

APPLICATION OF A SANDHILL CRANE MODEL TO THE MANAGEMENT OF HABITAT ALONG THE PLATTE RIVER

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Abstract: A geographic information system model was used to assess the quantity, quality, and juxtaposition of habitat for sandhill cranes (*Grus canadensis*) and whooping cranes (*G. americana*) in three study locations along the Platte River in central Nebraska. Based on the availability of wide treeless channels, model-predicted roosting habitat for sandhill cranes was greatest (57 ha) at the site with the highest crane-use (Mormon), moderate (30 ha) at the intermediate-use site (Uridil), and lowest (7 ha) at the low-use site (Guyer). Applying a more stringent width criterion for whooping cranes, no roost was predicted at the Guyer site, and only 0.2 ha of roost was predicted at the Mormon and Uridil sites. A Habitat Suitability Index (HSI) was constructed to measure the quantity, location, and preference for feeding and resting habitat. The highest HSI value was calculated for the Guyer site (2.1), where crane use is lower than at the Uridil (1.3) and Mormon (1.5) sites. These suitability values suggest that roosting sites are more limiting to cranes at the Guyer site than upland feeding and resting habitat. Under computer-simulated rehabilitation, roost area for sandhill cranes was increased by 55 ha at the Guyer site and by 18 ha at the Mormon site. Rehabilitation increased whooping crane roost area by 6.5 ha and 3 ha, respectively, at the two sites. HSI values also increased at both Mormon (+5%) and Guyer (+20%) with rehabilitation. Habitat Unit (HU) values, based on the area of roost habitat and the quality of adjoining feeding/resting habitat, corresponded well with crane distributions. Under rehabilitation, HU values for Mormon increased less than those for Guyer, suggesting that the roost and feeding habitat at Mormon is near saturation, and that management there should be directed towards habitat maintenance rather than rehabilitation.

PROCEEDINGS 1985 CRANE WORKSHOP

When European settlers came to Nebraska in the mid-1800's, the Platte was a prairie river bordered by marshes, sloughs, and wetlands. The river channel had a sandy, shifting bed interrupted in a few places by woodland islands and scattered trees along the riverbank. Beyond the wetlands adjacent to the channel, an endless sea of midgrass and shortgrass prairie extended up the slopes for mile upon mile in all directions. Tremendous changes have occurred since settlement. Farming, development, and diversion of the river have altered the traditional habitat of many migratory birds in the valley. Nearly three-fourths of the native meadows and prairies along the Platte have been converted to cropland or developed for homesites, urban communities, or commercial property (Currier et al. 1985). Diversion for irrigation and power generation has reduced the flow in the Platte by two-thirds (Eschner et al. 1981). Peak scouring flows, which shifted the sediment on the streambed and removed young cottonwood (*Populus deltoides*) and willow (*Salix rigida*, *S. amygdaloides*, *S. exigua*) seedlings, now occur only rarely. Tree and shrub communities have developed over an extensive portion of the historic channel and floodplain as a consequence of flow reductions. Much of the native riverine habitat for sandhill cranes, whooping cranes, ducks, geese, least terns, piping plovers, and other species has been lost (Krapu 1981, Currier et al. 1985).

In this paper, a computer model is used to assess the current status of roosting habitat for sandhill and whooping cranes, and to simulate rehabilitation and management proposals. Cranes require open, unvegetated river channels where they can roost at night in safety from predators and human disturbance. Large flocks of cranes congregate in the middle of the river channel, roosting on shallowly flooded (5 to 30 cm) sandbars. River segments with an unobstructed width (no woody vegetation to obstruct the view from the roost site) of at least 150 m are preferred by sandhill cranes; whooping cranes prefer even wider channels of 300 m or more (Krapu et al. 1984, Johnson and Temple 1980).

During daylight, the cranes feed and rest in alfalfa, native grasslands, and a variety of croplands (primarily corn) within a relatively short distance of the river roost. Individual sandhill cranes stay along the Platte for about 4 weeks during the spring staging period in March and April. Whooping cranes use the Platte during spring (April) and fall (October-

November) migration. Four-fifths of the continental population of sandhill cranes and all of the Aransas (Texas)-Wood Buffalo (Canada) flock of whooping cranes (about 95 birds) migrate through Nebraska twice each year.

The Platte River Whooping Crane Critical Habitat Maintenance Trust was created in late 1978 following a lawsuit over the construction of Grayrocks Dam and Reservoir in Wyoming. The Trust preserves, manages, and monitors habitat for all species of migratory birds along the Big Bend stretch (Overton to Chapman) of the Platte River in central Nebraska (Fig. 1). Management efforts are currently directed toward maintenance and improvement of habitat for endangered and threatened species (whooping crane, bald eagle, least tern, piping plover) and species which occur in great concentrations (sandhill crane, ducks, geese). The analysis presented here is a part of the Trust's management efforts.

STUDY AREA

The three study sites are 8-km segments of the Platte, near Overton (Guyer site), Wood River (Uridil site), and Grand Island (Mormon site) (Fig. 1). The Mormon site is part of Mormon Island Crane Meadows, and is currently managed as a migratory bird preserve. The Guyer and Uridil sites are being rehabilitated to provide habitat for migratory birds.

The Guyer site is characterized by a series of large, forested river islands (31% cover) dominated by cottonwood, red cedar (*Juniperus virginiana*), rough-leaf dogwood (*Cornus drummondii*), and false indigo-bush (*Amorpha fruticosa*). Historically, large concentrations of sandhill cranes have used this river segment (Currier et al. 1985), but broad, treeless stretches of river channel are no longer common, and cranes now roost there in relatively low numbers (625 cranes per km, U.S. Fish and Wildlife Service, unpublished data). There were extensive wetland meadows and grasslands south of the river at this site before 1979, but since then, many have been converted to cropland. Wetland meadow, grassland, and alfalfa account for 35% of the land cover in this segment.

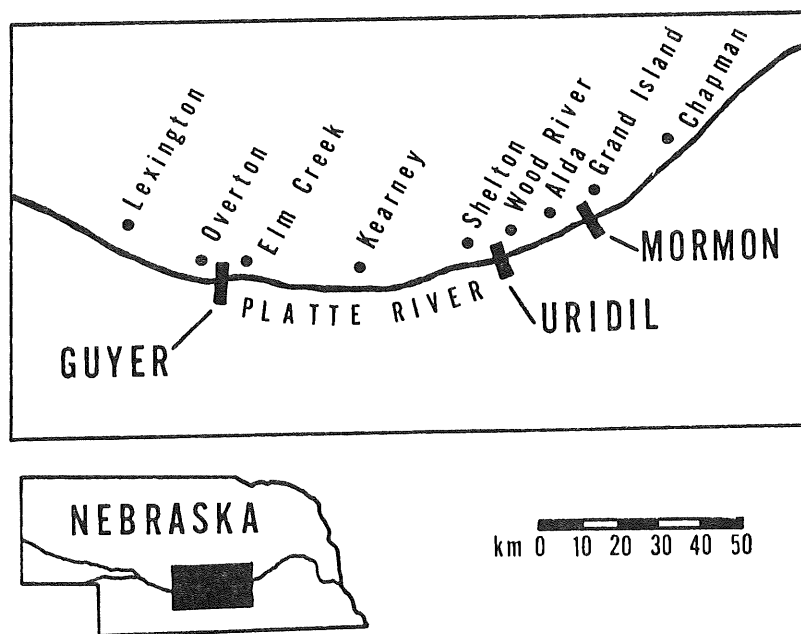


Fig. 1. Location of three study sites on the Platte River in central Nebraska.

Woodlands are also common at the Uridil site (18.8% cover), but the channel is less braided and more open than at Guyer. Although there are large forested islands in the segment, there is a treeless main channel (0.4 km wide in several locations) in which cranes roost in moderate to high numbers (6,250 cranes per km, U.S. Fish and Wildlife Service, unpubl. data). Five adult whooping cranes were sighted on the river at this location in October 1983 (Lingle et al. 1984). Wetland meadows, grasslands, and alfalfa fields account for 21% of the land area at this site.

At the Mormon site, the river flows in one main channel to the south and four smaller channels to the north. The main river channel is relatively free of woody vegetation and it provides one of the best roost sites for sandhill cranes along the Platte River (12,500 cranes per km, U.S. Fish and Wildlife Service, unpublished data). Wetland meadows, grasslands, and alfalfa fields (49% cover) dominate the vegetation in this segment. Woodland vegetation accounts for only 10% of the vegetative cover.

METHODS

The Trust and the U.S. Fish and Wildlife Service's Western Energy and Land Use Team (WELUT) cooperatively developed a geographic database for the 128-km stretch of the Platte between Overton and Chapman in 1982. The database was processed using the Map Overlay and Statistical System (Lee et al. 1985). A model was developed by Armbruster and Farmer (1981) to evaluate the database in accordance with the habitat requisites of the sandhill crane. The crane model was based on data gathered from North American crane experts and the Platte River Ecology Study (Krapu 1981).

Cranes avoid various human disturbances such as roads and buildings. Disturbances and buffer zones around disturbances were eliminated as potential habitat in the initial step of the model. Different types of disturbances received different buffer zone widths based on the severity of the disturbance (Armbruster and Farmer 1981). The product of the first step of the model was a map of disturbance-free habitat within each study area.

Relatively wide river channels are preferred by cranes for roosting. The second step of the model mapped suitable roost areas as those disturbance-free portions of the river channel having a minimum unobstructed width of 150 m for sandhill cranes and 300 m for whooping cranes. The methodology used to accomplish this step is described in Currier et al. (1985).

Diurnal feeding and resting activities of cranes are centered around the nocturnal roost. The third step of the model determined the quantity of feeding and resting habitat types, (i.e., wet meadow, grassland, alfalfa, cropland) within a series of 0.4 km-wide concentric bands around the predicted roost area. A habitat suitability index (HSI) for each feeding and resting habitat type was then calculated by the following equation:

$$HSI = \frac{\sum_{i=1}^{11} [(AHT_i) (DW_i) (HW)]}{TA}$$

where i = the distance-from-roost band ($i=1,2,\dots,11$)
 AHT_i = area of the habitat type in distance band i
 DW_i = weight given to distance band i
 HW_i = weight given to the habitat type
 TA = total area of study area.

Distance weights (DW_i) are presented in Table 1. Habitat closer to roost areas was given greater weight than habitat farther away. Habitat weights were based on time-budget and food habits data collected for sandhill cranes. The same weights were used in modeling whooping crane habitat, because similar data for whooping cranes were not available. The habitat type weights (HW) were calculated by the following equation:

$$HW = \frac{(\% \text{ time budget in habitat}) \times (\% \text{ time feeding in habitat})}{(\% \text{ dry weight of diet obtained in habitat})}$$

HSI values were used to compare feeding and resting habitat surrounding roost areas in the three study areas. Habitat Units (HU) were calculated to combine HSI values with the predicted

Table 1. Distance weighting values used in the sandhill crane model. The inverse of the midpoint of each distance class (in miles) was used to determine the weights.

Distance band	Distance		Weight (unitless)
	(km)	(mi)	
1	0 -1.61	0 -1.00	1.00
2	1.62-2.01	1.01-1.25	0.89
3	2.02-2.41	1.26-1.50	0.73
4	2.42-2.81	1.51-1.75	0.62
5	2.82-3.22	1.76-2.00	0.53
6	3.23-3.62	2.01-2.25	0.47
7	3.63-4.02	2.26-2.50	0.42
8	4.03-4.42	2.51-2.75	0.38
9	4.43-4.83	2.76-3.00	0.35
10	4.84-5.23	3.01-3.25	0.32
11	5.24-5.63	3.26-3.50	0.30

amounts of suitable roost areas into a single measure of habitat quality and quantity. HSI values were scaled to between 0.0 and 1.0 by dividing by the maximum HSI value for each width (150 m and 300 m). HU were then derived by multiplying hectares of roost by the scaled HSI values.

Simulated Habitat Changes

The database was manipulated to simulate management activities designed to improve habitat for sandhill and whooping cranes at the Mormon and Guyer sites. Trees and shrubs were cleared from riverine roost sites, specific disturbance features were removed or buffered, and wetland meadows were recreated. The model was then used to map new riverine roost sites and recalculate habitat suitability indices in order to measure the effects of the simulated management activities.

At the Guyer site roosting habitat was expanded by removing 140 ha of woodland. Upland feeding and resting habitat was improved by reseeding 390 ha of cropland to native grass and recreating 81 ha of wetlands. Simulated wetlands were represented as rectangular bands in the model calculations rather than according to drainage patterns. This representation did not change model calculations but simplified the simulation. The following disturbance features were removed: a gravel operation on the north bank of the river (5 ha), a gravel road (16 ha), and a homestead (5 ha).

Less extensive changes were simulated at Mormon. Woodlands were removed (39 ha) along the main channel and two smaller channels to the north. About 165 ha of wetland meadow were recreated by converting alfalfa fields to native grass. Disturbances were not eliminated at Mormon, and in one situation, woodlands adjacent to the channel were left in place because they screened a number of river roost sites from a disturbance.

RESULTS AND DISCUSSION

Roosting Habitat

At the 150 m width, roost area at Mormon (57.1 ha) was nearly double that at Uridil (30.2 ha), and 8 times the roost area at Guyer (7.1 ha, Table 2). No roost habitat was provided at the 300 m width at Guyer, and only 0.2 of roost existed at Mormon and Uridil at this width. Figs. 2, 3, and 4 illustrate the roost sites predicted by the model at Guyer, Uridil, and Mormon for sandhill (150 m width) and whooping (300 m width) cranes.

At Uridil, roost sites formed an almost continuous band along the main channel in the eastern portion of the segment at the 150 m width. Little roosting habitat was predicted in the western portion of the segment where there is greater encroachment of the river channel by

Table 2. Hectares of river roost available at a minimum unobstructed width of 150 m and 300 m in 1982 and under rehabilitated habitat conditions.

Location	1982 condition		Rehabilitated	
	150 m	300 m	150 m	300 m
Uridil	30.2	0.2	NA	NA ^a
Guyer	7.1	0	61.7	6.5
Mormon	57.1	0.2	74.7	2.8

^a No rehabilitation examined.

forest vegetation and more disturbance (roads, powerline, bridges). One area in the middle of the segment met the 300 m width requirement for whooping cranes, and, in fact, this site was selected by five adult whooping cranes for an overnight roost in October 1983. This area has been kept clear of woody vegetation for over 20 years to improve waterfowl hunting.

Substantial improvements in roosting habitat were predicted at Mormon and Guyer following computer-simulated rehabilitation. Nearly 18 ha of roost at the 150 m width was created at Mormon with the removal of 13 ha of woodlands (1.4 ha of roost for every 1.0 ha cleared). At the 300 m width there was a 2.6 ha increase in roost area. Habitat improvement at the Guyer site was even better. At the 150 m width, roost area expanded 54.6 ha (8 times that available in 1982), but 150 ha of woodland was removed to achieve this increase (0.4 ha roost per 1.0 ha of woodland cleared). At the 300 m width, clearing created 6.5 ha of roost area; no roost was available at this width before clearing.

The ratio of new roost area to cleared area is lower at the Guyer site because of an assumption made in the model. Unlike the situation at Mormon, trees and shrubs at Guyer are growing on raised river islands. These islands will probably not provide suitable roosting habitat immediately following clearing. Without stabilizing vegetation, however, cleared islands will begin to erode, gradually creating new roost sites on the riverbed. In the model calculations, it was assumed that 25 m within the perimeter of each cleared island would revert to river channel and become potential roost habitat.

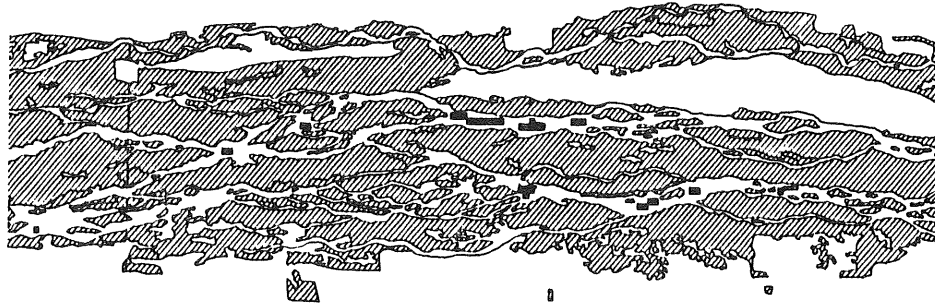
Under rehabilitation, more roost area meeting the 300 m width criterion was predicted at Guyer than at Mormon, even though there was more roost at Mormon at the 150 m width. Variation in channel morphology at the two sites undoubtedly accounts for this difference. The main roosting channel at Mormon is 0.4 km wide, while the channel at the Guyer site is nearly 1.6 km in width. Based only on channel configuration, roost area at a width of 300 m could be potentially four times greater at Guyer than at Mormon. Complete rehabilitation would be difficult to achieve, however, because the river channel at Guyer is heavily encroached with forest vegetation.

Habitat Suitability

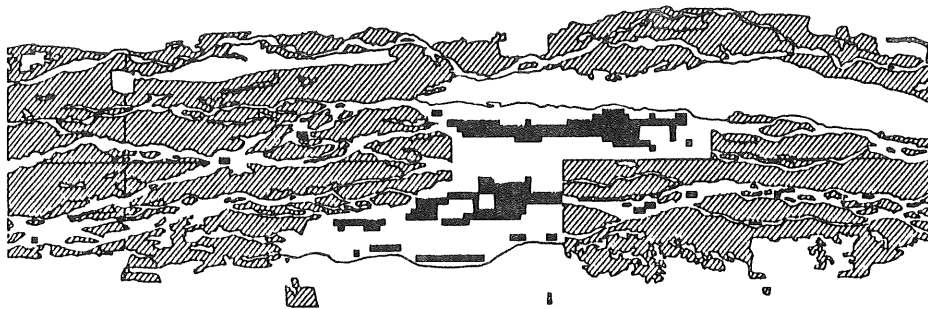
The suitability of feeding and resting habitat surrounding model-predicted roost sites was assessed following a determination of habitat weights. These weights were based on time budget and dietary data for sandhill cranes (Krapu 1981, Iverson, Vohs, and Tacha, unpubl., Habitat use by mid-continent sandhill cranes during spring migration) and calculated according to the equation presented above.

During daylight hours, sandhill cranes usually feed and rest in grasslands and croplands within 5.6 km of their river roost. Most of their nutrition (96% of the diet) is derived from waste corn. Snails, earthworms, beetles, and other invertebrates comprise the remaining 4% of the diet. Although invertebrate foods account for a relatively small proportion of the diet, sandhill cranes spend 42% of their diurnal time budget in the habitat types from which they derive these food items (27% in grasslands and 15% in alfalfa) (Krapu 1981). Fifty-five percent of their time was spent in cropland, where they obtained most of their diet. Sandhill cranes did not feed continuously in either grasslands or croplands. In alfalfa, grassland, and cropland, 50%, 39%, and 36% of the time, respectively, was spent feeding.

Based on these data, the habitat weight (HW) for grassland and alfalfa was 430.5, and that for cropland 22.3. This indicates that for the percentage of diet obtained, cranes spend a disproportionate amount of their time feeding in grasslands and alfalfa. The value of grasslands and alfalfa relative to croplands is the ratio of their HW values or about 19 to 1.



GUYER 1982 - 150 m



GUYER REHABILITATED - 150 m



GUYER REHABILITATED - 300 m

0 0.8 1.6 km

Fig. 2. Woodland (shaded) and model-predicted roost sites (black) at Guyer. Roost sites increased substantially following the simulated removal of woodlands in the center of the segment. There were no roost sites predicted at the 300 m width under 1982 conditions.

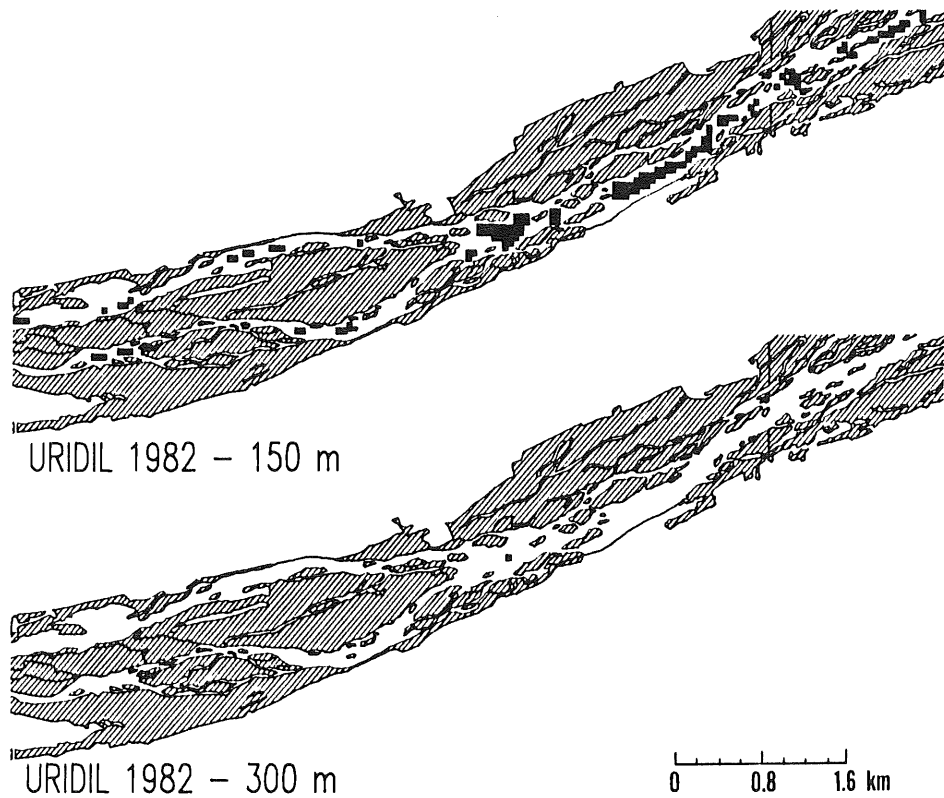


Fig. 3. Woodland (shaded) and model-predicted roost sites (black) at Uridil. Rehabilitation was not simulated at this site. The arrow indicates the only habitat predicted at the 300 m width (0.2 ha). Whooping cranes roosted in close proximity to this roost cell in the fall of 1983.

Grasslands with standing water (i.e., wet meadows) appear to be more important to cranes than other grasslands. Iverson et al. (unpubl.) found on the North Platte River that sandhill cranes showed a preference (% use as a ratio of % availability) of 8.7 to 1 for grasslands with standing water. In their studies, cranes spent 7.1% of their time in grasslands with standing water and 27.5% of their time in grasslands without water. Grasslands with water accounted for only 1.3% of the study area while the remaining grasslands accounted for 43.7% of the area. These data suggest that the relative HW for wet meadow (grasslands with water) should be 8.7 times the HW for grasslands and alfalfa. Such a calculation, however, would overestimate the importance of wet meadows, because a mixture of grasslands with and without standing water are included in this habitat type in the geographic database.

Between Sutherland and North Platte there are 23.2 km² of wet meadow in the database. In the same geographic area, Iverson et al. (unpubl.) found 3.38 square km of grasslands with standing water. On this basis, only 15% of the wet meadows in the database should be given a HW greater than the weight for grasslands. The HW for wet meadow was therefore calculated as 15% of 8.7,

times the HW for grasslands (19), or a value of 25. Relative weights for each habitat type were accordingly: corn (1), other crops (1), alfalfa (19), grassland (19), and wet meadow (25).

Habitat suitability Index (HSI) values for the three sites, weighted for distance (DW) and habitat type (HW) are presented in Fig. 5. HSI values for the 150 m width (1.29 to 2.55) were 27 to 49 % larger than those for the same sites and conditions at the 300 m width (0 to 1.85). This difference was expected, because more roost area was predicted at the 150 m width, making the area within 5.6 km of the roost larger as well.

HSI values for Uridil were 20% to 50% lower than the values for Guyer and Mormon. The high percentage composition of cropland at Uridil (72%), and the lack of wet meadows (1.8%) accounts for the lower habitat suitability at this site. HSI values for Guyer were, on the average, 38% to 62% higher than those for Mormon. This difference was unexpected because Mormon hosts nearly 20 times the number of cranes currently found at Guyer. The abundance of alfalfa and grassland (25% cover at the 150 m width) at Guyer is primarily responsible for the greater HSI value, even though wet meadows were more abundant at Mormon (20% cover at the 150 m width). The high HSI values for Guyer suggest that feeding and resting habitat is quite abundant, although roost sites are rather limited at this location.

HSI values were higher following simulated rehabilitation. At Mormon, there was a relatively small increase in HSI value (5%) at the 150 m width, but a substantial increase (39%) at the 300 m width. These increases were primarily the result of converting an alfalfa field near the river channel to wet meadow and the creation of two new roost sites (300 m width) after clearing. At Guyer, wet meadows were increased by 65% under rehabilitation, resulting in an

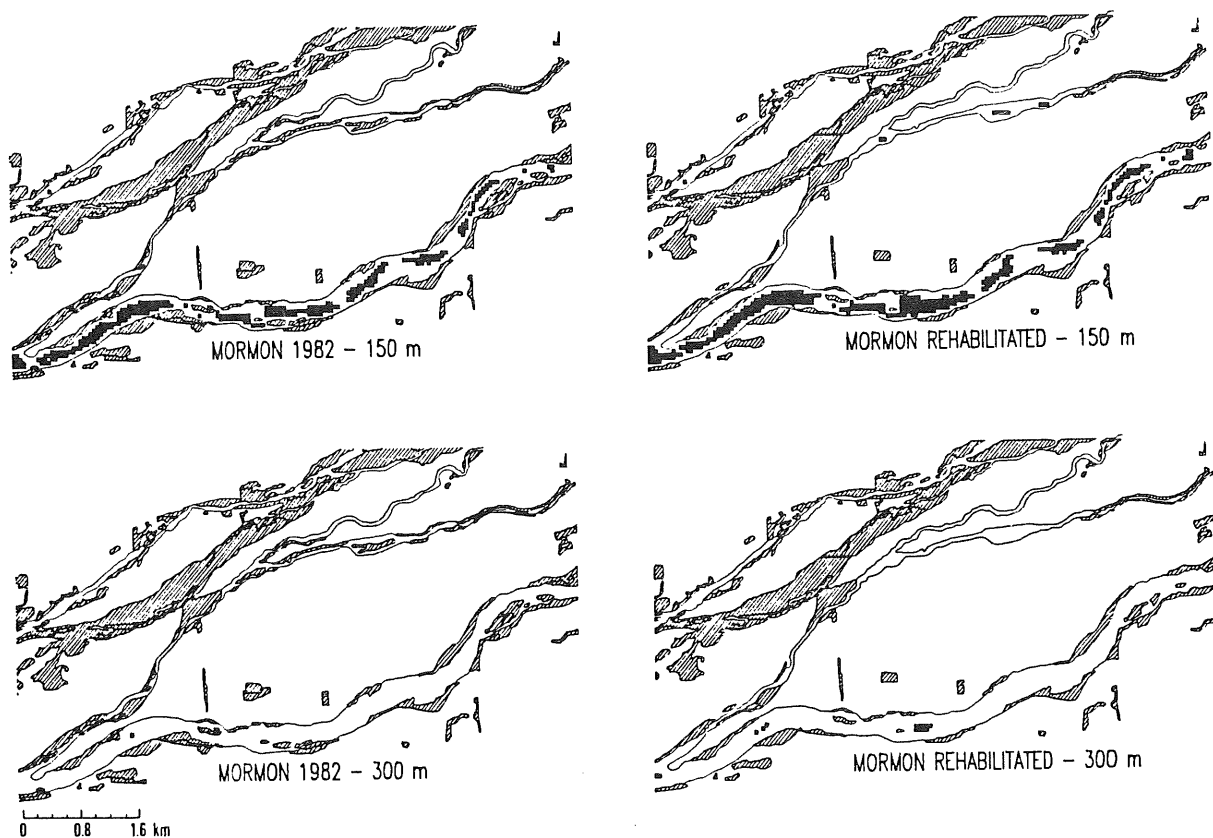


Fig. 4. Woodland (shaded) and model-predicted roost sites (black) at Mormon. Trees and shrubs were removed from one of the north channels under rehabilitation. Along the main channel (south) only shrub was removed in the simulated rehabilitation. Roost site improvement after rehabilitation was more moderate here than at Guyer.

Increase of 20% in HSI value at the 150 m width. HSI values for wet meadow at Guyer were equal or greater than those at Mormon following rehabilitation.

Values for feeding/resting habitat on the uplands and roosting habitat on the river channel were combined into a Habitat Unit (HU) value as a measure of overall habitat suitability at each site. There are a number of ways that the values for feeding/resting habitat could be mathematically integrated with those for roosting habitat. The approach used here and the use of the term "Habitat Unit" was patterned after U. S. Fish and Wildlife Service's Habitat Evaluation Procedures (1980). The HU values presented in Table 3 were derived by multiplying the area of roost habitat by scaled HSI values for feeding/resting habitat. Unlike most Habitat Evaluation Procedures, the area of total available habitat in this instance was restricted to a single habitat type, i.e., model-predicted roost sites.

Habitat area was restricted to roost sites because roost area appears to be the central component of the habitat complex (Krapu 1981, Currier et al. 1985). Although both feeding and roosting habitat are necessary components of the complex, roost sites occupy a much smaller area than feeding/resting habitat and appear to be more limiting to cranes. For example, the loss of large river roost sites along the Platte between Cozad and Lexington (Walkinshaw 1949, Currier et al. 1985), have led to the abandonment of entire river stretches by sandhill cranes, even though some roost sites remain and wetland meadows, grasslands, alfalfa fields, and croplands are abundant adjacent to the channel. Based on these observations, the area of roost habitat was treated as a measure of habitat quantity and the feeding/resting HSI was treated as a measure of habitat quality in the calculation of HU values.

Habitat Unit values (Table 3) at the 150 m width agree well with actual crane use at the three study sites. The HU value was lowest at Guyer (6.0), where only 650 cranes per km are found, intermediate at Uridil (15.4), where there are about 6,250 cranes per km, and high at Mormon (34.3), where crane numbers reach 12,500 per km. At the 300 m width very little roost habitat was provided at any of the study sites. This is reflected in the very low HU values at all three sites (0 to 0.1).

With simulated rehabilitation, HSI values for Guyer surpassed those for Mormon. Comparatively little improvement (40% compared with a 10-fold increase at Guyer) was made in HU value for sandhill cranes (150 m width) at Mormon under the simulated rehabilitation, suggesting that both feeding/resting habitat and roost habitat are near saturation at this site. Expansion of roost sites and cropland conversion did substantially improve the habitat for whooping cranes (300 m width) at Mormon (16-fold increase). These data suggest that management at Mormon should be directed primarily towards maintenance of existing habitat for sandhill cranes with limited rehabilitation of river roost sites where 300 m width habitat can be created for whooping cranes.

At Guyer simulated management suggests that substantial improvements can be made in feeding/resting and roost habitat for both sandhill (150 m width) and whooping cranes (300 m width) by clearing stretches of forest and shrub communities from the river channel and converting croplands near the river to wet meadows. The morphology of the river channel and lack of disturbances at Guyer make this site potentially able to support a larger number of birds than at Mormon. There are, however, no assurances that clearing 8 km of river channel will actually provide habitat approaching the quality of Mormon. A much larger stretch of river channel may have to be cleared to attract such numbers of birds. Mormon attracts so many birds partly because there are extensive stretches of open channel both upstream and downstream, which is not characteristic of Guyer.

The only way to determine if rehabilitation can provide more habitat is to experimentally clear sites and examine the response by cranes and other migratory birds. The Trust has cleared trees and shrubs from the river channel adjacent to Mormon and Shoemaker Islands (Currier 1984). There has been a positive response by least terns to the rehabilitated sites (Currier et al. 1985). Sandhill cranes are again roosting on sandbars and islands that have been cleared of trees and shrubs, but it is not yet clear if crane populations have shifted in response to the clearing (Currier et al. 1985). In recent years, whooping cranes have used two sites on the Platte (the Uridil site and the Audubon Society's Rowe Sanctuary near Gibbon) where woody vegetation was mechanically cleared (Lingle et al. 1984, Lingle et al. 1986). Forest vegetation adjacent to the river channel is also being removed at Elm Creek in an attempt to recreate wet meadows. This clearing operation is similar to that simulated at Guyer, and the response of sandhill and whooping cranes will eventually be evaluated.

Research on the distribution of cranes in the Platte Valley and their preferences for particular habitat types needs to be continued in order to refine and enhance the crane model.

Management of riverine habitat complexes must be undertaken before all the research questions are answered. Already 75% of the prairie and wetlands adjacent to the river, and two-thirds of the riverine roost habitat have been lost (Currier et al. 1985). If the habitat for sandhill and whooping cranes is to be maintained on the Platte, we must take an interactive approach to management, applying current knowledge to present day management, and directing future management according to new research information.

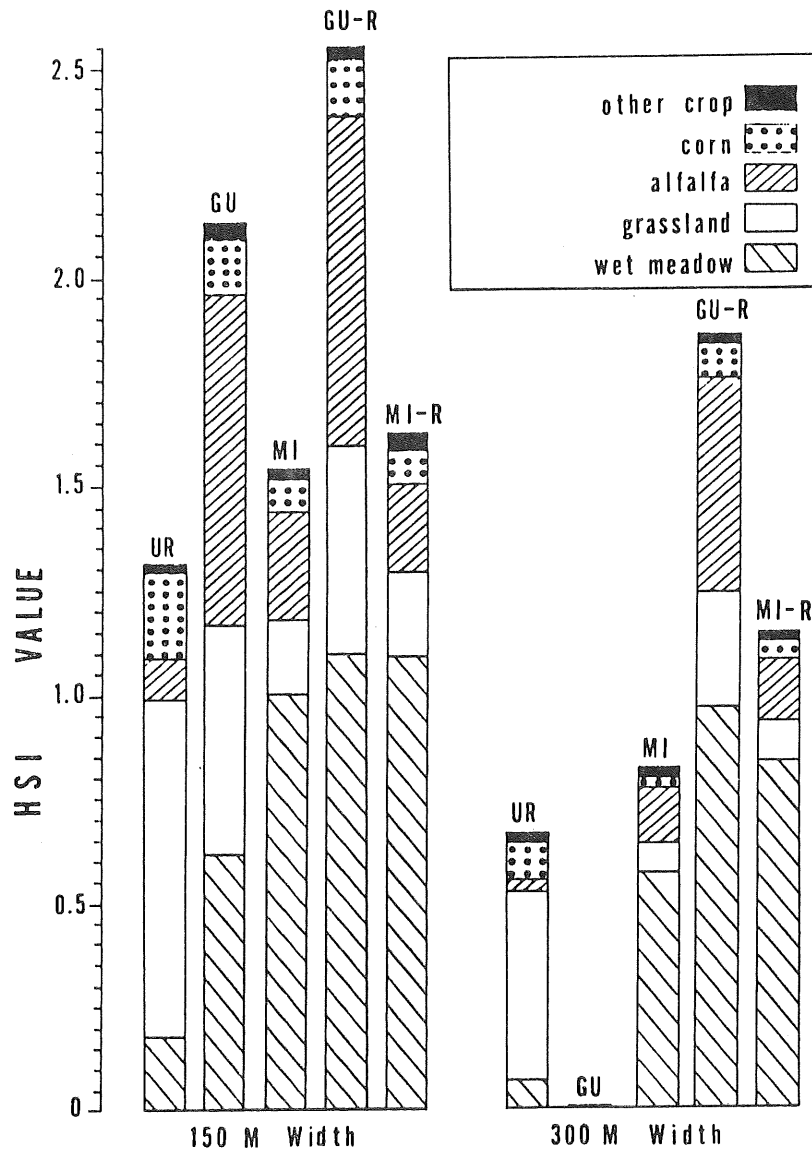


Fig. 5. Histograms of feeding/resting habitat suitability values for Guyer (GU), Uridii (UR), and Mormon (MI) in 1982 and under simulated rehabilitation (R). Histograms to the left are for the 150 m width (sandhill crane habitat). Those on the right are for the 300 m width (whooping crane habitat).

Table 3. Calculation of Habitat Units (HU) as a function of scaled HSI values for upland habitat and roost area.

Location	150 m width				300 m width			
	Total HSI	Scaled HSI	Total roost (ha)	Habitat units (scaled HSI X total roost)	Total HSI	Scaled HSI	Total roost (ha)	Habitat units (scaled HSI X total roost)
Uridil	1.29	0.51	30.2	15.4	0.66	0.36	0.2	0.1
Guyer	2.13	0.84	7.1	6.0	-	0	0	0
Mormon	1.54	0.60	57.1	34.3	0.82	0.44	0.2	0.1
Guyer-Rehab.	2.55	1.00	61.7	61.7	1.85	1.00	6.5	6.5
Mormon-Rehab.	1.62	0.64	74.7	47.8	1.14	0.62	2.8	1.7

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Proceedings 1985 Crane Workshop

LILLIAN ANNETTE ROWE SANCTUARY--MANAGING MIGRATORY CRANE HABITAT ON THE PLATTE RIVER, NEBRASKA

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Abstract: In 1974 the National Audubon Society established the Lillian Annette Rowe Sanctuary to protect and manage habitat for migrating sandhill cranes (*Grus canadensis*) and whooping cranes (*Grus americana*) on the Platte River in Nebraska. During the first decade of management the Sanctuary's grasslands were restored and river channel roosts were maintained. Research conducted during this time led to the development of a new management plan for grassland feeding and river roosting habitats for cranes. The grasslands will be managed by a combination of haying in the fall and prescribed burning in the spring and fall to improve invertebrate populations and reduce vegetative height. The river channel will be kept clear of encroaching vegetation through mechanical clearing by hand crews and experimental burning of cleared islands. Continued efforts to maintain instream flows will be essential to the successful protection of crane habitat on the Platte.

PROCEEDINGS 1985 CRANE WORKSHOP

The National Audubon Society (NAS) established the Lillian Annette Rowe Sanctuary in Nebraska in 1974. This was the first time that lands had been purchased along the Platte River specifically to protect habitat for migrating cranes. However, the Platte has long been recognized for the significant role it plays in crane migration across North America. More than 30 years ago Robert Porter Allen (1952) called for the creation of a refuge for cranes on the Platte and the U.S. Fish and Wildlife Service (USFWS) has designated a portion of the Big Bend region of the Platte as critical habitat for migrating whooping cranes.

Habitat along the Platte River has deteriorated significantly over the past 40 years, and the process of degradation continues. This deterioration was the reason that NAS staff felt it imperative to establish the Rowe Sanctuary. The site chosen for the sanctuary was one of only three portions of the river which were still classified as pristine (Frith 1974). Among the three, the site is the one closest to the heart of the whooping crane migration corridor.

Rowe Sanctuary, located between Gibbon and Kearney, encompasses 810 ha (2000 acres) of land either owned or leased by NAS. Sanctuary lands extend along 6.5 km (4 miles) of the Platte's main channel and include channel habitat and adjacent grasslands. The 324 ha (800 acres) of fee title lands are split evenly between these two major habitats. The proximity of extensive areas of both habitat types makes the area very valuable to the cranes.

First Decade Of Management

At the time of Rowe Sanctuary's acquisition the needs of the cranes while on the Platte were understood in general terms. Simply stated, their critical habitat needs were for open river channel for roosting and productive wet meadows for feeding. Initial management objectives, therefore, were to halt encroachment of vegetation into open river channel and to improve the grasslands. The first objective was met by using manual labor to chop brush on islands near the major crane roosts, as well as on smaller toeheads to prevent them from developing into islands. The work went slowly, but it has succeeded in preserving roosting sites that were used by sandhill cranes.

Restoration of grasslands was also recognized as a long-term effort. The sanctuary's most significant grassland is a 81-ha (200-acre) tract on its western unit. This range was in poor condition due to decades of overgrazing by previous owners. NAS staff were aware that several years of complete rest from either grazing or haying, with occasional spring burns to control exotics and woody invaders, would be needed to restore vigor of this grassland. In recent years, as range condition has improved, portions of the prairie have been hayed to open it up to use by cranes.

The third objective of Rowe Sanctuary's management during the first decade has been to carry out research and monitoring in order to better understand the needs of the cranes and to guide the design of the next phase of management. No fewer than 20 different research projects have been conducted on the sanctuary to date. Most of these were accomplished as part of a 3-year study funded by NAS and conducted by Kearney State College under the guidance of Dr. Harold G. Nagel. This study included inventories of the Sanctuary's flora and fauna, with voucher specimens stored at Kearney State College, as well as research on the Sanctuary's vegetative

ecology, soil invertebrates, island encroachment, and crane habitat usage. Besides funding specific studies on Rowe, NAS has also made the sanctuary available for appropriate and compatible research by others. This has included work by various college students and faculty. portions of USFWS's Platte River Ecology Study, and an instream flow study of the Platte currently being conducted by the Bureau of Reclamation in conjunction with USFWS.

New Management Plan

As a result of findings from research conducted during the last decade, a new management plan has been developed for Rowe Sanctuary, calling for more active management and protection of the sanctuary's resources. Under the new plan, the paramount goal of the management program is to preserve indigenous wildlife and ecosystems of the Platte River. In pursuit of this goal, the plan calls for a broad approach that involves habitat manipulation and monitoring, further scientific research, public education programs, and efforts to maintain the Platte River's flows. As was true at its founding, the primary focus of the Sanctuary's management continues to be protection and restoration of critical habitat for sandhill and whooping cranes, because these are the species that are most uniquely dependent upon the Platte River for their survival. The specific habitat requirements of both crane species during the spring on the Platte can be summarized in two critical needs: (1) nocturnal roosting habitat in the Platte River shallows and (2) diurnal feeding habitat in fields near the river.

Management Of Grassland Feeding Habitat

While on the Platte, sandhill cranes obtain 96% of their daily diet feeding in cornfields, mostly on waste corn left on the ground from the previous year's harvest (USFWS 1981). The remainder of their diet consists mostly of invertebrates found in grasslands. It appears that these invertebrates are an essential source of certain amino acids and minerals which are deficient in corn. Whooping cranes probably have a similar diet while on the Platte, although the exact proportions of different foods are unknown. Although the supply of corn does not appear to be threatened, the grassland feeding sites are endangered, mostly through drainage and conversion to cropland. Consequently, management of Rowe Sanctuary's upland sites is designed to maximize the area of available grassland--wet meadow and prairie--for the cranes.

The grasslands of Rowe Sanctuary are a western extension of the tallgrass prairie, dominated by grasses such as big blue stem (*Andropogon gerardi*), Indian-grass (*Sorghastrum avenaceum*), and switchgrass (*Panicum virgatum*). Prairie cordgrass (*Spartina pectinata*) may dominate in wetter sites. Management of these habitats for cranes involves more than the usual techniques of prairie management. Success of normal prairie management is measured by total plant and animal species composition of the land, but successful prairie management for cranes is measured largely by densities of certain invertebrate species and availability of those invertebrates to the cranes.

Studies conducted on Konza Prairie in Kansas have shown a significantly greater biomass of earthworms (James 1982) and other macroinvertebrates (Seastedt 1984) in the surface soil of tallgrass prairie burned annually for 5 years or more than in tallgrass prairie that has been free of fire for a similar length of time. Consequently, fire management for a healthy, productive grassland should be the first step in crane management. This type of management includes prescribed burning in spring to control cool season grasses and other exotic competitors, including invading woody species. Such prescribed burns are incorporated into Rowe Sanctuary's new management plan.

Regardless of how productive a grassland may be, and no matter how high the densities of soil invertebrates are, the cranes will not use the area if it is covered by tall vegetation. Therefore, a key facet of prairie management for cranes is reduction of the height of the prairie vegetation before the cranes' arrival. Fire has been used successfully in the past to reduce vegetation height and to increase availability of invertebrates for the cranes. Several observers have noted the attraction of both sandhill cranes and whooping cranes to recently burned ground in order to forage for food (Allen 1952, Wheeler and Lewis 1972, USFWS 1981).

Early spring burning along the Platte may be particularly useful in this regard. In early April of 1980 a portion of Rowe Sanctuary's grassland was burned and this management immediately attracted sandhill cranes, which fed on earthworms at the site. Just 5 days later a pair of whooping cranes were foraging on the burned ground. It seems worthwhile to conduct similar burns in the future and to monitor their effects on crane behavior. However, an early

spring burn for the cranes is not particularly useful for controlling cool season exotics and precludes the use of fire in early May when such results can be achieved. Therefore the use of fire for either purpose must occur in different years for any one management unit.

Fall burning of grasslands has been used successfully in other areas for waterfowl management and is worth investigating for crane management on the Platte. However, the conditions for burning in the fall in Nebraska are too often either impossibly wet or dangerously dry and windy. In fact, the likelihood of finding the right conditions for a safe, successful burn anytime between fall and early spring is unreliable at best. However, this is the time when the prairie would have to be burned to open it up for the cranes. Therefore, fire cannot be relied on as the only tool for crane management.

The other two obvious approaches to providing short-stature prairie vegetation are grazing and haying. Each method has its benefits and limitations. For a variety of reasons, Rowe Sanctuary's management plan calls for the use of haying. Several studies have indicated a possible preference by the cranes for pasture lands over hay lands. However, most of these studies have not taken into account the relative amount of wetland habitat within each use area, which may well be an overriding factor. Nagel's (1983) studies in and around Rowe Sanctuary indicated a greater use of pasture lands than of hay lands by sandhill cranes; however, the cranes seemed to concentrate on the wettest sites, which were predominantly in the pastures. Nevertheless, the difference between crane use of pasture and hay lands was not significant. Krapu et al. (1984) collected data indicating greater use of pasture lands than of hay lands by cranes. However, a careful look at the data for 1979 indicates that, in proportion to their availability along the Platte, the cranes actually used hayed prairie more than grazed prairie. Crane preference for hayed or grazed prairie appears to still be an open question.

Grazing is generally preferred over haying as a normal prairie management tool. But regular haying is much more effective than grazing in controlling woody plant invaders, which are the most serious management problem on Rowe Sanctuary's grasslands. Our greatest problems with encroaching woodlands and invading Russian olive (*Elaeagnus angustifolia*) trees have occurred in areas that were grazed exclusively before NAS ownership. Haying also avoids the need for extensive cross-fencing, with its known dangers to cranes. The major problem with haying is that repeated summer haying can reduce the nutrient reserves of grasses. However, this loss of nutrients can be largely avoided by waiting until after 30 September to hay (Nagel 1983), and that is what our management plan recommends.

In order to incorporate all of these various management strategies, as well as to compare different treatment schedules and frequencies, Rowe Sanctuary's largest grassland tract (81 ha) has been divided into four major management units. These four units are located side by side, and each includes all of the major vegetational zones on the prairie in order to better compare the results of management employed on each unit. Each unit receives a different schedule of burning and of fall haying.

The four different fall haying schedules are: (1) haying every year, (2) haying every other year, (3) haying 1 year out of 3, and (4) haying 2 years out of 3. The four different burn schedules are: (1) late spring burn every other year, (2) early spring burn 1 year out of 3 and late spring burn 1 year out of 3, (3) early spring burns 2 years out of 3 and late spring burn 1 year out of 3, and (4) fall burn every other year. The primary reason for using this mix of different haying and burning schedules on four adjacent prairie tracts is to be able to provide the cranes with a combination of different feeding conditions every year, while allowing portions of the prairie to rest in alternating years.

The net result of the combined management schedules on the four major management units is to provide the cranes each spring with up to 40 ha (98 acres) of hayed ground, 18 ha (44 acres) of ground burned in the preceding fall, and 15 ha (37 acres) of ground burned early in the spring. As much as 23 ha (58 acres) of prairie vegetation also will remain standing through winter as wildlife cover that will be burned in the late spring, after the cranes have migrated, to control cool season grasses.

This mix of different haying and burning schedules also allows us to compare the usefulness of each schedule for crane management. Each management unit will be monitored for crane use, invertebrate populations, range condition, and use by other indicator species. In this manner, the health of the prairie in each management unit will be monitored, along with the success of each management schedule in providing suitable feeding habitat for the cranes. After 5 years, the monitoring data will be used to reassess the management plan and to make changes where necessary. The results of other crane management strategies, including grazing, being used

both in the Platte River valley and elsewhere, will also be studied to determine their applicability on Rowe Sanctuary.

Management Of River Channel Roosting Habitat

The other major management challenge at Rowe Sanctuary is the maintenance of river roosting habitat for cranes. The cranes typically roost in broad shallow stretches of the Platte River. Just as they avoid tall vegetation on upland feeding sites, they also avoid areas of tall vegetation when they roost. A site that is suitable for roosting in other respects will generally be avoided by the cranes if it is near either an island or a riverbank with high weeds, brush, or trees. Consequently, clearing such vegetation is essential to the preservation of roosting habitat for cranes.

As in the past, Rowe Sanctuary will rely in the future largely on handcrews of NAS staff, contract labor, and volunteers to clear island vegetation. Although time-consuming and labor-intensive, this method has proven to be both successful and cost effective, because equipment costs are minimal. Under the new management plan efforts will be expanded, beyond simply maintaining existing roosts, to opening up new areas of river channel habitat for roosting, with the ultimate goal of clearing encroaching vegetation from all portions of the channel within the Sanctuary. The Sanctuary staff will also welcome the opportunity to use any heavy equipment that is loaned to us for these clearing operations in the future.

The initial clearing of river islands is only the first step in managing river channel roosting habitat. The second, all-important step, is maintaining those islands free of tall vegetation. With natural succession, a cleared island will quickly revegetate and ultimately require more clearing. Although this natural transition will always be a problem, our goal is to remove the regrowth while it is still small and easily controlled. The most obvious alternatives are repeated mechanical clearing, regular use of herbicides, or annual burning. In the past NAS staff have experimented with burning, and we will continue to do so in the future. If burning proves effective and workable in the long term, it would seem to be the preferred method. It is less labor-intensive and time-consuming than mechanical clearing or herbicide application, and much less costly in equipment and fuel or chemicals. Burning also avoids potential hazards associated with use of herbicides within the river channel.

Initial attempts at island burning on Rowe Sanctuary were either unsuccessful or only partially successful because of lack of fuel to carry the fire. Recently cleared islands had little ground cover beneath the shrub layer. However, in the autumn of 1984 an island that had been cleared 2 years earlier carried what appeared to be a very effective burn. Monitoring of regrowth in 1985 will determine just how effective the fire really was. There was enough grass cover to carry the fire 2 years after clearing. The only areas that failed to burn well were those which had resprouted with shrubs densely enough to shade out the grasses. Portions of islands will undoubtedly have to be cleared a second or even a third time in the future before a successful burn is possible. However, if this repeated clearing results in establishing a dense grass and sedge community over the entire island, it should assure the success of fire management. The work over the next few years should prove the success or failure of this method. In the meantime, we will continue to monitor the success of alternative river management strategies being used by other land managers.

Maintenance Of Instream Flows

No matter how successful Rowe Sanctuary's management of crane habitat is in the short term, the long-term success of all crane management on the Platte River is ultimately dependent upon maintenance of adequate instream flows. Diversion of water from the Platte, primarily for irrigation, has reduced the annual river flows by 70%. As a result, the channels have narrowed, former channels have lost their flow, and former wetlands are now dry. Even if existent flows can be maintained, unmanaged crane habitat on the Platte will steadily deteriorate to the point of uselessness, as has already happened along much of the river. But to make matters worse, plans currently exist for the diversion of all the remaining water in the Platte through a series of proposed water projects.

Any crane management strategy that fails to address the problem of diminishing Platte River flows will not succeed in the long run. Every additional diversion of water will accelerate the deterioration of crane habitat, thus increasing the difficulty and costs of crane habitat management. Therefore, a significant portion of Rowe Sanctuary's management effort is aimed at

monitoring and influencing water policy decisions on the Platte. This effort includes the encouragement of further research on the hydrology and ecology of the Platte River ecosystem, both on and off the sanctuary, increased education and information activities to promote public awareness of the plight of the cranes and the threats to their habitat, and greater involvement in the legal and political processes which will determine the fate of the Platte. But it will require the participation of crane researchers and managers and other interested individuals from far beyond the Platte River Valley to assure the protection of this critical habitat for sandhill cranes, whooping cranes, and other wildlife species.

With adequate flows in the Platte River, Rowe Sanctuary's lands can and will be maintained as high-quality habitat for cranes. Without adequate flows, it is unlikely that any of the critical crane habitat can be maintained for long in the Platte River watershed.

Postscript: On October 21, 1985, three adult-plumaged whooping cranes were observed roosting on the Platte River within the Lillian Annette Rowe Sanctuary. The roost site was in a reach of the river having an unobstructed width of 311 m, one of the widest channels remaining in the central Platte. This reach has been kept wide partially through the repeated mechanical clearing of woody vegetation from islands and riverbanks. This reach is also adjacent to the largest managed grassland on the Rowe Sanctuary. Both the river channel and the prairie in this area are actively managed for cranes.

Whooping cranes have been observed in this general area on at least 2 other occasions since 1974 (U.S. Fish and Wildlife Service 1981). The repeated use of this area by whooping cranes appears to confirm the feasibility of managing river channel and prairie to maintain those habitat conditions favored by cranes.

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STATUS OF WHOOPING CRANE MIGRATION HABITAT WITHIN THE GREAT PLAINS OF NORTH AMERICA

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Abstract: Conditions and potential threats to wetland habitat located within the whooping crane (*Grus americana*) migration corridor and direct hazards encountered by migrating birds are described. Wetland loss, disease exposure, utility line crossings, proposed irrigation projects, and environmental contaminants are among the major causes of concern. Much of the whooping crane migration habitat in the Great Plains has been destroyed and a large area of existing habitat is threatened by development. The question as to the need of critical habitat is discussed. Recommendations for protection of migrating whooping cranes and their habitat are listed.

PROCEEDINGS 1985 CRANE WORKSHOP

Few other bird species have evoked as much emotional furor and controversy as has the whooping crane. Unique to North America, this species has been the topic of discussion among diverse groups ranging from farmers, laymen, and bird enthusiasts to professional ornithologists, politicians, developers, and attorneys. Multi-million dollar lawsuits, commercial enterprises, massive research and educational efforts, and mass media coverage all have the whooping crane as a common denominator.

The Aransas-Wood Buffalo whooping crane population has made a modest "recovery" from a low of 16 individuals in 1941 to 85 individuals in 1984 (Whooping Crane Conservation Association 1984, Aransas National Wildlife Refuge unpubl. data). During the last 12 years this population has increased by about 65%; however, a natural catastrophe or a chemical spill at Aransas NWR could wipe out the entire flock. Their current population status is certainly brighter than it was in the 1940's, but whooping cranes are still wavering on the brink of extinction. Why has there not been a more dramatic increase in whooping crane numbers?

This paper examines the condition of migration habitat and potential threats to existing habitat of the "wild" flock of whooping cranes and recommends actions to reduce those threats.

Appreciation is extended to employees of the U.S. Fish and Wildlife Service for providing information. John VanDerwalker provided critical review of the manuscript. I am grateful to those who made possible my participation in the whooping crane telemetry study which inspired this report.

STUDY AREA AND METHODS

The "wild" flock of whooping cranes winters in the vicinity of Aransas National Wildlife Refuge along the Gulf coast of Texas and nests at Wood Buffalo National Park in northern Alberta and the Northwest Territories. Their migration route is a narrow 3,860 km (2,400 miles) long corridor connecting these two areas (Fig. 1). This distribution of the remaining wild flock is greatly reduced from the former range of this species which included nest records from Saskatchewan, Manitoba, Alberta, Northwest Territories, Illinois, Iowa, Minnesota, and North Dakota (Allen 1952:24 & 27).

To assess the status and potential threats to migration habitat in the Great Plains, government agencies in the United States and Canada were asked to provide information. Also, data were gathered from a literature review.

RESULTS

Wetland loss in the Great Plains

The whooping crane is a large, aquatic bird dependent on wetlands. The destruction of natural wetlands within the Great Plains has occurred at an accelerated rate since the turn of the century. Iowa has lost 99% (from 0.9 million ha [2.3 million acres] to 10,500 ha [26,000 acres]) of its natural wetland acres while North Dakota has lost 60% (from 2 million ha [5 million acres] to 0.8 million ha [2 million acres]) and South Dakota 35% (from 0.8 million ha [2 million acres] to 0.5 million ha [1.3 million acres]) (Tiner 1984). Between 1955 and 1978, 40% of the wetlands in Kansas were destroyed. In Nebraska, 90% (from 38,000 ha [94,000 acres])

to 3,440 ha [8,500 acres]) of the wetlands in the Rainwater Basins (Schildman and Hurt 1984) and 67% of the open channel habitat within the Platte River (Currier et al. 1985) are gone. Agriculture is responsible for 87% of the losses in the United States (Tiner 1984).

The situation in Canada is no better. About 61% of the aspen parkland wetlands in Alberta (Lynch-Stewart 1983) and about 50% of the prairie wetlands of Saskatchewan have been drained (Lorne Scott, pers. comm). An estimated 75% of the natural habitat in Saskatchewan south of the boreal forest has been destroyed (Lorne Scott, pers. comm). Here again, agricultural practices are primarily responsible.

In addition to direct drainage of wetlands, the extermination of the bison (*Bison bison*) affected the availability of migration habitat for cranes and other migratory birds. The excavations made by millions of bison throughout the Great Plains formed ephemeral wetlands. Not only did bison wallows provide brood habitat for waterfowl (Rudd 1974) but they also provided nutrient-rich feeding areas for whooping cranes (Allen 1952:94). The wholesale slaughter of the bison, perhaps once the most numerous ungulate ever to walk the face of this planet, certainly altered the ecology of the prairie. Bison wallows no longer provide habitat for migrating whooping cranes.

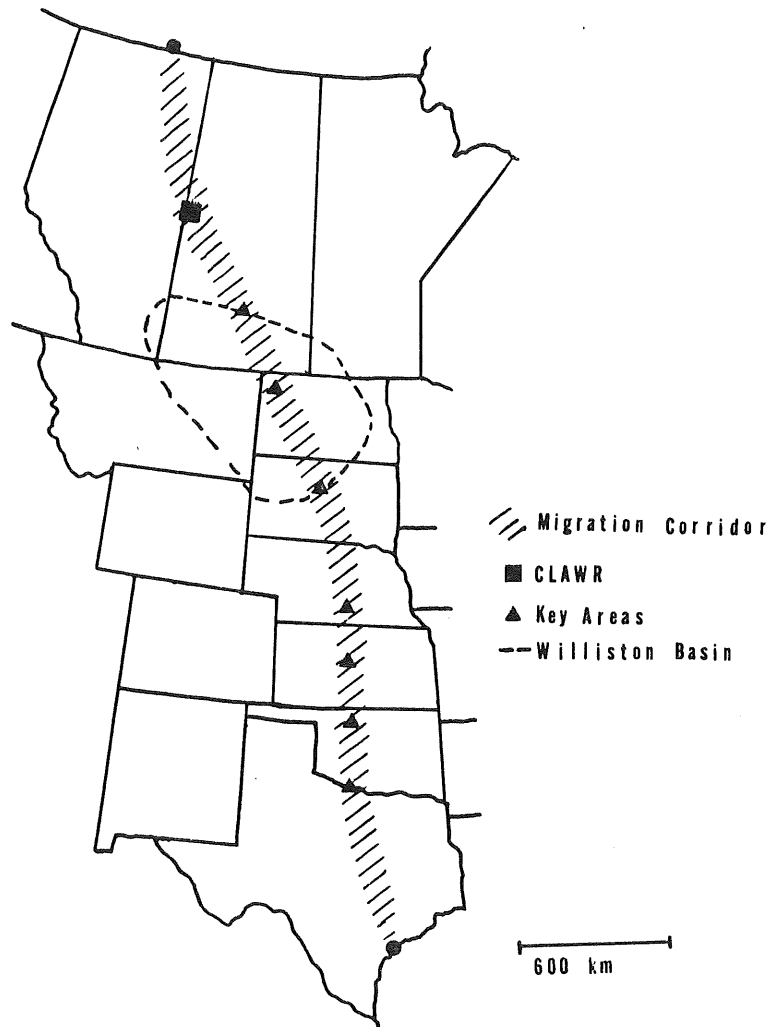


Fig. 1. Whooping crane migration corridor between Aransas NWR and Wood Buffalo National Park, and key stopover areas. The Williston Basin and Cold Lake Air Weapons Range (CLAWR) are illustrated.

Within the prairie states of Nebraska, North and South Dakota, and Minnesota; over 14,000 easements were granted to the Fish and Wildlife Service by 1972 (Mann 1983). This has "protected" more than one-half million wetlands in the Dakota's alone. Unfortunately an entire wetland complex is not always protected and few of them are assured a water supply. Illegal draining and alteration continues despite the easements, and contamination of many of the wetlands is a problem. In the Rainwater Basins of Nebraska, the U.S. attorney signed a consent decree in 1983 submitted by the Tri-Basin Natural Resources District (a local government entity) and local landowners, which effectively prevents the U.S. Fish and Wildlife Service from supplying water to several basins under their ownership. This decree is currently being challenged (Al Trout, pers. comm.).

Other Potential Threats

Oil and gas.-- The exploration and development of oil and gas resources in the Williston Basin, particularly in western North Dakota and southern Saskatchewan, has accelerated (Fig. 1). The number of wells drilled each year in North Dakota increased 40% from 343 in 1978 to 848 by 1981. Future exploratory drilling projections indicate significant activity and expansion of producing areas (Anderson and Bluemle 1982). Toxic sulfide gases released from pumping rigs have caused direct mortality to humans and wildlife but a more serious threat is the impending contamination resulting from pipeline leaks and breaks. Trace elements in drilling muds piled next to drilling rigs leach into watersheds and are another source of contamination.

A major oil spill occurred on the North Platte River near Glenrock, Wyoming in April 1980 due to a pipeline rupture. About 8,550 barrels of oil entered the river, coating it for 106 km (66 miles). Over 1,900 animals representing 66 species were affected (Mark Wilson, pers. comm.). A minor leak occurred at Quivira National Wildlife Refuge in Kansas, an area designated as whooping crane critical habitat, in December 1984. This incident was quickly cleaned up and no mortality was documented.

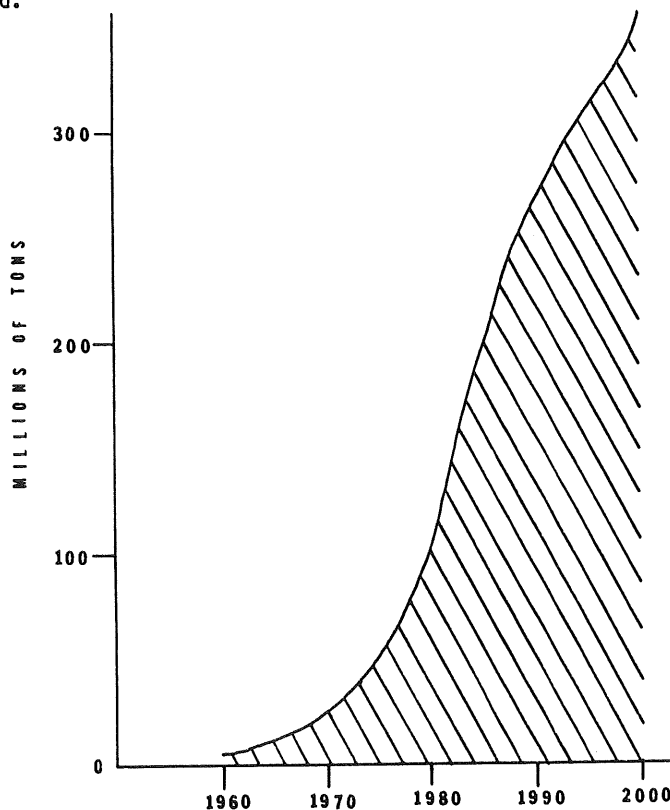


Fig. 2. Forecast of coal production in the Northern Great Plains (1960-1971 actual; 1975-2000 projected from NGPRP 1975).

Coal.-- Expansion of the surface mining of coal and the concomitant development of coal gasification and coal-fired power plants poses serious environmental problems, particularly in western North Dakota and southern Saskatchewan. The growth rate in energy consumption within the United States between 1947-1973 has averaged 3.2% annually. Energy derived from coal has led the way in meeting the demand. Coal production within the northern Great Plains states is projected by the year 2000 to increase over 10-fold from 1971 levels (Fig. 2) while per capita coal consumption will nearly triple (Northern Great Plains Resources Program [NGPRP] 1975). Many of these coal deposits lie within the whooping crane migration corridor. About 283,000 ha (700,000 acres) are underlain by surface mineable coal in North Dakota alone and about 0.6 million ha (1.5 million acres) of grassland in the Great Plains is underlain by surface mineable coal.

Water and air quality suffer as a direct result of surface mining. Total dissolved solids (TDS), biological oxygen demand (BOD), and temperature of streams generally increase and lead, manganese, and other trace element concentrations rise in groundwater (NGPRP 1975). Severe wind erosion and dust storms result from surface mining.

Both water and air quality suffer from sister operations of surface mining including coal gasification and power plants. Trace elements emitted to water include mercury, lead, arsenic, beryllium, and cadmium. Air pollution from emissions are caused by particulates, hydrocarbons, sulfur oxides, and nitrogen oxides (NGPRP 1975). The latter two photochemically convert to sulfates and nitrates in the atmosphere which increase the potential for "acid rain".

Rehabilitation of mined sites is particularly difficult in arid areas. The disruption of soil profile and porosity in the overburden and of the vegetation is difficult to overcome during rehabilitation. Energy companies are generally cooperative in avoiding wetlands directly; however, indirect impacts are generally not considered. The combined problems will become more serious in the future as the coal boom expands and intensifies (Fig. 2).

Government Subsidies.-- Federal programs in both Canada and the United States have provided incentives for farmers to drain and fill wetlands and to plow grasslands. In Saskatchewan, the Department of Agriculture and Prairie Farm Rehabilitation Administration authorized and assisted farmers in construction of flood-control or drainage projects and back-flood irrigation projects. Over 1,000 projects were constructed by 1974 which resulted in the construction of over 2,250 km (1,400 miles) of ditches and loss of over 2,000 wetlands ranging in size from a few hectares to over 1,200 ha (3,000 acres) (Brewster and Caldwell 1974).

In the United States, the U.S. Soil Conservation Service (SCS) and the Agricultural Stabilization and Conservation Service (ASCS) provide to farmers several cost-sharing programs which promote wetland drainage and conversion of grassland to cropland. The Payment-in-Kind (PIK) program of 1983 paid farmers the equivalent of about \$9 billion (\$0.8 billion in Nebraska alone) not to plant crops on certain lands (Agricultural Stabilization and Conservation Service, unpubl. data). To be eligible, the particular field had to be cultivated in at least 3 of the previous 5 years in order to establish a base yield. The farmers were then paid not to grow crops according to their base yield. Thus, areas not plowed were not eligible. The incentive now is to convert marginal land in order to establish a base yield and, thereby, qualify for future programs.

Advancements in agriculture technology have resulted in the introduction of sophisticated land leveling equipment and center-pivot irrigation systems. These enable farmers to grow crops on lands that were previously too wet or rough to plow. Leveling operations fill both small depressions that once held water during spring runoff and more permanent wetlands. Again, U.S. and Canadian government subsidies promote this development.

The dewatering of several major rivers due to diversions for irrigation and hydropower have directly or indirectly been subsidized by the U.S. government. In Kansas, flows in the Arkansas River have ceased between Garden City and Dodge City, a distance of about 80 km (50 miles), and have been greatly reduced within the 130 km (80 miles) stretch between Dodge City and Great Bend (Northern Flint Hills Audubon Society 1983). This loss of flow has impacted the vitality of Cheyenne Bottoms, a 16,600 ha (41,000 acres) marsh north of Great Bend. Flows from the Arkansas River used to be diverted to augment water conditions within Cheyenne Bottoms. This is the largest marsh within the Great Plains and about half of the total area is owned by the state. Cheyenne Bottoms and Quivira National Wildlife Refuge were designated as critical habitat for whooping cranes in 1978 (Federal Register 43[94]: 20938-20942). Unfortunately these two areas, along with Kirwin National Wildlife Refuge, are threatened by diminished water supplies (Northern Flint Hills Audubon Society 1983).

Similar problems exist in Nebraska. The Platte River bottoms, a 85 km (53 miles) long area in southcentral Nebraska, was designated as critical habitat in 1978 (Federal Register 43[94]:20938-20942). The extensive wetlands adjacent to the Platte River, especially before European settlement, provided ideal whooping crane habitat. Bison wallows and ephemeral wetlands would fill each spring and support tremendous quantities of aquatic vertebrate and invertebrate life. The cranes would feed extensively in these areas while the Platte, with its wide, unvegetated channel and numerous sandbars, provided ideal roost sites. Because of its geographic location approximately midway between wintering and summering areas, and its ideal habitat, the Platte River was and still is a unique oasis for migrating cranes. This uniqueness and importance to whooping cranes has been recognized by many authors (Swenk 1933, Allen 1952, Hill 1975, Johnson 1981, Krapu 1981). Allen (1952:94) remarked: "I believe that one reason for the great number of migration reports from Nebraska, most of them from the Platte River area, is that whooping cranes make that territory a major stop, remaining in the region for some days." Hill (1975) stated in reference to the Big Bend reach of the Platte River, an 130 km (80 miles) stretch between Overton and Grand Island, : "Nowhere along their 2,500 mile [4,025 km] migration route exists such a favorable combination of habitat types as in this location."

Wetland and open riverine habitat loss has occurred at an accelerated rate, particularly in the Platte River Valley and adjacent Rainwater Basins. The destruction of grasslands occurred rapidly, shortly after European settlement of the area. Between 1860 and 1911, 0.6 million ha (1.5 million acres) of land was under cultivation in the Big Bend area, about 90% of the area under cultivation in 1980. Within the Big Bend reach of the Platte River nearly two-thirds of the historic mean annual flow of the river has been diverted for agriculture and power production. Up to 97% of the optimum roost habitat has been lost since 1938 in many stretches. This loss of roost habitat coincides with completion of Kingsley Dam and Lake McConaughy on the North Platte River near Ogallala. Nearly 75% of the lowland prairie, upland grassland, and wet sedge meadow habitat in this reach have been destroyed (Currier et al. 1985). More than 90% of the wetlands in the Rainwater Basins have also been drained, filled, and cultivated.

Proposed Irrigation Projects in the Platte River Basin.-- The mean annual flow of the Platte River at Overton has been reduced from 2.7 million acre-feet historically to 0.8-1.0 million acre-feet by 1980 (Jim Henriksen, pers. comm.). The decrease in water discharge is primarily due to construction of on-stream reservoirs and greater consumptive use for irrigation. These projects have and continue to adversely alter roosting and feeding habitat for whooping cranes in Nebraska. Applications to divert an additional amount of at least 965,000 acre-feet annually from the Platte Basin are pending approval (Dept. of Water Resources unpubl. data, Woodward-Clyde 1981). This amount is about equal to the current annual flow at Overton and, if approved, would completely negate the value of the Platte River Basin for whooping cranes along with many other migratory bird species.

Agricultural Contaminants.-- The widespread conversion of grasslands and wetlands to cropland has introduced a new cause for environmental concern, that of chemical contaminants from application of fertilizers and pesticides. These chemicals leach into the groundwater or flow directly into surface water with run-off. Direct mortality of wildlife from agricultural contaminants has been documented and indirect mortality and nonlethal impairment to populations have also become evident. Two recent incidents involved insecticides and resulted in the death of several hundred waterfowl and some raptors. In November 1982, Thimet leached into two small wetlands in South Dakota killing 342 ducks, 4 geese, and 14 raptors. The concentration could have resulted in human mortality. In April 1980, unauthorized Diazinon application by a contract farmer killed eight snow geese and five Ross' geese at Bosque del Apache National Wildlife Refuge in New Mexico, an area designated as critical habitat for the Gray's Lake flock of whooping cranes (Mark Wilson, pers. comm.).

Widespread nitrate contamination of the groundwater, due to application of anhydrous ammonia fertilizer, has become particularly acute along the Platte River Valley in Nebraska. Nitrate in domestic water supplies has reached concentrations well above those recommended by the Food and Drug Administration and has forced the development of new well fields in several towns located within the Valley. Although losses of wildlife populations have not been documented, the threat is real. Sublethal levels of contaminants have entered the food chain throughout the migration corridor with potential effects as yet unknown.

Disease.-- As wetland habitat diminishes within the whooping crane migration corridor, migrating waterfowl and wading species are forced to congregate on fewer areas and population densities increase. Overcrowding invites disease epidemics. Nowhere is the problem more acute than in Nebraska's Rainwater Basins and adjacent Platte River. Waterfowl die-offs due to avian or fowl cholera, a disease caused by the bacterium *Pasteurella multocida*, have occurred since 1975 and have accounted for over 100,000 deaths of ducks and geese. The most severe outbreak occurred in the spring of 1980 with an estimated loss of nearly 90,000 birds (U.S. Fish and Wildlife Service, unpubl. data). The occurrence of this disease overlaps the migration period of whooping cranes. Until recently it was not known whether whooping cranes were susceptible to the disease (see Synder et al. this Proceedings).

To circumvent a potentially disastrous situation, the U.S. Fish and Wildlife Service, in cooperation with the Nebraska Game and Parks Commission, developed a contingency plan to haze whooping cranes from the vicinity of a known cholera outbreak (U.S. Fish and Wildl. Serv. 1977). Procedural guidelines are, at best, ill-defined. The current policy is to haze whooping cranes off an area experiencing substantial cholera activity. This consists of spooking the birds from the area by personnel approaching on foot or, in extreme circumstances, motorized vehicles and/or aircraft. It is not known how susceptible whooping cranes are to the disease or how they contract it. There have been several instances of whooping cranes occupying basins experiencing cholera and thus far, no cases of diseased whooping cranes have been recorded in Nebraska. The most recent hazing example was in April 1984 when two adult-plumaged birds were chased off a basin after they had rested there for about 80 minutes. Fowl cholera was present in that basin. However; there was no reason to believe that the privately owned wetlands these birds were chased to, and allowed to rest on, were not infected also. The question that is raised is what effect hazing has on the birds? The scarcity of suitable habitat in the proximity of the Rainwater Basins and Platte River valley makes that area even more important. If the birds migrate to this area, and are then hazed from it, what impact does this have on the well-being of the cranes?

Utility Lines.-- A vast array of utility lines crisscross the entire migration corridor from the central Gulf Coast of Texas north to the boreal forest. The hazard these lines present to migrating whooping cranes has become more evident in recent years. Between 1965 and 1984, there were six deaths and one injury documented in post-fledgling whooping cranes (U.S. Fish and Wildl. Serv., unpubl. data). Of these, four deaths and one injury or 71% were the result of a collision with utility lines. The other two deaths were the result of a hunting accident and an avian predator, both of which were on or near Aransas NWR, Texas. All of the powerline strikes occurred during migration; three in the fall and two in the spring. An additional four deaths and three injuries due to utility line collisions have been recorded in the Gray's Lake flock. It appears these fatalities are not random events because of their frequency. Utility lines situated near potential whooping crane roost sites and/or feeding areas are the greater hazard.

A precedent setting case involving transmission lines occurred in Oklahoma in 1984. The U.S. Fish and Wildlife Service issued a biological opinion under the authority of the Endangered Species Act of 1973 to the Federal Energy Regulatory Commission (FERC) which stated the construction of a transmission line by Central and Southwest Services of Texas would adversely effect the whooping crane unless certain measures were taken. The first measure was to develop a plan to provide guidelines for routing and construction of the powerlines to minimize bird strikes. The second measure was to mark certain sections of the static wires of the powerline to reduce the possibility of a strike. Sections adjacent to potential roosting and feeding areas would be marked with orange aviation marker balls (23 cm in diameter) at 30 m (100 ft) intervals. These recommendations were accepted by the power company; however, the effectiveness of marking will not be ascertained since monitoring of the powerline after construction was not required (Sidney Wilkerson, pers. comm.). In 1980 in Nebraska, the routing of a transmission line across the Platte River within the whooping crane critical habitat area was changed as a result of Fish and Wildlife Service's recommendation (Chuck Frith, pers. comm.).

Military Maneuvers.-- A unique hazard is encountered by migrating whooping cranes as they reach the southern edge of the boreal forest in Alberta and Saskatchewan. Twice a year in April-May and September-October, the Royal Canadian Air Force Base at Cold Lake hosts an event

known as Exercise Maple Flag at the Cold Lake Air Weapons Range (CLAWR) headquartered at Medley, Alberta. This semiannual event involves air force maneuvers with multi-national forces from Great Britain, the United States, and Canada. Low level bombing runs and radar evasive flights are conducted at these meets. CLAWR is about 56 km (35 miles) wide and completely intersects the whooping crane migration corridor (Fig. 1). Thus, these birds must run the gauntlet over the area during the time Exercise Maple Flag is being held. Since whooping cranes migrate at an elevation of about 360 m (1200 ft) (Paul Goossen, pers. comm.), the potential for collisions is relatively great although no whooping crane mortality has been documented to date. Avoidance of bird-aircraft collisions is of concern to the commander and a Bird Hazard and Warning Forecast System is activated during the migration period. However, the effectiveness of this system in detecting whooping cranes is not known.

Is Critical or Migration Habitat Necessary?

Certain areas serve as more than a random stopover point for migrating whooping cranes. The Platte River is and has been one such area, especially in spring (Johnsgard and Redfield 1977). There have been 19 confirmed sightings on or near the Platte and North Platte Rivers between 1942 and 1984 (Whooping Crane Recovery Team 1983, Lingle et al. 1984, Nebr. Game and Parks Comm. unpubl. data). The distribution of all sightings along the Platte and North Platte rivers from 1915 to 1984 shows an uneven pattern (Fig. 3). Nearly 60% of these sightings have occurred in a 35 km (22 miles) stretch (this represents about 4% of the total length of the Platte and North Platte rivers in Nebraska) between Gibbon and Odessa (bridge segments 7-9). These data suggest a finite migratory pathway as the cranes cross the Platte River.

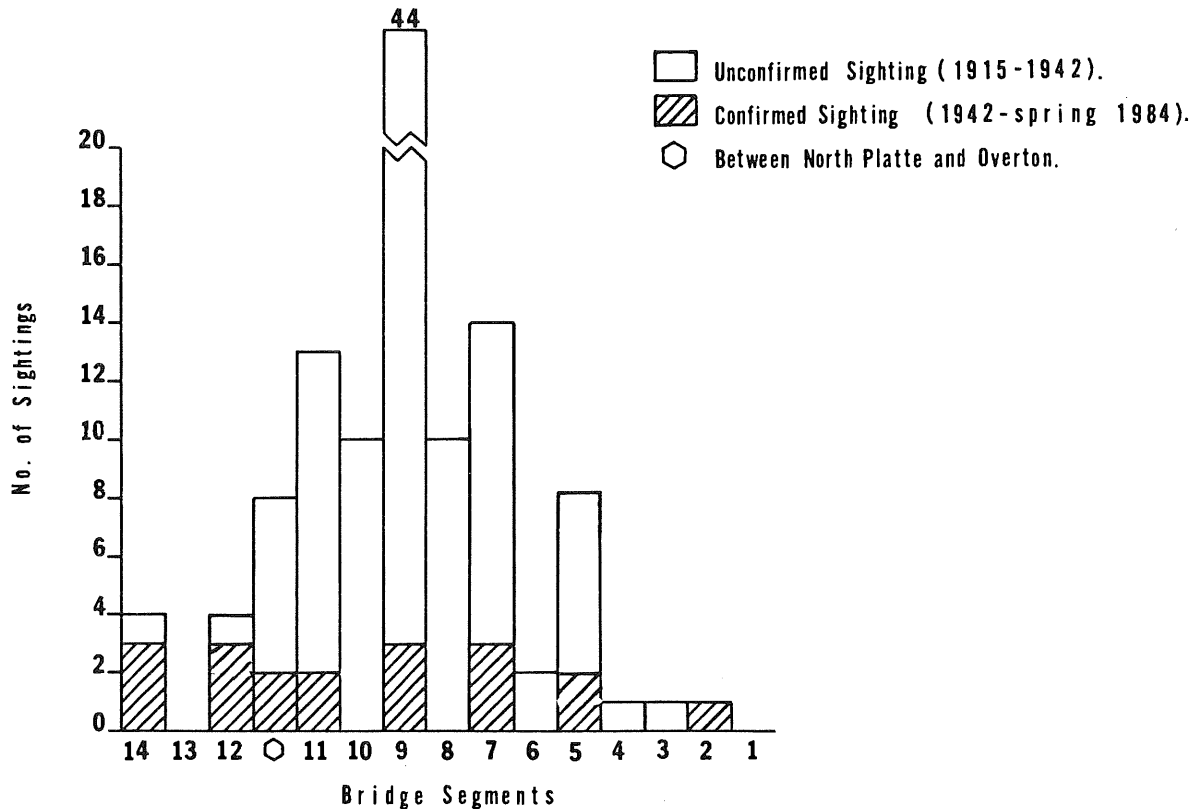


Fig. 3. Distribution of whooping crane sightings within 10 km of the Platte and North Platte rivers, Nebraska (Swenk 1933, Brooking 1943, Whooping Crane Recovery Team 1983, Lingle et al. 1984, Nebraska Game and Parks Comm. unpubl. data). Bridge segments 1-11 represent a 130 km stretch along the Platte River between North Platte and Sutherland, and segment 14 is near Lewellen; all of which are on the North Platte River.

Recent radio-telemetry studies confirm the premise that whooping cranes migrate along a very narrow corridor. A family group was followed south in the fall of 1982 and north in the spring of 1983. The two flight paths deviated only 8-85 km (5-53 miles) from one another in an east-west direction. The average distance between the flight lines was 45 km (28 miles) (U.S. Fish and Wildlife Service unpubl. data). The proximity of these flight paths is remarkable considering the distance and duration of migration which is about 1.5 to 2 months per year. Thus it seems these birds are "imprinted" to a rather precise pattern of flight.

Sighting information has revealed certain other areas that are migratory "hotspots". The Last Mountain Lake area in Saskatchewan is used extensively and may serve as a fall "staging" area. The northwest quarter of North Dakota is also used heavily. Other sites include: central South Dakota in counties bordering the Missouri River; southcentral Nebraska along the Platte River and Rainwater Basins; Cheyenne Bottoms and Quivira NWR in Kansas; Salt Plains NWR, Oklahoma; and the Red River along the Texas-Oklahoma border near Byers Lake (Fig. 1). Whooping cranes are apparently selecting particular regions within the migration corridor.

There are a number of people who believe the existence of "critical habitat" is not germane to survival of the whooping crane, especially during migration. Because cranes use cropland and man-made reservoirs, many people assume there is no need for any other type of habitat to meet the needs of migrating cranes. Several authors have described this species as being "flexible" and "opportunistic" in its food and nocturnal roost requirements (Johnson and Temple 1980, Johnson 1981, U.S. Fish and Wildl. Serv. unpubl. data). Grainfields are believed to be "selected" by migrating whooping cranes as preferred feeding sites. Perhaps whooping cranes are "selecting" grainfields because that is the principal habitat type available to them and, in many areas, the only habitat.

Again, the question that is raised is, "If whooping cranes are not dependent on 'critical habitat' and if they are 'flexible' and 'opportunistic', why hasn't the population exploded?" Some limiting factor has obviously been overlooked by those who believe that whooping cranes are both flexible and opportunistic. With the establishment of Wood Buffalo National Park in 1922 and Aransas NWR in 1937, the nesting and most wintering habitat was protected. Some migratory habitat was protected in Oklahoma and Kansas in the 1940's and 1950's; however, there has been no coordinated effort to protect and manage habitat throughout the migration corridor.

Where is the Migration Habitat in the Recovery Plan?

The Whooping Crane Recovery Plan was completed in 1980 (Olsen et al. 1980). This initial effort outlined a step-down plan with the objective of downlisting the whooping crane from the endangered to the threatened category by increasing the "wild" population to at least 40 nesting pairs and by other actions. Of the estimated \$13.5 million needed to implement this plan over a 3 year period from 1980 to 1983, \$84,500 (0.6% of the total) was allocated to identification and protection of critical habitat (Olsen et al. 1980:91). This amount is equivalent to \$12,070 to be spent in each of the seven states through which whooping cranes migrate. This sum would buy about 4 ha (10 acres) in each state assuming land values of \$2920 per ha (\$1,200 per acres) and identification costs nothing. Twenty thousand dollars was allotted to identify and reduce hazards along the migration route. More money (\$55,000) was allocated for a patrol boat and boat storage facilities at Aransas NWR than for migratory habitat protection in the seven states! On the more positive side, \$10 million was allotted for purchase of private lands near Aransas NWR; about 74% of the total amount. Habitat in Canada was not considered because the authority of the Recovery Team was restricted to the United States.

DISCUSSION/RECOMMENDATIONS

Our knowledge of whooping crane migration ecology has been greatly enhanced by color-marking of chicks which began in 1977 and the radio tracking study initiated in 1981 (see Howe, and Ward and Anderson this Proceedings). Certain key areas have been identified (Fig. 1). It seems now is an appropriate time to address and to take action on developing and implementing a plan designed to ensure adequate habitat throughout the migration corridor. An updated Recovery Plan would be the logical means of outlining such a strategy. In light of the current budget constraints in Canada and the U.S., and the host of threats outlined in this report, complacency now might well invite catastrophe.

A simple solution to the problem of protecting migration habitat is to deny its importance. This is exactly what may happen if we accept the theory that whooping cranes do not need "critical habitat" areas. The theory is the birds will have to go "someplace else". Unfortunately, we have reached a point in our agricultural and commercial development of the Great Plains where there are few "someplace else's" left. The crane's life requisites must be met throughout the year, even during migration. If this species is forced to become even more "flexible" and "opportunistic", then its fate may well be similar to the now extinct passenger pigeon (*Ectopistes migratorius*).

Recommendations for whooping crane migration habitat reconnaissance and protection follow:

- 1) Enforce a policy where all major utility lines adjacent to key habitat areas are marked with highly visible plastic balls or strips.
- 2) Develop an acquisition or protection plan within the migration corridor to ensure perpetual protection of wetlands and native grasslands. Priority should be given to migration "hotspots".
- 3) Develop a comprehensive contingency plan for hazing whooping cranes in Nebraska. Until such a plan is developed, implement a moratorium on hazing, except under the most extreme conditions.
- 4) Research priority should be given to eliminate the avian cholera problem in southcentral Nebraska.
- 5) Evaluate socio-biological needs of the birds, particularly in the spring. The important role the Platte River wet meadow habitat plays for sandhill cranes in pair-bond establishment and reinforcement, suggests that perhaps a similar habitat need exists for whooping cranes.
- 6) Review the practice of egg transplants from Wood Buffalo National Park. Perhaps only half of the nests located should have an egg removed and only half of the chicks should be banded. Close monitoring of survivorship of these chicks may shed some new light on recruitment and nesting ecology. From 1975 to 1984, all known nests had an egg removed. With the establishment of the Patuxent flock and the failure of the Gray's Lake birds to breed to date, a new approach to the problem may be appropriate.
- 7) Continue the radio tracking program on those birds with active transmitters. Vital data have been lost particularly with respect to 3 and 4 year old cranes due to the failure to monitor radioed birds during migration. Data are being lost which could be used to further our understanding of whooping cranes' migration ecology.
- 8) Closely monitor environmental contaminants throughout the migration corridor and alleviate contaminant problems where they occur.
- 9) Establish and protect instream flow regimes of certain rivers including, but not limited to, the following: Arkansas, Platte, Niobrara, Missouri, and Red rivers.
- 10) Standardize site evaluation forms and data collection for habitat used by whooping cranes throughout the migration corridor. Currently there is little coordination between state, provincial, and federal agencies regarding sighting information. The U.S. Fish and Wildlife Service office in Grand Island, Nebraska could serve in this capacity because they are responsible for housing all sighting reports.

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HABITAT CHANGES WITHIN THE MISSISSIPPI SANDHILL CRANE RANGE IN JACKSON COUNTY, MISSISSIPPI (1942-1984)

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Abstract: Habitat changes within the Mississippi sandhill crane (*Grus canadensis pulla*) summer range were quantitatively measured on four sets of aerial photographs (1942, 1958, 1976, and 1981) by using a reflecting projector, transcop viewer, and digital planimeter. Five habitat types (woodland, wooded drainage, savanna, agricultural land, and urban development) were delineated on each set of photos. Habitat types surrounding 10 single and multiple crane nesting territories were measured (hectares and percent of each habitat type) for each photo year. The average percent change in habitat types for the 10 nesting areas between 1942 and 1981 was: savanna declined from 74% to 14%; woodland increased from 18% to 70%; agricultural land from 8% to 9%; urban lands from a trace to 6%. The major factors influencing environmental changes are lumbering, open range grazing, fires, pine tree planting, urban development, agriculture, roads and highways, and habitat management on the Mississippi Sandhill Crane National Wildlife Refuge (MSCNWR). The effect of these changes on the crane population are discussed, but direct correlation between habitat changes and numbers of nesting cranes is difficult to assess because population data are missing in the years before 1942. Observations from 1965 through 1984 indicate some nesting sites were destroyed or not used because of adverse changes, and some nest sites were added or improved through refuge management. Cranes nest in mesic and hydric savannas, swamp edges, and other openings that are sheltered from disturbance by trees and brush. Habitat management includes: clearing and thinning of trees and shrubs by hand, machine, and prescribed burning; water control structures, elevated roads, and ditch plugging to improve water economy; and selective clearing and tree planting to separate territories from other cranes and to shield nesting sites from vehicular disturbance.

PROCEEDINGS 1985 CRANE WORKSHOP

The early history of the range of the Mississippi sandhill crane is fragmentary. The earliest explorer d'Iberville (Brasseaux 1981) in 1699 went 4 leagues (c. 16 km) into the interior from present day Ocean Springs, Mississippi, and saw "pretty pine forests, which included scattered clusters of other trees; several prairies, where I saw many deer, and soft sand everywhere." Le Page du Pratz (1774) visited the same area in 1723 and "found the fields pleasant enough, but less fertile than along the Mississippi; as they have some resemblance of the neighboring coast, which has scarce any other plants but pine that run a great way, and some red and white cedars."

Hilgard (1860) in 1855 passed through from the north to the coast, then from Gautier, Mississippi, west to Ocean Springs. He mentions meeting only operators of ferries at the river crossings and was fearful of traveling during the winter "at the risk of being caught in a very remote and thinly settled region." After crossing Bluff Creek, at the site of the present town of Vancleave, he found wet savannas, with scattered small longleaf pine and bald cypress, dominating the landscape.

The great longleaf pine forests were lumbered during the late 1800's and early 1900's and some cutting took place within the crane range. Minor operations, such as turpentine, the cooking of pine for charcoal, light lumbering, and pole cutting, ended in the 1940's. Cattle grazing, which started with the early settlers, continued in earnest when the lumbering boom ended and the land was virtually abandoned. Cattle, sheep, goats, and hogs roamed the unfenced range by the thousands. In Jackson County, the cattlemen burned the woods and savannas to provide green grass for livestock. In the early 1900's, wild fires, started by careless hunters, steam locomotives, and timber workers, annually burned an estimated 75% of the woodland of Mississippi (Lowe 1913).

In the 1950's paper companies began buying or leasing lands within the crane range to grow slash pine for pulpwood. The open range policy in Jackson County was repealed and fire prevention and fire suppression were intensified. Thousands of hectares of mesic and wet

savannas were planted to pine during the 1950's and 1960's (Valentine and Noble 1970).

The Mississippi Sandhill Crane National Wildlife Refuge (MSCNWR), established in 1974, now includes about 6,475 ha within the Fontainebleau, Gautier, and Ocean Springs units. A Recovery Plan for the Mississippi sandhill crane (Valentine 1984) outlined habitat manipulations to improve nesting, feeding, and roosting habitats through mechanical and hand clearing of pine trees, prescribed burning, and water management.

We have been able to quantify the changes in land-use from 1942 through 1981 by interpreting aerial photos. We chose to measure lands surrounding active crane nests found during 1965 through 1984. These territories were considered to be the best nesting habitats available to the cranes during the period. Little information on nesting was available before 1965.

Our objectives were to document and measure changes in the environment that have occurred over the years within the range of the cranes and to interpret how these changes affected crane nesting populations.

We wish, especially, to thank Pat O'Neil (Remote Sensing Specialist), U. S. Geological Survey, for his help and guidance. The staff of the National Mapping Division, Application of Systems Facility, USGS, National Space Technology Laboratories, Bay St. Louis, Mississippi, are thanked for assistance and use of their equipment. A. Taylor, I. Shanks, and R. Stewart, National Coastal Ecosystems Team, U. S. Fish and Wildlife Service (FWS), provided assistance and transportation. E. Otvos, Gulf Coast Research Laboratory, Ocean Springs, is thanked for the loan of aerial photos. The staff of the MSCNWR loaned aerial photos, and provided help and information. We are grateful to Orpha Valentine who reviewed and edited the paper; Loyd Mitchell provided vegetative data.

METHODS

U. S. Geological Survey quadrangle maps (7.5 minute series for 1976 and 1982) were used to establish a base scale of 1:24,000. Mylar sheets were placed over the topographic maps and major roads and other landmarks were transferred to the sheets. Four sets of aerial photos (1942, 1958, 1976, and 1981), two black and white and two color, were used to delineate habitat types. The various scales on the aerial photos were standardized by using a Kargyl Reflecting Projector and a LZK Karrons Transcope Viewer to match with the topographic map. An H. D. Foster Digital Planimeter was used to determine areal measurements of habitat types. A map measurer was used to determine distance from nesting sites to human developments, agricultural lands, and water bodies.

We began with the most recent aerial photos and worked back through time, delineating each nesting area into habitat types. The area covered included all of the nesting sites plus a large area surrounding the sites. The boundaries were designated by roads or other landmarks.

Mitchell (1984) described seven habitat types within the Gautier Unit (MSCNWR): woodlands, wooded drainage, pine plantation, hydric savanna, mesic savanna, agricultural land, and fallow land. We followed these habitat designations, but for convenience combined some categories. We used five types: woodlands (woodlands and pine plantation), savanna, wooded drainage, agricultural lands (agricultural and fallowland), and urban development.

Problems of interpretation arose when wooded drainage and pine plantation expanded through natural succession and growth, showing on later photos as forests. The borders of the photos were inconsistent in the various sheets and years. The total area varied with the use of individual photos; percentages shown are for the amount of area measured on the photo sheets.

STUDY AREA

The study area included most of the range of the Mississippi sandhill crane, roughly the southern half of Jackson County, west of the Pascagoula River (Fig. 1). The vegetation of the crane range has been described in general terms by Valentine and Noble (1970), and Valentine (1981b). Valentine (1981) measured tree and shrub cover surrounding Mississippi sandhill crane nest sites in swamp edges, pine plantations, and savannas.

Mitchell (1984) sampled the plant cover on the Gautier and Fontainebleau units of the MSCNWR through the use of line transects and plots in representative habitats. In 1983, the Gautier and Fontainebleau units totalled 3,530 ha and the Ocean Springs unit 2,880 ha.

Grasses (Poaceae) and sedges (Cyperaceae) comprised 46% of the ground cover in the combined habitat types. Pineland three-awn (Aristida stricta), toothache grass (Ctenium aromaticum), and bluestem grasses (Andropogon spp.) were the dominant ground cover taxa.

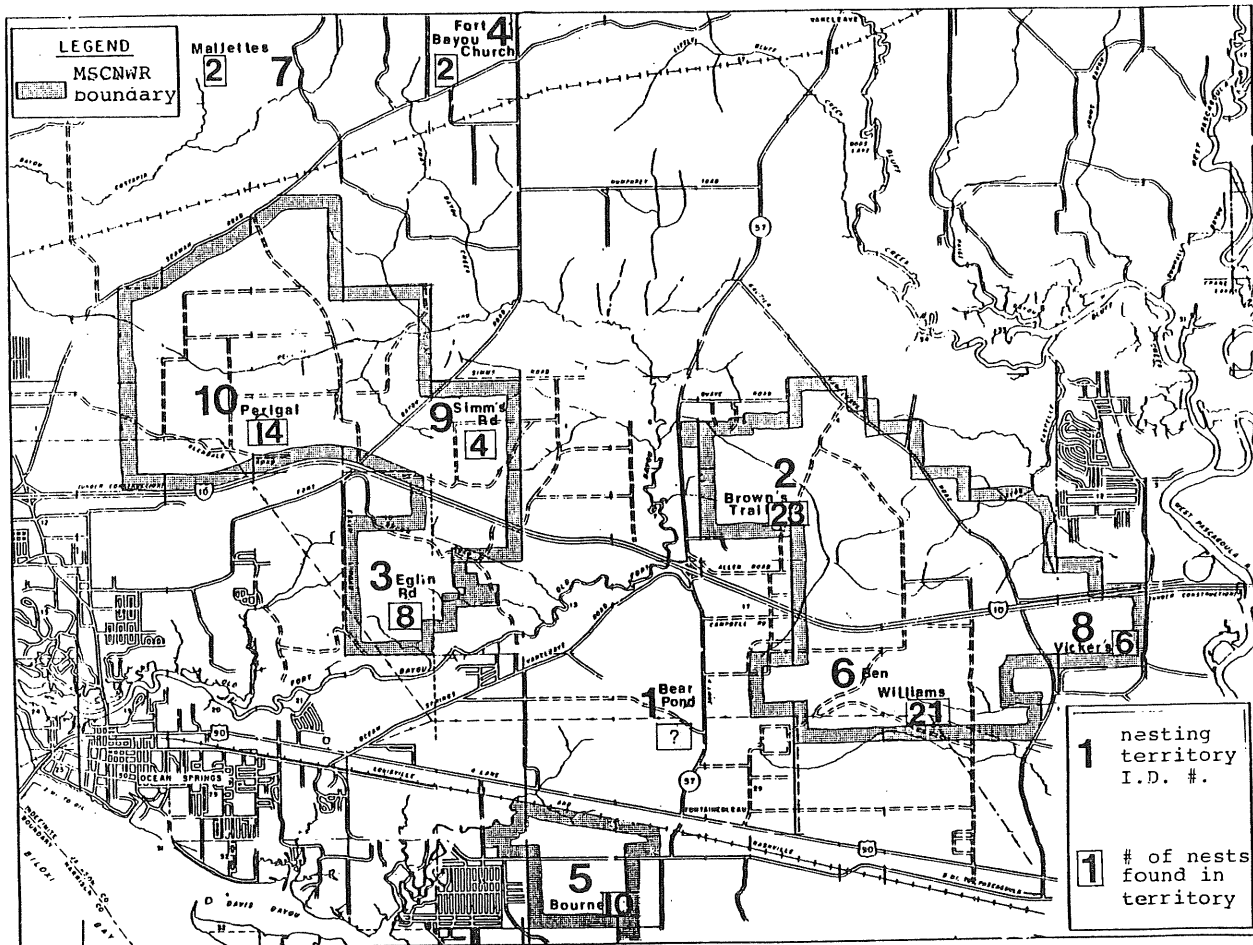


Fig. 1. Ten nesting areas used in the study of habitat changes within the range of the Mississippi sandhill crane, Jackson County, Mississippi. Nesting areas are identified by name and number with the number of active nests found during 1965-1984.

The pine woodland overstory was dominated by slash pine (*Pinus elliotii*) and longleaf pine (*P. palustris*). The ground cover consisted mainly of bitter gallberry (*Ilex glabra*), pineland three-awn, sweet gallberry (*L. coriacea*), sweetbay (*Magnolia virginiana*), and several other brush and grass species.

Pine plantation consisted of slash pine planted in both mesic and hydric savannas in the 1950's and 1960's. Pineland three-awn, bitter gallberry, and toothache grass were the most common ground cover. Within the hydric and mesic savanna, toothache grass and pineland three-awn were most abundant.

Pine plantation occupied 36% of 1,283 ha of the Gautier and Fontainebleau units of the refuge. About 600 ha of pine plantation were cleared by bulldozing during 1979 and 1980; most of these lands were prescribed burned a year or so after clearing.

Wooded drainage consisted of the swampy areas that bordered the small streams and broader wet sumps. The common shrubs and trees were blackgum (*Nyssa sylvatica*), swamp cyrilla (*Cyrtillaria cemifolia*), baldcypress (*Taxodium distichum*), southern wax myrtle (*Myrica cerifera*), and several other brush species.

In the refuge fields where pine trees had been cleared, the flora was similar to the natural mesic savanna with some differences in abundance. The trees had been uprooted on drier sites

by high blade bulldozing with a minimum of disturbance to the ground cover. On some higher sites where the pines were bedded and furrowed, bulldozers were used to clear the land for agriculture. Here the topsoil and plant cover were pushed into windows and left for several years, then reincorporated into the soil.

NESTING AREAS STUDIED

Eleven nesting areas were defined during the course of a 17 year (1965-1981) study by Valentine (1981b). Within those areas 20 individual territories were found. The nesting site, adjacent lands, the use by crane pairs, and habitat conditions were described by Valentine (1981a). An additional area, Bear Pond, where early observers (McIlhenny 1938, Turcotte pers. comm.) found nests, was also included in our measurements, but nests have not been found there by Valentine and cooperators. Habitat changes in the 10 nesting areas for years 1942 through 1981 are shown in Table 1.

Brown's Trail Area

The area is on the MSCNWR between State Highway 57 and the Gautier-Vancleave Road (Fig. 2). Brown's Trail formerly connected the two highways. Small farms and residences were located along Highway 57. In 1963, the developer of a subdivision called "Fountainbleau Acres", laid out 4.5 km of streets on about 160 ha of savanna, east of Highway 57, advertising, "5 acres, \$1,000 cash, \$140 down, and \$1,100". the subdivision made several hundred hectares unsuitable for cranes.

Three territories were designated with nesting sites between 0.8 km and 1.5 km apart. In 1965 through 1984, 23 nests were found there, exclusive of renests. At least two pair nested there 1965 and 1974. After that only one pair nested until 1981 when a pair moved temporarily into this area after its adjoining territory burned. The cranes nested in savanna and open pine plantation. Valentine (1981b) found the percent overstory at the savanna nest sites ranged from 1 to 7% (mean: 4%, N=10) and in the pine plantation 5 to 19% (mean: 10%, N=4).

In 1942, savanna covered 71% of the land with 15% in forest and 1% in agriculture (Table 1). Savanna was reduced to 29% by 1976, but increased to 38% by 1981 because of refuge clearing and prescribed burning. During the late 1970's Interstate Highway 10 bisected areas formerly in savanna (Fig. 2).

Ben Williams Area

Four territories were designated within this area that includes a large swamp with a narrow edge of nesting habitat. Twenty-one nests, exclusive of renests, have been found since 1965 (Fig. 1). Walkinshaw (1960) found two nests here in 1942, 150 m apart and in 1960 found one nest. Three pair nested in 1971; two pair between 1974 through 1976; and one between 1977 and 1984. In 1984 the pair that usually nested at the edge of the swamp moved about 3 km to an area that had been mechanically cleared of trees. Valentine (1981b) found that tree and shrub cover on this swamp edge occupied between 5 and 35% (mean: 17%, N=5) of 0.28 ha circular plots surrounding the nests.

In 1942, 62% of the area was in savanna and 35% in woods and swamp (Table 1). In 1976 only a narrow strip of savanna remained along the edge of the swamp. Little change in habitats occurred between 1976 and 1981. Interstate Highway 10 was constructed within 500 m of the northeast edge of nesting territory.

Perigal Swamp Area

Four nesting sites were designated as territories, but only two pair were found nesting during the same season. During 1971 through 1973 one pair occupied a territory. Nests were not found again until 1982 when one nest was found in a cleared area. This pair has moved each year to a different clearing (through 1984). Thirteen nests have been found during the period 1966 through 1984.

A large borrow pit dug for fill in the late 1960's during construction of Interstate Highway 10 forced a pair to abandon a territory. The pair moved about 600 m but used the site for only 2 more years. Most of the territories used between 1973 and 1982 appear to have been abandoned because of increasing density of trees and shrubs.

Table 1. Habitat changes in 10 Mississippi sandhill crane nesting areas in Jackson County, Mississippi determined by analysis of aerial photographs (1942, 1958, 1976, and 1981).

Nesting areas		% in habitat types			
		1942	1958	1976	1981
Brown's Trail	Woodland	15	9	45	29
	Savanna	71	63	29	38
	Wooded drainage	13	2	5	2
	Agriculture	1	23	16	22
	Urban			5	9
Ben Williams	Woodland	27	48	83	85
	Savanna	62	43	1	1
	Wooded drainage	8	6	11	6
	Agriculture	3	3	4	5
	Urban			1	3
Perigal Swamp	Woodland		41	97	90
	Savanna	100	59	3	10
Simms Road	Woodland	7	33	87	90
	Savanna	91	62	12	10
	Wooded drainage	2	4	1	
	Agriculture		1		
Fort Bayou Church	Woodland		14	70	69
	Savanna		47	7	10
	Agriculture		39	23	17
	Urban				4
Mary Bourne	Woodland	12	34	69	57
	Savanna	63	49	18	14
	Wooded drainage	2			
	Agriculture	23	17	12	13
	Urban			1	16
Eglin Road	Woodland	9	33	88	66
	Savanna	91	62	6	26
	Wooded drainage		4	1	1
	Agriculture		1	4	8
	Urban			1	
Vickers	Woodland		25	61	61
	Savanna		71	7	7
	Wooded drainage		2		
	Agriculture		2	8	8
	Urban			24	24
Mallettes	Woodland		15	87	68
	Savanna		83	13	20
	Agriculture		2		12
Bear Pond	Woodland	8	46	77	88
	Savanna	65	50	9	6
	Wooded drainage	17			
	Agriculture	10	3	1	1
	Urban		1	13	5

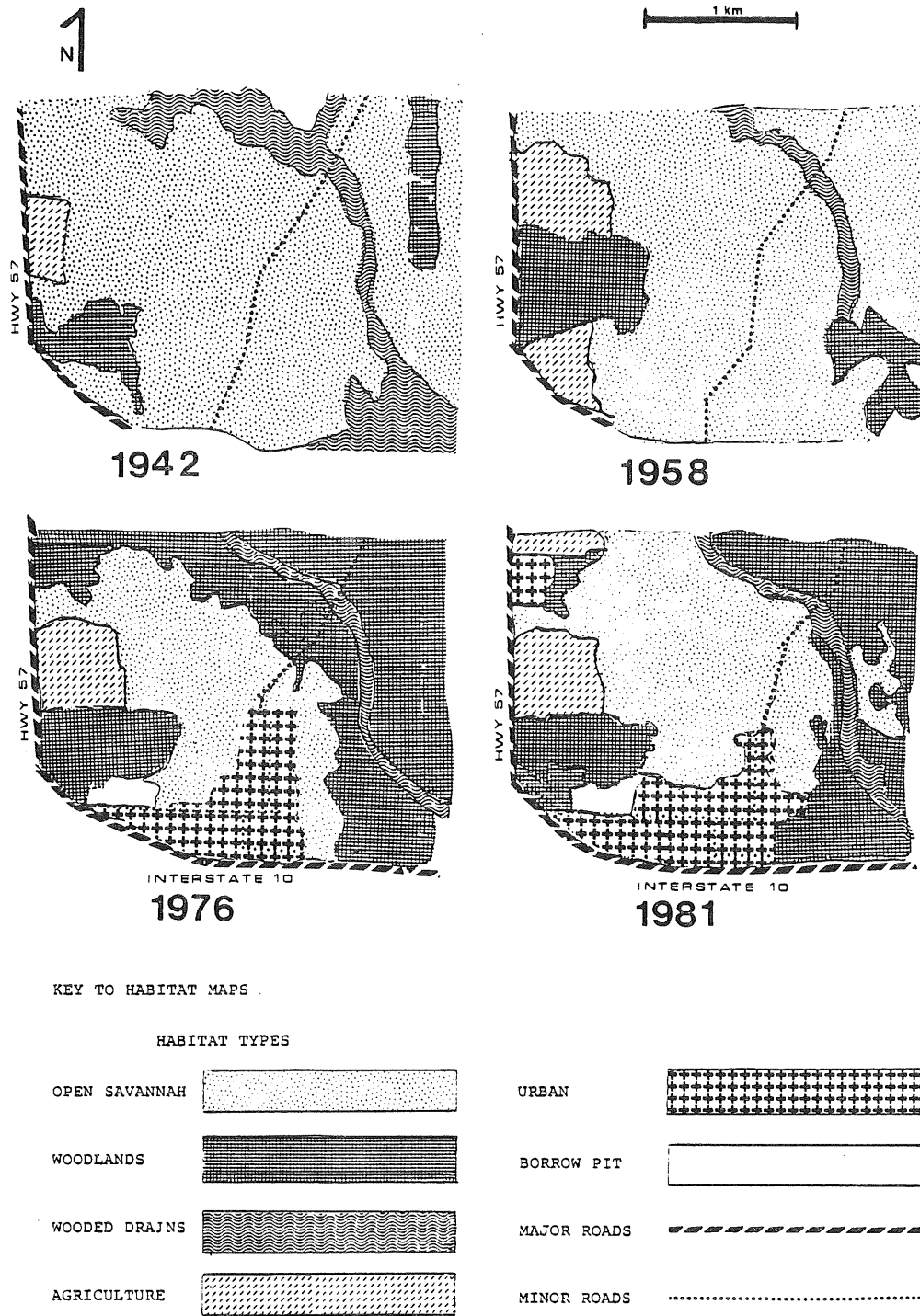


Fig. 2. Habitat changes in the Brown's Trail nesting area as determined by interpretation of four sets of aerial photographs (1942, 1958, 1976, and 1981) in Jackson County, Mississippi.

In 1942, except for several drains, the entire area was in open savanna (Fig. 3). By 1958 savanna was reduced to 59% and pine plantation occupied 41% of the area. Savanna (3%) continued to be displaced by pine plantation, which totalled 97% by 1976. In 1981 the area had opened up slightly because of clearing by refuge personnel (10% savanna and 90% pine plantation). St. Regis Paper Company constructed 18 km of roads between 1955 and 1965. Interstate Highway 10 forms the south boundary of the Perigal area, which is part of the Ocean Springs Unit.

Simms Road Area

This area held two territories during 1967 but only one in 1968 and 1969. Nests have not been found since 1969 but cranes are often seen during the spring, indicating that nesting may still occur there.

In 1942, 91% of the area was in open savanna and 9% in pine woodland or wooded drains. Only 12% savanna remained in 1976 with the rest in woodland. Little change in habitats occurred after 1976, except for about 50 ha hand-cleared by Young Adult Conservation Corps (YACC) and refuge personnel.

In the early 1970's St. Regis built a 2.4 km timber road into the area, extending a little used trail that had been there since the 1940's. No nesting was found after the road was built. Interstate Highway 10 forms the south boundary of the area, now part of the Ocean Springs Unit.

Fort Bayou Church Territory

Only one pair of cranes has nested in this territory (1968 and 1969) during our study. No data are available for 1942, but in 1958, 47% was in savanna, 14% woods, and 39% agricultural fields. In 1981 the region was 10% savanna, 69% forest, 17% agriculture, and 4% urban. Cranes stopped nesting in 1970 when the savanna was disked for agriculture.

Mary Bourne Territory

One nest was found annually 1968 through 1977 (10 nests) in a large savanna that had never been planted to pine. After 1977 a pair of cranes was usually seen in the territory each spring and inactive nests have been located but no active nests have been found. In May 1978 a crane was killed either by a vehicle or plane near an adjacent airport. If the dead crane had been part of the nesting pair, this may explain the absence of nesting; or the new pair may be nonbreeders.

In 1942 the area consisted of 63% savanna, 12% forest, and 23% agriculture. Savanna declined to 18% in 1976 and 14% in 1981. Agriculture remained about the same, but urban developments increased to 16% in 1981 (Fig. 4).

Agricultural lands consisted of small farms raising cattle, row crops, and pecans on a sandy ridge north of Simmons Bayou near Fontainebleau. Most of the pecan orchards were abandoned in the 1950's and grew into brush and pine. A small airport and a subdivision were developed between 1958 and 1981.

Eglin Road Territory

One nest was found each year from 1969 through 1972. There was a 4 year gap when none was found; then a nest was found in 1977, 1978, 1981, and 1983.

In 1942 savanna covered 91% of the area and woodland 9%. Forests increased to 33% by 1958 and savanna declined to 62%. In 1976 forests occupied 88% of the area and savanna only 6%. Agriculture and urban areas totalled 5% in 1976. An increase in savanna to 26% was manifest by 1981 due to hand-clearing by YACC crews and several fires.

Vickers Territory

This single pair was first found in 1975 and six nests have been found through 1984. The nesting site for five nests was a narrow marshy drain and one nest was found several hundred meters away in a mesic savanna that surrounded the main nesting site. A large subdivision borders the nesting habitat but is shielded by a strip of pine forest.

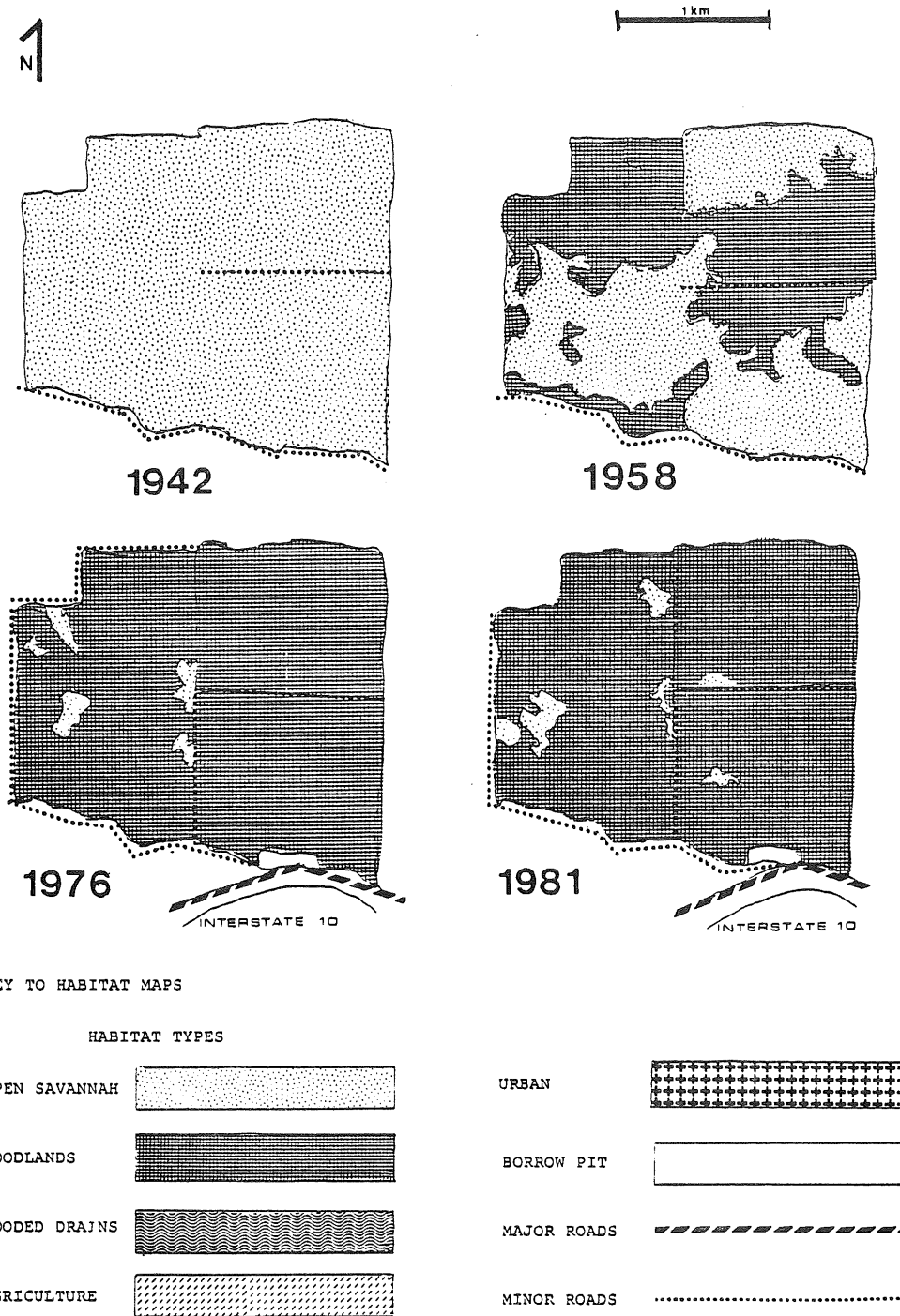


Fig. 3. Habitat changes in the Perigal nesting area as determined by interpretation of four aerial photographs (1942, 1958, 1976, and 1981) in Jackson County, Mississippi.

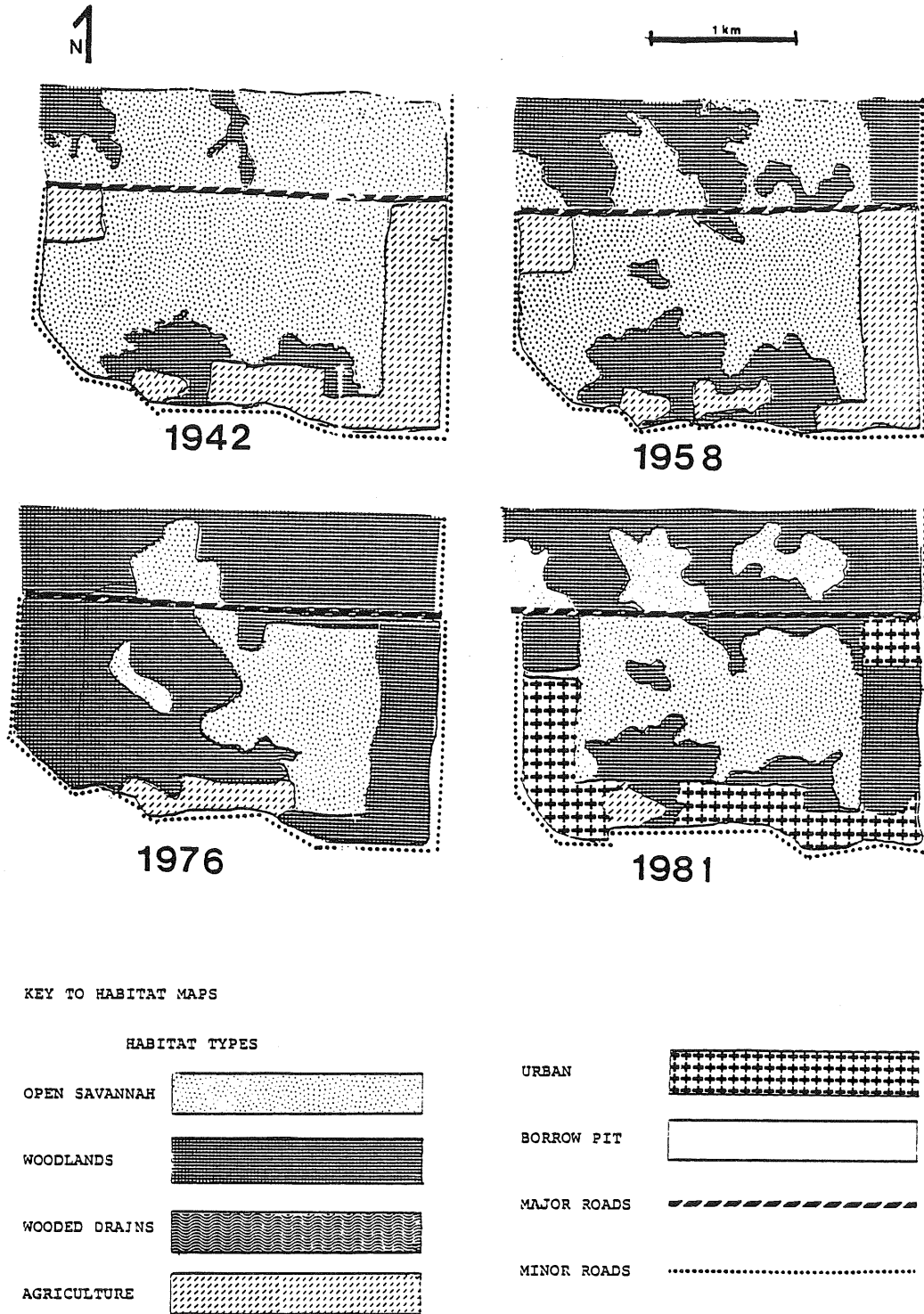


Fig. 4. Habitat changes in the Bourne nesting area as determined by interpretation of four sets of aerial photographs (1942, 1958, 1976, and 1981) in Jackson County, Mississippi.

Data are not available for 1942 but 71% was in savanna, 25% in forest, and 2% in agriculture in 1958. In 1976 savanna was reduced to 7%, forest had increased to 61%, agriculture to 8%, and urban to 24%. No changes were evident in 1981. Most of this tract had been owned by International Paper Company, but they had not managed the area for pine. Part of the land purchased by the FWS was a small cattle farm, now part of the Gautier Unit.

In 1958 there were 7.0 km of road in or near the territory. By 1981 Interstate Highway 10 was constructed through 4.0 km of the area and now forms the north boundary of the tract.

Mallette's Territory

This nesting territory was known to have a pair since the 1960's but it was not until 1978 that a nest containing eggs was found. Another was found in 1979 but none since then. Pairs have been seen here nearly each spring, inactive nests have been found and a released, captive-reared crane, bonded with a wild crane, occupied the territory and built start nests in 1983. Unfortunately, the released crane was shot on the territory in August 1983.

Data are not available for 1942. In 1958, 83% was in savanna, 15% in pine forest, and 2% in agriculture. By 1976 savanna had declined to 13%. By 1981 savanna increased slightly to 20%, mainly a result of wild fires. Agriculture increased to 12% due to land clearing for pasture.

In 1956 a narrow sandy track of 4.3 km ran through the area. By 1976 an additional 2.5 km of timber road had been constructed. The presence of the original trail did not discourage the cranes from breeding; one nest was found 63 m and another 94 m from the trail in 1978 and 1979. The trail became a popular hunting access road in the 1970's. A crane was found shot in the territory in 1980 and the captive-released crane shot in 1983 was found along the trail. The territory is within a Section 16 held by the State for the Jackson County school system.

Bear Pond Area

McIlhenny (1938) reported the first nest from here. One of his informants stated that two or three pairs regularly nested in Bear Pond. Turcotte (pers. comm.) found two nests with eggs in the late 1930's and early 1940's. Valentine and others have searched for nests at various times since 1963 but none has been found or reported.

In 1942, 65% of the lands were in savanna and 8% in forest. Agriculture and urban habitats totalled 11%. By 1981, 88% of the land was forested and only 6% savanna. Agriculture and urban developments totalled 13% by 1976 and 5% in 1981.

In 1942 there were 7.9 km of road within the area measured which increased to 18.7 km by 1981. Between 1958 and 1976 a high power line was built through 2.7 km of the region. In the 1980's most of the land was put on the real estate market. Large ditches were dug by dragline to drain the land in preparation for development. Despite the ditches and encroachment by trees and brush, there is still some savanna available as marginal nesting and feeding habitat.

DISCUSSION

In the pioneering days (1800's) hunting and herding were the main occupation. Little lumbering occurred until after the Civil War. Most of the land at that time was owned by the federal government. Later, through homestead acts, swamp land acts, grants to railroads and aids to education, the state, private individuals, and companies acquired lands that were eventually logged. The lumbering began slowly along the Pearl and Pascaquola rivers but gained impetus between the rivers after 1890.

The great mass of timber was cut by the early 1900's but smaller scale lumbering continued into the 1920's (Hickman 1962). Hilgard (1884) estimated that longleaf pine hills occupied 1,425 km² and pine flats 1,528 km² in Jackson County. The great longleaf pine forests were mainly north of the crane range.

In 1860 the area occupied by farms in Jackson County was about 22,000 ha which increased to 71,000 by 1890 then began decreasing to the low of 12,000 in 1982. Average farm size in 1890 was 200 ha which dropped to 20 in 1925 and rose to 50 ha in 1982. There were over 44,000 ha in pecan orchards in 1925 but by 1982 the figure had been reduced to 160 ha. Woodland pasture peaked at 16,000 ha in 1925, held steady until 1954, then declined to 5,000 ha in 1964. By 1982 only 950 ha were in wooded pasture (USDI Census Office, and U. S. Bur. Census, from Dewhurst 1985).

The turpentine industry began with the first colonists and persisted as a minor business within the crane range until World War II. Nearly everywhere on the refuge, relict live longleaf pine and old snags bear the "monkey-face" scars cut into trees by the turpentiners. Shards of the clay and discarded metal "cups" are scattered throughout the woods and savannas.

Land prices for virgin pine lands increased during the peak of lumbering and counties began raising taxes, so the lumbermen found it more profitable to remove the timber and get out. The cut-over lands were considered worthless by the lumbermen. Little was reforested but some timber corporations tried agriculture, which failed. Most cut-over land returned to the state for taxes or was sold to small farmers and investors. Leopold (1929) said a crane roost of 800 ha of cut-over land in Jackson County, owned by a timber company, was worth about \$5.00 per acre.

Agriculture in the early 1900's was marginal because stump clearing was difficult and the land poor. Settlement away from the coast was slow and most farms had only a few acres of corn in cultivation. Hogs and cattle roamed the cut-over land. Grazing and the attendant burning kept the range open. Livestock had to be fenced after the open range policy was abrogated during the 1950's. Pulpwood companies, such as St. Regis Paper Company and International Paper Company, had previously purchased or leased most of the larger tracts of land and in the 1950's began planting slash pine for pulpwood. The Mississippi Forestry Commission increased fire prevention and fire suppression. Burning of the savannas and forests was reduced.

Tree planting, mainly untried and experimental in this environment, was done on nearly all of the land owned and leased by St. Regis, from high ground down into and through savannas. On the better drained lands, the plantings were ridged and furrowed, but mostly the rows ran wherever the planter could go. Ditches were cut through the plantations to facilitate drainage. Many thousands of hectares were planted during the 1950's and 1960's.

St. Regis, during the 1950's and early 1960's, built 12.5 km of roads through their leased lands on the present Gautlier Unit. In the Ocean Springs Unit the company constructed 4.5 km on the Simms Road Area and 11.0 km in the lands between Old Fort Bayou Road and Seaman Road.

The coastal towns and cities south of the crane range have long been popular tourist attractions and pleasant places to live. Pascagoula became an industrial city during WW II with ship building and oil refineries as main industries. With economic and population growth, housing developments, individual farms, and residences began moving into the crane range in the 1950's-1960's. The refuge units are now islands, surrounded by urban developments, farms and residences, highways, and forest.

An attempt to correlate past land-uses with crane populations is frustrating because there are few early records. Hilgard (1860) who spent some time in the region speaks of the scarcity of any living thing. Leopold (1929) estimated "at least 50, and possibly 100 or more", but left no record that he saw any cranes. He said there appeared to be no immediate danger to the bird or its environment, but that smallscale "sniping" might prevent their increase. Local cooperators nest searching for McIlhenny (1938) found 11 in present Gautlier Unit. Our estimate of nesting pairs in the same area in 1984 was four. Walkinshaw (1949) estimated more than 25 pairs for the whole range in 1940.

The 1930's and 1940's may have been the peak era for the cranes: the human population was low; roads had not penetrated much of the crane range; and the forest industries, such as turpentine and lumbering, were nearly inactive. Cattle grazing and concomitant burning of the range were mixed benefits.

During the 1930's and 1940's, when openness was a characteristic of the crane range, nesting and feeding sites were probably much more abundant. Fewer roads and the greater distances of open country would have provided greater freedom from disturbance by vehicle traffic. The area was thinly settled and fewer people used the cut-over land after lumbering and turpentine were phased out. Undoubtedly some country people killed cranes to eat, as they did deer and any other wild game that came across their path, but in general the people enjoyed seeing cranes.

During the open range period (1900's-1940's) when livestock roamed at will, crane nesting habitat may not have been ideal because of overgrazing and wanton burning. The paradox of burning is that there may be long-term benefits in reducing brush cover, but the fires also destroy nesting material and may destroy nests, eggs, and young. Cattle might trample nests and chicks, and hogs would be predators on eggs and young.

World War II and post-war years (1942-1950) brought prosperity to the coastal cities of Jackson County, but the crane range had few people, no industry, and little growth. The end of open range, and slash pine planting by pulpwood companies (particularly by St. Regis Paper

Company), ended cattle grazing, reduced range fires, and began reforestation by design and natural succession. In the 1950's the stumps left by timber companies were pulled out and processed for the concentrated pitch. The resulting water-filled depressions provide drinking water for the cranes.

MISSISSIPPI SANDHILL CRANE NATIONAL WILDLIFE REFUGE

Valentine proposed acquisition of the refuge in 1963 and in 1970 the FWS began the formal process of refuge acquisition. The Nature Conservancy made the initial purchase of 700 ha in 1974 and a total of 1,051 ha by 1976. They also were able to purchase the bulk of the Ocean Spring Unit (2,440 ha) from St. Regis Paper Company. The FWS purchased these lands from the Nature Conservancy. The Department of Transportation, to comply with a federal court order, purchased 793 ha around the I-10 Interchange and along the Gautier-Vancleave Road. The FWS has been able to acquire the best available lands for cranes, through fee title and leases. Fee title lands totalled 6,411 ha in 1983.

By the 1970's most of the open savanna was gone and nesting habitat was found only in isolated wetter areas where tree planting had not succeeded and where fires were frequent enough to reduce tree and brush cover. After 20 seasons of nest searching by Valentine and others, we believe that most suitable nesting habitats have been found. Among 99 nests found (1965-1984), 46 were in open savanna, 33 in swamp edge, 9 in pine plantation, 5 on forest edge, and 6 in cleared areas. The ground cover was essentially the same but the tree and shrub overstory surrounding the nesting sites varied in density. Percent of woody vegetation was greatest along swamp edge, next, in pine plantation, and least in savanna (Valentine 1981b). No measurements were made in man-made clearings but there most of the trees were gone and brush cover was light.

The past and present cover of 24 sites that had active nests was compared (Table 2). In some situations, the nesting pair left their traditional territory and moved once or twice several kilometers. The original territory was called "inactive" despite the existence of the breeding pair and the new site was called "active" (Table 2). Among sites (six) with heavy cover, all were deserted; five with light cover were active and four were deserted. Seven sites, some formerly pine forests (four) and not used for nesting and three others used previously for nesting, were cleared by hand or machine. Four of these (pine forest clearings) were used after clearing and three had no nesting.

Among 12 currently active or potentially active nesting sites (9 territories), all but 1 are on the MSCNWR. Except for arson or accidental fires, the refuge sites are secure from habitat damage. Nests have not been found outside the refuge (1979-1984), but in March 1985 a nest was found in the Weber Territory. The territory contained two small savannas surrounded by planted pine and was considered safe from damage; however, during the winter of 1984-1985 the paper company that owns the land had bedded and furrowed most of the two savannas in preparation for tree planting, leaving less than a hectare undisturbed. The cranes had come in to nest after the equipment had gone.

Interstate Highway 10, completed in 1979, transects the breeding range from the Ocean Springs Interchange to the Martin Bluff Road, a distance of 17 km. There are three interchanges along this route: Old 90 at Ocean Springs, Mississippi 57, and Gautier-Vancleave Road. The construction of the latter was temporarily halted by court action. Old U. S. 90 bisects the Fontainebleau Unit of the refuge, a distance of 3 km.

Seaman Road forms the northwestern boundary (5.5 km) of the Ocean Springs Unit and the Gautier-Vancleave Road crosses the eastern side of the Gautier Unit. State Highway 57, on the west side of the Gautier Unit, is about 0.5 km or more away from the refuge boundary. Old Ft. Bayou Road splits the Ocean Springs Unit into two parts; Eglin Road forms the west boundary of the Eglin Territory and Brown Road goes through the refuge in the same locale.

The effect of the highways on the cranes has been varied. Interstate Highway 10 removed 340 ha of potential habitat and the digging of an excavation pit destroyed a nesting territory (Valentine 1981b). Vehicular noise and movement has precluded nesting in the open savannas adjacent to the highways. Where pine forests shield the highways, cranes have nested within 0.5 km of I-10 and within 80 m of a county highway. At least three cranes were killed by vehicles since 1978.

St. Regis Paper Company constructed 28 km of access roads on their holdings before acquisition by the FWS. One pair nested twice within 100 m of a little used trail off the refuge, but in one instance the cranes stopped nesting after St. Regis built an access road on their

Table 2. History of 24 sandhill crane nesting sites found between 1965 through 1984 in Jackson County, Mississippi.

Terr. no.	First found	Last used	Years of use	Active (1984)	Past cover	Present cover
Br1A	1965	1966	2	No	Light	Heavy
BR1B	1969	1984	13	Yes	Light	Light
BR2	1966	1981	8	No	Light	Cleared
Wm3	1965	1965	1	No	Light	Heavy
Wm4	1966	1983	13	No ^a	Light	Light
Wm5	1971	1974	5	No	Light	Heavy
Wm7	1984	1984	1	Yes ^a	Heavy	Cleared
Wm6	1971	1983	4	No	Light	Light
Per7A	1966	1970	3	No	Light	Heavy
Per8A	1966	1968	3	No	Light	Borrow pit
Per7B	1969	1971	2	No	Light	Heavy
Per8B	1972	1973	2	No ^b	Light	Heavy
Per14	1982	1982	1	No ^b	Heavy	Cleared
Per14a	1983	1983	1	No ^b	Heavy	Cleared
Per14b	1984	1984	1	Yes ^b	Heavy	Cleared
Sim9	1967	1969	3	No	Light	Cleared
Sim10	1967	1967	1	No	Light	Cleared
FTB	1968	1969	2	No	Light	Destroyed
Bour	1968	1977	10	No	Light	Light
EgRd	1969	1983	8	Yes	Light	Light
Vick	1975	1984	7	Yes	Light	Light
StR	1976	1981	2	No	Light	Light
Web	1977	1985 ^c	3	Yes	Light	Bedded
Mal	1978	1979	2	No	Light	Light

^a This pair left its traditional site and moved 2.5 km to another site.

^b This pair has used three different sites during 3 years.

^c An active nest found in March 1985; nesting area being plowed and bedded for pine planting.

property. The timber roads presently on the refuge provide access and serve as fire breaks. A strip of trees and brush is maintained along all of the highways that border refuge lands.

CONCLUSIONS

Mississippi sandhill cranes prefer to nest in savannas, or in other openings at edges of swamps, forests, or pine plantations. The history of the crane range indicates that nesting habitats have been constricted through the expansion of forests, pine plantations, urban developments, farms, residences, roads, and highways. The Mississippi sandhill crane nests in drier habitats than most cranes, with the exception of the Cuban and some populations of the lesser sandhill, but water is necessary in the maintenance of preferred habitats and for drinking.

The marshy nature of nesting habitats is maintained by a hardpan that forms hanging water tables near the soil surface. Water run-off has been diverted and quickened by ditches dug by pulpwood companies and through roadside ditches and highway borrow pits. Once established, forests can occupy marshy habitats and reduce surface water through use and transpiration.

Roads and highways have reduced crane habitat by their presence and indirectly by stimulating real estate development. Vehicle noises and movements further restrict crane use. Trucks and cars have killed cranes, both the captive-released and wild birds.

Refuge habitat management includes clearing and thinning of trees and shrubs by hand, machine, and prescribed burning; water control structures, road dams, and ditch plugging to improve water economy; and selective clearing and tree planting to separate crane territories and shield nesting and feeding habitats from disturbance.

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