Environmental Criteria for Nest Site Selection by Mississippi Sandhill Cranes

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Abstract: Seven environmental parameters were estimated at each nest site and 2 or 3 (per nest) systematically selected control (non-nest) sites during pre-nesting (March–April) and post-nesting (May–July) 1983 and 1984 on the Mississippi Sandhill Crane National Wildlife Refuge. Discriminant analysis revealed percentage of vegetation at the nest site was the only variable that differed between nests and control sites during pre-nesting and post-nesting periods for both years. Ground cover of water and water depth next to the nest differed from control sites during post-nesting 1983 and pre-nesting 1984. In 1984, an unusually dry year, the importance of standing water during post-nesting was reflected as a significant difference in bare ground. Foliage invertebrates were more abundant and diverse at nest sites. These data suggest that the amount and distribution of standing water during pre-nesting may be good predictors of invertebrate abundance and availability to young sandhill hatchlings.

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The Mississippi sandhill crane (*Grus canadensis pulla*) is one of 6 subspecies of sandhill crane which range extensively across North America, western Cuba, and the western edge of Siberia (Walkinshaw 1981). The Mississippi sandhill crane is a resident of the Gulf Coast, in southern Jackson County, Miss. Today, its range and population are diminished and in 1973 the Mississippi Sandhill Crane was added to the U.S. Department of Interior's endangered native fish and wildlife list. An inhabitant of the coastal prairies and savannas (Valentine and Noble 1970, Aldrich 1972), Mississippi sandhill cranes prefer hydric savannas and nearby agricultural fields (Dewhurst 1985). According to Valentine (1982) nesting habitat selection is as follows: savanna (57%), swamp edge (19%), pine plantation (13%), cleared pine plantation (5%), pine edge (4%) and cleared savanna (2%). Compared to the other sub-

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species, *G. c. pulla* nests in habitat with greater standing tree densities (Walkinshaw 1949).

Mississippi sandhill cranes (as are all cranes) are highly territorial during the breeding season (Walkinshaw 1965) and typically occupy territories from February through August (Smith 1986). Among greater sandhill cranes (*G. c. tabida*), territory size varies inversely with population density. Inter-territorial disputes occur more frequently when densities are high (Littlefield and Ryder 1968) and presumably the potential for intraspecific competition is greatest. Territory defense by sandhill cranes (as with many species) involves a considerable expenditure of energy as well as relatively high risk to injury (Krebs and Davies 1984). The benefit derived from such behavior must surely be related to reproductive success and presumably represents defense of some critical set of resources. Consequently selective pressures associated with territory selection and defense by Mississippi sandhill cranes are severe and probably influence many other life history attributes and processes.

Nesting cover, standing water and a nearby feeding area (e.g., meadow) are essential components of sandhill crane breeding territories (Walkinshaw 1965, Littlefield and Ryder 1968). One would suspect that any 1 or all of these resources are critical for reproductive success. Birds, however, occupy territories as early as February and often do not begin nesting until May. We suspect that tradition (i.e., the tendency to use a site year after year) plays an important role in nest site selection by many cranes. However, the environmental features that facilitate selection of nesting habitat 2–3 months prior to nesting and up to 5 months before hatching have not been determined.

Our objective was to determine environmental features that may discriminate nest sites from the available habitat and possibly serve as predictors of nesting habitat quality. Such information could provide valuable insight into Mississippi sandhill crane nesting ecology and behavior and provide the basis for habitat modifications and management.

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Study Area

At the time of this study, all known Mississippi sandhill crane nesting was confined to Mississippi Sandhill Crane National Wildlife Refuge in the southeastern corner of Jackson County, Mississippi. The refuge is comprised of 3 units: Ocean

Springs, 5 km north of Ocean Springs, includes 3,200 ha; Gautier, 15 km northeast of Ocean Springs, encompasses 3,200 ha; and Fontainebleau, 4.5 km north of the Gulf of Mexico and immediately south of Gautier, contains 470 ha.

The refuge is within the Gulf Coastal Plain and moist soils predominate because of nearly level topography, poor drainage, and a high water table. Most soils are loam to sandy loam with moderate amounts of organic matter, highly acidic, and low in fertility (Cole and Dent 1964, Norquist 1984). The vegetation is savanna, swamps (wooded drainages), and pine woodlands with 7 habitat types: mesic savanna, hydric savanna, wooded drainage, pine woodland, pine plantation, agricultural land, and fallow land (Mitchell 1984). Natural and planted pine woodlands contain similar plant communities. Natural pine woodlands are a mixture of longleaf pine (*Pinus palustris*) and slash pine (*P. elliotti*). Among plantations slash pine is dominant. Understory plants include pineland three-awn (*Aristida stricta*), bluestem grasses (*Andropogon* spp.), and panic grasses (*Panicum* spp.)

Methods

We located nest platforms during the pre-nesting period by conducting on-the-ground searches (beginning Feb 1983) within known territories. Because of the scarcity of active nests in any given year, known nests from the previous year were included in our evaluation of environmental features during the pre-nesting period. A test of the critical assumption that these nest sites do not change appreciably over a year supported our decision to include nests from the preceding year in our sample. After nests were located, we systematically selected 2 or 3 sites in the general vicinity of the nest as control (non-nest) sites. These sites had no previous record or evidence of nesting activity but appeared to be at least marginally suitable as potential nest sites. Once nesting was completed (as determined from visits to the nest by refuge personnel), we returned to each nest site and control site and repeated the sampling procedures used during pre-nesting. This schedule of sampling was repeated in 1984.

By not randomly selecting control sites, we may have biased our data. This bias however should result in more conservative conclusions. Randomly selected sites probably would have included open agricultural fields, asphalt parking areas or even interstate highway. Consequently, our control sites were generally more similar environmentally to nest sites than randomly selected sites. Thus, the results reported herein probably represent minimum differences between nest sites and the available habitat. Time and manpower constraints prevented a more intensive, random sampling of the refuge.

Sampling Procedure

At each nest and control site, a 30-m transect was established from the center of the nest (or sampling point) along each cardinal direction. During the post-nesting period, foliage invertebrates were sampled first to minimize the effect of our activity on abundance. An insect net was swept in a figure 8 pattern within the foliage along each transect while walking briskly (Shelford 1951). Invertebrates were preserved for identification with a binocular dissecting microscope. Abundance and species richness were determined for nests and control sites.

The following parameters were estimated starting immediately adjacent to the nesting platforms and continuing at 10-m intervals along each of the cardinal transects: percent ground cover of water and bare ground, percent cover of understory, vertical density of the vegetation (i.e., obstruction to vision), and caloric value of substrate organic matter. The percentage of herbaceous cover (% crown cover of grasses, forbs, and new-growth woody vegetation), bare ground, and standing water were estimated to the nearest 5% within a 20 × 50 cm rectangular plot (Pieper 1978). A density board (Wight 1938) was modified (1.83 m vertical board divided into 10 alternate black and white sections) to estimate percent cover of vegetation, by the proportion (5%) of each section that was visible. Soil-core samples were taken with a 25 10-cm bucket-auger soil sampler (Ben Meadows, Atlanta, Ga.) and frozen for analysis with an oxygen bomb calorimeter (Parr Instrument Co., Inc., Moline, Ill.). Also, water depth was recorded in each of the 4 cardinal directions at the nesting platform.

Shrub cover was estimated with the line-intercept method (Canfield 1941). Along each transect, the total length of 30-m tape intercepted by shrubs and small trees (to the nearest cm) was recorded. Stem density and basal area of tree species were estimated within a variable circular plot; the radius of the plot varied (30 m maximum) to include a minimum of 30 trees. The number of each tree species and corresponding diameter at breast height (dbh) were recorded; the area of each plot was computed from sampling radius. Uncommon species (≤ 1.5 stems/ha) were grouped into a single category.

Data Analysis

Data analysis was accomplished with a Honeywell DPS-8/50C, CP-6 computer utilizing SPSS-X statistical programs (SPSS, Inc. Chicago, Ill.). Discriminant analysis was performed on pre-nesting and post-nesting data and determined which environmental features best delineated nest sites from control sites (i.e., the available habitat) within a period. Once the analysis phase was completed, a classification procedure was used to determine the reliability of the discriminant variables in assigning sites to appropriate categories (i.e., nest site or comparison site). The Mann-Whitney 2-sample (U) test (Zar 1984) determined if invertebrate abundance or diversity differed between nest sites and comparison sites. A probability of < 0.05 was accepted as justification for rejecting the null hypothesis.

Results and Discussion

Five nest sites were located in 1983, but time did not permit collection of sufficient data for evaluation of pre-nesting habitat. The 5 nests and 11 control sites were sampled during post-nesting 1983 (Table 1). In 1984, 7 nests and 17 control

Table 1. Mean, *F*-values, and level of significance for nest site and selected site environmental parameters, post-nesting 1983, Mississippi Sandhill Crane National Wildlife Refuge, Gautier.

Variable	Nest (N = 5)	Selected (N = 11)	F-value	Probability
Water level (cm)	4.43	0.04	5.90	0.029
Water (%)				
0 m	62.35	1.59	24.39	<0.001
10 m	11.85	3.64	2.12	0.168
20 m	11.75	5.34	1.02	0.329
30 m	22.70	5.00	4.63	0.049
Bareground (%)				
0 m	2.00	9.09	0.33	0.575
10 m	0.75	11.02	0.92	0.354
20 m	0.25	12.09	1.51	0.240
30 m	2.00	10.39	0.80	0.385
Vegetation (%)				
0 m	35.65	89.32	10.28	0.006
10 m	87.40	85.34	0.03	0.860
20 m	88.00	82.57	0.28	0.602
30 m	75.30	84.61	0.64	0.438
Total line intercept (cm)	44.15	63.43	0.47	0.504
Density board (%)				
10 m	20.00	18.59	0.09	0.766
20 m	28.05	26.11	0.112	0.742
30 m	31.85	30.16	0.06	0.802
Tree density (stems/ha)				
Total	609.00	418.09	0.35	0.564
Pond cypress	44.40	5.81	2.29	0.153
Slash pine	525.40	410.72	0.14	0.714
Longleaf pine	0.00	6.09	0.44	0.519
Other tree density	38.60	1.54	3.48	0.083
Total dbh (cm)				
Total stems	257.80	326.72	0.44	0.516
Slash pine	162.60	22.18	0.32	0.582
Pond cypress	261.20	311.27	3.46	0.084
Longleaf pine	0.00	96.09	0.44	0.519
Other tree	131.20	33.36	3.39	0.087

sites were examined during pre-nesting; 6 nests and 11 control sites were sampled during post-nesting (Table 2).

Initial analysis indicated that within a specific site all variables were similar ($P > 0.05$) among cardinal directions. Accordingly, the following results are from analyses performed on combined data sets (i.e., the different cardinal transects were combined into a single sample for each site).

Multiple comparisons of environmental parameters between nest sites and control sites (Tables 1 and 2) revealed that percent cover of herbaceous vegetation at the platform was consistently less at nest sites. This difference may have resulted from construction of a nest platform, which involved removal of surrounding vegetation

Table 2. Mean, F-values, and level of significance for nest site and selected site environmental parameters, pre-nesting and post-nesting 1984, Mississippi Sandhill Crane National Wildlife Refuge, Gautier.

	Pre-nesting 1984				Post-nesting 1984			
Variable	Nest (N = 7)	Selected (N = 17)	F-value	Probability	Nest (N = 6)	Selected (N = 11)	F-value	Probability
Water level (cm)	7.34	1.71	5.18	0.033	0.00	0.00	—	—
Water (%)								
0 m	58.93	10.22	16.90	0.001	0.00	0.00	—	—
10 m	12.50	12.77	0.89	0.354	0.00	0.00	—	—
20 m	6.07	7.72	0.09	0.767	0.00	0.00	—	—
30 m	8.39	4.78	0.51	0.484	0.42	0.00	1.94	0.184
Bareground (%)								
0 m	0.00	1.47	0.40	0.533	30.42	1.82	7.13	0.018
10 m	0.00	4.26	0.99	0.330	9.58	3.64	1.19	0.293
20 m	0.00	4.56	0.88	0.358	1.25	1.36	<0.01	0.942
30 m	0.00	4.56	0.97	0.334	0.83	3.41	0.40	0.538
Vegetation (%)								
0 m	41.07	88.31	15.82	0.001	69.58	98.18	7.13	0.018
10 m	87.14	89.41	0.10	0.758	90.42	96.36	1.19	0.293
20 m	93.93	87.72	0.90	0.354	98.75	98.64	<0.01	0.942
30 m	91.61	90.81	0.01	0.902	98.75	96.59	0.28	0.606
Total line intercept (cm)	55.50	76.31	1.80	0.193	97.66	79.02	0.62	0.443
Density board (%)								
10 m	19.46	19.71	<0.01	0.940	20.21	21.59	0.17	0.684
20 m	29.11	26.10	0.66	0.424	29.17	30.00	0.02	0.882
30 m	37.14	35.22	0.16	0.696	35.42	38.18	0.13	0.722
Density (stems/ha)								
Total stems	614.57	363.18	1.00	0.328	234.50	165.64	0.13	0.723
Pond cypress	54.57	37.18	0.12	0.737	0.00	0.00	—	—
Slash pine	536.14	306.71	1.19	0.287	217.33	159.54	0.10	0.758
Longleaf pine	0.00	0.00	—	-	0.00	0.00	—	—
Other tree density	23.57	19.06	0.04	0.838	17.00	6.09	0.73	0.408
Total dbh (cm)								
Total stems	326.00	372.41	0.17	0.681	302.00	293.90	0.01	0.947
Slash pine	338.86	368.17	0.05	0.826	315.67	287.63	0.04	0.854
Pond cypress	82.57	147.17	0.26	0.612	0.00	0.00	—	—
Longleaf pine	0.00	0.00	—	—	0.00	0.00	—	—
Other tree	106.29	44.35	2.05	0.166	123.33	32.00	4.52	0.050

for placement on the platform. Plant removal apparently contributed to a virtually vegetation-free zone in the immediate vicinity of the nest. Previous nests that were successful presumably experienced prolonged and greater nest-side activity, show correspondingly greater impacts on the nearby vegetation and may have represented predictors of habitat quality in subsequent nesting attempts.

During 1983 post-nesting and 1984 pre-nesting, water depth and percent ground cover of water at the nest were greater than control sites. We suspect that water depth at the nest would have differed in the 1984 post-nesting period also, but the spring of 1984 was the driest of the decade (Smith 1986). Both nest and control sites were dry during pre-nesting sampling. The greater percent cover of bare ground at nest sites during 1984 post-nesting indicated an absence of vegetation (presumably associated with perennial flooding) and supported the conclusion that nests typically had more standing water than the average available habitat during both territory selection and nesting.

Our analysis generated discriminant models of environmental parameters that best separated, according to Wilks Lambda (Nie et al. 1975), nests from control sites for each period; corresponding models for post-nesting 1983, pre-nesting 1984, and post-nesting 1984 are presented in Table 3. Assignment of sites according to the variables of the discriminant model resulted in correct classification of all nest sites and control sites ($P < 0.0001$). Although the analyses were highly significant and subsequent classification of sample sites clearly discriminated, one should be cautious of any conclusions drawn from multivariate analysis of so few nests and control sites (Sokal and Rohlf 1981).

Six of the 7 variables that best discriminated selected sites from nest sites during 1983 post-nesting were directly or indirectly related to abundance and distribution of water. For example, percent water cover at the sample plot center was the first variable entered in the model; nest sites ($\bar{x} = 62.3\%$) had far more ($F = 24.39, P < 0.0001$) standing water than comparison sites ($\bar{x} = 1.6\%$). Percent water at 30 m and water level and percent water at the nest also were important discriminating variables with nests consistently exhibiting more standing water. Percent water at 10 m and standing biomass (i.e., total dbh) of pond cypress (*Taxodium distichum* var. *ascendens*) and other tree species (of which swamp blackgum, *Nyssa sylvatica* var. *biflora,* predominated) significantly improved the discriminating ability of our model (although each of these variables was not independently significant; Table 3). The ecological significance of more and larger pond cypress and swamp blackgum among nest sites (Table 1) may have been associated with the long-term pattern of water distribution on the refuge and its influence on the distribution of these tree species. Accordingly, longleaf pine which favors drier upland sites was absent from 1983 nest sites but occupied nearby sites within the territory (Table 1).

Percent water at 30 m and standing biomass of swamp blackgum also were part of the discriminant model for post-nesting 1984. Because of the unusually dry year and reasons discussed previously, we believe the discriminant variables percent bareground at the platform and at 30 m correspond to the 2 variables included in the 1983 post-nesting model, percent water at the nest and at 30 m. Together with den-

Table 3. Discriminant variables with associated cumulative level of significance and corresponding Wilks Lambda, and *F*-values with corresponding level of significance of each variable (independently) for nest and selected sites, Mississippi Sandhill Crane National Wildlife Refuge, Gautier, Mississippi

Variable	Summary table significance	Wilks lambda	*F* value	Independent significance
	Post-nesting 1983			
Water:				
0 m[a] (%)	0.0002	0.3647	24.39	0.0002
Pond cypress dbh	0.0005	0.8016	3.46	0.0838
Other tree dbh	0.0005	0.8051	3.39	0.0869
Water level (cm)	0.0002	0.7034	5.90	0.0292
Longleaf pine dbh	0.0001	0.9697	0.44	0.5191
Water: 30 m (%)	0.0001	0.7515	4.63	0.0494
Water: 10 m (%)	0.0001	0.8687	2.11	0.1679
	Pre-nesting 1983			
Pond cypress dbh	0.0001	0.9881	0.26	0.6122
Total tree density	0.0001	0.9564	1.00	0.3275
Other tree dbh	0.0001	0.9147	2.05	0.1661
Other tree density	0.0001	0.9981	0.04	0.8382
Density board: 20 m	0.0001	0.9707	0.66	0.4240
	Post-nesting 1984			
Bareground: 0 m (%)	0.0175	0.6678	7.13	0.0175
Water: 30 m (%)	0.0088	0.8854	1.94	0.1838
Other tree dbh	0.0035	0.7683	4.52	0.0504
Other tree density	0.0018	0.9538	0.73	0.4075
Line intercept (cm)	0.0025	0.9603	0.62	0.4433
Bareground: 30 m (%)	0.1583	0.9742	0.40	0.5383
Density board: 30 m	0.1175	0.9913	0.13	0.7225

[a]Immediately adjacent to nest or center of control site.

sity of swamp blackgum (other tree density), our discriminant variables for post-nesting 1984 were again weighted heavily toward environmental features directly or indirectly related to water distribution. Shrub cover (line-intercept) and obstruction to vision at 30 m (density board) also improved the model and were both probably related to vegetative cover, which provided isolation from other cranes, predators or other potential disturbances (Hammerstrom 1938, Walkinshaw, 1965, Riley 1982).

Data from the pre-nesting 1984 period (Table 3) supported the conclusion that standing water and vegetative cover were critical components and determinants of nesting habitat. Percent water cover at the nest was again a highly significant discriminating variable (Table 3). Except for vertical vegetative cover at 20 m, remaining discriminant variables were indicators of perennial flooding and long-term patterns of water distribution.

Water has been identified as a key characteristic of crane nesting habitat by several investigators (Walkinshaw 1953, Naylor et al. 1954, Littlefield and Ryder 1968, Drewien 1973, Graul et al. 1979, Layne 1982). Naylor et al. (1954) reported that nests in northeast California were located in remote, wet meadows; in years of low rainfall, breeding pairs shifted their territory to wetter areas or did not nest at all. However, the relationship of water to nesting success remains uncertain, especially for the Mississippi subspecies.

Data from this study suggest that there are environmental characteristics apparent during the period when territories are established that serve as indicators of specific habitat features at the time nesting takes place. Still, the question remains: what defendable resources (i.e., associated with reproductive success) are possibly related to the set of environmental characteristics identified in this study?

There was no observed difference in the caloric value of organic matter within the soil samples at nest sites as compared to control sites (Smith 1986). The variation within a site was extreme with 5-fold differences in calories/gram among cardinal transects. Foliage invertebrates (Table 4), however, were more abundant ($U'_{7,9}$ = 86.5, $P < 0.005$) at nest sites ($\bar{x}$ rank = 12.7) than control sites ($\bar{x}$ rank = 5.2). The number of observed species at nest sites ($\bar{x}$ rank = 11.6) also was greater ($U_{7,9}$ = 98.5, $P < 0.005$) than control sites ($\bar{x}$ rank = 5.9).

The greater abundance of invertebrates at nest sites may represent a critical source of prey for adults and/or chicks during this period. The movements and activities of Mississippi sandhill crane chicks prior to fledgling are not well known. Although chicks are apparently able to negotiate the water and vegetation without too much difficulty, observations indicate they remain near the nesting platform for at least a few days post-hatching (Littlefield and Ryder 1968, Walkinshaw 1976, Bennett 1978, Layne 1981, Kitagawa 1982). The secretive, protective nature of parents and the small size of hatchlings have made quantitative studies of food habits difficult. Chicks eat more animal matter than their omnivorous parents (Walkinshaw 1949, Littlefield and Ryder 1968, Voss 1976, Boise 1977, Bennett 1978, Layne 1981, Valentine 1981). Also, the foraging behavior of a breeding pair with chicks is altered from the typical feeding habits of adults (Voss 1976). Parents spend the majority of their time picking insects off nearby foliage and less time probing within the substrate. Crane chicks learn much of their feeding behavior and selection from their parents (Shettleworth 1984). The chicks are quite agile and are soon able to catch insects even in flight (Boise 1977).

Crane chicks usually begin feeding the second day after hatching, but generally stay within 10–35 m of the nest platform (Bennett 1978, Layne 1981). It is during this period that the availability of high energy, high nitrogen food would be most critical. Many precocial species that generally consume more vegetative matter as adults rely heavily on insects and other invertebrates during their period of rapid growth and development.

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Table 4. Number of surface invertebrates within nest sites and control sites among nesting territories (Ben Williams, Eglin Road, Perigal, and Brown's Trail) post-nesting (May 1983 and June 1984), Mississippi Sandhill Crane National Wildlife Refuge, Gautier.

	Ben Williams				Eglin Road			Perigal				Brown's Trail				
	Nest		Control		Nest	Control		Nest		Control		Nest		Control		
Taxa	1	2	1	2	1	1	2	1	2	1	2	1	2	1	2	3
Coleoptera	12	10	0	1	14	0	0	1	11	0	0	5	11	0	7	1
Hemiptera	0	3	1	1	1	0	0	20	2	0	0	0	1	2	1	0
Araneida	2	3	1	0	2	2	1	2	0	0	0	0	3	5	3	2
Diptera	0	1	0	0	0	3	0	0	1	0	0	3	3	2	3	0
Hymenoptera	1	0	0	0	0	0	0	0	4	0	0	1	3	0	0	0
Orthoptera	0	0	0	0	1	0	0	0	4	0	0	0	0	1	1	0
Lepidoptera	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
Odonata	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Acarina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Phalangida	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Total	16	17	2	2	20	5	1	23	22	0	0	10	22	10	15	3

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