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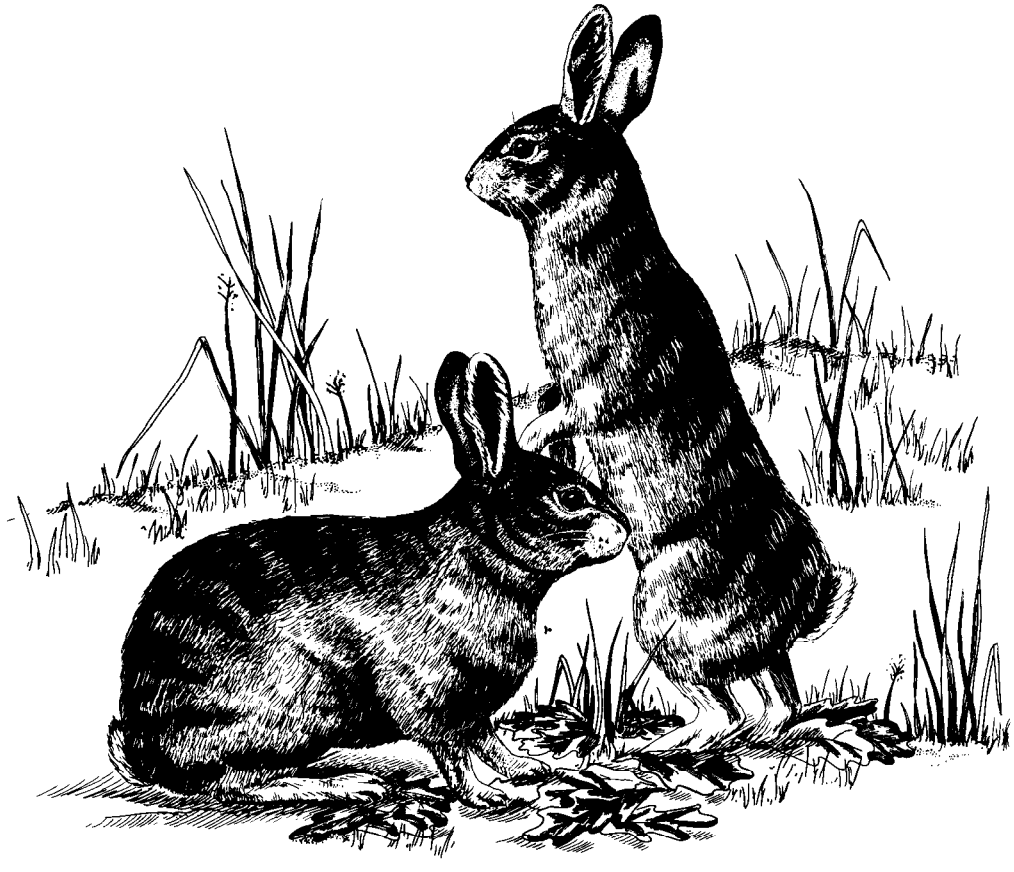
HABITAT SUITABILITY INDEX MODELS: EASTERN COTTONTAIL



Fish and Wildlife Service
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HABITAT SUITABILITY INDEX MODELS: EASTERN COTTONTAIL

by

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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 studies. 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 the HSI model that follows. In addition, this same information may be useful in the development of other models more appropriate to specific assessment, evaluation or management 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:

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EASTERN COTTONTAIL (Sylvilagus floridanus)

HABITAT USE INFORMATION

General

The eastern cottontail (Sylvilagus floridanus) is the most widely distributed cottontail in North America (Chapman et al. 1982). The species is considered to be a generalist that occupies a variety of habitats from southern Canada southward into South America (Chapman et al. 1980). The eastern cottontail's range overlaps that of six other species of cottontails (Sylvilagus spp.) and six species of hares (Lepus spp.). Eastern cottontails have been widely transplanted and are believed to be expanding their range northward, particularly in the Northeast (Chapman et al. 1982). The eastern cottontail has been successfully introduced into portions of Oregon and Washington which are outside of the species' natural range (Chapman and Morgan 1973). The eastern cottontail is primarily nocturnal and is a principal game species in the eastern United States.

Food

Cottontail food habits vary greatly depending upon the species, geographic region, and the availability of palatable plants (Chapman et al. 1982). Nearly every kind of grass, succulent herb, or flowering plant, native or introduced, will provide acceptable food for the cottontail (Sweetman 1944). The number of different plants consumed by cottontails in a given geographic area may exceed 100 species (DeCalesta 1971). Cottontails may exhibit food preferences on a local basis; however, a wide variety of vegetation is acceptable and will meet the cottontail's food requirements provided that the basic nutritional requirements of the species are met (Chapman et al. 1982). Herbaceous vegetation is typically selected during the growing season; the bark, buds, and twigs of woody vegetation are consumed during the balance of the year. The adoption of woody plants as a food source in winter results from the unattractiveness of frozen herbaceous vegetation and the reduced availability of herbaceous plants due to snow and ice coverage (Sweetman 1944). Reduced consumption of woody vegetation may occur in less severe winters and when herbaceous growth becomes available in protected sites. Dried herbaceous vegetation may comprise a substantial proportion of the cottontail's diet during periods of sparse snow cover (Korschgen 1980; Swihart and Yahner 1982-83). In southern regions with relatively mild winter climates, herbaceous vegetation alone may provide an adequate source of winter food (Swihart pers. comm.). The phenology and distribution of plant species may temporarily affect palatability and feeding preferences of cottontails, resulting in

variations in local rabbit concentrations (Bigham 1966). DeCalesta (1971) provided a detailed, regionalized summary of cottontail food habits for the contiguous United States.

Due to the wide variety of vegetation used, food availability is seldom a limiting factor and typically is not the most important consideration in cottontail management (Sweetman 1944; Dusi 1952). Haugen (1942) reported that the eastern cottontail will select suitable cover over an abundant food supply if the two are not found together. The availability of food did not prevent emigration of cottontails from a Tennessee study site that lacked adequate cover (Anderson and Pelton 1976).

Water

The eastern cottontail obtains sufficient moisture from succulent vegetation, dew, and available surface water (Schwartz and Schwartz 1959).

Cover

The eastern cottontail inhabits a wide range of successional and transitional habitats (Chapman et al. 1982). No single habitat type can be categorized as preferred cover because habitat preferences of the species vary by season, latitude, geographic region, and behavorial activities. However, the essential ingredients of eastern cottontail habitat appear to be an abundance of well-distributed escape cover interspersed within a grassland community that contains an abundance of forbs. Successional seres characterized as being "old field" have been identified as preferred eastern cottontail habitat (Friley 1955; Heard 1962; Nugent 1968). Beckwith (1954) described the vegetative succession associated with abandoned farmlands in Michigan and related shifts in vegetative structure and composition to accompanying wildlife populations. Beckwith concluded that eastern cottontails were generally restricted to shrubby cover associated with field edges, or to undisturbed sites associated with successional stages dominated by grasses. All successional stages were believed to provide numerous food plants for the species; therefore, suitable cover was believed to be a more limiting characteristic of the habitats evaluated. Cottontail numbers were expected to increase as trees and shrubs became established in the mid-successional stages.

The cover requirements of the eastern cottontail can be characterized as being composed of feeding cover and resting/escape cover (Trent and Rongstad 1974). Open areas are generally used for foraging at night whereas dense, heavy cover is typically selected for shelter during the day (Chapman et al. 1982). During summer the two basic cover requirements are generally provided by the same vegetation (Trent and Rongstad 1974). During late fall and winter both cover requirements become more restrictive due to the desiccation of herbaceous vegetation and the loss of foliage from woody vegetation. The reduction of available herbaceous cover forces cottontails to forage in less secure cover and travel greater distances during foraging activities. Similar conclusions were drawn by Janes (1959) who recorded average summer foraging distances for eastern cottontails of 53.3 m (175.0 ft) and winter foraging distances of 99 m (325 ft). Chapman et al. (1982) concluded that it is probable that eastern cottontails use woody cover considerably more during the

winter months, particularly where dense herbaceous vegetation provides adequate summer cover. Other studies also have reported increased reliance upon woody vegetation by eastern cottontails during the winter, presumably in response to decreased herbaceous cover (Kline and Hendrickson 1954; Bigham 1970). Winter forms (resting sites) in Minnesota were closer to overstory tree boles, surrounded by a greater number of woody stems, and associated with larger sapling-sized trees, than were randomly located points (Swihart and Yahner 1982a). Eastern cottontails in Illinois increased their use of woody vegetation as snow depth increased (Hansen et al. 1969). Trent and Rongstad (1974) recorded increased cottontail use of retreats (e.g., holes, woodpiles, and junkpiles) as vegetative cover decreased and snow depths increased. Areas dominated by dense, robust, herbaceous vegetation may provide adequate winter food and cover in southern portions of the eastern cottontail's range where extreme snowfall does not reduce vegetative cover (Swihart pers. comm.).

The importance of woody vegetation to survival and abundance of the eastern cottontail cannot be overemphasized (Swihart 1981). Trees and shrubs provide the eastern cottontail with food, shelter, and escape cover, and may be a limiting factor in defining the quality of eastern cottontail habitat throughout much of the rabbit's range. Trent and Rongstad (1974) also related cottontail survival to the abundance and distribution of suitable cover. Eastern cottontail concentration areas in Tennessee were characterized as being comprised of thick vegetative cover of poor penetrability in close proximity to other areas of sparse vegetative cover (Anderson and Pelton 1976). Preferred habitats were areas of dense, tangled cover, through which the rabbits were able to move in a variety of directions without being detected, or areas where rabbits were visible for only short periods of time as they moved across small openings. Ideally, eastern cottontail habitat is composed of areas with grassland; hedgerows; and low, dense, woody vegetation that provide escape cover and refuge sites (Smith 1950). The presence and abundance of woody vegetation was reported to significantly influence the use of habitat by cottontails in Minnesota (Swihart and Yahner 1982b). Eastern cottontails were more likely to establish residence within shelterbelts than in other nearby habitat types. Eastern cottontails captured in fencerow/roadside habitats, which typically contained no woody vegetation or woody vegetation of low quality, were generally transients or used the habitat on a temporary basis in conjunction with a contiguous shelterbelt. Extensive use of hedgerows by eastern cottontails in Maryland was attributed to greater abundance of horizontal cover, 0 to 0.5 m (0 to 1.6 ft) in height, than was present in other nearby cover types (Morgan and Gates 1983). The relatively dense woody cover near the ground surface within hedgerows provided numerous refuge sites for cottontails. Bigham (1970) recorded concentrated establishment of cottontail forms in Oklahoma where the overhead canopy cover of woody vegetation was $\geq$ 50% with little regard for stem density. Most escape sites were located where overhead canopy was $\geq$ 70% with low stem density. The removal of brushy fencerows was a major factor in the deterioration of cottontail habitat in Oregon (Verts and Carraway 1981). Tall, dense clump grasses [e.g., switchgrass (Panicum virgatum)] that stand well under winter snow provide winter cover for eastern cottontails, and may, to some degree, reduce the need for woody escape cover (Chapman et al. 1982).

Strip vegetation resulting from plantings, or from the fragmentation of larger blocks of habitat, is an important component of eastern cottontail habitat (Morgan and Gates 1983). Cottontails inhabiting shelterbelts in Minnesota were reported to be in better physical condition, and less prone to precipitous population declines, than were rabbits inhabiting wooded grassland or fencerow/roadside habitats (Swihart 1981). Shelterbelts supported higher winter densities of eastern cottontails than did wooded grassland habitats. Because of their linear design, shelterbelts exhibit a high perimeter to area ratio. Eberhardt et al. (1963) suggested that cottontail home ranges are typically oblong rather than circular; hence, shelterbelts and cottontail home ranges complement each other. Fencerows reduce the influence of barriers created by open fields and provide important travel corridors in farmland habitats (Bruna 1952 cited by Chapman et al. 1982; Wegner and Merriam 1979). Concentrated activity of small mammals in habitat corridors provided by fencerows or shelterbelts may relieve the isolating effect of farmland surrounding wooded habitats. Edwards et al. (1981) concluded that a major difficulty in cottontail management was that islands of suitable habitat are becoming both smaller and increasingly isolated. As habitat isolation increases, eastern cottontail abundance decreases because of an imbalance between emigration and immigration. Chapman (1971) reported that brush rabbits (S. bachmani) did not permanently inhabit clumps of brambles less than approximately 465 m^2 (5,000 ft^2) in area. Areas of cover of this size, or smaller, were used only if they were in proximity to larger units of cover.

Although the presence of cultivated land may increase seasonal food availability for the eastern cottontail, croplands generally eliminate the more permanent sources of food and cover typically available on uncropped lands (Friley 1955). Trent and Rongstad (1974) recorded less than 8% of eastern cottontail daytime resting sites within agricultural land. It appeared that only agricultural land within 91.4 m (300.0 ft) of a woodlot was used by the cottontail population inhabiting it. The continuous disturbance of soil and vegetation in heavily grazed areas results in low use by cottontails (Friley 1955).

Land use must be regarded as the most influential factor affecting long term cottontail abundance (Edwards et al. 1981). Although population cycles are possible, any periodicity in eastern cottontail abundance over the past 20 to 25 years has been of minor importance when compared to the influence of changing land use patterns (Chapman et al. 1982). Throughout much of their range, eastern cottontail abundance has declined due to: reductions in grasslands, stream and river bottom forests, and woodlots; the plowing or "improvement" of weedy and brushy pastures; and overgrazing. Edwards et al. (1981) concluded that the greatest declines in cottontail abundance in Illinois have occurred where agricultural land use has been most intense. A comparison of eastern cottontail population indices between 1956 and 1978 indicated that declines in cottontail abundance probably exceeded 70% on a statewide basis and 90 to 95% in intensively farmed portions of that State. Less severe reductions in cottontail abundance were recorded in areas with the best interspersion of woody cover, pasture, and grassland. Reduced eastern cottontail abundance appeared to be associated with a decrease in the number of individual farms and diminished acreage devoted to the production of hay and oats. Comparing eastern cottontail abundance in Illinois between 1939 and 1974,

Vance (1976) concluded that the major reduction in rabbit abundance could be attributed to the intensification of cash-grain farming. The emphasis on grain production has resulted in an increased average field size, a drastic reduction of grass-dominated cover types, and a reduced quantity and quality of fencerows. The loss of brushy fencerows was believed to be particularly detrimental to eastern cottontail populations. Brushy fencerows were reduced by 84% within the study area, and remaining fencerows were of poor quality due to their narrowness and sparse vegetative cover. Swihart and Yahner (1982b) concluded that nonwooded habitats with little artificial cover are unsuitable for permanent occupancy by eastern cottontails in a modern agro-ecosystem. Fencerows with little woody vegetation and roadside vegetation are generally unfit for year-round use by cottontails in intensively farmed areas. Long term reductions in eastern cottontail populations can be expected to continue unless there is a decline in intensive agricultural land use (Chapman et al. 1982).

Reproduction

Eastern cottontails typically construct nests in slanting holes that contain an outer lining of grass, or herbaceous stems, with an inner lining of fur (Chapman et al. 1982). Most cottontail nests are located in grass cover. Eastern cottontails in Michigan exhibited a spring movement from woody winter cover to upland herbaceous cover for the establishment of nest sites (Friley 1955). Fallow fields and hayfields were believed to be the most important nest cover. The use of croplands in Wisconsin by eastern cottontails for the establishment of nest sites was minimal (Trent and Rongstad 1974). Early nests of eastern cottontails are generally situated in grassy vegetation less than 15.0 cm (5.9 inches) tall (Chapman 1982). Nest sites located in an Iowa study were within 64.2 m (70.0 yd) of brush cover in herbaceous vegetation greater than 10.2 cm (4.0 inches) in height (Hendrickson 1940). Cottontail summer nests in hayfields were typically in vegetation less than 20.0 cm (7.8 inches) in height. Eastern cottontail nests located in a Maryland study were located near dense cover and were constructed against tree stumps or surrounded by vegetation, usually ferns (Filicinae) (Bruch and Chapman 1983).

Interspersion

Factors that affect the size of the eastern cottontail's home range include: (1) age and sex of the individual; (2) type, arrangement, and stability of the habitat; (3) season; (4) weather patterns; (5) population density; and (6) intraspecific and interspecific competition (Chapman et al. 1982). The home ranges of different ages and sexes overlap during most of the year, particularly during the fall and winter when cottontails tend to concentrate in areas providing the best combination of food and cover. Eastern cottontail home range size during late fall, winter, and early spring is a function of food distribution, regardless of sex or age (Trent and Rongstad 1974). As cover abundance becomes reduced in late fall and winter, eastern cottontail home ranges tend to become larger and are focused around some type of dense escape cover (Janes 1959; Chapman et al. 1982). The eastern cottontail's home range is roughly circular in uniform habitats and is used most near its center and least toward the periphery (Janes 1959). Eastern cottontails typically inhabit one home range for the duration of their life, although minor shifts

in home range use in response to vegetation changes and weather are common. Anderson and Pelton (1976) reported that eastern cottontails that did shift their home ranges were not observed to return to their original home range. Temporary home range departures were recorded after the onset of the breeding season. Unless a sudden reduction of cover occurred, cottontails remained within their home range. Harvesting of crops did result in evacuation of home ranges. Swihart and Yahner (1982b) also recorded abandonment of home ranges as a result of crop harvest. Emigration from home ranges within croplands resulted in autumn and winter concentrations of eastern cottontails within nearby wooded habitats.

Local populations of eastern cottontails may reach a density of 20 rabbits/ha (8/acre) although densities are normally lower (Chapman et al. 1982). The average winter home range size for male and female eastern cottontails in Tennessee was 2.8 ha (6.9 acres) and 2.2 ha (5.4 acres), respectively (Anderson and Pelton 1976). Male cottontails in Wisconsin had an average spring home range size of 2.8 ha (6.9 acres), and an average early summer home range of 4.0 ha (9.8 acres) (Trent and Rongstad 1974). Adult female eastern cottontails had an average spring home range of 1.7 ha (4.2 acres) and an average early summer home range of 0.8 ha (1.9 acres). Eastern cottontails in Kansas were believed to maintain an average home range of 3.4 ha (8.34 acres) (Janes 1959). The home ranges of male cottontails averaged 0.5 ha (1.16 acres) larger than those of females. Daily foraging activities were typically restricted to 10 to 20% of the overall home range.

Special Considerations

Habitat diversity and interspersion are the key elements in eastern cottontail management (Chapman et al. 1982). Interspersion of fields and woody vegetation along with creation of edge by breaking up large, continuous units of monotypic habitat have proven beneficial in habitat management for the species.

A variety of management techniques have been used to create or improve eastern cottontail habitat. Encouraging the growth of woody vegetation and developing artificial cover enhance cottontail habitat (Swihart 1981). The establishment of brushpiles is an effective means to increase an area's potential to support cottontails (Madson 1959, cited by Chapman et al. 1982; Pils et al. 1981; Swihart 1981). Brushpiles should be at least 4 to 6 m (13 to 20 ft) in diameter and 1 to 2 m (3 to 7 ft) in height (Chapman et al. 1982). Brushpiles should be situated near the edges of woodlots, fields, pastures, or other sites where vegetation provides food and limited additional cover. Brushpiles should be distributed at distances of 50 to 100 m (55 to 110 yds) whenever practical. However, the creation of brushpiles is considered only a temporary solution and their establishment should not be considered a substitute for more permanent vegetative cover. Most brushpiles lose their effectiveness for providing adequate cottontail cover within 3 to 5 years after their establishment. If the creation of brushpiles is the primary element of a habitat management program for cottontails, 1/3 to 1/4 of the brushpiles should be replaced annually. Thorny shrubs that maintain a low, dense, clump

growth form should be selected when shrub planting is considered as a management option (Chapman et al. 1982). Similarly, Morgan and Gates (1983) recommended that shrubs with a growth form similar to multiflora rose (Rosa multiflora) be selected when establishing escape cover for the eastern cottontail. The establishment of conifers, particularly spruce (Picea spp.) and shrubs (e.g., Lonicera spp., Viburnum spp., and Prunus spp.) in shelterbelts increases their suitability as eastern cottontail cover (Swihart 1981). However, coniferous species may not provide an adequate winter food source for the cottontail (Swihart and Yahner 1983; Swihart pers. comm.). Podoll (1979) provided a summary of vegetation useful as eastern cottontail food and cover and recommended techniques for establishment of structural diversity for the enhancement of shelterbelts as cottontail habitat. Regardless of species composition, strip habitat (e.g., windbreaks and shelterbelts) should consist of dense, woody vegetation ≥ 1 to 2 m (1 to 2 yds) in height and at least 5.0 m (5.4 yds) wide to provide ideal cottontail cover (Morgan pers. comm.). Swihart and Yahner (1983) provide guidance for shelterbelt planting stock in relation to species susceptibility to browsing damage by eastern cottontails and white-tailed jackrabbits (Lepus townsendii). Lord (1963) concluded that extremely dense or high grass can restrict use of an area by eastern cottontails. The mowing of such fields increased their use by cottontails. Hedgerows with mowed grass borders had greater eastern cottontail use than any other cover type surveyed in a Maryland study (Morgan and Gates 1983). Swihart and Yahner (1982-1983) postulated that the cessation of mowing between shelterbelt rows may allow the establishment of preferred cottontail winter forage [e.g., gooseberry (Ribes spp.) and blackcap raspberry (Rubus occidentalis)] and reduce potential damage to planted trees resulting from winter browsing. Limited grazing can be effectively used in cottontail management (Ellis et al. 1969). Pils et al. (1981) provided a summary of literature related to cottontail habitat management throughout the United States.

The eastern cottontail uses vegetative types associated with early and mid-successional stages; thus, natural succession should be taken into account in any management program that focuses on maintaining or enhancing eastern cottontail habitat (Chapman et al. 1982). Ellis et al. (1969) concluded that habitat management for upland game species, including cottontails, should be based upon the manipulation of natural succession. Management goals should be oriented toward the maintenance of appropriate successional patterns through periodic disturbance rather than the actual creation of habitat (e.g., planting to provide food and cover). Sharecropping, prescribed burning, and combinations of the two activities were recommended as being ecologically sound and economically feasible techniques in the management of vegetative succession.

Friley (1955) recommended that eastern cottontail management efforts be directed toward securing a cover pattern that provides nesting and escape cover within an area not exceeding 12 ha (30 acres). A ratio of 8 ha (20 acres) of cover to 40 ha (100 acres) of cropland was believed to be sufficient to support high numbers of eastern cottontails in Tennessee (Anderson and Pelton 1976). Fall densities of eastern cottontails approaching 2 to 3/ha (2 to 3/2.5 acres) is a realistic management goal on managed areas of 500 ha (1,236 acres) or larger, where forested cover types do not exceed 25% of the total area (Chapman et al. 1982).

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

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

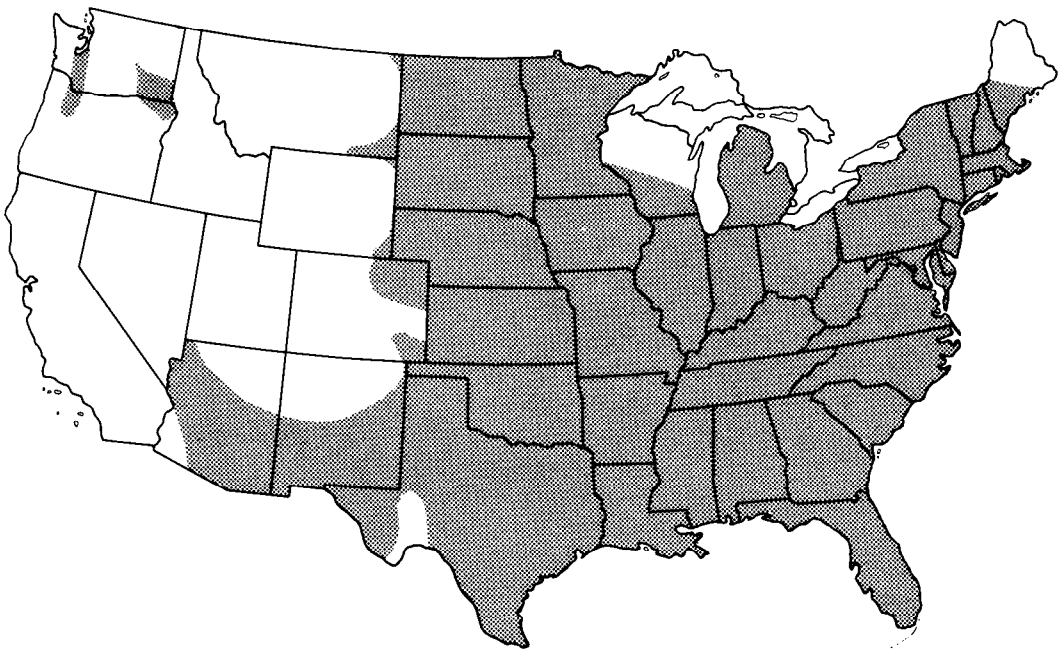


Figure 1. Approximate distribution of the eastern cottontail in the contiguous United States (modified from Chapman et al. 1982).

Season. This model has been developed to evaluate the potential quality of winter habitat for the eastern cottontail. Cover and food requirements for the species are more restrictive during winter than during the balance of the year. This model is based on the assumption that year-round eastern cottontail habitat will be present if winter cover and food of sufficient quality are available. As a result of less severe winter conditions, the eastern cottontail's dependence upon adequate winter cover and food may not be as pronounced in the more southern portions of the species' range.

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): Cropland (C); Pasture/Hayland (P/H); Evergreen Forest (EF); Deciduous Forest (DF); Evergreen Shrubland (ES); Deciduous Shrubland (DS); Evergreen Shrub Savanna (ESS); Deciduous Shrub Savanna (DSS); Grassland (G); and Forbland (F).

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. Specific information on the minimum habitat area required by the eastern cottontail was not located in the literature. However, the majority of mean home range sizes reported in the literature are less than 4 ha (10 acres) in area. Based on this information, it is assumed that a minimum of 4 ha (10 acres) of potential habitat is required to support a population of eastern cottontails.

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. An earlier draft of this model was reviewed by Dr. Joseph A. Chapman, Utah State University; Mr. Kevin Morgan, Wisconsin Department of Natural Resources; Dr. Robert K. Swihart, University of Kansas; and Dr. Richard H. Yahner, Pennsylvania State University. Improvements and modifications suggested by these persons have been incorporated into this model.

Model Description

Overview. The eastern cottontail uses a diversity of herbaceous and woody vegetation for food and cover on an annual basis. The species is adaptable and can successfully inhabit a variety of habitat types if sufficient food and cover are provided. In regions with severe winter weather, the eastern cottontail depends upon woody vegetation as a source of winter food, escape cover, and thermal cover. It is assumed that winter food and cover provided by woody vegetation are interdependent characteristics of the eastern cottontail's habitat. Areas providing an abundant supply of woody vegetation well interspersed with areas dominated by herbaceous vegetation and/or agricultural lands are assumed to characterize potentially optimum year-round eastern cottontail habitat.

The following sections provide documentation of the logic and assumptions used to translate habitat information for the eastern cottontail 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.

Winter cover/food component. The eastern cottontail subsists entirely upon herbaceous vegetation during the spring, summer, and early fall. During these seasons, herbaceous vegetation of sufficient height and density also provides shelter and escape cover. Row, grain, and hay crops provide additional cover and food on a seasonal or temporary basis. With the onset of winter, and the decreased availability and quality of herbaceous vegetation, the eastern cottontail becomes almost entirely dependent upon the buds, stems, twigs, and bark of woody vegetation as a food source. In response to the reduction of available herbaceous vegetation, shrubs and trees also become the eastern cottontail's major source of winter thermal and escape cover. This model is based on the assumption that year-round habitat quality for the eastern cottontail is defined by the quality and distribution of winter habitat. It is assumed that adequate amounts of spring/summer food and cover

(generally provided by herbaceous plants and/or agricultural crops) will never be more limiting than a source of suitable winter food and cover.

The abundance and distribution of shrubs, trees, and persistent herbaceous vegetation are assumed to be indicative of the potential quality of winter habitat for the eastern cottontail. This model does not take into account the locally important potential cover that may be provided by animal burrows, man-made features or other non-vegetative habitat features. It is assumed that sufficient amounts of winter cover must be present within, or adjacent to, a cover type in order for it to provide year-round eastern cottontail habitat. Cover types that do not contain or adjoin areas supporting woody vegetation may provide suitable spring/summer habitat. However, such areas will not provide suitable winter habitat and are therefore assumed to be characteristic of unsuitable year-round habitat for the species. Herbaceous dominated cover types adjacent to woody cover may be used to a limited degree by the eastern cottontail during the winter months. Linear woody cover types (e.g., fencerows, windbreaks, narrow riparian woodlands) are assumed to be used in their entirety by the eastern cottontail throughout the year. Large units of woody habitat (e.g., woodlots, forests) are assumed to receive their greatest amount of use where these habitats form an interface with croplands or other herbaceous dominated cover types. During the fall and winter, eastern cottontails will shift their use of habitat into the more secure cover provided by woodlands in response to disturbance from crop harvesting and decreased abundance of herbaceous vegetation. It is assumed that the interior portions of woodlots or forested cover types will be used to a greater extent by eastern cottontails during the winter months than during the spring or summer when nonwooded areas provide adequate food and cover.

Winter habitat quality for the eastern cottontail is assumed to be a function of habitat structure that includes: (1) percent shrub crown closure; (2) percent tree canopy closure; and, to a limited degree, (3) the percent canopy closure of persistent herbaceous vegetation. The assumed relationships between vegetative density and suitability index values for eastern cottontail cover/food habitat quality are presented in Figure 2.

Figure 2a presents the assumed relationship between shrub density [woody vegetation $\leq$ 5 m (16.5 ft) tall] and a winter cover/food index value. Optimum conditions are assumed to exist when shrub crown closure ranges between 20 to 50%. Shrub density below 20% is assumed to be indicative of lower habitat quality due to a minimum amount of available cover and winter food. Shrub density in excess of 50% is assumed to reflect slightly lower habitat quality due to a reduction in openings and the potential availability of herbaceous growth during green-up periods. Complete shrub canopy closure is assumed to indicate habitat of lower potential, not unsuitable habitat.

Figure 2b shows the assumed relationship between tree canopy closure and a winter cover/food index value for the eastern cottontail. The presence of trees is assumed to enhance an area's potential as eastern cottontail winter habitat. However, the presence of trees without a shrub understory is assumed to reflect eastern cottontail winter habitat of low quality. Dense forest stands, or woodlots (> 50% tree canopy closure), are assumed to inhibit the growth of intolerant shrubs resulting in less suitable winter habitat for the

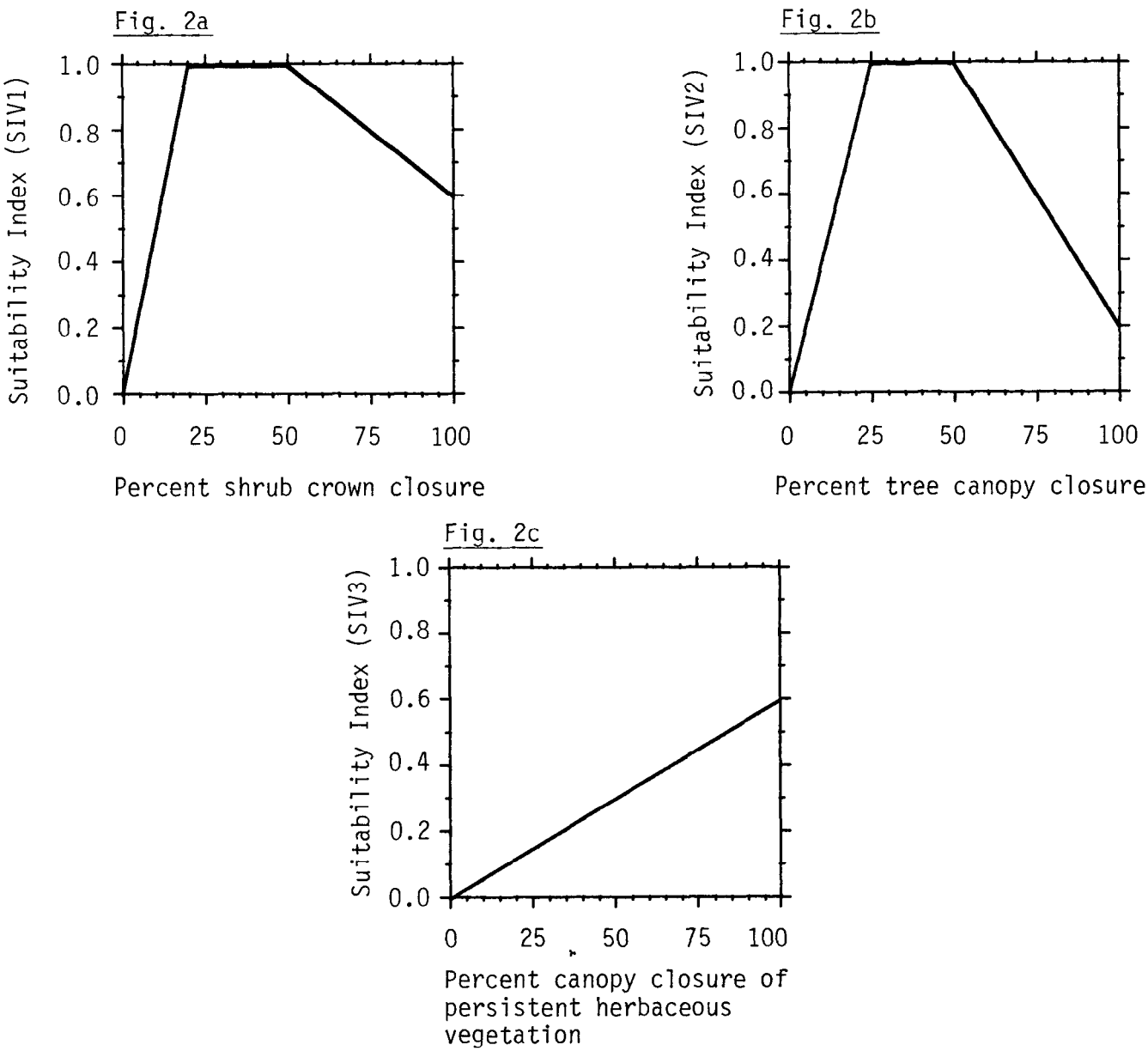


Figure 2. The relationships between habitat variables used to calculate the winter cover/food value for the eastern cottontail and the suitability indices for the variables.

species. Optimum tree density is assumed to range from 25 to 50% tree canopy closure. Tree canopy closure below 25% is assumed to reflect lower habitat quality due to reduced food and cover availability.

The relationship of nonwoody vegetation that normally remains standing after the growing season (i.e., persistent) to a suitability index value for eastern cottontail winter habitat quality is presented in Figure 2c, percent canopy closure of persistent herbaceous vegetation. In northern regions, the presence of persistent herbaceous growth may increase an area's ability to provide adequate winter habitat. However, even extremely dense, herbaceous vegetation is assumed to provide habitat of relatively low potential if woody vegetation is sparse or absent. Regions with little to no persistent snow cover may permit dense robust stands of herbaceous vegetation to play a greater role in meeting the eastern cottontail's winter cover and food requirements. Therefore, users of this model in southern portions of the cottontail's range may wish to assign greater weight to the herbaceous component of this model.

The index values calculated using the curves presented in Figure 2 are combined in Equation 1 to determine a winter cover/food index (WCFI) for the eastern cottontail in specific cover types.

$$WCFI = \text{maximum value of } \frac{(4(SIV1) + SIV2)}{5} + SIV3 \quad \text{or} \quad 1.0 \qquad (1)$$

As presented in the above equation, the density of shrubs, trees, and persistent herbaceous vegetation is assumed to be additive in the definition of winter habitat quality for the eastern cottontail. Cover types, with all three vegetative features present at optimum densities, have greater potential for meeting the eastern cottontail's winter habitat requirements than would a site with only one or two of the vegetative features present. Shrub density (SIV1) is assumed to be the most influential component in defining eastern cottontail winter habitat quality and is weighted in the equation to reflect this assumption. The percent tree canopy closure (SIV2) on any area is assumed to have only one-fourth the potential of the percent shrub canopy closure for providing suitable winter cover/food conditions. The presence of persistent herbaceous vegetation (SIV3) in association with shrubs and trees is assumed to increase an area's ability to provide adequate winter cover/food for the eastern cottontail. The structure of equation 1 permits an optimum value to be obtained in the complete absence of persistent herbaceous vegetation if sufficient amounts of woody vegetation are present. The presence of herbaceous vegetation enhances an area's winter cover/food potential if suboptimum densities of woody vegetation are present. Equation 1 may result in a value that exceeds 1.0 if robust herbaceous vegetation is present in an area that supports tree and shrub densities that are in the assumed optimum ranges. In such situations, the WCFI value should be reduced to 1.0. Cover types supporting only persistent herbaceous vegetation are assumed to have relatively low value as eastern cottontail winter habitat in the more northerly portions of the species' range.

Interspersion component. The major assumption of this model is that woody vegetation, particularly shrubs, must be present in order to provide high quality year-round habitat for the eastern cottontail. Although the total amount of woody vegetation present within a study area may be within the assumed optimum range to meet the eastern cottontail's winter cover and food requirements, the juxtaposition of woody vegetation and herbaceous dominated cover types may have a significant effect on an area's potential as year-round habitat. For example, even though only a small proportion of a study area may provide suitable winter cover/food, the area may still be ranked as relatively high in value if the existing cover is well distributed throughout the entire study area. Conversely, the overall value of an area may be relatively low as year-round eastern cottontail habitat, if woody vegetation is concentrated in one homogeneous block, even when the total percentage of the area with woody cover represents assumed optimum conditions.

Application of this model requires that a winter cover/food value be determined for each cover type within the evaluation area. The HSI for the eastern cottontail in evaluation areas composed of one homogeneous cover type is equivalent to the winter cover/food index (equation 1). In study areas composed of two or more cover types, an overall winter cover/food value can be calculated by multiplying the winter cover/food index (equation 1) for each cover type by the cover type's proportion (%) of the entire study area and summing these products.

The following steps should be taken to determine a winter cover/food index value for each cover type within the evaluation area.

1. Stratify the evaluation area into cover types.

2. Divide the area of each cover type by the total area of the evaluation area to determine the relative area (%) of each cover type.

3. Determine the winter cover/food index (WCFI) for each cover type through the use of equation 1.

4. Multiply the relative area of each cover type (%) (step 2) by its WCFI value (step 3).

5. Sum the products calculated in step 4 for all cover types to obtain a weighted WCFI value.

The steps outlined above are expressed by equation 2:

$$\text{WCFI weighted by area} = \frac{\sum_{i=1}^{n} WCFI_i A_i}{\Sigma A_i} \qquad (2)$$

where n = number of cover types

$WCFI_i$ = WCFI of individual cover type

A_i = area of cover type i

An interspersion value for an evaluation area may be determined by identifying those cover types that provide a WCFI value. If all cover types provide winter cover/food, the HSI is equal to the value determined through the application of equation 2. If one or more cover types have a winter cover/food index of 0.0, the degree of interspersion between cover types providing winter cover/food to those that do not provide the required resources must be calculated to determine a final HSI value.

The interspersion value may be calculated by measuring the length of perimeter of all cover types in the evaluation area that have a WCFI value > 0.0. Multi-row shelterbelts provide better eastern cottontail habitat than do single-row shelterbelts. Single-row shelterbelts should be considered as being linear habitat features; therefore, only their length should be included in calculation of the diversity index. In contrast, multi-row shelterbelts should have their entire perimeter included in the calculation. The perimeter of cover types that have a 0.0 WCFI value should not be included in the calculation.

The interface, or edge, between two cover types that each have a WCFI value > 0.0 should be counted only once in order to prevent double counting. Example 4 in Figure 4 illustrates this concept. The interspersion diversity index for a study area is calculated through using equation 3.

$$DI = \frac{TPWC}{2\sqrt{A\pi}} \tag{3}$$

where DI = diversity index

TPWC = the total perimeter of cover types containing winter cover/food (e.g., WCFI > 0.0) in study area

A = total area of study area

The diversity index value calculated using equation 3 is converted to a suitability index value by entering the diversity index value into the curve presented in Figure 3.

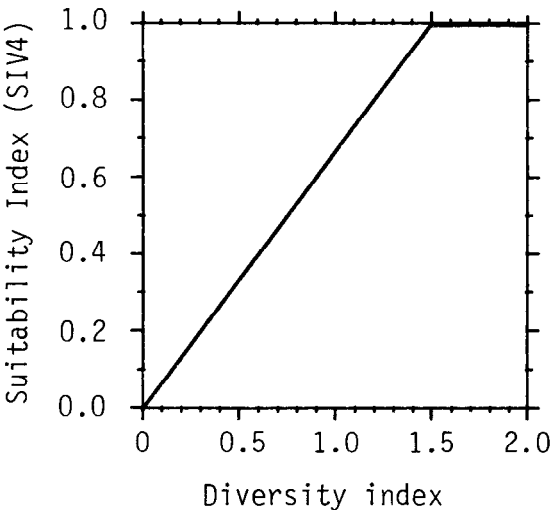
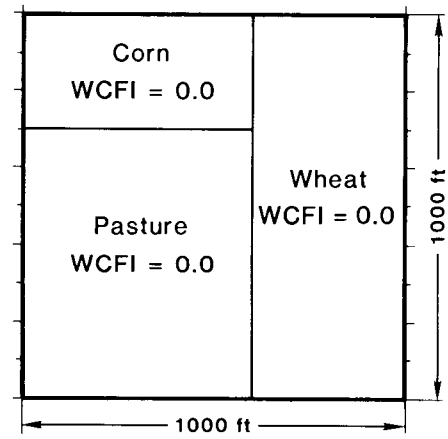


Figure 3. The relationship between the diversity index value calculated using equation 3 and a suitability index value.

The curve presented in Figure 3 was developed based on the assumption that areas composed of cover types containing no woody vegetation or dense, robust herbaceous vegetation are of almost no value as year-round eastern cottontail habitat regardless of the number and interspersion of cover types present. Equation 3 is provided to calculate a index value to estimate the degree of interspersion of cover types within an evaluation area. The diversity index value calculated using equation 3 will be of low value in areas that are comprised of few, large cover types. Conversely, areas characterized by a relatively large number of distinct cover types will have relatively large diversity index values. The diversity index value (equation 3) must be converted to a suitability index (SI) value using the curve (SIV4) presented in Figure 3. A diversity index value $\geq$ 1.5 is assumed to represent an optimum SI value. However, the precise value that represents optimum interspersion of cover types for the eastern cottontail is unknown. The optimum value of 1.5 for the diversity index was selected based on sample data sets similar to those presented in Figure 4. Users of this model may wish to adjust the optimum diversity index value based on their experience and knowledge of local optimum eastern cottontail habitat. Figure 4 illustrates example calculations of the diversity index for cover types providing winter cover/food for the eastern cottontail.

Example 1

Study area is composed entirely of cropland and pasture. Although different vegetative types are present within the study area, woody vegetation is entirely absent resulting in a diversity index of 0.0.



Example 2

Shrubland, providing potential year-round habitat, is bordered by pasture and corn. The entire shrubland edge is used to calculate the diversity index. The interface of corn and pasture is not included in the calculation since neither cover type provides winter cover or food.

$A = 1{,}000{,}000\ ft^2$

$TP = 2{,}800\ ft$

$$DI = \frac{2{,}800\ ft}{2\sqrt{1{,}000{,}000\ ft\ (3.1416)}}$$

$DI = 0.78$

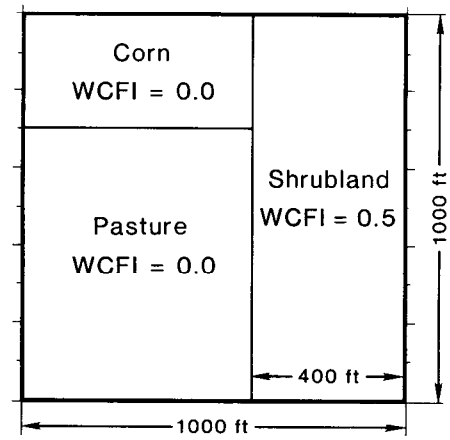
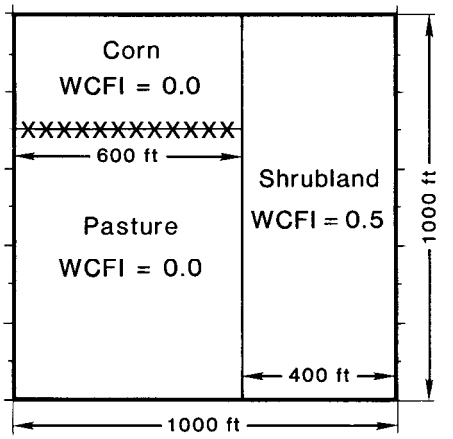


Figure 4. Example applications of diversity index used for the calculation of the interspersion of cover types that provide potential winter cover and food for the eastern cottontail.

Example 3

Vegetative characteristics are the same as example 2 except that a shrubby fencerow now separates the pasture from the corn field resulting in an increased diversity index value.



$A = 1{,}000{,}000\ ft^2$

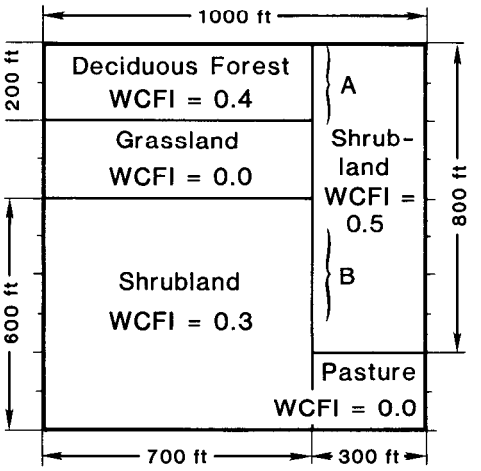
$TP = 3{,}400\ ft$

$$DI = \frac{3{,}400\ ft}{2\sqrt{1{,}000{,}000\ ft\ (3.1416)}}$$

$DI = 0.95$

Example 4

Area 4 is composed of a block of deciduous forest, two shrubland types, grassland, and pasture. The grassland and pasture cover types do not contain woody vegetation and have HSI values of 0.0. The deciduous forest and shrubland cover types have HSI values > 0.0, therefore the sum of the perimeters of each cover type is used to determine the diversity index for the study area. The values for the edge between the deciduous forest and shrubland (line A) and two shrubland types (line B) should be used in the calculation only once in order to prevent double counting resulting in an inaccurate index value. For example, if the deciduous forest perimeter is tallied, line A should be excluded from the tally of the adjacent shrubland perimeter.



$A = 1{,}000{,}000\ ft$

$TP = 6{,}000\ ft$

$$DI = \frac{6{,}000\ ft}{2\sqrt{1{,}000{,}000\ ft\ (3.1416)}}$$

$DI = 1.69$

Figure 4. (concluded).

Model Relationships

HSI determination. The calculation of a Habitat Suitability Index for the eastern cottontail considers the values obtained for the weighted winter cover/food index value (equation 1) and the diversity suitability index value derived from Figure 3. The relationship is expressed by a geometric mean of the indices for the two variables, as in equation 4.

$$HSI = (WCFI \times SIV4)^{1/2} \quad (4)$$

The availability of suitable amounts of winter cover and food and the distribution of those resources are assumed to be of equal value in defining habitat potential for the species.

Summary of model variables. Four habitat variables are used in this model to evaluate a winter cover/food value for the eastern cottontail. The relationships between habitat variables, the winter cover/food life requisite value, cover types, and an HSI value are summarized in Figure 5.

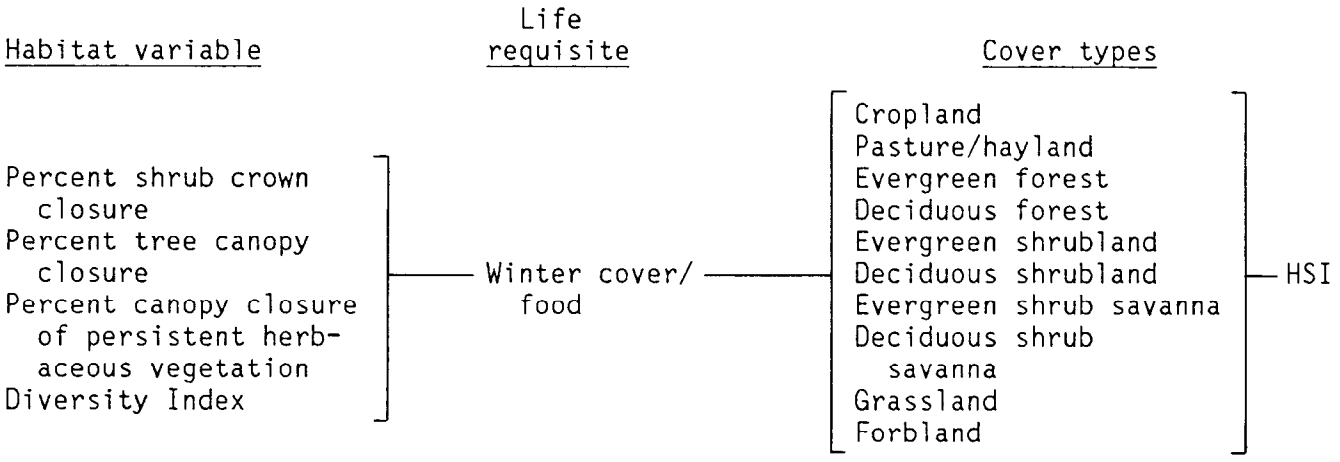


Figure 5. Relationships of habitat variables, life requisites, and cover types to an HSI for the eastern cottontail.

Application of the Model

Values for habitat variables used to evaluate the winter cover/food value for the eastern cottontail can be estimated from aerial photographs. More precise measures of variable values may be obtained by collecting field data using transects and/or quadrats. Figure 6 provides a definition of each variable and suggested field measurement techniques (Hays et al. 1981).

Variable (definition)		Cover types	Suggested techique
V_1	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].	P/H,EF,DF,ES, DS,ESS,DSS,G,F	Remote sensing, line intercept
V_2	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].	P/H,EF,DF,ES, DS,ESS,DSS,G,F	Remote sensing, line intercept
V_3	Percent canopy closure of persistent herbaceous vegetation (the percent of the ground surface that is shaded by a vertical projection of all non-woody vegetation that may be expected to remain standing after the growing season).	P/H,EF,DF,ES, DS,ESS,DSS,G,F	Line intercept, quadrat

Figure 6. Definitions of variables and suggested measurement techniques.

Variable (definition)	Cover types	Suggested techique
V_4 Diversity Index (a measure of the amount of cover type edge within the study site. The ratio of cover type edge to total area is compared to that for a circle having the same area as the study site, using the following formula: $DI = \frac{TPWC}{2\sqrt{A\pi}}$ where DI = diversity index; TPWC = total length of edge of cover types that provide winter cover/food; A = total area of study site. DI values ≥ 1.5 are assumed to represent optimum interspersion conditions for the easter cottontail).	Entire study area	Remote sensing, cover type map, planimeter, ruler

Figure 6. (concluded).

SOURCES OF OTHER MODELS

Urich et al. (1983) have compiled a series of habitat evaluation models, including a eastern cottontail model, applicable for habitat analysis in Missouri.

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16. Abstract (Limit: 200 words)

This report presents information on the key environmental variables influencing the suitability of a particular habitat for Eastern cottontail (Sylvilagus floridanus). A habitat model is developed which is scaled to produce a suitability index between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). This information is useful for impact assessment and habitat management.

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