HABITAT REQUIREMENTS OF CHARADRIIFORM BIRDS NESTING ON SALT FLATS AT SALT PLAINS NATIONAL WILDLIFE REFUGE

By

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ACKNOWLEDGMENTS

The purposes of this study were to describe habitat requirements and breeding ecology of the American avocet, inland least tern, and snowy plover on the salt flats of the Salt Plains National Wildlife Refuge, northwestern Oklahoma. Field studies were conducted during the summers of 1977 and 1978.

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INTRODUCTION

The 4,050 ha salt flats on the Salt Plains National Wildlife Refuge (NWR) is the largest of several salt flats in Oklahoma. Three species of Charadriiform birds, the snowy plover (Charadrius alexandrinus), American avocet (Recurvirostra americana), and inland least tern (Sterna albifrons athalassos) traditionally use the Salt Plains NWR as breeding grounds.

Although the American avocet is widely distributed in the western United States (Bent 1962), the Salt Plains NWR is its only regular nesting site in Oklahoma. The snowy plover, however, also breeds on salt flats in Woods County and in smaller numbers and less regularly on broad, sandy river beds or barren shores of large impoundments in western Oklahoma (Sutton 1967). The inland least tern may be endangered throughout its continental range. During 1975, an estimated 1,250 least terns were nesting along streams and on salt flats between Tennessee, New Mexico and Nebraska (Downing 1975).

The salt flats on Salt Plains NWR may be subject to habitat alteration by the proposed Arkansas-Red River Basin Chloride Control Project of the U.S. Army Corps of Engineers. The Corps project has been recommended to control salinity levels in the Arkansas River, and the Great Salt Plains has been identified as 1 of 5 major salt sources in southwestern Kansas and northwestern Oklahoma.

Specific information on habitat requirements for nesting is lacking

for the snowy plover, American avocet and inland least tern. The purpose of this study was to provide baseline, descriptive information about nesting activities of the birds on the salt flats. The specific 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, 3) quantitate reproductive success and apportion reproductive failure to appropriate factors, and 4) define probable impacts of the proposed Chloride Control Program on the breeding habitats of these species.

STUDY AREA

The Salt Plains NWR is located in Alfalfa County, Oklahoma, and includes a 4,050 ha reservoir and 4,850 ha of upland habitat, farm fields, ponds and marshes. The remaining 4,050 ha are a vast, saline flat lying west of the reservoir (Fig. 1). The Quaternary deposits forming the salt 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 thin crust of salt covers the flats, being precipitated as water evaporates from the brine solution drawn to the surface by capillary action. The salt crust is dissolved with each rain, reappearing as the surface dries and more salt precipitates. The brine in the bedrock aquifers and Quaternary sediments has a sodium chloride content ranging from 150-250 g/kg of brine. Other ions occurring in significant concentrations are calcium (0.15 g/kg), magnesium (0.1 g/kg), and sulphate (0.7 g/kg) (Johnson 1972).

Three principal streams flow through the salt flats (Fig. 1). The Salt Fork of the Arkansas River forms the northeastern boundary of the salt flats. Two smaller streams, Clay Creek and Cottonwood Creek, flow west-to-east across the flats and empty into the reservoir. In addition, several intermittant streams flow across the flats following heavy rains. These intermittant streams change their courses often, due to the gradual (0.75-1.50 m/km) slope of the surface, leaving

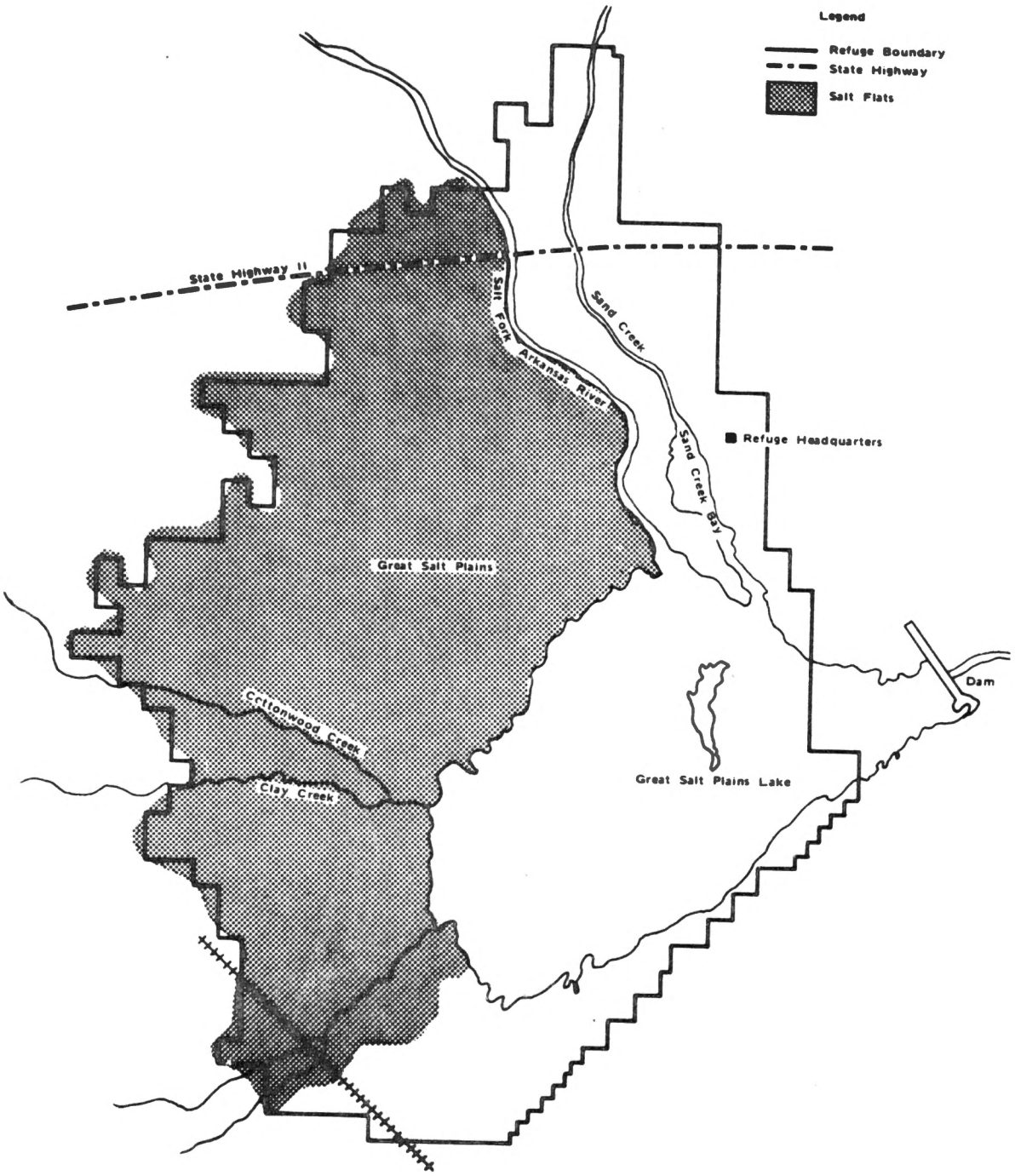

Fig. 1. Salt Plains National Wildlife Refuge showing locations of salt flats and inflow streams.

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.

The only plants occurring on the flats are salt cedar (Tamarix gallica) and inland salt grass (Distichlis stricta) that grow along the banks of upper Clay Creek, and sea purslane (Sesuvium verrocosum), an endangered plant species. The latter species is a small succulent that occurs sparsely along the banks of the Salt Fork River and Clay Creek.

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

METHODS AND MATERIALS

Field studies were initiated 29 April and continued through 20 July 1977. In 1978, fieldwork began 1 May and continued through 7 August. Sixty-six days were spent in the field in 1977, and 79 days during 1978.

Population Sizes and Breeding Distribution

Upon first observation, the salt flats on the refuge appear exceptionally unstructured. However, comments from refuge personnel indicated that population densities of birds were not uniform over the flats. Due to the initial inability to define subunits of the salt flats constituting homogenous habitats for nesting, indexing methodologies for determining population sizes were not feasible. Direct, observational censuses of the birds, therefore, were utilized to determine absolute minimum numbers of breeding birds.

Bi-weekly counts of breeding birds were made by systematically scanning portions of the salt flats with a 20X field telescope or 7X binoculars. I assumed that all adults were paired, and population sizes were thus determined by direct counts of adult birds. The surveys were conducted in the manner of a Christmas bird count, i.e., all birds seen were counted, with none being counted twice.

Factors Influencing Nest Dispersion

All nest sites located were plotted on a large map of the salt

flats. Gross environmental features, also plotted on the maps, could thus be compared with locations of nesting areas.

Upon cessation of nesting activities, each nest site was examined and environmental parameters in the vicinity were measured. For each nest, I measured distance to the nearest body of water, to the nearest nest of any species, and to the nearest nest of the same species. Also noted was whether or not the nest was associated with any debris. To determine whether debris abundance was related to distance from the lake shore, 6 transects were walked across the salt flats from the edge of the flats to the lake shore. Distance to the nearest piece of debris was measured at sampling points every 80 m along the transects.

To quantify further any preference by birds for nest sites near debris, prior to the 1978 nesting season, 6 50 X 100 m plots were established in an area heavily utilized for nesting in 1977, and concentrations of debris within the plots were altered (Fig. 2). The plots were arranged in a 3 X 2 grid, using 3 replicates (blocks) of 2 treatments (no debris vs. 2 X normal concentrations of debris). Blocks were arranged to minimize variation due to a stream flowing through the area.

To test whether nests were selectively located near water, I 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 comprising 3,600 squares. Intersections on the grid were numbered, and 180 were chosen 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 salt flats. The mean

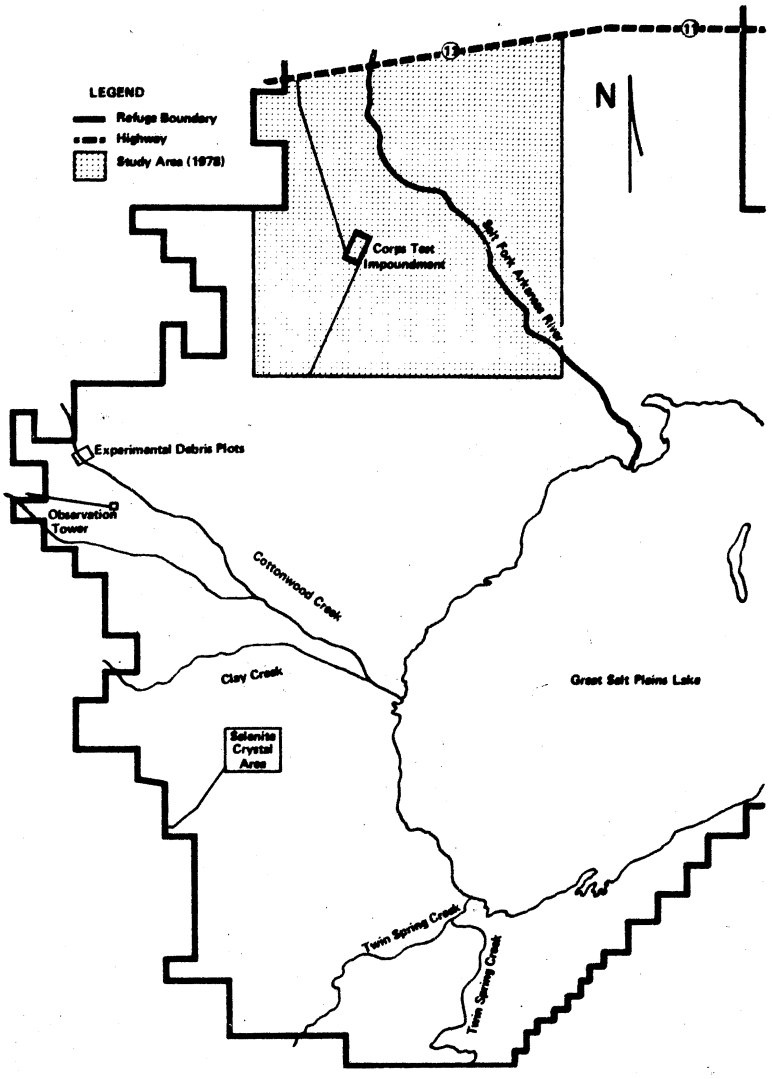

Fig. 2. Locations of experimental debris plots and 1978 study area.

distance to water from 180 actual nest sites was then compared statistically with the mean distance to water from the 180 random points.

Items utilized as food were collected and identified to document feeding habits of the nesting birds. Streams flowing through the salt flats were seined using a 12.5 cm diameter plankton net, and flying insects inhabiting the stream edges were collected using a sweep net. I also collected burrowing insects used by the snowy plovers, and small fish dropped by terns. These data were supplemented by direct observations of feeding birds.

Reproductive Success and Causes of Nest Failure

Nest sites to be monitored intensively were marked with 30 cm stakes and numbered consecutively each season. Stakes were placed about 1 m from a nest, and sprayed with fluorescent orange paint. Locations of all nests marked were plotted on maps of the salt flats. Each nest was examined at intervals of 1-3 days and its progress monitored until time of hatching or failure.

In addition, 6 time-lapse (8 mm) cameras recorded activities at 6 selected nest sites. The cameras were set to expose 1 frame/minute continuously from early incubation to hatching of the eggs.

Cases of nest failure encountered at unmarked nests were recorded to supplement data from marked nests. I also noted cases of mortality of adult birds on the flats during the nesting season.

Evaluation of Impacts of the
Chloride Control Program

I attended public meetings of the Corps of Engineers' Arkansas-Red River Basins Chloride Control Project and consulted with personnel from the U.S. Fish and Wildlife Service's Office of Ecological Services to keep abreast of the alternative plans for the desalinization project. These plans were then evaluated relative to their potential impacts on habitats used by the breeding birds for nesting and feeding. In addition, I evaluated possible mitigatory measures suggested by Ecological Services to offset habitat alteration as a result of the Corps project.

RESULTS

Population Sizes and Breeding Distribution

Active nests of plovers and terns were observed on the flats from 24 May-20 July 1977. In 1978 a snowy plover nest with a complete clutch of 3 eggs was observed in the northern reaches of the salt flats on 4 May. The first plover chicks of the season 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 of all 3 species were observed last on 6 August 1978.

Direct counts of adult birds revealed the following minimum numbers of breeding pairs on the Great Salt Plains in 1977 and 1978, respectively: least turn 80, 135; snowy plover 325, 260; American avocet 46, 53. The figures represent numbers of pairs engaged in breeding activities at the peaks of the respective nesting seasons.

Factors Influencing Nest Dispersion

Each species nested only in the nonvegetated areas of the salt flats. Periodic searches of vegetated sites each year revealed only 1 abandoned avocet nest of unknown age in a small clump of inland salt grass on the flat periphery.

Nests of all 3 birds occurred in a clumped distribution near either inflow streams or standing bodies of water present at the time of nest initiation (Fig. 3). Nest sites were located along Clay Creek,

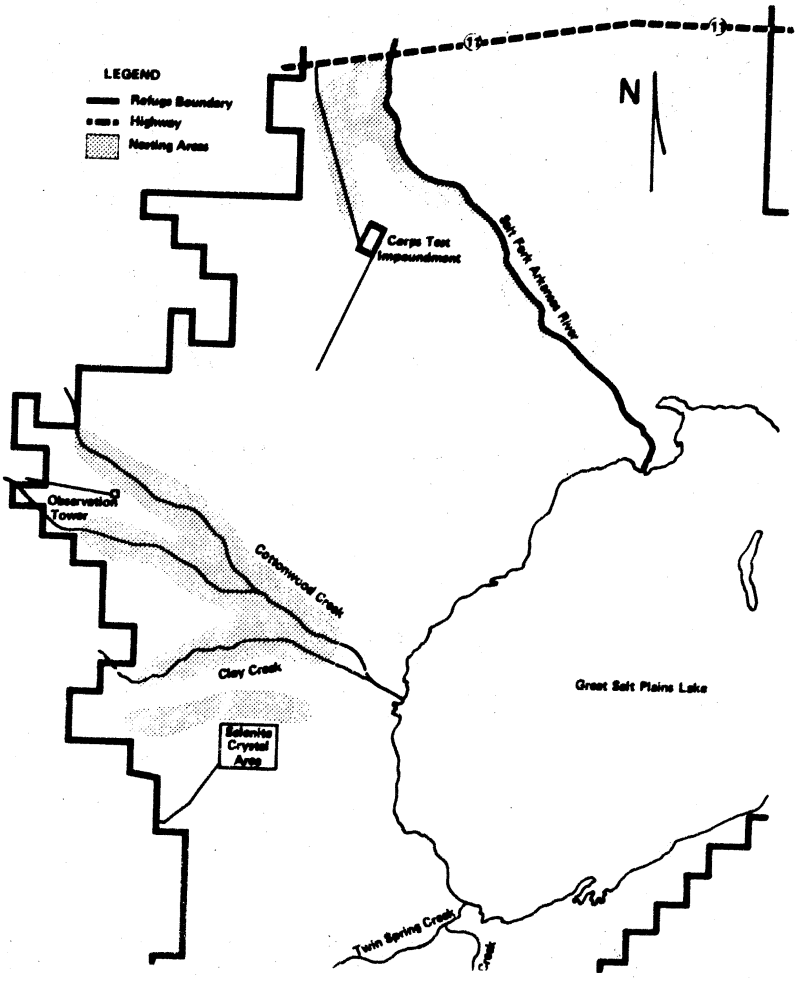

Fig. 3. Areas on the salt flats utilized by nesting shorebirds.

Cottonwood Creek, and the Salt Fork of the Arkansas River where those streams flow across the flats, the old road running northwest from the Corps of Engineers' test impoundment, and the area surrounding an intermittant stream which, after heavy rains, flows parallel to and about .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 for the least tern, snowy plover, and American avocet were 49.9 $\pm$ 46.1 m, 80.9 $\pm$ 103.8 m, and 75.1 $\pm$ 65.8 m, respectively. 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 an overlap in nesting areas and intermixing of species within breeding areas.

The mean distance to water from 180 nest sites of avocets, terns and plovers under intensive monitoring 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 = 11.6, P < 0.001).

Debris items (driftwood, fence posts, discarded refuse, etc.) were widely distributed on the flats. All 3 bird species showed a tendency to nest near debris items, with 63.2% of all nests being associated with (within 5 cm of) debris (Table 2). Where debris was subjectively judged to be abundant, however, 85.7% of the nests were associated with debris.

The abundance of debris on the salt flats was independent of distance from the lake shore. Linear regression and correlation analyses of debris-transect (Fig. 4) data revealed inconsistent regression coefficients and low coefficients of determination between

Table 1. Distance from nest to nearest water and to other nests for snowy plovers, least terns, and American avocets on Salt Plains NWR during 1977-1978.

Measurement	American avocet			Snowy plover			Least tern		
	N	Range	$\bar{X} \pm$ SD	N	Range	$\bar{X} \pm$ SD	N	Range	$\bar{X} \pm$ SD
Distance to nearest nest (any species) (m)									
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
Distance to nearest nest (same species) (m)									
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
Distance to nearest water (m)									
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 near debris	Nests not near debris, although debris abundant	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
Total	182	63.2	14.3	22.5

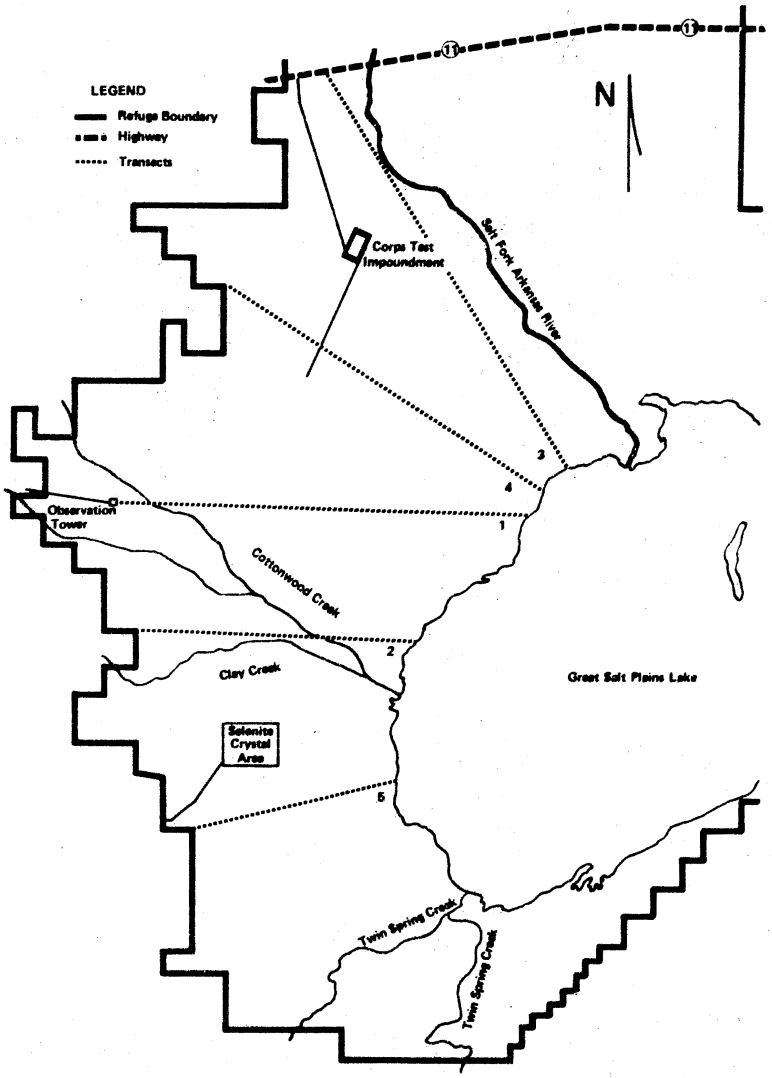

Fig. 4. Locations of debris transects walked across the salt flats.

the independent variable (distance from shore) and the dependent variable (debris density) (Table 3). Regression coefficients were positive for 3 transects and negative for 2. Correlation coefficients were positive for 2 transects and negative for 3, with coefficients of determination ranging from 0.000-0.361.

Response of birds to the experimental debris plots was relatively poor, because heavy rains and flooding of Cottonwood Creek caused most birds to nest farther upstream in 1978. Twenty-two nest scrapes (nest initiations) 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 2X normal concentrations of debris (Fig. 5). The difference in response to the 2 treatments was not significant ($F = 0.116$, $P > .05$). Three of the nests containing eggs were located in nondebris plots and 6 in the plots with supernormal concentrations of debris. The heavy rainfalls and the resultant flooding of the salt flats on the night of 31 May washed debris into some debris-free plots. Although I removed the debris from these plots as soon as weather conditions permitted, the debris had remained in the plots for 3 days following the flooding, and may have biased these results.

Each species was observed foraging only on the salt flats or along the lake shore bounding the flats on the east. Birds were never observed outside the salt flats area while actively engaged in nesting.

Potential food items for the nesting birds appeared abundant in the streams and on the salt flats. A 20 m sweep with the plankton net yielded hundreds of water boatmen (Family Corixidae). These small insects were the most abundant inhabitants of Clay and Cottonwood

Table 3. Slope coefficients (b_1) of linear regression analysis and coefficients of determination (R^2) for 5 debris transects on Great Salt Plains.

Transect	Slope coefficient (b_1)	Coefficient of determination (R^2)
1	.202	.361
2	.008	.00003
3	-.289	.065
4	-.386	.128
5	.175	.148

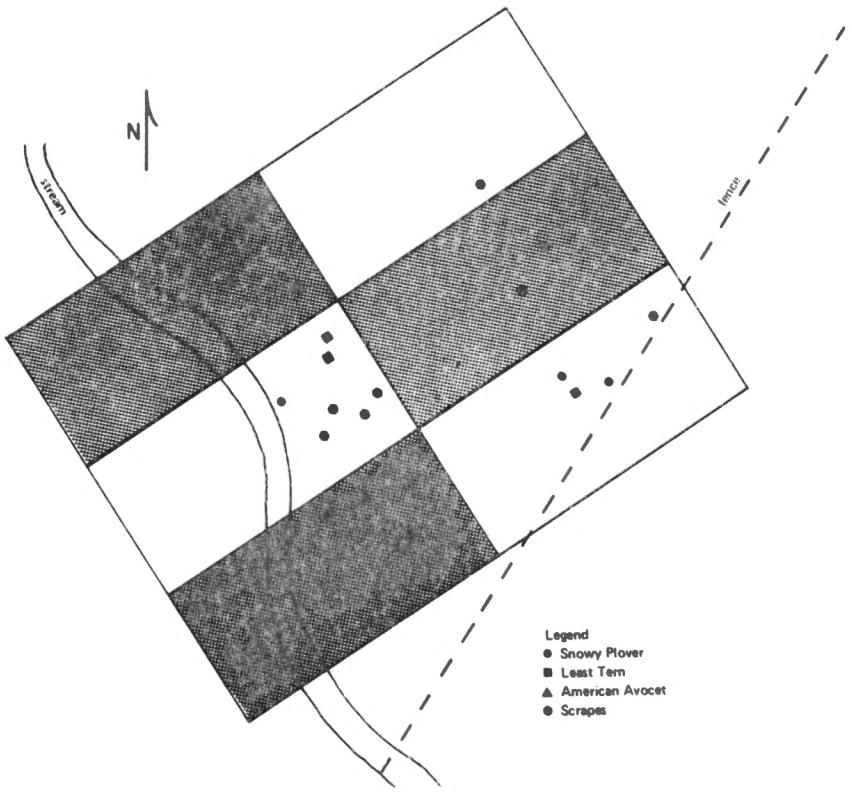

Fig. 5. Locations of nests within experimental debris plots. (No debris, shaded, vs. 2X normal concentration of debris.)

creeks; numbers of other invertebrates were insignificant in comparison. Although the 2 creeks were seined thoroughly from the edge of the salt flats to the lake shore, the only other invertebrates netted were 3 small nematodes and 1 unidentified larval insect. Observations of foraging birds indicated that water boatmen comprised the bulk of the American avocet's diet.

Bledius, a burrowing beetle of the family Staphylinidae, is distributed widely on the salt flats. Snowy plovers were commonly seen running from burrow to burrow, stopping at each 1 briefly to probe for its inhabitant. Also collected were shore flies, mainly of the genus Ephydra, that inhabit the stream edges. Snowy plovers were often observed running through the dense aggregations of flies at the water's edge and capturing 1 or more flies before repeating the behavior a few seconds later. Plovers and avocets were also occasionally observed feeding on larger insects such as lepidopterans, grasshoppers, or large beetles that were blown onto the flats from surrounding vegetated areas.

Least terns at the Great Salt Plains were observed capturing and carrying small fish. The terns foraged along Clay and Cottonwood creeks, the Salt Fork River, and along the lake shore on the east side of the salt flats. Fish collected on the salt flats where the terns had dropped them belonged to 3 species: the Arkansas River shiner (Notropis girardi), the plains killifish (Fundulus kansae), and the mosquitofish (Gambusia affinis).

Reproductive Success and Causes of Nest Failure

During 1977, 23 American avocet nests, 28 least tern nests, and 53 snowy plover nests were marked and monitored (Fig. 6). One avocet

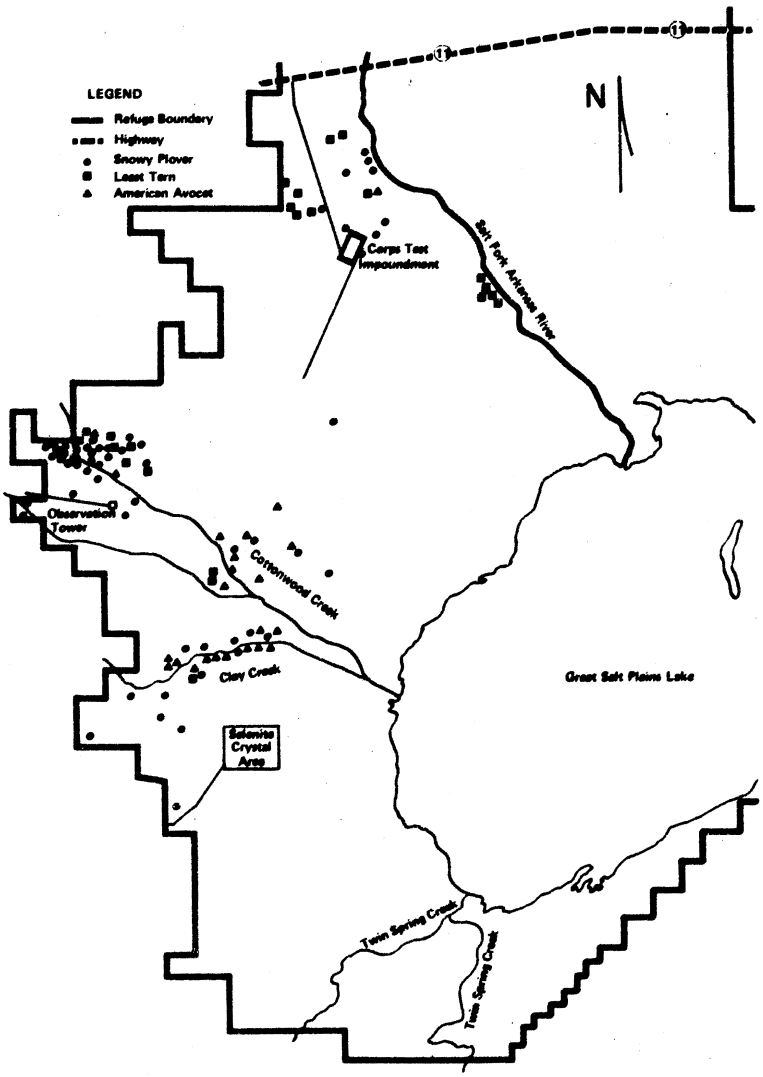

Fig. 6. Locations of nests monitored in 1977.

nest, 42 least tern nests and 37 plover nests were so treated during the 1978 season (Fig. 7).

Success of nests monitored during 1977 averaged 72.8% for the 3 species combined (Table 4). In 1978 the combined success of all nests under observation was only 26.3%. The difference in reproductive success was found to be significant between years (arcsine transformation, t = 12.9, $P < .0001$; Sokal and Rohlf 1969:608).

A major cause of nest failure was coyote (Canis latrans) predation, which accounted for 15 of 39 (38.5%) observed cases of nest failure in 1977, and 20 of 80 (25.0%) in 1978 (Table 5). Incidences of coyote predation were easily determined by observing the tracks left by the foraging coyote, or claw marks and egg yolk at the nest site. Coyote predation appeared to be greater near the edges of the salt flats, but tracks were found throughout the flats and some coyote predation occurred in all areas where birds nested. These observations were supplemented by a time-lapse movie camera that recorded a coyote as it ate 2 of 3 eggs in a least tern nest. The coyote left, leaving the 3rd egg in the nest untouched.

Flooding of the nesting areas was also a major cause of reproductive failure. In 1977, flooding was responsible for 11 of 39 (28.2%) nest failures. In 1978, flooding was the major factor limiting reproductive success, causing 41 of 80 (51.3%) nest failures. Heavy rains and the resultant flooding of the salt flats on the night of 31 May 1978 destroyed all nests (approximately 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 snowy plovers were found dead (presumably killed by hail) following the storm.

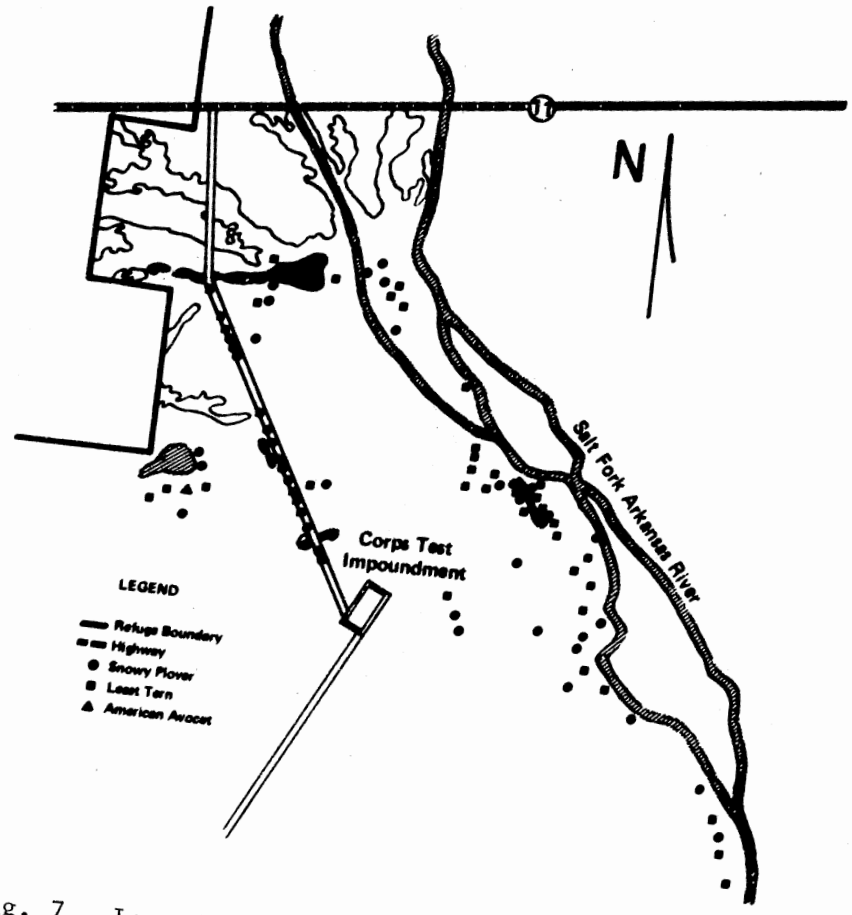

Fig. 7. Locations of nests monitored in 1978.

Table 4. Percentages of successful nests for the American avocet, snowy plover and least tern during 1977-1978.

		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	9 (0.0)
Totals	1977	103	75 (72.8)
	1978	80	21 (26.3)

Table 5. Causes of 119 recorded cases of nest failure of least tern, American avocet and snowy plover during 1977-1978.

	Year	N	%
Coyote predation	1977	15	38.5
	1978	20	25.0
Flooding	1977	11	28.2
	1978	41	51.3
Eggs blown from nest	1977	0	0.0
	1978	9	11.3
Eggs abandoned (unknown reason)	1977	8	20.5
	1978	8	10.0
Eggs abandoned (stuck to salt)	1977	2	5.1
	1978	2	2.5
Chicks dead from heat	1977	3	7.7
	1978	0	0.0

Necropsies performed on 7 of the birds revealed 4 were males and 3 were females.

Other causes of reproductive failure during 1977 and 1978 included high winds blowing eggs from the nest, abandonment of nests, and chicks dying from esposure to the intense heat (Table 5). In some cases of abandonment, the eggs within the nest had become encrusted with salt and stuck to the substrate, preventing turning by the adult during incubation.

DISCUSSION

Nesting Chronology and Population Sizes

Sutton (1967) lists 13 May, 15 May, and 31 May as the earliest dates for Oklahoma nestings of the snowy plover, American avocet, and least tern, respectively. Latest dates recorded for chicks still unable to fly for the snowy plover, American avocet, and least tern, respectively, are 15 August, 26 July, and 13 August. All nesting activities observed during 1977 took place within these dates. During 1978, however, new early dates for the nesting of snowy plovers and least terns in the state were recorded. The snowy plover nest discovered on 4 May contained 3 eggs, thus it is certain that the nest contained at least 1 egg by 2 May and quite possibly the 1st egg was laid on or before 1 May. As the incubation period of the snowy plover approximates 20 days, the presence of chicks in the southern portion of the salt flats on 24 May indicates active nests in that area also during early May. The least tern nest discovered on 23 May 1978 also predates any nest record for this species in Oklahoma. Active nests of all 3 species found on 6 August 1978 indicated that unfledged chicks may have been present on the refuge in late August. Thus, the 3 species apparently also nested later in the season than was previously recorded.

In his ground and aerial survey in 1975, Downing (1975) estimated 50 least terns nesting on sandbars and on salt flats along the Arkansas

River. This estimate was based on 32 birds actually seen, and Downing states that the flats at Salt Plains NWR and Quivera NWR in Kansas are the principal tern nesting habitats along the river. I 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. This discrepancy could be due to the limitations of his censusing technique, necessitated by the large area to be covered in a limited amount of time, or present populations of terns could be substantially higher than those of 1975. It would be interesting to know whether tern populations in other areas have undergone similar population fluctuations.

Numbers of least terns and American avocets nesting at Salt Plains NWR were greater in 1978 than in 1977. 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 Nest Dispersion

The settling response of birds in the nesting season results when appropriate environmental stimuli are sufficient to release the response. These stimuli are described by Hilden (1965) as being either proximate or ultimate factors in habitat selection. Proximate factors are those environmental cues for identifying habitats. Ultimate factors are those conditions essential to the survival and successful reproduction of the species.

Such indistinct factors as terrain and landscape comprise proximate factors. These stimuli of species-specific habitats are ill-defined and difficult to characterize quantitatively or descriptively. Klopfer and Hailman (1965) indicated that although it is obvious that some general habitat factors are being selected, the actual visual cues are often obscure. Even in the simplistic, relatively unstructured habitat of the salt flats, cues for the settling response are not obvious. The only apparent features breaking the expansiveness of the flats were pieces of debris and the inflow streams.

The distribution of debris across the salt flats appeared to be relatively uniform. The transects comparing debris density across the flats indicated that distribution was not related to distance from the lake shore. Thus, the concentration of nests on upper ends of inflow streams was not a response to any difference in debris densities in those areas.

Localized concentrations of debris occurred along the banks of the streams flowing across the salt flats. These concentrations were in the same areas used by nesting birds during this study. The birds, however, showed no significant preference for the debris-free or twice-normal (superstimulus) debris experimental plots. On the flats, the tendency for birds to choose locations near debris appeared to be more casual than causal during nest site selection.

Although individual plover nests were discovered up to 1.5 km from water, most nests of all 3 species were located in close proximity to water. The distribution of nests varied significantly from that of random points on the flats. The inflow streams appeared to be strong cues eliciting the settling reaction when birds selected a nest site.

During the 1978 season, nests were situated farther upstream than in 1977. This phenomenon seemed a result of the heavy rainfalls during the early stages of nesting. The creek channels are deeper in their upper reaches and those sites probably dried sooner after the storm when most birds started nesting/renesting.

Ultimate factors associated with habitat selection consist of food, requirements imposed by structural and functional characteristics of the species, and shelter from enemies and adverse weather. The fresh water inflow streams would constitute ultimate factors for nesting shorebirds on the salt flats. All food sources exploited by the shorebirds were available on the salt flats themselves, and the birds seldom left the flats while actively involved in nesting activities. These streams directly supply the vast majority of the food sources exploited by the nesting shorebirds, primarily small fish and water boatmen, and the shore flies that inhabit the stream edges. The relative absence of other invertebrates in the streams results in extremely low species diversity that is typical of such physically controlled ecosystems (i.e., subjected to physiocochemical limiting factors) (Odum 1971:148) as the saline Cottonwood and Clay creeks. The snowy plover's use of inflow streams for thermoregulation (Purdue 1976) might also be considered an ultimate factor in habitat selection by providing a form of "shelter" from adverse weather.

Niche segregation in relation to feeding among the nesting shorebirds is fairly well defined on the salt flats. Each species was observed to exploit food sources discrete from those of the other species; the possible exception was that the American avocet and snowy plover were both known to feed on the abundant, localized water boatmen

in the streams. Baker (1977) determined that relaxed competition in an environment of abundant resources may explain high niche overlap in 10 arctic shorebird species, and this seems to be the case with the snowy plover and American avocet at the Great Salt Plains. Baker and Baker (1973) have 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) went further, suggesting that birds (being in general relatively unspecialized in diet) tend to exploit whatever food is available in a habitat that was selected on other criteria. Thus, the food factor does not seem to have great significance in the evolution of species-specific habitat requirements, and plover-avocet competition for food on the salt flats is likely nonexistent.

Reproductive Success and Causes of Nest Failure

Reproductive success during the 1977 nesting season was high relative to that of 1978, and can be attributed to more favorable weather conditions during the critical egg-laying and incubation stages of nesting. Few heavy rainfalls and high winds were experienced during the incubation periods and the majority of nest failures in 1977 were attributable to coyote predation. Nesting success in 1978 was significantly lower than in 1977 and resulted from severe weather conditions during incubation.

Although effects of the 31 May 1978 storm on the reproductive rates of all 3 species were probably buffered somewhat by renesting, the damage sustained by the snowy plover population was greatest since a portion of the adult plover population was lost in the storm. No

dead avocets or terns were found after the storm, although many of the birds nested in close proximity to the plovers killed.

I conclude that the nesting seasons of 1977 and 1978 represent seasons of high and low nesting success, respectively. During most years I believe that nest success falls somewhere between these extremes. Since coyote predation and flooding of the nesting areas comprise the major factors operative on reproductive success, and as coyote predation appeared relatively constant both years, weather conditions during the incubation and early nesting stages of the reproductive cycle seem to be the principal factors determining nesting success in a given year. The gradual slope and propensity of the salt flats toward flooding, and the lack of shelter on the flats make the nesting environment especially sensitive to weather conditions.

A pertinent question relating to coyote predation during the term of the study is whether the foraging coyotes responded to stakes marking nests to be monitored, and thereby biased data collected on nest failures. I do not believe that the presence of our stakes appreciably influenced the coyote's search pattern or success in locating nests. Many unpainted stakes similar to the painted stakes marking nest sites remain from earlier activities on the salt flats by the military services and the Corps of Engineers, and the inability of coyotes to perceive color meant that the stakes were probably indistinguishable to coyotes. The coyote would not, therefore, become conditioned to associate a stake with the presence of a shorebird nest.

Impacts of the Chloride Control Project

Several salt flat habitats in northwestern Oklahoma and southwestern

Kansas may be subject to habitat alteration as a result of the U.S. Army Corps of Engineers' Arkansas-Red River Basins Chloride Control Project. Two other salt sources, the Big and Little Salt Plains located in Woods County, will also undergo habitat alteration if the desalinization program is carried out. Both areas support sizable breeding populations of the snowy plover and inland least tern. As populations of these shorebirds are dependent upon these salt flats for nesting habitat in Oklahoma, I used knowledge of the birds' breeding ecology gained from this study to predict probable impacts of the cloride control project on the populations, and to evaluate possible mitigation measures that might be implemented to offset habitat alteration.

Swickard (1974) initiated actions to supply replacement habitat for the endangered California subspecies of the least tern (S. a. browni) where beach development had destroyed areas traditionally used as nesting habitat. These measures, that consisted of depositing a sand substrate where a suitable nesting substrate was lacking, were successful where other proximate cues were present. The situation at the Salt Plains NWR, however, is different from that in California in that a suitable substrate will probably be retained while other important components of the habitat requirements are potentially threatened.

Current (October 1978) plans for the Great Salt Plains portion of the chloride control project call for diversion of all fresh water inflows around the salt flats and the construction of a large dike separating the salt flats from the existing Great Salt Plains Lake. The fresh water streams presently flowing across the flats are essential proximate and ultimate components of the habitat requirements for

breeding populations of the snowy plover, American avocet and inland least tern on the Salt Plains NWR. I conclude that the fresh water inflows onto the salt flats are vital to these species and their absence would almost certainly preclude further nesting attempts.

Possible mitigatory measures under consideration call for seasonal releases of water from the planned diversion channel for Clay and Cottonwood creeks. This measure would appear essential for the continued nesting of shorebirds on the Great Salt Plains, as the streams are strong proximate stimuli for the settling response of the birds.

Predicting the effectiveness of these seasonal releases of water would involve limnological data that is not available at this time. Other considerations would involve the compatibility of the intermittant flow of the streams with the life cycles of the food items presently found in the streams. Major considerations would include the temporal aspects of the release of water relative to establishment, and the volume of water (flow) needed relative to maintenance of those faunal populations.

SUMMARY

The objectives of this study were to determine sizes of breeding populations of the American avocet, snowy plover and inland least tern and their spatial and temporal distributions on Salt Plains NWR, to determine factors affecting nest dispersion, to determine factors limiting reproductive success and to evaluate probable impacts of the Arkansas-Red River Basins Chloride Control Program on the breeding habitats of these species. Scattered nesting records exist for small numbers of least terns and snowy plovers in western Oklahoma, but the majority of plovers and terns nesting in the state are dependent upon the salt flats habitat and the Salt Plains NWR is the only regular nesting site for the American avocet in Oklahoma.

Minimum numbers of breeding pairs of the American avocet, inland least tern and snowy plover breeding on the Salt Plains NWR in 1977 were 46, 80, and 325, respectively. Minimum numbers of breeding pairs in 1978, respectively, were 53, 135, and 260. Nests of all 3 species occurred primarily near either inflow streams or standing bodies of water present at the time of nest initiation. New early dates for nesting of the snowy plover (4 May) and least tern (23 May) were recorded, and active nests of all 3 species were observed on 6 August, indicating that unfledged chicks were present on the refuge in late August.

Statistical analysis of data collected at nest sites indicated that

nests of all 3 species were selectively placed near water, and that all were colonial in their nesting habits. The fresh water streams flowing onto the salt flats supply the majority of food supplies exploited by the nesting shorebirds. Water boatmen in the streams, shore flies (Ephydra), and burrowing beetles (Bledius) were the principal insects utilized by the shorebirds. Fish encountered in the diet of the least tern included the Arkansas River shiner (Notropis girardi), plains killifish (Fundulus kansae), and mosquitofish (Gambusia affinis). All food sources exploited by the shorebirds were found on the salt flats themselves, and birds were not known to leave the salt flats area while involved in nesting activities.

Major causes of nest failure were coyote predation and flooding of the nesting areas. During 1977, nest success was high (72.8%) and during 1978 nest success was low (26.3%). The difference in nesting success between the 2 seasons was significant and was the result of the inclement weather experienced during the 1978 nesting season.

The fresh water streams flowing across the salt flats were found to be essential proximate and ultimate components of the nesting habitat of these 3 species. The salt flats nesting habitat at Salt Plains NWR is potentially threatened by the chloride control program, and any mitigatory actions, in order to be effective, would necessarily provide for fresh water inflows onto the flats.

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