

## HABITAT REQUIREMENTS AND BREEDING SUCCESS OF CHARADRIIFORM BIRDS NESTING AT SALT PLAINS NATIONAL WILDLIFE REFUGE, OKLAHOMA

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The 4050-ha salt flats on Salt Plains National Wildlife Refuge (NWR) is the largest of several salt flats in northern Oklahoma. Three species of Charadriiform birds, the American Avocet (*Recurvirostra americana*), Snowy Plover (*Charadrius alexandrinus*), and Least Tern (*Sterna albifrons*) nest at Salt Plains NWR. The avocet is widely distributed in the western United States (Bent 1962), but Salt Plains NWR is its only regular nesting site in Oklahoma (Sutton 1967). The plover breeds in small numbers widely across western Oklahoma. The tern is threatened with an estimated 1250 birds breeding primarily along the Mississippi River, and in Nebraska, Oklahoma, and the upper Missouri River drainage (Downing 1980).

Specific information on the habitat requirements for nesting is lacking for inland populations of these species. The objectives of this study were to: (1) determine sizes of breeding populations and their spatial and temporal distributions on Salt Plains NWR, (2) contrast selected nesting habitats with apparent potential nesting habitats to determine the limits of habitat selection during nesting by the species, and (3) quantify reproductive success and identify causes of reproductive loss.

### STUDY AREA

Salt Plains NWR is located in Alfalfa County, Oklahoma, and includes a 4050-ha reservoir, a 4050-ha saline flat west of the reservoir, and 4850 ha of uplands (farm fields, ponds, and marshes). The Quaternary deposits forming the flats are 3-8 m thick and consist of alluvial and lacustrine sediments deposited over an irregular bedrock surface 10,000-50,000 years ago (Johnson 1972). A crust of salt covers the flats, precipitating as water evaporates from the brine solution drawn to the surface by capillary action. The salt crust dissolves with each rain, reappearing as the surface dries.

Three principal freshwater streams enter and flow across the salt flats (Fig. 1). The Salt Fork of the Arkansas River forms the northeastern boundary of the salt flats. Two smaller streams, Clay and Cottonwood creeks, flow west-to-east across the flats and empty into the reservoir. In addition, several intermittent streams flow across the flats after heavy rains. These intermittent streams change their courses often, due to the gradual (0.75-1.50 m/km) slope of the surface, leaving scattered standing pools that may last many weeks. Salinity of water standing and flowing across the flats varies considerably, but Purdue (1976) determined that all free water on the flats exceeds tolerance limits of Snowy Plovers.

Plants occurring on the flats were salt cedar (*Tamarix gallica*) and inland salt grass (*Distichlis stricta*) growing along the banks of upper Clay

Creek and the West Salt Fork, and sea purslane (*Sesuvium verrucosum*) which occurs sparsely along the banks of those streams. The South Cottonwood Creek site was characterized by sparse salt cedar, sedge grasses along the water's edge, and pondweed (*Potamogeton pectinatus*) in some of the pools. No emergent vegetation occurs downstream and runoff flows below ground level.

From 1942 to 1945, the salt flats were used as a gunnery and bombing range by the U.S. Army Air Corps. Remains of target structures, plane wreckage, and other debris occur across the flats. In addition, occasional flooding of the Salt Fork River and Clay and Cottonwood creeks plus temporary rises in the reservoir level have resulted in local concentrations of woody debris on the flats.

#### METHODS

Field studies were conducted 29 April through 20 July 1977, and 1 May through 7 August 1978. One-hundred-thirty-two man-days were spent in the field in 1977, and 158 in 1978.

We surveyed the flats biweekly for birds and nests by systematically scanning the area with a 20× spotting scope or 7× binoculars. Nest locations were plotted on a detailed map of the flats. Following cessation of nesting activities, we measured the distance from each site to the nearest body of water, the nearest nest of any species, and to the nearest nest of the same species. We also noted whether the nest was near driftwood, fenceposts, or discarded refuse. To determine whether debris abundance was related to distance from the lake shore, we walked six transects from the edge of the flats to the shore, measuring the distance to the nearest piece of debris at sample points every 80 m.

To quantify preference by birds for nest sites near debris, before the 1978 nesting season we established six 50 × 100 m plots in an area heavily used for nesting in 1977, and altered concentrations of debris within the plots. We arranged the plots in a 3 × 2 grid, using 3 replicates (blocks) of 2 treatments (no debris vs. twice-normal concentrations of debris). Blocks were arranged to reduce variation due to a stream flowing through the area.

To test whether nests were selectively located near water, we determined a mean distance to water from randomly selected points on the salt flats. All bodies of water were plotted on a map of the salt flats overlaid by a grid of 3600 squares. Intersections on the grid were numbered, and we chose 180 using a random numbers table. Distances from the randomly chosen points to water were measured on the map and converted to the actual scale of the flats. The mean distance from 180 nest sites to water was then compared to the mean distance from the 180 random points to water.

Food items were collected and identified to determine feeding habits of the nesting birds. A 12.5 cm diameter plankton net was towed in streams flowing through the salt flats, and a sweep net was used to collect flying insects inhabiting the stream edges. We also collected burrowing

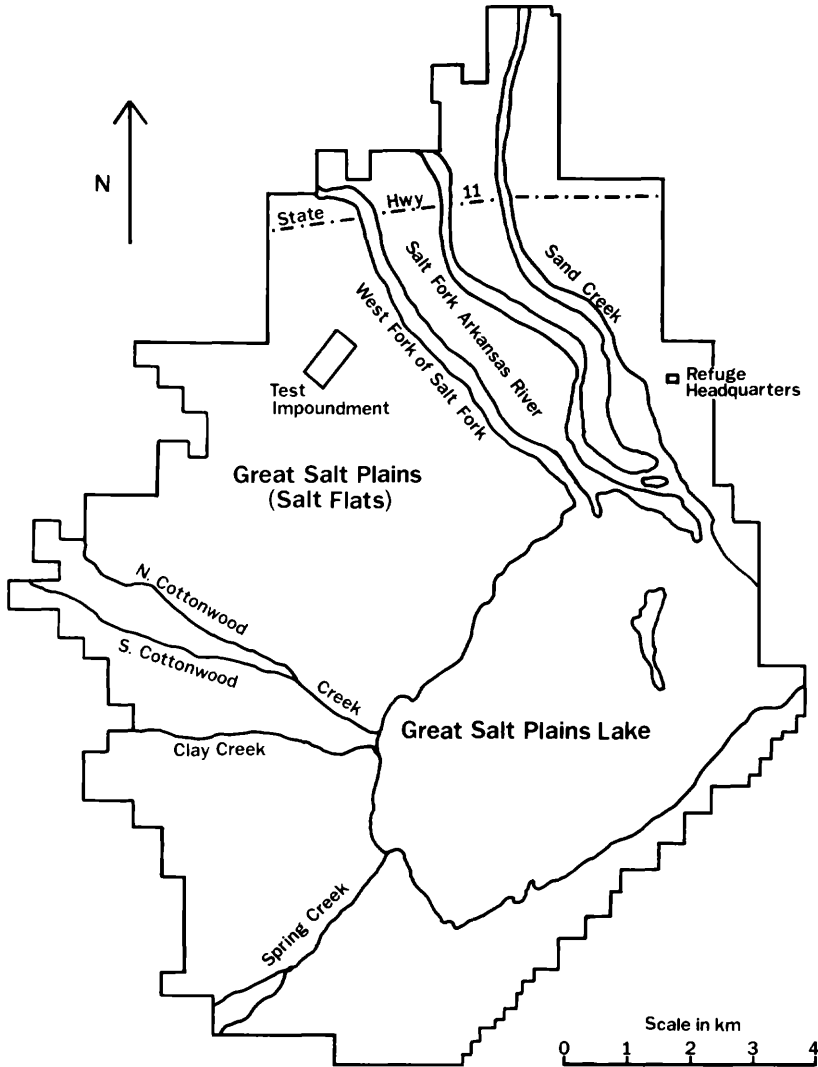


FIGURE 1. Salt Plains National Wildlife Refuge showing the locations of Great Salt Plains Lake, inflow streams, and the salt flats.

insects in areas where plovers were observed foraging, and small fish dropped by terns. These data were supplemented by direct observations of feeding birds.

Nest sites ( $n = 183$ ) were marked with 30 cm stakes and intensively monitored each season. Stakes were placed about 1 m from a nest, and sprayed with fluorescent orange paint. Each nest was examined at 1-3

day intervals and its status recorded until time of hatching or failure. In addition, 6 time-lapse (8 mm) cameras recorded activities at 6 selected nest sites each season. The cameras, placed about 10 m from nests, were set to expose one frame/min continuously from early incubation to hatching.

#### RESULTS

*Population sizes and breeding distribution.*—Active nests of plovers and terns were found on the flats from 24 May to 20 July 1977. In 1978 a Snowy Plover nest with a complete clutch of 3 eggs was found at the north edge of the flats on 4 May. The earliest plover chicks were observed 24 May 1978 along Clay Creek in the southern half of the flats. The first Least Tern nest observed in 1978 contained a complete clutch of eggs on 23 May. Active nests (with eggs or young) of all three species were observed last on 6 August 1978.

Direct counts of adult birds indicated minimum numbers of breeding pairs on the Great Salt Plains in 1977 and 1978, respectively, as: Least Tern 80, 135; Snowy Plover 325, 260; and American Avocet 46, 53.

*Factors influencing nest distribution.*—Each species nested only in the nonvegetated areas of the flats. Periodic searches of vegetated sites each year revealed only one abandoned avocet nest of unknown age in a small clump of inland salt grass on the flat periphery.

Nests of each species occurred in a clumped distribution near either inflow streams or standing bodies of water present at the time of nest initiation. Nests were located along Clay Creek, Cottonwood Creek, and the west branch of the Salt Fork of the Arkansas River, where those streams flow across the flats, along the old road running northwest from the Corps of Engineers' test impoundment, and in the area surrounding the intermittent stream which, after heavy rains, flows parallel to and about 0.5 km south of Clay Creek. During 1978, areas of nesting were farther upstream than in 1977.

Mean distances to nearest nest of any species were  $49.9 \pm 46.0$  m for the tern,  $80.9 \pm 103.8$  m for the plover, and  $75.1 \pm 65.8$  m for the avocet; mean distances to the nearest nest of the same species, respectively, were  $69.5 \pm 62.2$  m,  $100.8 \pm 108.9$  m, and  $140.9 \pm 103.1$  m (Table 1). These data indicate great variability in nest spacing and an overlap in nesting areas.

The mean distance to water from 180 nest sites of avocets, terns, and plovers in 1977 and 1978 was  $129.2 \pm 173.2$  m (Table 1). The mean distance to water from 180 randomly selected points on the flats was  $616.0 \pm 533.9$  m. The difference in mean distances was significant ( $t$  (adjusted) = 11.6,  $P < 0.001$ ).

Debris was widely distributed on the flats. All three species showed a tendency to nest near debris; 63.2% of all nests were within 5 cm of debris (Table 2). Where debris was subjectively judged to be abundant, however, 85.7% of the nests were within 5 cm of debris.

The abundance of debris on the salt flats was independent of distance

TABLE 1. Distance from nests of Snowy Plovers, Least Terns, and American Avocets to nearest water and to other nests on Salt Plains NWR during 1977-1978.

Distance (m)	American Avocet			Snowy Plover			Least Tern		
	n	Range	$\bar{x}$ SD	n	Range	$\bar{x}$ SD	n	Range	$\bar{x}$ SD
Nest of any species									
1977	23	16-300	75.1 ± 66.6	49	5-800	93.4 ± 129.3	27	5-250	56.0 ± 55.1
1978				35	10-230	63.3 ± 46.7	41	3-190	45.8 ± 39.4
Nest of same species									
1977	22	25-310	140.9 ± 103.1	47	7-800	114.4 ± 132.6	25	20-250	59.2 ± 48.0
1978				31	29-250	80.2 ± 52.2	40	3-300	76.0 ± 69.5
Water									
1977	23	3-300	60.4 ± 75.8	50	7-1500	113.5 ± 221.8	28	3-580	146.1 ± 171.8
1978				36	3-1150	195.9 ± 317.1	42	2-730	110.5 ± 133.7

TABLE 2. Percentages of nests of American Avocets, Snowy Plovers, and Least Terns associated with debris in 1977 and 1978.

Species	n	Nests within 5 cm of debris	Nest not within 5 cm of debris, although debris abundant in area	Nests in debris-free areas
American Avocet	23	56.5	8.7	34.8
Snowy Plover	93	67.7	16.1	16.1
Least Tern	66	59.1	13.6	27.3

from the lake shore. Analyses of debris data revealed inconsistent regression coefficients (2 positive, 3 negative) and low coefficients of determination (0.0–0.4) between distance from shore and debris density.

Response of birds to the experimental debris plots was poor because heavy rains and flooding of Cottonwood Creek caused most birds to nest farther upstream in 1978. Twenty-two nest scrapes (18 plovers, 3 terns, 1 avocet) were found within the debris plots, although ultimately eggs were laid in only 9. Ten scrapes were found in plots containing no debris and 12 were found in plots containing 2× normal concentrations of debris. The difference in response to the two treatments was not significant ( $F = 0.116$ ,  $P > 0.05$ ). Three of the nests containing eggs were in non-debris plots and 6 nests with eggs were in the plots with 2× normal concentrations of debris.

Each species foraged on the salt flats, in the streams, or along the lake shore bounding the flats on the east. Birds were not observed outside the salt flats area while actively engaged in nesting.

Potential food for the nesting birds appeared abundant in the streams and on the salt flats. A 20 m tow with the plankton net yielded many water boatmen (Family Corixidae). These small insects were the most abundant inhabitants of Clay and Cottonwood creeks; numbers of other invertebrates were insignificant in comparison. Although the two creeks were sampled from the edge of the salt flats to the lake shore, the only other invertebrates netted were 3 small nematodes and one unidentified larval insect. Observations of foraging birds suggested that water boatmen made up the bulk of the American Avocet's diet.

*Bledius*, a burrowing beetle, is distributed widely on the salt flats. Snowy Plovers were commonly seen running from burrow to burrow, stopping at each one briefly to probe. We also collected shore flies, mainly of the genus *Ephydra*, along stream edges. Snowy Plovers were observed running through the dense aggregations of flies at the water's edge and capturing one or more flies before repeating the behavior a few seconds later. Plovers and avocets also were observed feeding on lepidopterans, grasshoppers, or large beetles that were blown onto the flats from surrounding vegetated areas.

Least Terns at the Great Salt Plains captured small fish. The terns

foraged along Clay and Cottonwood creeks, the Salt Fork River, and the lake shore east of the flats. Fish collected where terns had dropped them belonged to three species: the Arkansas River shiner (*Notropis girardi*), the plains killifish (*fundulus kansae*), and the mosquitofish (*Gambusia affinis*).

*Reproductive success and causes of nest failure.*—In 1977, nests of 23 American Avocets, 28 Least Terns, and 52 Snowy Plovers were marked and monitored. Nests of one avocet, 42 Least Terns, and 37 plovers were similarly monitored in 1978.

Success of nests during 1977 averaged 72.8% for the 3 species combined (Table 3). In 1978 the combined success of nests was only 26.3%. The difference in reproductive success was significant between years (arcsine transformation,  $t = 12.9$ ,  $P < 0.001$ ; Sokal and Rohlf 1969:608).

Coyote (*Canis latrans*) predation accounted for 15 of 26 (57.7%) observed nest failures in 1977, and 20 of 61 (32.8%) in 1978. Coyote predation was easily detected by tracks on the flats, or claw marks, egg yolk and coyote scat at the nest site. Coyote predation appeared to be greater near the edges of the flats, but tracks were found throughout the flats and some coyote predation occurred in all areas where birds nested. Observations of sign were supplemented by a time-lapse movie camera that recorded a coyote eating two of three eggs in a Least Tern nest.

Flooding was also a major cause of reproductive failure. In 1977, flooding was responsible for 11 of 26 (42.3%) nest failures. In 1978, flooding was the major factor limiting reproductive success, causing 41 of 61 (67.2%) nest failures. Heavy rains and the resultant flooding of the salt flats on the night of 31 May 1978 destroyed all nests (about 100 plover, 30 tern, and 10 avocet nests) active at that time. Besides destroying the nests, the storm also reduced the population of adult Snowy Plovers. Eighteen plovers were found dead (presumably killed by hail) following the storm.

Other causes of reproductive losses during 1977 and 1978 included eggs being displaced from a nest, abandonment of one or more eggs, and chicks dying from disease, starvation, or exposure. In 4 instances of abandonment, the egg became encrusted with salt and stuck to the substrate, apparently preventing turning by the adult during incubation.

#### DISCUSSION

*Population sizes.*—In his ground and aerial survey in 1975, Downing (1980) estimated 50 Least Terns nesting on sandbars and salt flats along the Arkansas River. This estimate was based on 32 birds actually seen, and Downing stated that the flats at Salt Plains NWR, and at Quivera NWR in Kansas, were the principal tern nesting habitats along the river. We counted minimum populations of 160 and 270 terns nesting on Salt Plains NWR in 1977 and 1978, respectively, and believe that Downing's estimates were substantially below current population levels on the Arkansas River watershed. The discrepancy in population estimates could

TABLE 3. Percentages of successful nests (at least one chick hatched) of the American Avocet, Snowy Plover, and Least Tern during 1977–1978, Salt Plains NWR, Oklahoma.

Species	Year	No. nests monitored	No. successful nests (%)
Snowy Plover	1977	52	38 (73.1)
	1978	37	14 (37.6)
Least Tern	1977	28	18 (64.3)
	1978	42	7 (16.7)
American Avocet	1977	23	19 (82.6)
	1978	1	0 (0.0)

be due to either Downing's coverage of a large area rapidly, or to an increase in tern populations since 1975.

Numbers of Least Terns and American Avocets nesting at Salt Plains NWR increased in 1978. This increase may be attributable to high nesting success in 1977. The smaller Snowy Plover population in 1978 is due, at least in part, to the mortalities suffered by adult plovers during the storm of 31 May 1978.

*Factors influencing distribution of nests.*—Indistinct factors as terrain and landscape comprise proximate factors for habitat selection by birds (Hilden 1965). Visual cues associated with these factors are often obscure (Klopfer and Hailman 1965). Even in the simplistic, relatively unstructured habitat of the salt flats, cues for the settling response are unclear. The only apparent features breaking the expansiveness of the flats were pieces of debris and the streams.

The distribution of debris across the salt flats was relatively uniform. The clustering of nests on upper ends of inflow streams was not a response to different debris densities there. Concentrations of debris occurred locally on stream banks. Birds nested in these areas but showed no preference for the debris-free or twice-normal debris densities.

Foraging coyotes tend to follow lines of washed-up debris, possibly indicating a disadvantage for birds nesting near debris. However, only 58.3% of coyote predations were at nests near debris—not different from the 55.2% of nests located near debris.

Although plover nests occurred up to 1.5 km from water, most nests of the 3 species were near water. Streams appeared to be strong cues eliciting the settling reaction when birds selected nest sites.

Nests occurred farther upstream in 1977 than 1978, apparently a result of the heavy rainfalls early in the nesting season. The creek channels were deeper in their upper reaches, therefore the bordering flats probably dried sooner after flooding. Thus, suitable nesting or re-nesting habitat was first available along the streams' upper reaches.

Ultimate factors in habitat selection include food, requirements imposed by structural and functional characteristics of the species, and



shelter from enemies and weather (Hilden 1965). The freshwater inflow streams constitute ultimate factors for nesting shorebirds on the flats. All food sources exploited by the shorebirds were available on the salt flats, especially near or in the streams. The Snowy Plover's use of inflow streams for thermoregulation (Purdue 1976) might also be considered "shelter" from adverse weather.

Niche segregation relative to feeding among the nesting shorebirds was well defined on the salt flats. Each species had its own discrete food sources; although American Avocets and Snowy Plovers both fed on the abundant, localized water boatmen. Plover-avocet competition for this food item on the salt flats was likely nonexistent. Baker (1977) determined that relaxed competition in an environment of abundant resources may explain high niche overlap in 10 arctic shorebird species, and this explanation seems accurate with the Snowy Plover and American Avocet at the refuge. Baker and Baker (1973) found broader niche overlap in summer than in winter in 6 shorebird species, reflecting synchronization of reproduction with abundant food at the breeding grounds. Hilden (1965) suggested that birds, often unspecialized in diet, tend to exploit whatever food is available when the habitat is selected on the basis of other criteria.

*Reproductive success and causes of nest failure.*—Reproductive success during the 1977 nesting season was higher than in 1978, due to more favorable weather conditions. However, impacts of the 31 May 1978 storm on reproduction of the three species appeared buffered by re-nesting. Coyote predation appeared constant between years, and weather conditions during incubation and early nesting seem to be the principal factors determining nesting success in a given year.

#### SUMMARY

Habitat requirements and breeding ecology of the American Avocets, Least Terns, and Snowy Plovers were studied on the flats of the Salt Plains National Wildlife Refuge, northwestern Oklahoma. Direct counts of adult birds revealed 46 pairs of American Avocets, 80 pairs of Least Terns, and 325 pairs of Snowy Plovers breeding on the salt flats in 1977. Population sizes during 1978 were 53, 135, and 260 pairs, respectively, for the 3 species. A total of 183 nests of Snowy Plovers, Least Terns, and avocets were marked and their progress monitored. Measurements of environmental variables near the nest sites revealed that all 3 species nested in clumped distributions near streams or standing bodies of water, independent of woody debris or other discernible structuring of the flats. Food sources exploited by the birds included terrestrial and aquatic insects and small fish inhabiting the streams. All foods exploited by the birds occurred on the salt flats proper; most food species were associated with the freshwater inflow streams. The streams were essential proximate and ultimate components of the nesting habitats of these 3 species.

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