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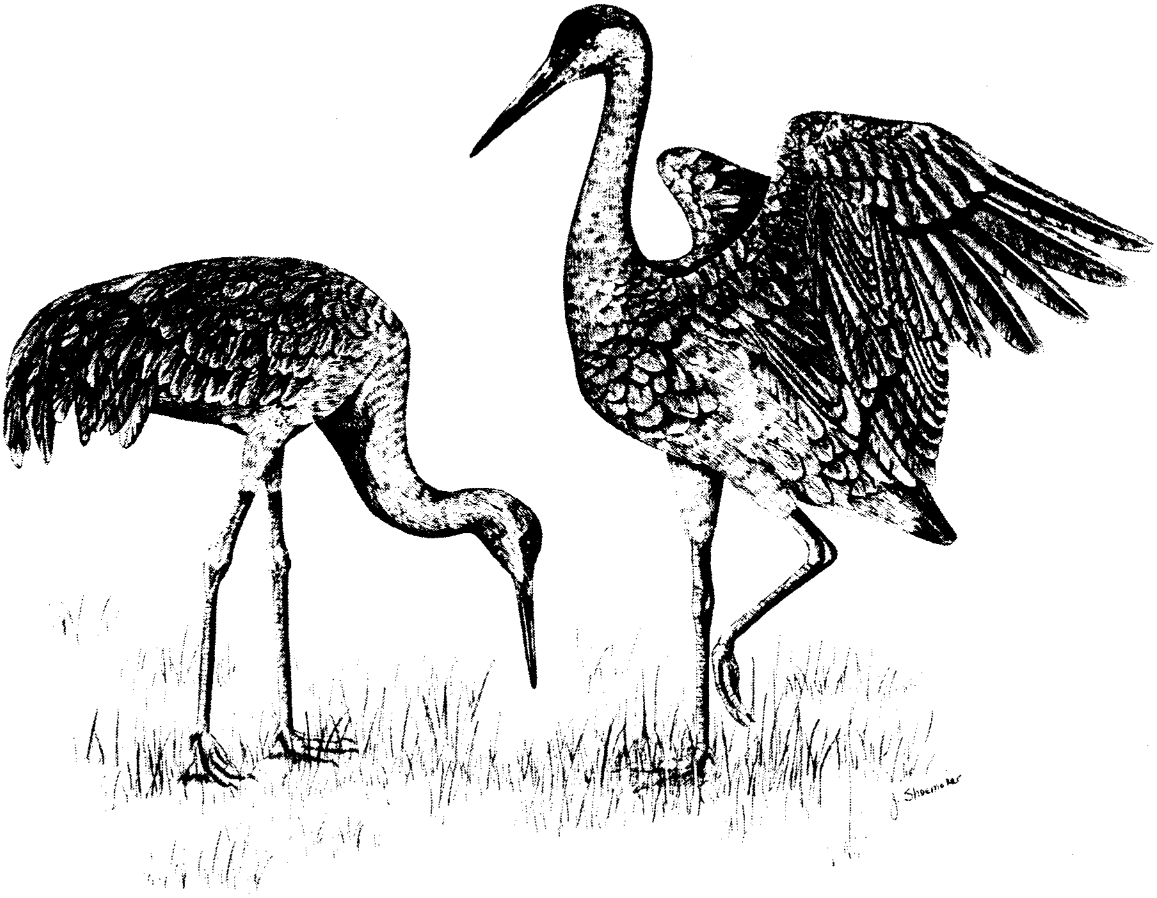
HABITAT SUITABILITY INDEX MODELS: GREATER SANDHILL CRANE



Fish and Wildlife Service

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HABITAT SUITABILITY INDEX MODELS: GREATER SANDHILL CRANE

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is a formalized synthesis of biological and habitat information published in the scientific literature and may include unpublished information reflecting the opinions of identified experts.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 suitability of habitat for that species. User feedback concerning model improvements and other suggestions that may increase the utility and effectiveness of this habitat-based approach to fish and wildlife planning are encouraged. Please send suggestions to:

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ACKNOWLEDGMENTS

I gratefully acknowledge the constructive reviews of Jerry Bartelt, Alan Bennett, David Best, Jeff DiMatteo, Roderick Drewien, Donald Frickie, Ronald Hoffman, Richard Hunt, James Kesel, James Lewis, Carroll Littlefield, Janet Smith, Scott Swengel, and Lawrence Walkinshaw. Several of these individuals also contributed reprints and/or unpublished information. The assistance of these individuals contributed greatly to the improvement of this model and is sincerely appreciated.

This document was illustrated by Jennifer Shoemaker and Susan Strawn. Word processing was provided by Carolyn Gulzow, Dora Ibarra, Elizabeth Graf, and Patricia Gillis.

GREATER SANDHILL CRANE (*Grus canadensis tabida*)

HABITAT USE INFORMATION

General

Six subspecies of sandhill cranes (*Grus canadensis*) are currently recognized (Lewis 1977). There are three nonmigratory forms: the Florida (*G. c. pratensis*), the rare Cuban (*G. c. nesiotes*), and the endangered Mississippi sandhill crane (*G. c. pulla*) (King 1981). The lesser (*G. c. canadensis*) and the Canadian sandhill cranes (*G. c. rowani*) are the most abundant of the migratory subspecies. This model attempts to characterize the reproductive habitat requirements of the greater sandhill crane (*G. c. tabida*), a subspecies that nests from latitude 40 degrees in the northern United States to 50 degrees north in southern Canada (Walkinshaw 1973).

Four distinct populations of greater sandhill cranes have been identified (Lewis 1977). The Eastern population nests in parts of Michigan, Wisconsin, Minnesota, Ontario, Manitoba (Lovvorn and Kirkpatrick 1981a), Illinois (Greenberg 1980), and Indiana (R.H. Hoffman, 6142 Territorial Road, Pleasant Lake, MI; letter dated September 7, 1985) and winters in Florida. The Rocky Mountain population nests in northwestern Colorado, northeastern Utah, western Wyoming, southern Montana, and southeastern Idaho (Drewien and Bizeau 1974) and winters in New Mexico, southeastern Arizona, and northern Mexico. The Colorado River Valley population nests in northeastern Nevada and probably southwestern Idaho and winters along the Colorado River in Arizona and southern California (Drewien et al. 1976). The Central Valley population nests primarily in Oregon and northeast California, but there is an undetermined number of cranes nesting in southern British Columbia and Washington (C.D. Littlefield, Malheur Field Station, Princeton, OR; letter dated February 24, 1986). This population winters in the Central Valley of California (Littlefield and Thompson 1979).

Greater sandhill cranes occur in North Dakota during fall migration (Johnson and Stewart 1973) and in southern Texas during the winter (Guthery and Lewis 1979; Tacha et al. 1986), but have not been associated with any of the four populations described above. A possible breeding area for these birds is the Interlake region of southcentral Manitoba (Lewis 1977; Melvin and Temple 1983). It is likely that the greater sandhill cranes breeding in and around Agassiz National Wildlife Refuge (NWR) in northwestern Minnesota and wintering near the Texas coast are members of this population (J. DiMatteo, Department of Biological Sciences, St. Cloud State University, St. Cloud, MN; letter dated February 27, 1986).

Greater sandhill cranes were officially listed as rare by the U.S. Department of the Interior in 1966 (U.S. Fish and Wildlife Service 1966), but were delisted in 1973 (U.S. Fish and Wildlife Service 1973). The Conservation Committee of the Wilson Ornithological Society estimated population size and status in 1975 as: Eastern, approximately 7,000 birds with population increasing; Rocky Mountain, 10,000-15,000 birds and increasing; Colorado River Valley, 1,000 birds with population status unknown; and Central Valley, approximately 3,500 birds and stable (Drewien et al. 1975). Since 1975, portions of the Central Valley population have been declining because of low annual recruitment (Littlefield and Thompson 1979; Stern et al. 1987). The size of the Eastern population was more recently estimated at approximately 15,000 birds (Lovvorn and Kirkpatrick 1981b); however, >6,000 cranes were surveyed in Wisconsin alone in 1985 (R.A. Hunt, Wisconsin Department of Natural Resources, Horicon Area Headquarters, Horicon, WI; unpubl.). Guthery and Lewis (1979) estimated that approximately 2,000 greater sandhill cranes wintered in south Texas in the early 1970's (Interlake population?), but the current size and status of this population is unknown.

Food

Sandhill cranes feed on a variety of plant and animal foods (Walkinshaw 1949) and can be categorized as opportunistic omnivores (Mullins and Bizeau 1978). Young cranes (colts) are fed by the pair for the first few days of life (Walkinshaw 1973) and then feed almost exclusively on animal food during the preflight period (Lewis 1977). Cranes nesting at Grays Lake, Idaho, confined their foraging activities to the nesting territory in good food years until the young were old enough to fly (Drewien 1973). In years of limited food, crane families leave their territories to search for food (R.C. Drewien, Grays Lake National Wildlife Refuge, Wayan, ID; letter dated September 27, 1985). Marsh-nesting cranes in Michigan also used their territories for feeding (Walkinshaw 1973). Cranes in Colorado, however, moved away from streambank nests after their eggs hatched and foraged in surrounding uplands supporting sagebrush (*Artemisia* spp.) and aspen (*Populus tremuloides*) stands (Bieniasz 1979). Greater sandhill cranes nesting in the Upper Peninsula of Michigan foraged in forest openings away from their bog nest sites (Taylor 1976).

Food items taken by marsh-nesting cranes include roots, browsed vegetation, snails (*Helisoma* spp.), crayfish (*Cambarus* spp.), small mammals, birds, frogs (*Hyla crucifer*, *Rana pipiens*), snakes, toads (*Bufo* spp.), and various insects (Walkinshaw 1973). Cranes will apparently attempt to take any potential food item of the proper size, including waterfowl eggs (Bennett 1978; Hoffman 1980) and ducklings (Littlefield 1976b). Large food items such as garter snakes (*Thamnophis sirtalis*) are torn apart by the adults before being fed to the chick (Bennett 1978).

Cranes nesting on small wetlands in southern Wisconsin made extensive use of uplands as feeding sites after their chicks hatched (Bennett 1978). Adults remained close to the nest for the first 2 days after hatching but then moved colts to upland feeding sites at 3-4 days of age. Cattle pastures that were heavily grazed seemed to be preferred by feeding cranes. Sites with short vegetation permitted easy movement for colts searching for the abundant soil invertebrates associated with moist depressions and cattle manure. The use of upland sites continued until the colts were approximately 5 weeks of age, at which time family groups shifted feeding activities back to wetlands (Bennett 1978).

Cranes often feed in grain fields in the spring before nest sites thaw and again in late summer after the young reach flight stage. Heavily used grains include barley (Hordeum vulgare) in Idaho (Drewien 1973), wheat (Triticum aestivum) in Colorado (Bieniasz 1979), and corn (Zea mays), wheat, and other crops in Michigan (Hoffman 1976; Taylor 1976) and Wisconsin (Bennett 1978). Hamerstrom (1938) felt that grain fields of buckwheat (Fagopyrum esculentum), corn, and oats (Avena sativa) were an important food source in areas of small marshes and interspersed agriculture.

Water

Cranes drink water and seem to prefer a pH range from 4.5 to 7.6 for their aquatic activities in the upper midwest (Walkinshaw 1973); however, western populations may tolerate more alkaline conditions (Drewien, unpubl.). Food, cover, and nesting requirements for sandhill cranes are intimately associated with water in the form of some type of wetland. Water requirements are difficult to separate individually and are discussed under the habitat component supplied.

Cover

A roost site is synonymous with nocturnal security cover for cranes. Many authors have alluded to the importance of roost sites within the nesting territory, but little quantitative information has been presented for the greater sandhill crane. Walkinshaw (1973) characterized roosting sites in Michigan as standing water 10 to 30 cm deep surrounded by deeper water or large expanses of marsh. The mean distance from roost sites to a nest site was 140 m. Cranes nesting in the Hiawatha National Forest in Michigan roosted within 3 km of the nest site (Taylor 1976). Hamerstrom (1938) and Crete and Grewe (1981) felt that ice formation and the resulting absence of open water for night roosting was the causal factor initiating fall migration from Wisconsin staging areas.

Bennett (1978) characterized 10 roost sites in southeastern Wisconsin. The actual roost sites were small (1.4 ha), but were all centered in large wetlands >300 ha in size. Cranes roosted in the open-water zone (5 to 15 cm deep) beyond the edge of emergent vegetation. Vegetation surrounding the roost site varied from aquatic emergents, such as cattails and American lotus (Nelumbo lutea), to oak (Quercus spp.) forest.

The characteristics of roost sites used during migration are better documented than are breeding season roosts. Greater sandhill cranes of the Eastern population selected roosts in northwestern Indiana with water <20 cm deep and free from human disturbance (Lovvorn and Kirkpatrick 1981a). Stable, uniformly shallow water conditions are important, and bare or sparsely vegetated mud flats surrounding the site seem to be preferred. Cranes avoid disturbance by maximizing either distance or visual isolation from human activity. For example, the average minimum distance from human activities in Indiana was 140 m for roosts surrounded by woody vegetation and 380 m for roosts visible from a road (Lovvorn and Kirkpatrick 1981a).

Reproduction

Most authors identify the primary components of greater sandhill crane reproductive habitat as a nest site, roosting area, feeding area, and isolation. These components can be supplied by large marsh complexes (Littlefield and Ryder 1968; Drewien 1973); smaller, scattered marshes (Hamerstrom 1938; Walkinshaw 1973; Hoffman 1983); bogs in northern boreal forests (Taylor 1976); intermittent streams in sagebrush parklands (Bieniasz 1979); and mountain meadows, beaver (Castor canadensis) ponds, and subirrigated wet meadows along riparian zones (Drewien and Bizeau 1974). The specific identity of the cover type does not appear to be as important as is the juxtaposition of water (supplying a nest and roosting site) and a food source, in an isolated situation.

Cranes mate for life (Walkinshaw 1949) and return to the same territory each year (Drewien 1973). Both members of the pair participate in defense of the territory, nest building, and incubation (Littlefield and Ryder 1968; Drewien 1973; Walkinshaw 1973). The male is the most active in territory defense. Littlefield and Ryder (1968) reported that, under crowded conditions (six nests in close proximity), males became preoccupied with territorial defense and failed to relieve their incubating mates. Five of six nests were lost to predators when the female finally left the nest to feed.

Nests are usually constructed from residual vegetation from the previous growing season (Littlefield and Ryder 1968; Drewien 1973; Walkinshaw 1973). Of 174 nests found in southern Michigan, 38% were built in cattails (Typha latifolia, T. angustifolia), 35% in sedges (Carex spp.), 17% in bulrushes (Scirpus validus), 6% in water willow (Decodon verticillatus), and 4% in miscellaneous plants (Walkinshaw 1973). Fifty-four percent of 113 nests were found in burreed (Sparganium eurycarpum) on Malheur NWR, Oregon, while 24.8% were located in hardstem bulrush (S. acutus), 9.7% in cattail (T. latifolia), and 11.5% in miscellaneous grasses, forbs, and willows (Salix spp.) (Littlefield and Ryder 1968).

Marsh vegetation occurred in a heterogeneous mixture at Grays Lake NWR, Idaho, and cranes appeared to use whatever was encountered for nesting (Drewien 1973). Dominant vegetation at 26.5% of nest sites was rush (Juncus balticus), 23.7% sedges, 12.2% hardstem bulrush, and 19.7% in three other genera accounting for >5% canopy coverage. Limited use of muskrat (Ondatra zibethica) lodges (Drewien 1973; Walkinshaw 1973), dikes and islands in deep marshes (Drewien 1973), and beaver dams (Bieniasz 1979), as nest sites, has been reported. Nests located in pastures near water at Grays Lake were constructed of cattle manure (Drewien 1973). Cranes nesting along small streams in Colorado used grasses and willow twigs remaining from beaver cuttings for nest materials (Bieniasz 1979).

Water depth, or proximity to water, may be more critical to nest placement than is vegetation type. Nests are usually located in, or next to, shallow water, and may require from 1 day to over a week to construct (Littlefield and Ryder 1968; Drewien 1973). Although wetland Types 1-8 (Shaw and Fredine 1956) were available in a Waterloo Township, Michigan, study area, only Types 3 (shallow marsh) and 4 (deep marsh) were used for nesting (Hoffman 1983). (A comparison between this wetland classification and a more recent system devised by Cowardin et al. 1979 is presented later in the model.) Sixty-five percent of these wetlands contained open water or were associated with a lake. Seventy-five percent of 377 nests located at Grays Lake NWR were situated in ≤25 cm of water or built on dry ground within 4.6 m of water (Drewien 1973). Nests were usually built around the periphery of the hardstem-bulrush-dominated marsh, with many cranes avoiding the deeper water dominated by bulrush and cattail. Grays Lake is actually a 8,900 ha Type 3 marsh, with some areas that could be classified as Type 4. At lower water levels, cranes do use the bulrush and cattail-dominated areas, indicating a selection for water depth and not plant cover type (Drewien, unpubl.). Crane nests at Malheur NWR were located in, or very near, standing water averaging 16.8 cm in depth (Littlefield and Ryder 1968). The average water depth around 144 nests in southern Michigan was 25.3 cm (Walkinshaw 1973). Nests found in northern Colorado sagebrush parks were always situated along willow-lined streams within 1 m of slow-moving water 15 to 16 cm deep (Bieniasz 1979).

Isolation from human activity appears to be an important criterion for selection and use of nesting territories by cranes. Several authors have commented on the propensity of cranes to desert their nests due to human disturbances (Littlefield and Ryder 1968; Drewien 1973; Walkinshaw 1973; Bieniasz 1979). Drewien (1973) noted the absence of nesting in a section of Grays Lake marsh located close to roads and cultivated fields. The few nests located <400 m from roads were screened by tall vegetation. Marshes (n = 26) used for nesting in Michigan were an average 320 m from cultivated fields, 431 m from roads, and 476 m from residences (Hoffman 1983). Cranes nesting in the Upper Peninsula of Michigan occupied remote bogs (wetland Type 8 of Shaw and Fredine 1956) located in extensive forest stands (Taylor 1976). Vegetation associated with these wetlands included sphagnum moss (*Sphagnum* spp.), leatherleaf (*Chamaedaphne calyculata*), cottonsedge (*Eriophorum* spp.), black spruce (*Picea mariana*), and jack pine (*Pinus banksiana*). Type 8 wetlands composed 32% of 113 wetlands surveyed on the Manistee National Forest in Michigan, but accounted for 74% of 31 wetlands judged as good or excellent crane habitat (L.H. Walkinshaw, 915 North Onondaga Road, Holt, MI; unpubl.). Cranes nesting in northern Colorado utilized small willow-lined drainages separated by sagebrush-covered ridges (Bieniasz 1979). Poor vehicular access to this high mountain park usually afforded isolation to nesting cranes until mid-incubation.

Interspersion and Composition

Drewien (1973) and Walkinshaw (1973) both believed that most greater sandhill cranes maintain a classic Type A territory (Hinde 1956) that supplies all courtship, mating, nesting, and food requirements; however, both of these researchers worked in very productive marshes. For example, Grays Lake may well offer close to ideal conditions for nesting cranes by supplying a diversity of cover types, from upland meadow to bulrush-cattail marsh, in close proximity around the periphery of a 8,900 ha marsh. Cranes can therefore maintain a breeding space in a fairly small physical area. Indeed, crane breeding densities at Grays Lake are the highest reported anywhere (Drewien 1973).

Food availability influences local movements and the duration of crane occupancy on the defended territory (Drewien 1973). Five territories at Grays Lake averaged 17 ha, and most families remained on site until young fledged. Drewien (1973) felt that 5 to 8 ha would be the minimum area required to support a nesting pair at Grays Lake. Eight territories at Malheur NWR averaged 25 ha (Littlefield and Ryder 1968), and territory size for 76 Michigan (Lower Peninsula) nests averaged 53 ha (Walkinshaw 1973). In the latter study, however, cranes apparently fed in fields located some distance from the defended nest site. Colorado cranes moved up to 0.8 km to sagebrush and aspen feeding areas (Bieniasz 1979), and bog nesting cranes in the Upper Peninsula of Michigan foraged in forest openings within a 3-km radius of the nest site (Taylor 1976). Drewien (unpubl.) has observed crane families searching for food >5 km from nesting territories during years of food shortages.

Hoffman (1983) calculated and compared the density of pairs in terms of total area used in several studies (Table 1). Density is dependent on area coverage and other, nonhabitat-related, variables that may not be comparable between studies, but the data presented in Table 1 should give some indication of relative trends among different local populations of cranes. Densities on breeding marshes in Marquette and Green Lake counties of Wisconsin (a subset of Bennett's 1978 study area) now exceed 2.0 pairs/km^2 (S. Swengel, International Crane Foundation, Baraboo, WI; letter dated September 11, 1985).

The above discussion indicates a behavioral flexibility of cranes to exploit food resources well removed from the defended area. In fact, the only critical habitat component common to all studies is a secure (isolated) nest site that is almost always associated with water. Size of wetland seems irrelevant as long as security is provided. Hamerstrom (1938:180) found cranes nesting in shallow water marshes of at least 16 ha in size, but additional security was provided to this "small nucleus" by a larger zone of aspen and grass marsh of at least 400 ha. Cranes nested on bogs as small as 0.2 ha in northern Michigan but never near human activities (Taylor 1976). Cranes will nest on beaver ponds as small as 0.04 to 0.08 ha, and Drewien (unpubl.) found several nests around wet seeps or springs in aspen-mountain shrub cover types. Cranes nesting on dry land at Grays Lake may be indicative of the limited exposure to nest predation experienced by this population (Drewien 1973).

Special Considerations

Adult cranes are long lived, but mortality can be high for eggs and young. Ravens (*Corvus corax*), raccoons (*Procyon lotor*), and coyotes (*Canis latrans*) destroyed eggs and killed young at Malheur NWR (Littlefield 1976b; Littlefield and Thompson 1987). Coyotes, common ravens, and California gulls (*Larus californicus*) were identified egg predators at Sycan Marsh, Oregon

Table 1. Comparison of greater sandhill crane densities from studies reporting use of both wetlands and uplands (from Hoffman 1983).

Investigator	Location	Pairs/km^2 (wetland and upland)
Drewien (1973)	Idaho	2.00
Littlefield (1976a)	Oregon	0.30
Hoffman (1983)	Michigan (1982)	0.30
	(1970)	0.20
Halbeisen (1980)	Michigan	0.10
Bennett (1978)	Wisconsin (1977)	0.03
	(1976)	0.02

(Stern et al. 1987). Raccoons were also important nest predators in Michigan (Walkinshaw 1973). Striped skunks (*Mephitis mephitis*), crows (*Corvus brachyrhynchos*), and ravens were the principal egg predators at Grays Lake, and a golden eagle (*Aquila chrysaetos*) killed and devoured an adult male crane incubating eggs (Drewien 1973). Bieniasz (1978) observed two adult cranes drive a swift fox (*Vulpes velox*) away from their colt, but Drieslein and Bennett (1979) believed red foxes (*V. vulpes*) can be an important predator on chicks up to 1 week of age. Littlefield and Ryder (1968) and Drewien (1973) reported adult mortalities resulting from collisions with powerlines and barbed-wire fences.

Cranes can cause serious crop damage. Wheat, both the kernels and new growth 5 to 10 cm tall, seems to be preferred, with corn a close second (Hoffman 1976). Cranes in the Upper Peninsula of Michigan caused some crop damage at fall staging areas (Taylor 1976) and to recently planted wheat (fall) and corn (spring) in southern Michigan (Hoffman 1976) and Wisconsin (Hunt and Gluesing 1976). Barley has been heavily damaged by cranes at the Grays Lake staging area (Drewien 1973). Some damage to wheat during staging periods has been reported from northern Colorado (Bieniasz 1979).

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. This model was developed for application within the breeding range of the five extant populations of greater sandhill cranes in the United States (Figure 1). Figure 1 should not be interpreted as an attempt

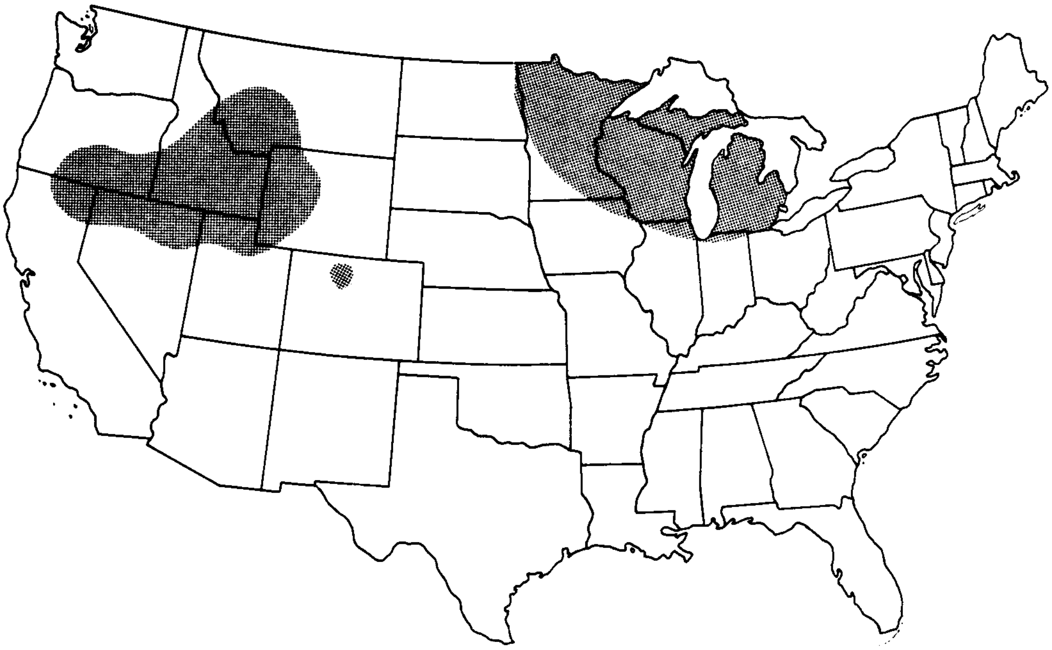

Figure 1. Approximate geographic area of applicability for the greater sandhill crane HSI model in the contiguous United States. Shading does not imply continuous current distribution, or that adjacent areas are unsuitable. For example, some nesting occurs in Washington, but the locations and magnitude are unknown (Littlefield, unpubl.).

to define specific areas currently occupied by breeding greater sandhill cranes. Rather, Figure 1 identifies the general locations presently used by the five crane populations described in this report, as well as intervening and surrounding areas that may be appropriate for model application. The distribution of greater sandhill cranes in southern Canada is not well known (Tebbel and Ankney 1979).

Season. The model was developed for application during the breeding season, from first arrival on site in late March-early April, until approximately mid-September, when young can fly.

Cover types. This model focuses on wetlands and can be applied to Forested Wetland (FW), Scrub-shrub Wetland (SW), Herbaceous Wetland (HW), Riverine (R), and Lacustrine (L) types (terminology follows U.S. Fish and Wildlife Service 1981). The model also requires the application of the wetland class and water regime descriptors of Cowardin et al. (1979). Surrounding uplands considered in this model include Cropland (C), Grassland (G), Pasture/Hayland (P/H), Deciduous Forest (DF), and Evergreen Forest (EF). All other types can be classified as nonforested uplands.

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous habitat that is required before a species will occupy an area. The smallest area used for nesting by greater sandhill cranes was a 0.2 ha bog in northern Michigan (Taylor 1976). It is unclear, however, whether or not the pair obtained all their food requirements from this area, or if they nested successfully. Most studies stress the importance of isolation of the nest site rather than the specific size or type of wetland used. For these reasons, no particular minimum size limit for a wetland is defined here. It is the responsibility of the user to determine if a wetland is large enough to support crane nesting.

Verification level. This model provides information useful for baseline assessments and habitat management. The potential of an area to support nesting greater sandhill cranes is described. The model is intended for planning applications over large geographic areas using good quality aerial photography. The model is a set of hypotheses describing assumed crane-habitat relationships and does not reflect proven cause and effect. The model should rank the quality of potential nesting areas as would an expert thoroughly familiar with the reproductive requirements of greater sandhill cranes.

Earlier drafts of this model were reviewed by:

Jerry Bartelt, Department of Natural Resources, Horicon Area Headquarters, Horicon, Wisconsin.

Alan Bennett, Okefenokee National Wildlife Refuge, Folkston, Georgia.

David Best, U.S. Fish and Wildlife Service, East Lansing, Michigan.

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Scott Swengel, International Crane Foundation, Baraboo, Wisconsin.

Lawrence Walkinshaw, 915 North Onondaga Road, Holt, Michigan.

Modifications suggested by these individuals have been incorporated into the model where possible. Use of the reviewers' names, however, does not necessarily imply that they concur with each section of the model, or the model in its entirety.

Model Description

Overview. The model is designed to evaluate a site's potential to support nesting greater sandhill cranes. The model identifies a range of suitability in terms of the assumed requirements supplied for each variable used to characterize habitat potential. Suitability is defined in terms of the assumed relationships between optimum conditions and the opposite extreme of no resources available. Conditions identified as optimum are often a compromise between biological and management considerations. For example, present critical habitat components appear to be met by wetland/upland complexes isolated from human disturbances during the March-June nesting period. From a practical standpoint, nest sites, roosting areas, and food can be most efficiently provided by large areas intensively managed for nesting sandhill cranes.

Optimum habitat conditions are assumed to exist when all requirements occur in close proximity over large contiguous areas, such as the marshes and/or wet meadows, and adjacent uplands at Grays Lake and Malheur NWR's. Wilson (1983) developed a greater sandhill crane pattern recognition model for southeastern Idaho and assumed that cranes could reach a nesting density of 6.2 pairs/km^2 under optimum conditions. This is similar to a density of 6 pairs/km^2 estimated from Drewien's (1973) data from Grays Lake. Other areas support nesting cranes but in lower densities. Although no data are presented for crane nesting densities in Colorado (Bieniasz 1979) or northern Michigan (Taylor 1976), descriptive information indicates densities of <0.1 pairs/km^2. These areas will receive some value as nesting habitat when evaluated with this model. However, it is assumed that other types of smaller wetlands and associated uplands cannot physically provide the optimum habitat conditions that will support crane-nest densities occurring on large marsh/upland complexes used as the standard of comparison in this model. This model assumes that the habitat potential of a site can be characterized by the identity of the wetland class(es), water regime(s), percent of the area in wetlands, and the size of the site.

Food/reproduction component. Habitat-use patterns differ between the various segments of the five extant populations (including Interlake population) of greater sandhill cranes nesting in the United States and parts of southern Canada. Two factors, however, are shared by all segments: association of the nest site with some type of wetland and isolation from human activities. Because large wetland complexes that can supply secure nest and roost sites also have the potential of supplying all food requirements, food and reproduction needs are considered together as the critical habitat component of this model. Water, cover, and spatial requirements are assumed to be synonymous with, or never more limiting than, the minimum requirements for food and reproduction as defined in this model.

The most commonly cited criterion used to describe crane habitat is the presence of some type of wetland. Wetland definitions abound, but for the purposes of this model:

> WETLANDS are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. ... wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year (Cowardin et al. 1979:3).

Much of the crane literature that identifies wetland use is founded on the classification system of Shaw and Fredine (1956). In contrast, most of the current wetland inventory work underway by the U.S. Fish and Wildlife Service's National Wetland Inventory Project utilizes the classification system of Cowardin et al. (1979). This model will follow the latter system. Persons with data in the format of Shaw and Fredine (1956) should refer to Table 2 for comparisons with the Cowardin et al. (1979) system. The following variables are used to determine the quality of an evaluation site in terms of the wetland(s) it supports and the assumed value to greater sandhill cranes.

Optimum conditions for food and reproduction are assumed to exist in emergent wetlands (SIV1, Figure 2) supporting erect, rooted, herbaceous hydrophytes such as cattails, bulrushes, sedges, and other plants commonly used for nest building. Emergent wetlands (a class level descriptor in Cowardin et al. 1979) are also assumed to provide a more diverse and abundant potential food supply than exists in other wetland classes. Cranes do use scrub-shrub (Walkinshaw 1965; Littlefield and Ryder 1968; Bennett 1978; Bieniasz 1979) and forested wetlands (Taylor 1976), but their relative value as nesting cover is unclear. Bennett (1978) found several thousand hectares of shrub swamp in southeastern Wisconsin that received no crane use, but tamarack (*Larix laricina*) swamps containing openings dominated by cattails and sedges were consistently used by nesting cranes (A. Bennett, Okefenokee National Wildlife Refuge, Folkston, GA; letter dated January 23, 1986). In fact, townships supporting the highest ratio of shrub swamps had the smallest crane populations. It is unclear, however, whether cranes were responding to the presence of shrubs, or to lowered water levels resulting from attempts at wetland drainage. Because of these uncertainties, scrub-shrub, forested, and moss-lichen wetlands are assigned rather low values (relative to emergent wetlands). I have assumed that wetlands classified as unconsolidated bottom or aquatic bed are characterized by water levels too deep to support emergent vegetation or crane use.

Table 2. Comparison of the wetland types of Shaw and Fredine (1956) with the wetland classes and water regime modifiers of Cowardin et al. (1979).

Shaw and Fredine (1956)	Cowardin et al. (1979)		
Wetland type[a]	Wetland class	Water regime	Water regime definitions
1. Seasonally flooded basins or flats	Emergent wetland Forested wetland	Temporarily flooded	Surface water present for brief periods during growing season, but water table usually lies well below soil surface for most of season
		Intermittently flooded	Substrate usually exposed, but surface water is present for variable periods without detectable seasonal periodicity
2. Inland fresh meadows	Emergent wetland	Saturated	Substrate saturated to surface for extended periods during growing season, but surface water seldom present
3. Inland shallow fresh marshes	Emergent wetland	Semipermanently flooded	Surface water persists throughout growing season in most years
		Seasonally flooded	Surface water present for extended periods, especially early in growing season, but absent by end of season in most years
4. Inland deep fresh marshes	Emergent wetland	Permanently flooded	Water covers land surface throughout year in all years
	Aquatic bed	Intermittently exposed	Surface water present throughout year except in years of extreme drought
		Semipermanently flooded	(As defined above)
5. Inland open fresh water	Aquatic bed	Permanently flooded	(As defined above)
	Unconsolidated bottom	Intermittently exposed	(As defined above)
6. Shrub swamps	Scrub-shrub wetland	All water regimes defined here except permanently flooded	
7. Wooded swamps	Forested wetland	All water regimes defined here except permanently flooded	
8. Bogs	Scrub-shrub	Saturated	(As defined above)
	Forested wetland		
	Moss-lichen wetland		

[a] Crane use has been reported only from wetland types 1-8; therefore, types 9-20 are not addressed.

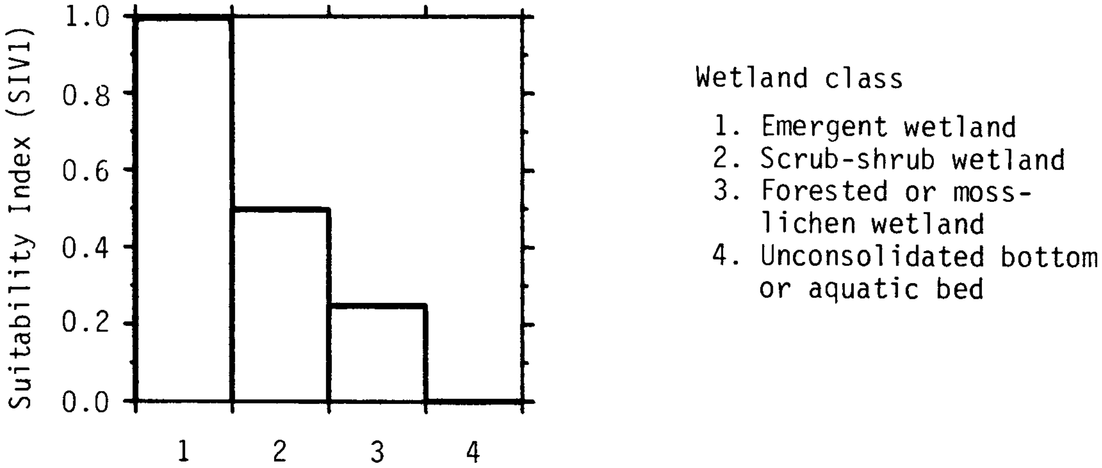

Figure 2. Relationship between classification of wetlands (Cowardin et al. 1979) on the evaluation area and their respective suitability indices.

The presence of water, at least through hatching, is assumed to be a critical factor in determining the suitability of an area for greater sandhill cranes. Cranes utilize relatively shallow water for their aquatic activities. Recorded water depths for both roosting and nest site location usually fall between 10 and 30 cm (Littlefield and Ryder 1968; Drewien 1973; Walkinshaw 1973; Lovvorn and Kirkpatrick 1981a), although the use of mud flats for roosting (Lovvorn and Kirkpatrick 1981a) and nests placed on bare ground in close proximity to water (Drewien 1973; Bieniasz 1979) are not uncommon in some situations. Deeper water interspersed with water 10 to 30 cm deep may provide security from terrestrial predators (Walkinshaw 1973).

Water depths in wetlands used by greater sandhill cranes often fluctuate during the breeding season in response to snow melt, irrigation drawdown, natural evaporation, and other factors. Because of these fluctuations, an estimate of relative water permanence is assumed to be a better indicator of habitat suitability than would be some estimate of mean depth. The water regime descriptors of Cowardin et al. (1979) are used to rank the permanence and timing of water availability for crane feeding, roosting, and nesting activities (SIV2, Figure 3). The assigned ranks reflect the assumption that

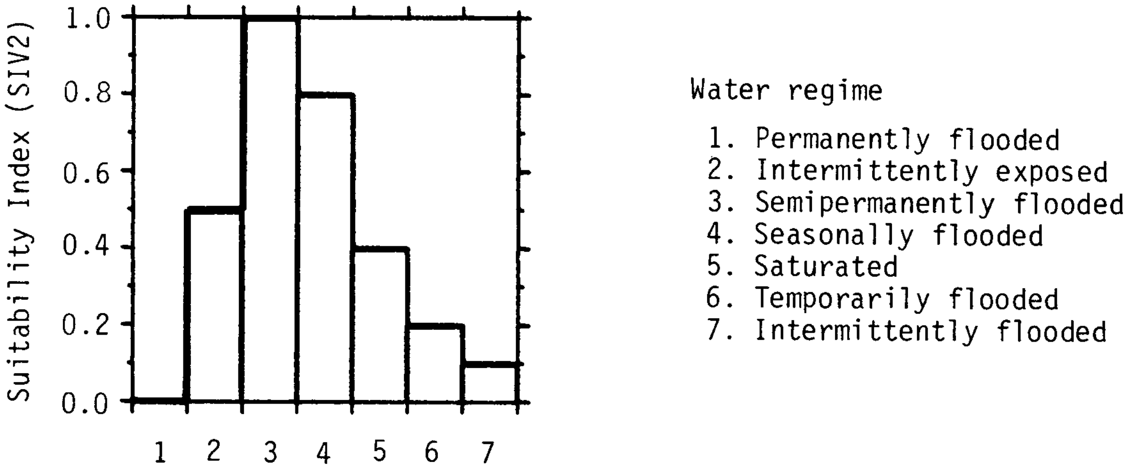

Figure 3. Relationship between water regimes of wetlands (Cowardin et al. 1979) located on the evaluation area and suitability indices.

semipermanently and seasonally flooded wetlands will provide reliable water sources but are still shallow enough to support emergent hydrophytes and crane use. Using the same logic, intermittently flooded wetlands do not exhibit a reliable water source and are of limited value, whereas wetlands permanently flooded are probably too deep for crane use and emergent herbaceous hydrophyte growth. Intermittently exposed, saturated, and temporarily flooded wetlands are assigned ranks assumed to reflect water permanence and resultant suitability as crane habitat. Artificially flooded wetlands, or those sites where the amount and duration of flooding is controlled by man, are not addressed in Figure 3. Model users dealing with artificially flooded wetlands are encouraged to assign ranks that best approximate the definitions presented in Table 2.

The minimum amount or percent of the area required in wetland is unknown, but for some areas in southern Idaho, Drewien believes that a direct relationship exists between the presence and the amount of wet meadow and the occurrence and extent of crane nesting activity (R.C. Drewien, Idaho Cooperative Wildlife Research Unit, Moscow, ID; pers. comm. in Wilson 1983). The maximum amount or percent of wetland required in an area is also unknown.

Wilson (1983) indicated that the presence of some (minimum of 60.8 ha/km segment) upland meadow adjacent to wet meadows along willow-lined streams increased the probability of high densities of nesting cranes.

Uplands are also important crane-use areas around large marshes such as Agassiz (J. DiMatteo, Agassiz National Wildlife Refuge, Middle River, MN; letter dated September 12, 1985), Grays Lake (Drewien, unpubl.), Malheur (C.D. Littlefield, Malheur National Wildlife Refuge, Burns, OR; letter dated September 16, 1985), and Horicon NWR's (Swengel, unpubl.). Croplands adjacent to wetlands are important food sources, and are more valuable to cranes than forested wetlands of comparable size (DiMatteo, unpubl.; J. Bartelt, Wisconsin Department of Natural Resources, Horicon Area Headquarters, Horicon, WI; letter dated September 17, 1985).

I have assumed that a mixture of cover types that includes 40% to 60% of the area in wetlands has the highest potential suitability for supplying the food/reproduction needs of nesting sandhill cranes (SIV3, Figure 4). Although some threshold response may occur as the percentage of wetlands in an area increases (Swengel, unpubl.), I have elected to represent the relationship between 0 to 40% wetland as linear. Areas supporting >60% wetlands are assumed to decrease in value because of the reduced area of upland available, but I

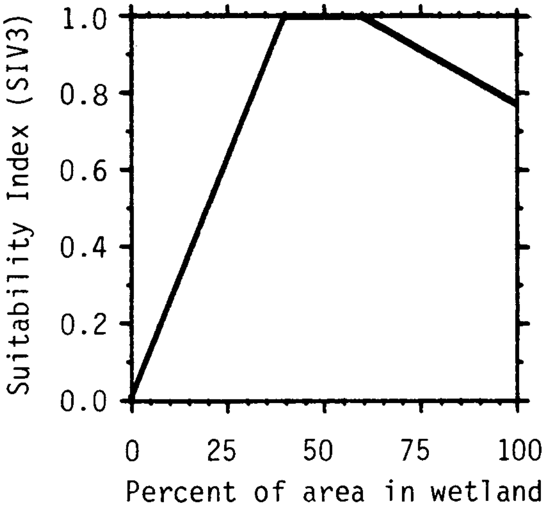

Figure 4. Relationship between the percent of the evaluation area in wetland and the suitability index.

have arbitrarily limited the reduction in value to a maximum of 0.25 (SIV3 = 0.75 at 100% wetland). It is further assumed that all uplands can be classified as agricultural (cropland, grassland, or hay/pasture), forested (deciduous and/or evergreen), or nonforested (all other upland types) and assigned suitability indices equal to emergent, forested, or scrub-shrub wetlands (Figure 2), respectively.

An area free from human disturbance is the second most commonly cited criterion used to describe crane habitat. Human activities can take a variety of forms and can occur at any time, but cranes are most intolerant of disturbance during the nest initiation-incubation period (Drewien, unpubl.; Littlefield, unpubl.). For example, fishermen can cause cranes to desert their nests (Bieniasz 1979; Drewien, unpubl.), and the presence of motorized boats lowers the potential suitability of wetlands as crane habitat (Swengel, unpubl.). Road construction can be highly disruptive to nesting cranes (Littlefield, unpubl.).

This model does not attempt to address all potential disturbances to nesting cranes. Instead, I have assumed that the potential for human disturbance to nesting cranes can be represented by existing or proposed roadways. Historically, cranes selected large marshes or isolated bogs for nest sites and were intolerant of any human disturbance (Walkinshaw, unpubl.). Now, however, many local populations are expanding and utilizing wetlands in close proximity to human developments such as roadways. This is especially true for the Eastern population where cranes now nest within 100 m of roadways in parts of Minnesota (DiMatteo, unpubl.), Wisconsin (Bartelt, unpubl.; Hunt, unpubl.), and Michigan (Hoffman, unpubl.). Crane response to roadways appears to depend on the intensity and timing of vehicular and foot traffic (DiMatteo, unpubl.; Drewien, unpubl.), the pair's prior experience with man (Hoffman, unpubl.; Walkinshaw, unpubl.), the presence or absence of concealing vegetation (Drewien, unpubl.), and probably numerous other considerations beyond the scope of this model.

I have assumed that the potential for human disturbance to nesting cranes can be represented in this model with a 100 m band on either side of existing or proposed roadways. The area within this zone of influence should be considered as unusable habitat during the period encompassing nest initiation through hatching. This period will vary with location but usually occurs in the months of April, May, and June. Users of this model are encouraged to modify the width of the zone of influence around roadways if they do not feel that 100 m adequately reflects local crane population response to human activity.

Inherent in the concept of a disturbance-free area is size. The smallest reported wetland used for nesting by greater sandhill cranes is 0.2 ha in the Hiawatha National Forest (Taylor 1976). An area of this size, however, probably could not supply all the food/reproduction needs of the pair and their colts. The minimum area assumed suitable for supplying food/reproduction requirements in this model is 16 ha (Drewien 1973; Wilson 1983) (Figure 5). Note that this assumption is not restricted to wetlands but includes all cover types within the evaluation area. The size of an area required to equate to optimum habitat conditions is unknown. For the purposes

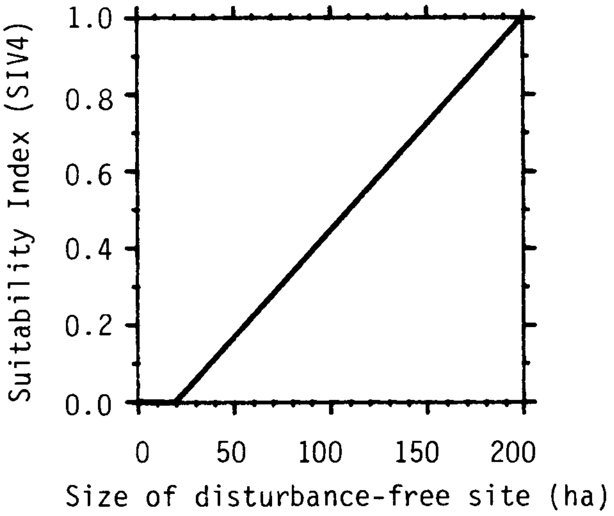

Figure 5. Relationship between the size of an evaluation area and its suitability index.

of this model, a contiguous area of 200 ha or more was arbitrarily selected as the minimum size capable of supplying optimum conditions for the food/ reproduction requirements of nesting greater sandhill cranes (Figure 5). Two hundred hectares is the approximate area remaining after a 100 m zone of influence is removed from around most standard (259 ha) sections.

HSI determination. The mathematical relationships between model variables were selected to mimic the assumed range of conditions from marginal suitability to optimum habitat. The suitability indices of the variables evaluating wetland class (SIV1) and water regime (SIV2) are assumed to be compensatory, with a high value for one variable compensating for a low value in the other. The two remaining variables serve to modify this compensatory relationship. Applications of this model that produce a 0.0 value for any of the four variables should be interpreted as indicating that the evaluation site is unsuitable for breeding greater sandhill cranes.

Determination of an HSI requires the delineation on a cover map of the area to be evaluated for crane use. The model assumes that a 100 m band along both sides of active roadways is unusable to greater sandhill cranes. An active road is defined as any mappable feature capable of supporting terrestrial vehicular traffic from late March through June. This unusable area should be identified and removed from consideration as crane habitat before attempting to apply the model.

The evaluation site should be stratified into cover types defined by wetland class (Figure 2) and water regime (Figure 3), or if upland, as cropland, grassland, hay/pasture, or as forested or nonforested. The area of each cover type should be determined and used to compute a wetland quality index (WQI) with equation 1:

$$\mathrm{WQI} = \frac{\sum_{i=1}^{n} (\mathrm{SIV1}_i \times \mathrm{SIV2}_i)^{1/2} \times \mathrm{WA}_i}{\mathrm{TWA}} \qquad (1)$$

where n = the number of wetland cover types in the evaluation area

$\mathrm{SIV1}_i$ = the suitability index (SIV1) for wetland class of wetland cover type i

$\mathrm{SIV2}_i$ = the suitability index (SIV2) for the water regime of wetland cover type i

WA_i = the area in wetland cover type i

TWA = the total area of all wetlands in the evaluation area

The WQI should then be adjusted to reflect the value of existing wetlands for the total evaluation area (TWQI) using equation 2:

$$\mathrm{TWQI} = \mathrm{WQI} \times \mathrm{SIV3} \qquad (2)$$

Assessment areas that are composed entirely of wetlands and are ≥200 ha have an HSI equal to TWQI. If uplands occur on site, however, or the usable area is <200 ha, then additional steps are required to determine HSI.

Uplands are assumed to contribute to the overall food/reproduction component of crane habitat suitability. The upland value (UV) for assessment sites containing at least some upland area can be determined using equation 3:

$$UV = \frac{\sum_{i=1}^{n} (UA_i \times V_i)}{TUA} \tag{3}$$

where n = the number of upland cover types in the evaluation area

UA_i = the area in upland cover type i

V_i = the index value for upland cover type i where agricultural (cropland, grassland, or hay/pasture) = 1.0; forested = 0.1; or nonforested = 0.4

TUA = the total area of all uplands in the evaluation area

The suitability of the food/reproduction component (SIFR) for the assessment site is determined by combining the values for both wetlands and uplands using equation 4:

$$SIFR = \frac{TWQI + UV}{2} \tag{4}$$

Areas ≥200 ha have an HSI equal to SIFR. For areas <200 ha, however, the value should be reduced using equation 5:

$$HSI = SIFR \times SIV4 \tag{5}$$

Application of the Model

Summary of model variables. Four habitat variables are used in this model to estimate habitat suitability for breeding greater sandhill cranes. The variables attempt to characterize the importance of an evaluation site in terms of wetland classification, water regime, percent wetland coverage, and size (Figure 6). Definition of habitat variables and suggested measurement techniques (Hays et al. 1981) are presented in Figure 7. Estimates for all four variables can be obtained from good quality aerial photographs that have had their wetlands classified according to Cowardin et al. (1979).

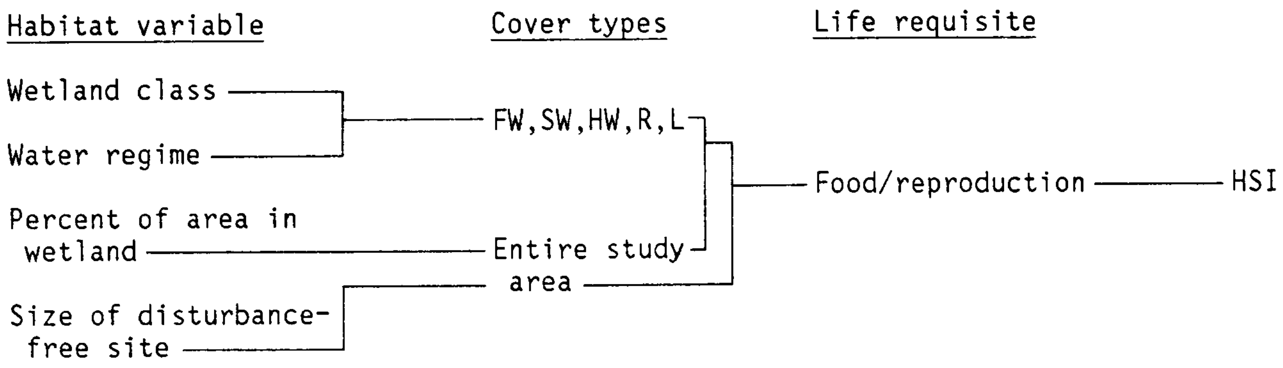

Figure 6. Relationships of habitat variables, cover types, and life requisites to the HSI for greater sandhill crane habitat.

Habitat variable	Cover types	Suggested techniques
Wetland class (description of the general appearance of the wetland in terms of either the dominant vegetation life form or the physiography and composition of the substrate as defined by Cowardin et al. 1979).	FW,SW,HW,R,L	Remote sensing, on-site inspection, National Wetland Inventory maps
Water regime (the permanence of water in a wetland as defined by Cowardin et al. 1979).	FW,SW,HW,R,L	Remote sensing, on-site inspection, National Wetland Inventory maps
Percent of area in wetland land (the area of wetland cover types in the evaluation area divided by the total area).	All	Remote sensing, planimeter, dot grid, on-site inspection, National Wetland Inventory maps
Size of disturbance-free site (the area of all cover types potentially usable by cranes that is at least 100 m from any existing or proposed roadway).	All	Remote sensing, planimeter, dot grid, on-site inspection, National Wetland Inventory maps

Figure 7. Definitions of variables and suggested measurement techniques.

Example application. Stern et al. (1987) recently presented data for Sycan Marsh, Oregon, that I have modified to exemplify model application. The example study area occupies approximately 9,300 ha that I have classified as an emergent wetland/upland complex. Within the emergent wetland, I have classified 1,395 ha as semipermanently flooded, 4,650 ha as seasonally flooded, and 1,860 ha as temporarily flooded. There are 1,395 ha of upland designated as agricultural (grassland) for this exercise. I have assumed that the entire 9,300 ha are usable by greater sandhill cranes because no roads currently exist in the study area.

The HSI for this example study area can be determined by incorporating the above information into equations 1-4. Only one wetland class occurs on the study area, emergent wetland (SIV1 = 1.0), but three different water regimes (SIV2) are represented. The wetland quality index (equation 1), therefore becomes [(1.0 x 1,395) + (0.89 x 4,650) + (0.45 x 1,860)]/7,905, or WQI = 0.81. Because some uplands occur on the study area, WQI is modified by equation 2 to yield TWQI = 0.69. The single upland cover type in this example receives an upland value of 1.0 (equation 3); UV is then combined with TWQI in equation 4 to obtain an estimate of study area suitability for food/reproduction (SIFR = 0.85). Because the study area is >200 ha, equation 5 is not required; HSI = SIFR.

Model assumptions. This model was developed from information obtained from the published literature, reports, and communications with professional biologists familiar with the species and its habitat requirements. The model attempts to identify those biological relationships assumed most important in explaining habitat potential, and then attempts to convert those relationships into algorithms that yield a single index of habitat suitability ranging in value from 0.0 to 1.0. This index is intended for use in land-use planning where the primary objective(s) involves comparisons of habitat potential between sites at the same point in time, or for the same site at different points in time. Correspondence between model output and short-term estimates of density, productivity, or other population parameters dependent on factors not addressed in this model should not be expected.

The model assumes that optimum habitat conditions for nesting can be supplied by extensive wetland/upland complexes such as those presently existing at Malheur, Grays Lake, and other large National Wildlife Refuges and State Wildlife Management Areas throughout the current breeding range of the greater sandhill crane. Optimum is defined by factors that attempt to maximize the number of breeding pairs, and nests, per unit area under management.

A management strategy that attempts to maximize breeding pairs and nests, however, may also increase the probability of predation, disease, or other density dependent mortality factors detrimental to local crane populations. Predation rates, for example, can be high in some local populations. A composite nest success of 29.8% was estimated at Sycan Marsh, Oregon, over a 4-year period, but annual recruitment averaged only 4.5% (Stern et al. 1987). This is the same marsh that was used to pattern the example model application in the preceding section, which produced an HSI of 0.85. The model presented in this report was developed to characterize habitat suitability in terms of maximum numbers of nesting pairs on large contiguous wetland/upland complexes; but it does not address nest success or recruitment, which are different performance measures and management objectives. In fact, there appears to be a positive correlation between territory size and the number of pairs successfully fledging two colts in the Great Lakes States (Crete and Grewe 1981). Individuals interested in evaluating nest success or potential recruitment should not expect relevant output when using this model.

The model assumes that large areas (≥200 ha) supporting a mixture of semipermanently flooded emergent wetlands and agricultural land possess the potential to supply optimum levels of the food/reproduction requirements for greater sandhill cranes. The model addresses the influences of human activity by excluding all cover types within 100 m on either side of existing or proposed roadways from consideration as crane habitat. No allowances are made for the potential screening effect of vegetation interposed between potential crane-use areas and roadways. Users should note that cranes are adaptable and, at least in the Great Lakes States, appear to be using smaller wetlands and becoming more tolerant of human activities as the populations of both species increase (Bennett and Nauman 1978; Hoffman 1983).

SOURCES OF OTHER MODELS

The Colorado Division of Wildlife has investigated the potential for reintroduction of greater sandhill cranes into historic nesting areas within the State (Geduldig 1979). The most important criteria identified from occupied sites in northern Colorado were freedom from human disturbance, elevation below 2,896 m, and potential food resources within 0.4 km of willow-lined drainages carrying water through June (Bieniasz 1978). Some of the habitat criteria used to evaluate introduction sites included elevation (<2,896 m), spring snow accumulation and distribution along willow-lined drainages, habitat type (willows, wet meadows, marsh), size of area, adjacent cover types (timber, sagebrush), and potential impact from fishing, hiking, and livestock grazing [Bieniasz (1978) observed that cranes abandon sites used by large flocks of sheep]. No numeric values were assigned to these criteria.

A pattern recognition model (Williams et al. 1977) developed for greater sandhill cranes in southeastern Idaho uses conditional probabilities to relate observed habitat patterns to the potential of a site to support high (6.2 pairs/km^2) or low (0.4 pairs/km^2) breeding crane densities (Wilson 1983). Evaluation criteria include the presence and size of both wet meadow and upland dry meadow, the length of roadway within 400 m of wet meadow, and the relative abundance of willow within the evaluation site. Wilson's (1983) model permits the retention of some habitat value as the length of roadway within 400 m of a wet meadow increases; the model presented in this document assumes no habitat value within 100 m of any roadway.

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A review and synthesis of existing information were used to develop a Habitat Suitability Index (HSI) model for the greater sandhill crane (Grus canadensis tabida). 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 U.S. Fish and Wildlife Service.

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