DRINKING, ROOSTING, AND FEEDING HABITATS OF SANDHILL CRANES WINTERING IN WESTERN TEXAS AND EASTERN NEW MEXICO

By

DONALD EDWARD HALEY

Bachelor of Science

University of Wyoming

Laramie, Wyoming

1980

Submitted to the faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
December, 1983

DRINKING, ROOSTING, AND FEEDING HABITATS OF
SANDHILL CRANES WINTERING IN WESTERN
TEXAS AND EASTERN NEW MEXICO

Thesis Approved:

Frank Schitoskey Jr.
Thesis Adviser

Larry G. Talent

Scott Shalaway

Norman N. Durham
Dean of the Graduate College

ACKNOWLEDGMENTS

I would like to thank Dr. Frank Schitoskey for his support, advice, and for serving as my major adviser. I thank Dr. L. Talent and Dr. S. Shalaway for advice, editorial comments, and for serving as members of my graduate committee. I greatly appreciate the problem solving and other logistical assistance that J. Gray consistently provided. I thank R. Moore for assisting me with field work. I thank Muleshoe National Wildlife Refuge personnel R. Krey, A. Jones, D. Noriega, and D. Gilliam for their assistance and hospitality. I thank T. Tacha and G.C. Iverson for valuable suggestions during the initial stages of this study. T. Tacha also helped acquire funding for this study. I appreciate the statistical assistance provided by W. Warde. I also thank the numerous Texas landowners who gave me access to their land. I would like to thank all the graduate students who helped me maintain my sanity.

This study was funded by contract 14-16-0008-2133, Accelerated Research Program for Webless Migratory Shore and Upland Game Birds, U.S. Fish and Wildlife Service. Additional funding was acquired from the Oklahoma Cooperative Wildlife Research Unit (OCWRU). The OCWRU has Oklahoma State University, Oklahoma Department of Wildlife Conservation, U.S. Fish and Wildlife Service, and the Wildlife Management Institute cooperating.

Finally, I want to thank my family for their support and for just being there.

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CHAPTER I

INTRODUCTION

This thesis is composed of 3 manuscripts written in formats suitable for submission to selected scientific journals. Each manuscript is complete without supporting materials. The manuscripts, "Habitat analysis and drinking requirements of wintering sandhill cranes" (Chapter II) and "Roost site selection by sandhill cranes wintering in western Texas" (Chapter III) were written for submission to the JOURNAL OF WILDLIFE MANAGEMENT in the Short Communication format. Chapter IV, "Effects of various habitat parameters on sandhill crane distribution and abundance", was written for submission to the SOUTHWESTERN NATURALIST.

CHAPTER II

HABITAT ANALYSES AND DRINKING REQUIREMENTS OF WINTERING SANDHILL CRANES

Drinking, Grus canadensis, playa, saline lake, salinity, sandhill cranes, springs, Texas

DONALD E. HALEY, Oklahoma Cooperative Wildlife Research Unit[1], Oklahoma State University, Stillwater, OK 74078

The purpose of this study was to describe the freshwater resources available and their use by sandhill cranes (*Grus canadensis*) wintering in western Texas and eastern New Mexico. This area holds large concentrations of wintering sandhill cranes (Lewis 1977) and yet their relationship with the limited freshwater sources is still unclear. Much of the freshwater in the region is highly mineralized (Cole 1966), which could pose physiological problems for the sandhill crane, a bird possessing a small salt gland, if any at all (Hughes and Blackman 1973, Franson et al. 1981).

A source of freshwater in an area of limited water attracts many wildlife species (Hensley 1954). Information on springs and wildlife using them is of special interest to wildlife managers, especially since the underground water supply (Ogallala aquifer) is shrinking (Bolen et

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[1]Oklahoma Cooperative Wildlife Research Unit, Oklahoma Department of Wildlife Conservation, Oklahoma State University, U.S. Fish and Wildlife Service, and the Wildlife Management Institute cooperating.

al. 1979).

Springs are one of the few reliable freshwater sources for wildlife in western Texas and eastern New Mexico. Some researchers have analyzed spring physiochemical properties; however, measurements were usually taken only once (Brune 1981, Reeves 1970). No studies have addressed temporal dynamics or effects of weather on the physical charasteristics of these springs.

Over 400,000 sandhill cranes were censused in western Texas in 1980 (Oklahoma Cooperative Wildlife Research Unit, OCWRU, unpubl. data). The majority of cranes on the study area roosted on three saline lake basins. High concentrations of birds allow the rapid spread of contagious diseases (Jensen and Williams 1964). Outbreaks of botulism and avian cholera, diseases sandhill cranes are susceptible to (Williams 1941, Rosen 1972), occur nearly annually in western Texas (Jensen and Williams 1964). A clearer understanding of specific habitat requirements of cranes would enable wildlife managers to manipulate numbers and distribution of birds to minimize disease outbreaks.

Study Area

The study area, located within the southern High Plains or Llano Estacado of western Texas and eastern New Mexico, encompassed approximately 20,000 km^2 (Figure 1). The study area was characterized by relatively flat terrain with 20-25 saline lake basins and numerous scattered playas. Most of the study area was planted in a vast cotton monoculture, but some sorghum, wheat, and rangelands were also present.

Average annual precipitation for the southern High Plains is 44 cm. However, 56 cm was recorded in 1982 and from November 1982 to February

1983 precipitation was 9 cm above normal (Climatological Data, 1982 and 1983, U. S. Weather Service).

Playas are shallow natural depressions formed through wind erosion, which periodically contain freshwater (Rettman 1981), whereas saline lake basins are ancient lake beds formed along prehistoric stream systems (Reeves 1966). Most saline lakes are saltier than seawater due to years of evaporation. Lakes receive some water from runoff from surrounding areas but springs also help fill many basins (Reeves 1965).

Ten study sites were established in western Texas and eastern New Mexico with a saline lake (Figure 1) at the center of each site. Each study site consisted of an area contained within a 16 km radius of the center of a lake basin and had an area of 800 km^2; this is equivalent to the daily activity range for sandhill cranes in western Texas (OCWRU, unpubl. data). The ten lakes studied included Rich and Mound lakes located near Brownfield, which are part of the Brownfield complex and 8 lakes in the Muleshoe complex.

Materials and Methods

This study was conducted from early October 1982 to early March 1983. Blinds or a 15 x 60 spotting scope were used to observe sandhill crane drinking locations and behavior. Cranes were identified as drinking by posture and subsequent swallowing motions (Tacha 1981). Water temperature, salinity, and water depth were taken at drinking sites of cranes throughout November and early December 1982 to determine crane preference levels. A YSI model 33 salinity meter was used to measure salinity and water temperature. In addition, water temperature, salinity, water depth, and surface area were compared between springs with crane tracks and springs without tracks as well as between springs heavily used and those lightly used. These measurements were taken on springs at least four times from December 1982 to March 1983. The effects of air temperature and precipitation on spring dynamics were analyzed. Climatological data were collected for the Muleshoe complex by Muleshoe National Wildlife Refuge (NWR) personnel and for the Brownfield complex by Earl Elrod of Brownfield.

Differences in salt content (e.g. springs flowing into saline lakes) may cause stratification of water layers of different density (Ruttner 1965). Stratification could enable a sheet of freshwater from the spring to flow out over saline lake water. This could cause sampling errors without knowledge of thickness of stratification layers, depth cranes drink at, and/or water sampling depth. A test to discover if water was stratified by salinity and temperature was conducted at 36 sites. A large syringe was used to collect water samples from various depths for analysis.

Cranes do not drink the salt water of saline lakes. The springs had salt concentration gradients that gradually increased from the source out to where the level was the same as the lake's. Once crane preference levels for salinity were established, tentative boundaries were used to help determine surface area of "drinkable" spring water. Boundaries were determined at each spring on each sampling date. Surface area was measured only for water greater than or equal to 0.5 cm and less than or equal to 30 cm deep. Water deeper than 30 cm was assumed to be too deep for cranes and 0.5 cm was the lowest depth at which cranes were observed drinking. Heavily vegetated areas of springs were assumed to be unavailable to the cranes for drinking water.

Surface areas of springs, playa lakes, and other measured water sources within each study site were compared with crane counts to determine the minimum amount of water needed to hold "x" number of cranes in an area. Crane counts and surface area measurements were taken at about 2 week intervals. Crane counts on each lake were averaged if more than 1 count was conducted at a basin in a 2 week period. Cranes were counted in small flocks as they left the roost in the morning or as they arrived in the evening.

Vegetation at and around springs was identified and animal species or their sign observed at or near the springs were recorded.

The Statistical Analysis System (Helwig and Council 1979) was used for statistical analysis.

Results

Drinking Sites

Forty-five springs, 3 cattle watering areas, 10 playa lakes, snow, and innumerable periodic mudholes in fields and on and along section line roads were available to cranes for fresh water on the study sites. Two saline basins contained freshwater for 3 weeks in February after considerable precipitation. Cranes were observed drinking at 25 springs, 2 cattle watering areas, 4 playa lakes, and 6 mudholes, and 9 cranes were observed eating snow (cranes which ate snow exhibited the same behavior as when drinking water). Cranes were never observed drinking water from saline basins or metal cattle tanks.

Water temperature, salinity, and water depth were measured at 55 crane drinking sites (Table 1). Mean salinity of water cranes were drinking was 6.1 o/oo (parts-per-thousand). One bird drank water with a salinity of 24 o/oo; which is only 11 o/oo less than seawater. I observed at least 3 other birds attempting to drink water of about this salinity; however, all of them responded by shaking the water from their bills and not lifting the head and neck in the typical swallowing posture. Ninety-one percent of the drinking sites had salinities less than 10 o/oo. Sandhill cranes have succumbed to salt poisoning when restricted to water with a salinity of 10 o/oo for over one week (Franson et al. 1981). Wetzel (1975) stated that most freshwater animals are restricted to waters with salinities less than 10 o/oo. For these reasons, only water sources with salinity less than 10 o/oo were considered available for sandhill cranes as drinking water.

There was always at least 1 individual observed drinking while a flock was at a spring, although the majority of the cranes may have been probing for invertebrates or loafing. Therefore, I assumed that springs with crane tracks were the sites of drinking cranes. This was useful in determining the differences in freshwater springs used by cranes and those which received no use (Table 2). Mean water temperature was significantly higher and surface area was significantly lower at springs without tracks compared with springs with tracks.

Although playa lakes generally had large surface areas of freshwater available, and all mudholes, cattle watering areas and most playas had salinities less than 1 oo/o, springs were definitely preferred by cranes. Some of the larger springs would be used by cranes throughout the day on most days, and 5,000 or more cranes could be present.

Cranes entered springs in two ways. One consisted of walking from the basin into a spring. Birds would occasionally walk from their roost in the basin to a spring, especially in the morning during foggy or stormy weather. They usually flew to the edge of the basin water and walked into the spring. Once cranes were established at springs other birds flying to the area would often land right in the spring. Apparently, birds situated at the springs signified that no danger was present. Cranes would typically begin drinking at a spring near the basin water perimeter. They usually moved towards the spring head, apparently aware of the salt concentration gradient direction. When a spring began to fill up with cranes, new arrivals were forced to drink saltier water closer to the basin. At one heavily used spring at Mound lake, a barbed wire fence cut across the spring 15-20 m from its head. Even when cranes filled the spring, none would fly to the other side of the fence and no tracks were ever found there. Fencing of select springs could be a cheap, feasible method of manipulating crane numbers in an area.

To further elucidate differences cranes may be able to detect in spring habitat, I compared heavily used springs with lightly used ones (Table 3). Heavily used springs were defined as springs that attracted cranes consistently throughout the study period. The amount of surface area of freshwater was the only major difference between the two, with heavily used areas having an average of nearly 4,000 more square meters of useable freshwater.

Spring Description

Five of the 10 lakes studied had freshwater springs flowing into them. Analysis of 36 sites tested for stratification revealed that salinity was significantly higher ($\underline{P} < 0.07$) at 2 cm than at 1 cm, with a difference in means of 0.7 o/oo. There was no significant difference between temperatures.

Analysis of variance (ANOVA) procedures revealed significant differences in water temperature and salinity at springs over time (Table 4). There was a significant change in freshwater surface area over time at Rich lake only. Water temperature was found to have a positive correlation ($\underline{P} < 0.001$ -Muleshoe, $\underline{P} < 0.0001$ -Brownfield) with average daily temperature (Figure 2), as would be expected. Average daily temperature was calculated by adding maximum and minimum daily temperatures and dividing by 2. Average daily temperature and 1 week and 1 month cumulative precipitation (prior to measurement dates) were compared with spring measurements to detect effects of weather on spring characteristics using ANOVA procedures. One week cumulative precipitation had significant effects ($\underline{P} < 0.02$) on water temperature, water salinity, and water depth. Water temperature was the only spring measurement found to be correlated with 1 month cumulative precipitation.

I correlated the number of springs per basin with the average number of cranes (Figure 3). The highest crane count was at a basin with 2 springs and the lowest counts at basins with no springs. Duncan's Multiple Range Test showed average counts of cranes at basins with 2 and 3 springs were significantly ($\underline{P} = 0.05$) higher than at basins with fewer or more springs.

Comparisons of crane counts with the occurrence of freshwater revealed that no playa lake water was present in a study site when crane counts were zero at that study site ($\underline{N} = 20$). The highest count at basins without springs was 8,500. Comparisons of crane counts and playa lake surface area were positively correlated (ANOVA $F = 7.28$, $P < 0.01$). Although, ANOVA procedures revealed no significant correlations in crane counts and surface area of springs in study sites or total freshwater in study sites, graphs of the data did show some general trends (Figure 4). These graphs showed average crane counts did not reach peaks at the largest surface areas of freshwater available. This suggests that with increased freshwater surface area, greater than surface areas associated with peak counts, other habitat factors become more important in limiting crane numbers.

Some of the springs had little vegetation in or near them. The majority of springs; however, were characterized by desert salt grass (*Distichlis stricta*), sedges (*Carex* sp.), bulrush (*Scirpus* sp.), and scattered salt cedar (*Tamarix* sp.). Cattail (*Typha latifolia*) was found at more permanent springs, generally near the mouth of the spring. The main vegetational difference between springs was less salt cedar and salt grass and denser stands of cattail, sedges, and bulrush extending further towards the basin at fresher springs.

Forty-two species of birds, 9 mammals, 1 fish, and 3 invertebrates were observed or their sign noted at springs or in associated vegetation (Appendix). Nine species of birds were observed drinking at springs.

Discussion

Drinking Sites

Cranes drank at nearly every type of water source available in the study area. Probably the only major restrictions for crane drinking areas would be water too saline, too deep or shallow, or too close to human use areas. The influence of human disturbance on sandhill crane drinking sites was not directly addressed in this study. Observations of cranes "testing" water and large concentrations of birds at fresher, more permanent springs showed that cranes did not randomly choose springs.

Although water less than 1.0 o/oo was usually available, the mean salinity of crane drinking sites was 6.1 o/oo. This value would be classified moderately saline according to the breakdown of saline waters by Krieger (1963). House finches showed no preference for distilled water or NaCl solutions less than 5.9 o/oo (Bartholomew and Cade 1958); however, they drank twice as much distilled water when offered saline solutions of 11.7 o/oo or greater. Red crossbills, a species known for its salt-eating habits, also showed a strong aversion to NaCl solutions greater than 11.7 o/oo (Dawson et al. 1965). Harriman (1967) found laughing gulls had a strong aversion to NaCl solutions greater than 11.7 o/oo, although they are generally marine. Although most sandhill cranes also drank water less than 11.7 o/oo, many were obtaining water within the "discrimination range" of some birds more likely to tolerate higher salinities in drinking water. I believe that there can be at least 2 reasons for this observation. 1) Cranes preferred drinking at sites with saltier water (springs) over sites with fresher water (playa lakes, etc.) because of reasons other than water salinity. Some possible reasons are less human disturbance at springs and proximity of springs to roosts. 2) Cranes are flexible in the amount of salinity they tolerate in drinking water. Possession of a salt gland or other physiological adaptations could be responsible for this (Bartholomew and Cade 1963). Franson et al. (1981) claimed that if there was any salt gland in sandhill cranes it was probably very small. They did not try to isolate other physiological processes for voiding excess salts in sandhill cranes.

Water temperature was significantly lower at springs visited by cranes, probably as a result of spring morphology. I believe one component of springs that could cause a water temperature difference between them is the degree of spring permanence. More permanent springs probably have a more direct link with cool underground waters. Subjectively, I would say cranes preferred and were most abundant at more permanent springs. An attribute of permanent springs that cranes would most likely select is larger size. Permanent springs had larger surface areas and springs with crane tracks had an average of about 3,000 m^2 more surface area than springs without tracks. Sandhill cranes prefer areas with larger expanses for roosting (Johnson and Stewart 1973, Soine 1982), and the same probably holds true for springs.

Spring Description

There was a small difference in mean salinity (0.7 o/oo) at 2 and 1 cm deep water strata and cranes probably could not discriminate between them. Sample sizes were too small for statistical testing on sites deeper than 2 cm, but there were more pronounced differences in salinity and temperature at depths greater than 6 cm with a general increase in temperature and a marked salinity increase. This probably results from persistent winds having less mixing effect on deeper waters. Larger sample sizes on windless days and at deeper sites would aid in understanding the degree of stratification taking place.

Springs were extremely variable in their salinities (0.4 to > 20 o/oo), although they apparently had the same groundwater source and similar depths. There were 4 factors which could be affecting their salinities: 1) weather, 2) strata through which water must pass, 3) water flowing over different amounts of precipitated salts, and 4) different rates of flow.

Weather apparently does affect the physiochemistry of springs. I believe these effects are due to the shallow depth and small area that springs cover. Precipitation, air temperature, and wind probably affect the springs more than anything else.

Wind not only affected springs by mixing water strata, but also through the action of wind tides. Wind tides occurred when strong winds blew consistently, pushing the shallow basin water to the leeward side of the lake. At Illusion Lake, on 22 December, winds gusting to 50 km/hr from the southwest moved the southwest water line nearly 0.8 km to the northeast in 6 hours. Most springs on the leeward sides of wind tides were inundated with very saline water and became unusable by cranes. Spring water on the windward side was blown farther into the basin, with the general effect of water depth decreasing and surface area and salinity increasing. Permanent springs were less affected by wind tides, mostly because of faster flow of water associated with these springs.

A previous study in the area (OCWRU, unpubl. data) found that the number of cranes counted at a basin was positively correlated with the number of springs at that basin. I found an increase in cranes at basins with from zero to 2 springs, but with more than 2 springs there appears to be no clear relationships. The discrepancy in the 2 studies probably resulted because the previous researchers calculated numbers of springs only once and did not determine the freshness of the springs. I found the number of fresh springs at a basin changing throughout the study and some springs present were always too saline to be used by cranes. Comparisons of crane counts with surface area of water showed that highest crane counts corresponded with relatively small amounts of playa, spring, and total freshwater. Minimum amounts of freshwater necessary to hold large numbers of cranes would be between 3 and 7 ha total freshwater, at least 1 ha playa water and 1 ha spring water within an 800 km^2 area of the center of the basin, and 1 ha spring water consisting of 2 or 3 springs in association with the basin. At various surface area values, there were low crane counts, probably because factors other than drinking water availability were limiting cranes numbers.

Springs are important to wildlife in the region studied; not only did I find that sandhill cranes use them heavily for drinking water but also 54 other species of wildlife depend on them for food, cover, and/or water. As mentioned earlier, the studied region is intensively farmed and the lake basins with associated vegetation and springs are havens for wildlife. The scarcity of water in the area would probably prohibit some of these wildlife species from existing there if the springs were to dry up permanently. Further research should be initiatated to better understand relationships between springs and the wildlife resource. Development of wells and simulation of springs should be investigated to ensure proper habitat for cranes and other wildlife when springs in the area dry up.

Acknowledgments

I thank F. Schitoskey for support, advice, and serving as my major adviser. I thank Dr. L. Talent and Dr. S. Shalaway for advice and for serving as members of my graduate committee. I thank J. Gray for immeasurable logistical assistance. R. Moore assisted with field work. I thank Muleshoe NWR personnel R. Krey, A. Jones, D. Noriega, and D. Gilliam for assistance and companionship. I thank T. Tacha for valuable suggestions during the initial stages of this study. T. Tacha also helped acquire funding for this study.

This study was funded by Contract 14-16-0008-2133, Accelerated Research Program for Webless Migratory Shore and Upland Game Birds, U.S. Fish and Wildlife Service. Additional funding was acquired from the Oklahoma Cooperative Wildlife Research Unit.

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Table 1. Water measurements at sites where sandhill cranes were observed drinking in the study area in western Texas and eastern New Mexico in the winter of 1982-1983.

Measurement	Drinking Sites			
	Mean	SE	N	Range
Water Temperature (°C)	14.0	0.65	55	3.0-21.3
Salinity (o/oo)	6.1	0.60	55	0.0-24.0
Water Depth (cm)	2.5	0.27	55	0.5-11.0

Table 2. Measurements of freshwater springs with sandhill crane tracks compared with springs without tracks in the winter of 1982-1983 in western Texas and eastern New Mexico.

	Tracks			No Tracks			
Spring Measurement	Mean	SE	N	Mean	SE	N	P[a]
Water Temperature (°C)	8.4	0.45	107	10.6	0.63	32	0.02
Salinity (o/oo)	6.7	0.24	107	6.8	0.45	32	NS[b]
Water Depth (cm)	2.4	0.36	99	4.3	0.86	28	NS
Surface Area (m^2)	4125.6	838.8	150	1254.5	434.5	50	0.003

[a]Observed significance level of t-value from t-test.

[b]Not significant at 0.05 level.

Table 3. Measurements of freshwater springs in western Texas and eastern New Mexico used heavily by sandhill cranes for drinking compared with springs used lightly.

	Heavily Used			Lightly Used			
	Mean	SE	N	Mean	SE	N	P[a]
Water Temperature (°C)	7.5	0.77	37	8.7	0.68	51	NS[b]
Salinity (o/oo)	6.4	0.31	37	7.2	0.39	51	NS
Water Depth (cm)	1.6	0.16	34	1.4	0.13	51	NS
Surface area (m^2)	6054.4	1972.3	53	2266.5	672.2	94	0.075

[a]Observed significance level of t-value from t-test.

[b]Not significant at 0.10 level.

Table 4. Observed significance levels of F-values from ANOVA tables of spring measurement changes over time in western Texas and eastern New Mexico from December 1982 to March 1983. Measurements were taken during 4 periods for Yellow Lake and 5 periods for the other lakes.

	Spring Measurements			
Spring Location	Water Temperature (°C)	Salinity (o/oo)	Water Depth (cm)	Surface Area (m^2)
Rich Lake	NS[a] (402)[b]	0.001 (402)	NS (647)	0.06 (68)
Mound Lake	NS (339)	0.001 (339)	NS (575)	NS (53)
Yellow Lake	NS (48)	NS (48)	NS (85)	NS (9)
Lower Pauls Lake	0.01 (181)	0.001 (181)	NS (326)	NS (44)
Combined	0.05 (970)	0.001 (970)	NS (1633)	NS (174)

[a]Not significant at .10 level.

[b]Sample sizes.

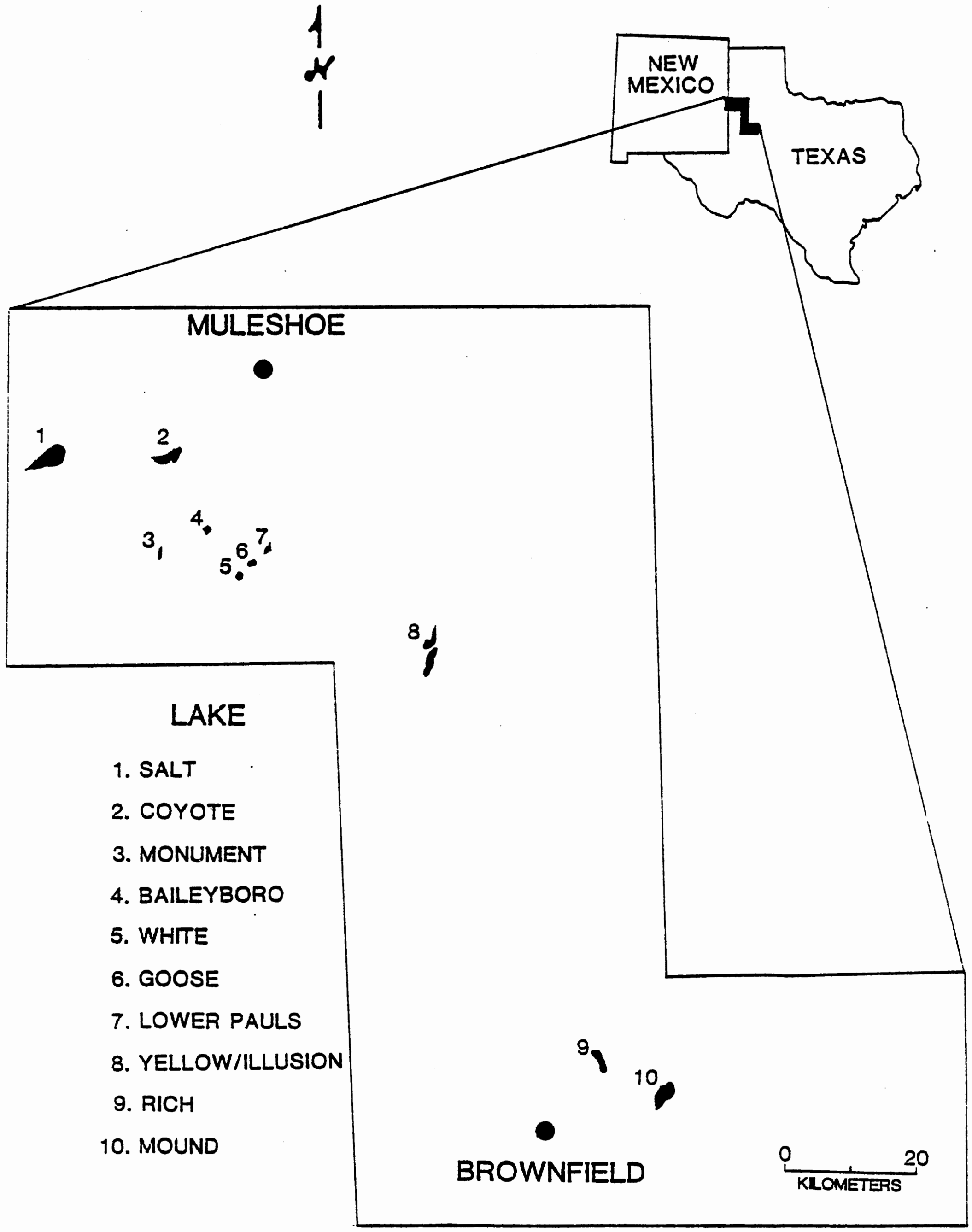

Figure 1. Study area in western Texas and eastern New Mexico illustrating the saline lake basins studied.

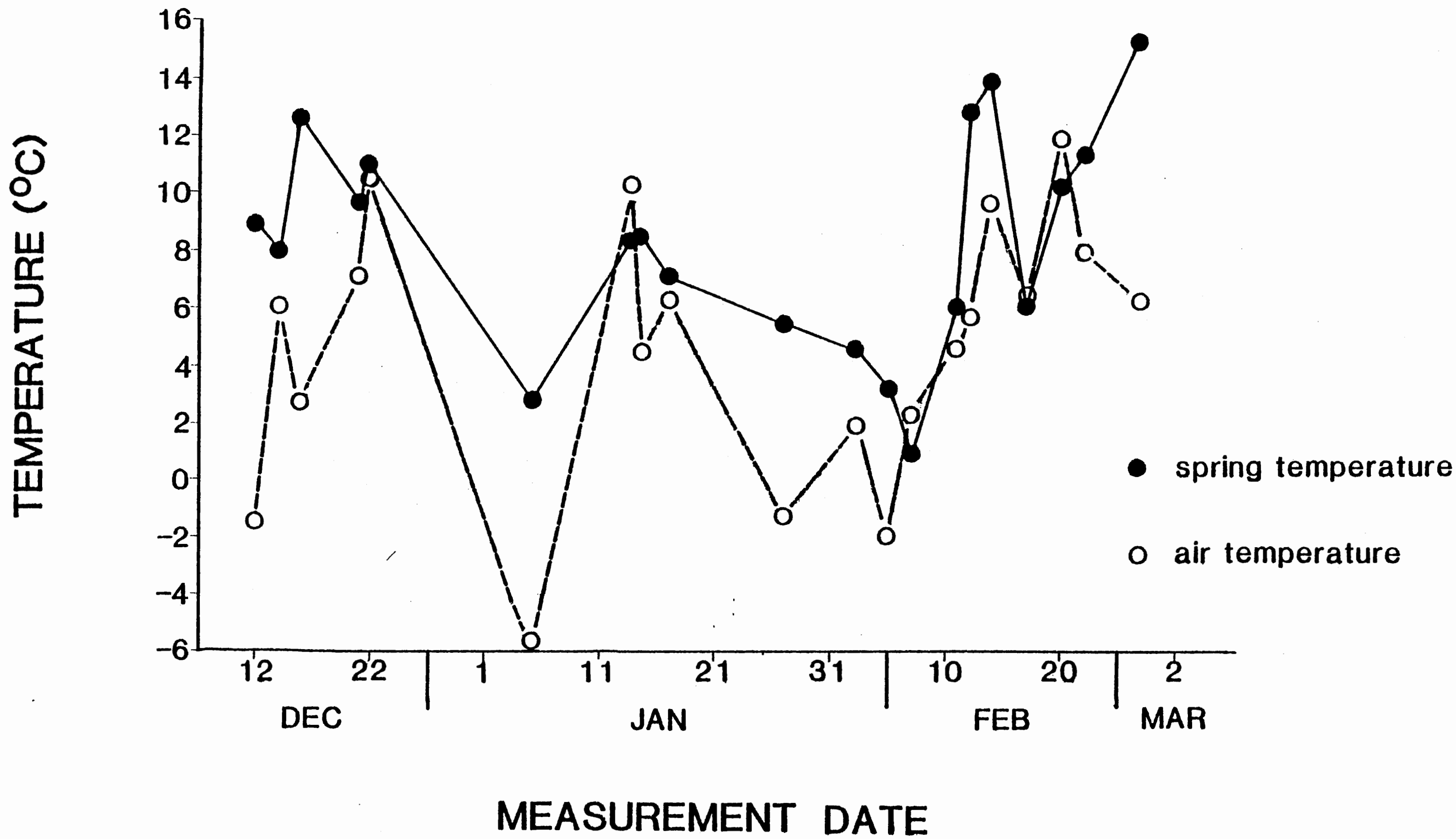

Figure 2. Plot of mean spring water temperatures and corresponding air temperatures illustrating their relationship over time.

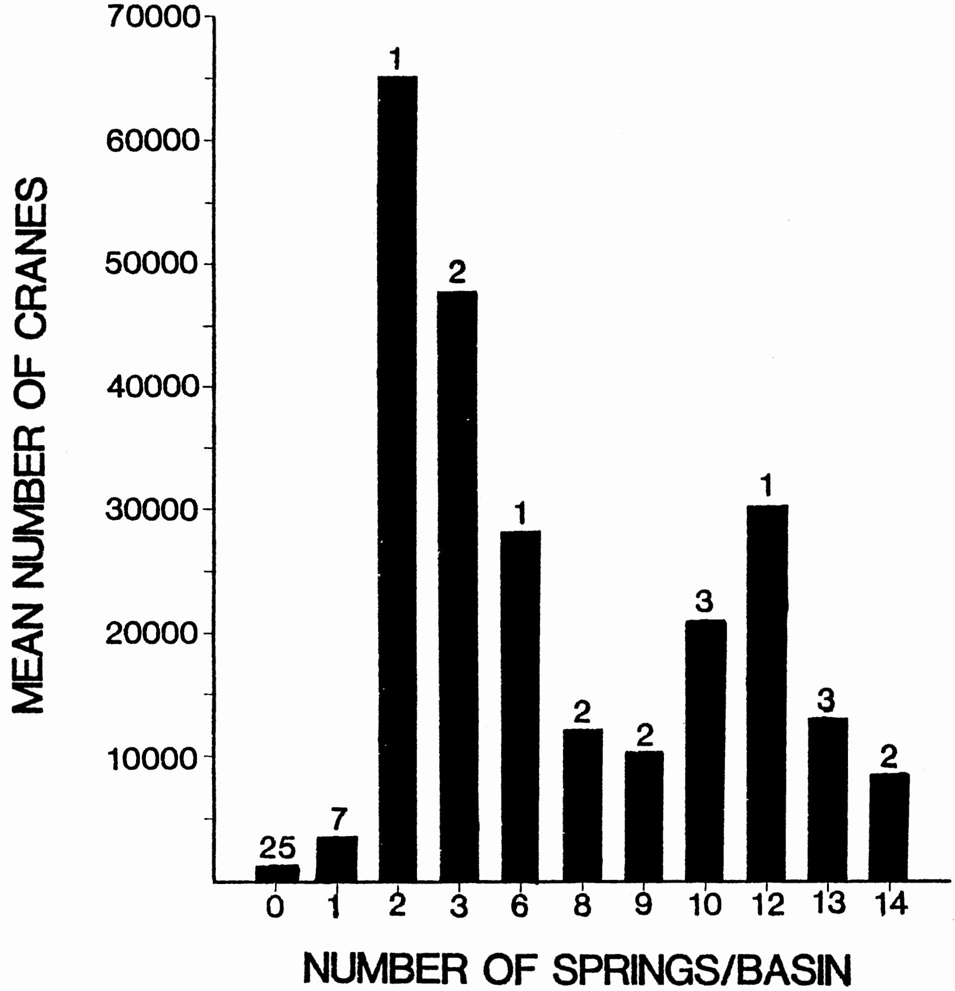

Figure 3. Graph of basins with varying numbers of springs compared with mean number of sandhill cranes counted. Sample sizes are indicated on the top of the bars.

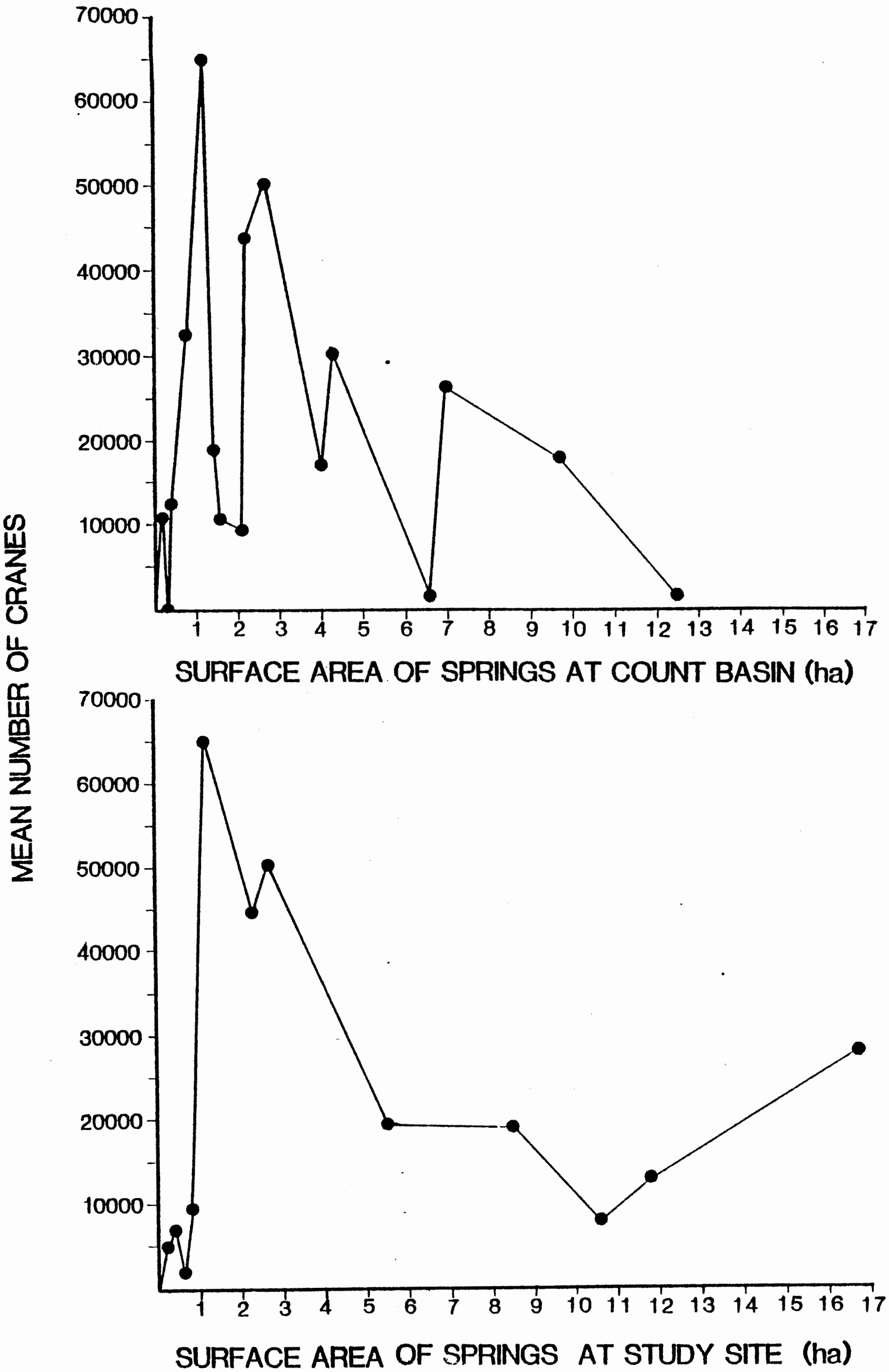

Figure 4. Plots of mean numbers of sandhill cranes counted with surface areas of springs, playa lakes, and total freshwater available.

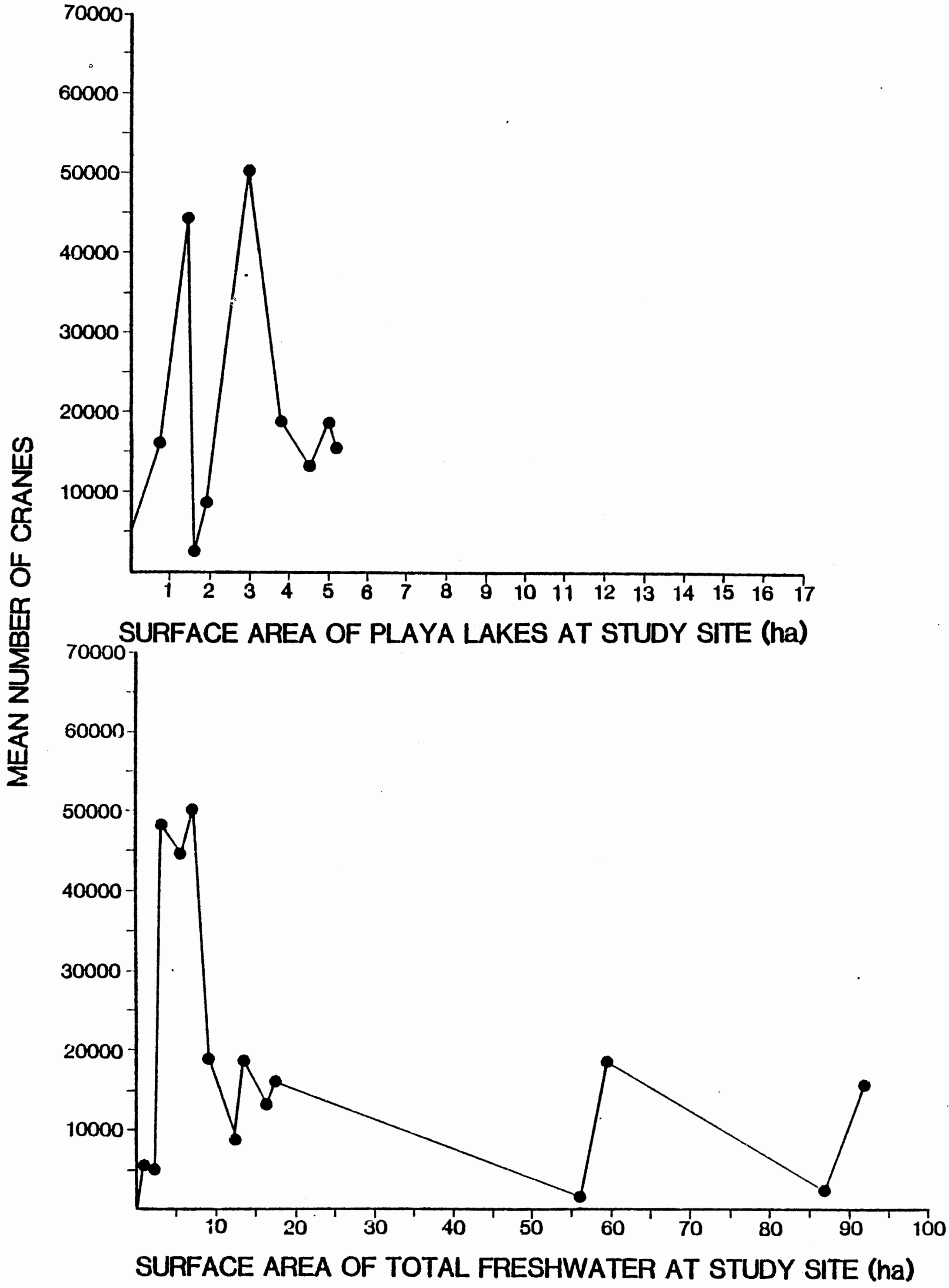

Figure 4. continued.

CHAPTER III

ROOST SITE SELECTION BY SANDHILL CRANES WINTERING IN WESTERN TEXAS

Grus canadensis, management, roost, saline lake, sandhill cranes, selection, Texas

DONALD E. HALEY, Oklahoma Cooperative Wildlife Research Unit[1], Oklahoma State University, Stillwater, OK 74078

Lack (1933) found that distributions of most birds could be explained only by the existence of specific habitat preferences. Verner (1975) suggested that good habitat management of a species requires knowledge of the proximate and ultimate factors it uses in habitat selection. Habitat characteristics most important for sandhill crane (*Grus canadensis*) roost site selection in North Dakota, that is, the proximate factors cranes cued in on, included large expanses of shallow water with soft bottom substrates that are not close to shore (Soine 1982). Another study in North Dakota found cranes preferred to roost at large shallow lakes with little or no emergent vegetation roosting areas (Johnson and Stewart 1973). Lovvorn and Kirkpatrick (1981) stated that sandhill cranes in Indiana selected roosts which had less than 20 cm of water and lacked human disturbance. Suitable habitat will not be

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[1]Oklahoma Cooperative Wildlife Research Unit, Oklahoma Department of Wildlife Conservation, Oklahoma State University, U.S. Fish and Wildlife Service, and the Wildlife Management Institute cooperating.

selected if proximate factors are missing (Verner 1975). No quantified work has been published on crane roosting habitat on the wintering grounds in western Texas. The factors sandhill cranes use in selecting roosting habitat in western Texas must be identified and quantified before proper crane management programs can be established.

The largest concentration of wintering sandhill cranes occurs in western Texas, with over 400,000 censused in 1980 (Oklahoma Cooperative Wildlife Research Unit, OCWRU, unpubl. data). The majority of cranes roost on three saline lake basins. High concentrations of birds facilitate the spread of contagious diseases (Jensen and Williams 1964). Outbreaks of botulism and avian cholera, diseases to which sandhill cranes are susceptible (Williams 1941, Rosen 1972), occur nearly annually in western Texas (Jensen and Williams 1964). A clearer understanding of roost habitat requirements of cranes would enable wildlife managers to manipulate the distribution and abundance of cranes, through roost habitat management, to minimize potential disease problems. This study investigated sandhill crane roost site selection requisites in western Texas in order to provide wildlife managers quantified information necessary to manipulate roost or potential roost sites to subsequently change or maintain crane distributions and abundance.

Study Area

The study area encompassed approximately 20,000 km^2 and was located within the southern High Plains or Llano Estacado of Texas (Figure 1). The physiography of the area was characterized by relatively flat terrain, 20-25 saline lake basins, and numerous scattered playas. Most of the area was a vast cotton monoculture, but some sorghum, wheat, and rangelands were present.

Playas are natural shallow depressions formed through wind erosion, which periodically contain freshwater (Rettman 1981). Saline lake basins are ancient lake beds formed along prehistoric stream systems (Reeves 1966). Saline lake basins contain water saltier than seawater, when water is present. The intersection of the water table by lake basins produces springs that add water to basins (Reeves 1965).

Average annual precipitation is 44 cm. Fifty-six cm was recorded in 1982 with 9 cm above average recorded for the period November 1982 to February 1983 (Climatological Data, 1982 and 1983, U.S. Weather Service). Weather was atypical during and proceeding the study period with little water upon arrival in October (when it is usually wet) and heavy precipitation in December and January (when it is usually dry). Most precipitation during the study period was snow and sleet.

Materials and Methods

Data were collected in January and February 1983, during which time peak numbers of cranes were found in the study area. Sampling points were randomly selected at active roost sites and at non-roost sites. Roost sites were areas of a lake covered by roosting cranes on the morning measurements took place. A non-roost site was the area on the same lake that was not used for roosting previously, appeared similar to active roost sites, contained water with a maximum depth of 30 cm, and did not overlap with an active roost site. Sampling sites, within a roost or non-roost site, were randomly selected using a random numbers table and a numbered grid placed over a map of the lake basin.

Measurements were usually initiated within 1 hour of the last crane departure from the lake basin.

Sixteen parameters were measured at each sampling point, including water depth, bottom slope, relative mud depth, total alkalinity, phenolphthalein alkalinity, salinity, water temperature, distance to and width of the nearest unvegetated shore, color of shore soil, wind speed, and distances to the nearest vegetation, nearest house, nearest road, nearest manmade structure, and nearest milo field. Water depth was also measured outside the sampling point in the 4 cardinal directions at 10 m intervals up to 50 m for determining bottom slope. Slope was determined using the formula: Slope = $\sum_{n}^{1} \left| \frac{WD_1 - WD}{d} \right|$,

where WD_1 was water depth of the furthest measurement along a transect, WD was water depth at the sample point, d was distance to the furthest measured point along the transect (some random sample points were within 50 m of shore), and n was the number of transects radiating from each sampling point (4) (Soine 1982).

Relative mud depth was determined by letting an approximately 4 kg weight, connected to a calibrated pole that had a crane foot attached to the bottom, settle from the surface of the substrate until it stopped. This simulated a crane standing in mud. Only 1 crane foot was used because cranes often roosted on one foot. Mud depth was determined by reading the calibrated pole before and after the weight settled.

Titration of water samples plus phenolphthalein indicator with sulfuric acid, to the endpoint, was used to determine phenolphthalein alkalinity. Titration with sulfuric acid to the endpoint, with a bromescol green-methyl red indicator, was used to determine total alkalinity. Salinity and water temperature were determined using a YSI

Model 33 portable salinity meter.

Distance to and width of the nearest unvegetated shore and distance to the nearest vegetation were measured with a meter tape. All other distances were measured with a meter tape if within 100 m of the sampling point; otherwise they were measured from topographic maps.

Wiens (1973) suggested soil color as an environmental characteristic important for habitat selection by birds. Soil color, for this study, was determined subjectively with the following breakdown: 1-white, 2-light gray or light brown, 3-medium gray or medium brown, 4-dark gray or dark brown, and 5-black. Wind speed was measured with a handheld anemometer.

The Statistical Analysis System (Helwig and Council 1979) was used for _t_-tests. The Biomedical Computer Program (Dixon and Brown 1979) was used for discriminant function analysis (DFA). _T_-tests compared individual variables without considering the effects of other variables and thus were easily interpretable. Stepwise DFA was used to reduce the 16 predictor variables into one linear composite (discriminant function) that maximally discriminates between roost and non-roost sites; however, the omission of critical habitat variables could drastically affect end results. After DFA was run, it was possible to determine if roost and non-roost sites differ overall. Also the discriminant function was used to classify old and new observations into the 2 groups (roost or non-roost).

Results

Nineteen sampling points at roost sites and 19 at non-roost sites were randomly selected. Coyote, Monument, and Salt Lakes never had cranes roosting on them when sampling was conducted and were not used. Cranes in the study area were never observed roosting anywhere but on saline lakes. One large playa lake outside the study area was used for roosting by cranes.

T-tests showed significant differences between roost and non-roost sites in slope ($P < 0.075$), distance to the nearest unvegetated shore ($P < 0.0001$), and distance to the nearest vegetation ($P < 0.001$) (Table 1). Non-roost sites had greater bottom slope than roost sites. Average distances to the nearest unvegetated shore and nearest vegetation were greater at roost sites than at non-roost sites. Water depth had a range at roost sites of 18.2 cm, in contrast to 29.7 cm at non-roost sites. Maximum distance to shore and distance to vegetation of roost sites was over 120 m greater than at non-roost sites. The minimum distance to the nearest road was over 110 m closer for non-roost sites than for roost sites.

Because of missing variables, only 16 roost and 15 non-roost sites could be used for stepwise DFA. An *F*-statistic was calculated, using the variables of the discriminant function, and showed a significant difference between roost and non-roost sites ($F = 14.2$, DF = 4, 26, $P < 0.01$).

The variables important in discriminating between the two groups, in order of importance, include bottom slope, water depth, distance to the nearest shore, and distance to the nearest house. Fifteen of the sixteen roost sites (93.8%) were correctly classified as being roost sites using the discriminant function. Fourteen of the 15 non-roost sites (93.3%) were correctly classified as being non-roost sites.

At the beginning of this study, before roost site measurements had begun, cranes were more variable in their selection of roost sites. As the study progressed cranes appeared to use more "permanent" roost sites, with the majority of cranes roosting at "permanent" sites and smaller groups of cranes occasionally roosting at previously unused sites. I believe physical characteristics of potential roost sites, due to weather, generally became less variable as the study progressed. Also, cranes became "locked in" on roost sites when they presumably found the proximate habitat factors they required.

The first group of cranes at a lake selected the roost site. Additional cranes coming to roost would key in on cranes already present and fill in around them. The only selection late arriving cranes made, that I was able to detect, was where to land around birds already present. This selection was most likely influenced by wind and water depth. Occasionally I would see a roosting crane flock in a configuration that followed the water depth contour. During high winds cranes would maintain a more or less linear flock formation oriented parallel to the wind direction.

When cranes began arriving at the study area in October, most saline lake basins were unexpectedly dry. Many cranes roosted on these dry saline lake beds where they had roosted in previous winters, although they typically prefer roosting in water. Once basins contained water, cranes were never again seen roosting on dry land. I believe cranes roosted on dry saline lake basins because of some type of recognition of the area from previous winters; that is, they were simply selecting ancestral or traditional wintering areas.

Discussion

It appears from these data that sandhill cranes do not randomly select roost sites. Certain roost habitat characteristics were found to be important in roost site selection. Consistency of roost sites used, with stabilization of physical characteristics of the lake basins, showed that cranes were selecting habitat characteristics and not simply using traditional sites. Traditional selection of roosts was best exemplified when cranes roosted on lake basins, used in previous winters, although the basins were dry and probably "unattractive" to the cranes.

Soine (1982) found negligible slopes to be an important habitat characteristic sandhill cranes selected in North Dakota. She calculated a mean bottom slope at roost sites exactly equal to the mean I found for western Texas roost sites. I never saw cranes roosting at sites with large slopes. Sites with large slopes generally became too deep for cranes ($>$ 30 cm) short distances ($<$ 50 m) from shore, and cranes preferred roosting greater than 100 m from shore.

Cranes apparently do not like to roost close to shore or vegetation. Krapu (1981) found that cranes in Nebraska avoided roosting on sections of the Platte River less than 50 m wide and preferred sections greater than 150 m for roosting. These figures are similar to the ones I calculated and illustrate that cranes probably try to isolate themselves from predators and/or human disturbances.

Although I did not measure height of vegetation in this study, it was an important selection factor for cranes on the Platte River because it can potentially limit their vision (Krapu 1981). Vegetation along the Platte River encroached on roost sites making them unusable by cranes. I would not anticipate a similar problem in western Texas because of the large size of saline lake basins and the presence of salty soils and waters, intolerable even for the persistent salt cedar (Tamarix sp.).

Although mean water depths of roost and non-roost sites were nearly equal, water depth still appeared to be an important habitat selection criterion to cranes. Range of water depth for roost sites was narrower than the range for non-roost sites, and DFA showed water depth to be the second most important variable for discriminating between the two groups. Lewis (1976) and Guthery (1972) suggested suboptimal water levels caused cranes to change roost sites, and most studies researching crane roosting habitat have found water depth to be important to some degree.

In western Texas, a water shortage problem exists due to the shrinking of the Ogallala aquifer (Bolen et al. 1979). As the water table declines, springs that help keep water in lake basins will dry up. Without springs, many of the lake basins used by the cranes could become permanently dry. This problem could have one of two main effects on the crane population as a whole. First, cranes could spread out into Texas, in all directions, looking for roosting water. This dispersal could have good or bad effects on the crane population depending on where the cranes end up and in what concentrations. A second possibility is that cranes might continue to roost on the same basins as they normally do even though the basins are dry. After saline lake basins have dried out a while, they become crusty and hard and can be driven across by off-road-vehicles (ORVs). For example, Salt Lake is often dry and is frequented by people in dune buggies and on motorcycles. Cranes attempting to roost on dry lake basins would be subject to harassment from people in ORVs and predators, resulting in a decline in the condition of the sandhill crane population.

I believe human disturbance may have affected crane selection of roost sites. Distance to the nearest house was found to be a factor in roost selection, and roost sites were situated further from roads than non-roost sites. Also, cranes preferred roosting further out in basins, away from the shore, possibly to create a buffer to human disturbance. On two occasions in December at Rich Lake and one at Mound Lake, hunters were on the lake shore shooting at cranes in the evening as they approached the roost. This caused most cranes to leave and roost on another basin for the night. Lewis (1976) suggested human disturbances as a factor causing cranes to change roost sites. Persistent harassment could cause complete abandonment of a basin for roosting, which would concentrate cranes further, increasing the likelihood of disease problems. Research on the effects of human disturbances on cranes at the wintering grounds should be initiated before problems develop.

Management Implications

Although atypical weather prevailed throughout this study I believe the findings have value, from a management standpoint. Sandhill cranes must select roost sites regardless of weather, and the habitat variables found to be important selection criteria also appear to be logical. Because data were collected for only 1 winter, management suggestions should be general.

Distribution and adundance of cranes can be changed by manipulating roost habitat. Numbers of cranes would most easily be changed by limiting or increasing the total amount of available roost habitat. Location of cranes in certain areas would be encouraged or maintained by assuring flat roosting areas that are not close to shore or vegetation, have a water depth somewhere between 5 and 20 cm, and have minimal human disturbance. Use of roost areas by cranes would be discouraged by draining basin water, sharply increasing bottom slope, increasing human disturbance, and/or increasing lake water level to over 30 cm. The most effective method would probably be increasing the water level by dredging and/or filling the basin with more water. Roost sites are only one crane requisite and other factors contribute to the crane's distribution and adundance (see Haley 1983). Development of a perfect roost area would be meaningless if no food or drinking water were in the vicinity.

The most immediate concern for sandhill cranes in western Texas, from a habitat management viewpoint, is securing habitat. Over 3/4 of the 20 or more saline lake basins in the area are privately owned. Of the 4 saline lake basins administered by the Muleshoe National Wildlife Refuge (NWR), only 1 consistently contained large numbers of roosting cranes. Before roost habitat can be managed, easements or basins themselves must be purchased. Otherwise, private landowners may alter the saline lakes at will, making them unusable by cranes.

Acknowledgments

I thank F. Schitoskey for support, advice, and serving as my major adviser. I am grateful to J. Gray for immeasurable logistical assistance. I thank Dr. L. Talent and Dr. S. Shalaway for advice and for serving as members of my graduate committee. I thank R. Moore for assistance in the field. I thank Muleshoe NWR personnel for assistance and companionship. W. Warde assisted with the statistical analyses. T. Tacha helped acquire funding for this study.

This study was funded by Contract 14-16-0008-2133, Accelerated Research Program for Webless Migratory and Upland GAme Birds, U.S. Fish and Wildlife Service. Additional funding was acquired from the Oklahoma Cooperative Wildlife Research Unit.

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Table 1. Mean habitat measurements of sandhill crane roost and non-roost sites in western Texas. T-value is the result of t-tests comparing roost and non-roost sites for each variable. SE = Standard Error, N = Sample Size, R = Roost, NR = Non-roost, and D. = Distance to the nearest.

Variable	Site	Mean	SE	N	Range	T-value	P[a]
Water Depth (cm)	R	10.0	1.02	19	4.0-22.2	-0.05	.96
	NR	10.1	2.10	19	0.3-30.1		
Bottom Slope (cm/m)	R	0.2	0.03	19	0.0-0.7	-1.91	.07
	NR	0.5	0.18	19	0.0-2.9		
Relative Mud Depth (cm)	R	3.7	0.42	17	0.5-6.4	-0.44	.66
	NR	4.0	0.57	17	0.0-8.0		
Total Alkalinity	R	39.6	6.20	16	12.6-98.8	0.39	.70
	NR	36.0	6.98	15	5.8-94.3		
Phenolphthalein Alkalinity	R	2.2	0.94	16	0.0-14.4	-0.66	.52
	NR	3.3	1.37	15	0.0-15.3		
Salinity (o/oo)	R	30.7	2.74	19	6.0-40.0[b]	0.07	.94
	NR	30.4	3.06	19	3.3-40.0		
Water Temperature (°C)	R	10.8	1.53	18	0.8-24.0	0.02	.99
	NR	10.8	1.39	17	2.0-22.0		
D. Unvegetated Shore (m)	R	147.	18.5	19	29.-313.	4.68	.0001
	NR	49.	9.7	19	3.-182.		
Shore Width (m)	R	85.	12.7	19	0.-168.	0.62	.54
	NR	72.	16.6	19	0.-229.		
D. Vegetation (m)	R	215.	22.7	19	56.-429.	3.49	.001
	NR	112.	18.7	19	4.-302.		
D. House (m)	R	2012.	240.6	19	381.-3658.	-1.11	.28
	NR	2378.	226.6	19	305.-3982.		
D. Road (m)	R	531.	79.3	19	133.-1391.	0.96	.34
	NR	421.	82.1	19	19.-1200.		
D. Structure (m)	R	398.	70.3	19	76.-1391.	0.15	.88
	NR	383.	73.0	19	19.-1200.		

Table 1 contd.

Variable	Site	Mean	SE	N	Range	T-value	P
D. Milo (m)	R	1388.	208.6	19	381.-3677.	0.06	.96
	NR	1372.	195.8	19	457.-3658.		
Soil Color	R	2.3	0.15	19	1.0-4.0	0.50	.62
	NR	2.2	0.15	19	1.0-3.0		
Wind speed (km/hr)	R	14.2	2.0	19	0.-29.	0.0	1.00
	NR	14.2	1.8	19	0.-29.		

[a]Observed significance level of *t*-value.

[b]Salinity meter only measured to 40 o/oo.

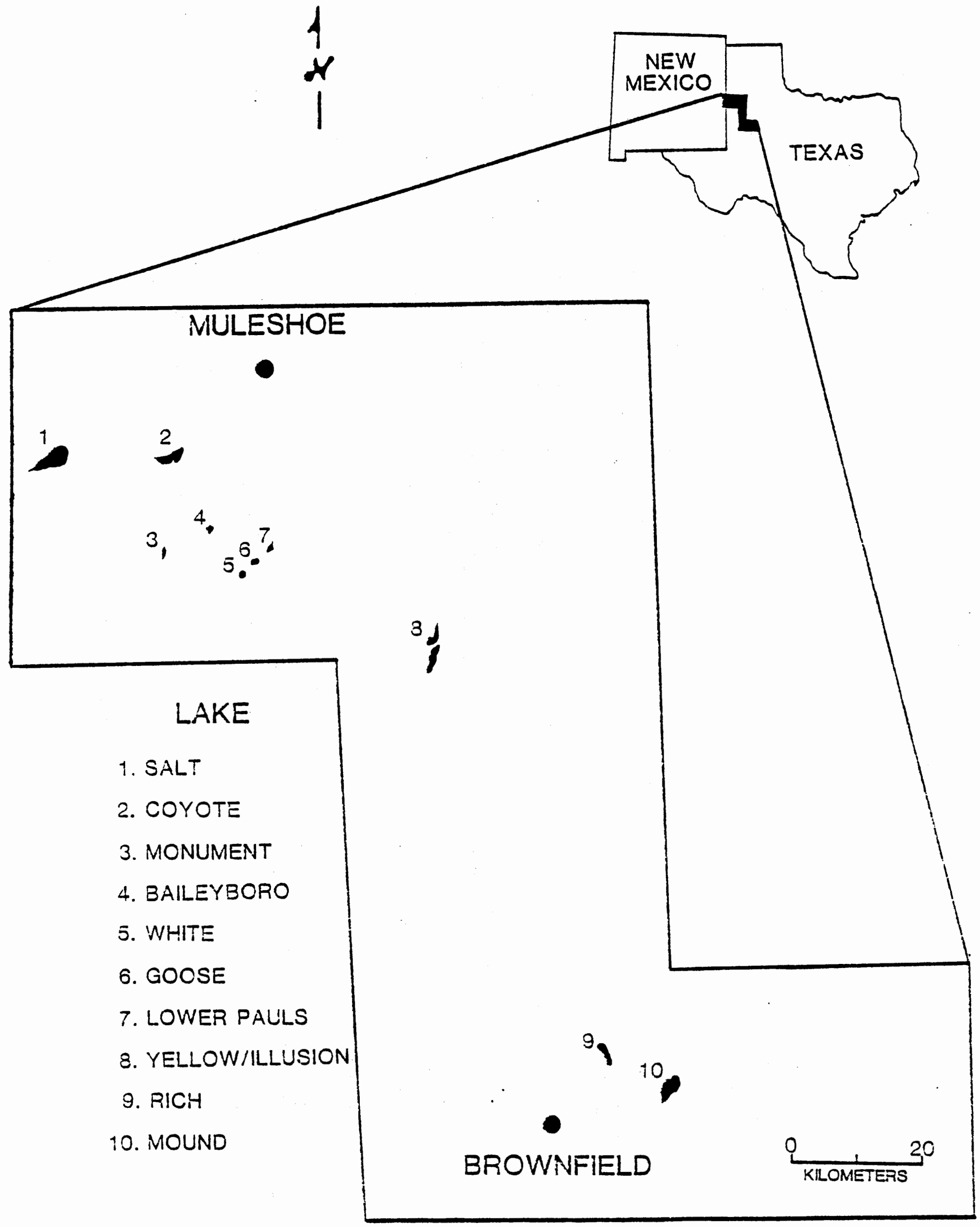

Figure 1. Study area in western Texas and eastern New Mexico illustrating the saline lake basins studied.

CHAPTER IV

EFFECTS OF VARIOUS HABITAT PARAMETERS ON SANDHILL CRANE DISTRIBUTION AND ABUNDANCE

DONALD E. HALEY, Oklahoma Cooperative Wildlife Research Unit[1], Oklahoma State University, Stillwater, OK 74078

Abstract

The effects of drinking, roosting, and feeding habitats on the distribution and abundance of wintering sandhill cranes (_Grus canadensis_) was investigated. Lack of fresh and roost water in the study area when cranes arrived in the fall was probably responsible for the drastically reduced wintering population during this study. Saline lake (roost) surface area contributed the most to temporal changes in sandhill crane numbers. Concentrations of more than 8500 roosting cranes were only found when at least 1 fresh spring was present along a saline lake perimeter. Feeding cranes in flocks of 1000 or more birds were found in significantly larger ($P < 0.05$) feeding fields than were smaller flocks. Direct and indirect effects of humans probably contributed to fluctuations in the distribution and abundance of wintering sandhill cranes.

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[1]Oklahoma Cooperative Wildlife Research Unit, Oklahoma Department of Wildlife Conservation, Oklahoma State University, U.S. Fish and Wildlife Service, and the Wildlife Management Institute cooperating.

The majority of sandhill cranes (Grus canadensis) winter in Texas with the largest concentrations in western Texas (Walkinshaw 1973). Over 400,000 cranes were counted in western Texas in February 1980 (Oklahoma Cooperative Wildlife Research Unit, OCWRU, unpubl. data). The same year over 200,000 cranes were counted on one lake in the same area. From 300,000 to 540,000 sandhill cranes staged along the Platte and North Platte Rivers in Nebraska in the springs of 1979 and 1980 which constitutes over 80% of the entire sandhill crane population (Krapu 1981). The majority of cranes staging in Nebraska in the spring wintered in western Texas. The potential for serious problems exists with over one-half of the crane population wintering on a relatively small area. First, disease outbreaks in a large concentration of birds could be catastrophic (Jensen and Williams 1964). Sandhill cranes have succumbed to botulism and avian cholera (Williams 1941, Rosen 1972) and an outbreak of either could conceivably wipe out a large portion of the sandhill crane population. Secondly, the effects of environmental catastrophes on a concentrated flock of birds could be disastrous. Hail storms, for example, have been known to kill large numbers of cranes (Merrill 1961). Finally, most crane-use areas in western Texas are on private lands and the effects of uncontrolled alteration of these areas on the crane population are unknown.

A shortage of biological and ecological information about the sandhill crane and its habitat exists (Drewein et al. 1975, Hunt and Gluesing 1976). This information is critical, for both maintaining the population at acceptable levels and preventing problems due to high concentrations of birds. My purpose in this study was to determine the effects of various habitat characteristics on the distribution and abundance of sandhill cranes wintering in western Texas and eastern New Mexico.

Study Area

The study area was located within the southern High Plains or Llano Estacado of eastern New Mexico and western Texas (Figure 1). The area contained approximately 20 large saline lake basins and was dotted with playas. Intensive agriculture dominated with some scattered short-grass prairie, scrub/grassland, and wetlands present. Most wetland vegetation was associated with playas, cattle watering areas, or springs found around many saline lake basins.

The study area encompassed approximately 20,000 km^2. Ten study sites were established in the study area with a saline lake basin representing the center of each site. Each study site was contained within a 16 km radius of the center of a lake basin. This represents the daily activity range for sandhill cranes in this area (OCWRU, unpubl. data). Two lake basins were located near Brownfield, Texas, and 8 on or near Muleshoe National Wildlife Refuge (NWR). Each study site overlapped at least one other study site. Yellow and Illusion basins were separated by only a narrow natural dam and were considered to be one basin (Yellow/Illusion) for this study.

Materials and Methods

This study was conducted from October 1982 to March 1983. Quantitative habitat data collection was initiated in early December. Data determining sandhill crane drinking site characteristics were collected in November and December and the methods and results are presented elsewhere (Haley 1983).

Habitat variables were measured at each study site at least 4 times at approximately 2 week intervals. During each period saline lake basins were censused at least once for cranes. Cranes were counted as they left their roosts in the morning or as they arrived in the evening. When more than one count was accomplished in a sampling period a mean count was calculated for analysis purposes.

Habitat measurements were conducted in a study site on the morning that a roost count was taken at the associated saline lake basin. Habitat measurements within each study site included the number of fresh springs and surface areas of playa lake water, total freshwater, and waste and unharvested milo fields. The number of fresh springs and surface areas of fresh springs, the lake basin, and basin water were measured at the saline lake basin. Fresh spring surface area was calculated using a 1 m^2 quadrat for small springs and a meter tape for larger areas. Playa lake water coverage was drawn on a map of each lake and later measured with a digitizer. Total freshwater surface area included fresh springs, playa lakes, cattle watering areas, and mudholes. Only water less than 30 cm and greater than 0.5 cm deep and with a salinity less than or equal to 10 parts-per-thousand (o/oo) (Haley 1983) was included for freshwater measurements. Saline lake basin surface area was measured from topographic maps with a Numonics electronic digitizer. Basin water coverage was drawn on a map of each lake, during each sampling interval, and later measured with a digitizer. Milo was previously determined to be the mainstay of the crane's diet within the study area (Iverson et al. 1982). Milo field surface area was estimated by driving approximately 30 miles of random transects through each study site and measuring the percentage area of milo fields. Sizes of fields were estimated using the vehicle's odometer. Percentage of milo from the transects was then extrapolated to include the entire study area.

Whenever a flock of cranes (more than 1 bird) was observed feeding in a field, measurements were taken to help determine possible factors cranes used in selecting feeding fields. These measurements were also used to determine if the size of a field affected the numbers of cranes feeding in that field. The measurements taken included the area of the field, type of crop, number of cranes in the field, distance from the center of the field to the nearest road (for this study infrequently used roads such as turn roads or trails consisting of 2 tire tracks were not included), and distances from the center of the flock to the center of the field and to the nearest road. Measurements were made at each study site and at some fields located outside the study area, as well. I also analyzed this data by dividing the crane flocks into 3 categories 1- $\leq$ 100, 2- $>$ 100 and $<$ 1000, and 3- $\geq$ 1000 cranes. This method was employed to see which characteristics of feeding fields were better suited for larger or smaller flocks of cranes. To compare fields cranes used for feeding with fields available to them, I drove transects through each study site measuring the area of available fields (milo, winter wheat, sunflower, and pasture) and the distance from the center of the field to the nearest road.

Statistical analyses were performed using the Statistical Analysis System (Helwig and Council 1979).

Results

Weather was atypical during the study period with drought conditions existing upon arrival of cranes in October and heavy precipitation in December and January. Nearly all playas and the majority of saline lake basins did not contain water at the beginning of the study. Cranes were first observed on the study area on 12 October 1982. Cranes arrived at the study area throughout October and early November and many roosted on dry lake basins. While Lewis (1974) and Guthery (1972) occasionally observed cranes roosting on dry land, and wet mud has been infrequently used in western Texas (OCWRU, unpubl. data), most literature on sandhill crane roost habitat emphasizes the need for shallow water (Johnson and Stewart 1973, Lewis 1976, Lovvorn and Kirkpatrick 1981, and Soine 1982). Most dry basins that cranes roosted on contained water, and cranes roosted on them in previous years (OCWRU, unpubl. data). Cranes probably selected these basins, at the beginning of this study, through tradition. There was an influx of cranes to the study area in December with a mean total increase of 80,000 birds (Table 1).

Crane numbers were much lower throughout this study than in previous years. The highest count during this study was 65,000 birds (Table 1) compared with over 200,000 counted on one lake in 1980 (OCWRU, unpubl. data). Several long-time crane hunters also noticed a decline in the number of birds in the area.

One-half of the saline lakes studied had no or very few cranes roosting on them throughout the study. All of these lake basins had some cranes roosting on them in the recent past (OCWRU, unpubl. data). The remaining 5 lakes have historically contained large numbers of roosting cranes (10,000 - > 200,000 birds) and nearly all cranes in the study area used only these for roosting.

The basin with the highest monthly mean number of roosting cranes was Yellow/Illusion (Table 1). This basin also had the highest crane count during this study. Monument and Coyote Lakes had the lowest monthly mean crane counts with no cranes ever observed roosting on them. Some crane tracks were present at the spring at Monument Lake early in the study.

Peak monthly mean counts were from December to March (Table 1). January was the month in which the mean total count (sum of each lake's monthly mean count) of cranes was highest in the study area and November contained the lowest mean total count.

Determination of the surface area of milo in the study area proved to be a problem. Hail storms during the summer of 1982 destroyed much of the cotton crop and large areas were replanted in milo. The range of surface area of standing and waste milo fields was from 20% to 50% of the total area, at the beginning of the study, and declined to 10% - 25% by the end of the study, due to plowing or burning. Previous studies in the area showed sandhill cranes subsisting on milo when it covered only 2% - 5% of the total surface area (OCWRU, unpubl. data). Milo was virtually unlimited to cranes in all study sites, and I did not use it in analyses. Milo may have limiting effects on cranes during a "normal crop" year.

There were 5 sampling periods between 12 December 1982 and 4 March 1983. Mean crane counts were nearly equal for the first 4 periods but there was a sharp decline for the last period (Table 2). This decline was probably due to cranes beginning their spring migration which corresponded with dates observed in previous years (OCWRU, unpubl. data).

In contrast to mean crane counts, mean habitat measurements throughout the 5 sampling periods were generally variable (Table 2). Nearly all of the largest water surface areas for each measurement were in the third and fourth periods. Precipitation was highest during period 3 and this extra water in the environment probably caused the larger surface areas and increased the number of springs in periods 3 and 4. There was no precipitation during periods 4 and 5 and this was reflected in the decline of all water surface areas and the numbers of springs in period 5.

Three habitat measurements were found to be significantly correlated ($P < 0.05$) with crane counts: number of springs at a basin, playa lake surface area, and basin water surface area (Table 3). Basin water surface area explained over 40% of the variation in crane counts with a general increase in cranes counted with an increase in surface area (Figure 2). I was unable to find any trends using the other 2 measurements except that no springs or little or no playa lake water corresponded with few or no cranes counted. Almost 1/2 of the crane counts were low or zero and corresponded with low or no springs or playa lake water surface area.

Cranes were observed feeding in milo, winter wheat, sunflower, and cotton fields. Birds were observed feeding in cotton fields only twice; these birds were probing for invertebrates (see Tacha 1981). Since cotton fields were of limited importance to cranes in this area (Iverson et al. 1983 and this study), cotton fields were not included as feeding fields available to cranes (available fields). Fields where cranes were observed feeding (feeding fields) ranged from 8 ha to nearly 260 ha (Table 4) and had a range similar to the one for available fields. However, the mean area of feeding fields was significantly greater ($\underline{P}$ < 0.0001) than the mean area of available fields (Table 4). Likewise, the mean distance from the center of the field to the nearest road was significantly greater ($\underline{P}$ < 0.0001) for feeding fields than for available fields with roads being 130 m further from the field center at feeding fields than at available fields. A few crane flocks (8) were centered within 50 m of a road and some birds in the flocks were on or near the road. In these cases the road was always a dirt section road with relatively light traffic.

The majority of crane flocks in feeding fields contained between 100 and 1000 birds (category 2) (Table 5). Although the number of flocks with greater than 999 birds (category 3) were fewer, the total number of birds in category 3 composed the majority of cranes observed in feeding fields. The area of feeding fields containing cranes in category 3 was significantly larger than fields containing crane flocks in categories 1 and 2 (Table 5). There were no other significant differences ($\underline{P}$ > 0.05) in habitat measurements between flock categories 1 and 2. There were significantly further distances from the field center to the nearest road and from the flock center to the nearest road for flocks in category 3 compared with flocks in category 1.

Discussion

Atypical weather before and during this study had a profound effect on the distribution and abundance of sandhill cranes in the study area. The date of the first arrival of cranes in the study area was similar to arrival dates in previous years (A. Jones, Muleshoe NWR, pers. comm.). However, the numbers of cranes counted throughout the study were drastically lower than in previous years (OCWRU, unpubl. data). There are at least two possible reasons for lowered crane counts in the study area. First, a catastrophic event (disease, etc.) could have wiped out a large portion of the population, sometime after the winter of 1981-1982. This theory does not hold since the numbers of cranes at the Platte and North Platte Rivers staging areas in Nebraska (a large portion of which are composed of cranes wintering in western Texas) during the spring of 1983 were apparently similar to previous years (G. Krapu, pers. comm.). Second, a large number of cranes normally wintering within the study area may have wintered elsewhere. This theory is supported by several undocumented sightings of numbers of sandhill cranes during the study in areas of Texas not normally used for wintering (mainly north and south of the study area). Portions of the crane population normally wintering in the study area may have dispersed upon arrival at the dry lake basins in search of more desirable roosting areas. Drinking water was also severely limited in the study area in October and November and could have contributed to crane dispersal. Restricted drinking water may become a perennial problem because human consumption of underground water supplies is surpassing the rate of groundwater recharge. Research on the numbers of dispersing cranes and the habitat to which they dispersed would be needed to clearly identify what was missing from the cranes normal wintering areas. A logical question at this point would be why did some cranes remain in the study area if something in the habitat caused other cranes to disperse. I do not believe that the habitat had reached its carrying capacity because food (milo) was virtually unlimited to cranes, there was roosting space available for a large number of cranes on the dry lake beds, and some available freshwater sources were unused or used by fewer cranes than later in the study when more cranes were present. Cranes have used this area for wintering since at least 1935 when Muleshoe NWR was established and census records were begun. I believe that traditional ties for the area were strong enough in some birds (perhaps older birds) to hold them there, although the habitat condition was less than optimal.

From November to December there was a large increase in monthly mean crane counts. Evidence from telemetry data suggests that there is flexibility in the particular saline lake that a crane will use throughout winter and frequent lake changes can occur (OCWRU, unpubl. data). During late November and December the weather was dominated by heavy rains and snowfall which helped fill basins and increase the numbers and surface areas of freshwater sources. Perhaps because of the crane's flexibility in choosing roost lakes (and perhaps intentional relocation) coupled with an increase in the attractiveness of the study area, cranes which originally dispersed from the study area (or never arrived) ended up in the study area. The theory that cranes will change roosting lakes throughout the winter is supported by the observation that from December to February the estimated total number of cranes remained fairly constant (around 100,000 birds) while, on the study area individual lakes often held drastically different numbers of cranes from one month to the next.

The number of springs at a basin and playa lake surface area were found to be significantly correlated with mean crane counts because a number of low crane counts corresponded with no springs or little or no playa water. This concentration of data points is reflected in the small amounts of variation in mean crane counts explained by these two habitat measurements (Table 3). Playa water did not seem to be important for holding large numbers of cranes in any particular study site. The highest crane count was in a study site which contained no playa lakes. Also, I rarely saw cranes drinking or loafing at playa lakes. Possibly playa lakes would receive more use by cranes in areas with limited numbers of alternative water sources. Springs were heavily used for drinking by cranes throughout this study (Haley 1983). Low numbers of cranes were mainly found at basins with 1 or no springs. The highest crane counts were at basins with 2 and 3 springs with no clear trend shown at basins with additional springs. Apparently cranes wintering in the study area in concentrations noted during the study period required at least 1 fresh spring on a roost basin before they would concentrate to over 8,500 birds (Haley 1983). Although cranes in the study area preferred springs over alternative water sources, other water sources may be suitable if other crane habitat requirements are fulfilled. Baileyboro Lake had no springs on the basin but up to 8500 cranes roosting there. However, there was a cattle tank overflow used by cranes within 2 km of the basin and springs at Lower Pauls Lake were within the Baileyboro study site.

Surface area of basin water was the most important habitat component measured in this study possibly affecting crane numbers. When there was no or a low amount of basin water at a lake, the lake was less attractive to cranes and no or few cranes roosted on it. There were 7 occasions when basin water surface areas were greater than 35 ha in which crane counts were also low or zero (Figure 2). On six of these occasions, there were either no springs on the lake or none within the study site. Lack of birds at lakes with no springs indicates that springs are important to sandhill cranes. On one occasion, at Mound Lake (378 ha surface area), persistent harassment of cranes by hunters near the lake shore caused a large number of birds to roost on other lakes. The effects of human disturbance were not directly assessed in this study but could have caused some of the changes in cranes noted.

Human disturbance possibly influenced crane selection of feeding fields since the centers of feeding fields were significantly further from the nearest roads than were the centers of available fields. There is a logical correlation between the distance of the center of a field to the nearest road and the area of a given field, which also was significantly greater at feeding fields than at available fields. Nevertheless, it appears that cranes did not randomly choose feeding fields in this study, but selected larger fields.

Large crane flocks (1000+ birds) were found in significantly larger ($\underline{P} < 0.05$) feeding fields than were smaller flocks. This difference was probably the result of the method of formation of large flocks. A large flock often started with a small number of birds and birds flying near the area were "decoyed" to the field and filled in around birds already present. A relatively small field, with 500 cranes present for example, could force later arriving cranes to land closer to a road or the edge of the field than they would readily choose. Conversely, a relatively large field with 500 cranes present has the potential for holding many more cranes before behavioral restrictions are activated.

Larger flocks were farther away from the roads than smaller flocks because larger flocks are usually found in larger fields. Cranes normally feed somewhere in the center of a field, as opposed to the edge, which is usually formed by a road. Possibly the area of larger fields permits all cranes that will accumulate there to occupy space that is not as close to the roads as it would be in smaller fields. That is, there was more room for more cranes in feeding fields which had large flocks (larger fields) than in feeding fields which had small flocks (smaller fields).

Acknowledgments

I thank F. Schitoskey for support, advice, and serving as my major adviser. I thank Dr. L. Talent and Dr. S. Shalaway for advice and for serving as members of my graduate committee. I thank J. Gray for logistical assistance. R. Moore assisted with field work. I thank Muleshoe NWR personnel R. Krey, A. Jones, D. Noriega, and D. Gilliam for assistance and companionship. I thank T. Tacha and G. C. Iverson for valuable suggestions during the initial stages of the study. T. Tacha also helped acquire funding for this study.

This study was funded by Contract 14-16-0008-2133, Accelerated Research Program for Webless Migratory Shore and Upland Game Birds, U.S. Fish and Wildlife Service. Additional funding was acquired from the Oklahoma Cooperative Wildlife Research Unit.

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Table 1. Sandhill crane roost counts in western Texas and eastern New Mexico during the winter of 1982-1983. Total count refers to the sum of each month's mean crane counts and represents an estimate of the number of cranes present in the study area for each month.

Saline Lake Basin	Monthly Mean Crane Counts: October	November	December	January	February	March	Range	Grand Mean
Yellow/Illusion	9600 (1)	-	32450 (1)	65000 (1)	47550 (2)	-	9600-65000	40430
Mound	4080 (4)	10200 (3)	26930 (6)	11890 (2)	20220 (6)	6000 (1)	1200-34500	16350
Lower Pauls	910 (2)	11200 (3)	28350 (1)	19380 (4)	15530 (3)	-	570-29000	13990
Rich	4030 (6)	6440 (5)	3240 (3)	12840 (3)	12230 (6)	24550 (1)	440-24550	8640
Baileyboro	-	0 (1)	7050 (1)	4430 (3)	5930 (3)	-	0-8800	4770
Goose	-	0 (2)	0 (1)	<1 (6)	530 (3)	-	0-1200	130
White	-	0 (2)	0 (1)	10 (6)	0 (4)	-	0-35	5
Salt	0 (1)	0 (3)	0 (1)	3 (2)	0 (3)	-	0-5	<1
Coyote	0 (1)	0 (1)	0 (1)	0 (2)	0 (1)	0 (1)	0	0
Monument	-	-	0 (1)	0 (2)	0 (2)	0 (1)	0	0
Total Count	18620	17840	98020	113550	101990	30550		

[a]Sample size

Table 2. Sandhill crane counts and habitat measurements during 5 sampling periods during the winter of 1982-1983 in western Texas and eastern New Mexico. Sample sizes for all measurements except precipitation were 10 for sample period 1-4, 8 for basin water surface area in sample period 5, and 9 for the remaining measurements in sample period 5.

	Sample Period				
	1	2	3	4	5
Measurement	Dec 12-Dec 31	Jan 1-Jan 19	Jan 20-Feb 11	Feb 12-Feb 19	Feb 20-Mar 4
Crane Count	10081 (4498.0)[a]	10720 (6443.4)	10289 (5018.7)	10856 (4704.0)	4994 (2771.0)
Spring Surface Area at Basin (ha)	1.81 (1.26)	1.20 (0.72)	1.53 (0.96)	1.13 (0.70)	0.68 (0.45)
Spring Surface Area at Study Site (ha)	3.66 (2.19)	2.34 (1.38)	3.02 (1.49)	2.17 (1.08)	1.75 (0.82)
Number of Springs at Basin	3.4 (1.7)	2.7 (1.5)	3.4 (1.5)	3.7 (1.6)	3.6 (1.8)
Number of Springs at Study Site	8.8 (3.0)	5.8 (2.9)	9.2 (2.4)	10.4 (2.6)	10.1 (2.8)
Playa Lake Surface Area (ha)	0.14 (0.10)	0.38 (0.26)	1.57 (0.66)	1.66 (0.76)	1.00 (0.54)
Total Freshwater Surface Area (ha)	4.00 (2.27)	2.89 (1.62)	32.30 (8.29)	47.21 (13.66)	2.55 (1.27)
Basin Water Surface Area (ha)	77.16 (39.40)	102.70 (42.40)	132.50 (43.05)	121.50 (41.44)	82.13 (40.31)
Basin Surface Area (ha)	343.30 (111.10)	343.30 (111.10)	343.30 (111.10)	343.30 (111.10)	303.22 (115.86)
Precipitation (cm)	2.0	2.2	4.3	0.0	0.0

[a]Standard error

Table 3. Observed significance levels (P) of habitat measurements and sandhill crane roost counts from regression analysis with the percentage of count variation explained by each variable (R^2).

Measurements	P	R^2
Spring Surface Area at Basin Counted	0.06	0.07
Spring Surface Area At Study Site	0.09	0.06
Number of Springs at Basin	0.01	0.13
Number of Springs at Study Site	0.34	0.02
Playa Lake Surface Area	0.01	0.13
Total Freshwater Surface Area	0.61	0.01
Basin Water Surface Area	0.0001	0.43
Basin Surface Area	0.13	0.05

Table 4. Sandhill crane flock counts and habitat measurements of fields where cranes were observed feeding compared with measurements of some fields available to cranes for feeding in western Texas and eastern New Mexico in the winter of 1982-1983.

Measurement	Mean	SE	N	Min	Max
Fields With Feeding Cranes					
Area (ha)	87.7	7.0	106	8.1	259.0
Distance of field center to nearest road (M)	441.0	23.2	106	91.4	1463.0
Distance of crane flock center to nearest road (M)	314.8	27.6	106	9.1	1828.8
Distance of crane flock center to field center (M)	233.8	15.1	106	0.0	731.5
Number of cranes in flock	892.5	144.0	106	3	9000
Fields Available to Cranes					
Area (ha)	51.6	4.9	104	2.0	259.0
Distance of field center to nearest road (M)	311.5	16.6	104	18.3	804.7

Table 5. Habitat measurements of fields where cranes were observed feeding seperated into 3 flock size categories and paired comparisons of habitat measurements of different sized flocks. SE = Standard error, N = Sample size.

Category Measurement	Mean	SE	N	$\underline{P}^a$
1 Less than 101 cranes				1 and 2
Area (ha)	78.8	11.6	34	0.77
Distance of field center to nearest road (M)	395.8	33.7	34	0.54
Distance of crane flock center to nearest road (M)	234.8	52.2	34	0.15
Distance of crane flock center to field center (M)	266.7	33.8	34	0.25
Number of cranes	33.7	4.2	34	0.0001
2 Between 100 and 1000 cranes				2 and 3
Area (ha)	74.4	9.7	45	0.01
Distance of field center to nearest road (M)	427.1	37.7	45	0.13
Distance of crane flock center to nearest road (M)	335.2	44.9	45	0.48
Distance of crane flock center to field center (M)	223.0	20.7	45	0.67
Number of cranes	423.5	35.0	45	0.0001
3 Greater than 999 cranes				3 and 1
Area (ha)	121.1	15.3	27	0.03
Distance of field center to nearest road (M)	521.2	48.5	27	0.04
Distance of crane flock center to nearest road (M)	381.7	39.2	27	0.04
Distance of crane flock center to field center (M)	210.3	21.7	27	0.19
Number of cranes	2755.6	376.7	27	0.0001

[a]Observed significance level from paired $\underline{T}$-tests.

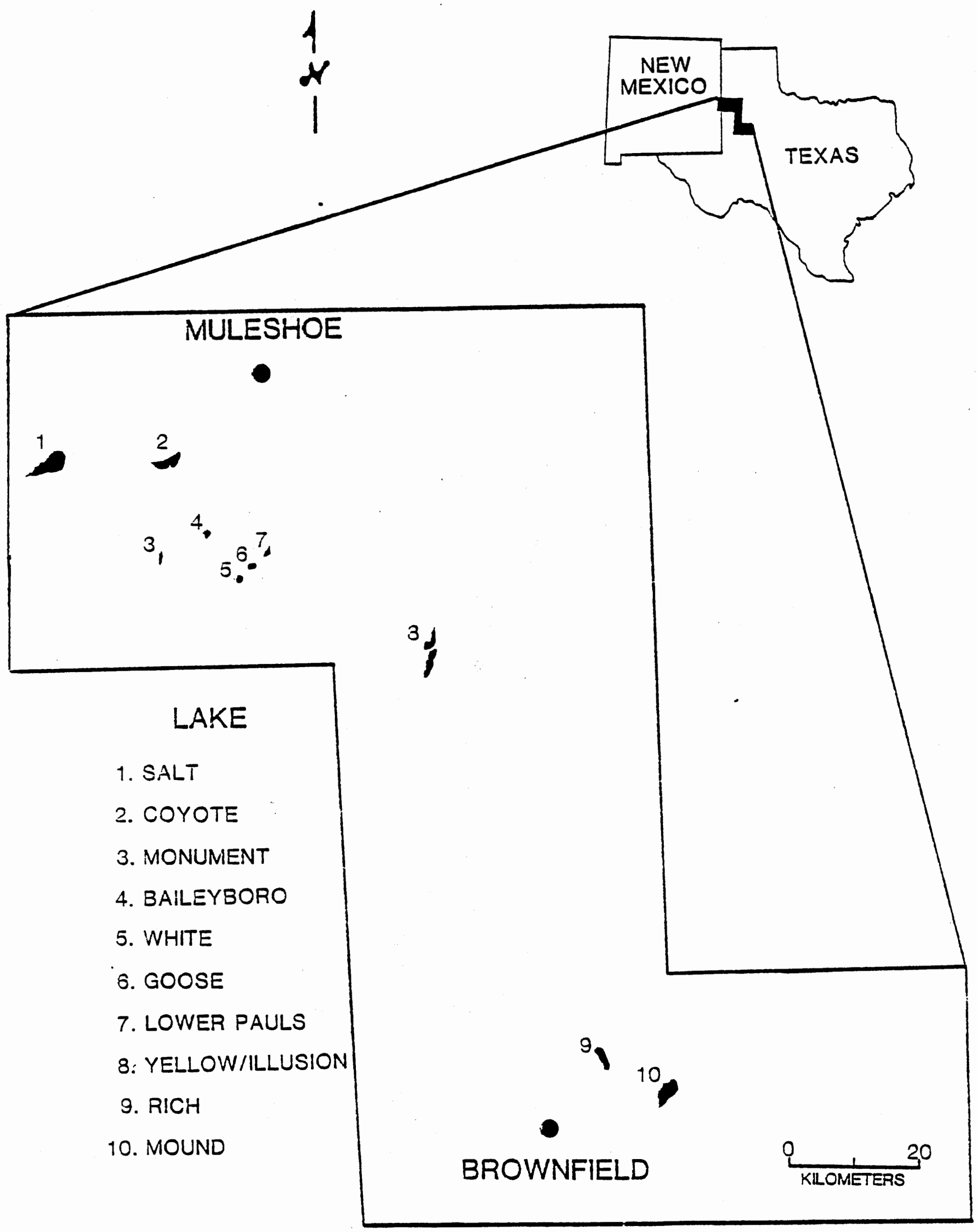

Figure 1. Study area in western Texas and eastern New Mexico illustrating the saline lake basins studied.

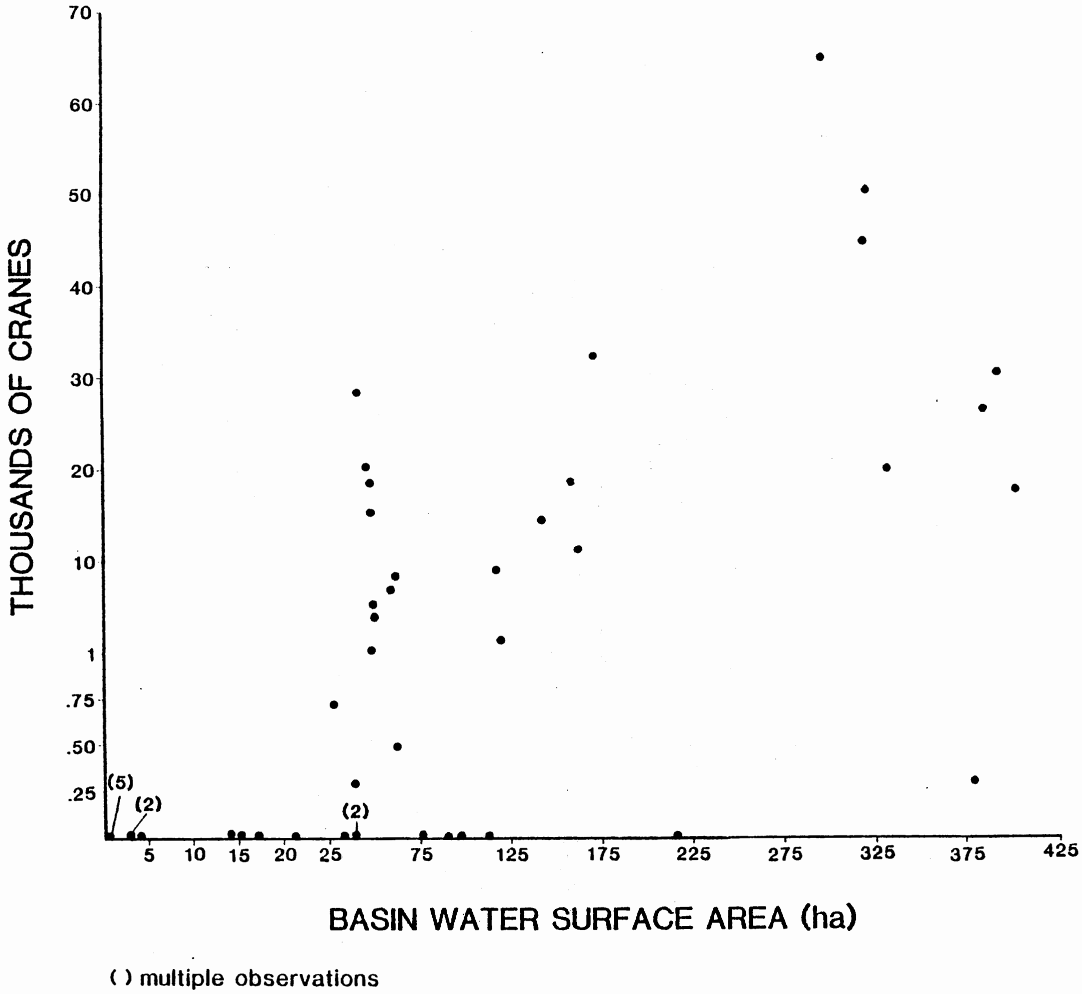

Figure 2. Comparison of crane counts with surface area of basin water at basin where count was conducted.

APPENDIX

WILDLIFE OBSERVED AT SPRINGS OR IN THE ASSOCIATED VEGETATION

INVERTEBRATES	
Brine shrimp	*Artemia salina*
Fairy shrimp	Order Anostraca
Water boatmen	Family Corixidae
FISH	
Plains killifish	*Fundulus zebrinus*
MAMMALS	
Desert cottontail	*Sylvilagus audubonii*
Deer mouse	*Peromyscus maniculatus*
Cotton rat	*Sigmodon hispidus*
Southern plains woodrat	*Neotoma micropus*
Ord's kangaroo rat	*Dipodomys ordii*
Coyote	*Canis latrans*
Raccoon	*Procyon lotor*
Badger	*Taxidea taxus*
Striped skunk	*Mephitus mephitus*
BIRDS	
Canada goose	*Branta canadensis*
Snow goose	*Chen caerulescens*

Mallard	_Anas platyrhynchos_
Common pintail	_Anas acuta_
American wigeon	_Anas americana_
Northern shoveler	_Anas clypeata_
Green-winged teal	_Anas crecca_
Northern harrier	_Circus cyaneus_
Prairie falcon	_Falco mexicanus_
Ring-necked pheasant	_Phasianus colchichus_
Great blue heron	_Ardea herodias_
Sandhill crane **	_Grus canadensis_
Virginia rail	_Rallus limicola_
Sora rail	_Porzana carolina_
American coot	_Fulica americana_
Killdeer	_Charadrius vociferus_
Baird's sandpiper	_Calidris bairdii_
Least sandpiper	_Calidris minutilla_
Common snipe	_Capella gallinago_
Great horned owl	_Bubo virgianus_
Short-eared owl	_Asio flammeus_
Barn owl	_Tyto alba_
Say's phoebe	_Sayornis saya_
Horned lark **	_Eremophila alpestris_
Cliff swallow	_Petrochilodon pyrrhonota_
Chihuahuan raven **	_Corvus cryptoleucus_
Common crow **	_Corvus brachyrhynchos_
Sedge wren	_Cistothorus platensis_
Marsh wren	_Cistothorus palustris_

Water pipit **	_Anthus spinoletta_
Sprague's pipit	_Anthus spragueii_
Western meadowlark	_Sturnella neglecta_
Red-winged blackbird	_Agelaius phoenicus_
Savannah sparrow	_Passerculus sandwichensis_
Lark bunting	_Calamospiza melanocorys_
White-crowned sparrow	_Zonotrichia leucophyrs_
Swamp sparrow	_Melospiza georgiana_
Song sparrow	_Melospiza melodia_
McCowen's longspur **	_Calcarius mccowenii_
Chestnut-collared longspur **	_Calcarius ornatus_
Lapland longspur **	_Calcarius lapponicus_
Smith's longspur **	_Calcarius pictus_

** denotes animal observed drinking at a spring.

VITA 2

Donald Edward Haley

Candidate for the Degree of

Master of Science

Thesis: DRINKING, ROOSTING, AND FEEDING HABITATS OF SANDHILL CRANES WINTERING IN WESTERN TEXAS AND EASTERN NEW MEXICO

Major Field: Wildlife Ecology

Biographical:

Personal Data: Born in Enid, Oklahoma, January 11, 1958, the son of Donald and Barbara Haley.

Education: Graduated from Parkway North High School, Creve Coeur, Missouri, June 1976; received Bachelor of Science degree in Wildlife Management and Conservation at University of Wyoming, August, 1980; completed the requirements for the Master of Science degree in Wildlife Ecology at Oklahoma State University, December, 1983.

Professional Experience: Biologist Aid, Wyoming Game and Fish Department, Summers of 1979,1980; Graduate Teaching Assistant, Oklahoma State University, Fall 1981; Graduate Research Assistant for Oklahoma Cooperative Wildlife Research Unit, 1982-1983.

Professional Organizations: The Wildlife Society, American Ornithologist's Union, The Cooper Ornithological Society, The Wilson Ornithological Society