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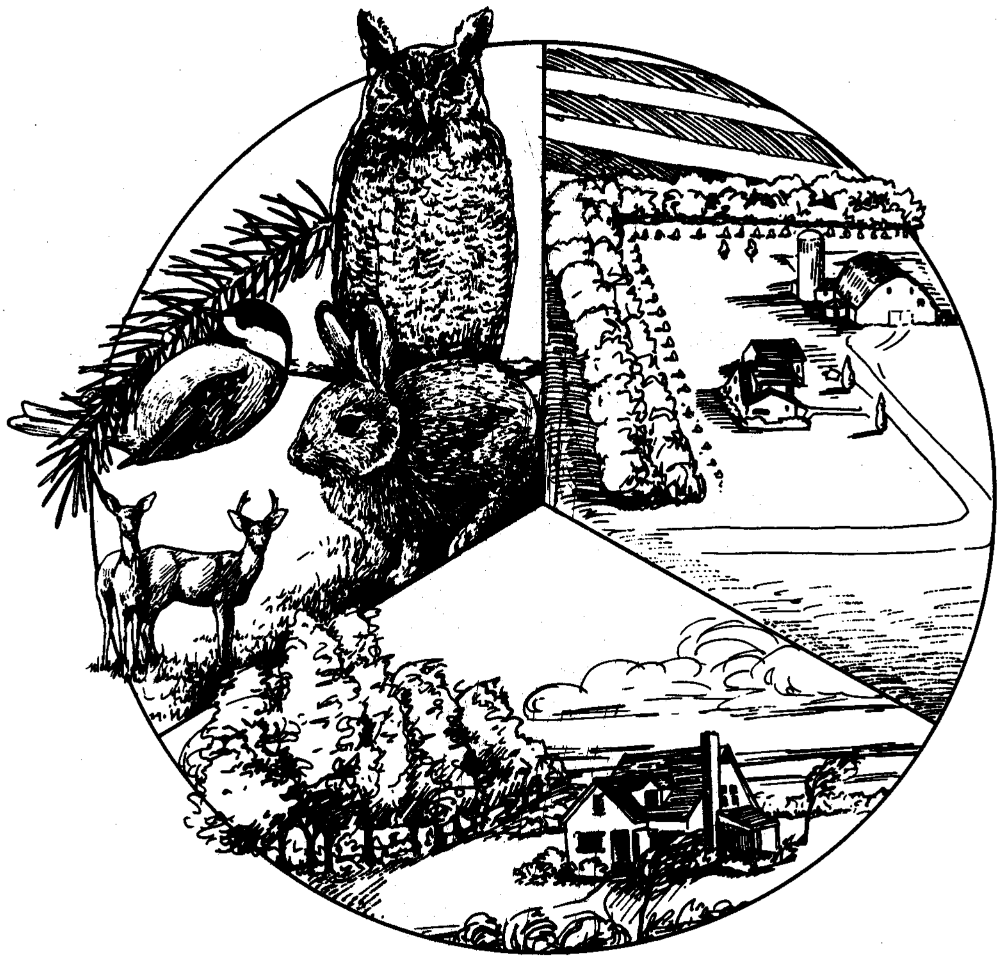

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HABITAT SUITABILITY INDEX MODELS: WILDLIFE SPECIES RICHNESS IN SHELTERBELTS

by

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PREFACE

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

The 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is a formalized synthesis of biological and habitat information published in the scientific literature and may include unpublished information reflecting the opinions of identified experts.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 quality 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:

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FIGURES

ACKNOWLEDGMENTS

The following reviewers are gratefully acknowledged for their many useful comments on earlier drafts of this model: Thomas E. Martin (Arizona State University, Tempe), Paul A. Vohs (U.S. Fish and Wildlife Service, Denver), and Richard H. Yahner (Pennsylvania State University, University Park).

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WILDLIFE SPECIES RICHNESS IN SHELTERBELTS

HABITAT USE INFORMATION

General

Farmstead shelterbelts consist of rows of shrubs and trees planted on the windward side of farmstead dwellings (Yahner 1983a). Field windbreaks are similar plantings designed to reduce wind erosion of agricultural land (Goldsmith 1976). The terms shelterbelt and windbreak are often used interchangeably in the literature.

Less than 3% of the land area of the Great Plains is in wooded cover (Griffith 1976). Shelterbelts in the Great Plains provide wooded habitat for a large variety of birds and other wildlife that would not be present in the area without shelterbelts (Popowski 1976). The absence of farmstead shelterbelts in intensively farmed portions of the Midwest would drastically lower populations of white-footed mice (*Peromyscus leucopus*) and southern red-backed voles (*Clethrionomys gapperi*) (Yahner 1983b). Shelterbelts in North Dakota contribute significantly to the habitat needs of the ring-necked pheasant (*Phasianus colchicus*), gray partridge (*Perdix perdix*), sharp-tailed grouse (*Tympanuchus phasianellus*), mourning dove (*Zenaida macroura*), cottontail rabbit (*Sylvilagus floridanus*), fox squirrel (*Sciurus niger*), and a variety of songbirds (Podoll 1979). Shelterbelts also provide a limited amount of food and cover for white-tailed deer (*Odocoileus virginianus*).

Cassel and Wiehe (1980) reviewed several reports on bird use of shelterbelts in North Dakota and noted that 64 species of birds used shelterbelts during the breeding season. Martin (1978) found 68 species of migratory birds and 44 species of breeding birds in a 2-year study of 69 shelterbelts in South Dakota. Shelterbelts in the Great Plains are present as a series of isolated woody habitats in an area of large expanses of croplands and grasslands. These "wooded islands" provide elevated song and display perches for breeding grassland and woodland birds, and feeding and nesting stations for migratory birds. Shelterbelts may serve as "stepping stones" between riparian habitats (Yahner 1983a), which are important wooded areas for wildlife (Emmerich and Vohs 1982).

Area and Configuration of Shelterbelts

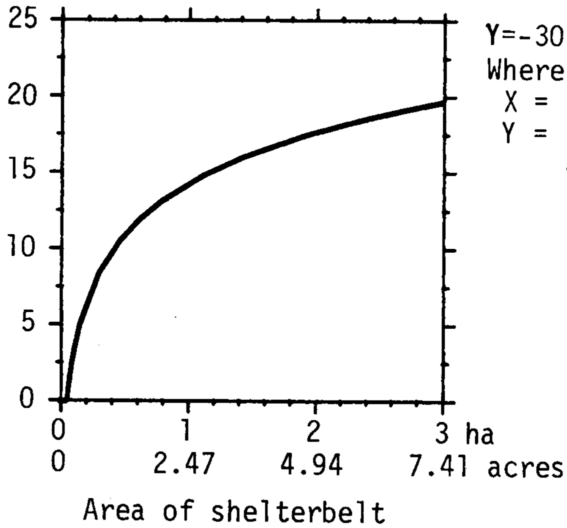
Shelterbelts with about 10 rows of shrubs, hardwoods, and evergreens, and ≥1.2 ha in size, were the most heavily used by wildlife in Kansas (Schwilling 1982). Several studies have shown positive correlations between the area of a shelterbelt and species richness (the number of wildlife species). The number of breeding bird species was positively correlated with shelterbelt area in both North Dakota ($r=0.73$, $P<0.001$, $n=81$) (Cassel and Wiehe 1980) and South Dakota ($r=0.83$, $P<0.001$, $n=69$) (Martin 1981a). Bird species richness during spring migration in South Dakota was also correlated with shelterbelt area ($r=0.82$, $P<0.001$, $n=69$) (Martin 1980). Shelterbelt size was positively associated ($r \geq 0.878$, $P<0.05$, $n=5$) with species richness of small mammals in Minnesota (Yahner 1983b). Species-area curves developed by Martin (1978) for both migratory and breeding birds in South Dakota shelterbelts are illustrated in Figure 1.

The slope of the species-area curve at a given area may vary depending on resource abundance and habitat diversity within a shelterbelt (Martin 1981b). Shelterbelts of high habitat diversity allow more bird species to coexist than equal sized areas with lower habitat diversity. In shelterbelts of uniform habitat diversity, area would be expected to be the best predictor of bird species richness (Martin 1978). In shelterbelts with high habitat diversity, both area and habitat conditions would be good predictors of bird species richness. Total bird species richness is not always the same in the same size shelterbelts, even in cases where habitat diversity is similar (Martin 1981a). Lower species richness values may occur due to a lack of species caused by chance or by competition with other species in similar guilds.

The width of shelterbelts is very important in determining the value of shelterbelts for wildlife in the northern Great Plains (Podoll 1979). Snow drifts commonly penetrate up to 30.5 m into shelterbelts, and belts less than this width have less value for wildlife in winter. Multirow shelterbelts provide winter cover for ring-necked pheasants, gray partridge, sharp-tailed grouse, cottontail rabbits, fox squirrels, and songbirds, while single-row belts provide winter cover for only the gray partridge. Multirow shelterbelts also provide both escape and loafing cover for white-tailed deer. The best configuration of multirow shelterbelts for wildlife is to have tall trees in the middle rows and lower shrubs in the outer rows of the belt.

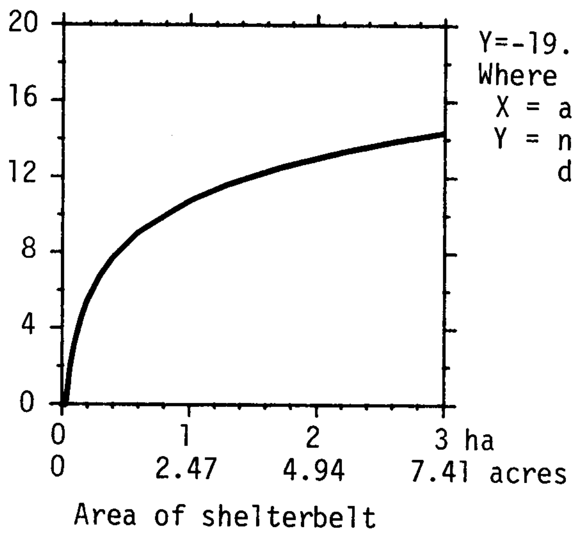
Cassel and Wiehe (1980) analyzed breeding bird counts from 81 shelterbelts in North Dakota; these data indicate that individual shelterbelts with a large number of rows (>20) contained more breeding birds per belt than did individual shelterbelts with ≤20 rows. The total combined species richness (20 breeding species) for all single-row belts ($n=10$), however, was comparable to total species richness (21 breeding species) for all shelterbelts with >20 rows ($n=4$). There was a difference in the types of birds found in belts with a few or many rows (Table 1). Belts with only a few rows attracted more birds associated with open habitats, whereas belts with many rows attracted more birds associated with forested habitats.

Number of bird species during migration



$Y = -30.514 + 4.872 \log_e(10{,}000X)$
Where
X = area of shelterbelt(ha)
Y = number of bird species during migration

Number of bird species during breeding season



$Y = -19.271 + 3.268 \log_e(10{,}000X)$
Where
X = area of shelterbelt(ha)
Y = number of bird species during breeding season

Figure 1. Species-area curves for birds in South Dakota shelterbelts (from Martin 1978).

Table 1. Breeding bird frequencies in shelterbelts of various row widths (from Cassel and Wiehe 1980).

	Frequency of occurrence	
	1-, 2-, or 3-row shelterbelts	>20 row shelterbelts
Least flycatcher (*Empidonax minimus*)	6%	100%
Yellow warbler (*Dendroica petechia*)	6%	75%
Northern oriole (*Icterus galbula*)	0%	75%
Northern flicker (*Coloptes auratus*)	6%	75%
Horned lark (*Eremophila alpestris*)	44%	0%
Vesper sparrow (*Pooecetes gramineus*)	78%	25%

Vegetative Structure and Composition of Shelterbelts

The number of bird species in shelterbelts in South Dakota and Minnesota was related to the vegetative structure of the shelterbelts (Martin 1978; Yahner 1983a). In South Dakota, area explained over 60% of the variation in bird species richness, while about 60% of the residual variation was explained by environmental variables (e.g., habitat features, plant species composition) (Martin 1978).

The highest bird species diversity in a study of South Dakota shelterbelts occurred in shelterbelts with a developed tree canopy and an understory with a full, lush grass layer (Martin and Vohs 1978). Dense shrub growth under the trees was not preferred, although tall, dense shrubs along the outside edges of shelterbelts increased the number of bird species using the shelterbelt. In Minnesota shelterbelts, vegetative variables that were positively correlated ($r \geq 0.75$, $P<0.05$, $n=7$) with total bird species richness for all seasons were stem density of canopy vegetation, mean diameter of trees at breast height, total basal area, percent canopy closure, and growth form diversity (Yahner 1983a). The complexity of the vegetative structure was a major factor in determining bird community structure in shelterbelts, with older belts having more mature plant communities and greater bird species richness. Table 2 contains a summary of data related to bird species richness and shelterbelt structure in Minnesota (Yahner 1980a,b; 1981a,b; 1982a,b).

Table 2. Bird species richness and shelterbelt structure in Minnesota (from Yahner 1980a,b; 1981a,b; 1982a,b).

Shelterbelt name	Bird species richness	Area (ha)	Age of shelterbelt (years)	Mean height of two tallest rows (m)	Percent canopy closure[a]
Sheep swine	8	0.21	7	2.4	1
Plant pathology	15	0.30	15	5.8	44
Forestry	16	0.32	30	10.4	22
North beef	18	0.71	33	11.9	29
Agricultural engineering	21	0.78	20	9.8	61
Sewage	22	0.37	32	17.1	77
Poultry	29	0.70	35	16.5	58

[a]Canopy was defined as woody vegetation >2 m in height and >10.1 cm dbh.

Most birds in North Dakota shelterbelts used belts >5 years old (Cassel and Wiehe 1980). Older shelterbelts supported more breeding species, and raptors and hole-nesting birds appeared to prefer shelterbelts >40 years old. The number of bird species was positively correlated ($r=0.56$, $P<0.001$, $n=81$) with the age of the shelterbelt. Average maximum canopy height was positively correlated with bird species diversity in South Dakota shelterbelts and was the most important variable affecting bird diversity in single-row windbreaks during both spring migration and the breeding season (Emmerich 1978).

After area, shelterbelt age explained the largest amount of the residual variation ($r^2=0.183$, $P<0.005$, $n=69$) for predicting migratory bird species richness in South Dakota shelterbelts (Martin 1978). Canopy coverage exhibited the second highest simple correlation ($r=0.354$, $P<0.01$, $n=69$) with migratory bird species richness, discounting area. Mowing, which eliminates the understory habitat, was negatively correlated with breeding bird species richness ($r=-0.395$, $P<0.005$, $n=69$).

Habitat features that created microhabitat complexity were positively associated with small mammal species richness in Minnesota shelterbelts (Yahner 1983b). Considering all seasons, forb density at 1.0 m height and average distance to fallen logs ≥7.5 cm in diameter were positively correlated ($r \geq 0.878$, $P < 0.05$, $n = 5$) with small mammal species richness. The highest trapping rates for cottontail rabbits during summer and autumn in Minnesota shelterbelts were obtained in areas of dense shrubby vegetation (Swihart and Yahner 1982).

Shelterbelts composed of a single species of trees are more vulnerable to mass insect outbreaks or diseases that can destroy the entire belt than are shelterbelts composed of a mixture of tree species (Martin and Vohs 1978). A mixture of tree species decreases vulnerability to disease, increases longevity, and makes shelterbelts more attractive to birds. The number of observed sightings of birds in Minnesota shelterbelts was greater than expected, in all four seasons, for trees in the genera *Picea*, *Populus*, and *Acer* (Yahner 1982c). Observations in these three genera (per season) ranged from 54.5% to 69.1% of total observations, yet only 29.6% of trees were of these genera.

Inclusion of a coniferous species greatly increases the value of shelterbelts in providing winter cover for birds (Martin 1978). Shrub species that form low, dense thickets are also beneficial in slowing wind and snow in shelterbelts during the winter. In a study of winter bird use of shelterbelts in North Dakota, Rotzien (1963) observed a total of 17 bird species in 8 shelterbelts over 3 winters. Most shelterbelts had very few bird species present at any one time, except during periods of snowfall or blowing snow. Shelterbelts appeared to serve as places of refuge during severe winter weather. Shelterbelts in Saskatchewan provided important fall and winter cover for gray partridges, sharp-tailed grouse, and ring-necked pheasants (Gray 1976).

Interspersion and Spatial Considerations

Bird use of shelterbelts may be affected by the isolation of the belts or by the presence of barriers to dispersal between belts (Martin 1981a). The effects of these factors were minimal in Martin's (1981a) study of South Dakota shelterbelts. Most of the bird species observed were commonly distributed in many shelterbelts, suggesting that isolation or dispersal were insignificant factors. Shelterbelts are well distributed throughout eastern South Dakota, with an average of a little more than two shelterbelts per 259 ha. Mean distance between shelterbelts in Martin's (1981a) study area was 554 m. These small distances should have a minimal effect on birds that use shelterbelts. In addition, the flat topography of eastern South Dakota does not inhibit dispersal. Lastly, statistical analyses showed that isolation of shelterbelts within the study area did not exhibit any negative effects on bird species richness.

Shelterbelt Management

If current trends of planting small and single-row shelterbelts continue, it could lead to substantial reductions in some bird populations on the Great Plains (Martin and Vohs 1978). This threat could be minimized by planting large shelterbelts or by planting a few small belts in close proximity to one another. Bird species diversity in eastern South Dakota wooded habitats is primarily dependent upon maintaining riparian woodland habitat; shelterbelts contribute to the area's avifauna, but support fewer species (although larger numbers) than riparian woodlands (Emmerich and Vohs 1982). Yahner (1983a) discussed specific management recommendations to enhance bird species richness in shelterbelts related to the following attributes: plant species composition, size, number of rows, spacing, grazing, mowing, snag availability, food plots, and adjacent tillage practices.

HABITAT SUITABILITY INDEX MODEL

Model Output

This model is designed to yield an output between 0 and 1, where 1 represents a shelterbelt with the maximum year-round number of vertebrate wildlife species (wildlife species richness) to be expected for an individual shelterbelt in the northern Great Plains, and outputs approaching 0 represent successively lower values of species richness.

Model Applicability

Geographic area. This model applies primarily to shelterbelts in the northern Great Plains States of North Dakota, South Dakota, and Minnesota.

Season. This model was developed to evaluate year-round conditions in shelterbelts.

Cover types. This model applies to shelterbelts and windbreaks, as defined on page 1.

Verification level. This model is a hypothesis of the relationship of habitat and area to wildlife species richness. Earlier drafts of this model were reviewed by Thomas E. Martin, Department of Zoology, Arizona State University, Tempe; Paul A. Vohs, U.S. Fish and Wildlife Service, Denver, Colorado; and Richard A. Yahner, Forest Resources Laboratory, Pennsylvania State University, University Park. Comments from these reviewers have been incorporated into this model. An application of the model (using data from Yahner 1980a,b; 1981a,b; 1982a,b) for seven Minnesota shelterbelts produced a correlation of $r=0.86$ ($P<0.05$, $n=7$) between the HSI and year-round bird species richness.

Model Description

Overview. The number of wildlife species in shelterbelts is related to their configuration, vegetative composition and structure, and size. In general, wildlife species richness will increase with an increase in vegetative structural complexity, plant species diversity, number of rows, or area.

It is assumed that interspersion of shelterbelts is not a critical factor influencing species richness of an individual shelterbelt, because shelterbelts are generally distributed in such a manner that isolation and dispersal of wildlife are not limiting factors.

Description of variables and relationships. Wildlife species richness in shelterbelts is generally positively associated with the age of the belt. Shelterbelt age is correlated with both tree volume ($r=.408$, $P<0.001$, $n=69$) and canopy coverage ($r=0.461$, $P<0.001$, $n=69$) (Martin 1978). Wildlife most likely respond to the vegetative condition of shelterbelts rather than to age directly. Direct measures of tree volume are time consuming; alternative and simpler measures of volume would be a combination of height and canopy closure. Analyses of Yahner's (1980a,b; 1981a,b; 1982a,b) data show a positive correlation between the average height of the two tallest shelterbelt rows and bird species richness ($r=0.89$, $P<0.01$, $n=7$). Based on the shelterbelts in these studies with the highest bird species richness, it is assumed that maximum suitability will occur when shelterbelt heights exceed 16.5 m, and that suitability will decline linearly as heights decrease to zero. The relationship between shelterbelt height and a suitability index (SIV1) is illustrated in Figure 2a.

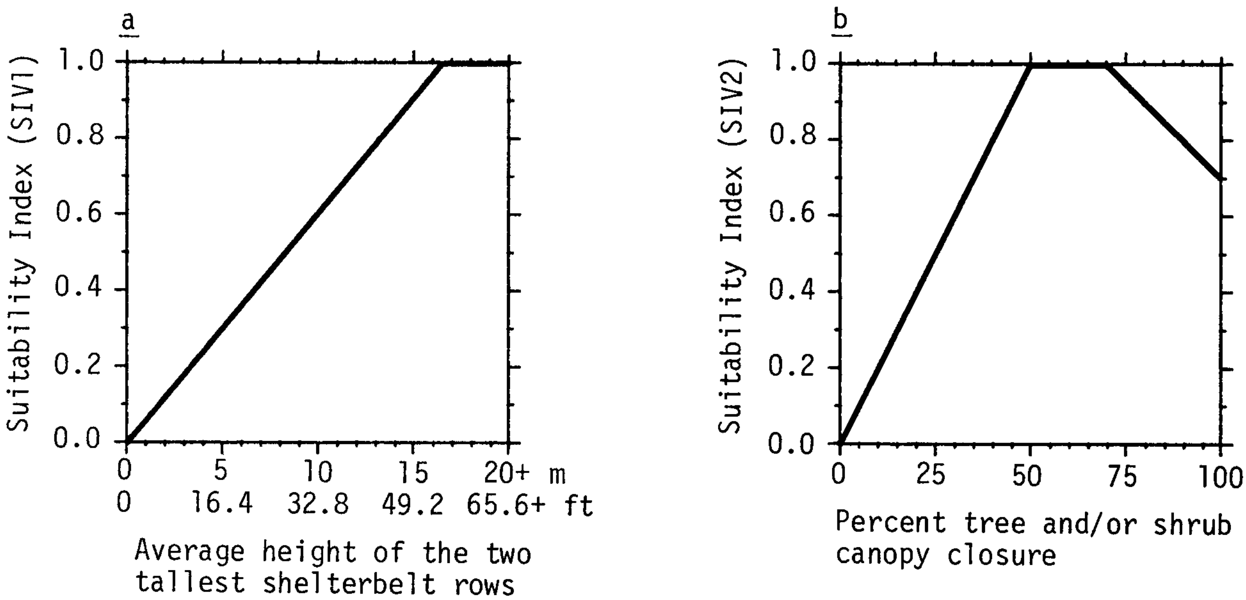


Figure 2. Relationships between variables used to assess woody vegetation height and density and suitability indices for the variables.

Canopy coverage of woody vegetation in shelterbelts is positively correlated with bird species richness in both South Dakota (Martin 1978) and Minnesota (Yahner 1983a). The average percent canopy cover in South Dakota shelterbelts was 54.4% (Martin 1978). These shelterbelts never achieved dense conditions due to the types of species planted and the plant spacing. Certain bird species [e.g., orchard orioles (Icterus spurius) and western kingbirds (Tyrannus verticalis)] exhibited negative correlations with canopy closure (Martin 1978), and too much canopy closure is actually detrimental (T. E. Martin, Department of Zoology, Arizona State University, Tempe; letter dated October 25, 1985). It is assumed that optimum canopy closure of woody vegetation (both shrubs and trees) exists between 50% and 70% canopy closure. Suitability is assumed to decline linearly as canopy closure approaches zero. Suitability is assumed to decline slightly as canopy closure increases from 70% to 100%, due to a decline in bird species richness. The relationship between canopy closure and a suitability index (SIV2) is illustrated in Figure 2b.

Other important factors affecting wildlife species richness are the number of rows in the shelterbelt, the diversity of woody vegetation, and the arrangement of shrub and tree rows within the belt.

Yahner (1983a) recommends 8-row shelterbelts as best for wildlife; such belts would be about 35 m in width. Podoll (1979) states that belts <30.5 m in width have less value to wildlife in winter due to snow penetration. It is assumed that maximum year-round wildlife species richness will exist in belts of ≥8 rows. Although it is possible that suitability will decline at some higher number of rows (Martin, unpubl.), no data are available to show at what point this might occur. Suitability is assumed to decrease to moderate levels as the number of rows declines to one, due to the fewer number of wildlife species occurring in such shelterbelts. The relationship between the number of rows and a suitability index (SIV3) is illustrated in Figure 3a.

The wildlife species richness of shelterbelts is related to the diversity of woody plant species. Increases in the number of woody plant species are accompanied by increases in the structural complexity of the shelterbelt (Martin, unpubl.). Shelterbelts in eastern South Dakota had an average of 4.4 species of trees and/or shrubs per belt (Martin 1978). Specific data relating wildlife species richness to the number of woody plant species was not found in the literature. This model assumes that ≥6 woody plant species per shelterbelt represents optimum conditions and that suitability will decline to moderate levels as the number of woody plant species declines to one. It is further assumed that a plant species must compose ≥1% (based on canopy closure) of the shelterbelt area to be considered in this variable. The relationship between number of woody plant species and a suitability index (SIV4) is illustrated in Figure 3b.

The arrangement of tree and shrub rows in a shelterbelt affects wildlife species richness. Shelterbelts with ≥2 outside shrub rows and an inner tree row provide habitat for a larger number of species than shelterbelts lacking these components. Shelterbelts with only shrub rows are assumed to have low

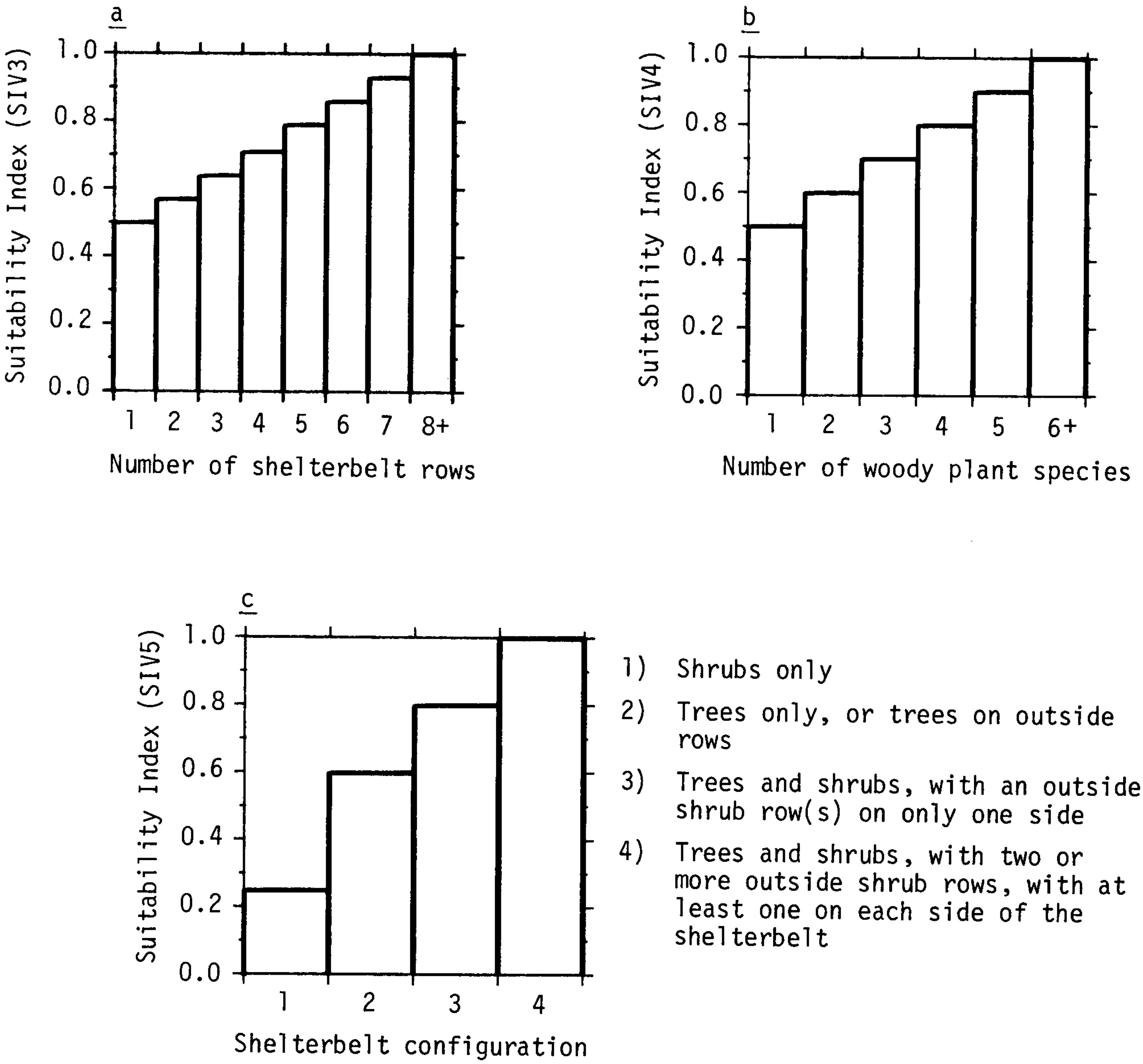
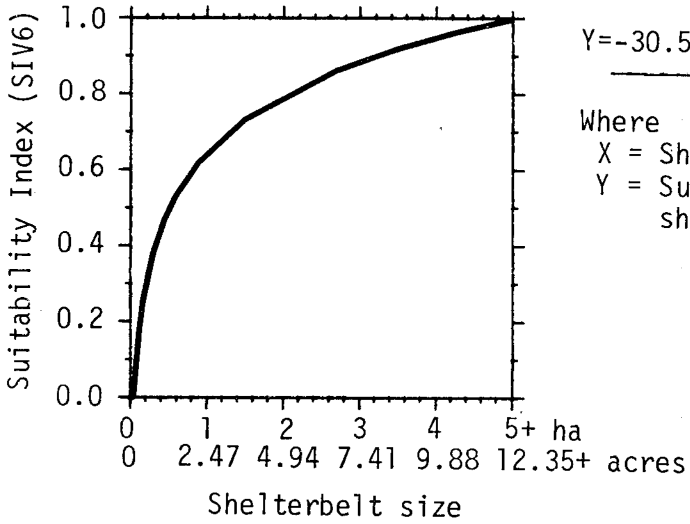


Figure 3. Relationships between selected habitat variables for shelterbelts and suitability indices for the variables.

suitability, whereas belts with only trees are assumed to have moderate suitability. The relationship between shelterbelt configuration and a suitability index (SIV5) is illustrated in Figure 3c.

The size of a shelterbelt is very important in determining its value to a variety of wildlife species. Martin (1978) developed species-area curves for breeding and migratory birds in South Dakota shelterbelts (see Figure 1). The equations for these curves indicate that species richness increases continually with increases in area. For purposes of this model, several assumptions are made regarding the species-area curve. First, it is assumed that the vast majority of existing or planned shelterbelts are ≤5 ha (50,000 m^2). Second, it is assumed that 5 ha represents an optimum sized shelterbelt, for purposes of comparison with other belt sizes. Third, the specific equation used for the suitability index (SIV6) for shelterbelt size [based on Martin's (1978) migratory bird species-area curve] represents a reasonable general shape to express the relationship of shelterbelt size to overall wildlife species richness. Use of this equation for shelterbelts <0.05 ha in size will produce suitability index values <0. It is assumed that such belts will not be frequently encountered, and that they should be given a zero suitability index value due to their small size. The relationship between shelterbelt size and a suitability index (SIV6) is illustrated in Figure 4.

Although the output of this model is intended to predict wildlife species richness, it is likely that the variables are also positively correlated with wildlife productivity. Productivity of birds in shelterbelts is related to area, foliage density, and structural complexity (T. E. Martin, Department of Zoology, Arizona State University, Tempe; letter dated June 10, 1986).



$$Y = \frac{-30.514 + 4.872 \log_e(10{,}000X)}{22.19}$$

Where
X = Shelterbelt size(ha)
Y = Suitability index for shelterbelt size

Figure 4. The relationship between shelterbelt size and a suitability index for this variable.

HSI determination. The overall HSI for wildlife species richness in shelterbelts is determined by Equation 1. An HSI should be calculated for each individual shelterbelt in the study area (see the Application of the model section for information on methods to combine values for more than one shelterbelt).

$$HSI = \frac{SIV1 + SIV2}{2} \times \frac{SIV3 + SIV4 + SIV5}{3} \times SIV6 \qquad (1)$$

Equation 1 is based on the following logic:

1. The two major factors affecting species richness in shelterbelts are the environmental variables (SIV1 through SIV5) and size (SIV6). If either of these factors is present at low suitability, this will severely limit species richness. This is accounted for in the equation by taking the product of these two factors.

2. Environmental variables describing shrub and tree volume (SIV1 and SIV2) can strongly limit species richness, as shown in the SI graphs.

3. Environmental variables related to number of rows, diversity of plant species, and shelterbelt configuration (SIV3, SIV4, and SIV5) cause only moderate effects on species richness, as shown in the SI graphs.

4. An application of the model (using data from Yahner 1980a,b; 1981a,b; 1982a,b) for seven Minnesota shelterbelts produced a correlation of $r=0.86$ ($P<0.05$, $n=7$) between the HSI and year-round bird species richness.

Application of the model. This model was developed from information pertaining to wildlife species richness on individual shelterbelts. For many applications, however, the objective will be to assess species richness for a large number of shelterbelts. There are several methods that can be used to apply the model to multiple shelterbelts and derive a single HSI value. Each of the following methods has specific implications and assumptions that users should consider carefully prior to applying the model.

1. The typical application of an HSI model using the Habitat Evaluation Procedures (U.S. Fish and Wildlife Service 1980) suggests that the HSI be multiplied by area to determine Habitat Units (HU's). The assumption is that HSI is independent of area. This assumption is not true for the shelterbelt HSI model (see Figure 4). Thus, it is difficult to interpret the meaning of specific HU values. For example, consider the following two situations:

Situation #1 = 20 shelterbelts, 1 ha each, 0.6 HSI each = 12 HU's
Situation #2 = 1 shelterbelt, 5 ha, 1.0 HSI = 5 HU's

These data imply that situation #1 is the better habitat in terms of species richness. However, this may or may not be the case. The species richness data from shelterbelts indicate that shelterbelts with low species richness values generally contain a subset of the species of shelterbelts with high species richness values. In general, increasing the number of small shelterbelts will not increase the number of species that require a large area. This would indicate that the single shelterbelt in situation #2 would have more wildlife species than all 20 of the belts in situation #1 combined, which is opposite the implication of the HU data.

2. A second possible method of applying this model to multiple shelterbelts is to consider the best condition to be the project area or project alternative that has the shelterbelt with the highest HSI value, regardless of the number of shelterbelts within this area. This method implies that a single shelterbelt with a high HSI value is most desirable because of the large number of wildlife species it contains, and that such a shelterbelt is more desirable than any number of shelterbelts with lower HSI's. This method assumes that the number of wildlife species for several smaller belts will never equal or exceed the number of wildlife species in the belt with the highest number of wildlife species. This implies that species richness would not be affected by eliminating all shelterbelts except the one with the highest HSI. Although this may be accurate in some instances, this method has potential weaknesses because it does not account for the total amount of shelterbelts. Removal of all low-value shelterbelts may affect wildlife species richness due to the reduced interactions between populations of different belts and the "stepping stone" benefits of dispersed shelterbelts.

3. The difficulty of the size of the shelterbelt being considered twice in HU calculations (see 1, above) could possibly be avoided by calculating overall HU's by multiplying the average HSI by the number of shelterbelts instead of shelterbelt area. Thus, HU = (average HSI) x (# of belts). This method, however, has one of the same implications as method 1, i.e., many low-value shelterbelts can be equal to or better than a few high value shelterbelts. This may or may not be reasonable, as discussed previously.

If the wildlife resource objective is to maximize wildlife species richness across all shelterbelts, each of the above methods has specific implications in meeting this goal. Another option would be to develop an HSI model whose output is a direct estimate of overall species richness for any number of shelterbelts. Such a model would have to consider not only the conditions within each shelterbelt, but also the interrelationships between shelterbelts of various sizes and habitat conditions, the spatial arrangement of these belts, the type of adjacent and nearby plant cover, barriers to wildlife dispersal, and other factors related to sustaining the maximum level of wildlife species over time. The data and information to develop such a model are not easily obtained; most available data on shelterbelts consist of measures of species richness or diversity within an individual belt.

This model may be useful in typical HEP applications where the objective is not related to overall species richness across all shelterbelts. In such cases, the user must accept the tradeoffs implied in the interpretation of HU values. If these tradeoffs are understood and acceptable, the model may be used in the typical manner.

Another important factor to consider in applying this model is the desired proportions of shelterbelts compared to other vegetative/wildlife communities that exist in the Great Plains. From a narrow point of view, wildlife species richness in shelterbelts might be enhanced to the point where certain wildlife species of grasslands are eliminated. Thus, users should consider not only the wildlife in shelterbelts, but also the consequences of various amounts of shelterbelts on other plant and animal communities of concern. In addition, it should be noted that species richness does not consider the habitat needs of individual wildlife species which may be of concern. Clearly stated wildlife resource objectives are a prerequisite to proper application of this model.

Summary of model variables. The six variables that are used in this model to determine the HSI value of a shelterbelt are: average height of the two tallest shelterbelt rows, percent tree and/or shrub canopy closure, number of shelterbelt rows, number of woody plant species, shelterbelt configuration, and shelterbelt size.

Definitions of variables and suggested measurement techniques (Hays et al. 1981) are provided in Figure 5.

Model assumptions. A number of assumptions were made in the development of the suitability index relationships and the HSI equation in this model. Major assumptions are listed below.

1. The volume of woody vegetation is strongly related to wildlife species richness.

2. Shelterbelts with just one row containing only one plant species have the potential to support about half the number of wildlife species as an optimum shelterbelt.

3. This model does not consider the proximity of other shelterbelts and assumes that isolation and dispersal are not factors that limit wildlife species richness in Great Plains shelterbelts.

4. Either area (size) or habitat features can limit the number of wildlife species occupying a shelterbelt.

A thorough understanding of these assumptions is essential to apply the model or to revise the model appropriately when the assumptions are not valid.

Variable (definition)	Suggested technique
Average height of the two tallest shelterbelt rows (m).	Graduated rod; trigonometric hypsometry
Percent tree and/or shrub canopy closure (the percent of the ground surface that is shaded by a vertical projection of the canopies of all woody vegetation).	Line intercept or quadrat
Number of shelterbelt rows (the total number of rows in the shelterbelt, regardless of woody vegetation height)	Site inspection or remote sensing
Number of woody plant species (the number of woody plant species that have ≥1% canopy closure within the shelterbelt).	Line intercept or quadrat
Shelterbelt configuration (the arrangement of tree and shrub rows, as defined below: 1) shrubs only 2) trees only, or trees on outside rows 3) trees and shrubs, with an outside shrub row(s) on only one side 4) trees and shrubs, with two or more outside shrub rows, with at least one on each side of the shelterbelt).	Site inspection or remote sensing
Shelterbelt size (m^2).	Remote sensing; planimeter

Figure 5. Definitions of variables and suggested measurement techniques.

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A review and synthesis of existing information were used to develop a Habitat Suitability Index (HSI) model for evaluating potential species richness in shelterbelts. 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.

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