FINAL REPORT

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Endangered and Threatened Species Conservation

ATTRACTING INTERIOR LEAST TERNS TO ENHANCED NESTING HABITAT ON A RESERVOIR IN NORTHEAST TEXAS

Prepared by:

Aron Flanders

TEXAS PARKS & WILDLIFE

Robert Cook
Executive Director

Matt Wagner
Program Director, Wildlife Diversity

Mike Berger
Division Director, Wildlife

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FINAL REPORT

STATE: ____Texas_______________ **GRANT NUMBER:** ___E - 54___________

GRANT TITLE: ATTRACTING INTERIOR LEAST TERNS TO ENHANCED NESTING HABITAT ON A RESERVOIR IN NORTHEAST TEXAS

REPORTING PERIOD: ____10/01/04 to 9/30/06__

OBJECTIVE(S):

To create permanent nesting habitat for Interior Least Terns on mainland connected areas and islands above conservation pool level and to determine mortality therein at Cooper Lake, Texas.

1. Nest Site Enhancement and Attractants.
2. Surveys and Monitoring.
3. Nesting Habitat Measurements.

Significant Deviation:

None

Summary Of Progress:

Please see Attachment A.

Location: Delta County, Texas

Cost: ____

Prepared by: _Craig Farquhar______________ **Date:** _6 December 2006

Approved by: ________________________________ **Date:**________________________
Neil (Nick) E. Carter

ATTRACTING INTERIOR LEAST TERNS TO ENHANCED NESTING HABITAT ON A RESERVOIR IN NORTHEAST TEXAS

Aron A Flanders, NRS III, Cooper Wildlife Management Area, 829 CR 4795, Sulphur Springs, Texas 75482
Voice: (903) 945-3132
Fax: (903) 945-3023
E-mail:cooper@neto.com

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September 2004 – September 2006

ATTACHMENT A

ABSTRACT

Interior least terns (*Sternum antillarum athalassos*) were federally designated as endangered in 1985. Protection and enhancement of nesting habitat on reservoirs might be important for increasing breeding productivity due to loss of nesting habitat along rivers. Our objectives were to (1) create nesting habitat for interior least terns above conservation pool elevation, (2) compare nest site selection, breeding productivity, and expenses among enhanced ground sites, nesting rafts, nesting platforms, and natural-nest sites, (3) evaluate soil properties relative to nest success and (4) compare productivity of nesting colonies at Jim Chapman reservoir (Cooper Lake) to productivity estimates from other studies. A nesting platform, 2 nesting rafts, and 2 enhanced ground nesting sites were established near known breeding areas. Areas were surveyed biweekly and habitat variables were measured after nest fate was determined. Thirty-two nests were monitored at 2 colonies in 2005 and 58 nests were monitored at 3 colonies in 2006. One nesting pair selected an enhanced nest site in 2005. This site had more ($P < 0.01$) coverage of rock and less bare ground compared to colony sites. During 2006-2006, nests were within 15 cm of objects more frequently ($P < 0.01$) than random sites. The percent cover of wood was also higher ($P < 0.01$) at nest sites compared to random sites. Hatching success was significantly higher in 2006 compared to 2005. Conversely, fledging rates were higher in 2005 than 2006. Cooper Lake appears to provide suitable habitat for breeding interior least terns under certain conditions; however, annual production is highly variable. Overall, nest success and fledging rate (fledglings/pair) were 74% and 0.65, respectively.

INTRODUCTION

The interior least tern (ILT) (*Sterna antillarum athalassos*) was Federally listed as endangered in 1985 (Federal Register 1985) and is endangered in Texas, except within 80 km of the Gulf Coast. Population decline is reportedly due to losses of breeding habitat on rivers, primarily caused by hydrological changes (Sidle and Harrison 1990, Thompson et al. 1997). Without adequate river habitat, reservoirs may offer alternative sites for protection and enhancement of nesting habitat to increase breeding productivity. On reservoirs, enhancing and attracting ILT to ground-nesting sites above normal reservoir elevation may provide more sustainable habitat than areas at lower elevations that are prone to flooding events. In addition, ILT may select and benefit from artificial nesting structures, such as floating rafts (Bockpoel and Jarvie 1995, Collis et al. 2002) and rooftops (Gore and Kinnison 1991). Furthermore, the placement of decoys and coarse nesting material may help establish terns at new or prepared colony sites (Burger 1988, Mallach and Leberg 1999). Our objectives were to (1) create and attract ILT to nesting habitat above normal reservoir elevation at Cooper Lake, (2) compare nest site selection, nesting habitat, and breeding productivity among management techniques and colonies, (3) evaluate soil properties relative to nest success and (4) compare productivity of breeding colonies at Cooper Lake to productivity estimates from traditional breeding areas.

OBJECTIVE

To create permanent nesting habitat for Interior Least Terns on mainland connected areas and islands above conservation pool level and to determine mortality therein at Cooper Lake, Texas.

LOCATION

Cooper Lake (95°41'.50, 35°19'.00) is located on the South Sulphur River in Hopkins and Delta Counties, Texas. Historical ILT breeding colonies are located North of Cooper Lake along the Red River (Figure 1). This 7,712-ha lake was completed in 1991 and is within the Red River Basin. The South Sulphur River watersheds that flow into the reservoir are within the Blackland Prairie. Upland soils are dark, calcareous, high shrink-swell, clayey soil and at lower elevations reddish brown to dark gray, slightly acid, very fine, smectite group, with high plasticity, loamy to clayey, and alluvial (Ressel 1979, Hatch et al. 1990). Climate in the area is humid subtropical with a mean annual precipitation of 127 cm. Average monthly temperatures range from 39.1° C in August to 0.1° C in January (Ressel 1979). During the 2005 field season, the reservoir elevation was 0.69-1.72 m below normal pool elevation, exposing 804-1,849 ha of soil. During 2006, the reservoir elevation was 2.49-4.14 m below normal pool elevation, exposing over 3,300 ha of soil along the shoreline and islands.

METHODS

Ground nesting sites were enhanced to attract breeding interior least terns on Cooper Lake in Delta County, Texas during 2005 and 2006. Additionally, artificial nesting structures, a platform and a raft, were established in 2005. Ground nesting sites and artificial nesting structures were established at locations adjacent to historical nesting activities.

In order to protect ground nesting areas from inundation, elevation of nesting areas ranged from 440-445 feet above mean sea level. Nesting sites were $\geq$ 2 ha in size on Pelican Peninsula and Tarapin Peninsula. Nesting sites were enhanced by disking, applying an aquatic approved herbicide, and depositing gravel. A disk was towed by a tractor in areas with $\leq$ 3% slopes. Areas were disked to a depth of $\leq$ 10 cm in March. Aquatic herbicide was applied on the 2 peninsula sites in April and May. Additionally, herbicide was applied to a 2005 island colony site during spring 2006. The 2 peninsula areas were disked and harrowed during April and May. The soil substrate was harrowed in order to smooth depressions and create a uniform grade.

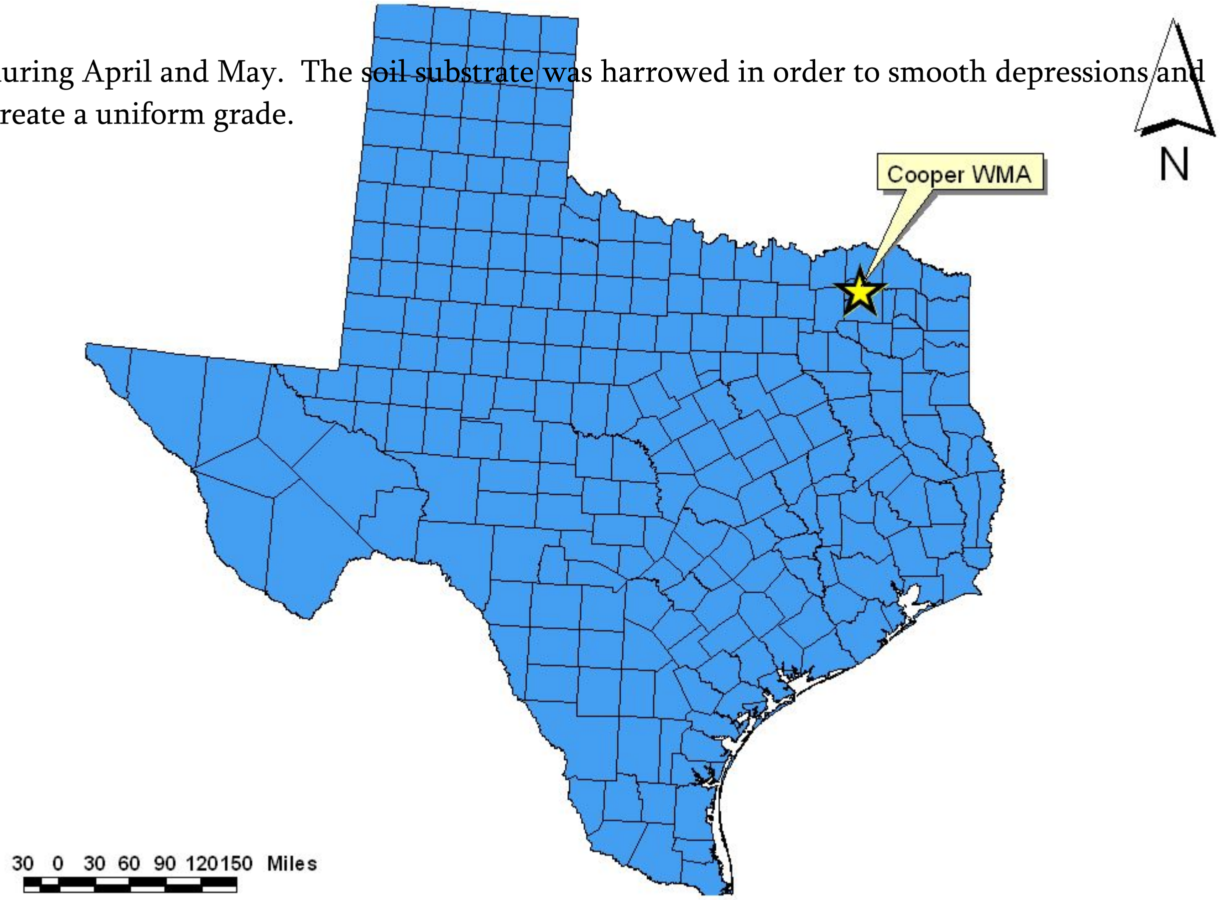

Figure 1. Interior least tern project location at Cooper WMA in Hopkins and Delta Counties, 2004-2006.

Driftwood, logs, and other materials that provided cover for chicks were protected and deposited on the area. Light colored pebbles with a diameter $\leq$ 1 cm were distributed on 1 930-m^2 area (30.5 m x 30.5 m) on each peninsula in order to attract terns to the areas, examine nest site selection, and compare hatching success on substrate types. Gravel was spread to a depth of 2.5 cm.

Nesting Raft

A raft was constructed based on Canadian Wildlife Service guidelines (Dunlop et al. 1992). The raft was 4.9 m x 4.9 m and 16 dock floats were used for floatation. A gravel substrate covered the deck to a depth of 5 cm. Driftwood was also spread around the decking. The raft was anchored adjacent to a historical nesting location. Water depth at the site ranged from 3 to 1.5 feet, depending on reservoir elevation.

Terrestrial Nesting Platform

A 3.7 m x 7.3 m terrestrial nesting platform was constructed. The platform was 1.8 m tall in order to limit predation by ground predators. The roof had a slight pitch in order to facilitate drainage (Fisk 1978). The platform was established at the edge of conservation pool level. Gravel and driftwood were deposited on the roof. A 15 cm high perimeter barrier was constructed around the roof (Fisk 1978, Schaefer 2001).

Social Attractants

Decoys were set out during the first week of May. Two pair and 2 single decoys were placed on the platform, raft and ground nesting areas (Burger 1988). The single decoys were spaced $\geq$ 1.5 m from the paired decoys (Burger 1988). Paired decoys faced the same direction.

Surveys and Monitoring

Surveys were conducted biweekly in potential nesting areas from April to August, 2005-2006. Boat routes were conducted 4 times a month to document any new locations of least tern activities. The number of adult and juvenile individuals, their behavior and occupied habitat type were recorded during surveys. Behavior was recorded as foraging, loafing, territorial display, group mobbing, mating, courtship display, incubation, flight or carrying fish. Additionally, low flights, hovering, landing and other activities associated with enhanced ground nest sites, decoys or artificial structures were recorded. The distance individuals landed from paired or single decoys was recorded.

Colonial site visits were before 10:00 and were < 45 minutes. Discovered nests that were difficult to locate were marked with rebar 7.6 m from the nest site. During each visit, the number of adults, chicks, juveniles, nests, and eggs were recorded. Additionally, the presence of a scrape, adult incubation, adult defense, or disturbance was recorded. Three to 4 day interval surveys provided a 65-70% probability of observation of hatched immobile chicks before they left the nest. If chicks were absent, nest fate (e.g. depredated, hatched, abandoned, flooded or unknown) was determined by following methods outlined by Koenen et al. (1996).

The initial number of eggs was recorded for calculating nest success. The recruitment or number of chicks fledged per colony was monitored. A chick was considered fledged at first flight.

Nesting Habitat Measurements at Terrestrial Sites

In order to prevent disturbance and limit attracting predators to nest sites, habitat characteristics were quantified at the nest locations, associated random locations and artificial sites (platform, raft, and enhanced ground nesting sites) after nest fate was determined. The exception to this measurement time was the measured distance of each nest from the reservoir's shoreline and the temperature of the nesting substrate. The distance of the nest from the reservoir's shoreline was recorded during initial nest observations.

The substrate temperature, time recorded, air temperature, wind speed and relative humidity was recorded 7.6 m from a colony site or nest site and within artificial enhancement areas (i.e. raft, platform, land) once per week during the 2005 breeding season. The substrate temperature was measured with a hygro-thermometer. The hygro-thermometer was held perpendicularly, 1 foot above the surface being measured. The temperature was recorded between 08:00 and 10:00, with all recordings taken within a 30 minute interval. The order that temperature was recorded at nest areas (ground, platform, and raft) was rotated each week.

Soil samples were collected to a depth of 2.5 cm within a 15-cm radius, centered on each nest location (Thompson and Slack 1982). Soil samples were taken at nest sites and enhanced nesting areas. Soil samples were collected from 9 randomly selected nest sites at each of the 2 colonies and 10 random points within the 2-ha ground nesting area in 2005. In 2006, soil samples were collected from 58 nest sites. Soil texture was determined by using the hydrometer method (Bouyoucos 1936). Vertical cover was measured using a Robel pole (Robel et al. 1970). The pole was viewed at a distance of 4m and at a height of 99 cm in each of the cardinal directions. The pole was centered on nest sites, associated random locations and within enhanced nesting areas. The pole was 4 feet in height with 10-cm intervals marked on the pole. The distance and orientation (0-360^{o}) of objects, $\geq$ 5 cm long or wide, $\leq$ 15 cm of the edge of nest scrapes, random points and points within enhanced ground sites was recorded. The percent cover of vegetation, wood, gravel, and bare ground was estimated within 2 Daubenmire frames randomly placed within 1 m of nests, random sites and enhanced ground sites (Daubenmire 1959).

Statistical Analysis and Calculations

A majority of the data did not conform to the assumptions, homogeneity of variance and normality, for parametric tests; therefore, a nonparametric analogue, such as Kruskal-Walllis was used under these conditions.

Behavioral observations were compared among the disked, gravel, platform, and raft sites using a nonparametric Kruskal-Wallis test. A one-way ANOVA was used to compare substrate temperatures among the 2005 colonies, raft, platform, and enhanced ground sites. A Kruskal-Wallis test was used to compare habitat variables among the nest sites, random points, colonies, and enhanced ground nesting sites. A 2 x 4 Chi-Square contingency test for independence was used to compare the frequency of objects near scrapes and random points. Hatching success (proportion of eggs per nest that hatched) and breeding productivity (fledglings per nesting pair) was calculated. A nest was considered successful if $\geq$ 1 egg hatches. The apparent estimator (i.e. raw percentages) of nest success was used instead of the Mayfield method (Mayfield 1961) because the apparent estimator appears appropriate when studying colonial nesters, which exhibit high visibility, nesting synchrony, susceptibility to catastrophic mortality and a high frequency of observations are made (Johnson and Shaffer 1990). Habitat variables were compared between successful and unsuccessful nests using a Kruskal-Wallis test.

The soil composition for randomly selected nest sites ($n = 18$) at Cooper Lake was calculated. The proportion of sand, silt, and clay was compared between successful nests ($n = 9$) and unsuccessful nests ($n = 9$) using a Kruskal-Wallis test. The proportion of sand, silt, and clay was compared between these hatch success categories using a Kruskal-Wallis test. The proportion of sand, silt, and clay at nests where inundation and egg-sticking occurred was compared to nests where egg sticking and inundation did not occur using a Kruskal-Wallis test.

All statistical calculations were performed using SAS JMP software. Statistical significance was set at $P < 0.01$ level.

RESULTS

Initial colony establishment took place on 21 June in 2005 and 7 June in 2006. Nest establishment dates were earlier in 2006 compared to 2005 (Figure 2). The number of flights < 5 m in height over disked, gravel, platform, and raft sites varied (Table 1) in 2005. In 2006, no individuals were observed adjacent to artificial structures or enhanced ground sites. During the 2005 and 2006 breeding seasons, 1 pair of ILT nested on an enhanced ground nesting site, 9 nests were located on shoreline adjacent to an enhanced ground nesting area, 6 nests were located on additional shoreline exposed due to drought conditions, and 81 nests were located on islands exposed due to drought conditions (Table 2). Due to logistics, the nesting habitat and breeding productivity of the 2006 shoreline colony containing 6 nests was not observed. The enhanced ground nesting areas ($n = 2$) had significantly higher ($P < 0.01$) percent ground cover of rock material and significantly lower ($P < 0.01$) bare ground cover compared to colonial nest sites ($n = 3$) (Table 3). The percent cover of vegetation was higher ($P < 0.01$) at the shoreline colony and enhanced ground site compared to the island colonies. Substrate temperature was similar ($P > 0.01$) among artificial structures, enhanced ground nesting sites and colony sites. Nest scrapes ($n = 90$) were more frequently ($\chi^2 = 48.76$, df = 1, $P < 0.01$) within 15 cm of objects (i.e. wood, rock or other fragmentary material) than random points ($n = 90$). Successful and unsuccessful nests were within 15 cm of objects at similar ($\chi^2 = 1.654$, df = 1, $P = 0.200$) frequencies. Vertical cover was similar ($P > 0.01$) at nest sites and random sites. The percent ground cover of wood was higher ($P < 0.01$) at nest sites compared to random sites. Other habitat variables were similar between nest sites and random sites (Table 4). The percent cover of bare ground, rock, wood, vegetation or other materials did not differ ($P > 0.01$) between successful and unsuccessful nests. Nest success was significantly higher ($P < 0.01$) in 2006 compared to 2005 colonies (Table 5). Predation and inundation events were higher ($P<0.01$) in 2005 compared to 2006. The number of eggs per nest of the 2005 island A colony was lower ($P < 0.01$) compared to other colonies. Nesting parameters were calculated for 2005 and 2006 ILT nests ($n = 90$) (Table 6). During 2005 and 2006, egg loss was due to predation (6.9%), abandonment (8.2%), inundation (6.0%) and unknown causes (6.0%). Egg predation was caused by feral hogs (*Sus scrofa*) ($n = 3$), fire ants (*Solenopsis invicta*) ($n = 5$), various birds ($n = 7$), and coyotes (*Canis latrans Say*) ($n = 2$). However, bird predation may have taken place after eggs were lost due to other factors, such as exposure or breakage caused by egg sticking during incubation. Also, fire ants were present on Island A in 2006 and predated a nest with 3 eggs during initial pipping.

The created nesting site, shoreline colony, and island colony varied ($P < 0.05$) relative to percent sand, silt, and clay (Figure 3). The percent sand ($\bar{x} = 20.52$, SE = 1.14), silt ($\bar{x} = 69.95$, SE = 2.26), and clay ($\bar{x} = 7.96$, SE = 0.17) at all randomly selected nest sites ($n = 18$) was combined for comparisons of soil properties relative to nest success. The proportion of sand, silt, and clay did not differ ($P > 0.05$) between successful ($n = 9$) and unsuccessful ($n = 9$) nests (Figure 4). Also, the proportion of sand, silt, and clay was similar between the hatch success categories (Table 7). The proportion of sand, silt, and clay was similar ($P > 0.05$) at nest sites where inundation and egg sticking occurred and at nests where inundation and egg sticking did not occur (Table 8).

The average rainfall amount (cm) per rain event from June-August in 2005 ($\bar{x} = 1.35$, SE = 0.41) and 2006 ($\bar{x} = 0.69$, SE = 0.30) were calculated. Temperatures were at or above 37.8° C for 10 consecutive days in July 2006 compared to 2 days in July 2005.

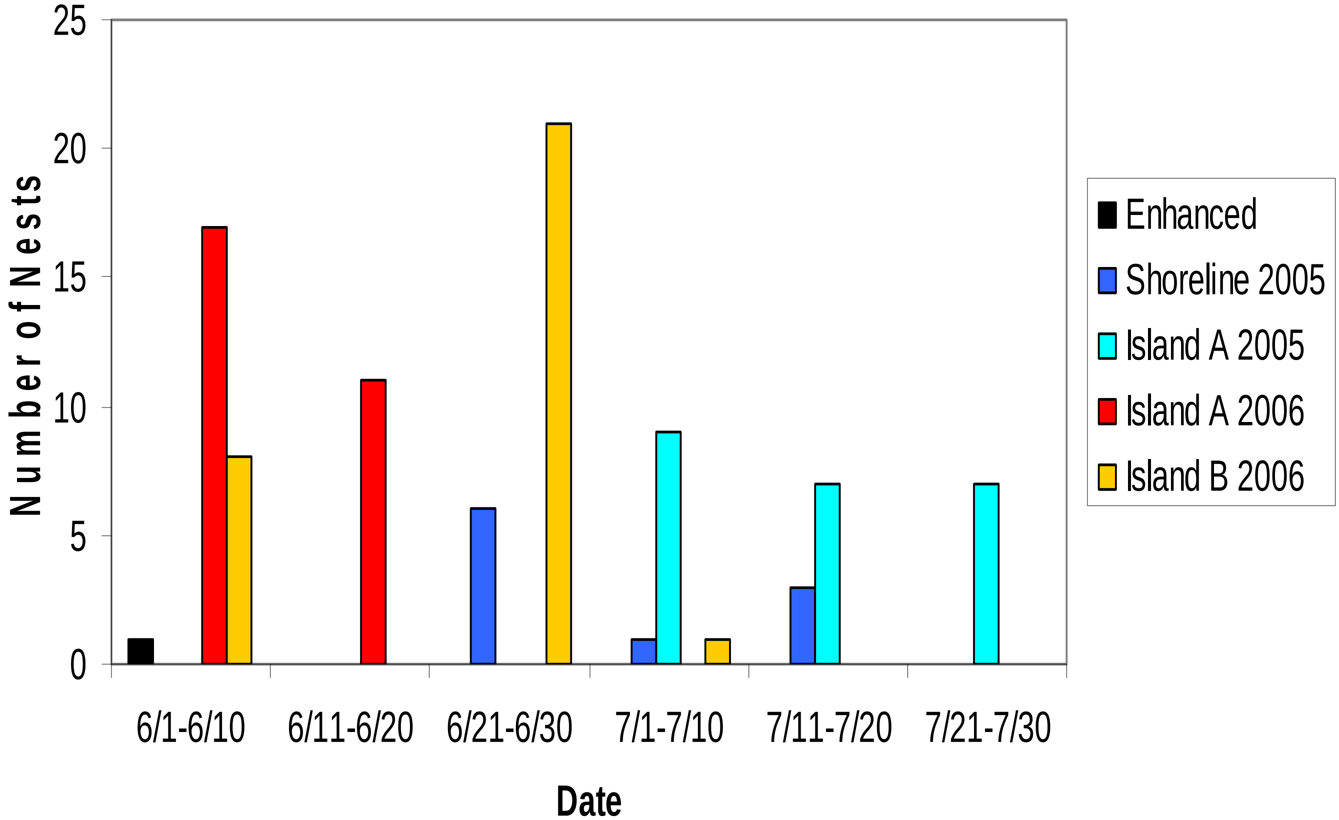

Figure 2. Chronology of nest initiation for interior least terns at Jim Chapman Reservoir in Delta County, Texas, 2005 and 2006.

Table 1. Number of interior least tern's (mean and standard error) low flight, landing, defense or courtship behavior at disk, gravel and decoy, platform, and raft sites during surveys ($n = 9$) before breeding colony establishment at a reservoir in northeast Texas, 2005.

Behavior[a]	**Disked** $\bar{x}$ **(SE)**	**Gravel & Decoys** $\bar{x}$ **(SE)**	**Platform & Decoys** $\bar{x}$ **(SE)**	**Raft & Decoys** $\bar{x}$ **(SE)**	$\boldsymbol{X^2_3}$[A]	***P***
Low flight	2.44 (1.01)	3.00 (0.91)	0.33 (0.24)	0.11 (0.11)	12.77	0.005
Land	0.56 (0.34)	0.67 (0.47)	0.00 (0.00)	0.00 (0.00)	0.08	0.780
Defense	0.44 (0.34)	0.44 (0.44)	0.00 (0.00)	0.00 (0.00)	NA[b]	NA[b]
Courtship	0.44 (0.24)	0.33 (0.24)	0.00 (0.00)	0.00 (0.00)	NA[b]	NA[b]

[a] An adult was assigned to a behavior no more than once per visit.
[b] NA data were not compared due to a low frequency of observations
[A] Chi-square statistic from Kruskal-Wallis nonparametric test.

Table 2. Distribution of interior least tern nests on a reservoir in northeast Texas, 2005-2006.

Colony Name	2005 Number of nests	2006 Number of nests
Enhanced Site	1	0
Shoreline Pelican Point	9	6
Island A	23	28
Island B	0	30
Total Nests	33	64

Table 3. Habitat measurements (mean and standard error) at interior least tern nest sites within colonies and random points within enhanced ground sites at a reservoir in northeast Texas, 2005-2006.

Parameter measurement	Enhanced Site (n= 18) $\bar{x}$ (SE)	Shoreline colony (n=9) $\bar{x}$ (SE)	Island A colony (n=51) $\bar{x}$ (SE)	Island B colony (n=30) $\bar{x}$ (SE)	χ^2_3 [A]	P
Percent bare	77.06 (3.73)	92.14 (2.40)	94.88 (0.88)	96.45 (1.15)	30.79	<0.001
Percent rock	17.33 (4.15)	0.00 (0.00)	0.13 (0.08)	0.08 (0.05)	62.65	<0.001
Percent vegetation	5.61 (0.84)	7.22 (2.47)	2.97 (0.79)	1.97 (1.15)	24.16	<0.001
Percent wood	0.00 (0.00)	0.47 (0.28)	1.79 (0.51)	1.20 (0.37	8.47	0.037
Percent other	0.00 (0.00)	0.11 (0.11)	0.19 (0.08)	0.30 (0.19)	2.23	0.527

[A] Chi-square statistic from Kruskal-Wallis nonparametric test.

Table 4. Habitat measurements (mean and standard error) at interior least tern nest sites (n = 90) and random points (n = 90) at a reservoir in northeast Texas, 2005-2006.

	Nests	Random		
Parameter measurement	$\bar{x}$ (SE)	$\bar{x}$ (SE)	χ^2_1 [A]	P
Percent bare	95.13 (0.68)	94.38 (1.52)	4.49	0.034
Percent rock	0.10 (0.05)	0.10 (0.05)	0.09	0.770
Percent vegetation	3.06 (0.65)	5.00 (1.53)	0.05	0.825
Percent wood	1.46 (0.32)	0.34 (0.14)	12.99	< 0.001
Percent other	0.22 (0.08)	0.34 (0.23)	1.10	0.294

[A] Chi-square statistic from Kruskal-Wallis nonparametric test.

Table 5. Breeding productivity measures and nest characteristics (mean and SE) for a 2005 shoreline colony, 2005 island A colony, 2006 island A colony and 2006 island B colony of interior least terns at a reservoir in northeast Texas, 2005-2006.

Parameter measurement	Shoreline n = 9 $\bar{x}$ (SE)	Island A 2005 n = 23 $\bar{x}$ (SE)	Island A 2006 n = 28 $\bar{x}$ (SE)	Island B 2006 n = 30 $\bar{x}$ (SE)	χ^2_3 [A]	P
Percent of nests with scrape	0.89 (0.11)	0.43 (0.11)	1.00 (0.00)	1.00 (0.00)	39.76	< 0.001
Number of eggs per nest	2.22 (0.15)	1.65 (0.13)	2.82 (0.09)	2.67 (0.71)	39.89	< 0.001
Number of eggs hatched per nest	0.78 (0.32)	0.70 (0.18)	2.57 (0.17)	2.40 (0.18)	44.30	< 0.001
Nest success (nests hatching ≥ 1 egg)	0.44 (0.18)	0.43 (0.11)	0.93 (0.05)	0.90 (0.06)	24.38	< 0.001
Hatching success (% hatched per nest)	35.19 (14.82)	35.51 (9.51)	88.69 (5.29)	80.56 (6.59)	25.12	< 0.001
Eggs predated per nest	0.56 (0.38)	0.30 (0.15)	0.11 (0.11)	0.00 (0.00)	8.55	0.036
Eggs abandoned per nest	0.22 (0.22)	0.30 (0.13)	0.07 (0.05)	0.23 (0.10)	2.47	0.48
Eggs inundated per nest	0.56 (0.29)	0.34 (0.13)	0.00 (0.00)	0.00 (0.00)	18.36	< 0.001

Eggs unknown fate	0.11 (0.11)	0.22 (0.09)	0.21 (0.13)	0.03 (0.03)	4.21	0.239

[A]Chi-square value from Kruskal-Wallis test because assumptions for parametric tests were not met.

Table 6. Breeding productivity measures for interior least terns during the 2005 and 2006 breeding seasons at a reservoir in northeast Texas.

Year	Number of pairs	Number of nests	Hatching success %	Number of successful nests (%)	Number fledged	Productivity Fledglings/pair	Productivity Fledglings/nest
2005	22	32	35.42	14 (44)	21	0.95	0.66
2006*	46	58	84.48	53 (91)	23	0.50	0.40
Total or average	68	90	68.15	67 (74)	44	0.65	0.49

* The 2006 shoreline colony of 6 pairs of breeding adults and 6 nests was omitted.

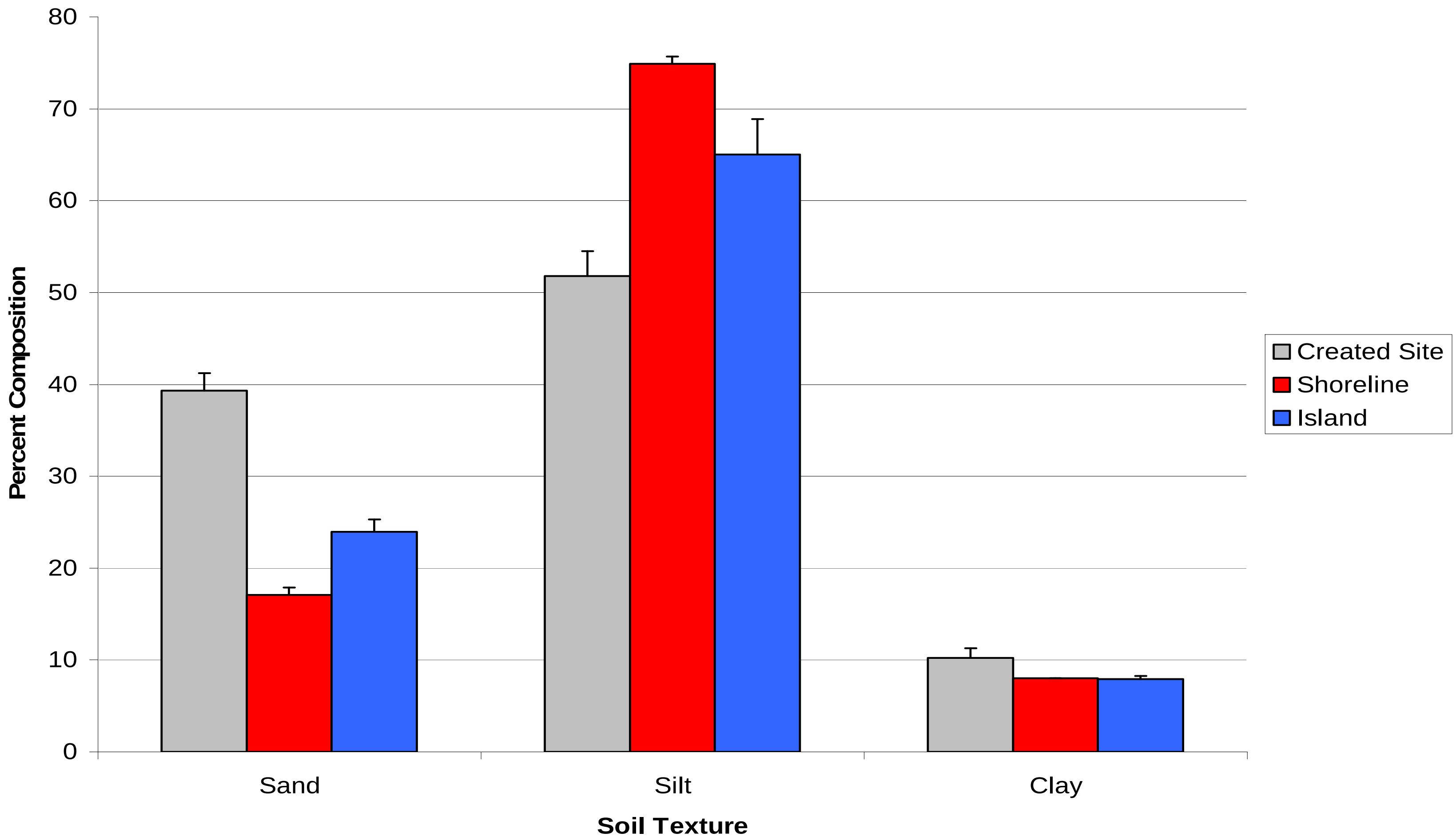

Figure 3. The percent sand, silt, and clay (mean and standard error) from random points at a shoreline colony (*n* = 9), island colony (*n* = 9), and a created ground-nesting site (*n* = 10) at a reservoir in northeast Texas, 2005. Vertical bars represent the standard error of means.

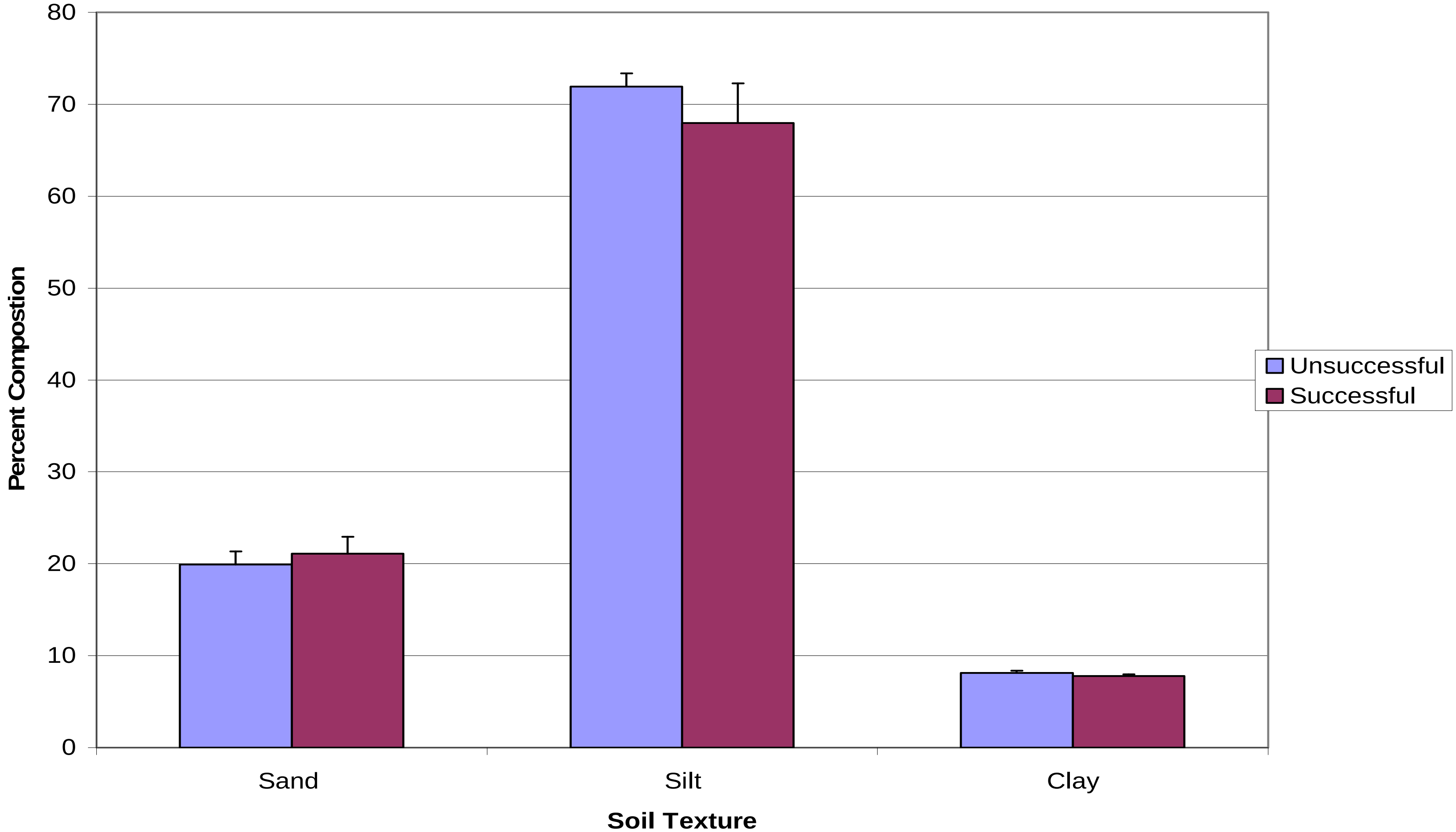

Figure 4. Percent sand, silt, and clay at successful ($n = 9$) and unsuccessful ($n = 9$) nests from randomly selected nest sites ($n = 18$). Vertical bars represent the standard error of means.

Table 7. The proportion of sand, silt, and clay (mean and standard error) between hatching success categories (0-50% and 51-100%) at randomly selected nest sites (*n* = 18) at a reservoir in northeast Texas, 2005.

	Hatching success			
	0-50%	51-100%		
Soil Texture	$\bar{x}$ (SE)	$\bar{x}$ (SE)	X^2_1 [A]	*P*
Percent sand	20.81 (1.27)	19.76 (2.65)	0.16	0.692
Percent silt	71.10 (1.26)	66.98 (7.91)	0.20	0.657
Percent clay	8.10 (0.17)	7.6 (0.40)	0.97	0.324

[A] Chi-square statistic from Kruskal-Wallis nonparametric test

Table 8. The proportion of sand, silt, and clay (mean and standard error) at randomly selected nests (n = 18) where inundation and egg sticking occurred (n = 7) and at nests where inundation and egg sticking did not occur (n = 11) at a reservoir in northeast Texas, 2005.

	Inundation and egg sticking			
	Yes	No		
Soil Texture	$\bar{x}$ (SE)	$\bar{x}$ (SE)	$X^2{}_1$[A]	P
Percent sand	21.18 (1.92)	20.09 (1.46)	0.53	0.467
Percent silt	70.54 (1.91)	69.58 (3.57)	0.67	0.414
Percent clay	8.29 (0.29)	7.75 (0.19)	2.57	0.109

[A] Chi-square statistic from Kruskal-Wallis nonparametric test

DISCUSSION

The use of decoys appeared to attract ILT in Indiana (Johnson and Castrale 1993) and has been reported to affect least tern breeding behavior (Burger 1988). During 2005 courtship and initial nest site selection, we primarily observed ILT activities associated with the disked, gravel, and decoy area. In fact, adults were observed performing courtship behavior within the gravel and decoy site. However, only 1 pair of ILT selected to nest at a prepared site with decoys present. Nest site selection was likely impacted by the increased availability of nesting habitat due to lowered reservoir levels. During the 2005 and 2006 field seasons, the reservoir elevation was 0.69-4.14 m below normal pool elevation, exposing 804-3,300 ha of additional nesting habitat along shorelines and islands. If this additional habitat were not available, ILT may have selected the prepared areas. Furthermore, Thompson and Slack (1982) reported the distance to water's edge to be a primary component of nest site selection. The reservoir drawdown substantially increased the distance from the enhanced sites to the water's edge, which may have also caused ILT to select areas other than the enhanced sites above reservoir pool elevation. Additionally, the prepared sites had more cover of gravel than ILT nest sites. This difference in habitat composition may have also impacted nest site selection. For example, Conway et al. (2003) reported 75% ILT nest sites on sand and 25% on gravel. Conversely, least terns have also been reported to prefer supplemental shell over bare ground for nesting (Mallach and Leberg 1999).

Previous studies have documented terns adapting to nesting on artificial structures. For example, Dunlop et al. (1992) reported high reproductive success on nesting rafts in Toronto by common terns. Additionally, Gore and Kinnison (1991) reported that hatching success of least tern rooftop colonies in Florida was equal to or higher than some ground nesting colonies. In contrast, ILT did not select the raft or platform for nesting at Cooper Lake. As previously discussed, our results may vary under different reservoir elevations; however, ILT appeared to select the enhanced ground site more than the artificial structures based on behavioral observations and the single nest site selected within the enhanced ground site.

Least terns have been reported to place fragmentary material near scrapes (Thompson et al. 1997). Although Conway et al. (2003) found 65% of ILT nests within 15 cm of 1 $\geq$ object, it was not statistically significant. In our study, ILT nests were within 15 cm of objects more often than random points. In fact, 73% of nest scrapes were near wood, rock or other debris compared to 21% of random points. Also, adults appeared to select nesting sites near fragmentary material because objects near scrapes were present during nest initiation. This nesting behavior may play a role in camouflaging nest sites; however, this is beyond the scope of our project. Nonetheless, breeding habitat enhancement for ILT should include the protection or addition of fragmentary material which may help attract adults or benefit productivity.

Other habitat variables were similar among nest sites, random points, successful, and unsuccessful nests. Our nest habitat results were similar to past research (Thompson and Slack 1982, Byre 2000, Conway et al. 2003). The only difference was the amount of bare ground at nest sites. We do not consider this biologically significant because it was largely due to plant germination and growth towards the end of incubation. Habitat parameters were measured after nest fate was determined so plants grew throughout incubation.

Past research has estimated hatching success for ILT colonies at 65.0% on the Red River during 1998 (Conway et al. 2003), an average of 56.0% during 8 breeding seasons on the Canadian River (Byre 2000), and 51.0-68.0% during 4 years on the Mississippi River Valley (MRV) (Smith and Renken 1993). Our hatching success rate of 34.3% at Cooper Lake during 2005 was 16.7-33.7% lower than these estimates. Conversely, hatching success was 85% in 2006. Predation and flooding events were higher in 2005 than 2006, which lowered hatching success. Precipitation amounts were lower in 2006; therefore, inundation did not play a major role. Also, the 2005 shoreline colony was impacted by terrestrial predators; whereas, the 2006 island colonies were not. Furthermore, the 2005 island A colony exhibited late nest initiation dates, significantly lower number of eggs per nest, and significantly lower scrape presence. Due to the late nest initiation dates in 2005, more nests were exposed to migratory avian predators during late summer. Moreover, the low numbers of eggs and scrapes observed at the 2005 island A colony may be due to physiologically stressed or inexperienced breeders, which may have lower hatching success. Average hatching success for 2005 and 2006 was 68%, which is high compared to the other studies. In a span of 2 years, hatching success exhibited high annual variability, similar to other studies (Thompson et al. 1997).

Annual production for ILT has been estimated at 1.21 fledglings / pair and 1.00 fledglings / nest on the Canadian River in Oklahoma during 1991-1998 (Byre 2000), 0.50 – 0.70 fledglings / pair throughout Oklahoma from 1982 to 1992 (Hill 1992), and averaged 0.70 fledglings / pair along the MRV during a 4-year study (Smith and Renken 1993). Kirsch and Sidle (1999) proposed that 0.51 fledglings / pair was necessary for population maintenance and 52% of ILT colonies were found to have fledging success < 0.51 from 1984 to 1995. Although hatching success was higher in 2006, 2006 breeding productivity was significantly lower at 0.50 fledglings / pair compared to an estimated 0.95 fledglings / pair in 2005. Lower productivity in 2006 may have been due to heat stress. A number of young chicks (2-4 days old), not exhibiting signs of predation or trauma, were discovered dead during 2006. These mortalities were found during 10 consecutive days of temperatures $\geq 37.8^{\circ}$ C in July. During July 2005, only 2 days had maximum temperatures this high. Again, annual breeding productivity was highly variable for ILT at Cooper Lake. These findings are similar to other studies which also reported high annual variability in breeding success (Kirsch and Sidle 1999).

2005 SOIL ANALYSIS

Dredge islands in the Atchafalaya Delta of coastal Louisiana were reported to consist of 60 % sand and 29 % silt and clay (U. S. Army Corps of Engineers 1977). Similarly, Thompson and Slack (1982) reported high amounts of silt and clay at dredge material deposition sites along the Texas coast being used by least tern nesting colonies. In fact, 3 sites were reported to have > 45% silt and clay composition. In contrast, least tern colonies on natural sites along the Texas coast were primarily sand with < 10% silt and clay (Thompson and Slack 1982). The soil composition of ILT nest sites at Jim Chapman (Cooper) Lake averaged 21% sand, 71% silt, and 8% clay. The soil composition at Cooper Lake appears to have higher amounts of fine particles (i.e. silt and clay) than the aforementioned dredge material sites. On dredge islands, Mallach and Leberg (1999) reported higher hatching success for gull-billed terns (*Sterna nilotica*) and black skimmers (*Rhyncops niger*) nesting on fragmentary shell compared to nests on fine-textured soils. They reported hatching success for nests on fine-textured soils to average 35.2. We did not find a difference in soil composition among breeding productivity measures, flooding or egg sticking events for nests at Cooper Lake. This may have been due to the availability of nesting substrates at Cooper Lake; however, we did not collect random samples from all available nesting sites. Areas below normal reservoir pool may be uniformly high in silt and clay. Also, Mallach and Leberg (1999) added shell deposits to some colony sites for comparison. These sites were preferred by least terns on dredged islands because they were selected more than bare soil sites. The addition of fragmentary material at Cooper Lake colony sites below conservation pool may allow for comparison of breeding productivity between nests on bare soils and nests on fragmentary material. Soil composition data for ILT colony sites on rivers are needed for comparison to Cooper Lake and other reservoirs where breeding takes place. The deposition dynamics and subsequent build up of soil on reservoirs may create nesting substrates different from historical river nesting sites. Drought conditions during our study may have impacted results associated with soil texture and inundation or egg sticking events. Precipitation events and amounts were significantly lower than 20 year averages.

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LITERATURE CITED

Blokpoel, H., and Jarvie, S. 1995. Use of reefrafts to create habitat for birds and fish, p. 51-54. *In* J. R. M. Kelso and J. H. Hartig. Methods of modifying habitat to benefit the Great Lakes ecosystem. CISTI (Canadian Institute of Science and Technological Information) Occasional Paper No. 1.

Bouyoucos, G. J. 1936. Directions for making mechanical analyses of soils by the hydrometer method. Soil Science 43: 225-229.

Burger, J. 1988. Social attraction in nesting least terns: effects of numbers, spacing and pair bonds. The Condor 90: 575-582.

Byre, V. J. 2000. Productivity, habitat assessment, and management of least terns nesting along the Canadian River in central Oklahoma. Sam Noble Museum of Natural History 8: 1-13.

Collis, K., D. D. Roby, C. W. Thompson, D. E. Lyons, and M. Tirhi. 2002. Barges as temporary breeding sites for Caspian terns: assessing potential sites for colony restoration. Wildlife Society Bulletin 30(4): 1140-1149.

Conway, W. C., L. M. Smith, and J. D. Ray. 2003. Breeding biology of an interior least tern (*Sterna antillarum athalassos*) colony in Childress County of north Texas. Texas Journal of Science 55(1): 49-58.

Daubenmire, R. F. 1959. A canopy coverage method of vegetational analysis. Northwest Science 33:43-64.

Diggs, Jr., G. M., B. L. Lipscomb, and R. J. O'Kennon. 1999. Shinners and Mahler's illustrated flora of North Central Texas. Austin College Center for Environmental Studies and the Botanical Research Institute of Texas, Austin, Texas, USA.

Dunlop, C., Blokpoel, H., and Jarvie, S. 1992. Nesting rafts as a management tool for a declining Common Tern (*Sternahirundo*) colony. Colonial Waterbirds 14: 116-120.

Federal Register. 1985. Endangered and threatened wildlife and plants: interior population of the least tern determined to be endangered. Federal Register 50: 21784-21792.

Fisk, E. J. 1978. The growing use of roofs by nesting birds. Bird Banding 49 (2): 134-135.

Gore, J. A., and M. J. Kinnison. 1991. Hatching success in roof and ground colonies of least terns. The Condor 93: 759-762.

Hatch, S. L., K. N. Gandhi, and L. E. Brown. 1990. Checklist of the vascular plants of Texas. Texas Agricultural Experimental Station, Texas A&M University System, College Station, Texas, USA.

Hill, L. A. 1992. Status of the least tern and snowy plover on the Red River 1991. U. S. Fish and Wildlife Service, Ecological Services, Tulsa, Oklahoma, USA.

Johnson, R. R., and J. S. Castrale. 1993. Management of breeding interior least terns in Indiana. Proceedings of the Indiana Academy of Science 102: 59-65.

Johnson, H. D., and T. L. Shaffer. 1990. Estimating nest success: when Mayfield wins. Auk 107: 595-600.

Kirsch, E. M., and J. G. Sidle. 1999. Interior least tern status. Journal of Wildlife Management 63: 470-483.

Koenen, M. T., R. B. Utych, and D. M. Leslie, Jr. 1996. Methods used to improve least tern and snowy plover nesting success on alkaline flats. Journal of Field Ornithology 67: 281-291.

Mallach, T. J., and P. L. Leberg. 1999. Use of dredged material substrates by nesting terns and black skimmers. Journal of Wildlife Management 63: 137-146.

Mayfield, H. 1961. Nesting success calculated from exposure. Wilson Bulletin 73: 255-261.

Ressel, D. 1979. Soil survey of Lamar and Delta Counties, Texas. U. S. Department of Agriculture, Soil Conservation Service, Texas Agricultural Experiment Station, USA.

Robel, R. J., J. N. Briggs, A. D. Dayton, and L. C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23: 295-297.

Smith, J. W., and R. B. Renken. 1993. Reproductive success of least terns in the Mississippi River Valley. Colonial Waterbirds 16: 39-44.

Schaefer, Joe. 2001. Tern of Florida, University of Florida, 7pp.

Sidle, J. G., and W. F. Harrison. 1990. Recovery plan for the interior population of the least tern (*Sterna Antillarum*). U.S. Fish and Wildlife Service, Washington D. C., USA.

Thompson, B. C., M. E. Schmidt, S. W. Calhoun, D. C. Morizot, and R. D. Slack. 1982. Subspecific status of least tern populations in Texas: North America implications. Wilson Bulletin 104: 244-262.

Thompson, B. C., J. A. Jackson, J. B. Burger, L. A. Hill, E. M. Kirsch, and J. L. Atwood. 1997. Least Tern *Sterna antillarum*. The Birds of North America, No. 290 (A. Poole and F. Gill eds.), The Academy of Natural Sciences, Philadelphia, Pennsylvania, USA and the American Ornithologists' Union, Washington, DC, USA.

Thompson, B. C. and R. D. Slack. 1982. Physical aspects of colony selection by least terns on the Texas coast. Colonial Waterbirds 5: 161-168.

United States Army Corps of Engineers. 1977. Final supplement to environmental impact statement; Atchafalaya River and Bayou Chene. Boeuf and Black, Louisiana. U.S. Army Corps of Engineers New Orleans District, New Orleans, Louisiana, USA.