower tree diameters will be more valuable if they have high canopy closures.

- C. Model relationships. This section contains suitability index curves and equations to quantitatively describe the relationships discussed in the previous section. These curves and equations can be used to produce an HSI for the gray squirrel.

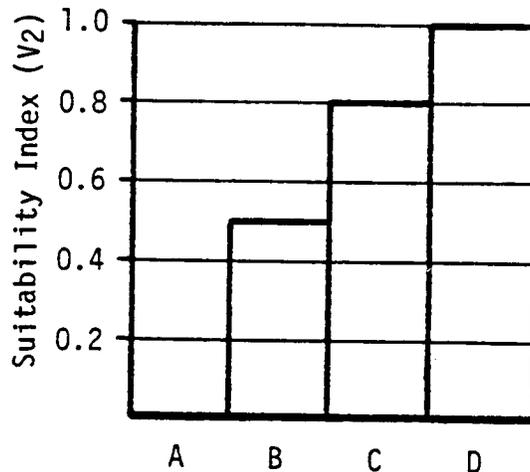
- (1) Suitability index curves

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Cover Type	Variable	
DF,DFW,EF	(V <sub>1</sub> )	Percent canopy closure of hard mast producing trees (oak, hickory, walnut, pecan, beech, and others) which are $\geq 25.4$ cm (10 in) dbh.



DF,DFW,EF	(V <sub>2</sub> )	Diversity of hard mast producing trees (oak, hickory, walnut, pecan, beech, and others).
		A) None present in forest or stand. B) 1 species present. C) 2 species present. D) $\geq 3$ species present.

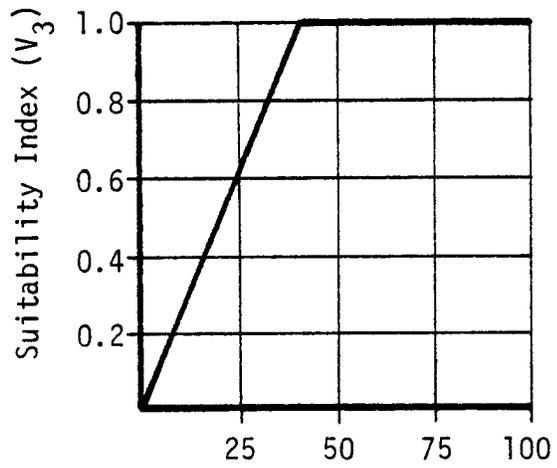


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DF,DFW,  
EF

(V<sub>3</sub>)

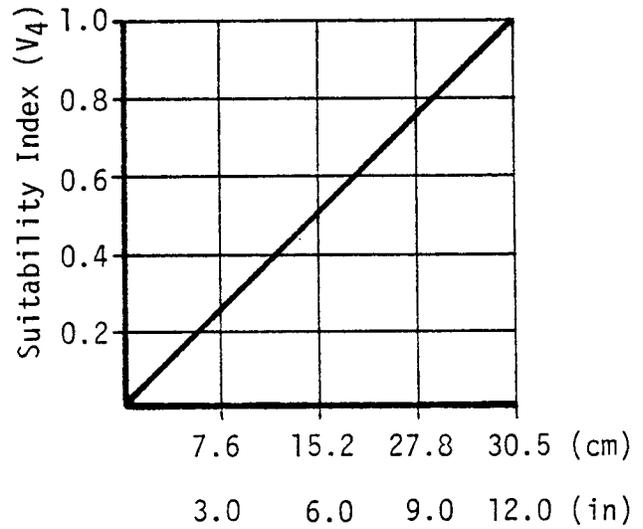
Percent tree canopy closure.



DF,DFW,  
EF

(V<sub>4</sub>)

Average dbh of overstory trees.



Appendix A. Habitat Use Information and HSI Model for the Gray Squirrel(2) Equations

- a) Equation for food component. The following equation integrates the index values for each variable to obtain a life requisite value for food in each cover type.

$$\text{Food Value} = (V_1 \times V_2)^{1/2}$$

- b) Equation for cover/reproduction component. The following equation integrates the index values for each variable to obtain a life requisite value for cover/reproduction in each cover type.

$$\text{Cover/Reproduction Value} = (V_3 \times V_4)^{1/2}$$

- D. HSI determination. Based on the limiting factor concept, the HSI is equal to the lowest life requisite value.

A.4 Application of the model. The level of detail needed for a particular application of this model will depend on time, money, and accuracy constraints. Detailed field sampling of all variables will provide the most reliable and replicable HSI values. Any or all variables can be estimated, in order to reduce the amount of time required to apply the model. Increased use of subjective estimates decreases reliability and replicability, and these estimates should be accompanied by appropriate documentation to insure that decisionmakers understand both the method of HSI determination and quality of the data used in the HSI model.

The measurement techniques in Table A-1 are suggested for the variables used in this model. A field form can be developed from this list.

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Table A-1. Suggested measurement techniques and definition of habitat variables.

Variable (Definition)	Cover Types	Suggested Technique
(V <sub>1</sub> ) Percent canopy closure of hard mast producing trees (the percent of the ground that is shaded by a vertical projection of the canopies of trees which produce a hard shelled fruit, and are equal to or exceed 25.4 cm [10 in] dbh)	DF,DFW,EF	Transect, line intercept
(V <sub>2</sub> ) Diversity of hard mast producing trees (the number of hard mast producing tree species present in the stand)	DF,DFW,EF	Transect, tally, ocular estimate
(V <sub>3</sub> ) Percent tree canopy closure (the percent of the ground surface that is shaded by a vertical projection of the canopies of all trees)	DF,DFW,EF	Transect, line intercept
(V <sub>4</sub> ) Average dbh of overstory trees (the average diameter at breast height [1.4 m/ 4.5 ft] above the ground of those trees that comprise the uppermost canopy in a forest or stand)	DF,DFW,EF	Transect, line intercept, dbh tape

A.5 Sources of other models. No other habitat models were located for the gray squirrel during literature searches.

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A.6 References cited

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