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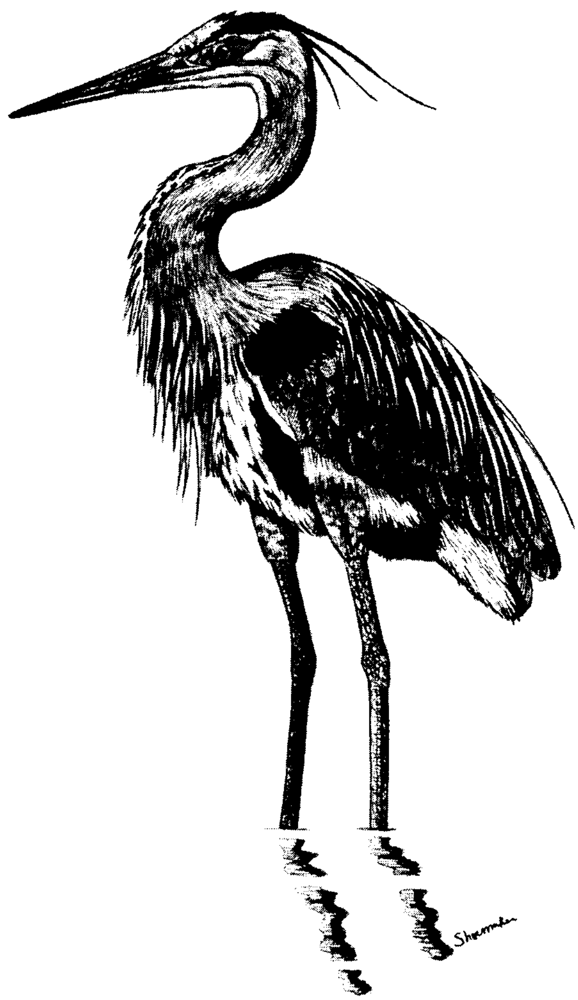

Fish and Wildlife Service

U.S. Department of the Interior

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HABITAT SUITABILITY INDEX MODELS: GREAT BLUE HERON

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is a formalized synthesis of biological and habitat information published in the scientific literature and may include unpublished information reflecting the opinions of identified experts.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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We gratefully acknowledge Drs. Charles J. Henny, U.S. Fish and Wildlife Service, Corvallis, OR, and Jeffrey A. Spendelow and R. Michael Erwin, U.S. Fish and Wildlife Service, Laurel, MD, for their critical reviews of this great blue heron model. Word processing was provided by Carolyn Gulzow, Dora Ibarra, and Elizabeth Graf. Cathy Short edited the manuscript. The cover was illustrated by Jennifer Shoemaker.

GREAT BLUE HERON (*Ardea herodias* L.)

HABITAT USE INFORMATION

General

The great blue heron is the largest, most widely distributed, and best known of the American herons (Henny 1972). Great blue herons occur in a variety of habitats from freshwater lakes and rivers to brackish marshes, lagoons, mangrove areas, and coastal wetlands (Spendelow and Patton in prep.). They breed (American Ornithologists' Union 1983:45-46):

> ...from south-coastal and southeastern Alaska (west to Prince William Sound), coastal and southern British Columbia, northern Alberta, southern Keewatin, central Manitoba, southern Ontario, southern Quebec, New Brunswick, Prince Edward Island and Nova Scotia south, at least locally, throughout the United States and much of Mexico to Guerrero, Veracruz, the Gulf coast and interior southern Florida, also in the Galapagos Islands; ... [They winter] from south-coastal and southeastern Alaska, the coasts of British Columbia and Washington, central Oregon, southern Idaho, western Montana, northern Wyoming, central Nebraska, central Missouri, the Ohio Valley, southern Ontario and the southern New England coast south throughout the southern United States, Middle America, Bermuda and the West Indies to northern Colombia, northern Venezuela, western Ecuador and the Galapagos Islands...

Food

Great blue herons feed anywhere they can locate prey (Burleigh 1958). This includes the terrestrial surface but primarily involves catching fish in shallow water, usually ≤ 50 cm deep (Bent 1926; Meyerriecks 1960; Bayer 1978). Thompson (1979b) reported that great blue herons along the Mississippi River commonly foraged in water containing emergent or submergent vegetation, in scattered marshy ponds, sloughs, and forested wetlands away from the main channel. He noted that riverbanks, jetties, levees, riprapped banks, mudflats, sandbars, and open ponds were used to a lesser extent. Herons near southwestern Lake Erie fed intensively in densely vegetated areas (Hoffman 1978).

Other studies, however, have emphasized foraging activities in open water (Longley 1960; Edison Electric Institute 1980). Exposed mud flats and sandbars are particularly desirable foraging sites at low tides in coastal areas in Oregon (Bayer 1978), North Carolina (Custer and Osborn 1978), and elsewhere (Kushlan 1978). Cooling ponds (Edison Electric Institute 1980) and dredge spoil settling ponds (Cooper et al. in prep.) also are used extensively by foraging great blue herons.

Feeding behavior includes standing in one place, probing, pecking, walking at slow speeds, moving quickly, flying short distances and alighting, hovering over water and picking up prey, diving headfirst into the water, alighting on water feet-first, jumping from perches feet-first, and swimming or floating on the surface of the water (Meyerriecks 1960; Dennis 1971; Kushlan 1976, 1978). Diving for fish in deep water has been observed occasionally but is considered to be unusual behavior for this species (Bent 1926; Dickinson 1947; Gordin 1977).

Fish are preferred food items of the great blue heron in both inland and coastal waters (Kirkpatrick 1940; Palmer 1962; Kelsall and Simpson 1980), although a large variety of dietary items has been recorded. Frogs and toads, tadpoles and newts, snakes, lizards, crocodilians, rodents and other mammals, birds, aquatic and land insects, crabs, crayfish, snails, freshwater and marine fish, and carrion have all been reported as dietary items for the great blue heron (Bent 1926; Roberts 1936; Martin et al. 1951; Krebs 1974; Kushlan 1978).

Great blue herons feed alone or occasionally in flocks. Solitary feeders may actively defend a much larger feeding territory than do feeders in a flock (Meyerriecks 1962; Kushlan 1978). Flock feeding may increase the likelihood of successful foraging (Krebs 1974; Kushlan 1978) and usually occurs in areas of high prey density where food resources cannot effectively be defended.

Social feeding is strongly correlated with colonial nesting (Krebs 1978), and a potential feeding site is valuable only if it is within "commuting" distance of an active heronry. The maximum observed flight distance from an active heronry to a foraging area was 29 km in Ohio (Parris and Grau 1979). Most flight distances from heronries to foraging areas along the Mississippi river were about 5 km although some distances extended up to 20.4 km (Thompson 1979b). Mathisen and Richards (1978) observed shorter flight distances in Minnesota, mostly within 4.0 km.

Individuals or groups of herons leaving a colony may be oriented toward food resources by other individuals or groups returning to the heronry after feeding (Krebs 1974; DesGranges 1979; Parris and Grau 1979; Rodgers and Nesbitt 1980). This behavior may enhance the ability of herons to optimize foraging on shifting food resources (Ward and Zahavi 1973).

Water

The great blue heron routinely feeds on soft animal tissues from an aquatic environment, which provides ample opportunity for the bird to satisfy its physiological requirements for water.

Cover

Cover for concealment does not seem to be a limiting factor for the great blue heron. Heron nests often are conspicuous, although heronries frequently are isolated. Herons often feed in marshes and areas of open water, where there is no concealing cover.

Reproduction

A wide variety of nesting habitats is used by the great blue heron throughout its range in North America. Trees are preferred heronry sites, with nests commonly placed from 5 to 15 m above ground (Burleigh 1958; Cottrille and Cottrille 1958; Vermeer 1969; McAloney 1973). Smaller trees, shrubs, reeds (*Phragmites communis*), the ground surface, rock ledges along coastal cliffs, and artificial structures may be utilized in the absence of large trees, particularly on islands (Lahrman 1957; Behle 1958; Vermeer 1969; Soots and Landin 1978; Wiese 1978). Most great blue heron colonies along the Atlantic coast are located in riparian swamps (Ogden 1978). Most colonies along the northern Gulf coast are in cypress - tupelo (*Taxodium* - *Nyssa*) swamps (Portnoy 1977). Spendelow and Patton (in prep.) state that many birds in coastal Maine nest on spruce (*Picea* spp.) trees on islands. Spruce trees also are used on the Pacific coast (Bayer 1978), and black cottonwood (*Populus trichocarpa*) trees frequently are used as nest sites along the Willamette River in Oregon (English 1978). Miller (1943) stated that the type of tree was not as important as its height and distance from human activity. Dead trees are commonly used as nest sites (McAloney 1973). Nests usually consist of a platform of sticks, sometimes lined with smaller twigs (Bent 1926; McAloney 1973), reed stems (Roberts 1936), and grasses (Cottrille and Cottrille 1958).

A variety of wading birds may occupy a heronry along with great blue herons (Giles and Marshall 1954; Kushlan and White 1977; Burger 1978; Wiese 1978). For example, great blue heron, little blue heron (*Egretta caerulea*), cattle egret (*Bubulcus ibis*), great egret (*Casmerodius albus*), snowy egret (*Egretta thula*), tricolored heron (*Egretta tricolor*), black-crowned night-heron (*Nycticorax nycticorax*), and glossy ibis (*Plegadis falcinellus*) were present in 30 or more colonies along the Atlantic coast (Custer et al. 1980). The number of breeding herons and species per colony was significantly correlated in consecutive years in these colonies (Custer et al. 1980).

Heron nest colony sites vary, but are usually near water. Wooded sites are used in mainland areas (Vermeer 1969). These areas often are flooded (Sprunt 1954; Burleigh 1958; English 1978). Islands are common nest colony sites in most of the great blue heron's range (Vermeer 1969; English 1978; Markham and Brechtel 1979). Many colony sites are isolated from human habitation and disturbance (Mosely 1936; Burleigh 1958). Mathisen and Richards (1978) recorded all existing heronries in Minnesota as at least 3.3 km from human dwellings, with an average distance of 1.3 km to the nearest surfaced road. Nesting great blue herons may become habituated to noise (Grubb 1979), traffic (Anderson 1978), and other human activity (Kelsall and Simpson 1980).

Heron nest colony sites are largely traditional, although the interchange of individual herons between heronries is common (Kelsall and Simpson 1980). Colony sites usually remain active until the site is disrupted by land use changes. A few colony sites have been abandoned because the birds depleted the available nest building material and possibly because their excrement altered the chemical composition of the soil and the water. Heron excretia can have an adverse effect on nest trees (Kerns and Howe 1967; Wiese 1978).

Heronries often are abandoned as a result of human disturbance (Markham and Brechtel 1979). Werschkul et al. (1976) reported more active nests in undisturbed areas than in areas that were being logged. Tree cutting and draining resulted in the abandonment of a mixed-species heronry in Illinois (Bjorkland 1975). Housing and industrial development (Simpson and Kelsall 1979) and water recreation and highway construction (Ryder et al. 1980) also have resulted in the abandonment of heronries. Grubb (1979) felt that airport noise levels could potentially disturb a heronry during the breeding season.

Special Considerations

Human disturbance, habitat destruction, and the resulting loss of nesting and foraging sites probably have been the most important factors contributing to declines in some great blue heron populations in recent years (Thompson 1979a; Kelsall and Simpson 1980; McCrimmon 1981). Pesticide and heavy metal contamination also may be a factor. Several authors have observed eggshell thinning in great blue heron eggs, presumably as a result of the ingestion of prey containing high levels of organochlorines (Graber et al. 1978; Ohlendorf et al. 1980). Konermann et al. (1978) blamed high levels of dieldrin and DDE use for reproductive failure, followed by colony abandonment in Iowa. Vermeer and Reynolds (1970) recorded high levels of DDE in great blue herons in the prairie provinces of Canada, but felt that reproductive success was not diminished as a result. Thompson (1979a) believed that it was too early to tell if organochlorine residues were contributing to heron population declines in the Great Lakes region.

Loss of nesting habitat in certain coastal sites may be partially mitigated by the creation of dredge spoil islands (Soots and Landin 1978). Several species of wading birds, including the great blue heron, use coastal spoil islands (Buckley and McCaffrey 1978; Parnell and Soots 1978; Soots and Landin 1978). The amount of usage may depend on the stage of plant succession (Soots and Parnell 1975; Parnell and Soots 1978), although great blue herons have been observed nesting in shrubs (Wiese 1978), herbaceous vegetation (Soots and Landin 1978), and on the ground on spoil islands.

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. This model is designed to evaluate treeland habitats near water as potential heronry sites and aquatic habitats near potential heronry sites as foraging habitats. Habitat criteria included in the model are general, and the model may be applicable throughout the United States.

Season. The model is intended for use in habitat evaluations throughout the spring-summer breeding period.

Cover types. The model was developed to evaluate herbaceous wetland, shrub wetland, forested wetland, riverine, lacustrine, and estuarine habitats (U.S. Fish and Wildlife Service 1981) as foraging habitats and forested wetlands as nesting habitat for the great blue heron.

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous habitat that is required before a species will live and reproduce in an area. Minimum habitat area for the great blue heron includes wooded areas suitable for colonial nesting and wetlands within a specified distance of a heronry where foraging can occur. A heronry frequently consists of a relatively small area of suitable habitat. For example, heronries in the Chippewa National Forest, Minnesota, ranged from 0.4 to 4.8 ha in size and averaged 1.2 ha (Mathisen and Richards 1978). Twelve heronries in western Oregon ranged from 0.12 to 1.2 ha in size and averaged 0.4 ha (Werschkul et al. 1977). Only groves of trees ≥ 0.4 ha in area are evaluated as potential heronry sites in this HSI model.

Verification level. This model was developed from descriptive information in the literature and describes the potential of an area as breeding, foraging, or breeding-foraging habitat for the great blue heron. The model is intended to rank the quality of potential heronry sites and foraging habitats in the same way as would an expert who was thoroughly familiar with the reproductive and foraging requirements of the species. The model should not be expected to rank habitats in the same way as population data because many other habitat and nonhabitat factors can affect the population and biomass of a wildlife species.

Model Description

Overview. This HSI model is intended to evaluate areas that potentially can be used as foraging habitat or nest sites by the great blue heron. This HSI model evaluates only suitable aquatic areas as foraging sites even though the great blue heron sometimes feeds in upland sites. The variables used to evaluate a potential foraging site include the presence of suitable forage fish, water conditions suitable for the foraging activity of this wading bird, and the likelihood that the aquatic habitat will be free from human disturbance during the reproductive season or while the bird is in residency. The model only evaluates the quality of treeland habitats near water as potential nest sites, even though great blue herons occasionally nest on artificial structures, the ground, cliffs, and in shrubs and young trees. The variables used to evaluate the reproductive potential of an area include the presence of suitable treeland habitats, the likelihood that these habitats will be free from human disturbance during the reproductive season, and the distance between the treeland habitats and active heronries and between treeland habitats and foraging sites. The assumptions used to develop these variables are listed below and summarized later in the Assumptions Section. The logic for this species-habitat model is presented in Figure 1.

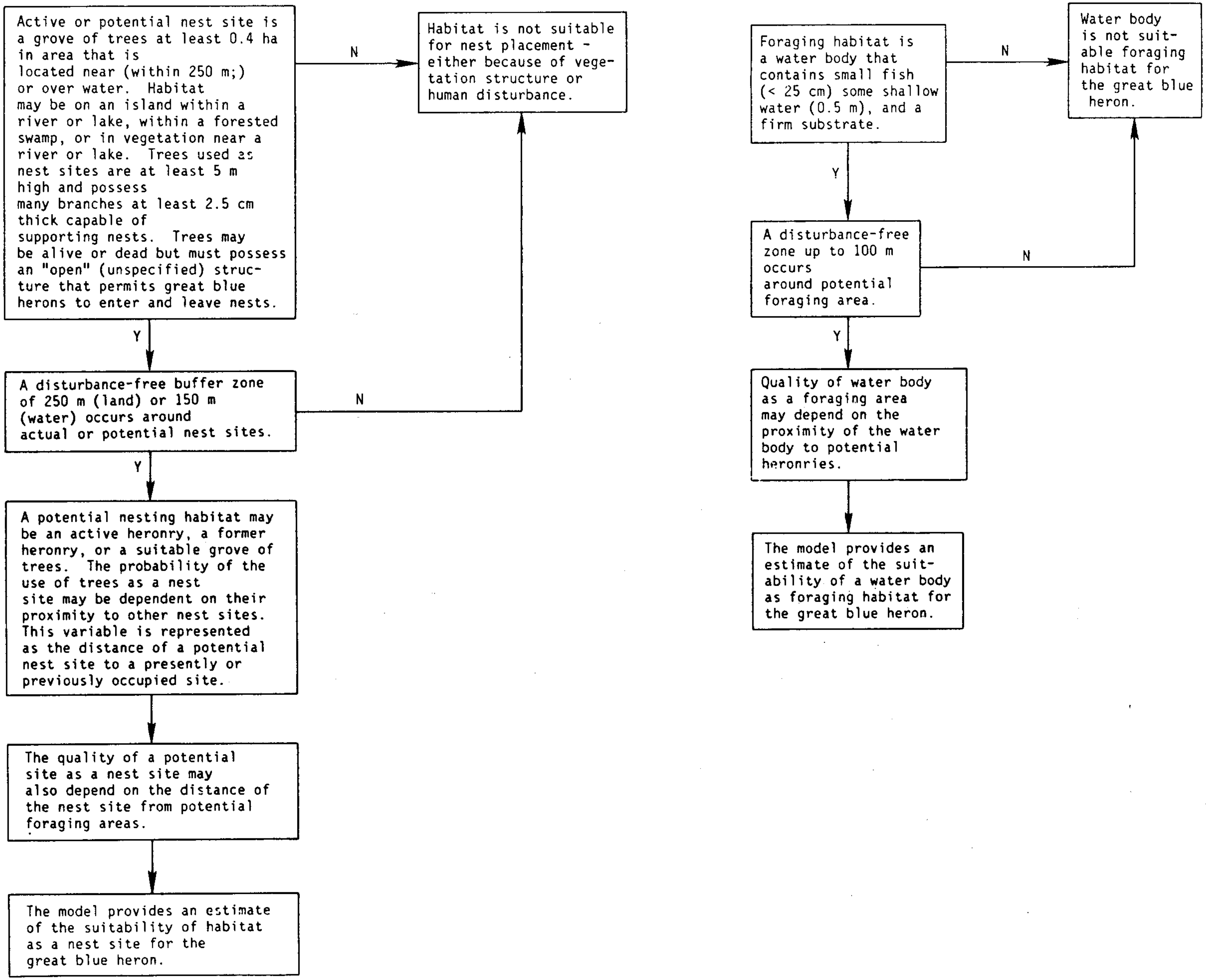

Figure 1. Logic used to develop the model describing the quality of nesting and foraging habitat for the great blue heron.

Potential feeding areas for great blue herons include streams, ditches, lakes, coastal flats, herbaceous wetlands, swamps, estuaries, and similar areas that contain fish, have suitable foraging substrates, and are within a specified distance of an actual or potential heronry. Feeding sites must be in areas with little human disturbance. Wetlands vary in terms of the fish biomass they support, which could limit the size of nearby heron colonies. Suitable bodies of water with large populations of fish logically can be assumed to support a larger heronry than would suitable water bodies with small populations of fish. The relationship, however, between the size of the heronry and the size of the available prey base, expressed either in terms of fish biomass or area of the water body, is not well established in the literature. The number of active nests in 11 heron colonies (data from Werschkul et al. 1977) was significantly related to the area of the nearest estuary in ha (x) ($Y = 33.2 + 0.017x$; $r = 0.74$). Much of the significance of this relationship, however, was due to one very large heron colony situated near one very large estuary along the Oregon Coast. Consequently, size of foraging area is a descriptive variable, rather than a quantitative variable, in the model. The model does not cite any minimum size for foraging habitats for the great blue heron.

Heronry sites in this model are presumed to be groves of trees, at least 0.4 ha in area. These trees can be alive or dead but need to have sturdy limbs for nest placement and an open canopy or exposed limbs so herons can readily enter and leave their nests. The grove of trees also must be free from human disturbances. Nests usually are placed within a short horizontal distance of water but we found no specific information in the literature about this distance. We arbitrarily chose 250 m as representing "closeness to water"; groves of trees have to be at least 0.4 ha in area and within 250 m of permanent water to be considered as a potential nest site in this model.

The size of a grove of trees is not a model variable. Werschkul et al. (1977) listed data about the area and number of active nests within a heron nest colony but there was only a small negative correlation ($r = -0.15$) associating these two variables. The height of individual trees is not a variable in this model, although tree height was considered in a regression predicting the number of active nests in a nest colony on the basis of the size of the nearest estuary and average tree height within the heron nest colony (Werschkul et al. 1977). Average tree height only added 3% to the r^2 value ($r^2 = 0.58$ to $r^2 = 0.55$) for the simple correlation between the number of active nests and the size of the nearest estuary. We assumed that herons select an "adequate tree structure" for nest placement, rather than a particular tree height or species. Reports of great blue herons successfully nesting on wooden platforms attached to power poles (e.g., Meier 1981) seem supportive of this hypothesis.

The following sections document the logic and assumptions used to translate habitat information for the great blue heron into the variables selected for the HSI model. Specifically, these sections describe the assumptions inherent in the model, define and justify the suitability level of each variable, and describe the assumed relationships between variables.

Food component. Aquatic habitats are evaluated as foraging sites in this HSI model.

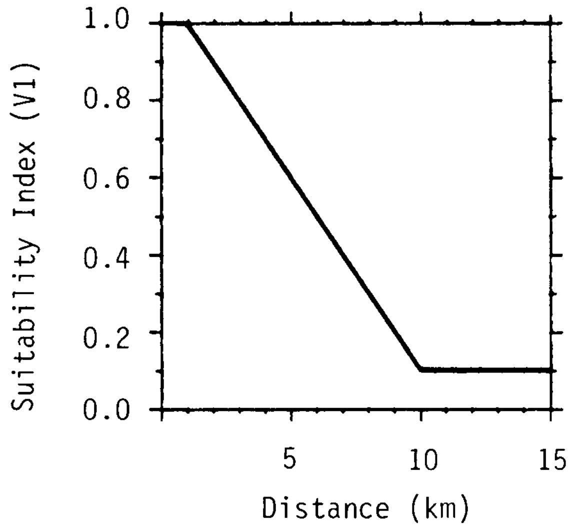

Figure 2. Distance between foraging areas and heronry sites modifies SI values.

The distance between foraging areas and potential heronries is Variable 1 (V1) in the model. A SI of 1.0 is given if foraging habitats are within 1.0 km of heronries or potential heronries. The increased energy expenditure associated with longer foraging flights is reflected by a lower SI. Distances $\geq$ 10 km between foraging sites and nest sites are given a SI of 0.1.

The usual foraging behavior of great blue herons is successful only in shallow (up to 0.5 m deep), clear water with a firm substrate and a huntable population of small fish ($\leq$ 25 cm in length). Fish up to about 20 cm in length dominated the diet of herons foraging in southwestern Lake Erie (Hoffman 1978). Ninety-five percent of the fish eaten in a Wisconsin study were $\leq$ 25 cm in length (Kirkpatrick 1940). Variable 2 in the model estimates the suitability of herbaceous wetland, shrub wetland, forested wetland, riverine, lacustrine, or estuarine habitats as foraging areas for the great blue heron.

V2 = 1.0 if potential foraging habitats usually have shallow, clear water with a firm substrate and a huntable population of small fish.

V2 = 0.0 if potential foraging habitats usually do not provide the desirable combination of conditions.

A potential foraging area needs to be free from human disturbances several hours a day while the herons are feeding. This variable (V3) can be expressed either by stating that the potential foraging area is generally free from human disturbances during the 4 hours following sunrise or preceeding sunset or that a surrounding disturbance-free zone occurs. It is assumed in this model that a great blue heron tolerates human habitation and activities about 100 m from a foraging area and occasional, slow moving, vehicular traffic about 50 m from a foraging area.

V3 = 1.0 if there usually is no human disturbance near the potential foraging zone during the 4 hours following sunrise or preceding sunset or the foraging zone is generally about 100 m from human activities and habitation or about 50 m from roads with occasional, slow-moving traffic.

V3 = 0.0 if the above conditions are not usually met.

The multiplication of suitability indices for Variables 1-3 provides an estimate of the value of a variety of aquatic sites as foraging habitat for the great blue heron. The suggested equation for the foraging index (FI) is:

$$FI = (V1 \times V2 \times V3)$$

Reproductive component. Nest sites of the great blue heron are located most frequently in trees near or over water. This model evaluates habitats for nest sites if those habitats are within 250 m of water. Many authors have emphasized the close association of heronries with water, and there are few apparent parameters that effectively predict nest site placement in sites away from water. Upland sites away from lakes, swamps, rivers, coastal inlets, estuaries etc. are not evaluated with this model; this could be a major limitation of the model.

Variable 4 (V4) in the model defines a potential nest site as a grove of trees at least 0.4 ha in area located over water or within 250 m of water. These potential nest sites may be on an island within a river or lake, within a woodland dominated swamp, or in vegetation near a river or lake. Trees used as nest sites are at least 5 m high and have many branches at least 2.5 cm in diameter that are capable of supporting nests. Trees may be alive or dead but must have an "open canopy" that allows an easy access to the nest.

V4 = 1.0 if potential treeland habitats usually fulfill all of these conditions.

V4 = 0.0 if potential treeland habitats usually do not fulfill all of these conditions.

Variable 5 (V5) in the model pertains to levels of human disturbances around potential nest sites. The great blue heron is so sensitive to human disturbance that even a casual disturbance may impact successful reproduction. Werschkul et al. (1976) determined that heron nests within 148 m of a logging disturbance were inactive, while nests 219 m from the logging disturbance were active, although the herons were shifting their nesting activities away from the disturbance by constructing new nests on the distal side of the heronry.

Heronries in the Chippewa National Forest, Minnesota, occurred in very isolated locations, which suggested a low tolerance for human activities (Mathisen and Richards 1978). Great blue herons are especially sensitive early in the breeding season. The recommended "disturbance-free" exclusion zone around a potential nesting site is conservative enough so that a heron will initiate nesting behavior on arrival at a potential nest site in early spring. The herons seem more tolerant of human intrusions after eggs are laid and while caring for newly hatched nestlings (Vos 1984). Herons seem more tolerant of disturbances on water than disturbances on land around a nest site. The recommended disturbance-free zone around a potential nest site is 250 m on land or 150 m on water. Houses, roads, and similar disturbances should not occur within this zone; activities, like dredging, timbering, and mechanized agriculture, should not occur in the exclusion zone from February through August.

V5 = 1.0 if the exclusion zone is usually free from human disturbances during the nesting season.

V5 = 0.0 if the exclusion zone is usually not free from human disturbance during the nesting season.

Variable 6 (V6) in the model considers the proximity of a potential nest site to an occupied heron nest site. The probability that a grove of trees near water will be used as a nest site seems to be related to the distance between the potential nest site and established nest sites. Great blue herons may move from one colony to another or a colony may break up into small units (Kelsall and Simpson 1980). This dynamic action may occur as a result of predation within the heronry (Kelsall and Simpson 1980) or adverse land use practices, such as timbering, at a heronry (English 1978); or may represent usual heron behavior. Fifty-eight of 68 great blue herons marked one year were observed at the same heronry the next year (Kelsall and Simpson 1980). Three other marked individuals were observed at a colony 22 km away. These data, although minimal, suggest that the interchange of herons between nest colonies may be a function of the distance separating the colonies and that the probability of a suitable site being selected as a new heronry may be a function of the distance of that site from an established heronry. It is assumed, from the data of Kelsall and Simpson (1980), that suitable areas within 1 km of a heronry are the best candidates for the establishment of new heronries. Custer et al. (1980) state that nesting areas within 1 km of one another could be considered part of the same colony. Suitable treelands within 1 km of an established heronry are given an SI of 1.0 because they are potential satellite nest sites for that colony. Treelands greater than 1 km from an existing colony have a lower SI. The rate of decrease in SI values associated with increasing distance from an existing nest colony was selected arbitrarily.

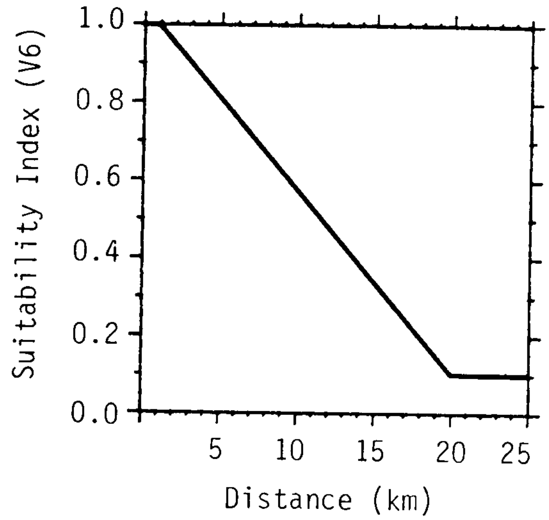

Figure 3. Distance between a potential nest site and an active nest site modifies SI values.

Variable 1 (V1) in the model considers the distance between foraging areas and heronry sites. A smaller energy expenditure by adult herons is required to support fledglings if an abundant source of food is close to the nest site than if the source of food is distant. Nest sites frequently are located near suitable foraging habitats. For example, 24 of 31 heronries along the Willamette River in Oregon were located within 100 m of known feeding areas (English 1978). Most heronries along the North Carolina coast were located near inlets, which have large concentrations of fish (Parnell and Soots 1978). The average distance from heronries to inlets was 7.0 to 8.0 km. The average distance of heronries to possible feeding areas (lakes ≥ 40 ha in area) varied from 0 to 4.2 km and averaged 1.8 km on the Chippewa National Forest in Minnesota (Mathisen and Richards 1978). Collazo (1981) reported the distance from the nearest feeding grounds to a heronry site as 0.4 and 0.7 km. A distance between a potential nest site and a foraging area of ≤ 1.0 km is given an SI of 1.0. The increased energy expenditure associated with longer foraging flights is reflected by a lower SI. Distances ≥ 10 km between nest sites and foraging areas are given an SI of 0.1.

The multiplication of suitability indices for Variables 1 and 4-6, and the calculation of the square root of that product, provides an estimate of the value of woodland sites near water as potential nesting habitat for the great blue heron. The square root of the product is used because only two variables (V1 and V6) are described as continuous functions in this portion of the model. The suggested equation for describing the reproductive life requisite index (RI) of the heron on its breeding range is:

$$RI = (V1 \times V4 \times V5 \times V6)^{1/2}$$

HSI determination. The multiplication of suitability indices for Variables 1-6 and the calculation of the square root of that product provides an estimate of the quality of treeland habitat near water as combined reproductive and foraging habitat for the great blue heron. The suggested equation is:

$$HSI = (V1 \times V2 \times V3 \times V4 \times V5 \times V6)^{1/2}$$

Application of the Model

Summary of model variables. This model is intended for use in evaluating wooded habitats near water as potential colony sites and a variety of aquatic sites as foraging habitats for the great blue heron. The model is applicable throughout the breeding range of the heron, which includes the conterminous 48 States. A tree diagram identifying the variables described in the model is presented in Figure 4. The model is based on the assumption that most great blue herons nest within 250 m of water; there are no variables in the model to predict the habitat quality of any nest site more than 250 m from water.

The recommended approach for a biologist applying this model is to use current, good quality, aerial photographs of the study area. The photographs should be interpreted to delineate rivers and lakes, islands in rivers and lakes, and forested swamps. A 250 m zone is drawn around each of those wetlands. Treeland areas within that zone are potential areas for evaluation as heronry sites. A second zone is drawn around each treeland area to be evaluated. This zone, 250 m in width if over land or 150 m in width if over water, is evaluated for the types of human disturbance likely to occur during the breeding season. Criteria used to predict human disturbance include the presence of houses, roads, commercial operations (including dredging and timber harvesting), and mechanized agricultural operations. Suitable potential heronry sites in disturbance-free areas are groves of trees at least 0.4 ha in area, with trees at least 5 m tall that have limbs sturdy enough to support heron nests and provide an open canopy so that herons can fly to and from their nest.

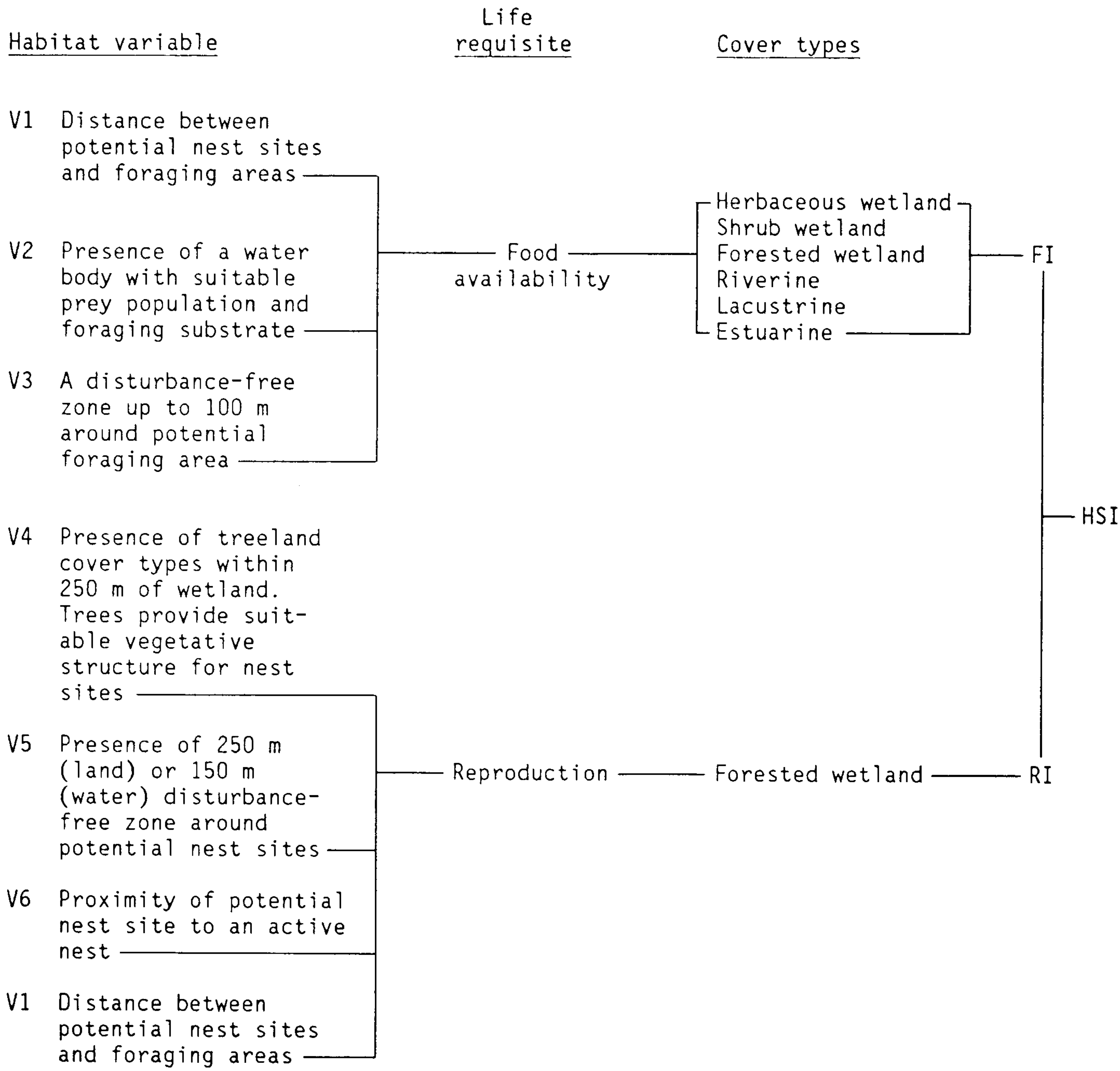

Figure 4. The relationship of habitat variables, life requisites, and cover types to an HSI for the great blue heron.

Herons tend to use the same heronry for many years if it continues to provide suitable nesting habitat. They may temporarily vacate a heronry, establish a new heronry, or even eventually reoccupy an old heronry. Areas of woodland that are presently used as heronries, or that have been used as heronries in the recent past, are delineated on the aerial photograph or on maps prepared from the photographs. The location of present or former heronries can be determined from local sources, published information, or aerial surveys of the general study area. A buffer zone of 250 m over land or 150 m over water is drawn around each of the heronry sites delineated on the photograph or map. An effort is made to determine or predict whether or not human disturbances are likely to impact the current or future use of these heronries.

Current or former heronries that have a disturbance-free zone of 250 m over land or 150 m over water receive an SI of 1.0 for Variable 5 in this model. Other identified potential nest sites also are assigned an SI. The SI's for these potential heronry sites diminish as their distance from current or former heronry sites increases because herons develop new heronries in suitable vegetation close to old heronries.

Heronries presumably are established near adequate foraging areas; the energy expenditure for feeding fledglings is less when little travel is required for successful foraging. Potential foraging areas are wetlands with huntable populations of small fish and shallow water in areas that are relatively free from human disturbance. Potential foraging areas can be located on an aerial photograph or a map developed from an aerial photograph. Ground truthing is required to determine if the wetlands depicted on the aerial photograph contain suitable fish and foraging areas. The distance from actual or potential heronries to foraging areas in wetlands can be measured on the aerial photograph.

Definitions of the variables and suggested field measurement techniques are provided in Figure 5.

Variable (definition)		Cover type	Suggested technique
V1	Distance between potential nest sites and foraging areas	Herbaceous Wetland (HW) Shrub Wetland (SW) Forested Wetland (FW) Riverine (R) Lacustrine (L) Estuarine (E)	Foraging areas are wetlands with huntable populations of small fish (≤ 25 cm) and suitable foraging substrates. These wetlands are marked on the aerial photograph or the map prepared from the aerial photograph. The distance between these foraging areas and potential nest sites are measured with a map measurer (Hays et al. 1981).
V2	Presence of a water body with suitable prey population and foraging substrate.	HW,SW,FW,R, L,E	Determine the presence of wetlands on aerial photographs or on a map prepared from the aerial photographs, and ground truth individual wetlands to determine if they possess a huntable fish population and suitable hunting sites. Cross out, on the aerial photograph or the map prepared from the aerial photograph, wetlands that do not provide suitable prey and foraging substrates for the heron.

Figure 5. Definitions of variables and suggested measurement techniques.

Variable (definition)		Cover type	Suggested technique
V3	A disturbance-free zone up to 100 m around potential foraging area. [Occasional vehicular traffic may occur within 50 m of a foraging area.]	HW,SW,FW, R,L,E	Determine, from the aerial photograph, the presence of human structures suggesting frequent human disturbance within 100 m of a potential foraging area. Ground truth to determine the type of human disturbance, if any, present within 100 m of a potential foraging site. Occasional vehicular traffic or mechanized agricultural operations within 50 m of a foraging area may be tolerated by herons. Cross out, on the aerial photograph or the map prepared from the aerial photograph, potential foraging areas subject to frequent human disturbance.
V4	Presence of treeland cover types within 250 m of wetland. Trees provide suitable vegetative structure for nest sites.	FW	Interpret good quality, current, aerial photographs to determine presence of habitat potentially useful as colony sites within the bounded area. Mark areas of potential habitat on the aerial photograph or on a map prepared from the photograph.

Figure 5. (continued).

Variable (definition)		Cover type	Suggested technique
V5	Presence of 250 m (land) or 150 m (water) disturbance-free zone around potential nest sites.	FW	Determine, from the aerial photograph, the presence of human structures suggesting frequent human activities within the disturbance-free zone (250 m over land or 150 m over water) of potential colony sites. Ground truth to determine the presence of other regular human activities, if any, within the disturbance-free zone. Cross out, on the aerial photograph or the map prepared from the aerial photograph, potential nest sites subject to frequent human disturbance.
V6	Proximity of potential nest site to an active nest site.	FW	Location of present or former nest sites can be determined from: (1) local natural history groups (2) published records, and (3) aerial surveys of the study area. Mark, on the aerial photograph or a map produced from the aerial photograph, the position of established nest sites. Determine, with a map measurer (Hays et al. 1981), the distance between established and potential nest sites.

Figure 5. (concluded).

Model assumptions. We have assumed that it is possible to synthesize the results from a wide variety of studies compiled from different seasons of the year, different years, and a wide variety of breeding and foraging sites throughout North America into one model that describes the relative quality of certain habitats for the great blue heron. Our basic assumptions about habitat criteria important to this heron are based on descriptive and correlative relationships in the literature. Our descriptions of habitat quality will be in error if authors have made incorrect judgments or measurements or if we have emphasized the wrong data sets or misinterpreted the meaning of published data.

The great blue heron nests on certain artificial structures, which are on the ground, on cliffs, in shrubs, and in trees. We have assumed that trees are the usual nest sites and restricted the applicability of this HSI model to treeland habitats. We assumed that we could better predict the utility of treelands to herons if we concentrated our efforts on treelands near water (most treeland nest sites are near water). The model emphasizes characteristics of treelands within 250 m of water. Suitability characteristics of such treelands are described as suggested in the literature. Species and height of trees appear to be insignificant factors in determining how herons select nest sites. Limb structure suitable for nest placement, proximity to established heronries, proximity to food sources, and frequency of human disturbance during the breeding season seem to be the important criteria determining where herons select nest sites.

The great blue heron feeds on upland sites and in suitable aquatic habitats. We have assumed that aquatic areas are the most significant foraging habitat for the heron and identified the presence of fish, a suitable foraging substrate, distance to heronry, and level of human disturbance around the foraging site as the significant evaluation variables. Data were not available to justify model variables based on the relationship between colony size and the size of the available fishery represented either in terms of area of surface water or fish biomass.

The values for Variables 1 through 6 are estimates. The available ecological information does not seem sufficient to suggest: (1) other significant variables; (2) more appropriate values for the present variables; or (3) more definitive interrelationships between the variables. We have assumed that the habitat variables describing treeland habitat can be combined arithmetically to evaluate the potential usefulness of groves of trees as nest sites, that the habitat variables for aquatic habitat can be combined arithmetically to evaluate the quality of aquatic habitats as foraging sites, and that a single HSI can be developed to evaluate habitats that provide both nesting and foraging opportunities for great blue herons.

SOURCES OF OTHER MODELS

Kushlan (1978:283) provided a generalized model of the functional role of wading birds in a pond in a seasonally fluctuating marsh. The intent of Kushlan's model was to demonstrate how wading birds in general impact the pathways of energy flow within a marsh. Werschkul et al. (1977) developed a regression relationship that predicted the number of nests within great blue heron nest colonies along the Oregon coast on the basis of the size of nearby estuaries along the Oregon coast that provided feeding habitat for the bird. A simple regression relationship developed from their data accounted for 55% of the variation (r^2 = 0.55, r 0.74) in the number of active nests within 11 heronries. Much of the significance of that relationship, however, occurred because one very large heronry was located near one very large estuary. No models were found in the literature that attempt, as does the present HSI model, to predict the possible usefulness of habitats as heronries or the usefulness of various wetlands as foraging sites for the great blue heron.

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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.

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