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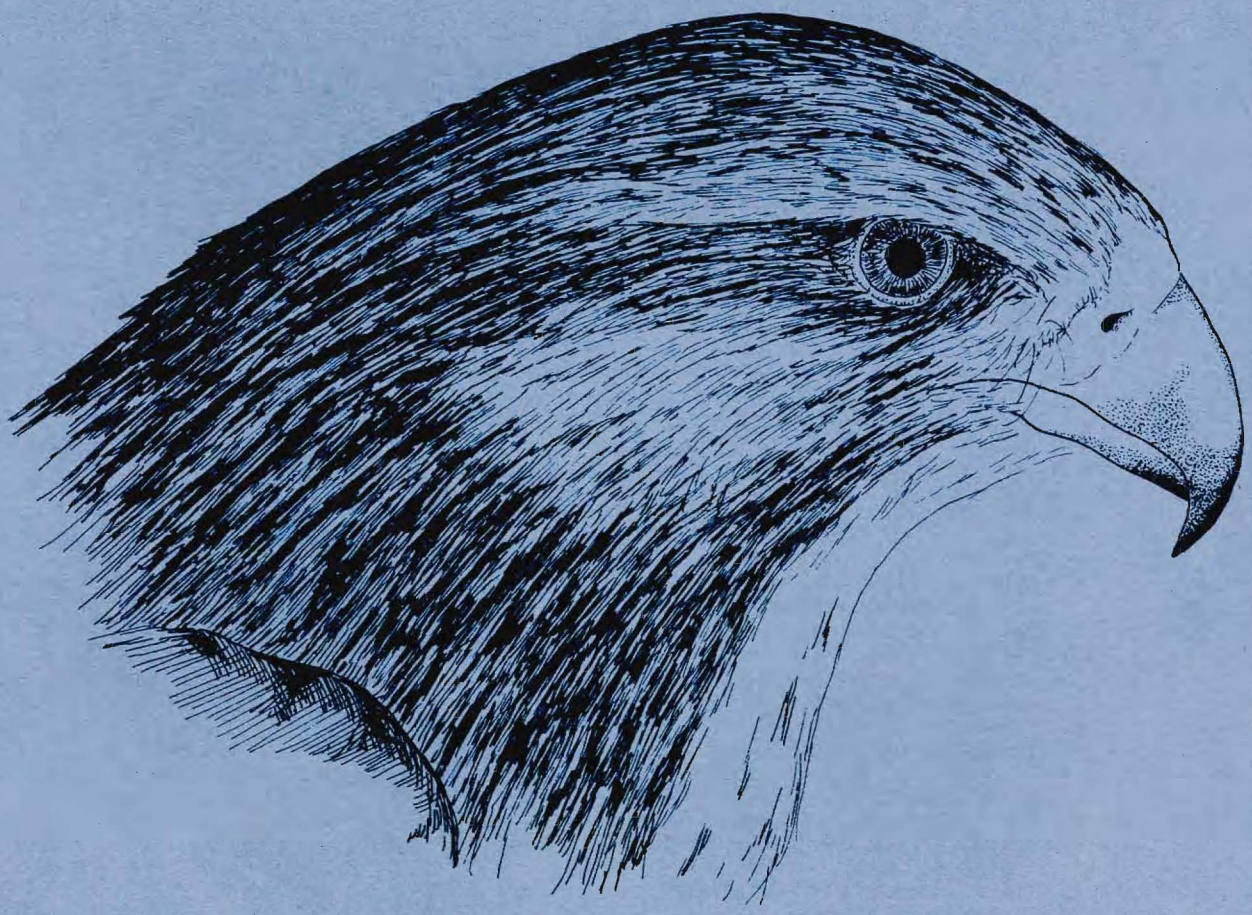
FEBRUARY 1982

HABITAT SUITABILITY INDEX MODELS: FERRUGINOUS HAWK



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The Biological Services Program was established within the U.S. Fish and Wildlife Service to supply scientific information and methodologies on key environmental issues that impact fish and wildlife resources and their supporting ecosystems. The mission of the program is as follows:

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- To gather, analyze, and present information that will aid decisionmakers in the identification and resolution of problems associated with major changes in land and water use.

- To provide better ecological information and evaluation for Department of the Interior development programs, such as those relating to energy development.

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FWS/OBS-82/10.10
February 1982

HABITAT SUITABILITY INDEX MODELS: FERRUGINOUS HAWK

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. Several types of habitat information are provided. The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. The habitat use information provides the foundation for HSI models that follow. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

The HSI Model Section documents a habitat model and information pertinent to its application. The model synthesizes the habitat use information into a framework appropriate for field application and is scaled to produce an index value between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). The application information includes descriptions of the geographic ranges and seasonal application of the model, its current verification status, and a listing of model variables with recommended measurement techniques for each variable.

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

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FERRUGINOUS HAWK (*Buteo regalis*)

HABITAT USE INFORMATION

General

The ferruginous hawk inhabits grasslands, shrublands, and steppe-deserts of the Western United States. It is a common nester in Colorado, Idaho, Montana, Utah, and Wyoming (Call 1978). Populations in the more Northern States tend to be migratory, spending the winter in New Mexico, Colorado, Kansas, Texas, and Oklahoma (Call 1979).

Ferruginous hawks thrive in areas that favor the production of rabbits (Lagomorpha), prairie dogs (*Cynomys* spp.), or ground squirrels (*Citellus* spp. and *Spermophilus* spp.) (Call 1979), provided that suitable nesting sites are available. Foraging habitat consists of nonforested, nonmountainous areas, such as desert shrub and grassland communities. Nesting habitat consists of communities with isolated trees, woodland edges, buttes, cliffs, and/or grassland with some relief.

Food

Analysis of prey items collected from nests in many studies indicate that jackrabbits (*Lepus* spp.) often constitute the most important prey item, based on biomass (Weston 1969; Platt 1971; Smith and Murphy 1973; Howard 1975; Howard and Wolfe 1976; Woffinden and Murphy 1977; Thurow et al. 1980). In some of these studies, analysis of prey items was based not only on prey biomass but also on percent frequency of occurrence. For instance, the northern pocket gopher (*Thomomys talpoides*) was the most frequent prey item in Howard's study (1975) conducted in northern Utah and southern Idaho, whereas the Ord's kangaroo rat (*Dipodomys ordii*) was most frequent in the studies conducted in Utah by Weston (1969) and Woffinden and Murphy (1977). In some studies, prey species other than jackrabbits were most important, based on biomass. Thirteen-lined ground squirrels (*Spermophilus tridecemlineatus*) comprised 41% of the prey biomass in Colorado (Olendorff 1973). In South Dakota, the Richardson's ground squirrel (*Spermophilus richardsonii*) comprised 68% of the total prey biomass (Lokemoen and Duebbert 1976). In all of the study areas listed above, however, jackrabbits remained an important, if not the most important, prey item. Other known prey items include desert cottontails (*Sylvilagus audubonii*), antelope squirrels (*Ammospermophilus* spp.), deer mice (*Peromyscus maniculatus*), and passerine birds (Weston 1969).

Significant fluctuations in raptor densities may be an indication of the abundance and diversity of prey species (Howard and Wolfe 1976). This predator-prey relationship seems to exist in certain ferruginous hawk populations. A decline in ferruginous hawk numbers in Utah was directly correlated with a drop in the jackrabbit population (Woffinden and Murphy 1977; Smith et al. 1981). Ferruginous hawk fledgling success and nesting densities in southern Idaho and northern Utah were closely correlated with the cyclic black-tailed jackrabbit (*Lepus californicus*) population (Thurow et al. 1980).

Fluctuations of small mammal populations often are caused by intrinsic factors that have little relationship to habitat suitability (Odum 1971). Although manipulation of these cyclic populations is not normally possible, range management practices that result in ranges in good condition that will support abundant and diverse prey may provide suitable food alternatives to predators, such as the ferruginous hawk, during periods of jackrabbit decline (Call 1979). The nesting success of some populations of ferruginous hawks in Utah, where jackrabbit numbers declined dramatically, was attributed to the presence of a broad prey base (Woffinden and Murphy 1977). Ground squirrels were the major prey for immature ferruginous hawks in southern Idaho and northern Utah during midsummer when jackrabbit availability became limiting (Thurow et al. 1980).

Land management practices that dramatically alter the density and structure of native vegetation can adversely affect jackrabbit and alternate prey populations, resulting in a reduction of breeding ferruginous hawks. For example, conversion of extensive tracts of brushland and native vegetation to either agriculture or monotypic fields of grass is particularly disruptive to the production of both jackrabbits and cottontails because they survive best in mixtures of brush and grassland types (Call 1979). It is also disruptive to ground squirrels and other rodents (Murphy 1978). However, moderate amounts of rangeland and agricultural land support colonization by pocket gophers and ground squirrels, which may provide alternate prey species for the ferruginous hawk.

Areas providing an interspersion of tall cover and open spaces are preferred by jackrabbits (Taylor and Lay 1944; Lechleitner 1958). Jackrabbits are normally associated with areas that have shrubs at least 0.6 m (2 ft) tall (Orr 1940) and use this shrub cover for hiding and resting (Bear and Hansen 1966). Black-tailed jackrabbits fed primarily on grasses during spring and summer in Idaho, whereas in fall the diet was comprised primarily of forbs and shrubs (Fagerstone et al. 1981).

Ferruginous hawks usually hunt by flying low over open fields, seldom rising more than a few feet above the ground (Weston 1969). They normally hunted in sagebrush-grassland areas in Utah (Smith and Murphy 1973). Habitat use by foraging raptors is sometimes, but not always, a function of prey density. Studies have shown that raptors often forage over areas where cover conditions make prey more vulnerable (Craighead and Craighead 1956; Wakeley 1978). Thus, an area supporting many concealed prey individuals may be less important to raptors than an area supporting a few vulnerable individuals. Although overgrazed areas temporarily may provide vulnerable prey, it is unlikely that such areas will support an adequate prey base for a long period of time (Call 1979).

Water

Water does not appear to be limiting to the ferruginous hawk (Bartholomew and Cade 1963). Most water is supplied by the metabolic process of digesting food.

Cover

Cover for concealment does not appear to be limiting to the ferruginous hawk. On the plains of Colorado, ferruginous hawks used fence posts, telephone poles, and dead trees as perch sites (Marion and Ryder 1975).

Reproduction

The ferruginous hawk is a versatile nester, using isolated trees, cliffs, buttes and cutbanks, manmade structures, ground locations, and trees in the juniper-sagebrush ecotone. Of 71 nests on the plains of Colorado, 69% were in trees, 11.3% on erosional remnants, 5.6% on the ground, 5.6% on cliffs, 5.6% on creek banks, and 2.9% on manmade structures (Olendorff 1973). Most ferruginous hawk nesting studies indicate a preference for tree nests (Olendorff 1973; Powers et al. 1973; Smith and Murphy 1973; Howard 1975; Lokemoen and Duebbert 1976; Thurow et al. 1980). Despite the abundance of potential ground nest sites (Call 1979), the ferruginous hawk is vulnerable to tree removal management practices (Platt 1971; Howard 1975; Woffinden 1975; Murphy 1978; Call 1979). Peripheral trees should be left throughout the treatment area during tree removal and chaining operations to provide nest sites (Howard and Wolfe 1976). Tree nests provide protection from ground predators (Fitzner et al. 1977) and shade for nestlings (Tomback and Murphy 1981).

Ground nests in southern Idaho and northern Utah were constructed in areas of rangeland where no suitable nest trees were available (Thurow et al. 1980). They were usually located near a small hill. Typical nest locations of ferruginous hawks in pristine North Dakota prairies were on the ground, usually on hilltops (Rolfe 1896 cited by Lokemoen and Duebbert 1976). Knolls were preferred nesting sites in Utah and were heavily utilized (Smith and Murphy 1973). Ground nests in South Dakota were always located in prairies with tall herbaceous cover or prairies that were in a lightly grazed condition (Lokemoen and Duebbert 1976).

Ferruginous hawks accept both modified and completely artificial nest structures (Call 1979). Use of manmade structures for nesting appears to occur most often when natural nesting substrates are scarce or unavailable, such as in deserts, grasslands, and areas with few shrubs or trees.

Juniper (*Juniperus* spp.) is most commonly used for tree nesting, but pine (*Pinus* spp.), willow (*Salix* spp.) (Williams and Matteson 1947), cottonwoods (*Populus* spp.) (Olendorff 1973), and sagebrush (Smith and Murphy 1973) have been used. The nest may be located as high as 12 m (40 ft) from the ground (Call 1978), but is usually 2 to 3 m (6 to 10 ft) from the ground (Weston 1969). Steep-sided canyons and pinyon-juniper woodland interiors were usually avoided as nesting areas in Utah, probably due to the low abundance of lagomorphs (Smith and Murphy 1973). Tree nests were located in cropland in South Dakota, but were always close to undisturbed prairie (Lokemoen and Duebbert 1976). Olendorff (1973) contends that cultivation is detrimental to ferruginous hawk nesting populations.

Interspersion

The juniper-sagebrush ecotone is commonly used habitat by the ferruginous hawk in the semi-arid Western United States (Powers et al. 1973; Smith and Murphy 1973; Thurow et al. 1980). Wooded foothills interspersed with valleys and large desert expanses provide optimal nesting sites because of the combination of human inaccessibility, remoteness, and ease of surveillance of the surrounding area (Smith and Murphy 1973). While most nests were constructed in junipers and the perimeters of the valley foothills, home ranges extended into the desert, the principal hunting area of the ferruginous hawk.

Ferruginous hawks generally nest within a short distance of their food supply (Smith and Murphy 1973). Average territory size of ferruginous hawks is 2.6 to 7.7 km^2 (1 to 3 mi^2), with a diameter of 1.6 to 4 km (1 to 2.5 mi) (Call 1978). Hunting forays of nine adults on the Utah-Idaho border were usually less than 0.8 km (0.5 mi) from the nest site, but extended up to 1.9 km (1.2 mi) (Howard and Wolfe 1976). Home range diameters averaged from 3.2 to 3.4 km (2 to 2.1 mi), with minimum and maximum diameters of 2.4 km (1.5 mi) and 4.2 km (2.6 mi), respectively.

Special Considerations

The ferruginous hawk is sensitive to human disturbance and, consequently, is prone to nest desertion (Olendorff and Stoddart 1974; Fyfe and Olendorff 1976; Woffinden and Murphy 1977). Human disturbance and habitat alteration are the two factors considered most responsible for the decline of the ferruginous hawk throughout its range (Thurow et al. 1980).

Due to their sensitivity to human disturbance, ferruginous hawks rarely nest near well traveled roads or extensive cultivation (Weston and Ellis 1968; Olendorff 1973). They avoid pure grassland areas with no trees. The problem of damage to isolated trees by animals seeking shade and rubbing posts can be alleviated by erecting artificial nest structures and protecting trees by constructing fenced enclosures.

Vegetation management for ferruginous hawks should emphasize maximizing the amount of edge and interspersion (Howard and Wolfe 1976). Where crested wheatgrass plantings are planned, a minimum of 20% of the area should be left in scattered islands of shrubby vegetation.

The ferruginous hawk has been on the Blue List of declining birds for the last 10 years (Tate 1981). The presence of the ferruginous hawk on this list has been attributed to its intolerance of disturbances during the breeding season and habitat loss through overgrazing and conversion of feeding areas to agricultural use.

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. This model was developed for the area encompassing the principal breeding range of the species. This area, which is north of Arizona

and New Mexico, is semi-arid land classified by Bailey (1978) as the dry domain.

Season. This model will produce HSI values based upon breeding habitat needs for the ferruginous hawk.

Cover types. The ferruginous hawk, like most raptors, is opportunistic and utilizes several cover types. Some cover types are more suitable than others, but all of the following are utilized to some degree: Grassland (G); Pasture and Hayland (P/H); Forbland (F); Cropland (C); Desertic Woodland (DeW); Desertic Shrubland (DeS); Desertic Herbland (DeH); Evergreen Shrubland (ES); Deciduous Shrubland (DS); Evergreen Shrub Savanna (ESS); Deciduous Shrub Savanna (DSS) (U.S. Fish and Wildlife Service 1981).

Mountainous areas and the interior of forested areas are not used by the ferruginous hawk. Although forested areas are not considered as a useable cover type, ferruginous hawks will nest in trees and large shrubs along the edge of forests and wooded areas that are adjacent to "open" areas.

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous suitable habitat that is required before an area will be occupied by a particular species. This information was not found in the literature for the ferruginous hawk. If local information is available to define the minimum habitat area, and less than this amount of area is available, the HSI for the species will be zero.

Verification level. This model was critiqued by Joseph R. Murphy, Ph.D., Brigham Young University, and Richard P. Howard, U.S. Fish and Wildlife Service. Murphy concluded that this model is as reasonable as can be expected, given the fact that field tests have not been completed (Murphy, pers. comm). Howard concluded that this model accurately reflects the biological realities of the ferruginous hawk, contains reasonable assumptions, and displays a mathematical index which is flexible enough to subtract or add variables for more precise adjustments (Howard, pers. comm). Comments from both reviewers have been incorporated into the current model.

Model Description

Overview. The HSI model for the ferruginous hawk considers the quality of the life requisites in each cover type and interspersion of life requisites when the habitat is composed of two or more cover types. Figure 1 illustrates how the HSI is related to cover types, life requisites, and specific habitat variables. Food and reproduction needs of the ferruginous hawk are considered in this model. It is assumed that water and cover resources will never be more limiting than food and reproduction.

In the following life requisite sections, the rationale for developing the model is presented. Specifically, these sections cover the following: (1) identification of variables used in the model; (2) definition and justification of the suitability levels of each variable; and (3) description of the assumed relationships between variables.

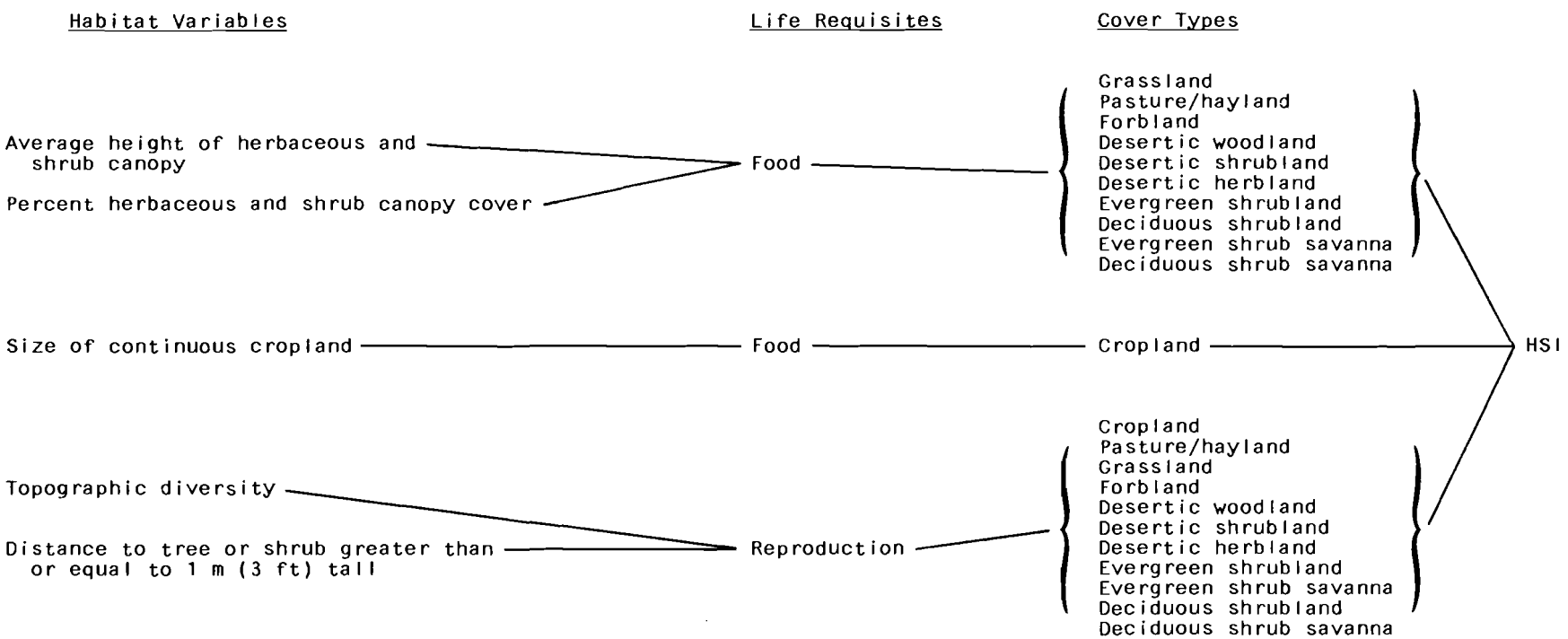


Figure 1. Relationships of habitat variables, life requisites, and cover types in the ferruginous hawk model.

Food component. Food suitability for the ferruginous hawk is related to the availability of suitable prey. This relationship is based on the premise that optimum conditions for prey do not necessarily reflect optimum conditions for the predator. For this reason, coupled with the fact that the ferruginous hawk hunts several prey species, a general approach to modeling food suitability for this raptor is presented. Food suitability in all cover types other than cropland is determined by assessing both the abundance and accessibility of prey, as determined by the height and density of the vegetation.

The abundance of major prey species is assumed to be related to the volume and structure of both herbaceous and shrub vegetation. The accessibility of prey is related to the level of concealment provided for prey by the vegetation and the degree of access by the hawk to all huntable areas. Food suitability for the ferruginous hawk is optimum when the vegetation occurs at a mix of heights and densities which optimizes prey abundance and minimizes hunting interference.

It is also assumed that very dense, tall vegetation will provide abundant prey, but very poor accessibility for the ferruginous hawk. Vegetation that is low and very dense will provide lower levels of prey abundance but increased accessibility. For this model, it is assumed that optimum vegetation heights occur when the average height of herbaceous and shrub vegetation is between 15 and 60 cm (6 and 24 in). It is further assumed that suitability will decrease as average vegetation heights approach both 0 and 120 cm (0 and 48 in).

Optimum food suitabilities are assumed to occur at different combinations of average vegetative heights and densities (Fig. 2). Habitats with average vegetative heights of 15 cm (6 in) will provide optimum food when vegetative densities approach 100% canopy cover. Habitats with vegetation heights increasing to 60 cm (24 in) will provide optimum food at successively lower densities, down to an average canopy closure of 60%. Vegetative densities less than 60% canopy closure will always be less than optimum.

A major assumption of this model is that the average vegetative height and density conditions in a particular habitat actually reflect a mix of individual heights and densities, and not a uniform, homogeneous condition. Optimum prey abundance and accessibility are assumed to occur in this mixed, or more structurally diverse, conditon. The average condition is more readily measured or estimated in the field, and hence is the variable included in this model.

Food suitability in cropland cover types is related to the size of each contiguous unit of cropland. Prey species often use croplands as a food source, provided that adequate cover is nearby. It is assumed that prey abundance will decrease as the cropland size increases, due to the decreasing amount of nearby cover in larger cropland fields. Small croplands [less than 16 ha (40 ac)] are assumed to provide the best conditions, while croplands larger than 128 ha (316 ac) are assumed to be of very low suitabilities. Due to the frequency of disturbance and cultivation, croplands in the best condition are assumed to be only half as valuable as noncroplands in the best condition.

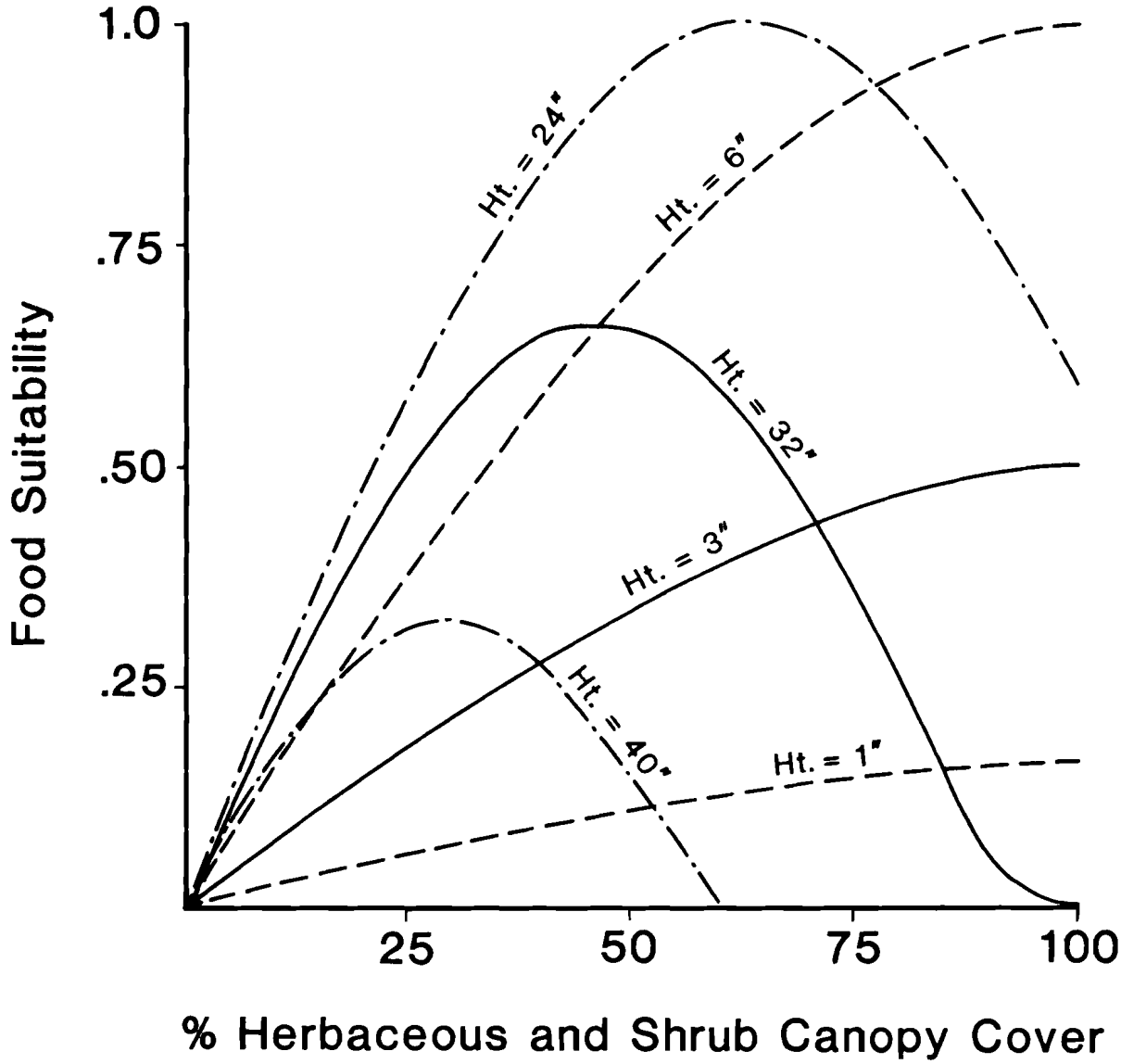


Figure 2. The relationship of percent of vegetative canopy cover and vegetative height, to food suitability for the ferruginous hawk. Individual curves show the change in suitability for the particular height class indicated on the curve.

Reproduction component. Reproductive suitability for the ferruginous hawk is related to the availability of nesting sites. It is assumed that the availability of suitable nest sites can be adequately assessed by measuring the suitability of potential ground nesting sites and the abundance of trees and large shrubs.

The availability of trees or large shrubs is considered to be the most important factor for nesting. It is assumed that the presence of a tree or large shrub within a distance of 1.6 km (1.0 mi) of random sample points will provide optimum nesting conditions, whereas the lack of shrubs or trees within 4.8 km (3.0 mi) will not contribute any value to reproductive requirements. Shrubs ≥ 1 m (3.3 ft) in height are considered large enough to support the large bulky nest of the ferruginous hawk.

Suitability of ground nests is assumed to be related to topography. Ferruginous hawks appear to favor elevated sites for nesting, be it ground, cliff, or tree nests. Ground nests described in the literature were usually associated with rolling terrain, where nests could be situated on hills, knolls, or rims. Areas that are flat, with no breaks in topography to provide ground nest sites, will not be suitable unless trees or shrubs are present. Mountainous areas with slopes exceeding 25% are assumed to be unsuitable for ferruginous hawks regardless of the presence of trees or shrubs. Areas with rolling terrain provide optimum ground nest sites, however, it is assumed that the best ground nest sites will only provide one-half the suitability of the best conditions for tree or shrub nests.

Overall reproductive value is assumed to be equal to the combined suitabilities of the variables for topography, and shrubs and trees.

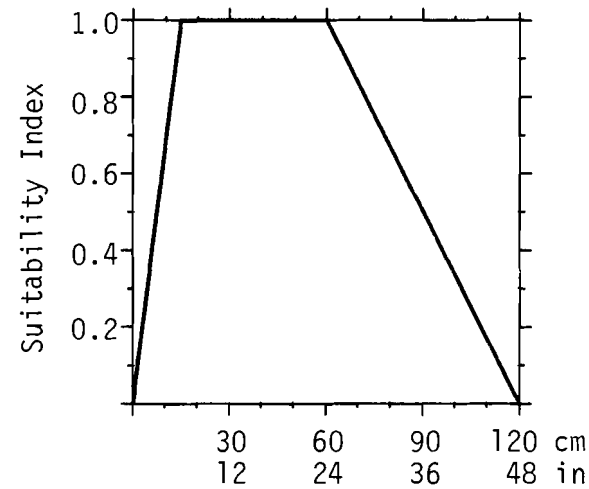
Special habitat component. Ferruginous hawks are highly sensitive to human disturbance during the nesting season. Habitat alteration due to agricultural development and direct human disturbance are the two factors believed to be most responsible for the decline of the ferruginous hawk throughout its range. It is difficult to accurately quantify the effects of human disturbance. Habitat evaluations for the ferruginous hawk should take into account the nature, length, location, and season of any human disturbances. Overall habitat quality values will be lower in areas where significant human disturbances are likely to occur.

Interspersion component. It is assumed that the best habitat for the ferruginous hawk contains high quality food over 75% of the habitat. This estimate is based on data that indicate that ferruginous hawks generally hunt over large portions of their home range. High quality food is not required over 100% of the area because the effective hunting range is usually smaller than the home range, i.e., hunting activities are concentrated in areas where prey capture rates are highest.

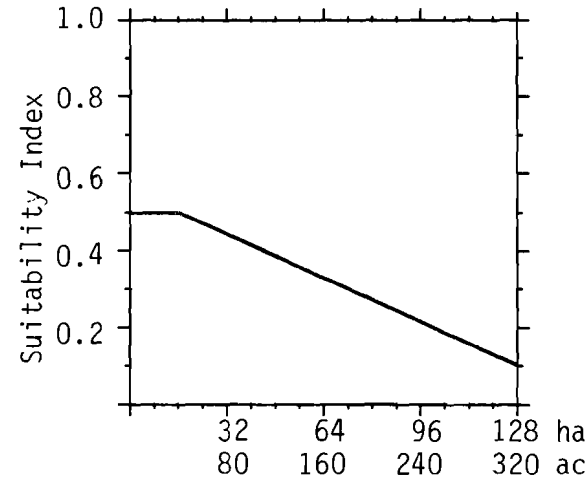
Interspersion of nesting sites is addressed in the variable for distance to a tree or shrub and subjectively considered in the topographic variable. Low reproduction values will thus indicate a poor interspersion of nest sites and indicate that effectively less of the habitat is useable by the ferruginous hawk.

Model Relationships

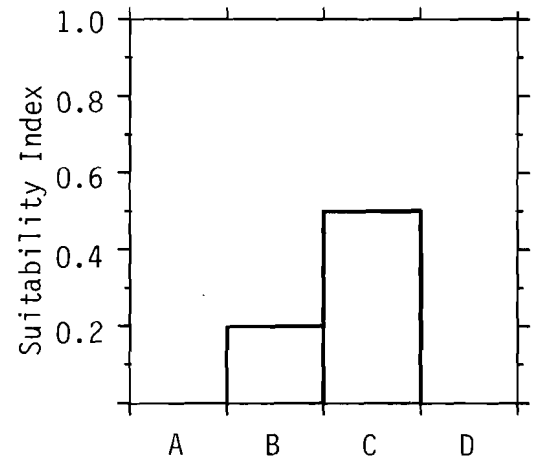
Suitability Index (SI) graphs for habitat variables. This section contains suitability index graphs that illustrate the habitat relationships described in the previous section.

Cover type	Variable		
G,P/H,F,DeW, DeS,DeH, ES,DS, ESS,DSS	(V_1)	Average height of herbaceous and shrub canopy (summer).	
G,P/H,F,DeW, DeS,DeH, ES,DS, ESS,DSS	(V_2)	Percent herbaceous and shrub canopy cover.	Note: No SI graph is needed. The actual percent of cover should be incorporated into the proper equation in Figure 3.

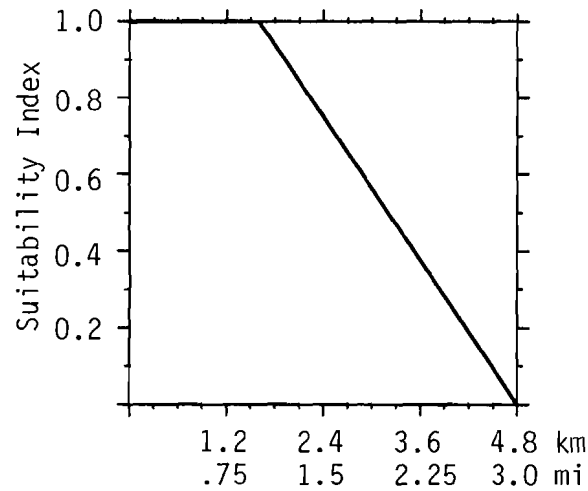
C	(V_3)	Size of continuous cropland.



C,P/H,G, F,DeW,DeS, DeH,ES,DS, ESS,DSS	(V_4)	Topographic diversity. A) Flat terrain, no hills or breaks in topography B) Generally flat terrain, with scattered hills or breaks in topography C) Rolling terrain with frequent breaks in topography D) Mountainous terrain, > 25% slope

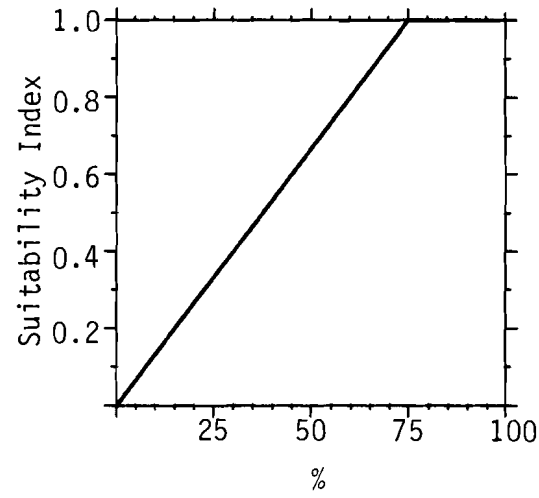


C,P/H,G, F,DeW,DeS, DeH,ES,DS, ESS,DSS	(V_5)	Distance to tree or shrub ≥ 1 m (3.3 ft) tall.



Suitability Index (SI) graphs for interspersion variables. This section contains curves used in computing the overall life requisite value for food.

Cover type	Variable	
C,P/H,G, F,DeW,DeS, DeH,ES,DS, ESS,DSS	(V_6)	Percent area in equivalent optimum food.



Equations. In order to determine life requisite values for the ferruginous hawk, the SI values for appropriate variables must be combined through the use of equations. A discussion and explanation of the assumed relationships between variables was included under Model Description, and the specific equations in this model were chosen to mimic these perceived biological relationships as closely as possible. The suggested equations for obtaining life requisite values are presented in Figure 3.

HSI determination. Determination of an HSI for a multicover type user involves consideration of both habitat variables and interspersion variables. Several steps and calculations are necessary in order to properly determine an HSI score. They are as follows:

1. Compute the food and reproduction values for each cover type by collecting field data for each variable by cover type and entering this data into the proper suitability index curve. The resulting index values are used in the appropriate life requisite equations.

Life requisite	Cover types	Equation
Food	G,P/H,F,DeW,DeS, DeH,ES,DS,ESS,DSS	$\text{Food} = V_1 \times \text{SIN} \dfrac{360 \times (P1 \times CC\%)}{400 \times [P1-(HT-P2)]}$ for values of $\dfrac{P1 \times CC\%}{P1-(HT-P2)} \leq 200$ Food = 0.0 for values of $\dfrac{P1 \times CC\%}{P1-(HT-P2)} > 200$ Where: V_1 = SI value from graph for V_1 CC% = % herbaceous and shrub canopy cover HT = Average height of herbaceous and shrub vegetation P1 = Height of vegetation above which food value is zero for any value of canopy closure [= 120 cm (48 in) for this model, SI of 0.0 on graph for V_1]. P2 = Height of vegetation at which optimum food values occur at 100% canopy cover [= 15 cm(6 in) for this model, SI of 1.0 on graph for V_1].
Food	C	V_3
Reproduction	C,P/H,G,F, DeW,DeS,DeH, ES,DS,ESS,DSS	$\min(1, V_4 + V_5)$ <u>Note</u>: See Special Habitat Component discussion on p. 9 for effects of human disturbance.

Figure 3. Equations to determine life requisite values by cover type for the ferruginous hawk.

2. Determine the relative area (%) of each cover type within the study area as follows:

$$\text{Relative area (\%) for cover type A} = \frac{\text{Area of cover type A}}{\text{Total area of all cover types used by the species}} \times 100$$

Be certain that you consider only those cover types used by the species in determining this percentage.

3. Determine the percent of the area in the equivalent of optimum food by multiplying the food value for each cover type by the relative area (%) of that cover type. Sum these values, and enter this percent into the food composition suitability graph (V_6) to obtain an overall food index.

4. Multiply the reproduction value in each cover type by the relative area (%) of that cover type and sum these values to obtain an overall reproduction index. This index value accounts for the interspersion of nest sites. A low reproduction value will indicate poor interspersion of nest sites and will mean that effectively less of the total habitat is useable by the ferruginous hawk.

5. The HSI is determined by multiplying the food index by the reproduction index. This will take into account the quality, quantity, and distribution of the food and reproduction life requisites.

Application of the Model

If it is desirable to decrease the cost and amount of time necessary to apply this model, it is recommended that the reproductive value be estimated or assumed to be not limiting. This recommendation is based on the following two reasons. First, it is assumed that reproductive value is easier and more accurately estimated using subjective methods than is food value. The variables used to measure food value are more indirect than those used to measure reproductive value, which reflects the tangible nature of nest site characteristics and the difficulties involved with measuring prey abundance and prey accessibility. Second, it is assumed that food will usually be more limiting than reproduction because the ferruginous hawk is such a versatile nester.

Definitions of variables and suggested field measurement techniques (Hays et al. 1981) are provided in Figure 4.

Variable (definition)		Cover types	Suggested technique
(V_1)	Average height of herbaceous and shrub canopy (summer) (the average height from the ground surface to the dominant height stratum of the vegetative canopy).	G,P/H,F,DeW,DeS, DeH,ES,DS,ESS, DSS	Line intercept and graduated rod
(V_2)	Percent herbaceous and shrub canopy cover (the percent of the ground surface that is shaded by a vertical projection of herbaceous and shrub vegetation).	G,P/H,F,DeW,DeS, DeH,ES,DS,ESS, DSS	Line intercept and Daubenmire plot
(V_3)	Size of continuous cropland (the average size of each contiguous block of cropland)	C	Aerial photograph and dot grid
(V_4)	Topographic diversity (the most prevalent and characteristic topographic feature present).	C,P/H,G,F,DeW, DeS,DeH,ES,DS, ESS,DSS	Ocular estimate or aerial photograph
(V_5)	Distance to tree or shrub ≥ 1 m (3.3 ft) tall (the distance from random points to the nearest tree or shrub, including the edge of shrub or forested cover types).	C,P/H,G,F,DeW, DeS,DeH,ES,DS, ESS,DSS	Aerial photograph, dot grid

Figure 4. Definitions of variables and suggested measurement techniques.

SOURCES OF OTHER MODELS

No other habitat models for the ferruginous hawk were located.

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16. Abstract (Limit: 200 words)

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

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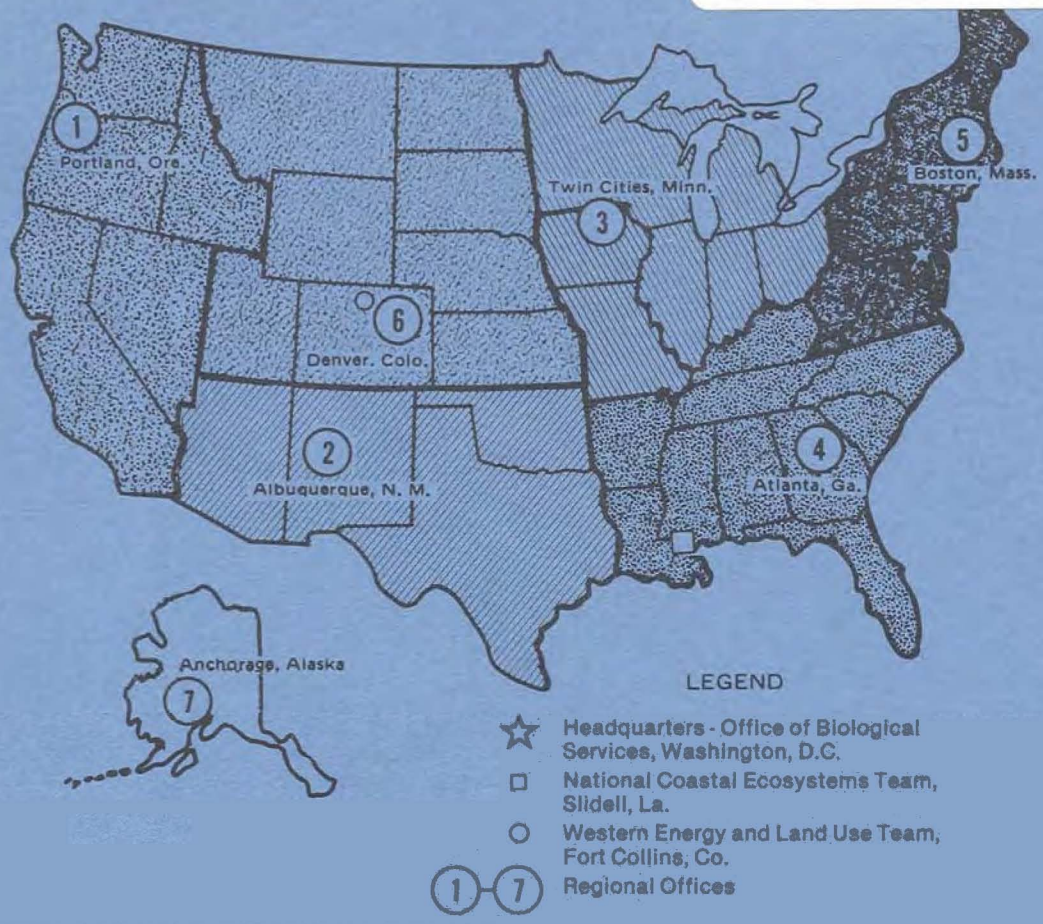

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