# BREEDING ECOLOGY OF GREAT HORNED OWLS AND BARRED OWLS IN RELATION TO NESTING INTERIOR LEAST TERNS AT SALT PLAINS NATIONAL WILDLIFE REFUGE, OKLAHOMA: 1995 AND 1996

By

BRYAN RENO WINTON

Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

1991

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
May, 1997

**BREEDING ECOLOGY OF GREAT HORNED OWLS AND BARRED OWLS IN RELATION TO NESTING INTERIOR LEAST TERNS AT SALT PLAINS NATIONAL WILDLIFE REFUGE, OKLAHOMA: 1995 AND 1996**

**Thesis Approved:**

D.M. Leslie Jr.

**Thesis Advisor**

James H. Shaw

Lowell Caneday

Thomas C. Collins

**Dean of the Graduate College**

## ACKNOWLEDGEMENTS

I thank the very helpful, cooperative, and friendly folks at Salt Plains National Wildlife Refuge for accomodations and support including: R. Krey, H. Beierman, R. Shepperd, T. Ogburn, W. Miller, R. Hill, D. Knous, and K. Brown (YCC). Thanks also to J. Stahl (ODWC), S. Stahl (USACE), P. Beierman, A. Beierman, and C. Beierman for friendship and information.

M. Koenen, S. Schweitzer, and K. Wood deserve recognition for entertaining endless questions and providing direction for future least tern research. M. Koenen, J. Heltzel, D. Simon, Sr., D. Simon, Jr., D. Knous, V. Barko, and E. Winton are acknowledged for assisting with tern, plover, and avocet research, while M. Koenen and M. Cole are acknowledged for assisting with owl research. I thank R. Pfau and C. McMillen for small mammal expertise and L. Williams for assistance with small fish identification. T. Ulrich visited the alkaline flat to take photographs of least terns and snowy plovers for three days in 1995.

C. Toepfer, V. Tilmans, B. Schrock, G. Robel, M. Cole, S. Chappell, J. Pike, D. Nicholson, B. Welch, M. Stewart, D. Hartley, B. Coppedge, C. Packert, J. Whittier, J. Sinclair, D. Crosswhite, T. Dustin, T. Henderson, J. Rackley, A. Fallon, S. Morrow, S. Stoodley, D. Simon, Sr., B. Neal, and

S. Ditchkoff contributed to the enjoyment and survival of my educational experience. D. Leslie, Jr., J. Shaw, L. Caneday, L. Talent, R. Lochmiller, D. Waits, L. Perkins, B. Fisher, M. Payton, C. Goad, T. Mills, K. Castle, A. Cross, K. Bull, and A. Stoecker provided professional advice and taught classes I enjoyed most. G. Balazs and M. Brock afforded me on-the-job experience in wildlife research and motivated my educational re-entry.

The Oklahoma Cooperative Fish and Wildlife Research Unit staff: D. Leslie, Jr., B. Fisher, J. Gray, H. Murray, and B. Newkirk provided invaluable support and patience with me throughout my graduate school endeavors--especially J. Gray who kept me copy-machine qualified. D. Leslie, Jr., my senior advisor, deserves a thousand thanks for redirecting my educational endeavors and entertaining my cyclic flow of questions and concerns. The support and open-door policy of D. Leslie, Jr. and the unit staff and employees made research activities exciting.

This research was funded by the Oklahoma Cooperative Fish and Wildlife Research Unit and Department of Zoology at Oklahoma State University, the National Biological Service, and Salt Plains National Wildlife Refuge. The financial support made this all possible but the professional support and freedom from committee members: D. Leslie, Jr., J. Shaw, and L. Caneday made it worthwhile. Finally, I thank C. Bohan, L. Ditto, and D. Leslie, Jr. for affording me career experience and employment opportunity with the U.S. Fish and Wildlife Service, Lower Rio Grande Valley National Wildlife

Refuge in Alamo, Texas.

My parents, C. Winton and L. Winton are applauded for their continued understanding, support, and confidence in me and my educational ambitions. Without their financial and motivational support, none of this would have been possible.

Lastly, my wife, E. Winton, and son, T. Winton made the ultimate sacrifice by tolerating me for three years during classes and dedicated thesis research. Their limitless support throughout this endeavor will take a lifetime to repay.

## PREFACE

Thesis chapters were written in manuscript format suitable for submission to scientific journals or professional publications. Chapter I of this thesis follows the journal format of The Southwestern Naturalist and Chapter II follows the format of Journal of Field Ornithology. Chapter III is written according to guidelines in Condor and Chapter IV is written for submission to the Bulletin of the Oklahoma Ornithological Society.

The goal of research efforts in 1995 and 1996 was to document avian predator impact on endangered interior least terns nesting at Salt Plains National Wildlife Refuge. Chapter I describes baseline habitats and pair densities of sympatric barred owls and great horned owls at Salt Plains National Wildlife Refuge, and suggests barred owl habitat needs exclude them from being predators of least terns. Chapter II describes site-specific nesting success and microhabitat use for least terns throughout the alkaline flat. Chapters III and IV were methodologically similar to Chapter II, but on sympatric nesting species: snowy plovers and American avocets/black-necked stilts, respectively. Ring-billed gulls were newly documented avian predators on snowy plovers eggs and chicks, and two diurnal great horned owl sightings occurred on the alkaline flat in 1995 during the Charadriiform nesting season.

TABLE OF CONTENTS

APPENDICES

## LIST OF TABLES

Tables | Page

Chapter I



Chapter II

Chapter III



Chapter IV

## LIST OF FIGURES

Figure Page

Chapter I



Chapter II

Chapter III



Appendix B.

## Chapter I

# HABITAT ASSOCIATIONS AND BREEDING PAIR DENSITIES OF SYMPATRIC BARRED OWLS AND GREAT HORNED OWLS IN NORTHCENTRAL OKLAHOMA

ABSTRACT — We identified sighting-, scale-, and species-dependent differences in habitat associations surrounding activity centers of sympatric barred owls (Strix varia) and great horned owls (Bubo virginianus) in northcentral Oklahoma in 1995-1996 using taped vocalizations, remote sensing, and manual GIS techniques. Barred owl pairs were associated with closed (62.8%) and open (8.0%) forest canopies and fallow agriculture (10.6%), and great horned owl pairs were associated with open (22.1) and closed (34.6%) forest canopies, and clear features (26.4%). Breeding densities for barred owl pairs were one pair every 144 ha, and great horned owl pairs were one pair every 230 ha within a contiguous 1155 ha forested region of Salt Plains National Wildlife Refuge.

Barred owls (Strix varia) prefer bottomland deciduous forests with large diameter trees located near streams or stagnant pools (Allen 1987; Sutton 1967), and great horned owls (Bubo virginianus) also use timberlands (Sutton 1967).

Conflicting information exists on abundance of great horned owls and barred owls in northcentral Oklahoma, where they nest sympatrically. Sutton (1967) reported that great horned owls were locally abundant while barred owls were only an occasional winter visitor, being at the western edge of their range in northcentral Oklahoma. Recent studies lump barred owls and great horned owls with other owls as wide-ranging species that breed regularly in Oklahoma (Tyler 1995).

Tape playback of conspecific vocalizations of Strigidae owls is an effective census technique (Nowicki 1974; Lynch 1984), especially for barred owls and great horned owls (Emlen 1972; McGarigal and Fraser 1984; 1985; Morrell et al. 1991; Laidig and Dobkin 1995). Although radiotelemetry has been used to determine habitat use of owls (Nicholls and Warner 1972; Ganey and Balda 1994; Sparks et al. 1994), broadcast owl calls can provide insight into habitat associations (McGarigal and Fraser 1984; Laidig and Dobkin 1995).

This research was motivated by three factors: 1) the possibility that barred owls and great horned owls prey on endangered interior least terns (Sterna antillarum) and other shorebirds nesting on the alkaline flat at Salt Plains National Wildlife Refuge (NWR)(Johnston 1956; Morris and Wiggins 1986; Weir and Hanson 1989; Holt 1994; Renken and Smith 1995); 2) a paucity of information regarding abundance and habitat characteristics of sympatric barred owls and great horned owls in Oklahoma; and 3) the need to further understand habitat preferences of barred owls because the endangered northern spotted owl (Strix occidentalis) hybridizes with barred owls (Hamer et al. 1994).

STUDY AREA — This study was conducted in the northeastern part of Salt Plains NWR in Alfalfa County, Oklahoma (36°47'N, 98°11'W). Average elevation at Salt Plains NWR where owl censuses were conducted was 347.9 m above mean sea level. Average annual precipitation in Alfalfa County is 65 cm (USDA, Soil Conservation Service, 1953).

Habitat features in and around the refuge included bottomland forests (open and closed canopies), agriculture (farmed and fallow fields), clear land (grasslands and sandbars), water sources (wetlands, ponds, rivers, and Great Salt Plains Reservoir), and human modifications (roads and dwellings). Dominant bottomland tree species on the refuge included: eastern cottonwood (Populus deltoides), American elm (Ulmus americana), black willow (Salix nigra), red mulberry (Morus rubra), hackberry (Celtis occidentalis), green ash (Fraxinus pennsylvanica), and eastern redcedar (Juniperus virginiana). Dryland agriculture and cattle grazing dominated land-use activities outside the refuge.

METHODS AND MATERIALS — Tape playback of conspecific vocalizations was used to determine pair densities and habitat associations of sympatric barred owls and great horned owls nesting in an 1155 ha forested region in the northeastern corner of Salt Plains NWR (Fig. 1.). Remote sensing and manual geographic information system (GIS) techniques were used to quantify natural and man-made habitat components present around single and pair/group sightings of barred owls and great horned owls at two scales: 1) 64.8 ha (0.25 mile$^2$ with 625 pixels) and 2) 259.2 ha (1.0 mile$^2$ with 2,500 pixels). Owl presence was determined from auditory responses to taped vocalizations (solicited) or visual verification (unsolicited). Single owl and pair/group locations were recorded and plotted on 1:16,600 scale (1 cm = 157 m or 1" = 1320') color aerial photos taken on 2 December 1989 and used to quantify percent composition of habitat features surrounding activity centers at both scales. Manual rastor-GIS procedures were used by overlaying a transparent grid over aerial photographs and classifying habitat types. Grids were aligned with existing roadways and section lines. Quantification of habitat features at two scales allowed for identification and comparison of scale-dependent differences in habitats between and within species.

Broadcasted vocalizations for each species were played at low volume during daylight hours (0700-2100 hr) at 0.1-km intervals along a 14-km survey route to index owl abundance and record habitat associations during the nesting period. Barred owls and great horned owls were censused separately from February through May in 1995 and 1996. Surveys were conducted when wind speed was low and precipitation negligible to maximize hearing auditory responses (Laidig and Dobkin 1995). The sampling period corresponded with the timing of territorial defense for each species when owls were most responsive (Bent 1938; Morrell and Yahner 1995).

Incidental sightings (unsolicited) of both species were recorded throughout the study area and surrounding areas and used to determine habitat associations when sightings occurred in areas represented by aerial photos. Habitats surrounding owls observed incidentally (unsolicited sightings) may have been more representative of habitat use because they represented sightings of undisturbed owls. Observations of American crows (Corvus brachyrhynchos) were documented at owl sightings because mobbings by crows can influence diurnal movements of owls.

Broadcasting equipment included a Unitech ST-2 speaker-amplifier system and a portable cassette player (Sony Walkman) using Johnny Stewart brand tapes for each species (Sheda's, Chelsea, Iowa). Calls were rotated 360 degrees, broadcasted for 10-min at each station--sounded every 30 sec for the first 7 min and once a minute for the remaining 3 min. The broadcasting period was followed by a 10-min post-broadcast observation period. Broadcasting was terminated immediately after a sighting or response was made. Time until response and direction of approach were recorded to differentiate unique individuals, pairs, or groups and facilitate accurate density estimates (Bosakowski 1987, Winton et al. 1994, Laidig and Dobkin 1995).

Owls were solicited with broadcast equipment during daylight hours because information on nesting habitat was needed. Nighttime calling was avoided because it identified foraging habitat rather than nesting habitat requirements (Winton et al. 1994). All sites were called 1-3 times each year or until occupancy was determined. Resighting attempts were conducted at all sighting locations to determine affinity for identified activity centers and aid in habitat association and pair density determinations.

Habitat features were quantified using remote sensing from color aerial photos in this study--61% of all barred owls sightings and 75% of all great horned owl sightings were delineated at photo nadir. Habitat types classified by pixel at each activity center included: closed canopy (≥40% tree cover); open canopy (<40% tree cover); clear land (pasture, grassland, and sandbars); farmed agricultural land; fallow agricultural land; water sources (wetlands, ponds, rivers, and Great Salt Plains Reservoir); roads (paved and heavily traveled gravel), and dwellings (houses, barns, and the refuge headquarters and maintenance buildings). The dominant habitat in each pixel was identified based on its percentage of occurrence (≥50%), except for river and road features which were determined cumulatively to prevent underestimation of linear features.

Pair densities in the 1155 ha area was determined by calculating the average abundance based on two years of censuses. Pair densities were determined because this represented the viable portion of the populations. Densities of barred owls and great horned owls were determined for pairs only because single owls may not have been territory holders or breeders (Winton et al. 1994). Owl densities were determined by considering direction of approach and response time to broadcast calls. Chi-square analyses (Steel and Torrie 1980) were performed to identify if habitat associations differed by: 1) sighting (at fixed scale and species); 2) scale (at fixed sighting and species); and 3) species (at fixed sighting and scale).

RESULTS — Precipitation during February-May in 1995 and 1996 was highly variable (Table 1). Both years deviated from the 20-yr average. Temperature ranges in February and May differed between years.

We observed 42 barred owls during 23 sightings and 23 great horned owls during 12 sightings within the study area in 1995 and 1996 (Table 2). Single-owl sightings (potential floaters) of barred owls during both years comprised 22% of the observations. Single-owl sightings of great horned owls during both years comprised 42% of the observations (Table 2). In general, barred owls glided in quietly toward our call, and great horned owls hooted from their present location before approaching.

Twenty of 23 (87%) barred owl sightings were solicited with broadcast equipment. Three barred owls were incidentally sighted. Nine of 12 (75%) great horned owl sightings were made incidentally, and only three were solicited with broadcast equipment. Incidental sightings of both species represented 38% of all owl observations.

American crows were observed at 8 of 23 (35%) barred owl sightings. In contrast, crows were associated with only 2 of 12 (17%) great horned owl sightings, but represented 66% (2 of 3) of the solicited great horned owl sightings.

Closed canopy, open canopy, and clear features were present in all activity centers (single and pair/group sightings) for both species ($n$ = 35) at two scales. Water was present in 91% of all barred owl sightings and 92% of all great horned owl sightings at the 64.8-ha scale and occurred in all sightings for both species at the 259.2-ha scale. Farmed agricultural land was present in 91% of the barred owl sightings and 75% of the great horned owl sightings at the 259.2-ha scale. Fallow agriculture was present in 78% of the barred owl sightings and 83% of the great horned owl sightings at the 259.2-ha scale.

Man-made features included roads and dwellings. Roads were present in 65% of all barred owl sightings at the 64.8-ha scale and present in 83% of all barred owl sightings at the 259.2-ha scale. Roads were present in 92% of all great horned owl sightings at both scales. Dwellings were present in 30% of all barred owl sightings at the 64.8-ha scale and 61% if all sightings at the 259.2-ha scale. Dwellings occurred in 50% of all great horned owl sightings at both scales. (Table 3).

Barred owls and great horned owls used unique natural and man-made habitats by sighting: 1) barred owl single versus pair/group sightings at 64.8-ha ($X^2$ = 99.101, 6 df, $P$ < 0.001); 2) barred owl single versus pair sightings at 259.2-ha ($X^2$ = 453.864, 6 df, $P$ < 0.001); 3) great horned owl single versus pair sightings at 64.8-ha ($X^2$ = 148.988, 6 df, $P$ < 0.001); 4) great horned owl single versus pair sightings at 259.2-ha ($X^2$ = 692.524, 6 df, $P$ < 0.001).

Barred owls and great horned owls used unique natural and man-made habitats between scales. Single sightings between scales and pair/group sightings between scales were significantly different for both species: 1) barred owl single sightings ($X^2$ = 56.809, 6 df, $P$ < 0.001); 2) barred owl pair/group sightings ($X^2$ = 40.028, 6 df, $P$ < 0.001); 3) barred owl cumulative sightings ($X^2$ = 39.182, 6 df, $P$ < 0.001); 4) great horned owl single sightings ($X^2$ = 64.196, 6 df, $P$ < 0.001); 5) great horned owl pair/group sightings ($X^2$ = 32.054, 6 df, $P$ < 0.001); and 6) great horned owl cumulative sightings ($X^2$ = 21.528, 6 df, $P$ < 0.001).

Barred owls and great horned owls used unique natural and man-made habitats between species at fixed sighting and scale. Between-species comparisons at 64.8-ha by sighting were: 1) single ($X^2$ = 305.673, 6 df, $P$ < 0.001), 2) pair/group ($X^2$ = 187.883, $P$ < 0.001), and 3) cumulative ($X^2$ = 190.348, 6 df, 6 df, $P$ < 0.001). Between-species comparisons at 259.2-ha by sighting were: 1) single ($X^2$ = 1015.509, 6 df, $P$ < 0.001), 2) pair/group ($X^2$ = 718.224, 6 df, $P$ < 0.001), and 3) cumulative ($X^2$ = 611.348, 6 df, $P$ < 0.001).

Paired Student's $t$-tests of within-species comparisons with fixed sighting and scale resulted in significant differences for all features (P < 0.001), except roads--for barred owl single versus cumulative sightings (0.3 < $P$ <

0.2) and barred owl single versus pair/group sightings (0.2 > $\underline{P}$ > 0.1) at the 64.8-ha scale. Water, fallow agriculture, and road features were not significantly different for great horned owls at fixed sightings at the 64.8-ha scale ($\underline{P}$ > 0.5). Between-species comparisons of features were significantly different for all features ($\underline{P}$ < 0.001), except water ($\underline{P}$ > 0.05) at the 64.8 ha scale.

We identified eight separate barred owl pairs and five separate great horned owl pairs in the 1155 ha northeastern forested part of the refuge. This represented a density of one barred owl pair per 144 ha and one great horned owl pair per 230 ha. Nineteen additional great horned owls were solicited or incidentally sighted (unsolicited) outside the study area in the southern part of the refuge dominated by exotic salt cedar (Tamarix spp.)(25%), along the refuge periphery (50%), and in adjacent farmlands ≤10 km outside the refuge (25%). Barred owls were not sighted outside the study area.

DISCUSSION — Climate differed between years during the study with above average temperatures and rainfall in 1995, and drought conditions in 1996 (Table 1). Weather can affect habitat selection in avian species (Jorde et al. 1984). Differences in climate between years may have influenced relative abundance of owl species observed.

Nine of 12 great horned owls within the study area were sighted incidentally (unsolicited). Habitat information surrounding these sightings may be more representative of requirements than was determined from habitat associations surrounding solicited sightings of both species. Incidental sightings represented habitat use because birds were located while moving about naturally in their environment.

There is no record that great horned owls prey on American crows in Oklahoma (Sutton 1967). The decreased occurrence of crows associated with sightings of great horned owls (2 of 12) versus barred owls (8 of 23) suggested crows may indeed be potential prey, as other studies have found (Bosakowski et al. 1989; Bosakowski and Smith 1992). Mobbing by crows was likely influenced by broadcasting owl calls during daylight hours when crows were active, increasing the likelihood of interaction. Crow mobbing represented a research-related disturbance to owls in this study.

Barred owl density was higher than great horned owl density in the 1155 ha forested region at Salt Plains NWR, but barred owls were not found outside the study area. Overall, great horned owls were the most abundant large Strigidae on and outside the refuge. Great horned owls dominated in sparsely forested areas and fencelines surrounding the refuge, and in salt cedar stands (*Tamarix* spp.) in the southern and northwestern part of the refuge. One great horned owl pair nested successfully (2 juveniles) inside a goose-box in a wetland surrounded by homogeneous salt cedar stands at the southern end of the refuge in 1995. Another pair successfully produced two juveniles on private land about 300 m west of the entrance to the selenite crystal digging area at Salt Plains NWR in 1995.

A single great horned owl was observed foraging on two occasions in June 1995 on the alkaline salt flat near Cottonwood Creek in nesting habitat used by endangered interior least terns (Sterna antillarum) and delisted Category 2 snowy plovers (Chardrinus alexandrius). Great horned owls are documented predators of least tern adults and chicks (Lingle 1993, Renken and Smith 1995). However, no sightings or ancillary information were obtained to suggest that barred owls preyed on nesting birds on the alkaline flat in 1995 and 1996.

Many of the great horned owl sightings from outside the study area were not available on color aerial photographs. Therefore, these additional great horned owl sightings could not be included in the habitat evaluations. Many of these outside areas had habitats dominated by farmed and fallow agriculture--quite different than habitat associations on the refuge. Regardless, these sightings helped confirm that great horned owls were not strongly associated with any particular habitat, which is consistent with the view that this species is a habitat generalist (Fuller 1979, Petersen 1979, McGarigal and Fraser 1984, Bosakowski et al. 1989a, Laidig and Dobkin 1995).

On the morning of 12 July 1996, heavy fog coincided with three road-killed great horned owls (including two juveniles) on state highways immediately surrounding the refuge, which suggested that a relatively abundant population of great horned owls existed on the refuge periphery. Because only one other great horned owl was salvaged from roads near the refuge in 1995 and 1996, we hypothesize that the three great horned owl casualties observed were fog-related.

Barred owl habitat included >50% closed canopy at both scales for all sightings. Water, clear fields, and fallow agriculture were increasingly important for pair/group sightings at the 259.2-ha scale. Proximity to roads was only slightly higher for barred owls at the 64.8-ha scale.

Density of barred owls in the northeastern region of the refuge, the rarer of the 2 large Strigidae, was significant. Home range size for barred owls was 229 ha in Minnesota (Nicholls and Warner 1972), and ranged from 118 ha in summer to 282 ha in Michigan (Elody and Sloan 1985). Our density estimates for barred owl pairs (1:144 ha) indicate a relatively dense population of barred owls in comparison to other studies (Allen 1987). An update of the refuge brochure on avian species is warranted, because the status and abundance for barred owls is currently listed as uncommon during all seasons throughout the year, which is not the case.

Although significant differences between habitat features did exist within and between owl species, single and pair/group sightings were given equal weight for determining habitat associations. A weighting of pair/group sightings when computing cumulative habitat associations may have given a better depiction of suitable habitat needs for nesting owls. Similiarly, single owl sightings could have represented floaters or non-breeders residing in suboptimal habitat.

Scale-dependent differences in habitat associations surrounding single and pair/group sightings for each species suggest more research is needed in order to ascertain which scale best depicts habitat use. In this study, the 64.8 ha scale was much easier to classify and likely provided a better indication of breeding habitat needs.

Response differences to taped vocalizations between species indicated that barred owls were three times more likely to be solicited with broadcast equipment. This may have been due to the wider range of vocalizations displayed by barred owls, whereas great horned owls often vocalized with the same hoot series.

Features present in all sightings of both species at both scales included closed canopy, open canopy, and clear areas (grasslands, pastures, sandbars). The dominant presence of these habitat features may reflect availability more than selection (Hobbs and Hanley 1990). Water was present in all sightings for both species at the 259.2-ha scale suggesting that owls will travel up to 1.1 km for free-standing water. Presence of water did not differ between species at the 64.8-ha scale.

Information obtained on proximity of farmed and fallow agriculture features to owl sightings may be limited in value because land use and farming practices change annually. However, land-use practices during this study were very similar to those implemented in 1989, when aerial photos were taken.

Man-made features (roads and dwellings) represented a possible source of repeated disturbance to owls, while the presence of crows at owl sightings, although natural, could also be considered disturbance. Barred owl activity centers had fewer roads at both scales indicating a greater sensitivity to disturbance, than for great horned owls. However, presence of dwellings was higher for barred owls at the 259.2-ha scale, although the number of dwellings per sighting was often quite higher for great horned owls. Only 30% of all barred owl sightings had dwellings at the 64.8-ha scale versus 50% for great horned owls. Significant differences existed between all features within and between species except for roads, which may have reflected the rarity or uniform distribution of this feature overall.

The relatively high density for barred owls in the habitats identified should not be misinterpretted as high habitat quality or habitat use (Van Horne 1983). The abundance of barred owls in the study area was likely influenced by sheer availability and scarcity of contiguous timbered lands outside the refuge.

ACKNOWLEDGEMENTS — The authors thank C. Goad, J. Shaw, and L. Caneday for assistance with various aspects of the manuscript. M. Koenen and M. Cole are recognized for assistance with owl censuses. We are especially grateful to Salt Plains NWR, particularly Manager Rod Krey, for access on the refuge, accomodations, and use of color aerial photographs. This manuscript is part of a thesis submitted by the senior author in partial fulfillment of the requirements for a M.S. degree at Oklahoma State University. Primary funding and support was provided by the National Biological Service, Salt Plains NWR, and the Oklahoma Cooperative Fish and Wildlife Research Unit (U.S. Nat. Biol. Serv., Okla. State Univ., Okla. Dept. Wildl. Conserv., and Wildl. Manage. Inst., cooperating).

## LITERATURE CITED

ALLEN, A.W. 1987. Habitat suitability index models: barred owl. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.143).

BENT, A.C. 1938. Life histories of North American birds of prey: Part 2. U.S. Natl. Mus. Bull. 170. Dover, New York.

BOSAKOWSKI, T. 1987. Census of barred owls and spotted owls. Pp. 307-308 in R. W. Nero, R.J. Clark, R.J. Knapton and R.H. Hamre [Eds.], Biology and conservation of northern forest owls. U.S. Forest Serv. Gen. Tech. Rep. RM-142, Fort Collins, Colorado.

_____, R. SPEISER, and D.G. SMITH. 1989. Nesting ecology of forest-dwelling great horned owls, Bubo virginianus, in the eastern deciduous forest biome. Can. Field-Nat., 103:65-69.

_____, and D.G. SMITH. 1992. Comparative diets of sympatric nesting raptors in the eastern deciduous forest biome. Can. J. Zool., 70:984-992.

ELODY, B.J., AND N.F. SLOAN. 1985. Movements and habitat use of barred owls in the Huron Mountains of Marquette County, Michigan, as determined by radiotelemetry. Jack-pine Warbler 63:3-8.

EMLEN, J.T. 1972. Vocal stimulation in the great horned owl. Condor, 75:126-127.

FULLER, M.R. 1979. Spatiotemporal ecology of four sympatric raptor species. Ph.D. dissertation, Univ. Minnesota, Minneapolis, Minnesota.

GANEY, J.L., and R.P. BALDA. 1994. Habitat selection by Mexican spotted owls in northern Arizona. Auk, 111:162-169.

HAMER, T.E., E.D. FORSMAN, A.D. FUCHS, and M.L. WALTERS. 1994. Hybridization between barred and spotted owls. Auk, 111:487-492.

HOBBS, N.T., and T.A. HANLEY. 1990. Habitat evaluation: Do use/availability data reflect carrying capacity? J. Wildl. Manage., 54:515-522.

HOLT, D.W. 1994. Effects of short-eared owls on common tern colony desertion, reproduction, and mortality. Colon. Waterbirds, 17:1-6.

JOHNSTON, R.F. 1956. Predation by short-eared owls on a salicornia salt marsh. Wilson Bull., 68:91-102.

JORDE, D.G., G.L. KRAPU, R.D. CRAWFORD, and M.A. HAY. 1984. Effects of weather on habitat selection and behavior of mallards wintering in Nebraska. Condor, 86:258-265.

LAIDIG, K.J. and D.S. DOBKIN. 1995. Spatial overlap and habitat associations of barred owls and great horned owls in southern New Jersey. J. Raptor Res., 29:151-157.

LILLESAND, T.M., and R.W. KIEFER. 1994. Remote sensing and image interpretation. John Wiley & Sons, Inc., New York.

LINGLE, G.R. 1993. Causes of nest failure and mortality of least terns and piping plovers along the central Platte River. Pp. 130-134, in K.F. Higgins and M.R. Brashier, eds. Proceedings, the Missouri River and its Tributaries: Piping Plover and Least Tern Symposium. South Dakota State Univ., Brookings, South Dakota.

LYNCH, P.J. and D.G. SMITH. 1984. Census of eastern screech-owls (Otus asio) in urban open-space areas using tape-recorded song. Amer. Birds, 38:388-391.

MCGARIGAL, K. and J.D. FRASER. 1984. The effect of forest stand age on owl distribution in southwestern Virginia. J. Wildl. Manage., 48:1393-1398.

_____ and _____. 1985. Barred owl responses to recorded vocalizations. Condor, 87-552-553.

MORRELL, T.E., and R.H. YAHNER. 1995. Proportion of area occupied by great horned owls in southcentral Pennsylvania. Wildl. Soc. Bull., 23:733-737.

_____, _____, and W.L. HARKNESS. 1991. Factors affecting detection of great horned owls by using broadcast vocalizations. Wildl. Soc. Bull., 19:481-488.

MORRIS, R.D., and D.A. WIGGINS. 1986. Ruddy turnstones, great horned owls, and egg loss from common tern clutches. Wilson Bull., 98:101-109.

NICHOLLS, T.H., and D.W. WARNER. 1972. Barred owl habitat use as determined by radiotelemetry. J. Wildl. Manage., 36:213-224.

NOWICKI, T. 1974. A census of Screech Owls using tape-recorded calls. Jack-Pine Warbler 52:98-101.

PETERSEN, L. 1979. Ecology of great horned owls and red-tailed hawks in southeastern Wisconsin. Wisconsin Dept. Nat. Res. Tech. Bull. No. 111, Madison, Wisconsin.

RENKEN, R.B., and J.W. SMITH. 1995. Annual adult survival of interior least terns. J. Field Ornithol., 66:112-116.

SPARKS, E.J., J.R. BELTHOFF, and G. RITCHISON. 1994. Habitat use by Eastern screech-owls in central Kentucky. J. Field Ornithol., 65:83-95.

STEEL, G.D., AND J.H. TORRIE. 1980. Principles and procedures of statistics: A biometrical approach. McGraw-Hill, Inc. New York.

SUTTON, G.M. 1967. Oklahoma Birds: Their ecology and distribution, with comments on the avifauna of the southern Great Plains. Univ. Oklahoma Press, Norman.

TYLER, J.D. 1995. Oklahoma owls. Bull. Oklahoma Ornithol. Soc., 28:17-18.

VAN HORNE, B. 1983. Density as a misleading indicator of habitat quality. J. Wildl. Manage., 47:893-901.

WEIR, D., and A. HANSON. 1989. Food habits of great horned owls, Bubo virginianus, in the Northern Taiga of the Yukon Territory and Alaska. Can. Field-Nat., 103:12-17.

WINTON, B., L. MANNING, J. AHRENS, and T. SCHEIFFE. 1994. 1994 Spotted owl inventory and monitoring: Crater Lake National Park. Tech. Rep., Klamath Falls, Oregon.

Table 1 — Temperature ranges (C°) and rainfall (cm) for months owl censuses were conducted at Salt Plains National Wildlife Refuge, Oklahoma in 1995 and 1996 in comparison to the 20-year rainfall average.

| | | Month | | | |
|---|---|---|---|---|---|
| Year | Climate | Feb | Mar | Apr | May |
| 1995 | Temp (HI/LO) | 22/-7 | 28/-16 | 30/-2 | 30/4 |
| | Rainfall | 0.41 | 4.05 | 9.56 | 16.69 |
| 1996 | Temp (HI/LO) | 34/-21 | 26/-15 | 32/-3 | 40/3 |
| | Rainfall | 0.08 | 2.26 | 0.15 | 4.74 |
| 20-Yr avg[1] | Rainfall | 3.18 | 6.18 | 6.49 | 12.69 |

[1] Average obtained from Salt Plains NWR 1995 Annual Narrative.

Table 2 — Total number of barred owl and great horned owl sightings by year located within the 1155 ha forested region censused at Salt Plains National Wildlife Refuge, Oklahoma, 1995 and 1996.

| Species | Year | Single owl Sightings | Pair/Group Sightings | Total |
|---|---|---|---|---|
| Barred owls | 1995 | 2 | 7 | 9 |
| | 1996 | 3 | 11 | 14 |
| | Both years | 5 | 18 | 23 |
| Great horned owls | 1995 | 4 | 4 | 8 |
| | 1996 | 1 | 3 | 4 |
| | Both years | 5 | 7 | 12 |

Table 3 — Means and standard errors for percent occurrence of habitat features surrounding activity centers of single and pair/group barred owl and great horned owl sightings quantified at 64.8 ha and 259.2 ha scales.

| | | 64.8 ha SCALE | | | | 259.2 ha | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sighting: | | Single owl | | ≥ Two owls | | Single owl | | ≥ Two owls | |
| Owl species | Feature | $\bar{X}$ | SE | $\bar{X}$ | SE | $\bar{X}$ | SE | $\bar{X}$ | SE |
| Barred | Closed canopy | 65.3 | 16.0 | 62.8 | 14.3 | 50.1 | 12.7 | 52.3 | 13.0 |
| | Open canopy | 18.1 | 16.5 | 8.0 | 5.0 | 20.8 | 14.9 | 5.6 | 3.4 |
| | Farmed agric | 2.1 | 4.6 | 3.9 | 6.1 | 4.3 | 5.6 | 6.1 | 7.6 |
| | Fallow agric | 0.0 | 0.0 | 10.6 | 10.5 | 1.5 | 1.4 | 11.5 | 10.2 |
| | Clear | 8.2 | 7.6 | 6.2 | 4.1 | 12.9 | 8.1 | 10.1 | 5.3 |
| | Water | 5.6 | 8.1 | 8.1 | 9.1 | 9.3 | 10.8 | 13.9 | 9.2 |
| | Roads | 0.8 | 0.6 | 0.6 | 0.6 | 1.1 | 0.4 | 0.5 | 0.4 |
| Great horned | Closed canopy | 21.0 | 20.7 | 34.6 | 19.9 | 18.8 | 16.8 | 27.1 | 19.2 |
| | Open canopy | 27.7 | 31.3 | 22.1 | 16.6 | 26.8 | 27.6 | 19.7 | 17.2 |
| | Farmed agric | 20.9 | 29.7 | 1.4 | 3.2 | 19.5 | 34.3 | 4.3 | 5.8 |
| | Fallow agric | 6.1 | 10.5 | 6.5 | 13.2 | 17.5 | 21.5 | 6.7 | 5.6 |
| | Clear | 15.2 | 9.4 | 26.4 | 18.3 | 12.7 | 5.3 | 31.0 | 21.8 |
| | Water | 7.3 | 13.3 | 7.3 | 7.0 | 3.7 | 4.8 | 10.2 | 10.3 |
| | Roads | 1.8 | 1.5 | 1.7 | 1.7 | 1.1 | 0.6 | 1.1 | 0.6 |

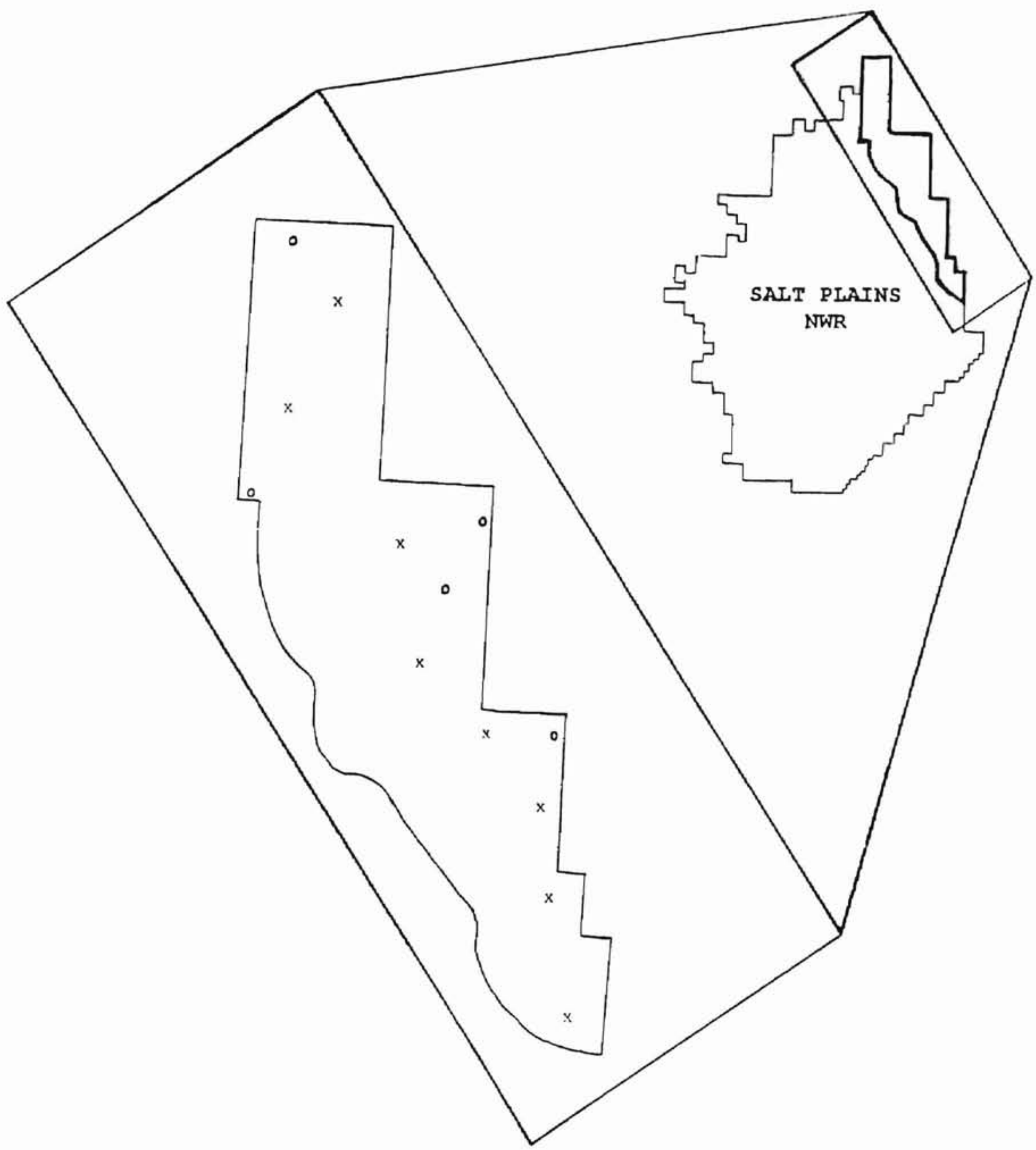


**Fig. 1. — Forested habitat (1155 ha) censused and breeding pair distributions of barred owls (x) and great horned owls (o) at Salt Plains National Wildlife Refuge, Oklahoma, 1995 and 1996.**

Chapter II

# BREEDING ECOLOGY AND ABUNDANCE OF INTERIOR LEAST TERNS ON THE ALKALINE FLAT AT SALT PLAINS NATIONAL WILDLIFE REFUGE, OKLAHOMA, 1995-96

Abstract.--Nesting success of endangered interior least terns (Sterna antillarum) on the alkaline flat at Salt Plains National Wildlife Refuge was assessed with the Mayfield Method and apparent nesting success in 1995 and 1996. Mayfield Method estimates for all nests were 29% nesting success in 1995 and 37% nesting success in 1996. Nesting inside electric fence predator exclosures was significantly higher in 1995, but nesting success inside versus outside electric fences, by strata, or cumulatively within years, did not differ using approximate 95% confidence intervals for Mayfield Method estimates. Microhabitats were recorded at all nests. Nests near debris were most common (75%), but nests in the open (away from debris)(17.5%) had the highest mean apparent nesting success for both years (43%). The Colony Point Count census method was conducted to ascertain peak numbers of least tern breeding pairs; 41 in 1995 and 58 in 1996. Six consecutive years of nest mapping near the selenite crystal digging area and Clay Creek suggest least tern nest site-selection was

influenced more by water availability than by human presence or habitat improvements.

Breeding ecology of endangered interior least terns nesting on the alkaline flat at Salt Plains National Wildlife Refuge (NWR) has been monitored closely since the early 1980's (Boyd 1990, Grover and Knopf 1982, Hill 1985; 1993, Koenen et al. 1996a, Schweitzer 1994, Utych 1993). Man-made habitat improvements on the flat have been constructed since 1990 to reduce nest losses from natural factors (Koenen et al. 1996b, Utych 1993) in response to least tern recovery objectives (U.S. Fish and Wildlife Service 1990). Despite efforts, flooding and predation continue to limit productivity of interior least terns at Salt Plains NWR, listed as endangered since 1985 (U.S. Fish and Wildlife Service 1985).

Least tern research objectives in 1995-96 were to: (1) determine site-specific nesting success on the alkaline flat at Salt Plains NWR, (2) quantify microhabitat features associated with nest site selection, (3) monitor use and measure efficacy of electric fence predator exclosures and habitat improvements, (4) determine peak numbers of nesting tern pairs annually, (5) measure and map nest sites within 1500 m of the active selenite crystal digging area, and (6) determine impact of avian predators, specifically Strigidae owls. Continued research on nesting least terns at Salt Plains NWR was necessary to identify sites or microhabitat-types on the alkaline flat with significantly higher nesting success. Results of this study could facilitate placement of future fenced exclosures and selection of man-made habitat improvements, thereby attracting and protecting an increased percentage of the least tern colony annually at Salt Plains NWR.

## STUDY AREA

Salt Plains NWR is located in Alfalfa County in north-central Oklahoma (36°45'N, 98°15'W). A 5095-ha alkaline flat provides nesting habitat for snowy plovers (Charadrius alexandrinus), least terns, American avocets (Recurvirostra american), killdeer (Charadrius vociferus), black-necked stilts (Himantopus Mexicanus) (Koenen et al. 1994), and common nighthawks (Chordeiles minor)(Appendix A.), listed in order of abundance. The alkaline flat, located along the western one-third of the refuge, is predominately featureless (Boyd 1990) but has three ephemeral streams and a river flowing across it into the Great Salt Plains Reservoir (Fig. 1). Spring Creek enters the flat from the south, Cottonwood and Clay creeks enter from the west, and the West branch of the Salt Fork Arkansas River enters from the north traversing the northeastern edge of the flat.

Summer climate at Salt Plains NWR is extremely variable with regard to wind, temperature, and rainfall (Williams and Grover 1975). As a result, the Great Salt Plains Reservoir fluctuates in elevation and inundates a varying percentage of least tern nesting habitat and nests each year (Hill

1993, Koenen 1996a, Utych 1993). During dry conditions, the alkaline flat is snow white with salt precipitate covering the surface (Reed 1978). Dependent upon timing and duration of rain events, the alkaline flat can turn from white to various shades of brown to black. Localized rain pulses can inundate nesting habitat, flush eggs from nests, and expose otherwise camoflaged eggs to mammalian and avian predators--natural factors that repeatedly cause low annual production for species nesting on the alkaline flat at Salt Plains NWR (Grover and Knopf 1982, Hill 1985, Koenen 1995, Utych 1993). Heavy rains have also facilitated the continued establishment of exotic salt cedar (Tamarix spp.) onto the alkaline flat, further reducing available nesting habitat and providing concealment for mammalian predators (Hill 1993, Koenen 1996a).

Habitat improvements have been implemented on the alkaline flat since 1990. First improvements included plowed ridges and gravel mounds to provide elevated nesting sites safe from sheet flooding (Koenen et al. 1996a) and more recently "wooden T's" to simulate driftwood debris-like microhabitat. One-dimensional hand-painted decoys were used in 1995 and 1996 to attract least terns into electric fences with habitat improvements, and two nest platforms were constructed in 1996 to encourage nesting off the substrate safe from sheet-flooding.

Electric fence predator exclosures (fences) encompass habitat improvements and have been erected on the alkaline flat since 1991. In 1995, only three fenced areas remained;

a 4.5-ha and 24-ha fenced area on the north end of the alkaline flat, and a newly completed (June 1995) 20-ha fenced area located northwest of the selenite crystal digging area between Clay and Cottonwood creeks (Fig. 1). Additional information on the history and construction of electric fences at Salt Plains NWR has been documented previously (Koenen 1995, Utych 1993).

Public access onto the alkaline flat has been restricted except for a rotating area with six sites designated for selenite crystal digging from 1 April through 31 October annually. Human disturbance from crystal digging was found to have negligible impact on nesting least terns at Salt Plains NWR from 1991 through 1994 (Koenen 1995, Utych 1993).

## METHODS

An all-terrain vehicle (ATV) facilitated research activities on the alkaline flat at Salt Plains NWR. The ATV was offloaded at two locations: 1) immediately south of state highway 11 at the north end of the alkaline flat (north launch), and 2) south of the 1994 selenite crystal digging area (crystal dig launch). Off-loading site and time on the flat were recorded for all visits both years.

Due to the study area size, ATV trails were established to facilitate relocating nests. ATV trails were favored because the alkaline flat becomes easily scarred when moist. Tank tracks from military activity in the 1930's were still visible. On other occasions, trails disappeared completely after rainfall and creeks reshaped areas making nests difficult to relocate. With trails, we justified disturbing a small percentage of the nesting birds regularly versus potentially disturbing all nesting birds if no trails were used. Although trails may attract predators and are sometimes used as resting sites by fledging chicks (Schweitzer 1994), ATV speed and engine noise were kept low to avoid crushing chicks and reduce noise-related disturbance, respectively. At monitored nests, binoculars were used from atop the ATV to check egg status to avoid creating foot trails directly to nests.

Least tern nests were located throughout the alkaline flat between 15 May and 15 August in 1995 and 1996. The flat was searched completely each week to insure representative nests from all sites were monitored. After discovery, tern nests were marked with 30 cm dowels placed about 10 m from the nestcup (Koenen 1995, Utych 1993) and monitored until outcome was determined (hatched, flooded, predated, wind, abandoned, addled, or unknown). Nest monitoring was conducted during crepuscular hours to minimize heat stress on adults and reduce occurrence of addled eggs (Dryer 1985, Hill 1985). A microcassette recorder was used during nest monitoring to decrease disturbance to incubating adults by reducing time in the colony. All least tern chicks encountered were captured and banded by protocols used by the U.S. Fish and Wildlife Service and included in apparent nesting success computations.

Least tern nests were regionally compiled into five strata (Fig. 1) based on distribution of nesting sites and fluvial patterns to assess site-specific differences in nesting success. Strata A was located in the northernmost region of the flat immediately south of State Highway 11, bordering the West branch of the Salt Fork Arkansas River to the east and included the 4.5-ha and 24-ha electric fenced areas. Strata B extended south of Strata A and also bordered the West branch of the Salt Fork Arkansas River. Strata C was located southwest of Strata B between the western edge of the refuge east to the reservoir in an area traversing Cottonwood Creek. Strata D was located south of Strata C and slightly north of the digging area and extended from the western refuge boundary to the reservoir. Strata D included the 20-ha electric fenced area. Strata E was located east of the digging area south to Spring Creek.

A nest was recorded as hatched if $\geq$1 egg hatched--partial losses were ignored (Mayfield 1961, 1975). Egg status was recorded on all visits. Site-specific differences in nesting success were determined using 95% confidence intervals (Johnson 1979) for Mayfield Method estimates (Mayfield 1961; 1975) for all strata, inside versus outside electric fences, and cumulatively for each year. Apparent nesting success (% of total) was also computed for comparison because outcome of all nests could be considered (Miller and Johnson 1978).

Habitat improvements and electric fence predator exclosures were used to reduce nest losses due to flooding and provide protection from mammalian predators, respectively. Nest monitoring inside electric fences was conducted on foot to reduce ATV activity and give nesting birds a disturbance-free perception of improvements and surrounding areas inside fences. Flat-soled shoes (slippers) were worn on the alkaline flat because heeled shoes leave deep tracks visible to mammalian and avian predators.

Habitat improvements implemented during this study included: 12 gravel mounds and 24 wooden T's in 1995 and 100 wooden T's in 1996--all placed within the confines of the 20-ha electric fenced area located in Strata D. Wooden T's were implemented in this study to provide microhabitat to supplement the absence of natural debris. Wooden T's were constructed from standard 5cm x 10cm boards cut and fastened in a 45cm x 20cm "T" configuration to provided two $90^{\circ}$ corners as potential nest sites by terns (Fig. 2). Wooden T's were anchored flat-side to the substrate by 3" nails (head down). Wooden T's were oriented four to a group (25 groups) about 30 m apart in a configuration to identify if wind direction influenced nest site selection (Fig. 3).

Two-dimensional painted least tern decoys were used experimentally to assess attractiveness and ability to influence colony site selection. Least tern decoys have been used with some effectiveness (Kotliar and Burger 1984). Fifteen pairs of decoys were used inside the 4.5-ha electric fenced area in 1995 and inside the 24-ha electric fenced area in 1996--fences in Strata A. Decoy orientation differed between years.

Nesting platforms were constructed inside the 4.5-ha electric fenced area in 1996 to encourage terns to nest off the substrate safe from sheet-flooding. Least terns have been documented roof nesting (Fisk 1975, Gore and Kinnison 1991). Two 1.2 $m^2$ platforms, one 0.8 m in height and the other 1.2 m in height were erected inside the 4.5 ha electric fence predator exclosure. Gravel and sand substrates were added to provide open soil/sand microhabitat.

Microhabitat features were recorded for all nests after discovery to ascertain differences in nesting success by microhabitat type. Microhabitat categories included nests located 1) $\leq$5 cm from driftwood debris, 2) $\leq$5 cm from other debris types (e.g. hay, glass, bone), 3) in open soil/sand, 4) on/near man-made habitat improvements (plowed ridges, gravel mounds, wooden T's, platforms), and 5) other (e.g., near live vegetation or selenite crystal outcroppings). Substrate texture was recorded for open soil/sand nests in 1996 because substrate differences can influence nesting success (Carreker 1985).

The Colony Point Count (CPC) census method (Hutto et al. 1986, Verner 1985) was used to ascertain peak numbers of breeding least tern pairs at Salt Plains NWR in 1995 and 1996. Schweitzer (1994) concluded that the CPC was the best census method to ascertain abundance of breeding least tern pairs on the alkaline flat compared to the variable circular plot and Purdue census methods. The CPC census is a fixed-radius point count technique that enables the researcher to move quickly between points and minimize disturbance and overcounting (Hutto et al. 1986, Verner 1985). Additional methodological information on the CPC method with least terns at Salt Plains NWR is provided by Schweitzer (1994). In 1995 and 1996, the CPC method was conducted with slight modification; non-stationary census points were used because nesting sites within each nesting season changed in response to flooding or predation.

In 1995 and 1996, nests ≤1500 m from the selenite crystal digging area were mapped for the sixth consecutive year to plot least tern nest site-selection in response to a rotating public use area, and changing water availability. Selenite crystal digging units were established south of Clay Creek and public use rotated annually between units. Clay Creek water availability differed between years.

## RESULTS

Precipitation from 1 May through 31 July varied from 50.6 cm in 1995 (wet year) to 28.5 cm in 1996 (dry year). Climate and lake level differences occurred between the 1995 and 1996 nesting season (Table 1).

In 1995, the ATV was launched 68 times; 43 times at north launch and 25 times at crystal dig launch. In 1996, the ATV was launched 56 times; 37 times at north launch and 19 times at crystal dig launch. A total of 105 days and 417

ATV hours was spent on the alkaline flat during both years constructing habitat improvements and conducting nest monitoring, censusing, banding, and other research activities (Table 2).

Nests were monitored every 1-6 days ($\underline{X}$ = 2.58 ± 0.88 S.E.) in 1995 and every 1-7 days ($\underline{X}$ = 2.71 ± 0.92 S.E.) in 1996 until hatching or outcome was determined. Nests were checked 398 times an average of 3.62 visits per nest before outcome was determined in 1995 and 472 times an average of 4.72 visits per nest before outcome was determined in 1996. Nests on the alkaline flat were concentrated near the seasonally emphemeral streams (Boyd 1990).

A total of 233 least tern nests was monitored to completion at Salt Plains NWR in this study. Least terns were recorded nesting at 26 sites on the alkaline flat in 1995 and at 32 sites in 1996. Least terns averaged 2.14 eggs per clutch (Table 3). June had the most nesting activity both years, which paralleled the findings of Hill (1985) and Utych (1993). Of all monitored nests, 66% in 1995 and 84% in 1996 were located in June.

Mayfield Method determined nesting success was 29% in 1995 and 37% in 1996, and apparent nesting success was 26% in 1995 and 33% in 1996 (Table 4). Although no statistical differences were identified during any year using the Mayfield Method, Mayfield Method estimates and apparent nesting success were higher inside versus outside electric fence predator exclosures in 1996 (Table 4).

Hatching success of least terns was 0.55 chicks pair$^{-1}$

in 1995 (64 hatchlings from 117 nests; 29 banded) and 0.58 chicks pair$^{-1}$ in 1996 (67 hatchlings from 116 nests; 36 banded). Although fledgling success was not determined, it was presumably lower than hatching success because of timeliness of flooding and coyote predation both years.

Apparent nest losses from flooding accounted for 42% of all nests in 1995 (wet year) and 30% of all nests in 1996 (dry year). In 1995, only three of 31 nests hatched inside the 24-ha electric fenced areas, mostly due to flooding. Nest translocation to prevent flooding loss has been successful in sympatric species of least terns (Prellwitz et al. 1995).

Nest numbers and relative occurrence of predation (highest to lowest) by strata changed from Strata A, D, B, E, C in 1995 to Strata C, E, B, D, A in 1996. However, Strata B, E, and C had no predation in 1995; 11 of 12 predated nests (92%) occurred in Strata A. Mammalian predators, specifically coyotes (Canis latrans) continued to periodically devastate nests each year. A striped skunk (Mephitis mephitis) meandered directly to and predated a monitored open soil/sand least tern nest in Strata C in 1996.

Least terns nested near driftwood debris most frequently in 1995 (56%) and second most frequently in 1996 (35%)(Table 6). Nests near other debris types were rarely observed in 1995 (11%) but frequently encountered in 1996 (47%), specifically hay debris from the reservoir. Seventy-five percent of all nests observed both years occurred near debris. Nests in open soil/sand represented 17.5% of all nests monitored for both years with 43.5% apparent nesting success--much higher than resulted from nests associated with other microhabitat types (Table 6). Open soil/sand was the dominant microhabitat type available in Strata D, which had the highest mean nesting success for both years using Mayfield Method estimates and was closest to the selenite crystal digging area in an area largely devoid of driftwood and other debris. Apparent nesting success for open soil/sand nests did not differ significantly by substrate texture in 1996 ($\underline{t}$ = 0.19, $\underline{P}$ > 0.5).

Use of man-made habitat improvements by least terns inside electric fence predator exclosures was 10% of all monitored nests in 1995 and 4% of all monitored nests in 1996. Least terns did not nest on gravel mounds inside the 20-ha fence, although snowy plovers did (n = 3). In 1995, a single wooden T established during Koenen's study (1995) provided microhabitat for two successful least tern nests inside the 4.5-ha electric fence. In this study, wooden T's were not used by two least tern pairs nesting inside the 20-ha electric fence in 1995, but in 1996 three of four least tern nests inside the 20-ha fence were near wooden T's. Nest site orientation and outcome near wooden T's was recorded (Fig. 4). Nests near wooden T's had 33% apparent nesting success in 1996.

Decoys inside electric fences did not attract more least terns than fences without decoys. Relative distribution of nest sites in Strata A differed each year seemingly unifluenced by decoys and more by water availability. Least terns were observed resting $\leq 3$ m from decoys on several occasions in early nesting season during both years. Decoys did not exclude terns from nesting inside fences.

Nesting platforms were available for nesting terns in 1996 but were not used. A single scrape was observed in the 1.2 m platform in early July but no nesting occurred.

In 1995, maximum absolute counts of 41 least tern pairs were observed on 22 June using the CPC census method. With 30 ($\pm$ 5.66 S.E.) fixed census points and about 212 ha censused, this corresponded to 0.39 terns $ha^{-1}$. Daily census counts of flushed terns, conducted independently of the CPC census, revealed 61 least tern pairs between 22 June and 4 July 1995--the interval between the first and second CPC census. Assuming these terns had been censused by CPC over the same number of fixed points, this would have corresponded to 0.58 terns $ha^{-1}$. On 5 July 1995, 36 least tern pairs were censused using the CPC, and on 21 July, 38 pairs were censused. In 1996, maximum absolute counts of 58 least tern pairs occurred on 14 June using the CPC census, or 0.55 terns $ha^{-1}$ in 1996. On 2 July 1996, 55 least tern pairs were censused using the CPC and on 18 July, 34 pairs were censused. No daily census counts revealed more than 58 pairs of least terns in 1996.

Ring-billed gulls (Larus delawarensis) were newly documented avian predators responsible for several snowy plover nest failures inside and outside electric fences at

Salt Plains NWR in 1995 and 1996 (Chapter 3), and suspected predators of terns based on direct observations, tracks, and yolk stains near nestcups (Table 5). A diurnal great horned owl (Bubo virginianus) was sighted and observed on the alkaline flat on two occasions in 1995 although no predation was observed. Owl pellets were found inside the 4.5-ha electric fence in Strata A in 1995. A peregrine falcon (Falco peregrinus) was observed in flight-pursuit and nearly caught an adult snowy plover on the alkaline flat in 1996. Their impact on least terns is not known.

Least tern nest locations were measured and mapped in relation to the center of the active selenite crystal digging unit to document six consecutive years of nesting (Koenen 1995)(Fig. 5) with reference to proximity and availability of water in Clay Creek in 1995 and 1996 (Fig. 6), which gives insight into all years when considering rainfall. Least terns rarely used active or unused digging sites except in 1993 when digging activity was conducted in the southernmost unit farthest from Clay Creek. Also, 1993 was a wet year (e.g., Mississippi River flooded) when Clay Creek exceeded its banks and inundated nesting sites used in previous years by least terns. Again in 1995, relatively high creek levels resulted in least terns nesting farther south with more nests close to the active digging unit than was observed during previous years, except in 1993 (Fig. 5).

# DISCUSSION

Climatic conditions varied widely between years influencing nesting success of least terns. Previous researchers have experienced similar variations in climate between years while studying least terns at Salt Plains NWR (Koenen 1995, Utych 1993).

We should be concerned about public perception of ATV activity on the alkaline flat to monitor endangered species, because ATV activity could have a negligible impact on nesting species at Salt Plains NWR. The favored north launch may be incompatible with the shorebird observation area scheduled for completion in 1997. Additionally, the crystal dig launch may not be an appropriate site to initiate research activities, as in the past. The old observation tower site along the western boundary provides the best offload and load location for initiating ATV activity--keeping recreation-like disturbance and public use misinterpretations minimized.

The alkaline flat is often windy, which makes traditional note-taking cumbersome. Therefore, a microcassette recorder was used during nest monitoring in this study. A microcassette recorder can be used while moving atop an ATV, keeps one had free, and increases research capabilities (Hart et al. 1993, Taoka et al. 1989). Drawbacks to using microcassette recorders do exist; they can fail (battery powered), are not resistant to the elements, and verbal information must later be transcribed--

a beneficial drawback because pertinent ancillary information often came to mind during transcription further increasing research capabilities.

Contrary to Mayfield's claim that apparent nesting success often overestimates true success (Mayfield 1961; 1975), we found apparent nesting success higher than Mayfield Method estimates in only three of 16 group comparisons (Table 4). An advantage of using the Mayfield Method includes using fragments of nest monitoring information in calculating nesting success using exposure (Mayfield 1961; 1975). However, in our study, only 53% of all nests monitored in 1995 and 59% of all nests monitored in 1996 could be used to calculate nesting success using the Mayfield Method (Table 4). This method excluded nearly one-half of the potential nesting information because nests were required to be resighted $\geq 1$ time to be included. Evidence of flooding, predation and hatching on the initial visit (discovery) were not included in Mayfield Method calculations. Apparent nesting success results were included for all comparisons in addition to the Mayfield Method because all nests discovered could be included in the nesting success computations, possibly providing a better look at overall nest losses. Strata were selected based on regional distribution and fluvial patterns of nesting Charadriiformes in 1995 and did not change between years although nesting sites increased in 1996.

Average clutch size in 1995 and 1996 (2.14) was lower than the 2.62 eggs per clutch reported by Hill (1985) for least tern nests at Salt Plains NWR in 1982-84. Koenen and Leslie (1996) found little differences in eggshell thicknesses of least tern eggs in 1993-1994 to measurements made prior to DDT use, suggesting contamination was not responsible for reduced nesting success. Although egg production was lower in our study, it remained well within the mean clutch size for least terns reported by Bent (1963) and Sutton (1967).

Productivity estimates of least terns at Salt Plains NWR have been consistently lower than 0.6 fledglings pair$^{-1}$ (Hill 1993). Fancher (1992) reported that consecutive years with less than 0.7 fledglings pair$^{-1}$ would result in a net decline in the local population. Therefore, it is critically important that future studies assess the true annual fledgling productivity of least terns at Salt Plains NWR and identify if the alkaline flat acts as an ecological sink (Howe et al. 1991, Pulliam 1988) for nesting birds.

In the past, researchers have defined least tern colonies differently at Salt Plains NWR (Koenen 1995, Schweitzer 1994). A "colony" refers to the location of a breeding area, where colony members share the same foraging and roosting areas, and the same general nesting areas; and a "site" refers to the location of a discrete and contiguous group of nesting birds (Caffrey 1994). In the past, researchers have used the terms "colony" and "site" interchangeably regarding least terns at Salt Plains NWR. Based on definitions, only one least tern colony exists at Salt Plains NWR and utilizes numerous nesting sites on the alkaline flat.

A difference in microhabitat use by nesting least terns was noted between years. Driftwood debris was the dominant microhabitat type observed near nests in 1995, but other debris types (dead vegetation) were most frequently noted in 1996. This change in use may have been influenced by the August 1995 flood that raised the reservoir level depositing erodible hay from Ralston Island onto the flat, creating new nesting habitat for least terns in 1996.

Nests in open soil/sand represented $\leq$20% of all monitored nests for terns for both years, but the relative proportion of use for this microhabitat category may have been underestimated due to difficulty in locating nests in the open. Although not statistically significant, higher apparent nesting success for open soil/sand nests compared to other microhabitat types was biologically significant because it suggested that habitat improvements implemented since 1990 (ridges, gravel mounds, wooden T's and platforms) may promote reduced nesting success because they are visible and attractive to predators.

Differences in least tern use inside and outside electric fences between years was highly variable: 41 nests inside fences in 1995 (wet year) and 8 nests inside fences in 1996 (dry year). The poor nesting success in 1995 was likely due to the untimely nature of major flooding events that coincided with colony arrival. Also, tern nesting inside electric fences in Strata A was highest in 1995 when the West branch of the Salt Fork Arkansas River (Fig. 1) exceeded its banks making juxtaposition of fences favorable to least tern nest site selection (close to water). When drought conditions persisted in 1996, the West branch of the Salt Fork Arkansas River was distant from Strata A fences. The differences in least tern use inside and outside electric fences in Strata A supports our hypothesis that least terns selected nest sites near water more than near habitat improvements. In Strata D, nest sites were consistently found in close proximity to water but varied in distance from human activity by year (Fig. 5). Future research should focus on monitoring the level of the Arkansas River in relation to least tern nesting inside electric fences in Strata A, and the level of Clay Creek in relation to least tern nesting inside the electric fence in Strata D, in addition to continued mapping of nests in proximity to the crystal digging units.

Although the total number of breeding pairs censused using CPC differed only slightly between years, terns arrived, initiated, and completed nesting earlier in 1996. Nest initiation in 1995 may have been delayed due to repeated inundation of former nesting sites. Our CPC census values in 1995 (0.39 terns $ha^{-1}$) and 1996 (0.55 terns $ha^{-1}$) were similiar to Schweitzer's (1994) findings in 1993 (0.38 terns $ha^{-1}$). Four CPC censuses per nesting season at 2-week intervals were recommended by Schweitzer (1994), but only 3 could be completed during each year of this study. Future CPC censuses should be conducted weekly during the month of June to ascertain peak use by breeding least tern pairs and reduce the potential for census bias (Thompson 1986).

Koenen (1995) and Hill (1985) documented coyotes (canids) as the sole mammalian predator at Salt Plains NWR. Coyotes may become conditioned to associate ATV trails, footprints, and 30 cm dowels (nest markers) with least tern nests. Precautions against predators is needed.

Avian predators were not identified as a threat to least terns at Salt Plains NWR during nest monitoring from 1982 through 1985 (Hill 1985) or in 1991 and 1992 (Utych 1993). However, Koenen et al. (1996a) documented ring-billed gulls (Larus delawarensis) as predators on artificial nests of Japanese quail (Coturnix coturnix) on the alkaline flat. Nocera and Kress (1996) documented gulls predating terns at night and Maxson et al. (1996) documented ring-billed gulls usurp tern colony sites despite deterrents. Nonetheless, avian predation is a recently documented phenomenon at Salt Plains NWR.

Great horned owls and barred owls (Strix varia) have been identified as predators on least tern chicks and adults (Kirsch 1996, Renken and Smith 1995, Wilson et al. 1993) and other terns (Morris and Wiggins 1986, Nisbet 1975). Koenen (1995) suspected great horned owls were predators on terns inside electric fences. Findings from colatteral research efforts on Strigidae distribution, relative abundance, and habitat associations suggest great horned owls may be predators, but barred owls are not a threat to least terns or other species nesting on the alkaline flat at Salt Plains NWR (Chapter 1).

Strata-specific predation differences between years demonstrated the parallel and dynamic nature of least tern nest site-selection and behavior of predators on the alkaline flat, suggesting no particular strata is consistently more or less vulnerable to predation. We hypothesize that predator distribution is likely influenced more by site-selection of nesting least terns each year than by preference for a particular foraging site. However, we suspect juxtaposition to cover is important to mammalian predators at Salt Plains NWR (Koenen et al. 1996a).

Flooding events were common in 1995 and resulted in high stream levels along Clay Creek that coincided with least terns nesting near the active selenite crystal digging unit (Fig. 6). Drought conditions persisted summer 1996, reducing Clay Creek to small intermittent pools causing least terns to nest farther from the active digging unit, and demonstrating their affinity to water. Mapping of least tern nests in relation to the active selenite crystal digging area for six consecutive years revealed that nest site-selection and electric fence use was influenced by water availability, specifically creek levels during nest initiation, more than from human disturbance or near habitat improvements. We hypothesize that least tern behavior (nest site-selection) is influenced more by proximity of water during nest initiation than by a predetermined distance from human activity.

In this study, natural factors (predation and flooding) continued to threaten recovery efforts for endangered interior least terns at Salt Plains NWR. Predation is the most consistently documented natural factor responsible for nest losses in least terns at Salt Plains NWR, but sheet-flooding is the most devastating (Boyd 1990, Grover and Knopf 1982, Koenen 1995). Decoys did not attract more terns into fences than fences without decoys. The sixth consecutive year of nest monitoring (1995) revealed that avian predators, specifically ring-billed gulls, can have pernicious effects on nesting birds at Salt Plains NWR, and man-made habitat improvements inside electric fences may attractant this predator. However, electric fences prevented mammals from predating least tern nests inside fences in 1996.

## ACKNOWLEDGEMENTS

We thank M. Koenen, L. Talent, R. Lochmiller, S. Schweitzer, R. Utych, and K. Wood for providing essential background information and research ideas concerning least terns in Oklahoma. We acknowledge the gracious support of Salt Plains National Wildlife Refuge, especially manager R. Krey, for accomodations and research support. We extend our appreciation to J. Shaw and L. Caneday for comments on earlier drafts of this manuscript. Funding was provided by Region 2 of the U.S. Fish and Wildlife Service, Salt Plains National Wildlife Refuge, and the Oklahoma Cooperative Fish and Wildlife Research Unit (U.S. National Biological Service, Oklahoma Department of Wildlife Conservation,

Oklahoma State University and Wildlife Management Institute, cooperating).

LITERATURE CITED

BENT, A.C. 1963. Life histories of North American gulls and terns. Dover Publications Inc., New York, pp. 270-279.

BOYD, R.L. 1990. Habitat management and population ecology studies of the least tern in Kansas and Oklahoma, 1990. Kansas Dept. Wildl. and Parks. Nongame Wildl. Prog. Rep., Baldwin City, Kansas.

CAFFREY, C. 1994. California least tern breeding survey, 1994 season. Calif. Dept. Fish and Game, Wildl. Manage. Div., Bird and Mammal Conserv. Prog. Rep. 94-3, Sacramento, California.

CARREKER, R.G. 1985. Habitat suitability index models: least tern. U.S. Fish and Wildl. Serv. Biol. Rep. 82(10.103).

DRYER, M.P., AND P.J. DRYER. 1985. Investigations into the population, breeding sites, habitat characteristics, threats and productivity of the least tern in North Dakota. U.S. Fish and Wildl. Serv. Res. Info. Paper No. 1, Bismarck, North Dakota.

FANCHER, J.M. 1992. Population status and trends of the California Least Tern. Trans. West. Sect. Wildl. Soc. 28:59-66.

FISK, E.J. 1975. Least tern: Beleagured, opportunistic and roof-nesting. Amer. Birds 29:15-16.

GORE, J.A., AND M.J. KINNISON. 1991. Hatching success in roof and ground colonies of least terns. Condor 93:759-762.

GROVER, P.B., AND F.L. KNOPF. 1982. Habitat requirements and breeding success of Charadriiform birds nesting at Salt Plains National Wildlife Refuge. J. Field. Ornithol. 53:139-148.

HART, J.A., G.L KIRKLAND, JR., AND S.C. GROSSMAN. 1993. Relative abundance and habitat use by Tree Bats, Lasiurus spp., in Southcentral Pennsylvania. The Canadian Field Nat. 107:208-212.

HILL, L.A. 1985. Breeding ecology of interior least terns, snowy plovers, and American avocets at Salt Plains National Wildlife Refuge, Oklahoma. M.Sc. thesis, Oklahoma State Univ., Stillwater, Oklahoma.

_____. 1993. Status and distribution of the least tern in Oklahoma. Bull. Oklahoma Ornithol. Soc. 26:1-24.

HOWE, R.W., G.J. DAVIS, AND V. MOSCA. 1991. The demographic significance of "sink" populations. Biol. Conserv. 57:239-255.

HUTTO, R.L., S.M. PLETSCHET, AND P. HENDRICKS. 1986. A fixed-radius point count method for nonbreeding and breeding season use. Auk. 103:593-602.

JOHNSON, D.H. 1979. Estimating nest success: the Mayfield Method and an alternative. Auk 96:651-661.

KIRSCH, E.M. 1996. Habitat selection and productivity of least terns on the lower Platte River, Nebraska. Wildl. Monogr. 132:1-48.

KOENEN, M.T. 1994. First nesting record of black-necked stilts for Oklahoma. Bull. Oklahoma Ornithol. Soc. 27:1-4.

_____. 1995. Breeding ecology and management of least terns, snowy plovers, and American avocets. M.Sc. thesis, Oklahoma State Univ, Stillwater, Oklahoma.

_____, AND D.M. LESLIE, JR. 1996. Evaluation of interior least tern eggshell thickness. Colon. Waterbirds. 19:143-146.

_____, _____, AND M. GREGORY. 1996a. Habitat changes and success of artificial nests on an alkaline flat. Wilson Bull. 108:292-301.

_____, R.B. UTYCH, AND D.M. LESLIE, JR. 1996b. Methods used to improve least tern and snowy plover nesting success on alkaline flats. J. Field Ornithol. 67:281-291.

KOTLIAR, N.B., AND J. BURGER. 1984. The use of decoys to attract least terns (Sterna antillarum) to abandoned colony sites in New Jersey. Colon. Waterbirds 7:134-138.

MAYFIELD, H.F. 1961. Nesting success calculated from expsure. Wilson Bull. 73:255-261.

_____. 1975. Suggestions for calculating nest success. Wilson Bull. 87:456-466.

MAXSON, S.J., S.A. MORTENSEN, D.L. GOODERMOTE, AND C.S. LAPP. 1996. Success and failure of ring-billed gull deterrents at common tern and piping plover colonies in Mennesota. Colon. Waterbirds 19:242-247.

MILLER, H.W., AND D.H. JOHNSON. 1978. Interpreting the results of nesting studies. J. Wildl. Manage. 42:471-476.

MORRIS, R.D., AND D.A. WIGGINGS. 1986. Ruddy turnstones, great horned owls and egg loss from common tern clutches. Wilson Bull. 98:101-109.

NISBET, I.C.T. 1975. Selective effects of predation in a tern colony. Condor 77:221-226.

NOCERA, J.J., AND S.W. KRESS. 1996. Nocturnal predation on common terns by great black-backed gulls. Colon. Waterbirds 19:277-279.

PRELLWITZ, D.M., K.M. ERICKSON, AND L.M. OSBORNE. 1995. Translocation of piping plover nests to prevent nest flooding. Wildl. Soc. Bull. 23:103-106.

PULLIAM, R.H. 1988. Sources, sinks, and population regulation. Amer. Nat. 132:652-661.

REED, J.E. 1978. Preliminary projections of the effects of chloride-control structures on the quaternary aquifer at Great Salt Plains, Oklahoma. U.S. Geological Survey, Water-Resources Investigations pp. 80-120.

RENKEN, R.B., AND J.W. SMITH. 1995. Annual adult survival of interior least terns. J. Field Ornithol. 66:112-116.

SCHWEITZER, S.H. 1994. Abundance and conservation of endangered interior least terns nesting on salt flat habitat. Ph.D. thesis, Oklahoma State Univ., Stillwater, Oklahoma.

SUTTON, G.M. 1967. Oklahoma birds, their ecology and distribution with comments on the avifauna of the Southern Great Plains. University of Oklahoma Press, Norman.

TAOKA, M., P. WON, AND H. OKUMURA. 1989. Vocal behavior of Swinhoe's Storm-petrel (Oceanodrama monorhis). Auk. 106:471-474.

THOMPSON, B.C. 1986. Biological and human biases in the census of least terns. Colon. Waterbird Group Newsletter. 9:52-53.

U.S. FISH AND WILDLIFE SERVICE. 1985. Interior population of the least tern determined to be endangered. Federal Register. 50:21,784-21,792.

_____. 1990. Interior population of the least tern (Sterna antillarum): recovery plan. U.S. Fish and Wildlife Service, Twin Cities, Minnesota.

UTYCH, R.B. 1993. Compatibility of selenite crystal digging with breeding ecology of least terns and snowy plovers at Salt Plains National Wildlife Refuge. M.Sc. thesis, Oklahoma State Univ., Stillwater, Oklahoma.

VERNER, J. 1985. Assessment of counting techniques, p. 247-302. In R.F. Johnson [ed.], Current ornithology. Vol. 2, Plenum Press, New York.

WILLIAMS, G.E., AND E.S. GROVER. 1975. Soil survey of Alfalfa County, Oklahoma. U.S. Dept. Agric., Soil Conserv. Serv.

WILSON, E.C., W.A. HUBERT, AND S.H. ANDERSON. 1993. Nesting and foraging of least terns on sand pits in central Nebraska. Southwest. Nat. 38:9-14.

TABLE 1. Climate and lake level ranges for Salt Plains National Wildlife Refuge and Great Salt Plains Reservoir area collected daily by U.S. Army Corps of Engineers, Great Salt Plains State Park, Jet, Oklahoma, for months peak nesting occurred in endangered interior least terns (*Sterna antillarum*), 1995 and 1996.

| | 1995 | | | | | 1996 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Air temp.(C) | | Total precip. | Lake level[a] | | Air temp.(C) | | Total precip. | Lake level[a] | |
| Month | Min | Max | (cm) | Low | High | Min | Max | (cm) | Low | High |
| May | 3 | 30 | 16.69 | 343.27 | 344.20 | 3 | 40 | 4.74 | 342.93 | 343.04 |
| June | 12 | 31 | 24.15 | 343.18 | 344.81 | 12 | 37 | 13.46 | 342.95 | 343.17 |
| July | 15 | 42 | 9.72 | 343.03 | 343.49 | 15 | 43 | 10.31 | 342.87 | 344.18 |

[a]Lake level ranges given in meters above sea level; readings collected daily at 0800 hr.

TABLE 2. All-terrain vehicle (ATV) activity conducted between 15 May and 15 August in 1995 and 1996 on the alkaline flat at Salt Plains National Wildlife Refuge, Oklahoma, to construct habitat improvements and monitor nesting success of least terns, snowy plovers, American avocets, and black-necked stilts.

| Year | No. days on flat | Total visits | Total hours | Visits per day | | Visit duration (hr) | |
|---|---|---|---|---|---|---|---|
| | | | | $\bar{X}$ | SD | $\bar{X}$ | SD |
| 1995 | 56 | 68 | 250.58 | 1.21 | 0.41 | 3.69 | 1.58 |
| 1996 | 49 | 56 | 166.17 | 1.14 | 0.41 | 2.97 | 1.55 |
| Both years | 105 | 124 | 416.75 | 1.18 | 0.41 | 3.33 | 1.57 |

TABLE 3. Clutch sizes and nesting success comparisons for least terns at Salt Plains National Wildlife Refuge, Oklahoma in 1995 and 1996.

| Year | Clutch Sizes | | | | | | Total eggs | Apparent nesting success[a] | Mayfield nesting success[b] |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | $\bar{X}$ | SD | N | | | |
| 1995 | 19 | 54 | 33 | 2.13 | 0.69 | 106 | 226 | 26 | 29.09 |
| 1996 | 13 | 59 | 28 | 2.15 | 0.63 | 100 | 215 | 33 | 37.36 |
| Both years | 32 | 113 | 61 | 2.14 | 0.66 | 206 | 441 | 30 | 33.68 |

[a]Apparent nesting success represented as percent hatched (%) of all nests monitored.
[b]Mayfield Method estimates of nesting success from exposure (Mayfield 1961; 1975).

TABLE 4. Nest success, confidence intervals, and losses by strata, inside and outside electric fence predator exclosures, and cumulatively by year for least terns on the alkaline flat at Salt Plains National Wildlife Refuge, Oklahoma, 1995 and 1996.

| | A | B | C | D | E | In | Out | All |
|---|---|---|---|---|---|---|---|---|
| 1995 | | | | | | | | |
| n | 19 | 6 | 6 | 19 | 12 | 17 | 45 | 62 |
| Success[a] | 0.18 | 0.12 | 0.22 | 0.46 | 0.49 | 0.20 | 0.34 | 0.29 |
| 95% C.I. | 0.07-0.43 | 0.04-0.30 | 0.05-0.95 | 0.24-0.86 | 0.26-0.92 | 0.08-0.47 | 0.21-0.54 | 0.19-0.44 |
| Predation | 7 | 0 | 1 | 0 | 0 | 5 | 3 | 8 |
| Flood | 6 | 5 | 3 | 6 | 4 | 6 | 18 | 24 |
| Other[c] | 2 | 0 | 0 | 0 | 1 | 2 | 1 | 3 |
| n | 44 | 18 | 11 | 27 | 17 | 41 | 76 | 117 |
| Success[b] | 0.18 | 0.11 | 0.27 | 0.56 | 0.41 | 0.15 | 0.33 | 0.26 |
| Predation | 12 | 0 | 3 | 0 | 0 | 8 | 7 | 15 |
| Flood | 20 | 12 | 3 | 11 | 6 | 19 | 33 | 52 |
| Other[c] | 4 | 4 | 2 | 1 | 4 | 7 | 8 | 15 |
| 1996 | | | | | | | | |
| n | 12 | 14 | 18 | 13 | 12 | 6 | 63 | 69 |
| Success[a] | 0.27 | 0.37 | 0.58 | 0.45 | 0.15 | 0.47 | 0.36 | 0.37 |
| 95% C.I. | 0.11-0.60 | 0.17-0.77 | 0.38-0.87 | 0.24-0.82 | 0.04-0.51 | 0.19-1.00 | 0.26-0.51 | 0.27-0.51 |
| Predation | 2 | 3 | 2 | 6 | 1 | 1 | 13 | 14 |
| Flood | 7 | 3 | 4 | 1 | 7 | 2 | 21 | 23 |
| Other[c] | 1 | 1 | 1 | 0 | 1 | 0 | 3 | 3 |
| n | 12 | 22 | 39 | 19 | 24 | 8 | 108 | 116 |
| Success[b] | 0.17 | 0.36 | 0.38 | 0.32 | 0.25 | 0.38 | 0.32 | 0.33 |
| Predation | 2 | 4 | 7 | 7 | 3 | 1 | 22 | 23 |
| Flood | 7 | 6 | 10 | 3 | 12 | 3 | 35 | 38 |
| Other[c] | 1 | 4 | 7 | 3 | 3 | 1 | 16 | 17 |

[a]Nesting success calculated from exposure using the Mayfield Method (Mayfield 1961; 1975).
[b]Apparent nesting success (Percent of total) using all observed nesting information.
[c]Nest losses from wind, and abandoned or addled eggs.

TABLE 5. Documented predators by class, year, and location (inside vs. outside electric fences) impacting least terns nesting on the alkaline flat at Salt Plains National Wildlife Refuge, Oklahoma, in 1995 and 1996.

| | | Predator | | | |
|---|---|---|---|---|---|
| Year | Location | Mammal | Avian | Unknown | n |
| 1995 | Inside | 4 | 4 | 0 | 8 |
| | Outside | 4 | 3 | 0 | 7 |
| 1996 | Inside | 0 | 1 | 0 | 1 |
| | Outside | 11[a] | 5 | 2 | 8 |
| 1995-96 | Inside | 4 | 5 | 0 | 9 |
| | Outside | 15 | 8 | 2 | 5 |

[a]Includes a single nest lost to a striped skunk (*Mephitis mephitis*)

TABLE 6. Percent use and apparent nesting success by microhabitat type for least terns at Salt Plains National Wildlife Refuge, Oklahoma, in 1995 and 1996.

| | Microhabitat Type | | | | |
|---|---|---|---|---|---|
| Outcome | (D1)[a] | (D2)[b] | (O)[c] | (E)[d] | (U)[e] |
| **1995** | | | | | |
| n | 59 | 12 | 21 | 10 | 3 |
| % Use | 0.56 | 0.11 | 0.20 | 0.10 | 0.03 |
| % Success | 0.20 | 0.33 | 0.43 | 0.20 | 0.33 |
| Hatched | 12 | 4 | 9 | 2 | 1 |
| Flooded | 24 | 4 | 9 | 2 | 1 |
| Predation | 8 | 0 | 1 | 4 | 0 |
| Uncertain | 15 | 4 | 2 | 2 | 1 |
| **1996** | | | | | |
| n | 38 | 52 | 16 | 4 | 0 |
| % Use | 0.35 | 0.47 | 0.15 | 0.04 | 0.00 |
| % Success | 0.32 | 0.21 | 0.44 | 0.25 | 0.00 |
| Hatched | 12 | 11 | 7 | 1 | 0 |
| Flooded | 9 | 19 | 4 | 2 | 0 |
| Predation | 6 | 8 | 3 | 1 | 0 |
| Uncertain | 11 | 13 | 2 | 0 | 0 |
| **Both years** | | | | | |
| n | 97 | 64 | 37 | 14 | 3 |
| % Use | 0.45 | 0.30 | 0.17 | 0.07 | 0.01 |
| % Success | 0.25 | 0.23 | 0.43 | 0.21 | 0.33 |
| Hatched | 24 | 15 | 16 | 3 | 1 |
| Flooded | 33 | 23 | 13 | 4 | 1 |
| Predation | 14 | 8 | 4 | 5 | 0 |
| Uncertain | 26 | 17 | 4 | 2 | 1 |

[a]Nests ≤ 5cm from driftwood debris (D1).
[b]Nests ≤ 5cm from other debris (hay, glass, bone)(D2).
[c]Nests in open soil/sand (O).
[d]Nests on man-made elevation (ridges, mounds, abandoned military road)(E).
[e]Nests near live vegetation or selenite crystal outcroppings (U).

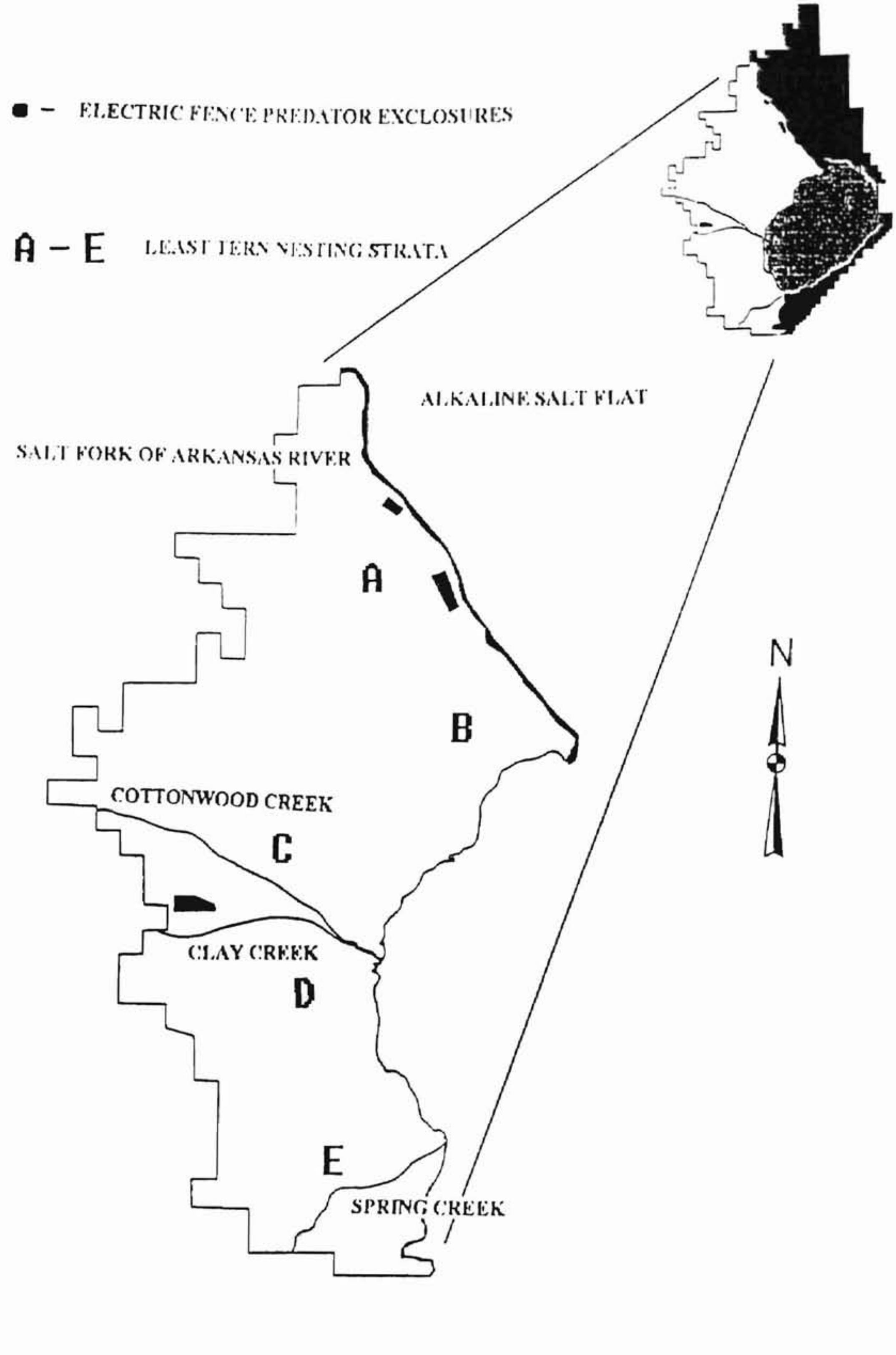


**Fig. 1. Location of least tern nesting strata, electric fence predator exclosures, and ephemeral streams on the alkaline flat at Salt Plains National Wildlife Refuge, Oklahoma, 1995 and 1996.**

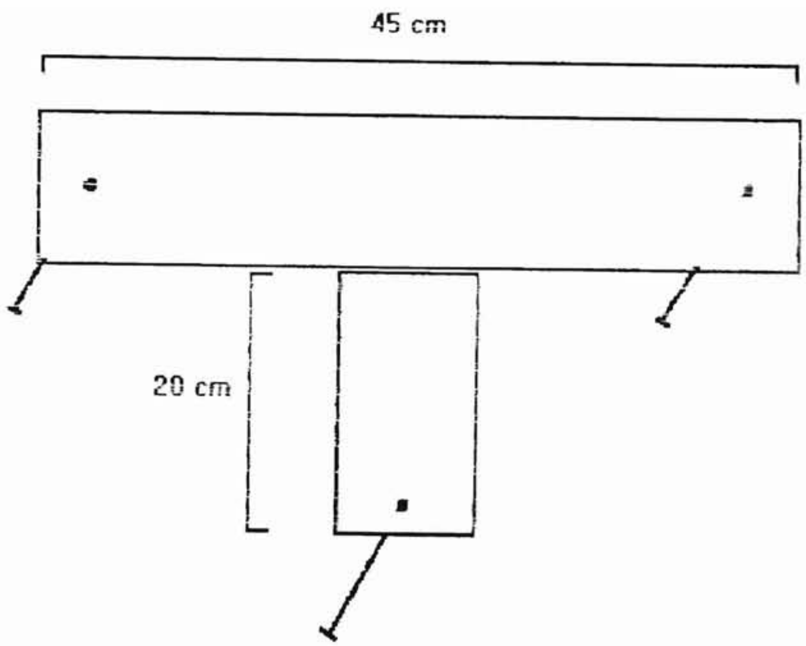


Fig. 2. Wooden T dimensions constructed to provide 2-90 degree corners for potential least tern nest sites and location of nails to anchor T's on the alkaline flat inside electric-fence predator exclosures at Salt Plains National Wildlife Refuge, Oklahoma, in 1995 and 1996.

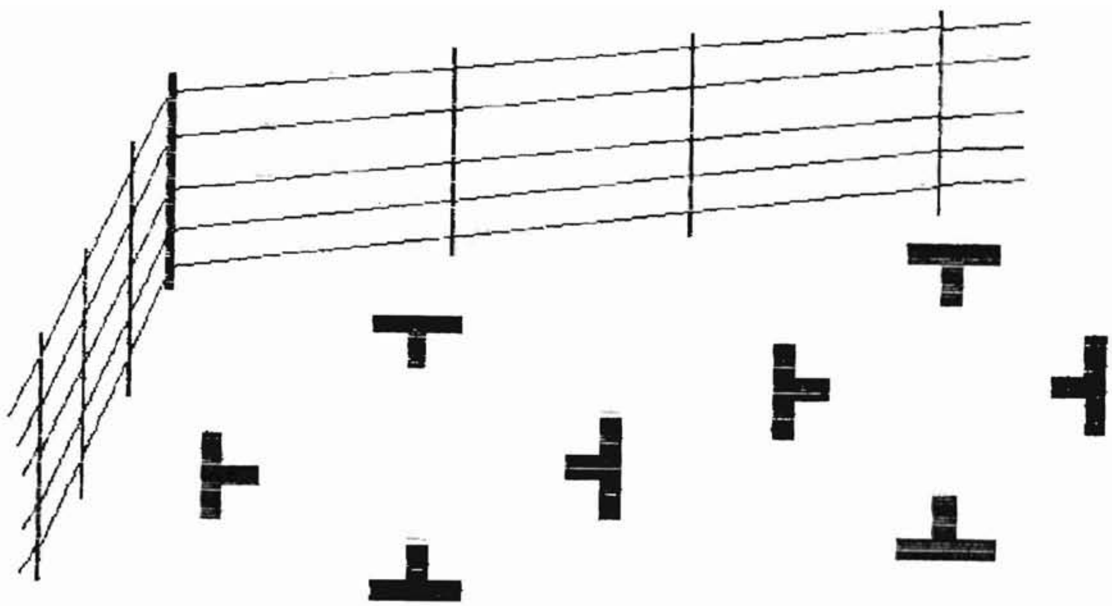

Fig. 3. Wooden T orientation and configuration for 25 groups of four T's anchored inside the 20-ha electric-fence predator exclosure at Salt Plains National Wildlife Refuge, Oklahoma, in 1996.

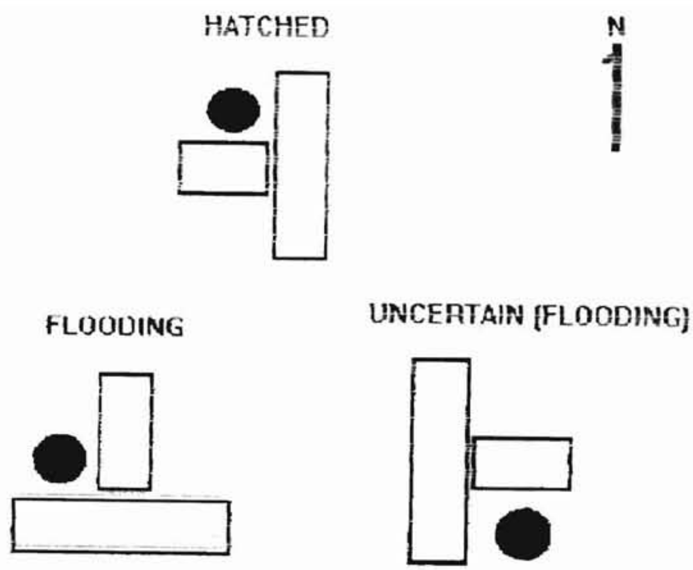


**Fig. 4. Nest site-selection and outcome for least tern nests near wooden T's inside the 20-ha electric-fence predator exclosure at Salt Plains National Wildlife Refuge, Oklahoma, in 1996.**

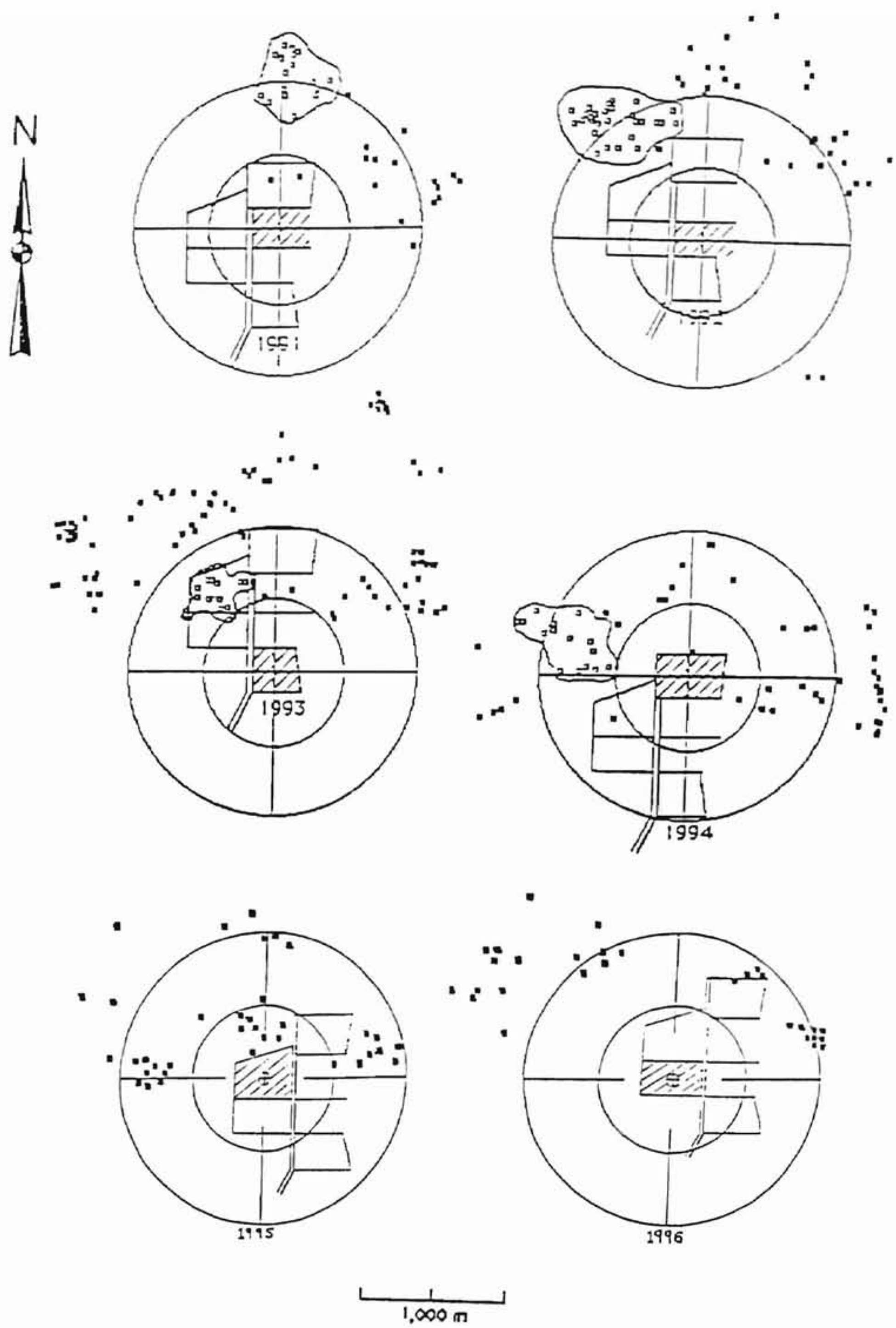


Fig. 5. Mapping of least tern nests ≤1500 m from active selenite crystal digging areas for six consecutive years (Koenen 1995) to identify site-selection in relation to rotating public use at Salt Plains National Wildlife Refuge, Oklahoma, 1995 and 1996 (Figure in 500 m increments)

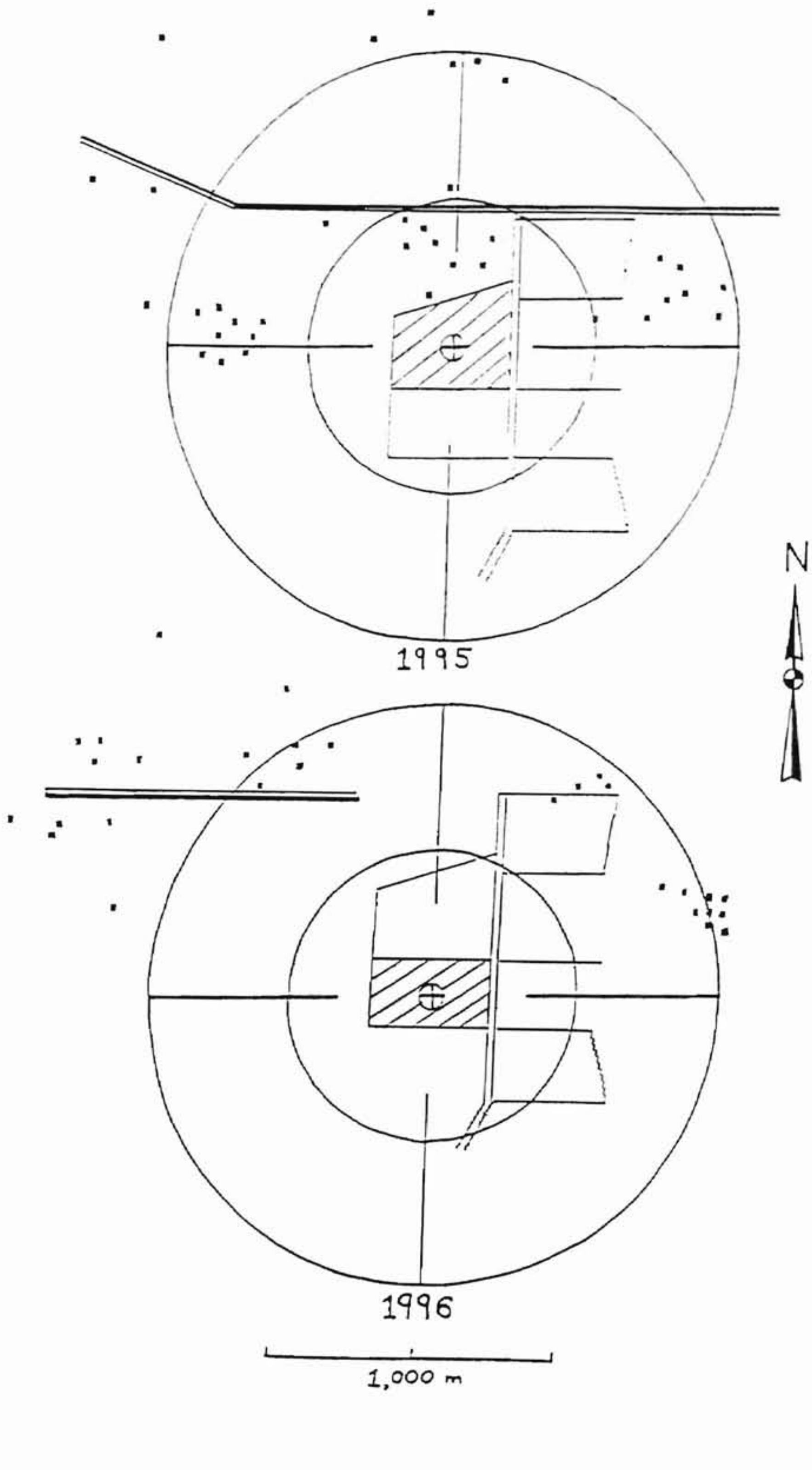


**Fig. 6. Mapping of least tern nests ≤1500 m from the active selenite crystal digging areas in relation to location and availability of water in Clay Creek at Salt Plains National Wildlife Refuge, Oklahoma, in 1995 and 1996 (Note approximate location of Clay Creek in relation to the 1994 crystal digging area and re-examine Fig. 5.).**

## Chapter III

## BREEDING ECOLOGY OF SNOWY PLOVERS AT SALT PLAINS NATIONAL WILDLIFE REFUGE IN NORTHCENTRAL OKLAHOMA

The inland population of the western snowy plover (Charadrius alexandrinus) was listed as a Category 2 species in 1991 (U.S. Fish and Wildl. Serv. 1991) and delisted in 1995 (U.S. Fish and Wildl. Serv. 1995). The coastal population of snowy plovers was listed as threatened in 1993 (U.S. Fish and Wildl. Serv. 1993). Snowy plovers are more abundant inland than at coastal sites (Wilson 1986, Page et al. 1995). Salt Plains National Wildlife Refuge (NWR) annually supports a breeding population of inland western snowy plovers.

The breeding ecology of snowy plovers on the alkaline flat at Salt Plains NWR in northcentral Oklahoma has been intensively studied (Sutton 1967, Purdue 1976, Grover and Knopf 1982, Hill 1985, Utych 1993, Koenen et al. 1996a). Previous research focused on adaptations (Purdue 1976), habitat requirements, breeding success (Grover and Knopf 1982, Grover and Grover 1982, Hill 1985, Utych 1993, Koenen et al. 1996a), and efficacy of electric-fence predator exclosures and habitat improvements, and the compatibility of a public-use area in nesting habitat (Utych 1993, Koenen

1995, Koenen et al. 1996a). Flooding, predation, and hail storms are natural factors that continue to reduce annual productivity in snowy plovers at Salt Plains NWR (Grover and Knopf 1982, Hill 1985, Schweitzer 1994, Koenen et al. 1996a).

The objectives of this study were to: 1) determine site-specific nesting success of snowy plovers on the alkaline flat at Salt Plains NWR; 2) quantify microhabitat features associated with nest site selection; 3) monitor use and efficacy of electric-fence predator exclosures and habitat improvements on the alkaline flat; and 4) assess the variability of rainfall on the alkaline flat compared to nearby areas. The primary goal of research in 1995-96 was to identify sites and/or microhabitat types with significantly higher nesting success to support future management decisions regarding placement of habitat improvements--information requiring intensive monitoring and unobtainable from aerial surveys (Base 1985).

## STUDY AREA AND METHODS

Salt Plains NWR is located in Alfalfa County in northcentral Oklahoma (36°45'N, 98°15'W). A 5095-ha alkaline flat, located along the western one-third of the refuge, provides nesting habitat for snowy plovers, endangered interior least terns (*Sterna antillarum*), American avocets (*Recurvirostra americana*), and black-necked stilts (*Himantopus mexicanus*), in order of abundance.

Cottonwood, Clay, and Spring creeks and the West branch of the Salt Fork of the Arkansas River are ephemeral streams that traverse the flat and empty into the Great Salt Plains Reservoir.

Spring rainfall at Salt Plains NWR is highly variable, and the reservoir level is subject to extreme fluctuation. The alkaline flat can change from bright white (dried salt precipitate) to black during periodic or prolonged rain. Heavy rains facilitate the continued establishment of exotic salt cedar (Tamarix spp.) onto the alkaline flat reducing available nesting habitat (open soil/sand). Salt cedar provides cover for mammalian predators, especially coyotes (Canis latrans)(Hill 1985, Koenen et al. 1996b). As a result, flooding and predation have been the dominant causes of nest failure at Salt Plains NWR (Grover and Knopf 1982, Hill 1985, Koenen et al. 1996a) and other alkaline flats (Page et al. 1983; 1985).

Rainfall totals were collected daily by the U.S. Army Corps of Engineers (USACE) at Great Salt Plains Dam, located 11km ESE of the alkaline flat. Daily totals from USACE were compared for both years to daily totals that we collected in a glass rainguage atop a cornerpost of a 4.5-ha electric-fence predator exclosure, located in the northern region of the flat. We were interested in measuring variation between USACE rainfall totals to our totals from a known location on the alkaline flat.

Public access onto the alkaline flat was prohibited except for a small public-use area designated for selenite crystal digging from 1 April to 15 October annually. Peak digging coincided with the snowy plover breeding season but had minimal impact (Utych 1993, Koenen 1995). Researcher access onto the alkaline flat has been facilitated by an all-terrain vehicle (ATV)(Utych 1993, Schweitzer 1994, Koenen 1995).

Nests on the alkaline flat were located and monitored between 15 May and 15 August in 1995 and 1996. Nests were concentrated along the seasonally ephemeral streams (Boyd 1990). Nests were marked with 30-cm dowels placed about 10 m from the nestcup (Koenen 1995, Utych 1993) and monitored until hatching or outcome was determined. Nests were monitored during crepuscular hours to minimize heat stress to adults and eggs (Dryer and Dryer 1985, Hill 1985). Egg status was recorded on all visits, and a nest was recorded as successful if $\geq$1 egg hatched (Mayfield 1961; 1975). The relative abundance and distribution of snowy plover breeding pairs were based on number of nests monitored by strata, because nest searching effort was uniform and snowy plovers seldom renest in the same area after nest completion (Paton 1995). Apparent nesting success (percent of successful nests) was compared with nesting success using 95% confidence intervals (Johnson 1979) from Mayfield Method estimates (Mayfield 1961; 1975). Comparisons were made: 1) by strata; 2) inside versus outside electric fence predator exclosures; and 3) cumulatively between years.

Areas of snowy plover nesting were divided into 5 strata from N-S (A thru E), as influenced by the regional distribution of nests on the alkaline flat (Fig. 1). We wanted to identify if any region on the alkaline flat had statistically higher nesting success. Microhabitat features adjacent to each nest on the flat were recorded upon nest discovery to identify microhabitat-specific differences in nesting success. Microhabitat features included nests: 1) $\leq$5 cm from driftwood debris; 2) $\leq$5 cm from other debris types (i.e., hay, bone, metal, glass, etc.); 3) in open soil/sand; 4) on elevated man-made habitat improvements (plowed ridges, gravel mounds, and wooden T's) implemented since 1990 (Chapter 2); and 5) near live vegetation.

Habitat improvements at Salt Plains NWR (plowed ridges and gravel mounds) have been used by snowy plovers in the past (Koenen 1995, Utych 1993) but have not provided added protection against flooding (Koenen et al. 1996a). Wooden T's were used in 1995 and 1996 to supplement fenced sites lacking debris. Twenty-four wooden T's were used in 1995 and an additional 100 were used in 1996 inside a 20-ha electric fence in Strata D. Three electric-fence predator exclosures (4.5-ha and 24-ha in Strata A; 20-ha in Strata D) encompassed the habitat improvements on the flat and have provided protection against mammalian predators, specifically coyotes (Utych 1993, Koenen 1995). We documented success of nests inside versus outside electric-fence predator exclosures in this study. Substrate texture (soft versus hard soil/sand) also was recorded for nests in open soil/sand in 1996 because substrate differences have influenced nesting success in sympatric species (Carreker

1985). With information on site-specific nesting success, placement of future habitat improvements and electric fences could occur in the most beneficial region of the flat.

## RESULTS

Four hundred and fifteen snowy plover nests were monitored to completion in 1995 and 1996 on the alkaline flat at Salt Plains NWR. Snowy plovers nested in a clumped distribution at 30 sites throughout the alkaline flat in 1995 and 45 sites in 1996. Snowy plover nests were monitored every 1-7 days in 1995 ($\underline{X}$ = 2.51; S.E. = 0.83), and every 1-6 days in 1996 ($\underline{X}$ = 2.69; S.E. = 0.92). Snowy plovers averaged 2.66 eggs per clutch (S.E. = 0.62) in 1995 (wet year), and 2.83 eggs per clutch (S.E. = 0.46) in 1996 (dry year)(Table 1). June was the month of highest nesting activity during both years (55% in 1995 and 66% in 1996), consistent with Hill (1985) and Utych (1993). Snowy plover chicks were banded by protocol of the Bird Banding Laboratory and U.S. Fish and Wildlife Service each year--34 in 1995 and 56 in 1996.

Number of nests monitored by strata (high-low) changed from Strata D (78), B (71), A (58), C (17), E (14) in 1995 to Strata C (63), D (42), B (38), A (17), E (17) in 1996 (Table 2). Statistical differences in nesting success were not significant by strata, inside versus outside electric fences, or cumulatively between years based on 95% confidence intervals around Mayfield estimates ($\underline{P}$ <

0.05)(Table 2). However, apparent nesting success was substantially higher in Strata C and D in 1995, and A, D, E, and inside electric fences in 1996, than at other sites (Table 1).

Mayfield estimates of nesting success and apparent nesting success were 37% in 1995, and nesting success averaged 58% (Mayfield Method) and 51% (apparent nesting success) in 1996 (Table 2). Mayfield estimates of success were higher than apparent nesting success percentages in 50% of all possible comparisons during both years (Table 2).

Microhabitat-specific nesting success and relative abundance were recorded for both years (Table 3). Nests located $\leq$5 cm from driftwood debris were observed with the highest frequency in 1995 (34%) and were third most common in 1996 (23%). Nests located $\leq$5 cm from dead vegetation (hay) debris)(39%) and in the open (28%) were the most observed nesting microhabitats in 1996. Nests $\leq$5 cm from all debris types were observed 46% of the time in 1995 and 62% of the time in 1996 (Table 3).

Open soil/sand nests were observed at 24% of all monitored nests for both years. In 1996, we found that 21 of 33 (64%) nests were on hard open soil/sand substrate (clay) and 36% were on soft open soil/sand substrate (sand). Snowy plover nests in hard soil experienced 54% apparent nesting success, and nests in soft sand experienced 31% apparent nesting success in 1996.

Use of man-made habitat improvements declined from 27% of all nests in 1995 to 10% of all nests in 1996 (Table 3).

Snowy plovers often nested on gravel mounds and ridges but did not use wooden T's in 1995 and used only 3 wooden T's in 1996. Mayfield estimates were higher for nests inside electric fences than outside during both years; 10% higher in 1995 and 4% higher in 1996 (Table 2). However, nesting success has not been significantly higher inside fences than at unfenced sites (Koenen 1995) when comparing large samples using the Mayfield Method. Nests on man-made habitat improvements and $\leq$5 cm from driftwood debris encountered the highest predation in 1995, and nests $\leq$5 cm from other debris types encountered the highest predation in 1996.

Predation by strata (high to low) changed from Strata A (12), B (10), D (5), C (2), E (0) in 1995 to Strata C (10), B (6), D (4), E (3), A (0) in 1996 (Table 1). In 1995, 12 of 70 nests (17%) inside electric-fence exclosures were predated (10 by avian predators), and 17 of 168 nests (10%) outside exclosures were predated (7 by avian predators)(Table 4). In 1996, no nests were predated inside electric-fence predator exclosures, but 23 of 160 nests (14%) were predated outside exclosures (14 by mammals, 4 by avian predators, and 5 from unknown predators)(Table 4). Nest visibility increased with duration and frequency of rainfall because the substrate darkened exposing eggs.

Ring-billed gulls (Larus delawarensis) were observed preying on snowy plover eggs on 24 July (inside a 24-ha electric fence) and 30 July in 1995, and on 13 July 1996, and preying on eggs and chicks on 28 July 1995. The 30 July 1995 sighting was 3 h prior to a diurnal great horned owl sighting on the flat. Great horned owls are potential predators at Salt Plains NWR (Chapter 1). Additionally, a peregrine falcon (Falco peregrinus) was observed on seven occasions on the alkaline flat during both years and seen in flight-pursuit, nearly capturing a snowy plover on 23 July 1996.

Flooding impacted snowy plover nests the most in Strata B ($n$ = 31) and D ($n$ = 33) in 1995 and in Strata B ($n$ = 12) and C ($n$ = 19) in 1996 (Table 2). Nests lost to flooding corresponded to strata with the most monitored nests (relative use). Nests inside electric fences with habitat improvements were afforded higher protection from flooding in 1995 (29% nests loss inside versus 40% lost outside). However, nest losses from flooding in 1996 were slightly higher inside electric fences (29%) than outside fences (25%)(Table 2). A single rain event of 8.9 cm destroyed 44 of 109 monitored nests (40%) on 16 June 1996.

Precipitation totals from the USACE at Great Salt Plains Dam during 1 May through 31 July varied from 50.6 cm in 1995 (wet year) to 28.5 cm in 1996 (dry year). USACE daily rainfall totals and our measurements on the flat in Strata A were compared on 30 rain events for both years (16 in 1995; 14 in 1996). Significant differences in daily rainfall amounts did exist between collection points in 1995 ($t$ = 3.153, $P$ < 0.005) and 1996 ($t$ = 2.717, $P$ < 0.01). Reservoir levels from May through July fluctuated during both years: 343.03-344.81 m in 1995 and 342.87-344.18 m in 1996.

## DISCUSSION

No significant differences existed in nesting success for snowy plovers by strata or inside versus outside electric fences using approximate 95% confidence intervals for Mayfield estimates (Johnson 1979), but differences in apparent nesting success by strata and inside versus outside fences did exist by year. Mayfield (1961; 1975) warned that apparent nesting success often overestimates true success and that his method is advantageous because fragments of nest-monitoring information can be incorporated into the calculation of nesting success. However, the Mayfield Method does not incorporate data from nests destroyed soon after discovery, whether lost from natural or human-induced causes. We included this information in our apparent nesting success calculations.

Washed out and predated eggs from non-monitored nests (failed nests) and hatched chicks sighted (banded) $\geq$500 m from monitored nests (successful nests) were included in calculations of apparent nesting success. We assumed washed out and predated eggs or hatched chicks had an equal likelihood of detection during nest-monitoring. Therefore, we suggest that apparent nesting success calculations may be more representative of true success in our study because more information was incorporated into the values.

Snowy plovers were more abundant throughout the alkaline flat at Salt Plains NWR in 1995 (wet year) than in 1996 (dry year), as were American avocets (<u>Recurvirostra</u>

americana)(Chapter 4), possibly due to insect availability. Strata delineations were influenced by nesting distribution of birds and not microhabitat types. Strata D had the most nesting snowy plovers in 1995 and the second most in 1996. Strata C was not explored as thoroughly in 1995 as in 1996, due to homogeneity, unfamiliarity, and repeated inundation of this central region of the alkaline flat. Based on our analyses of nesting success, Strata D would be the most appropriate location to implement future habitat improvements or electric fences on the alkaline flat at Salt Plains NWR.

Microhabitat types most commonly associated with nests included: 1) debris (ca. 50% of all nests), 2) open soil/sand (25%), and 3) man-made habitat improvements (25%). Nests in hard open soil/sand (clay) were more successful than nests in soft sand. Nests in soft sand were often in areas recently flooded so were vulnerable to reinundation.

Snowy plovers readily nested on gravel mounds and plowed ridges (elevated areas). However, man-made habitat improvements implemented since 1990 have afforded only minimal protection from flooding (Koenen et al. 1996a). Electric fences have afforded some protection against mammalian predators (Utych 1993, Koenen 1996a) but not from avian predators. Ring-billed gulls were observed preying on snowy plover nests in 1995 and 1996 for the first time at Salt Plains NWR. Great horned owls were identified as potential predators. In general, distribution of predators was higher in strata with more nests. Predator impact was lower in Strata C due to greater distance from vegetation (Koenen et al. 1996b). Human activity (diggers) and an increased use of nests in the open (difficult to see) may have affected predation in Strata C compared to other strata.

In the past, climatological information (rainfall) on the alkaline flat has been inferred from data collected from Cherokee (11 km WSW) or Great Salt Plains Dam (11 km ESE)(Purdue 1976). Significant differences in rainfall totals confirmed that variation exists between sites. Localized rain pulses that destroyed nests on the alkaline flat were not always detected or accurately measured from USACE collection points.

Nesting success in Strata D averaged 45% during both years. Flooding and predation continued to limit productivity in snowy plovers (Hill 1985, Boyd 1990, Koenen 1995). Ring-billed gulls were observed predating snowy plover eggs and chicks for the first time at Salt Plains NWR, especially inside electric fences in 1995. Information concerning impact by avian predators on fledging chicks is needed to better access overall reproductive success. Also, habitat improvements that protect nesting plovers from sheet flooding without attracting predators are needed to increase production of snowy plovers at Salt Plains NWR. Rainfall readings collected on the alkaline flat were significantly different than nearby sources and helped explain widespread nest loss on occasion.

## ACKNOWLEDGEMENTS

Funding for this study was provided by Region 2 of the U.S. Fish and Wildlife Service, Salt Plains National Wildlife Refuge, and the Oklahoma Cooperative Fish and Wildlife Research Unit (U.S. National Biological Service, Oklahoma Department of Wildlife Conservation, Oklahoma State University and Wildlife Management Institute, cooperating). M. Koenen, J. Heltzel, V. Barko, E. Winton, D. Simon, Sr., and D. Simon, Jr. assisted with field research. J. Shaw, and L. Caneday reviewed the manuscript and made many helpful suggestions.

## LITERATURE CITED

BASE, D.L. 1985. Rangewide survey of nesting interior least terns (Sterna antillarum athalassos) and snowy plovers Charadrius alexandrinus) in Oklahoma. Nongame Program Work Plan, Oklahoma Dept. Wildl. Conserv. 9pp.

BOYD, R.L. 1990. Habitat management and population ecology studies of the least tern in Kansas and Oklahoma. Kansas Dept. Wildl. and Parks, Nongame Wildl. Program. 49pp.

CARREKER, R.G. 1985. Habitat suitability index models: least tern. U.S. Fish and Wildl. Serv. Biol. Rep. 82(10.103).

DRYER, M.P., AND P.J. DRYER. 1985. Investigations into the population, breeding sites, habitat characteristics, threats and productivity of the Least Tern in North

Dakota. U.S. Fish and Wildl. Serv., Resource Information Paper No.1. 17pp.

GROVER, P.B., AND F.L. KNOPF. 1982. Habitat requirements and breeding success of Charadriiform birds nesting at Salt Plains National Wildlife Refuge, Oklahoma. J. Field Ornithol. 53:139-148.

_____, AND M. GROVER. 1982. Breeding Charadriiform birds of the Great Salt Plains. Bull. Oklahoma Ornithol. Soc. 15:11-14.

HILL, L.A. 1985. Breeding ecology of interior least terns, snowy plovers and American avocets at Salt Plains National Wildlife Refuge, Oklahoma. M.S. thesis, Oklahoma State Univ., Stillwater. 106pp.

JOHNSON, D.H. 1979. Estimating nest success: the Mayfield Method and an alternative. Auk 96:651-661.

KOENEN, M.T. 1995. Breeding ecology and management of least terns, snowy plovers and American avocets. M.S. thesis, Oklahoma State Univ., Stillwater. 109pp.

_____, R.B. UTYCH, AND D.M. LESLIE, JR. 1996a. Methods used to improve least tern and snowy plover nesting success on alkaline flats. J. Field Ornithol. 67:281-291.

_____, D.M. LESLIE, JR., AND M. GREGORY. 1996b. Habitat changes and success of artificial nests on an alkaline flat. Wilson Bull. 108:292-301.

MAYFIELD, H.F. 1961. Nesting success calculated from exposure. Wilson Bull. 73:255-261.

_____. 1975. Suggestions for calculating nest success. Wilson Bull. 87:456-466.

PAGE, G.W., J.S. WARRINER, J.C. WARRINER, AND P.W.C. PATON. 1995. Snowy plover (Charadrius alexandrinus). In The birds of North America, No. 154 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C.

_____, L.E. STENZEL, AND C.A. RIBIC. 1985. Nest site selection and clutch predation in the snowy plover. Auk 102:347-353.

_____, _____, D.W. WINKLER, AND C.W. SWARTH. 1983. Spacing out at Mono Lake: Breeding success, nest density, and predation in the snowy plover. Auk 100:13-24.

PATON, P.W.C. 1995. Breeding biology of snowy plovers at Great Salt Lake, Utah. Wilson Bull. 107:275-288.

PURDUE, J.R. 1976. Adaptations of the snowy plover on the Great Salt Plains, Oklahoma. Southwestern Nat. 21:347-357.

SCHWEITZER, S.H. 1994. Abundance and conservation of endangered interior least terns nesting on salt flat habitat. Ph.D. Thesis, Oklahoma State Univ., Stillwater. 129pp.

SUTTON, G.M. 1967. Oklahoma Birds: their ecology and distribution, with comments on the avifauna of the Southern Great Plains. Univ. Oklahoma Press, Norman.

U.S. FISH AND WILDLIFE SERVICE. 1991. Endangered and threatened wildlife and plants; animal candidate review for listing as endangered or threatened species. Federal Register 56(225):58,804-58,810.

_____. 1993. Endangered and threatened wildlife and plants; determination of threatened status for the Delta Smelt and the Pacific coast population of the western snowy plover. Federal Register 58:12,864-12,874.

_____. 1995. Policy on Candidate Assessment and Petition Management Under the Endangered Species Act. Memorandum, U.S Fish and Wildlife Service, Tulsa, Oklahoma. 2pp.

UTYCH, R.B. 1993. Compatibility of selenite crystal digging with breeding ecology of least terns and snowy plovers at Salt Plains National Wildlife Refuge in Oklahoma. M.S. thesis, Oklahoma State Univ., Stillwater. 45pp.

WILSON, R.A. 1986. Snowy plover (Charadrius alexandrinus): Section 4.4.1, U.S. Army Corps of Engineers Wildlife Resources Management Manual, Tech. Rep. EL-86-54.

Table 1. Clutch size of snowy plover nests monitored at Salt Plains National Wildlife Refuge, Oklahoma, 1995 and 1996.

| Year | Clutch size | | | | | | Total eggs | Percent hatched |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | *N* | *X* | SE | | |
| 1995 | 14 | 33 | 131 | 178 | 2.657 | 0.62 | 473 | 31 |
| 1996 | 4 | 12 | 103 | 119 | 2.832 | 0.46 | 337 | 46 |

TABLE 2. Nest success[ab], confidence intervals, and losses by strata (A-E), inside and outside electric fence predator exclosures, and cumulatively for snowy plovers nesting on an alkaline flat at Salt Plains National Wildlife Refuge, Oklahoma, 1995 and 1996.

| | Strata | | | | | Fences | | |
|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | In | Out | All |
| 1995 | | | | | | | | |
| n | 58 | 71 | 17 | 78 | 14 | 70 | 168 | 238 |
| Success[a] | 0.38 | 0.27 | 0.47 | 0.44 | 0.43 | 0.37 | 0.38 | 0.37 |
| % Use | 24.4 | 29.8 | 7.1 | 32.8 | 5.9 | 29.4 | 70.6 | 100.0 |
| Predation | 12 | 10 | 2 | 5 | 0 | 12 | 17 | 29 |
| Flood | 14 | 31 | 4 | 33 | 6 | 20 | 68 | 88 |
| Other[c] | 10 | 11 | 3 | 6 | 2 | 12 | 20 | 32 |
| n | 24 | 26 | 6 | 36 | 6 | 31 | 67 | 98 |
| Success[b] | 0.50 | 0.16 | 0.17 | 0.45 | 0.40 | 0.44 | 0.34 | 0.37 |
| 95% C.I. | 0.32-0.77 | 0.07-0.39 | 0.02-1.21 | 0.30-0.67 | 0.14-1.13 | 0.28-0.68 | 0.23-0.48 | 0.28-0.49 |
| Predation | 4 | 3 | 1 | 1 | 0 | 4 | 5 | 9 |
| Flood | 4 | 14 | 2 | 14 | 3 | 8 | 29 | 24 |
| Other[c] | 2 | 0 | 0 | 1 | 0 | 2 | 1 | 3 |
| 1996 | | | | | | | | |
| n | 17 | 38 | 63 | 42 | 17 | 17 | 160 | 177 |
| Success[a] | 0.71 | 0.39 | 0.40 | 0.71 | 0.59 | 0.71 | 0.49 | 0.51 |
| % Use | 9.6 | 21.5 | 35.6 | 23.7 | 9.6 | 9.6 | 90.4 | 100.0 |
| Predation | 0 | 6 | 10 | 4 | 3 | 0 | 23 | 23 |
| Flood | 5 | 12 | 19 | 5 | 3 | 5 | 40 | 45 |
| Other[c] | 0 | 5 | 9 | 3 | 1 | 0 | 18 | 18 |
| n | 9 | 17 | 25 | 16 | 10 | 9 | 68 | 77 |
| Success[b] | 0.61 | 0.44 | 0.40 | 0.83 | 0.85 | 0.61 | 0.57 | 0.58 |
| 95% C.I. | 0.34-1.07 | 0.22-0.85 | 0.22-0.69 | 0.63-1.08 | 0.62-1.17 | 0.34-1.07 | 0.45-0.73 | 0.46-0.73 |
| Predation | 0 | 4 | 5 | 2 | 1 | 0 | 12 | 12 |
| Flood | 3 | 2 | 6 | 0 | 0 | 3 | 8 | 11 |
| Other[c] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

[a] Apparent nesting success (Percent of total) using all observed nesting information.
[b] Nesting success calculated from exposure using the Mayfield Method (Mayfield 1961; 1975).
[c] Nest losses from wind, and abandoned or addled eggs.

TABLE 3. Microhabitat use and apparent nesting success by type and year for snowy plovers on the alkaline flat at Salt Plains National Wildlife Refuge, Oklahoma, in 1995 and 1996.

| | Microhabitat | | | | |
|---|---|---|---|---|---|
| Outcome | (D1)[a] | (D2)[b] | (O)[c] | (E)[d] | (U)[e] |
| **1995** | | | | | |
| Hatched | 10 | 4 | 15 | 17 | 6 |
| Flooded | 20 | 6 | 7 | 9 | 2 |
| Predation | 4 | 2 | 0 | 7 | 0 |
| Uncertain | 25 | 8 | 16 | 14 | 1 |
| Total | 59 | 20 | 38 | 47 | 9 |
| Percent use | 34 | 12 | 22 | 27 | 5 |
| **1996** | | | | | |
| Hatched | 9 | 32 | 18 | 8 | 1 |
| Flooded | 11 | 8 | 5 | 3 | 0 |
| Predation | 7 | 6 | 5 | 1 | 0 |
| Uncertain | 6 | 11 | 12 | 2 | 0 |
| Total | 33 | 57 | 40 | 14 | 1 |
| Percent use | 23 | 39 | 28 | 10 | 1 |
| **1995-1996** | | | | | |
| Hatched | 19 | 36 | 33 | 25 | 7 |
| Flooded | 31 | 14 | 12 | 12 | 2 |
| Predation | 11 | 8 | 5 | 8 | 0 |
| Uncertain | 31 | 19 | 28 | 16 | 1 |
| Total | 92 | 77 | 78 | 61 | 10 |
| Percent use | 29 | 24 | 25 | 19 | 3 |

[a]Nest is located $\leq$5 cm from driftwood debris
[b]Nest is located $\leq$5 cm from other debris (hay, glass, bone)
[c]Nest is located in open sand
[d]Nest is located on man-made elevation (ridges, mounds, gravel road)
[e]Nest is located in association with other materials (cattle feces, selenite crystals, inside driftwood, live vegetation)

Table 4. Predation by species and year for snowy plovers nesting inside and outside electric fences on the alkaline flat at Salt Plains National Wildlife Refuge, Oklahoma, 1995 and 1996.

| Year | Location | Mammal | Avian | Uncertain | n | Total nests |
|---|---|---|---|---|---|---|
| 1995 | | | | | | |
| | Inside | 1 | 10 | 1 | 12 | 70 |
| | Outside | 5 | 7 | 5 | 17 | 168 |
| 1996 | | | | | | |
| | Inside | 0 | 0 | 0 | 0 | 17 |
| | Outside | 14 | 4 | 5 | 23 | 160 |
| Both years | | | | | | |
| | Inside | 1 | 10 | 1 | 12 | 88 |
| | Outside | 19 | 11 | 10 | 40 | 328 |


**Figure 1. General location of the 5 strata (A thru E), regionally selected from N-S and influenced by nesting distribution of Charadriiformes on the alkaline flat at Salt Plains National Wildlife Refuge, Oklahoma in 1995 and 1996.**

Chapter IV

# BREEDING ECOLOGY OF RECURVIROSTRIDAE AT SALT PLAINS NATIONAL WILDLIFE REFUGE, OKLAHOMA, 1995-1996

Nesting success and microhabitat use of American avocets (Recurvirostra americana) and black-necked stilts (Himantopus mexicanus) were monitored at Salt Plains National Wildlife Refuge (NWR) in northcentral Oklahoma in 1995 and 1996. American avocets have been monitored for 10 of the past 20 years at Salt Plains NWR (Grover and Grover 1982, Grover and Knopf 1982, Hill 1985, Utych 1993, Koenen 1995), and the first nesting record for black-necked stilts in Oklahoma was documented in 1993 (Koenen et al. 1994). American avocets and black-necked stilts nested in association with endangered interior least terns (Sterna antillarum) and snowy plovers (Charadrius alexandrinus) on the 5,095-ha alkaline flat at Salt Plains NWR.

American avocet and black-necked stilt nests were monitored between 5 June and 24 July 1995, and American avocet nests were monitored between 17 May and 23 July 1996. Six pairs of black-necked stilts were repeatedly censused in June and July 1995, and two black-necked stilt nests found on 25 and 27 June were monitored to completion in 1995.

Black-necked stilts did not nest at Salt Plains NWR in 1996 after nesting there for the three previous years (Koenen et al. 1994).

Twenty-one American avocet nests and two black-necked stilt nests were monitored to completion in 1995, and 26 American avocet nests were monitored to completion in 1996. American avocet nests were concentrated at 9 sites throughout the alkaline flat in 1995 and at 11 sites in 1996. Nests of both species were concentrated north of the selenite crystal digging area near Cottonwood Creek in the central region of the alkaline flat.

Most American avocet nests were located in June during both years--87% in 1995 and 50% in 1996. Modal clutch size of American avocets was 4 eggs during both years, consistent with Hill (1985). Mean clutch size during both years was 3.93 eggs (S.E. = 0.25). Nest-monitoring intervals ranged from 1-5 days in 1995 to 1-6 days in 1996 ($\underline{X}$ = 2.65, 0.88 S.E.). Nests were visited an average of 4.4 times before outcome was determined for both years. Nesting success was determined using 95% confidence intervals (Johnson 1979) for Mayfield Method estimates (Mayfield 1961; 1975). Microhabitat types were recorded for all monitored Recurvirostridae nests on the alkaline flat. Microhabitat types included: 1) nests near debris (D1; D2); 2) nests in open soil/sand (O); 3) nests on elevated man-made habitat improvements (i.e., plowed ridges, abandoned gravel road (E); and 4) nests near live vegetation (R). Microhabitat-specific nesting success was determined using apparent nesting success (% of total observed nests).

Total observed nesting success for American avocets using the Mayfield Method (1961; 1975) was 58% in 1995 and 50% in 1996 (Table 1). Fourteen of 21 nests in 1995 and 17 of 26 nests in 1996 were used to calculate nesting success from exposure (Mayfield 1961). Nesting success of American avocets using the Mayfield Method was significantly higher in our study than: Hill (1985) reported in 1982; (8.4%); 1983 (17.1%); or Koenen (1995) reported in 1992 (7%); and 1993 (3.1%), at Salt Plains NWR. American avocets experienced comparable nesting success in 1991 (49%)(Koenen 1995) and in 1995 and 1996. The increased nesting success in recent years may be contributed to a decline in relative abundance of American avocets since the early 1980's. Fewer American avocets were widely dispersed with more resources available per individual.

In 1995, 35% of all monitored American avocet nests were found along Cottonwood Creek with 88% apparent nesting success. In 1996, 73% of all monitored American avocet nests were found along Cottonwood Creek with only 26% apparent nesting success. In 1995, five American avocet nests (24% of total observed) were monitored inside two electric-fence predator exclosures located in the northern region of the alkaline flat with 60% apparent nesting success. In 1996, no American avocet nests were located inside electric-fence predator exclosures. No significant differences in nesting success were observed between nests inside electric-fence predator exclosures versus nests found outside exclosures in 1995 using Mayfield Method (Table 1). Black-necked stilts were not observed nesting within the electric-fence predator exclosures during any year.

Eleven American avocet nests were lost to flooding and 8 were lost to predation during both years (Table 2). Predated nests were destroyed by coyotes (Canis latrans)(64%), and avian predators (presumably ring-billed gulls (Larus delawarensis)(36%). One nest inside an electric fence exclosure was avian-predated in 1995 (Table 3).

Of the two black-necked stilt nests, 4 eggs successfully hatched in one nest on 12 July, and 3 of 4 eggs were successful in the second nest on 14 July. Black-necked stilts experienced 100% nesting success in 1995. Koenen (1995) also documented black-necked stilts experiencing 100% nesting success at Salt Plains NWR.

American avocet nests on elevated man-made habitat improvements were the microhabitat type most observed in 1995 (47%) with 33% apparent nesting success (Table 2). American avocet nests near: 1) debris, and 2) live vegetation resulted in $\geq$50% apparent nesting success in 1995, and nests: 1) near driftwood debris, and 2) on elevated man-made habitat improvements resulted in $\geq$50% apparent nesting success in 1996 (Table 2). American avocet nests near hay debris were observed most frequently in 1996 (50%) with 45% apparent nesting success. American avocet nests on elevated man-made habitat improvements had the highest apparent nesting success with 67% in 1996 (Table 2).

American avocet nests in open soil/sand experienced the lowest overall apparent nesting success during both years (0% in 1995 and 25% in 1996)(Table 2). Hill (1985) observed American avocets nesting near debris 63% of the time and in open areas 37% of the time, but noted near equal nesting success between microhabitat types. Black-necked stilts experienced high nesting success in open soil/sand in 1995 (n = 2).

Other studies have found higher nesting success for Charadriiformes in open areas (Page et al. 1985). Least tern nests in 1995 and 1996 at Salt Plains NWR experienced higher apparent nesting success in association with open soil/sand than near other microhabitat types (Chapter 2). The reduced success for American avocet nests in open soil/sand may be partially due to larger egg size or adult behavior, both of which could attract predators (Simmons and Crowe 1951).

Increased overall nesting success for American avocets from 1985 to 1995 may be partially due to a decline in the relative abundance in the nesting population of American avocets at Salt Plains NWR, leaving more resources available per nesting pair. Hill (1985) monitored 122 American avocet nests in 1982 and 1983, and we monitered only 47 nests in this study, despite intensive nest searches.

Like least terns (Chapter 2) and snowy plovers (Chapter 3), American avocets initiated nesting earlier in 1996 (May 17) than in 1995 (June 5). Although the 1995 nesting season was likely delayed by flooding, American avocets experienced higher apparent nesting success--possibly due to an increased use of elevated man-made habitat improvements and high apparent nesting success for nests associated with live vegetation. Decadent vegetation dominated in 1996.

Black-necked stilts have been known to exhibit strong natal philopatry and moderate site tenacity (James 1995). The absence of nesting black-necked stilts at Salt Plains NWR in 1996 was unexpected. However, long distance movements of Recurvirostridae have been documented (Robinson and Oring 1996), often influenced by local environmental conditions (Boettcher et al. 1995). The climatic differences between 1995 (flood year) and 1996 (drought year) likely caused the decline in relative abundance of American avocets (and snowy plovers) in 1996, which coincided with fewer insects and invertebrates, resulting from low water. Black-necked stilts may have sought other nesting areas as a result of limited forage due to drought in 1996.

Despite large eggs and body size, American avocets overall experienced substantially higher nesting success than least terns (Chapter 2) and snowy plovers (Chapter 3), sympatric breeders, on the alkaline flat in 1995 and 1996. American avocet nest losses occurred from flooding and predation in 1995 and 1996--natural factors limiting productivity of all nesting birds at Salt Plains NWR. Habitat improvements at Salt Plains NWR have increased productivity in American avocets, although the local population has declined.

We thank the staff at Salt Plains National Wildlife Refuge, especially Manager Rod Krey, for accomodations and research support. Appreciation is extended to Marcus Koenen and Dennis Simon for assistance with nest-monitoring in 1995. Primary funding and support was provided by the National Biological Service, Salt Plains NWR, and the Oklahoma Cooperative Fish and Wildlife Research Unit (U.S. Nat. Biol. Serv., Okla. State Univ., Okla. Dept. Wildl. Conserv., and Wildl. Manage. Inst., cooperating).

LITERATURE CITED

Boettcher, R., S.M. Haig, and W.C. Bridges, Jr. 1995. Habitat-related factors affecting the distribution of nonbreeding American avocets in coastal South Carolina. Condor 97:68-81.

Grover, P.B., and M. Grover 1982. Breeding Charadriiform birds of the Great Salt Plains. Bull. Oklahoma Ornithol. Soc. 15:11-14.

_____, and F.L. Knopf. 1982. Habitat requirements and breeding success of Charadriiform birds nesting at Salt Plains National Wildlife Refuge, Oklahoma. J. Field Ornithol. 52:139-148.

Hill, L.A. 1985. Breeding ecology of interior least terns, snowy plovers, and American avocets at Salt Plains National Wildlife Refuge, Oklahoma. M.S. thesis, Oklahoma State University, Stillwater, Oklahoma, 106pp.

James, R.A., Jr. 1995. Natal philopatry, site tenacity, and age of first breeding of the black-necked stilt. J. Field Ornithol. 66:107-111.

Johnson, D.H. 1979. Estimating nest success: the Mayfield Method and an alternative. Auk 96:651-661

Koenen, M.T., M. Oliphant, J. Key, and E. Key. 1994. First nesting record of black-necked stilts for Oklahoma. Bull. Oklahoma Ornithol. Soc. 27:1-4.

_____. 1995. Breeding ecology and management of least terns, snowy plovers and American avocets. M.S. thesis, Oklahoma State University, Stillwater, Oklahoma, 109pp.

Mayfield, H.F. 1961. Nesting success calculated from exposure. Wilson Bull. 73:225-261.

_____. 1975. Suggestions for calculating nest success. Wilson Bull. 87:456-466.

Page, G.W., L.E. Stenzel, and C.A. Ribic 1985. Nest site selection and clutch predation in the snowy plover. Auk 102:347-353.

Robinson, J.A., and L.W. Oring. 1996. Long-distance movements by American avocets and black-necked stilts. J. Field Ornithol. 67:307-320.

Simmons, K.E.L., and R.W. Crowe. 1951. Displacement-sleeping in the avocet and oystercatcher as a reaction to predators. British Birds 44:405-410.

Utych, R.B. 1993. Compatibility of selenite crystal digging with breeding ecology of least terns and snowy plovers at Salt Plains National Wildlife Refuge in Oklahoma. M.S. thesis, Oklahoma State University, Stillwater, Oklahoma, 45pp.

Table 1. American avocet nesting success[a] (Mayfield Method), approximate 95% confidence intervals[b], and losses for all nests inside and outside electric fence predator exclosures at Salt Plains National Wildlife Refuge, Oklahoma, 1995 and 1996.

| Year | | Inside | Outside | Cumulative |
|---|---|---|---|---|
| 1995 | n | 3 | 12 | 15 |
| | Nest Success[a] | 0.77 | 0.50 | 0.58 |
| | 95% C.I.[b] | 0.45-1.00 | 0.26-0.92 | 0.49-1.00 |
| | Predation | 0 | 2 | 2 |
| | Flooding | 0 | 3 | 3 |
| | Other[c] | 1 | 0 | 1 |
| 1996 | n | 0 | 17 | 17 |
| | Nest Success[a] | - | 0.50 | 0.50 |
| | 95% C.I.[b] | - | 0.30-0.81 | 0.30-0.81 |
| | Predation | - | 5 | 5 |
| | Flooding | - | 3 | 3 |
| | Other[c] | - | 0 | 0 |
| Both years | n | 3 | 29 | 32 |
| | Nest Success[a] | 0.77 | 0.50 | 0.53 |
| | 95% C.I.[b] | 0.45-1.00 | 0.33-0.73 | 0.38-0.75 |
| | Predation | 0 | 7 | 7 |
| | Flooding | 0 | 6 | 6 |
| | Other[c] | 1 | 0 | 1 |

[a]Nesting success calculated using the Mayfield Method (Mayfield 1961; 1975).
[b]95% confidence intervals (C.I.) calculated from Mayfield estimates (Johnson 1979).
[c]Nests lost from abandoned, wind-blown, or unknown causes.

Table 2. Percent use, apparent nesting success, and losses by microhabitat type for American avocets nesting on the alkaline flat at Salt Plains National Wildlife Refuge, Oklahoma, 1995 and 1996.

| | Microhabitat type | | | | |
|---|---|---|---|---|---|
| | D1[a] | D2[b] | O[c] | E[d] | R[e] |
| **1995** | | | | | |
| n | 2 | 4 | 1 | 9 | 3 |
| % Use | 11 | 21 | 5 | 47 | 16 |
| % Success | 50 | 75 | 0 | 33 | 100 |
| Hatched | 1 | 3 | 0 | 3 | 3 |
| Flooded | 0 | 1 | 1 | 3 | 0 |
| Predation | 1 | 0 | 0 | 2 | 0 |
| Other | 0 | 0 | 0 | 1 | 0 |
| **1996** | | | | | |
| n | 4 | 11 | 4 | 3 | 0 |
| % Use | 18 | 50 | 18 | 14 | 0 |
| % Success | 50 | 45 | 25 | 67 | 0 |
| Hatched | 2 | 5 | 1 | 2 | 0 |
| Flooded | 1 | 3 | 2 | 0 | 0 |
| Predation | 1 | 2 | 1 | 1 | 0 |
| Other | 0 | 1 | 0 | 0 | 0 |
| **Both years** | | | | | |
| n | 6 | 15 | 5 | 12 | 3 |
| % Use | 15 | 37 | 12 | 29 | 7 |
| % Success | 50 | 53 | 20 | 42 | 100 |
| Hatched | 3 | 8 | 1 | 5 | 3 |
| Flooded | 1 | 4 | 3 | 3 | 0 |
| Predation | 2 | 2 | 1 | 3 | 0 |
| Other | 0 | 1 | 0 | 1 | 0 |

[a]- Nest is $\leq$5 cm from driftwood debris
[b]- Nest is $\leq$5 cm from other debris (e.g. hay)
[c]- Nest is in open soil/sand away from debris
[d]- Nest is on man-made habitat improvements (e.g. plowed ridge)
[e]- Nest is $\leq$5 cm from live vegetation

Table 3. Predated nests of American avocets by type and year for nesting inside and outside electric-fence predator exclosures on the alkaline flat at Salt Plains National Wildlife Refuge, Oklahoma, 1995 and 1996.

| | Predator | | | |
|---|---|---|---|---|
| | Mammal | Avian | Uncertain | *n*[a] |
| 1995 | | | | |
| Inside | 0 | 1 | 0 | 1 |
| Outside | 2 | 2 | 0 | 4 |
| 1996 | | | | |
| Inside | 0 | 0 | 0 | 0 |
| Outside | 5 | 1 | 0 | 6 |
| 1995-1996 | | | | |
| Inside | 0 | 1 | 0 | 1 |
| Outside | 7 | 3 | 0 | 10 |

[a] Total number of nests lost by known factors--includes monitored nests with exposure (Mayfield Method) and nests without exposure used in calculating apparent nesting success.

## Appendix A.

### COMMON NIGHTHAWKS NEST SUCCESSFULLY IN TRANSITIONAL HERBACEOUS RANGELAND-ALKALINE FLAT HABITAT

The common nighthawk (Chordeiles minor) is a summer resident at Salt Plains National Wildlife Refuge (NWR) in Alfalfa County, Oklahoma. Common nighthawks often lays eggs in well-drained, treeless, barren areas in Oklahoma (Sutton 1967) and have been observed in Oklahoma as early as 14 February on their spring migration from South America (Tyler and McKee 1991). Nesting habitat for the common nighthawk includes coastal sand dunes and beaches, logged or slashburned areas of forest sites, woodland clearings, prairies and plains, sagebrush and grassland habitat, farm fields, open forests, rock outcrops, and flat gravel rooftops in cities (Poulin et al. 1996). This note represents the first documented nesting of common nighthawks in transitional herbaceous rangeland (Koenen et al. 1996)-alkaline flat habitat at Salt Plains NWR.

In 1995 and 1996, a single common nighthawk nest was located and monitored each year in transitional herbaceous rangeland-alkaline flat habitat along the western boundary at Salt Plains NWR. In 1995, a common nighthawk nested successfully on sparsely vegetated sand hillocks north of Clay Creek and the selenite crystal digging area. The nest was inside a vegetated knoll with barren areas in the interior located 1 m north of the northwest corner of the 20-ha electric fence predator exclosure. The single nest containing two eggs was monitored until hatching in July. Egg shell fragments provided evidence of success, but no juveniles were observed. In 1996, a common nighthawk nested successfully in similar habitat north of Cottonwood Creek further north of the selenite crystal digging area. Only one egg was layed in a shallow scrape in a bald spot within a vegetated sand hillock. Egg fragments were located in July indicating a successful nest, but no juveniles were observed.

Common nighthawks nested both years on vegetated knolls located on the alkaline flat $\leq$50 m from contiguous herbaceous rangelands to the west. Habitat used by common nighthawks at Salt Plains NWR included: 1) sparse-medium density vegetation on sand hillocks, and 2) found along the western boundary in the transition zone of herbaceous rangeland to alkaline flat habitat. The common nighthawk has not been previously documented nesting in transitional habitat of herbaceous rangeland-alkaline flat at Salt Plains NWR.

## LITERATURE CITED

KOENEN, M.K., M. OLIPHANAT, J. KEY, AND E. KEY. 1994. First nesting record of black-necked stilts for Oklahoma. Bulletin of the Oklahoma Ornithological Society 27:1-4.

_____, D.M. LESLIE, JR., AND M. GREGORY. 1996. Habitat changes and success of artificial nests on an alkaline flat. Wilson Bull. 108:292-301.

POULIN, R.G., S.D. FRINDAL, AND R.M. BRIGHAM. 1996. Common nighthawks (Chordeiles minor) <u>in</u> The Birds of North America, No. 213. The Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, D.C.

SUTTON, G.M. 1967. Oklahoma birds. University of Oklahoma Press, Norman. 674pp.

TYLER, J.D., AND T. MCKEE 1991. Early nighthawk records for northcentral Texas and southwestern Oklahoma. Bulletin of the Oklahoma Ornithological Society 24:21-22.

## Appendix B.

## RELATIVE ABUNDANCE OF CICONIIFORM AND ASSOCIATED SPECIES AT SALT PLAINS NATIONAL WILDLIFE REFUGE

State highway 11 traverses 6 km (east-west) through Salt Plains National Wildlife Refuge (NWR), in Alfalfa County, Oklahoma. Sand Creek and two branches of the Salt Fork Arkansas River cross below the highway feeding the Great Salt Plains Reservoir (Fig. 1). These moving water bodies provided a flyway for Ciconiiform and associated species migrating between Ralston Island in the reservoir and adjacent farmfields and rangelands outside the refuge in 1995 (wet year).

In 1995, from 15 May-2 July, a complete census of avian species was recorded daily on all trips made along the 6 km highway traversing Salt Plains NWR. The goal of these counts was to identify the relative abundance of Ciconiiform and associated species, and gain insight into what visitors might see while traveling through Salt Plains NWR in early summer. Additionally, we wanted to compare species relative abundance from the highway counts to relative percent of nesting species on Ralston Island--conjunctive research (Koenen et al. 1996).

Two thousand two hundred and thirty-nine birds were censused along the highway in 1995 during this study.

Percent breakdown of sighted birds included: 1,833 (81.9%) cattle egrets (Bubulcus ibis); 179 (8%) great egrets (Ardea alba); 91 (4.1%) little blue herons (Egretta caerulea); 75 (3.4%) snowy egrets (Egretta thula); 44 (2%) white faced ibis (Plegadis chihi), a newly documented nesting species in Oklahoma (Shepperd 1996); 16 (0.007%) great blue herons (Ardea herodias); and only one (0.0004%) black-crowned night heron (Nycticorax nycticorax) was observed. Cattle egret percent composition observed along the highway in this study (81.9%) was comparable to counts of percent composition of cattle egret nests on Ralston Island at Salt Plains NWR in 1982 (81%)(Talent and Hill 1982), and in 1995 (83.6%)(Koenen et al. 1996).

Great blue herons, white-faced ibis, and black-crowned night herons were observed least often, while cattle egrets were observed most often on the highway counts and Ralston Island counts in 1995 (Koenen et al. 1996). Boat-tailed grackles (Quiscalus mexicanus) and double-crested cormorants (Phalacrocorax auritus) were observed nesting on Ralston Island in 1995 (<1% each), but were not included in censuses on the island or along state highway 11.

We found that relative abundance of several Ciconiiform and associated species sighted along state highway 11 mirrored the relative occurrence of those nesting species at Ralston Island in 1995 (Koenen et al. 1996). We identified the cattle egret as the bird most likely observed from 15 May-2 July on state highway 11 at Salt Plains NWR during a year with abundant rainfall.

## LITERATURE CITED

KOENEN, M.K., B.R. WINTON, R.S. SHEPPERD, AND D.M. LESLIE, JR. 1996. Species composition of a Ciconiiform rookery in northcentral Oklahoma. Bulletin of the Oklahoma Ornithological Society 29:3-6.

SHEPPERD, R.S. 1996. White-faced ibises nest at Salt Plains National Wildlife Refuge, Oklahoma. Bulletin of the Oklahoma Ornithological Society 29:1-2.

TALENT, L.G., AND L.A HILL. 1982. Unpublished Report, Salt Plains NWR.

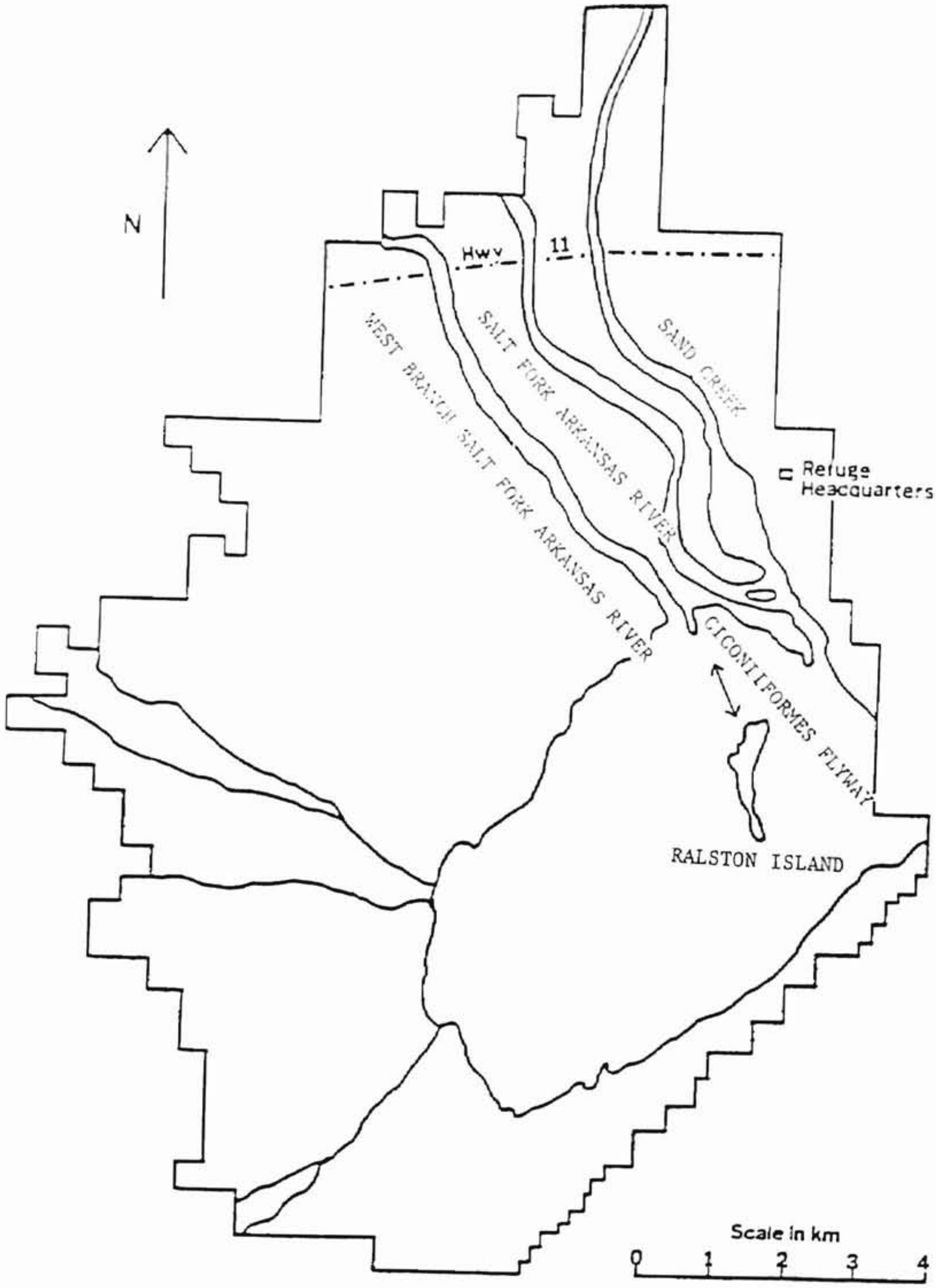


**Fig. 1. The Salt Fork Arkansas River and Sand Creek Ciconiiform flyway from Ralston Island in Great Salt Plains Reservoir to adjacent farmfield and wetlands north outside Salt Plains National Wildlife Refuge, Oklahoma, 1995.**

**VITA**

**Bryan Reno Winton**

**Candidate for Master of Science Degree**

**Thesis:** Breeding Ecology of Great Horned Owls and Barred Owls in Relation to Nesting Interior Least Terns at Salt Plains National Wildlife Refuge, Oklahoma: 1995-1996

**Major:** Environmental Sciences (Zoology)

**Biographical:** Born in Vinita, Oklahoma, on 18 May, 1964. Raised on a farm in Ozark highlands ecoregion in Delaware County, northeastern Oklahoma.

**Education:** High School diploma from Ketchum High School, Ketchum, Oklahoma in May 1982; Associate of Arts degree in Forestry from Northeastern Oklahoma A&M College, Miami, Oklahoma in December, 1985; received Bachelor of Science degree in Wildlife and Fisheries Ecology from Oklahoma State University, Stillwater, Oklahoma in May 1991. Completed the requirements for Master of Science degree in Environmental Sciences at Oklahoma State University in May 1997.

**Professional Experience:** Refuge Operations Specialist, Lower Rio Grande Valley National Wildlife Refuge (9/96-present); Graduate Research Assistant, Department of Zoology, Oklahoma Cooperative Fish and Wildlife Research Unit, Oklahoma State University (1/95-9/96); Lead Biological Technician, Crater Lake National Park, Spotted Owl Census (5/94-8/94); Biological Technician, National Marine Fisheries Service, NOAA, Honolulu, Hawaii, Protected Species Investigation (Hawaiian monk seal research)(2/94-5/94); Biological Technician, National Marine Fisheries Service, NOAA, Honolulu, Hawaii, Marine Turtle Research Program (Green Turtle Fibropapilloma)(2/92-2/94); Scientific Observer, National Marine Fisheries Service, NOAA, Seattle, Washington, High Seas Driftnet Observer (7/91-1/92); Research assistant, Oklahoma Department of Wildlife Conservation, Oklahoma City, Oklahoma, White-tailed deer jaws (11/89 & 11/90). Worked seasonally as a marina mechanic on Grand Lake 'O the Cherokees, Oklahoma (5/78-7/89).

**Military Experience:** United States Marine Corps active (8/85-8/89) and reserve (8/89-8/91); Enlisted noncomissioned officer; Overseas tour (Okinawa): 40 months; Highest rank: E-5 (Sgt) Schools: Combat engineer (active); anti-tank missiles (reserve)

**Professional Organizations:** The Wildlife Society; Southwestern Association of Naturalists; Oklahoma Ornithological Society; National Rifle Association