Biological Services Program
and
Division of Ecological Services

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JULY 1982

HABITAT SUITABILITY INDEX MODELS: GRAY SQUIRREL

Fish and Wildlife Service
U.S. Department of the Interior

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This model is designed to be used by the Division of Ecological Services in conjunction with the Habitat Evaluation Procedures.

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July 1982

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by

Arthur W. Allen
Habitat Evaluation Procedures Group
Western Energy and Land Use Team
U.S. Fish and Wildlife Service
Drake Creekside Building One
2625 Redwing Road
Fort Collins, CO 80526

Western Energy and Land Use Team
Office of Biological Services
Fish and Wildlife Service
U.S. Department of the Interior
Washington, DC 20240

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PREFACE

This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-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. The habitat use information provides the foundation for HSI models that follow. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

The HSI Model Section documents a habitat model and 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 application information includes descriptions of the geographic ranges and seasonal application of the model, its current verification status, and a listing of model variables with recommended measurement techniques for each variable.

In essence, the model presented herein is a hypothesis of species-habitat relationships and not a statement of proven cause and effect relationships. Results of model performance tests, when available, are referenced. However, models that have demonstrated reliability in specific situations may prove unreliable in others. For this reason, feedback is encouraged from users of this model concerning improvements and other suggestions that may increase the utility and effectiveness of this habitat-based approach to fish and wildlife planning. Please send suggestions to:

Habitat Evaluation Procedures Group
Western Energy and Land Use Team
U.S. Fish and Wildlife Service
2625 Redwing Road
Ft. Collins, CO 80526

CONTENTS

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GRAY SQUIRREL (Sciurus carolinensis)

HABITAT USE INFORMATION

General

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

Food

Fruits, floral parts, buds, bark, roots, fungi, and animal matter are seasonally important foods for the gray squirrel (U.S. Forest Service 1971). 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 principle food item during the winter months. Hickories (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).

A significant relationship existed between the annual seed crop and subsequent squirrel densities in an Ohio study (Nixon et al. 1975). The survival of summer-born juvenile squirrels was drastically reduced when the seed crop fell below 145.7 kg of sound seed per ha (130 lb/acres), because of the increased competition for mast from older individuals and other wildlife species. A mast production greater than 168 kg/ha (150 lb/acres) is needed to sustain reasonably high squirrel densities. Approximately 8.5 m^2 (71.8 ft^2) of basal area in trees of seed producing size [≥ 25.4 cm (10 in)] will produce this amount of seed.

A variety of mast producing species should be present over a range of sites in order to minimize the effect of crop failure (Nixon et al. 1975). Mast crops vary by species, age of tree, soil and weather influences and seed production by individual trees (Spurr and Barnes 1980). Weather is unlikely to have a major impact on seed production in a forest that contains several tree species because the time of flowering will vary by species.

Large, dominant trees with exposed, sunlit crowns are the primary seed producers in closed stands (Spurr and Barnes 1980). Smaller trees with shaded 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). However, pregnant and lactating females often use free water (Barkalow pers. comm.). Therefore, free water should be available within the normal home range.

Cover

Optimum gray squirrel habitat in Illinois was 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 (9 inches)]. 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), hackberry (Celtis occidentalis), and hawthorn (Crataegus spp).

Tree cavities are almost always used by gray squirrels for rearing their winter litters (Barkalow pers. comm.). Although leaf nests are often used by fox squirrels, they are seldom used by gray squirrels (Nixon pers. comm.). 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 (2 acres) was recommended as necessary to provide enough winter shelter for gray squirrels (Sanderson 1975). Two to five den trees per 0.4 ha (2 to 5/acre) are optimum (Brown and Yeager 1945; U.S. Forest Service 1971). Forest stands occupied by gray squirrels in Illinois never averaged less than 6 cavities/ha (2.4/acre) (Nixon et al. 1978). The average number of cavities was twice the number available in stands that were not occupied by gray squirrels.

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 optimum gray squirrel habitat.

Ash (Fraxinus spp.), elm, oaks, hickories, beech (Fagus spp.), cypress (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 1937; Nixon 1968). Blackgum (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 nested in live trees with a dbh of at least 40.0 cm (15.7 inches) (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 (12 inches) (Baker 1944).

Reproduction

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

Interspersion

The home range of the gray squirrel in Missouri was from 4 to 16 ha (10 to 40 acres) (Schwartz and Schwartz 1959). The mean minimum home range for gray squirrels in Virginia was 0.49 ha (1.2 acres) (Doebel and McGinnes 1974). Male gray squirrels generally have a larger range than do females, and their range often overlaps with those of other adult squirrels (Bakken 1959; Cordes and Barkalow 1972). Breeding females defend their territory against other female gray squirrels (Nixon et al. 1975) and are more sedentary than adult males or subadults (Nixon et al. 1980). Therefore, they are more susceptible to habitat changes that affect the availability of denning sites and food.

Areas occupied by gray squirrels in northern and central Illinois were at least 20% forested (Nixon et al. 1978).

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 (Bakken 1952, cited by Taylor 1974). 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 in Texas were more common in poorly drained lowland areas, while fox squirrels were more frequent in upland and well drained bottomland habitats (Goodrum 1937). 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 fence rows 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 model is applicable throughout the geographic range of the species.

Season. This model will produce HSI values for year-round habitat needs of the gray squirrel.

Cover types. This model is intended to evaluate gray squirrel habitat in the following cover types (terminology follows that of U.S. Fish and Wildlife Service 1981): Deciduous Forest (DF) and Deciduous Forested Wetland (DFW).

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. The mean minimum home range for the gray squirrel is at least 0.49 ha (1.2 acres). For purposes of this model, it is assumed that a habitat of less than 0.4 ha (1 acre) will provide no suitability; the HSI will equal 0.0 in such areas.

Verification level. This model was 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 this model.

Model Description

Overview. All habitat requirements of the gray squirrel can be satisfied within deciduous forests or deciduous forested wetlands. Therefore, this model treats the gray squirrel as using only these cover types, and habitat evaluation based on this model only considers the quality of life requisites provided by deciduous forested cover types. The cover and reproductive needs of the gray squirrel are assumed to be identical. It also is assumed that the availability of water will never be more limiting than the winter food or cover/reproduction potential of the site.

The following sections document 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 cover: (1) identification of variables used in the model; (2) definition and justification of the suitability levels of each variable; and (3) description of the assumed relationships between variables.

Figure 1 illustrates the relationships of habitat variables, life requisites, and cover types for the gray squirrel.

Winter food component. A wide variety of vegetative food is consumed by the gray squirrel during the spring and summer. The late summer, fall, and winter diet consists mainly of hickory, beech, and oak mast. It is assumed that the availability of fall and winter food will always be more critical than the availability of spring and summer food. Mixed forest stands will provide a more stable winter food supply than stands that consist of only one mast producing species. A forest stand should have at least 8.5 m^2 per hectare (36 ft^2/acre) of basal area of seed producing trees [$\geq$ 25.4 cm (10 inches) dbh]. It is assumed that the optimum density of mast trees is between 40 to 60% canopy closure. When tree canopy closure is greater than 60% mast quality and quantity decreases because tree crowns are shaded by adjacent trees.

Winter food quality is a function of the density and species diversity of mast producing trees of the proper size in the stand. Habitats which lack trees that produce hard mast will have no winter food for gray squirrels.

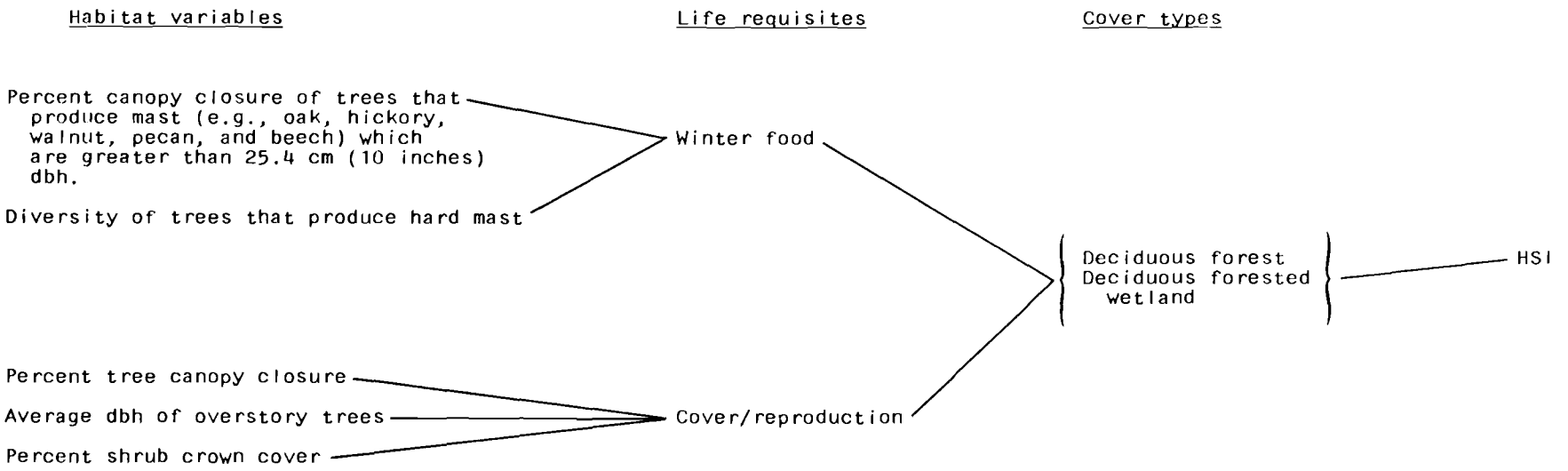


Figure 1. Relationship of habitat variables, life requisites, and cover types in the gray squirrel HSI model.

Species diversity in a forest contributes to a stable food supply. Optimum conditions are assumed to exist when the forest stand contains at least four species of trees that produce hard mast.

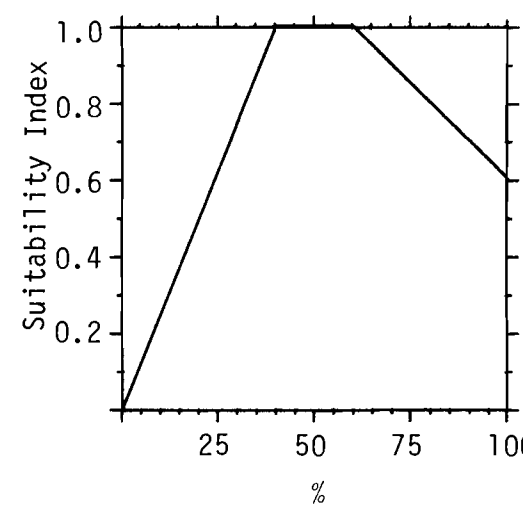
Cover/reproduction component. Dense forest stands that have overstory trees with large diameter, and a moderately dense understory provide optimum cover for gray squirrels. Gray squirrels are almost entirely dependent on tree cavities for winter cover and litter rearing. Forest stands dominated by mature to overmature trees are assumed to contain enough cavities to meet the cover requirements of the gray squirrel. Optimum conditions are believed to occur when tree canopy closure ranges from 40 to 75% and the average dbh of overstory trees is at least 38.1 cm (15 inches). Overstory trees with an average dbh of 12.7 cm (5 inches) or less indicate a forest stand that is too young to contain the cavities required by gray squirrels.

The density of shrubby understory vegetation in a forest will influence the cover/reproduction value for gray squirrels. Optimum understory shrub crown cover is assumed to range from 20 to 30%. Forest stands that do not have a shrub understory will be of slightly less value than stands with optimum shrub density. When shrub density increases above 30%, the cover/reproduction value of the stand will decrease, regardless of the percent closure or size of overstory trees. It is assumed that, although understory shrub density may greatly reduce the value of a stand value as gray squirrel cover/reproduction habitat, it will never completely limit the ability of the stand to provide cover.

Model Relationships

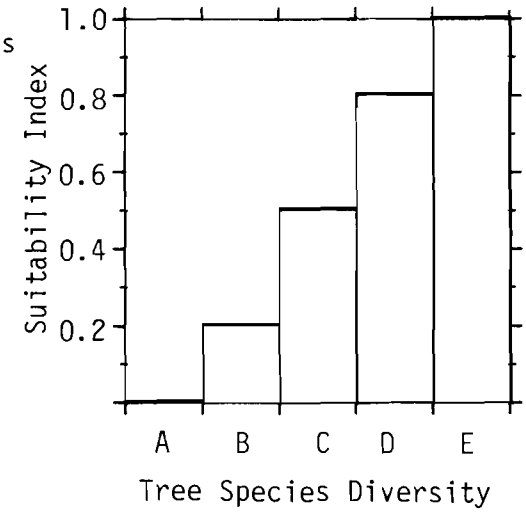
Suitability Index (SI) graphs for habitat variables. This section contains suitability index graphs that illustrate the habitat relationships described in the previous section.

Cover type	Variable	
DF,DFW	V_1	Percent canopy closure of trees that produce hard mast (e.g., oak, hickory, walnut, pecan, and beech) which are ≥ 25.4 cm (10 inches) dbh.

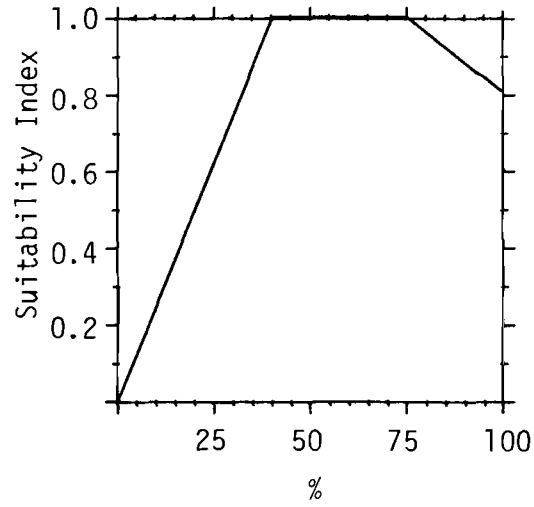


DF,DFW V_2 Diversity of tree species that produce hard mast.

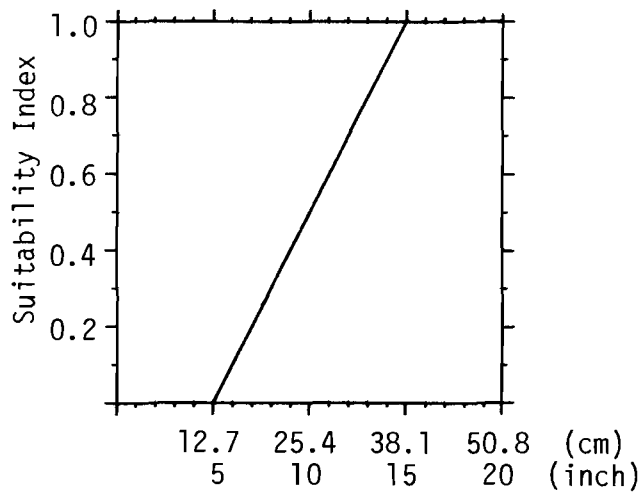
A) None present
B) 1 species present
C) 2 species present
D) 3 species present
E) 4 or more species present



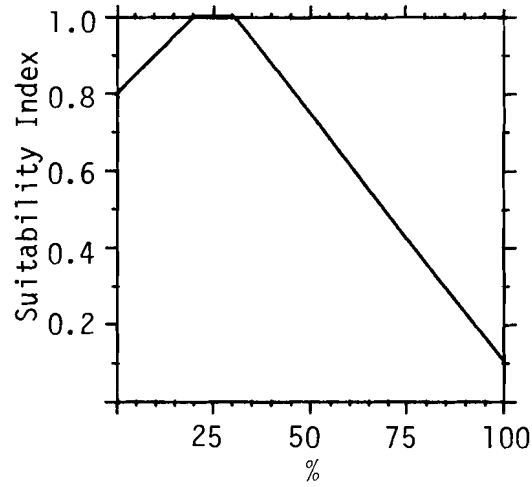
DF,DFW V_3 Percent tree canopy closure.



DF,DFW V_4 Average dbh of overstory trees.



DF,DFW	V_5	Percent shrub crown cover.



Equations. In order to obtain life requisite values for the gray squirrel, the SI values for appropriate variables must be combined through the use of equations. A discussion and explanation of the assumed relationships between variables was included under Model Description, and the specific equations in this model were chosen to mimic these perceived biological relationships as closely as possible. The suggested equations for obtaining life requisite values for the gray squirrel are presented Figure 2.

Life Requisite	Cover Type	Equations
Winter food	DF,DFW	$(V_1 \times V_2)^{1/2}$
Cover/reproduction	DF,DFW	$(V_3 \times V_4)^{1/2} \times V_5$

Figure 2. Equations for determining life requisite values by cover type for the gray squirrel.

HSI determination. The HSI for the gray squirrel will equal the lowest of the values obtained for Winter Food or Cover/reproduction.

Application of the Model

Definitions of variables and suggested field measurement techniques (Hays et al. 1981) are presented in Figure 3.

Variable (definition)		Cover types	Suggested technique
V_1	Percent canopy closure of trees that produce hard mast (e.g., oak, hickory, walnut, pecan, and beech) which are ≥ 25.4 cm (10 inches) dbh [the percent of the ground that is shaded by a vertical projection of the canopies of trees which produce a hard shelled fruit and have a dbh of at least 25.4 cm (10 inches)].	DF,DFW	Calculated area of plant using crown diameter on strip quadrat
V_2	Diversity of tree species that produce hard mast (the number of tree species present in the stand or sample site that produce hard mast).	DF,DFW	Transect, tally
V_3	Percent tree canopy closure [the percent of the ground surface that is shaded by a vertical projection of the canopies of all woody vegetation > 5.0 m (16.5 ft) tall].	DF,DFW	Transect, line intercept, remote sensing
V_4	Average dbh of overstory trees [the average diameter at breast height (1.4 m; 4.5 ft) above the ground of those trees that are ≥ 80 percent of the height of the tallest tree in the stand].	DF,DFW	Cruise for tallest tree, sample with optical range finder and Biltmore stick on strip quadrat
V_5	Percent shrub crown cover [the percent of the ground surface that is shaded by a vertical projection of the canopies of woody vegetation < 5 m (16.5 ft) tall].	DF,DFW	Transect, line intercept

Figure 3. Definitions of variables and suggested measurement techniques.

SOURCES OF OTHER MODELS

No other habitat models for the gray squirrel were located.

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Habitat Evaluation Procedures Group
Western Energy and Land Use Team
U.S. Fish and Wildlife Service
Drake Creekside Building One
2625 Redwing Road
Fort Collins, Colorado 80526

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16. Abstract (Limit: 200 words)

Habitat preferences and species characteristics of the gray squirrel (Sciurus carolinensis) are described in this publication. It is one of a series of Habitat Suitability Index (HSI) models and was developed through an analysis of available scientific data on the species-habitat requirements of the gray squirrel. Habitat use information is presented in a review of the literature, followed by the development of a HSI model. The model is presented in three formats: graphic, word, and mathematical. Suitability index graphs quantify the species-habitat relationship. These data are then synthesized into a model which is designed to provide information for use in impact assessment and habitat management activities.

17. Document Analysis a. Descriptors

Wildlife
Animal behavior
Animal ecology
Habitability
Mathematical models
Mammals
Squirrels

b. Identifiers/Open-Ended Terms

Gray squirrel
Sciurus carolinensis
Habitat suitability
Habitat preference
Habitat management
Habitat suitability index models
Habitat requirements
Species-habitat relationships
Impact assessment

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U.S. FISH AND WILDLIFE SERVICE
REGIONAL OFFICES

REGION 1
Regional Director
U.S. Fish and Wildlife Service
Lloyd Five Hundred Building, Suite 1692
500 N.E. Multnomah Street
Portland, Oregon 97232

REGION 2
Regional Director
U.S. Fish and Wildlife Service
P.O. Box 1306
Albuquerque, New Mexico 87103

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Regional Director
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