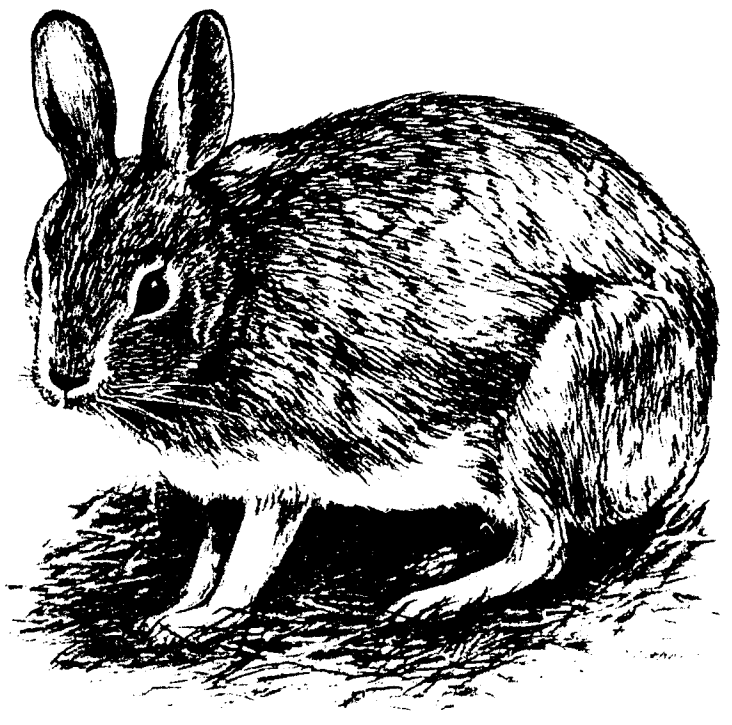
BIOLOGICAL REPORT 82(10.107)
AUGUST 1985

HABITAT SUITABILITY INDEX MODELS: SWAMP RABBIT



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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
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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? _____

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? _____

Were the model equations logical? Yes ____ No ____
Appropriate? Yes ____ No ____

How were or could they be improved? _____

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

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

Model Evaluator or Reviewer _____ Date _____

Agency _____

Address _____

Telephone Number Comm: _____ FTS _____

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HABITAT SUITABILITY INDEX MODELS: SWAMP RABBIT

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This report should be cited as:

Allen, A. W. 1985. Habitat suitability index models: Swamp rabbit. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.107). 20 pp.

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 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:

Habitat Evaluation Procedures Group
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ACKNOWLEDGMENTS

Previous drafts of the swamp rabbit HSI model were reviewed by Dr. Edward P. Hill, Mississippi Cooperative Fish and Wildlife Research Unit, Mississippi State; Dr. George Hurst, Mississippi State University, Mississippi State; Mr. Randy Roach, U.S. Fish and Wildlife Service, Daphine, Alabama; and Mr. Robert Strader, U.S. Fish and Wildlife Service, Lafayette, Louisiana. The comments and suggestions of these individuals have added significantly to the quality and applicability of this HSI model, and their contributions and time are gratefully acknowledged. The cover of this document was illustrated by Susan Strawn. Word processing was provided by Carolyn Gulzow, Elizabeth Graf, and Dora Ibarra.

SWAMP RABBIT (Sylvilagus aquaticus)

HABITAT USE INFORMATION

General

Swamp rabbits (Sylvilagus aquaticus) occur primarily in wetland and wetland-associated habitats throughout much of the southeastern United States (Chapman et al. 1982). Suitable habitats range from bottomland hardwood forests to the herbaceous dominated coastal marshes of Texas, Louisiana, Mississippi, and Alabama. The swamp rabbit's range extends northward from the coast of the Gulf of Mexico to extreme southwestern Indiana, and eastward from eastern Texas to western South Carolina. The species' northern limit does not extend beyond the southern swamp forest community type (Chapman and Feldhamer 1981). The swamp rabbit's geographic range has greatly diminished as a result of wetland drainage and alteration of wetland habitats (Korte and Fredrickson 1977; Chapman et al. 1982). The swamp rabbit is one of the least studied Sylvilagus, furthermore, the majority of studies describing its habitat relationships have been conducted in peripheral areas of its range (Chapman and Feldhamer 1981).

Food

Sedges (Carex spp.) and grasses (Gramicea) appear to be primary foods of the swamp rabbit (Terrel 1972). Swamp grass (Carex lupulina) was the most commonly consumed food from late spring to mid-winter in Missouri (Toll et al. 1960). The bark and twigs of woody vegetation were the primary food in late winter with blackberries (Rubus spp.), hazels (Corylus spp.), holly (Ilex decidua), and common spicebush (Lindera benzoin) being the most commonly utilized species. The most frequently consumed winter foods of swamp rabbits in Indiana were sedges, crossvine (Bignonia capreolata), and poison-ivy (Toxicodendron radicans) (Terrel 1972). Crossvine was reported to be the most important food of swamp rabbits in a Mississippi study (Smith 1982). Forbs were the principle component of the swamp rabbit's summer diet in Louisiana (Garner 1969).

In general, the food habits of Sylvilagus species are not highly restrictive (Chapman et al. 1982). A wide variety of herbaceous vegetation is characteristically consumed during the spring, summer, and early fall; the bark, buds, and twigs of woody vegetation are consumed during the remainder of the year. Reduced dependence on woody vegetation may occur in less severe winters or in regions where herbaceous vegetation remains available. Grasses were the swamp rabbit's principle winter food in Louisiana (Garner 1969). Toll et al. (1960) concluded that swamp rabbits consumed foods in proportion to availability and abundance. The availability of an adequate food supply did not appear to be a limiting factor for the swamp rabbit in Indiana (Terrel 1972).

Water

Dietary water requirements of the swamp rabbit were not located in the literature. The presence of water and wetlands are an integral part of swamp rabbit habitat, and are discussed in the following sections.

Cover

The swamp rabbit is rarely found far from water and wetland habitats (Chapman et al. 1982). The species is dependent upon floodplain bottomland forests along tributaries and estuaries of large rivers, streams, swamps, and marshes (Blair 1936, Lowe 1958; Chapman and Feldhamer 1981). The swamp rabbit's range is considered to be limited to within 2 km of a major source of water (Terrel 1972). Preferred habitat was described as a system of small sloughs, low ridges, and grass-dominated marshes. Consistently occupied swamp rabbit home ranges monitored in Georgia all contained either a floodplain pond, bordered riverine habitat, or both (Lowe 1958). Swamp rabbits readily swim and utilize water as escape cover (Conaway et al. 1960; Toll et al. 1960; Hill 1967; Terrel 1972). Seasonal flooding forces swamp rabbits out of their normal habitat onto higher ground within wetlands or into upland habitats (Conaway et al. 1960). However, they return to normally occupied habitats following flooding and typically reinhabit previously occupied sites. Remnant stands of forested wetland habitat are poor quality habitat since extended flooding forces swamp rabbits into unsuitable upland cover thereby increasing predation and other forms of mortality (Korte and Fredrickson 1977).

Swamp rabbits utilize brushpiles, downfall, and dense herbaceous vegetation for cover (Hunt 1959; Terrel 1972). Standing hollow trees were also frequently used for shelter. Forms (resting sites) were often constructed in sites where access to escape cover provided by water is available (Lowe 1958). The tops of old stumps, low tree crotches, logs, and tangles of honeysuckle (Lonicera japonica) were sites where forms were commonly established in Georgia. Dense tangles of vines often provide excellent security and escape cover for the swamp rabbit in bottomland hardwood forests (G. A. Hurst, Department of Wildlife and Fisheries, Mississippi State University, Mississippi State; pers. comm.). Swamp rabbit forms in Missouri were often near, or adjacent to, tree boles (Korte 1975).

Specific plant composition of swamp rabbit habitat varies geographically. Overall species diversity, the presence of specific plant species, tree size, shrub density, and seedling density had negligible influence on site preferences for swamp rabbits in Missouri (Korte 1975). However, tree and sapling distribution and overstory canopy density were believed to affect swamp rabbit habitat quality by in turn influencing the abundance and distribution of understory vegetation. Sites with relatively open overstories received greater use by swamp rabbits than did sites with greater overstory density. The relatively open sites provided greater insolation thereby increasing herbaceous and shrub growth used for food and cover. The mortality of large, single trees within bottomland hardwood forests resulted in improved habitat quality for the swamp rabbit for similar reasons (Fredrickson 1980). Downed limbs and trunks of large trees provided cover, and subsequent herbaceous growth within the resulting forest openings furnished readily available forage. Based on

the reduced quantity of herbaceous growth within closed canopy forests, even-aged forests with closed canopies are considered less suitable for swamp rabbits than are forests with open overstories (Korte 1975). Habitat quality can be enhanced by increasing stand diversity so as to encourage canopy openings. Clearings 0.1 to 0.5 ha spaced several hundred meters apart were recommended to enhance overall habitat quality within even-aged stands. Smith (1982) concluded that any timber management activities that opened the forest canopy resulted in improved swamp rabbit habitat. The availability of herbaceous forage was greatest in a recently clear-cut area and least in mature bottomland forest. Forest stands subjected to thinning had intermediate amounts of vegetation suitable for swamp rabbit use when compared to clear-cut and unharvested stands. The author recommended that small, 4 to 8 ha blocks of improvement and final harvest cuts in bottomland hardwood forests would maintain high quality swamp rabbit habitat in southern bottomland hardwood forests.

Alteration of landscape features due to the foraging activities and establishment of impoundments by beavers are of direct benefit to swamp rabbit habitat quality (E. P. Hill, Mississippi Cooperative Fish and Wildlife Research Unit, Mississippi State; pers. comm.). Beaver activities produce increased habitat diversity as a result of the creation of relatively permanent standing water within impoundments, increased habitat edge, and greater plant diversity, all in close proximity (Arner et al. 1976; Reese and Hair 1976). The opening of homogeneous and closed forest canopies adjacent to beaver impoundments contribute to greater shrub and herbaceous growth thereby increasing food and cover quality for the swamp rabbit. Downed stems and limbs produced as a result of beaver foraging can provide additional escape cover for the swamp rabbit.

The upland boundaries of swamp rabbit habitat occasionally overlap habitats occupied by the eastern cottontail (S. floridanus). Habitat sympatry was evident in Missouri but swamp rabbits tended to inhabit the more wooded areas, while the eastern cottontail was restricted to cover types dominated by herbaceous vegetation (Toll et al. 1960). Habitat overlap between these species was also reported in Indiana (Terrel 1972). Swamp rabbits were nearly six times more abundant within selectively logged forest stands as were eastern cottontails. The two species were equally abundant in old field habitats. An abundance of succulent herbaceous vegetation and adequate cover induced swamp rabbits from bottomland habitats into an ecotone between bottomland habitat and prairie also occupied by eastern cottontails in Texas (Hunt 1959). However, the ecotone was used by swamp rabbits only in spring during the period of greatest herbaceous growth and density. Swamp rabbits replaced eastern cottontails in Texas as succession advanced and woody vegetation crowded out herbaceous growth (Taylor and Lay 1949).

The largest recorded populations of swamp rabbits in Louisiana occurred in the early twentieth century when second growth forests became established following removal of virgin bottomland forests (Richardson 1963 cited by Korte 1975). The greatest amount of swamp rabbit use in Indiana was recorded within selectively logged forest (Terrel 1972). Primary cover attributes of the high use area were: (1) 22 tree stems (≥ 36 cm dbh)/ha; (2) a mean basal area of

stems > 10.2 cm dbh of 50.6 m^2/ha; and (3) a mean density of 4,843 shrubs (stems < 10.2 cm dbh/ha). Lower swamp rabbit density was recorded in mature forest stands where trees averaged 77/ha, basal area averaged 80.2 m^2/ha, and shrubs averaged 3,262/ha.

Swamp rabbits in Louisiana inhabit fresh, intermediate, brackish, and saline coastal marshes (Gosselink 1984). The species is particularly numerous in coastal marshes of Louisiana where canal banks and chenieres (wooded, elevated sites) provide an abundance of vegetative cover and sites that remain relatively dry (Lowery 1974). Preferred, high quality swamp rabbit habitat in an intermediate coastal marsh in extreme southern Louisiana was characterized as cordgrass (Spartina patens) - dominated cover with highly interspersed eastern baccharis (Baccharis halimifolia) < 1.2 m in height (Gould 1969). Cover types of decreasing importance to the species were described as cover dominated by baccharis > 1.2 m in height, with moderate interspersion of cordgrass, and stands of reed (Phragmites communis) and baccharis > 1.2 m tall lightly interspersed with cordgrass. Solid stands of cordgrass were the least preferred habitat type.

Reproduction

The nests of swamp rabbits are usually on the ground, are constructed with stalks of herbaceous vegetation, and are lined with fur (Goodpaster and Hoffmeister 1952). Nests are commonly under brush, plant debris, or in other dense vegetative cover (Lowe 1958).

Interspersion and Composition

Swamp rabbits require relatively large tracts of suitable habitat (≥ 100 ha) to maintain viable populations (Korte 1975). Small or narrow areas of suitable habitat may be intermittently inhabited by swamp rabbits (Hill, unpubl.). Beaver activity associated with small streams within narrow floodplains enhance vegetative and structure diversity resulting in greater swamp rabbit habitat potential within these restricted cover types. The mean home range size for swamp rabbits in Indiana was 4.4 ha (Terrel 1972). Population density was estimated to be 1 rabbit/2.4 ha. The average home range of swamp rabbits in Georgia bottomlands was 7.6 ha with an estimated density of 1 rabbit/ 7.1 ha (Lowe 1958). The minimum home range for female swamp rabbits in west-central Louisiana was 2.4 ha (Mullin 1979). The maximum home range was 4.0 ha. The minimum and maximum home range size for male swamp rabbits was 1.5 ha and 3.0 ha, respectively. Estimated peak densities of swamp rabbits were 1 rabbit/ 0.6 ha in lowland habitats and 1 rabbit/0.8 ha in upland pine dominated habitats. Minimum home range size for male and female swamp rabbits in Missouri was 0.7 ha and 0.3 ha respectively (Toll et al. 1960).

Special Considerations

Although the swamp rabbit is usually confined to wetlands, the species is opportunistic in food habits and cover requirements within these habitat types (Terrel 1972). However, habitat requirements of the species are incompatible with modern land use practices such as drainage, channelization, and agricultural uses, that impact wetland habitats. Land uses that create

remnant, small woodlots and narrow bands of wetland-associated vegetation immediately adjacent to stream or river channels virtually eliminate swamp rabbit habitat. Land clearing and conversion of bottomland hardwood forests to agricultural use has been the primary factor contributing to the loss of swamp rabbit habitat throughout its range (Korte 1975). Terrel (1972) estimated that approximately 10% of potentially suitable swamp rabbit habitat remained in Indiana of the 40,500 ha present prior to settlement of the area.

The near demise of the swamp rabbit in Missouri has been attributed to the conversion of bottomland hardwood forests to row crops (Korte and Fredrickson 1977). Bottomland hardwood forests declined in area by approximately 90% from 1870 to 1970. As of 1973, < 8,100 ha of potential habitat remained in the state. Swamp rabbit habitat potential within the remaining acreage is further reduced by road right-of-ways, expanding urbanization, small, isolated units of forested habitat, and areas that are inundated for long periods. Extensive tracts of forest cover have become uncommon in the state. Suitable habitats adjacent to rivers and streams have become restricted to islands and small tracts of cover that remain at the junctions of tributary streams. Due to continued demands for conversion of bottomland habitats, the swamp rabbit will likely continue its decline in Missouri until it becomes restricted to publicly owned lands or sites where forests are commercially managed (Korte and Fredrickson 1977). Attempts to appreciably reestablish swamp rabbits throughout the Southeast would necessitate the acquisition of substantial areas of bottomland habitats and subsequent reversion of disturbed lands to former plant communities (Korte 1975).

The marsh rabbit (S. palustris) occupies habitats similar to that of the swamp rabbit's, but apparently the species are not sympatric (Lowe 1958). No difference in habitat selection between the two species was reported, although they were never observed in the same locality. Blair (1936) concluded that the marsh rabbit was confined to marshy habitats and, the single most important factor limiting the distribution of this species was the availability of water. A small population of marsh rabbits was associated with hammocks in Florida while a larger population was associated with cattail (Typha spp.) - dominated habitat. Overall, little is known about many aspects of marsh rabbit biology and its habitat relationships (Chapman and Willner 1981).

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. This model has been developed for application throughout the swamp rabbit's range (Fig. 1.).

Season. This model has been developed to evaluate the potential quality of year-round habitat for the swamp rabbit.

Cover types. This model has been developed to evaluate potential habitat quality in the following cover types (terminology follows that of U.S. Fish and Wildlife Service 1981): Evergreen Forested Wetland (EFW); Deciduous Forested Wetland (DFW); Evergreen Scrub-Shrub Wetland (ESW); Deciduous Scrub-Shrub Wetland (DSW); and Herbaceous Wetland (HW).

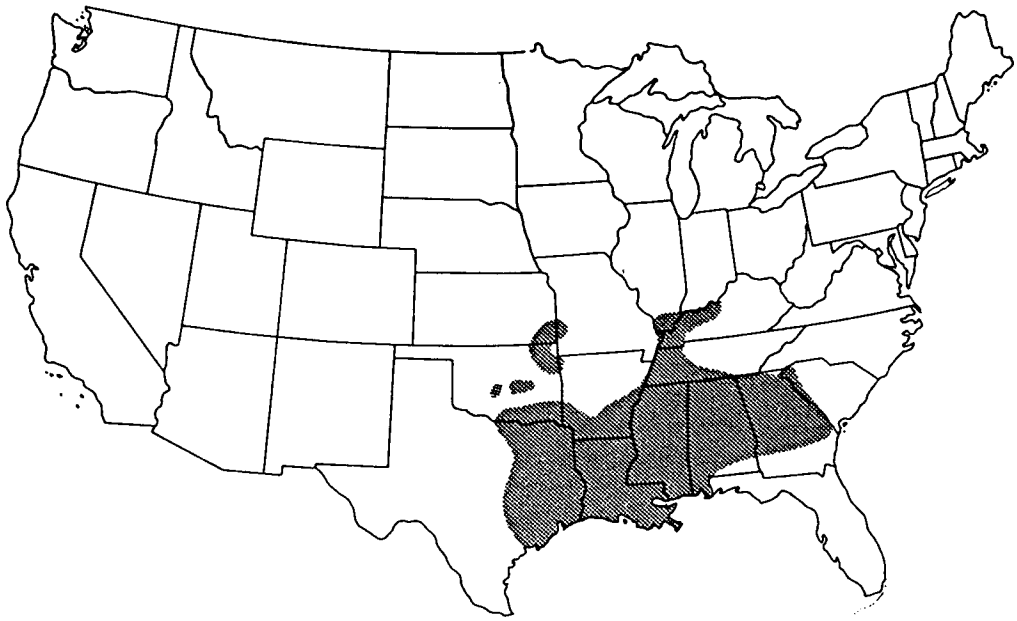


Figure 1. Approximate distribution of the swamp rabbit (modified from Chapman et al. 1982).

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. Narrow riparian bands and small isolated units of wetland habitat surrounded by, or adjacent to, areas of intensive land use (e.g., row crops, heavy grazing) probably have minimum value as swamp rabbit habitat (Korte and Fredrickson 1977). It can be concluded that the value of wetlands as swamp rabbit habitat is directly related to the size of the evaluation area. Larger wetlands will have greater potential to maintain swamp rabbit populations. Korte (1975) concluded that swamp rabbits require relatively large tracts (≥ 100 ha) of wetland habitat to maintain viable populations. Based on this information it can be assumed that isolated wetland habitats < 100 ha probably have minimum, if any, potential as long term swamp rabbit habitat. However, this model may be applied and used to evaluate swamp rabbit habitat quality in wetland areas < 100 ha if the evaluation area is within or contiguous to, other suitable swamp rabbit habitat.

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 Dr. Edward P. Hill, Mississippi Cooperative Fish and Wildlife Research Unit, Mississippi State; Dr. George Hurst, School of Forest Resources, Mississippi State University; Mr. Randy Roach, U.S. Fish and Wildlife Service, Daphne, Alabama; and Mr. Robert Strader, U.S. Fish and Wildlife Service, Lafayette, Louisiana. Improvements and modifications suggested by these persons have been incorporated into this model.

Model Description

Overview. The swamp rabbit is dependent upon herbaceous, forested, and shrub-dominated wetlands to meet its year-round habitat requirements. Upland habitats are used by the species on a temporary basis when displaced by flooding. Limited use of upland habitats may also occur in response to seasonal food availability within these cover types. However, this model is based on the assumption that wetland habitats dominated by relatively dense, low growing vegetation are a mandatory requirement for suitable swamp rabbit habitat. How overall habitat potential is influenced by the quality of upland habitats that surround or are adjacent to potentially suitable wetlands is not addressed in this model. However, the effects of adjacent land use may have a major influence on overall swamp rabbit habitat quality, depending upon the cover type size and diversity of water regimes within the wetland area being evaluated. The habitat potential of small wetlands (e.g., < 100 ha) may be minimal if surrounding land use eliminates upland cover required by the species during displacement by flooding. Conversely, intensive land use adjacent to large (e.g., ≥ 100 ha) wetlands may have only minor influence on habitat quality if the wetland contains areas influenced by differing water regimes, thereby permitting swamp rabbits to modify habitat use without forced emigration into nearby uplands. In general, herbaceous, forested, and shrub-dominated wetlands adjacent to upland cover types that provide diverse and dense vegetative cover will have greater habitat potential for the species than those wetlands that adjoin intensively used areas with minimal vegetative cover.

Cover is assumed to be the most critical life requisite that defines habitat quality for the swamp rabbit. Habitat suitability is assumed to be a function of the abundance of vegetative cover and water regimes. Food availability is assumed not to be limiting in the swamp rabbit's range, since herbaceous vegetation is generally available throughout the winter in the southeast. The swamp rabbit does depend on woody browse during extreme winters in the more northern parts of its range. Food availability under such conditions is assumed to be directly related to cover conditions as evaluated by the density of shrubs and/or herbaceous vegetation.

The swamp rabbit is restricted to wetland cover types. Therefore, it is assumed that water will be present within, or immediately adjacent to, cover types for which this model is applicable and the availability of water will normally not be a limiting characteristic of the swamp rabbit's habitat. The reproductive habitat requirements of the species are also assumed to be a reflection of habitat quality as measured by cover conditions.

The plant composition of potentially suitable swamp rabbit habitat ranges from shrub and forest dominated lowland wetlands to herbaceous dominated marshes associated with the Gulf of Mexico. In the northern parts of their range swamp rabbits appear to be at least partially dependent upon woody vegetation for food and cover during the winter when all herbaceous growth ceases. Conversely, the biomass of herbaceous vegetation in the subtropical climate of the Gulf Coast remains relatively constant resulting in minimum, if any, swamp rabbit dependence on woody vegetation for winter cover or food. Therefore, separate models have been formulated for evaluation of swamp rabbit habitat quality in shrub/forest dominated wetlands and herbaceous dominated coastal marshes.

The following sections provide documentation of the logic and assumptions used to translate habitat information for the swamp rabbit to the variables and equations used in the HSI model. Specifically, these sections cover: (1) identification of variables; (2) definition and justification of the suitability levels of each variable; and (3) description of the assumed relationships between variables.

Food/cover component. The swamp rabbit inhabits wetland cover types dominated by woody vegetation associated with bottomland hardwood forests throughout much of the southeast. Coastal marshes dominated by nonwoody plants also provide food and cover and are suitable swamp rabbit habitat. Within the range of the swamp rabbit uplands are inhabited by the eastern cottontail and are normally unsuitable as permanent swamp rabbit habitat.

Food/cover habitat quality within bottomland hardwood wetlands is assumed to be a function of shrub crown closure and herbaceous canopy closure. The abundance of herbaceous and shrub vegetation is assumed to be a function of the overstory density, or tree canopy closure in bottomland forests. The production of understory vegetation (i.e., herbaceous vegetation and shrubs) is assumed to vary inversely with tree canopy closure. Therefore, mature, closed canopy forested wetland habitats support minimal production of herbaceous vegetation and are assumed to have little food/cover for the species. Moderately open canopies within forested wetlands are assumed to provide suitable conditions for both herbaceous and shrub components of the understory and represent high quality swamp rabbit habitat. Sparsely stocked bottomland forests are assumed to have maximum production of shrubs and herbaceous vegetation and represent at least seasonally ideal habitat quality for the species. However, such sites probably have reduced year-round habitat potential for the species due to reduced cover availability during the winter months. This is probably particularly true for the more northern areas in the species' range.

Figure 2a presents the assumed relationship between tree canopy closure (woody vegetation ≥ 5 m tall) and a suitability index value for the swamp rabbit. Optimum habitat conditions are assumed to occur when tree canopy closure ranges from 25 to 60%. Tree canopy closure in excess of 60% is assumed to indicate lower habitat potential for the species due to reduced understory density. However, even totally closed stands are assumed to have moderate habitat potential for the swamp rabbit. Minimum year-round habitat quality for the swamp rabbit is assumed to exist in nonstocked to sparesly-stocked bottomland forests. Habitat quality for the species is assumed to increase as tree density increases.

Figure 2b represents the assumed relationship between shrub crown closure and habitat quality for the swamp rabbit. Low growing woody vegetation is assumed to provide a primary source of security cover and a potential source of winter food. The importance of woody vegetation as a winter food source is probably increased in the more northern parts of the species range due to the absence of herbaceous vegetation in winter. Wetlands that are devoid of shrubs are assumed to represent poor year-round habitat for the species. Habitat quality for the swamp rabbit is assumed to increase as the density of shrubs increases. A shrub canopy closure ≥ 50% is assumed to represent optimum food/cover habitat quality for the species.

Figure 2c represents the assumed relationship between herbaceous canopy cover and habitat quality for the swamp rabbit. Herbaceous vegetation is the swamp rabbit's primary source of food and provides critical protective and escape cover. Areas that do not support herbaceous vegetation are assumed to have no year-round habitat potential for the swamp rabbit. Habitat quality is assumed to increase as the density of herbaceous vegetation increases. Herbaceous canopy closure of ≥ 75% is assumed to reflect optimum food/ cover habitat conditions for the species.

Vines are an important food source for the swamp rabbit. In addition, dense, low tangles of vines provide outstanding cover for the species. Depending upon the species and age of the plant, vines can be considered to represent either herbaceous or woody vegetation. This model does not include a variable to estimate the abundance or density of vines. However, vines should be considered as an important component of swamp rabbit habitat quality and included in the evaluation of vegetative conditions as represented by either shrub crown closure or herbaceous canopy cover.

The index values displayed in Figure 2 are used to calculate a food/cover index (FCI) for the swamp rabbit. Depending on the level of detail permitted for sampling two options are available for determination of the FCI. Equation 1 may be used to obtain an indirect measure of understory density in forested habitats. A more accurate measure of the FCI for the swamp rabbit can be obtained by measuring shrub and herbaceous density. Equation 2 should be applied in shrub dominated habitats and forested habitats where tree canopy closure is less than 25%.

$$FCI = SIV1 \quad (1)$$

$$FCI = \frac{SIV2 + SIV3}{2} \quad (2)$$

Equation 2 assigns equal weight to percent shrub crown closure (Fig. 2b) and percent herbaceous canopy cover (Fig. 2c) in defining the FCI for the swamp rabbit. Optimum conditions are assumed to exist only when both components are present at optimum densities. The total absence of either shrubs or herbaceous vegetation will not limit a site's potential as swamp rabbit habitat, however, the FCI may be extremely low if one component is absent. Users of this model in the more northern latitudes of the swamp rabbit's range may wish to assign greater weight to the shrub component (Fig. 2b) of the FCI.

Wetlands dominated by relatively tall, dense herbaceous vegetation provide suitable year-round swamp rabbit habitat in the southern portions of its range. Coastal marshes dominated by robust vegetation such as reed (Phragmites communis), switch grass (Panicum virgatum), bulrush (Scirpus spp.), and cattail provide food and cover for the species. The presence of elevated sites dominated by woody vegetation may enhance an area's value as

swamp rabbit habitat but are not believed to be mandatory to provide suitable habitat in coastal marshes. Figure 3 represents the assumed relationships between density and height of herbaceous canopy cover in herbaceous dominated wetlands and habitat quality for the swamp rabbit. Wetlands supporting 75% or more herbaceous canopy cover are assumed to provide optimum food/cover conditions for the swamp rabbit (Fig. 3a). Wetlands devoid of herbaceous vegetation are assumed to represent unsuitable swamp rabbit habitat. The height of herbaceous vegetation is also assumed to influence swamp rabbit habitat quality in herbaceous wetlands (Fig. 3b). Herbaceous vegetation with an average canopy height of ≥ 1 m is assumed to reflect optimum conditions. Average canopy height of ≤ 0.25 m is assumed to provide poor protective cover for the species and represents unsuitable habitat.

The relationship between percent herbaceous canopy cover and average height of the herbaceous canopy is assumed to be compensatory in defining swamp rabbit habitat quality in herbaceous wetlands. Low densities of herbaceous vegetation will be compensated for if the vegetation is relatively high. Conversely, if herbaceous vegetation is sparse and low, swamp rabbit habitat quality will be low. Year round habitat quality is assumed to be unsuitable if the average height of the herbaceous canopy is ≤ 0.25 m regardless of vegetative density. The index values displayed in Figure 3 are used to calculate a food/cover index (FCI) for the swamp rabbit in herbaceous wetlands using Equation 3.

$$FCI = (SIV4 \times SIV5)^{1/2} \quad (3)$$

Water component. Upland habitats, regardless of the density and quality of woody and herbaceous vegetative conditions, are assumed to be unsuitable year-round habitat for the swamp rabbit. Although the swamp rabbit will use water as escape cover, extensive, permanently flooded wetlands are assumed to be unsuitable habitat for the species (Fig. 4). Intermittently exposed wetlands normally contain surface water throughout the year, except in years of extreme drought, and are assumed to have minimum value as swamp rabbit habitat during years of normal precipitation. Surface water typically persists throughout the growing season within semipermanent wetlands. Desiccation of semipermanent wetlands will make them available to swamp rabbits, and they are assumed to have moderate habitat potential. Surface water is typically present for extended periods within seasonally flooded wetlands. It is assumed that these wetlands will allow for abundant herbaceous growth and represent relatively high habitat potential for the swamp rabbit. Temporarily and intermittently flooded wetlands typically support surface water for only brief periods. These wetland types are assumed to represent optimum habitat conditions for the swamp rabbit as a result of minimal displacement due to flooding and potentially abundant vegetative growth that provides both food and cover.

Fig. 3a

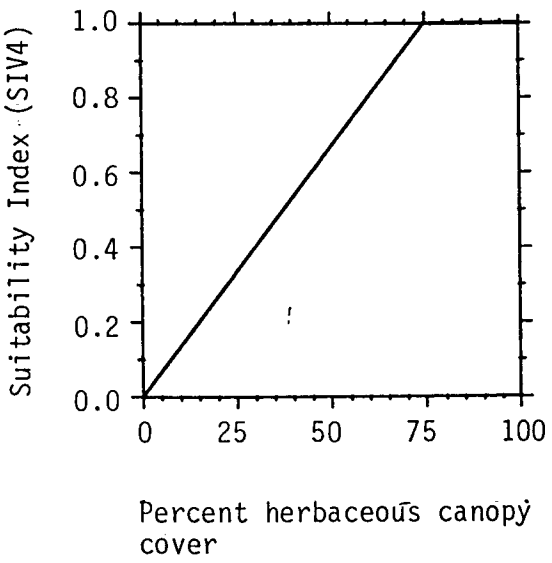


Fig. 3b

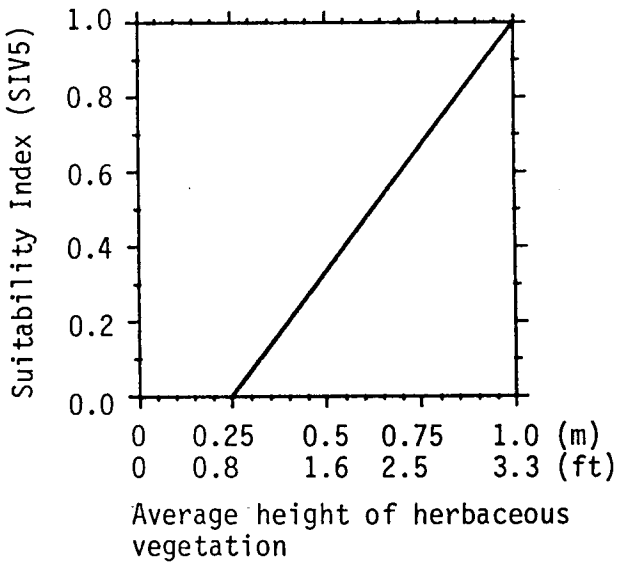
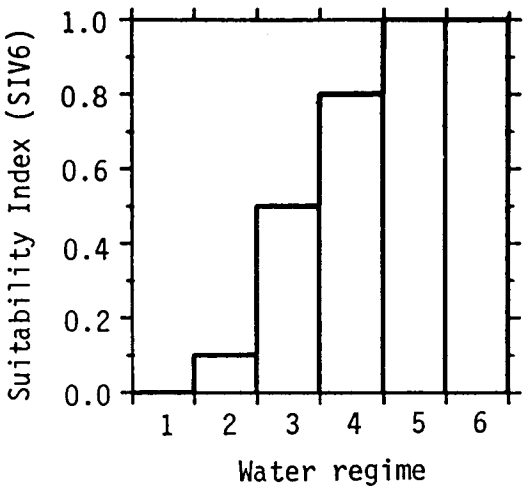


Figure 3. The relationships between habitat variables used to evaluate food/cover in herbaceous dominated wetlands and the suitability indices for the variables.



1. Permanently flooded
2. Intermittently exposed
3. Semipermanently flooded
4. Seasonally flooded
5. Temporarily flooded
6. Intermittently flooded

Figure 4. The relationship between water regime categories (Cowardin et al. 1979) and suitability indices for the variable.

HSI determination. The SIV6 determined from the relationships presented in Figure 4 is used in Equation 4 to obtain the HSI value for swamp rabbit habitat in all appropriate cover types.

$$HSI = FCI \times SIV6 \quad (4)$$

The index value determined for water regime (Fig. 4) is used to directly modify the value calculated for the Food/Cover Index (Equation 1, 2, or 3). The water regime modifier (SIV6) is used to reflect the amount of available habitat based on water permanency throughout the evaluation area.

Determination of an HSI value for the swamp rabbit considers only the life requisite value for food/cover as determined by the abundance of suitable vegetation. Water regime (SIV6) is used to modify the food/cover life requisite value based upon its assumed influence on vegetative abundance and habitat use for the species. The reproductive habitat requirements are assumed to be a reflection of the quality of habitat conditions represented by the variables used to calculate the food/cover life requisite value.

HSI determination is based on values assigned to vegetative and water regime conditions within specific cover types. The characteristics of micro-habitat (e.g., specific den, form, or refuge site criteria) are not addressed in habitat evaluation due to the variability of sites that may be used and the difficulties of measuring such ambiguous habitat characteristics. Assignment of SI values for water regime (SIV6) by broad cover type categories may result in an underestimation of habitat quality in intermittently exposed, semi-permanently flooded and seasonally flooded wetlands where small elevated sites and other habitat features provide suitable refuge during flooding.

The values assigned to SIV6 variable are based on expected water permanence within wetlands as defined by Cowardin et al. (1979). A single water regime value can be assigned to an entire evaluation area. However, if data are available and time permits, a more accurate estimation of swamp rabbit habitat potential may be obtained by determining a HSI weighted by areas subject to various water regimes, as follows:

1. Stratify the evaluation area (potential swamp rabbit habitat) into cover types.

2. Determine the total area of each cover type identified in Step 1 and calculate the relative percent of the total evaluation area represented by each cover type.

3. Estimate the habitat variables (Fig. 2 or 3) and water regime (Fig. 4) for each cover type identified in Step 1.

4. Determine a FCI (Equation 1, 2, or 3) value for each appropriate cover type.

5. Determine a HSI by multiplying the FCI for each cover type by the appropriate water regime value (Equation 4).

6. Multiply the area (%) of each wetland cover type by its respective HSI value (Step 5).

7. Sum the products calculated in Step 6 for all wetland cover types to obtain a weighted HSI value.

The steps outlined above are expressed by equation 5.

$$\text{Weighted HSI} = \frac{\sum_{i=1}^{n} HSI_i \, A_i}{\sum_{i=1}^{n} A_i} \qquad (5)$$

where n = number of wetland cover types being evaluated

HSI = (FCI x SIV6) for individual cover type i

A_i = area of cover type i

Application of the Model

Summary of model variables. The relationships between habitat variables, cover types, life requisites and HSI are summarized in Figure 5. Figure 6 provides definitions and suggested measurement techniques (Hays et al. 1981) for the variables used in the swamp rabbit HSI model.

Model assumptions. The swamp rabbit HSI model has been constructed based upon the following major assumptions:

1. Swamp rabbits require forested and shrub-dominated wetland habitats to meet their year-round habitat requirements in the northern portions of their range.

2. Relatively dense understory composed of shrubs and herbaceous vegetation represent optimum food/cover conditions in tree and shrub-dominated habitats. Closed stands inhibit herbaceous vegetation and, therefore, have lower year-round habitat potential for the species.

3. Habitats dominated only by herbaceous vegetation can provide suitable year-round habitat for the swamp rabbit in southern portions of its range if the vegetation is sufficiently tall and dense.

4. The food/cover requirements also reflect the reproduction habitat requirements of the species. Physiological requirements for water are assumed to not be limiting under typical conditions.

5. Wetlands experiencing temporarily and intermittently flooded water regimes represent optimum wetland conditions for the swamp rabbit. Permanently flooded and upland cover types are unsuitable year-round habitat.

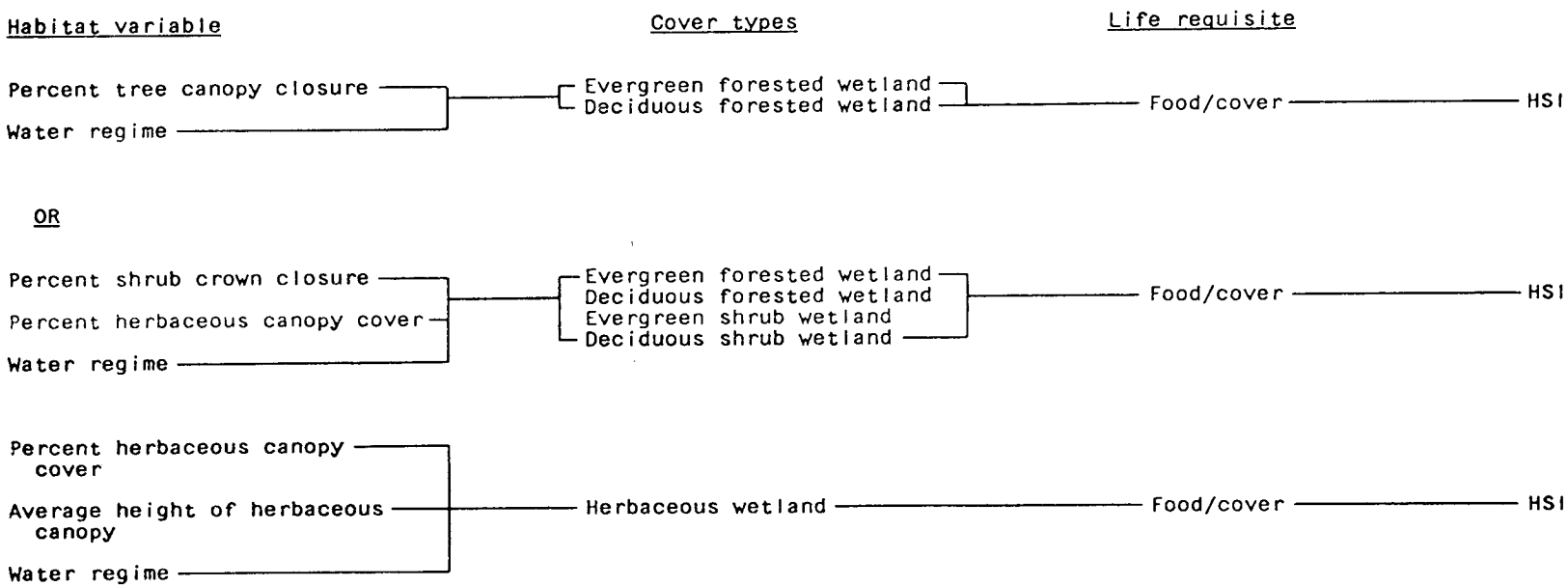


Figure 5. Relationships of habitat variables, life requisites, and cover types to an HSI for the swamp rabbit.

Variable (definition)	Cover types	Suggested technique
Percent tree canopy closure [the percent of the ground surface that is shaded by a vertical projection of the canopies of woody vegetation ≥ 5.0 m (16.5 ft) in height].	EFW,DFW	Remote sensing, line intercept, ocular estimation
Percent shrub crown closure [the percent of the ground surface that is shaded by a vertical projection of the canopies of woody vegetation < 5.0 m (16.5 ft) in height].	EFW,DFW,ESW, DWS	Remote sensing, line intercept, quadrat, ocular estimation
Percent herbaceous canopy cover [the percent of the ground surface that is shaded by a vertical projection of all nonwoody vegetation (grass, forbs, sedge, etc.)].	EFW,DFW,ESW, DSW,HW	Line intercept, quadrat
Average height of herbaceous canopy (the average vertical distance from the ground surface to the dominant height stratum of the herbaceous vegetative canopy).	HW	Line intercept, quadrat, graduated rod
Water regime [the permanence of surface water in a wetland (as defined by Cowardin et al. 1979)] as follows:	EFW,DFW,ESW, DWS,HW	Remote sensing, on site inspection, National Wetland Inventory maps
Permanently flooded: Water covers the land surface throughout the year in all years.		
Intermittently exposed: Surface water is present throughtout the year, except in years of extreme drought.		
Semipermanently flooded: Surface water persists throughout the growing season in most years.		

Figure 6. Definitions of variables and suggested measurement techniques.

Variable (definition)	Cover types	Suggested technique
Seasonally flooded: Surface water is present for extended periods, especially early in the growing season, but is absent by the end of the season in most years.		
Temporarily flooded: Surface water is present for brief periods during the growing season, but the water table usually lies well below the soil surface for the most of the season.		
Intermittently flooded: The substrate is usually exposed, but surface water is present for variable periods without detectable seasonal periodicity].		

Figure 6. concluded.

SOURCES OF OTHER MODELS

No other habitat models for the swamp rabbit were located in the literature.

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50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. Biological Report 82(10.107)	2.	3. Recipient's Accession No.
4. Title and Subtitle: Habitat Suitability Index Models: Swamp Rabbit			5. Report Date: August 1985 6.
7. Author(s): Arthur W. Allen			8. Performing Organization Rept. No.
9. Performing Organization Name and Address: Western Energy and Land Use Team U.S. Fish and Wildlife Service Drake Creekside Building One 2627 Redwing Road Fort Collins, CO 80526-2899			10. Project/Task/Work Unit No. 11. Contract(C) or Grant(G) No. (C) (G)
12. Sponsoring Organization Name and Address: Western Energy and Land Use Team Division of Biological Services Research and Development Fish and Wildlife Service Department of the Interior, Washington, DC 20240			13. Type of Report & Period Covered 14.

15. Supplementary Notes: The Biological Report series was initiated in October 1984 to replace the FWS/OBS series published since 1976. The report number assigned to this model follows consecutively from the Habitat Suitability Index models published as FWS/OBS-82/10._), now numbered as Biological Report 82(10.).

16. Abstract (Limit: 200 words)

A review and synthesis of existing information were used to develop a Habitat Suitability Index (HSI) model for the swamp rabbit (Sylvilagus aquaticus). 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 the U.S. Fish and Wildlife Service.

17. Document Analysis a. Descriptors

Lagamorpha
Wildlife
Habitability
Mathematical models

b. Identifiers/Open-Ended Terms

Swamp rabbit
Sylvilagus aquaticus
Habitat suitability

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Release unlimited	Unclassified	20
	20. Security Class (This Page) Unclassified	22. Price

(See ANSI-Z39.18) See Instructions on Reverse

☆ U.S. GOVERNMENT PRINTING OFFICE: 1985--580-332 / 25354

OPTIONAL FORM 272 (4-77)
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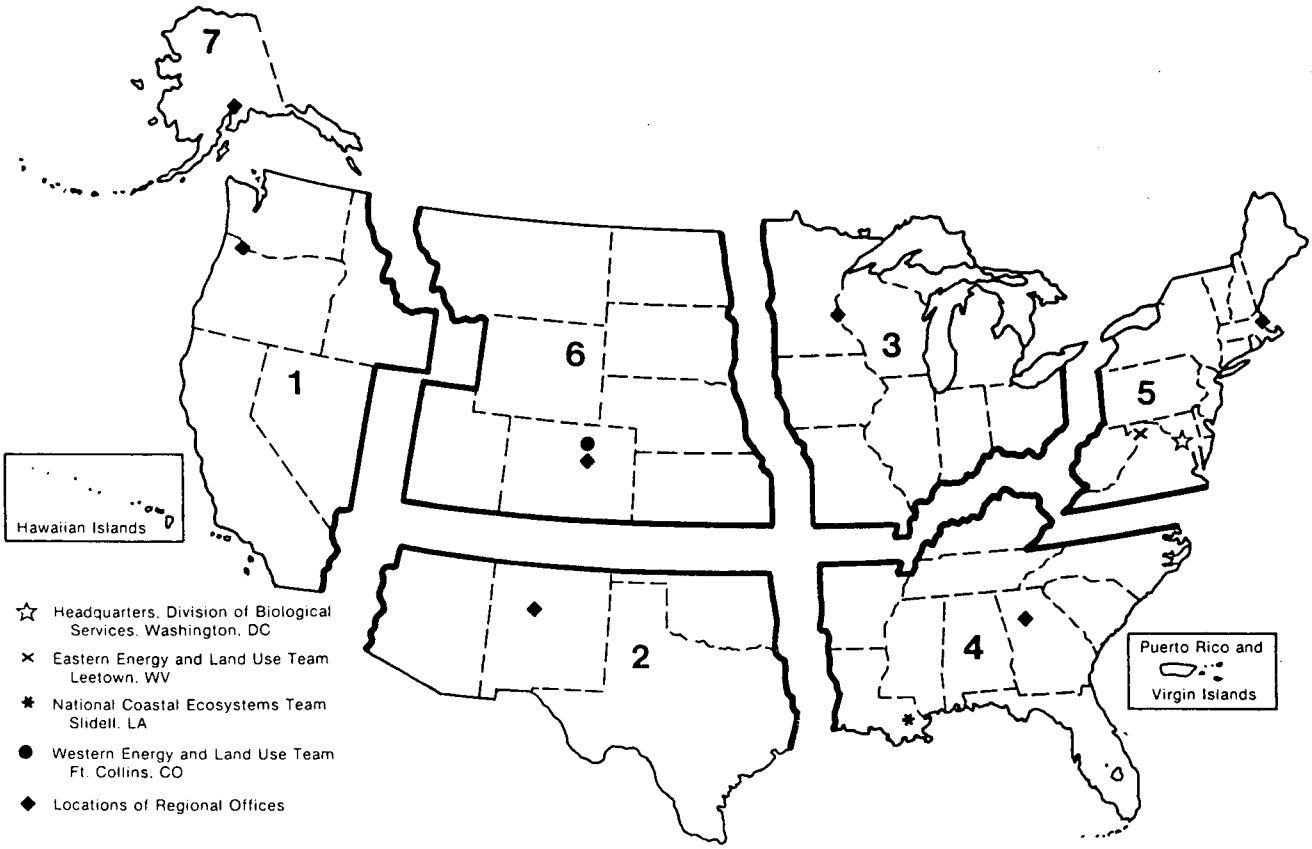

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