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Abstract: Three stratified random samples of the 416 National Wetland Inventory (NWI) maps within the western Oklahoma portion of the Wood Buffalo-Aransas whooping crane (*Grus americana*) migration corridor were used to evaluate the availability of wetland roost sites. Wetlands were eliminated as potential roosts if visibility was obscured by vegetation or slope, or if certain human activities occurred within 100−800 m. Thirty percent of all wetlands >0.04 ha passed map review, but only 7% passed when ground truthed. NWI map review was a poor predictor of suitability (33% correct) but a good predictor of unsuitability (97% correct). Most (>75%) wetlands in western Oklahoma are man-made impoundments dug to water livestock. They are generally small (<1 ha), dammed, in steep drainages, and tree-lined. Most stock ponds do not meet the horizontal visibility requirements of roosting whooping cranes. Map review of wetlands >1 ha (no randomized field review) suggests that 2−4 suitable crane roosts are available per 100 km^2 in the migration corridor in Oklahoma. Three major rivers and approximately 20 large reservoirs (>16 ha) provide the best roost sites. Without adequate ground truthing, review of NWI maps, even when supplemented by Soil Conservation Service photo maps, overestimate suitable roost sites, especially in areas where rainfall is sufficient to support woody vegetation >1 m in height.

Key Words: *Grus americana*, habitat, maps, migration, Oklahoma, whooping crane

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The whooping crane is one of the best known endangered species and has received considerable attention during the past half century. In the 1940's and early 1950's protection and management were concentrated on the wintering grounds at Aransas National Wildlife Refuge, Texas, then the species' only known area of use (Allen 1952). An equal emphasis on management and research occurred at Wood Buffalo National Park, Northwest Territories, Canada, after the breeding grounds were discovered there in 1954. During the 1960's and 1970's establishing a captive and an additional wild flock became integral parts of management efforts (Erickson 1975, Drewien and Bizeau 1978). Since the mid-1970's there has been an increased emphasis on documenting and understanding the migration routes and stopover roosting habitat used by Wood Buffalo-Aransas whooping cranes (Lingle et al. 1984; Howe 1987, 1989; Ward and Anderson 1987). As information has accrued on migratory roost sites, it has been possible to develop suitability criteria and indices for non-traditional roosts (Armbruster 1990), which are defined as sites used only a few nights (usually only 1 night) during migration (Melvin and Temple 1982). Concern about the availability of suitable roosts within the migration corridor (Lingle 1987) has prompted efforts to inventory potential roost sites.

The U.S. Fish and Wildlife Service (USFWS) initiated its current and ongoing National Wetland Inventory (NWI) program in 1974 based on a detailed hierarchical classification system (Cowardin et al. 1979). The goal of NWI is to provide baseline data on the physical characteristics and extent of all United States wetlands so that these diminishing habitats might be better managed (Montanari and Townsend 1977). The purpose of this study was to evaluate the utility of NWI maps, when used in conjunction with aerial photo maps and suitability criteria (Armbruster 1990), in predicting stopover roost availability for migrant whooping cranes in western Oklahoma (Fig. 1).

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METHODS

I used NWI maps, U.S. Soil Conservation Service (SCS) aerial photo maps, whooping crane roost suitability criteria (Armbruster 1990), and ground truthing to estimate the density of potential whooping crane roosts in western Oklahoma. There are 14 common NWI wetland types (Cowardin et al. 1979) in the study area. Eleven have potential as whooping crane roost sites and can be grouped into 3 general wetland types: open water, emergent, and riverine (Table 1).

Two U.S. Geological Survey map scales are pertinent to this study: 1:24,000 and 1:100,000. NWI maps are 1:24,000 topographic maps (157.5 km^2) upon which

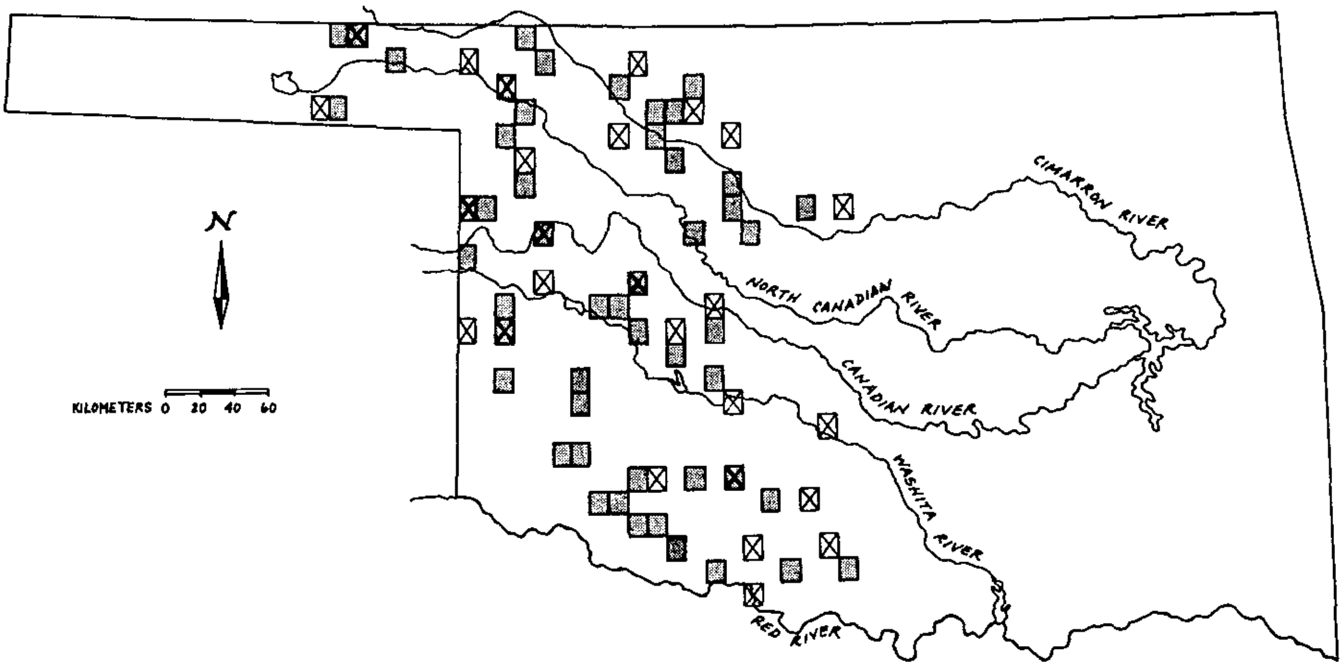

Fig. 1. Rivers, reservoirs, and sample NWI maps in western Oklahoma. Sample I maps contain an X and Sample III maps are shaded. Sample II sections occurred within Sample I maps.

USFWS biologists have mapped and categorized wetlands. There are 32 (4 × 8) NWI maps within each smaller scale 1:100,000 map and 13 1:100,000 maps within the whooping crane migration corridor in western Oklahoma. I conducted 3 stratified random samples of the 416 (13 × 32) NWI maps available to evaluate roosting habitat availability within this study area.

Sample I

This 26 (6%) map sample was obtained by randomly selecting 2 NWI maps from each of the 13 1:100,000 map units (Fig. 1). Previous migration studies have documented that >50% of stopover roosts were in wetlands <1 ha (Howe 1987, 1989). Therefore any wetland large enough (>0.04 ha) to appear on a NWI map was evaluated. Wetlands were subtotaled on each 640-acre section (256 ha) and totalled for the entire NWI map (157.5 km^2).

All wetlands were categorized by type (open, emergent, or riverine) and size (> or <1 ha). I used a Wainer Land Area and Slope Indicator to estimate wetland size. Streams were difficult to categorize by size. Therefore the entire reach of a stream in a section was considered 1 wetland; a stream that crossed more than 1 section was recorded in each section. This portion of my evaluation was equivalent to Armbruster's (1990) Suitability Index of Wetland Size (SIWS) (Fig. 2a).

A Suitability Index of Horizontal Visibility (SIHV) for each wetland was then determined. A wetland <50 m from obstructions >1 m high, such as shrubs, trees, or steep slopes along >15° of shoreline is considered unsuitable for crane roosting (Armbruster 1990) and was assigned SIHV of 0.1 (Fig 2B). I examined SCS photos to determine distance to trees and tall shrubs from each wetland. SCS photo maps were 10–30 years old, sometimes making direct comparisons difficult. I used contour lines on NWI maps to estimate slope; 2 or more 3-m contour lines within 60 m of the shoreline for >180° portion of the wetland also resulted in an SIHV of 0.1 and deletion from further consideration.

Those wetlands meeting the SIHV criteria were then evaluated for disturbance factors (Table 2) (Armbruster 1990). If at least 0.04 ha of a wetland was beyond the range of all disturbance factors, as measured on the NWI map, it had Passed Map Examination (PME).

Sample II

I randomly selected 3 sections (2.56 km^2) from each NWI map in Sample I (n = 78) to ground truth that sample. During November 1990 I visited all sample sections. For each wetland an SIHV was estimated and

Table 1. Wetland classifications (Cowardin et al. 1979) commonly encountered on Oklahoma NWI maps and their stopover roost categories.

Map code	Wetland classification	Stopover category
PUBHh	Palustrine, Unconsolidated Bottom, H = permanent, h[a] = impounded	Open
PUBHx	Palustrine, Unconsolidated Bottom, H = permanent, x = excavated	Open
POWHh	Palustrine, Open Water (unknown bottom), H = permanent, h = impounded	Open
PUSC	Palustrine, Unconsolidated Shore, C = seasonal	Open
PUSA	Palustrine, Unconsolidated Shore, A = temporary	Open
PUSAf	Palustrine, Unconsolidated Shore, A = temporary, f = farmed	Open
PEM1C	Palustrine, EMergent, 1 = persistent, C = seasonal	Emergent
PEM1Cd	Palustrine, EMergent, 1 = persistent, C = seasonal, d = ditched	Emergent
PEM1A	Palustrine, EMergent, 1 = persistent, A = temporary	Emergent
PFO1C	Palustrine, FOrested, 1 = broad-leaved, deciduous, C = seasonal	None[b]
PSS1C	Palustrine, Shrub/Scrub, 1 = broad-leaved, deciduous, C = seasonal	None[b]
R4SBC	Riverine, 4 = Intermittent, Stream Bed, C = seasonal	None[c]
R2USC	Riverine, 2 = Lower Perennial, Unconsolidated Shore, C = seasonal	Riverine
L1UBHh	Lacustrine, Unconsolidated Bottom, H = permanent, h = impounded	Open

[a] **d**, **f**, **h**, or **x** (indications of human efforts) could be attached with most of the other letter codes as well.
[b] Wooded wetlands were excluded from potential stopover habitat considerations because of horizontal visibility problems.
[c] Seasonal streams are generally dry during migration or narrow and tree/shrub lined, causing horizontal visibility problems.

disturbance factors evaluated. If SIHV and disturbance criteria were met, I determined a Suitability Index of Water Depth (SIWD) by either measuring or estimating water depth. An SIWD of 1 was assigned if water was <30 cm deep at 20 m from shore; otherwise SIWD was 0 (Armbruster 1990). Those wetlands passing all 3 tests had Passed Ground Truthing (PGT). PGT results were compared directly with PME roosts quantified in the same sections during Sample I.

Sample III

Ground truthing indicated that few small (<1 ha) wetlands were suitable as whooping crane roosts. I therefore randomly selected 3–4 NWI maps from each 1:100,000 unit (Fig. 1), to sample wetlands >1 ha. In this sample, I grouped non-riverine wetlands as impoundments or "other." Impoundments were indicated on NWI maps by a subscript (Cowardin et al. 1979). "Other" included primarily seasonal wetlands, both with and without emergents. I followed the same procedures outlined in Sample I to eliminate unsuitable wetlands.

Sample III was not ground truthed. During November 1990, however, I ground truthed 38 wetlands >1 ha in size that were near Sample II sections. All were impounded wetlands. The ground truthing of these large wetlands, though not randomly selected, provided an indication of the suitability of larger man-made wetlands as crane roosts.

Analysis

I totalled wetlands by type, size, and suitability criteria for each NWI map in Samples I and III and for each section for Sample II. Wetlands/NWI map (Samples I and III) and wetlands/section (Sample II) were converted to wetlands/100 km^2 and wetlands/km^2, respectively. I used regression analysis to evaluate the relationships between variables within Samples I and III and a binary response model to test the ability of PME wetlands to predict PGT wetlands in Sample II. Statistical tests were conducted on non-riverine wetlands only because streams, as linear habitat, were not discrete wetland units.

RESULTS

Sample I

Nearly 8,000 wetlands were evaluated on NWI maps. Most (70%) did not meet SIHV or disturbance suitability criteria. Thirty percent of the wetlands passed map examination, but only 3% were >1 ha (Table 3).

The average number of PME roosts/100 km^2 was 55 (range = 7–181). PME roosts increased significantly (*F*

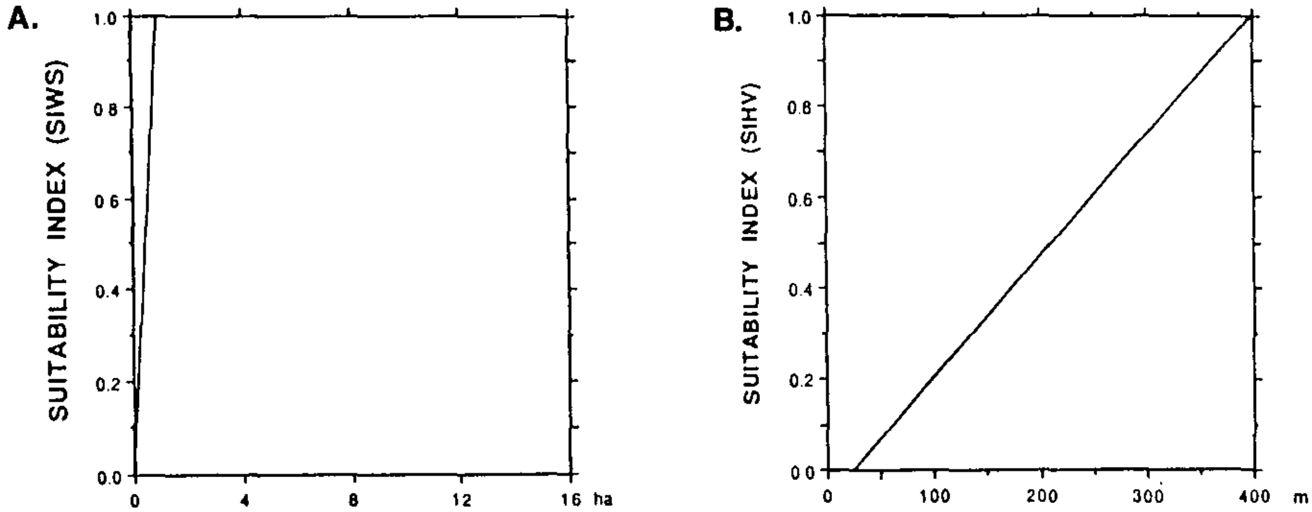

Fig. 2. Predicted relationships between (a) wetland size and (b) horizontal visibility and roosting suitability for non-traditional (migration) stopover sites (from Armbruster 1990).

= 10.96, P = 0.003) from northwest to southeast Oklahoma. There was a mean of 194 (range = 46–547) wetlands >0.04 ha/100 km^2. Total wetlands >0.04 ha/100 km^2 also increased significantly (F = 18.51, P = 0.001) from northwest to southeast. Total wetlands were a good predictor (F = 54.97, P = 0.001) of PME roosts by the equation:

$$\text{PME} = 0.292\ (\text{total wetlands}) - 2.7.$$

Sample II

The percentages of PME wetlands/km^2 in Sample II were similar to those of Sample I; the 78 2.56 km^2 sections in Sample II appeared to be representative of the larger sample. However, while 30% of the wetlands passed map examination, only 7% passed ground truthing (Table 3).

The purpose of ground truthing was to test the predictive value of map examination. The binary response model produced a 2 × 2 contingency table (Table 4) which showed a high association between map and ground examinations (χ^2 = 10.72, df = 1, P = 0.001). NWI map review was a poor predictor of suitability, since it was correct only 15 of 45 times (33%). However, it correctly predicted unsuitability 32 of 33 times (97%).

Sample III

Of wetlands >1 ha, there were significantly more impounded wetlands/100 km^2 ($\bar{x}$ = 6.5) than all others ($\bar{x}$ = 1.7) (t = 5.60, P < 0.001). Because a much lower percentage of impoundments passed SIHV and disturbance tests (Table 3), the PME means of impoundments ($\bar{x}$ = 1.0) and others ($\bar{x}$ = 0.95) were not significantly different (t = 0.17, P = 0.87).

Total wetlands >1 ha averaged 8.2/100 km^2 (range = 0–21). These larger wetlands also increased significantly (F = 13.55, P = 0.001) from northwest to southeast. Roosts >1 ha passing map examination averaged 2/100 km^2. PME roosts did not increase to the southeast (F = 0.25, P = 0.617) nor were total wetlands an indicator of PME large roosts (F = 3.94, P = 0.054).

Table 2. Disturbance types and their estimated zones of influence (m) on whooping crane selection of stopover roosts. From Armbruster and Farmer (1982) as adapted by Armbruster (1990).

Disturbance type	Width of affected area (m)[a]
Private road	100
Power line	100
Gravel road	200
Rural dwelling	200
Recreation area	200
Paved road	400
Railroad	400
Bridge	400
Urban dwellings	800
Commercial development	800

[a] Width of a band on each side of a linear feature, or radius of a circle around a point.

Table 3. Percentages of western Oklahoma wetlands that passed or failed map and/or field examination.

Sample	Wetland type	*n*	Passed examination (%)		Failed examination (%)		
			<1 ha	>1 ha	Visibility	Disturbance	Depth
I	Open	6,624	25	2	48	25	
	Emergent	1,297	30	5	38	27	
	Riverine	69		38	62	0	
	Totals	7,990	26	4	47	25	
II_{map}	Open	318	27	1	45	27	
	Emergent	54	35	2	37	26	
	Riverine	3	0	100	0	0	
	Totals	375	28	2	43	27	
II_{ground}	Open	323	3	1	86	9	1
	Emergent	50	17	2	69	12	0
	Riverine	3	0	100	0	0	0
	Totals	376	5	2	84	9	1
III	Impounded	488		15	76	9	
	Other	121		59	27	14	
	Riverine	83		60	40	0	
	Totals	692		28	63	9	

Half of the 38 wetlands >1 ha in my non-random field sample were judged to be suitable whooping crane roosting habitat (PGT). Mean SIHV was 0.3 (150 m) with a range of 0.1–1.0 (50–500 m).

Rivers

Riverine areas occurred on 60 sections in Sample I, and 38% of those areas passed map inspection. During the field check of Sample II, all 3 PME rivers in the 78 sections (4%) also passed ground truthing. Riverine areas were identified in 83 sections in Sample III; 60% of these reaches passed map examination.

DISCUSSION

The increase in wetlands from northwest to southeast in the whooping crane migration corridor in Oklahoma coincides with a doubling of average annual precipitation over the same gradient. Boise City in the northwest has an average annual rainfall of 40 cm while Ardmore in the southeast averages 86 cm/year (U.S. Department of Commerce 1985). Higher rainfall in the east and south also contribute to woody vegetation growth around wetlands, resulting in visual barriers that decrease roost site suitability.

Although not quantified as part of this study, I estimate that >75% of the wetlands on western Oklahoma NWI maps were identified as permanent man-made impoundments. The principal purpose of these ponds is to provide year-round water sources for livestock. These stock ponds are generally small (<1 ha), with steep banks, dams, a tree-lined shore, and most do not meet horizontal visibility requirements (Armbruster 1990) of roosting whooping cranes.

The highest ranking wetlands for crane roosting located during ground truthing were rivers and seasonal depressions in wheat fields. Ten (45%) of 22 non-riverine, PGT roosts encountered were wheat field depressions in only 2 (3%) northwestern sections in Sample II. Although most were dry when inspected, they are more likely to have water during spring crane migration (April) and would have large shallow areas and good horizontal visibilities. Their clumped occurrence within Sample II suggests that this type of seasonal wetland is not uniformly distributed through the study area.

Sample III of wetlands >1 ha was initiated because ground truthing of smaller wetlands suggested that suitable roosting habitat was limited. Sample III map review showed an average of 2 PME wetlands >1 ha/100 km^2. PME wetlands >1 ha did not increase from northwest to southeast, but it was not determined if they were uniformly distributed. My non-random sample of 38 wetlands >1 ha in November 1990 indicates that approximately 50% of these wetlands are suitable crane roost sites. These 2 estimates give a range of 2–4 roosts/100 km^2. Whether

Table 4. A 2 x 2 contingency table of Sample II sections containing (Yes) or not containing (No) suitable whooping crane roosts.

		Map examination		
		No	Yes	Total
	No	32	30	62
Ground truthing	Yes	1	15	16
	Total	33	45	78

this is adequate for migrating whooping cranes is not known, nor was it possible to determine if availability is equal throughout western Oklahoma.

Western Oklahoma is drained by 5 major streams, the Cimarron, North Canadian, Canadian, Washita, and Red Rivers. These rivers flow generally from west to east, perpendicular to the whooping crane migration corridor (Fig. 1). The degradation of Nebraska's Platte River's crane roosting habitat as a result of dams, water diversions, and vegetation encroachment is well documented (Currier et al 1985). Oklahoma's prairie rivers most likely also provided excellent roosting habitat for migrant cranes before European settlement. During my field survey I crossed these 5 rivers several times and recorded a SIHV at each crossing. The North Canadian and Washita Rivers had no areas with SIHV's >0.1. Both rivers were narrow (<25 m wide), incised, and bordered by trees and shrubs. This was likely caused by several major dams on each river within Oklahoma. Smaller tributaries of the Red River, the North Fork, Salt Fork, Otter Creek, and Cache Creek, had similar physical characteristics. Lewis (1976) documented the invasion of the North Fork stream channel by saltcedar (*Tamarix gallica*) and the resultant loss of a traditional winter sandhill crane (*Grus canadensis*) roost there.

In contrast, the Cimarron, Canadian, and Red Rivers all had reaches where SIHV's exceeded 0.4 (200 m). None of these rivers are dammed within western Oklahoma. These rivers provide many kilometers of suitable roosting habitat for migrant whooping cranes, and whooping crane use has been documented this past decade on the Cimarron River (USFWS 1986).

Although large (>16 ha) man-made reservoirs have degraded downstream riverine roosting habitat, they have also created new roosting areas. As of 1986 there had been 34 confirmed sightings of whooping cranes at Great Salt Plains Reservoir (Great Salt Plains National Wildlife Refuge), 6 sightings at Foss Reservoir (Washita National Wildlife Refuge), 2 confirmed records at Ft. Cobb Reservoir, and 1 record at Ft. Supply Reservoir (USFWS 1986). A cursory check of Great Salt Plains, Ft. Supply, Ellsworth, Fuqua, and Waurika Reservoirs during my November 1990 field visit indicated that all 5 had roosting areas with acceptable SIHV values and low potential for disturbance by man. Additional reservoirs, particularly in southcentral Oklahoma, may be providing additional roosting sites for migrant whooping cranes.

CONCLUSIONS AND RECOMMENDATIONS

Map review of wetlands >0.04 ha recorded on NWI maps overestimated the distribution and abundance of suitable whooping crane roosting habitat in western Oklahoma. Ground truthing of NWI wetlands revealed that wetlands <1 ha seldom were suitable roost sites. NWI maps show wetland size and type and distances to human disturbances can be easily measured, but visual obstructions are generally not shown. Use of SCS photo maps helped to eliminate many wetlands with trees and shrubs, but incorrectly predicted suitability of 23% of all wetlands available. Thus NWI map and SCS photo map review was a poor predictor of roost site suitability (0.33) though a good predictor of unsuitability (0.97).

Map review can be used to eliminate unsuitable wetlands and indicate which wetlands need on-site inspection. Predictive values from this study may be applicable to Texas and Kansas,where rainfall amounts are similar, but their use in the Nebraska, South Dakota, North Dakota, and Montana portions of the whooping crane migration corridor is not recommended.

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