Least Terns Nesting on Natural and Artificial Habitats in Georgia, USA

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Abstract.—Although increasing numbers of Least Terns (*Sterna antillarum*) are nesting on artificial substrates such as dredged-material and roofs, it is not known if these colonies are successfully fledging young. Aspects of Least Tern nesting ecology were studied in 1996 and 1997 along Georgia's coast. Numbers of nests, eggs, chicks, and fledglings at beach, dredged-material, and roof colonies were surveyed using walk-through counts from late April to mid-July. Numbers of nests ranged from 6 to 929 and they did not differ between years or among habitat types. Percent hatching success ranged from 0 to 53.4% and did not differ between years or among habitat types when the data were compared among colonies. High within-habitat type variability due to catastrophic colony failures masked differences in hatching success among habitat types. Causes of mortality included tidal flooding and human disturbance on beaches; extreme temperatures, predation by raccoons, dogs, cats, birds, and fire ants on dredged-material islands; and extreme temperatures, flooding, avian predation, and falling off roofs on buildings. More than 70% of Least Terns in Georgia are nesting with ~30% hatching success on flat, gravel-covered roofs. These roofs could provide better refugia and nesting habitat if they continued to be gravel-covered rather than vinyl-covered, if drains were screened, and if ~30 cm parapets were constructed around the perimeter. *Received 4 May 1998, resubmitted 3 March 1999, accepted 14 April 1999.*

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Historically, Least Terns (*Sterna antillarum*) nested on mainland and barrier island beaches, but more recently they have begun to nest on dredged-material islands and gravel rooftops (LeGrand 1989; Gore and Kinnison 1991; Young 1991; Cimbaro 1993; Cooper 1994; Murphy and Dodd 1995; Zambrano *et al.* 1996). The proportion of Least Terns nesting on beaches in the southeastern U.S. has decreased as the numbers of those nesting on artificial habitats, especially roofs, have increased (Murphy and Dodd 1995; Savereno and Murphy 1995; Zambrano *et al.* 1996; Shae 1997). The frequency of roof colonies as a proportion of all colonies in South Carolina increased from 14 to 61% during 1989-1995 (Murphy and Dodd 1995). This movement from natural to artificial habitats probably resulted from increased human disturbance and associated low success on beaches, and from increased availability of suitable dredged-material islands and roofs.

Although roof-nesting Least Terns have been reported in Maryland, North Carolina, South Carolina, Georgia, Florida, and Louisiana, only three studies of the reproductive success of roof colonies have been published (Roche 1977; Gore and Kinnison 1991; Cimbaro 1993). This study examined the nesting success of Least Terns on beach, dredged-material, and roof habitats along Georgia's coast.

Our main objective was to determine if Least Tern colonies on artificial habitats were as successful as those nesting on natural beaches. Causes of mortality were identified and used to develop management recommendations for increasing the recruitment of Least Terns in Georgia.

STUDY AREA

Both natural beach colony sites were on barrier islands, Ossabaw (31E44'N, 81E06'W) and Sea Islands (31E09'N, 81E21'W), and were about two ha in size. The colony sites were sandy spits with < 20% vegetation coverage, consisting of sea oats (*Uniola paniculata*), seaside panicum (*Panicum amarum*), sea-purslane (*Sesuvium portulacastrum*), sea-beach sandwort (*Honkenya peploides*), and morning-glory (*Ipomoea* spp.). Both spits were posted with signs to limit human disturbance. Although no signs of mammalian predators were seen on Sea Island, raccoons (*Procyon lotor*) and feral hogs (*Sus scrofa*) were known to frequent the Ossabaw Island spit (S. Kyles, Georgia Department of Natural Resources, pers. observ.).

Three sandy dredged-material colonies were located in Brunswick and at the Kings Bay Naval Submarine Base. The Mainside Spoil basin (30°47'N, 81°30'W), Andrews Island (31°07'N, 81°30'W), and Crab Island (30°48'N, 81°30'W) colony sites were seven, eight, and ten ha in size, respectively. Access to all sites was restricted and signs were posted at Andrews Island and the Kings Bay Mainside Spoil basin. The substrate at Andrews Island was disked each March to control vegetation such as salt-cedar (*Tamarix* spp.), cocklebur (*Xanthium strumarium*), southern sandbur (*Cenchrus echinatus*), sea-blite (*Suaeda linearis*), and common ragweed (*Ambrosia artemisiifolia*). In 1996, the Mainside Spoil site had too much vegetation, such as salt-cedar, broomsedge (*Andropogon* sp.), and dogfennel (*Eupatorium capillifolium*), to attract nesting terns. Fresh dredged-material was added to the Mainside site in 1997, making it again suitable nesting habitat for Least Terns. Raccoons were present on the submarine base while Boat-tailed Grackles (*Quiscalus major*), dogs (*Canis familiaris*), cats (*Felis domesticus*), and a coyote (*Canis latrans*) were seen on Andrews Island.

Two roof colonies were located in Savannah and one in Brunswick. These roofs were generally flat and covered with small gravel or stones to a one to four cm depth. The Dixie Crystals roof (32°04'N, 81°08'W) was 82 × 317 m and the Gulfstream roof (30°08'N, 81°11'W) was 55 × 134 m. The 10 × 75 m Glynn County Mall roof (31°12'N, 81°29'W) was the only one with parapets or walls > 30 cm around the entire roof. Fans, skylights, screened vents, and air conditioning units provided shade on each roof.

A natural beach site on Tybee Island (31°58'N, 80°54'W) and the Trident Refit Facility (TRF), a roof site on Kings Bay Naval Submarine Base (30°47'N, 81°30'W), were used as replicate sites during surface temperature observations. There were no nesting colonies at these sites during our study, but they had been used in previous years.

METHODS

In 1996 and 1997, we conducted biweekly surveys at two beach, two dredged-material, and two roof colonies, using walk-through counts of nests, eggs, chicks, and fledglings (Savereno 1992). Surveys were limited to before 1000 h and after 1600 h to minimize heat stress to the birds and eggs. Losses of eggs and chicks were recorded and the causes of mortality determined, when possible. Evidence included high water marks within a colony, standing water, reports of hail, high (> 50°C) temperatures, panting and shade-seeking behaviors, predator tracks, scat, feathers, visual sightings, and abandonment. Because losses may have gone unobserved between survey dates, our data represent the minimum numbers of nests, eggs, and chicks. Extreme temperatures on the roofs appeared to be a major mortality factor for eggs and chicks in 1996. Therefore, we used Optic Stowaway data loggers (Onset Corp.) to record surface temperatures at 2.5 cm above the substrate in all colonies and at Tybee Island beach and Kings Bay TRF roof during the 1997 reproductive season.

Percentage hatching success was defined as the proportion of total eggs laid that hatched. We calculated the mean number of nests per habitat type and mean percent hatching success for each colony and habitat type. A general linear model was used to test for significant differences at $P < 0.05$ significance level. Observed hatching success was used instead of the Mayfield method because the outcome of a given nest was not independent of the outcome of other nests in the colony (Mayfield 1961, 1975; Johnson and Shaffer 1990). Also, the two Florida studies of roof colonies we used as comparisons did not use Mayfield's method (Gore and Kinnison 1991; Cimbaro 1993). Counts of fledglings were likely biased by differences in observability among habitat types. Therefore, hatching success was the most reliable estimator of reproductive success compared among habitat types.

RESULTS

Population and Colony Sizes

From 1995 to 1997, Georgia's nesting population of Least Terns varied from 905 to 1,847 pairs (Table 1). The percentage of nests on beaches decreased from 11% in 1995 to 1% in 1997, while the percentage of nests on dredged-material and gravel roofs increased from 89% to 99%.

The number of nests per colony varied from six at Sea Island beach in 1997 to 929 at Dixie Crystals roof in 1996 (Table 2). The mean number of nests per habitat type was not different ($P = 0.51$), likely due to high within-type variability.

Hatching and Fledging Success

The hatching success of Least Tern eggs ranged from 0 to 53% (Table 2). Significant differences ($P = 0.0001$) among colonies within habitat types prevented us from pooling nest data by habitat type. Catastrophic nest failures due to tidal flooding and predation masked differences in hatching success among habitat types ($P = 0.21$) and between years ($P = 0.94$).

Because our estimates of fledging success were probably biased by lower detectability of fledglings in beach and dredged-material colonies than in roof colonies (Table 3), no tests for differences in fledging success among habitat types were performed. The number of fledglings seen on a survey ranged from 0 to 55. At least 72 chicks in 1996 and 142 in 1997 fledged in Georgia. Numbers of fledglings per pair ranged from 0 to 0.5.

Table 1. Distribution of Georgia Least Tern colonies and nests in 1995, 1996, and 1997.

	Year		
	1995[1]	1996	1997
Minimum number of nesting pairs[2]	905	1563	1270
Number of nests	905	1847	1460
Number of colonies	12	14	8
Percentage of colonies on beaches	42	43	25
Percentage of colonies on dredged- material	33	21	38
Percentage of colonies on roofs	25	36[3]	38
Percentage of nests on beaches	11	6	1
Percentage of nests on dredged-material	39	23	26
Percentage of nests on roofs	50	72[3]	73

[1]M. J. Harris. 1996. Georgia Department of Natural Resources, unpubl. data. Differences in survey intensities may account for all or part of the two-fold increase in population seen from 1995 to 1996.

[2]Excludes renesting attempts.

[3]Three unsurveyed roof colonies were estimated to have had ≥25 nesting pairs.

Causes of Mortality

While no losses of eggs or chicks were directly related to human disturbance, walkers, picnickers, horseback riders, and kayakers used the isolated, sparsely vegetated beach spits for recreation. Patrollers monitoring sea turtles disturbed the Ossabaw Island colony at night (S. Kyles, Georgia Department of Natural Resources, pers. comm.). Although signs prohibited entry at Andrews Island and the Kings Bay Mainside Spoil basin, fossil hunters entered both dredged-material colonies. Fossil hunters at the Mainside Spoil basin disturbed the colony. Human disturbance on roofs was limited to surveyor disturbance and routine equipment maintenance. Maintenance personnel were aware of the birds and did not step on any eggs or chicks.

Great Horned Owl *(Bubo virginianus)* primary feathers were found in Sea Island beach, Andrews Island dredged-material, and the Savannah roof colonies. Two chicks at Gulfstream and one at Dixie Crystals were

Table 2. Numbers of nests and hatching success of eggs in Least Tern colonies along the Georgia coast.

	Number of nests		Hatching success (%)	
Habitat type and colony	1996	1997	1996	1997
Beach				
Ossabaw Island	19	12	0	0
Sea Island	68	6	29	0
$\bar{X}$ ± SE	44 ± 25	9 ± 3	15 ± 15	0
Dredged-material				
Crab Island	31	8	0	0
Andrews Island	384	216	19	32
Mainside Spoil	0	160	0	22
$\bar{X}$ ± SE	208 ± 177	128 ± 62	10 ± 10	18 ± 10
Roof				
Gulfstream	294	664	35.9	29
Dixie Crystals	929	156	22.7	33
Glynn Co. Mall	>50[1]	238	-[1]	53
$\bar{X}$ ± SE	611.5 ± 317.5	352.7 ± 157.5	29.3 ± 6.6	38.5 ± 7.6

[1]Glynn County Mall was not surveyed in 1996, but ≥50 nests were present (M. J. Harris. 1996. Georgia Department of Natural Resources, unpubl. data).

Table 3. Numbers of chicks and fledglings recorded in Least Tern colonies in Georgia.

Habitat type and colony	Live chicks in nests		Dead chicks		Fledglings[1]		Fledglings/pair	
	1996	1997	1996	1997	1996	1997	1996	1997
Beach								
Ossabaw Island	0	0	0	0	0	0	0	0
Sea Island	28	0	0	0	0[2]	0	0	0
Dredged-material								
Crab Island	0	0	0	0	0	0	0	0
Andrews Island	33	109	7	25	0	23	0	0.12
Mainside Spoil	0	56	0	0	0	5	0	0.05
Roof								
Gulfstream	174	249[3]	160	292[3]	40	54[4]	0.14	0.08
Dixie Crystals	398	93	165	24	32	5	0.04	0.04
Glynn Co. Mall	na[5]	218	na[5]	120	na[5]	55	na[5]	0.26

[1]The maximum number of fledglings seen on all survey dates was used to estimate number of chicks fledged.

[2]Five juveniles were seen loafing on the Sea Island beach in July 1996, but we were unable to determine their colony of origin.

[3]We stopped surveying for 5 weeks in 1997 to minimize chicks falling off roofs. Consequently, we missed the hatching of some chicks which were later found dead.

[4]Fledglings were counted with binoculars from ladders that accessed the Gulfstream roof.

[5]The Glynn County Mall was not surveyed in 1996 because we did not have access to the roof.

beheaded in typical owl fashion (Dolbeer *et al.* 1996). Because owls hunt at night and roost in secluded woodlots, no pellets were found at the colony to determine how many of the chick losses could be attributed to owl predation. Other potential avian predators seen near roofs included Loggerhead Shrikes (*Lanius ludovicianus*), American Crows (*Corvus brachyrhynchos*), and Boat-tailed Grackles (*Quiscalus major*).

Tidal flooding and shifting sand reduced the success of both beach colonies. Spring high tides washed away or covered eggs with < 5 cm of sand. Feral hog and raccoon tracks were found in the Ossabaw colony, but no losses were attributed to these predators.

Dredged-material colonies suffered predation by dogs, cats, coyotes, raccoons, and possibly herons (*Egretta* spp.) or Boat-tailed Grackles. Fire ants (*Solenopsis invicta*) at Andrews Island bit the feet of young chicks, causing the chicks to run and wobble in their attempts to escape. Other chicks were found partially consumed by fire ants, but we were unable to determine if fire ants killed the chicks. Other chicks appeared to have died while hatching, after pecking a hole in the shell and then dehydrating from high temperatures.

The Dixie Crystals and Gulfstream roof colonies experienced severe flooding from a thunderstorm in June 1996 that washed eggs and chicks into rain gutters. Hail produced by the storm punched holes in some eggs. Other eggs and chicks were found around screened drains or on the ground.

Hundreds of addled eggs and dead chicks were found in the roof colonies. Fewer dead eggs and chicks were seen at Andrews Island dredged-material site. Inviable eggs were cracked, discolored, lightweight, or had yolk dried on the shell. Most dead chicks did not have any external signs of injury. The lowest and highest temperatures, 1.6°C and 67.6°C, were recorded at roof colonies (Table 4). Roof colonies had significantly higher mean daily maximum temperatures than beach ($P = 0.0062$) and dredged-material ($P = 0.019$) colonies, and more temperature readings were in extreme temperature categories (60-65°C and 56-59°C) in roof colonies than in beach or dredged-material colonies ($P < 0.05$). Although the mean daily minimum temperatures did not differ among habitat types ($P = 0.20$), the coldest temperature occurred at Glynn County Mall on a rainy weekend when many chicks had already hatched.

Table 4. Maximum and minimum daily surface temperatures in beach, dredged-material, and roof Least Tern colonies along Georgia's coast in 1997.

Habitat type and colony	Maximum temperature[1] (°C)	Minimum temperature[1] (°C)
Beach		
Ossabaw Island	54	10
Sea Island	60	11
Tybee Island[2]	61	17
$\bar{X}$ (95% C.I.)	58[a] (54-63)	12[a] (8-16)
Dredged-material		
Crab Island	57	14.9
Andrews Island	64	8.8
Mainside Spoil	59	16.2
$\bar{X}$ (95% C.I.)	60[a] (56-64)	13[a] (9-18)
Roof		
Gulfstream	68	8
Dixie Crystals	65	2
Glynn Co. Mall	67	2
Kings Bay TRF[3]	67	14
$\bar{X}$ (95% C.I.)	67[b] (65-68)	8[a] (2-14)

[1]Means followed by different superscript letters within a column are different ($P \leq 0.05$).
[2]Not a colony site in 1997.
[3]Used by Least Terns in 1994, but not used since.

The next survey indicated that at least 78 chicks died, presumably from hypothermia.

Surveyor disturbance was a problem by early June when many chicks were present on the roofs. In 1996, chicks fell off the roofs when fleeing from the survey crew. Walls with parapets stopped some chicks and prevented them from falling. Surveys were decreased from twice a week to once every two weeks to decrease disturbance to chicks.

In 1997, walk-through surveys at Gulfstream were stopped from 5 May to 30 June when chicks were wandering throughout the roof. This roof lacked any kind of parapet or wall. Counts of chicks and fledglings during this period were made from the tops of ladders leading to the roof. Dead chicks continued to be found on the ground between survey periods. Only one chick at Dixie Crystals and two at the Glynn County Mall fell during our surveys in 1997. No more chicks fell at the mall after we screened the rain spouts with hardware cloth.

DISCUSSION

Reproductive Success

Our estimates of hatching success are similar to those reported for Andrews Island and Ossabaw Island (Corbat 1990; Harris and Goodloe 1995): 10% in 1993 and 40% in 1994 on Andrews Island, and 3% in 1986 and 40% in 1987 on Ossabaw Island. Kyles and Hagge (Georgia Department Natural Resources, unpubl. data) noted that Ossabaw Island's 1995 colony was flooded repeatedly and probably did not produce any chicks.

Estimates of reproductive success among habitat types are limited (Roche 1977; Gore and Kinnison 1991; Cimbaro 1993; Savereno and Murphy 1995). Roche (1977) found greater success in roof versus ground colonies. Gore and Kinnison (1991) reported 29% hatching success for roof colonies compared to 10% for beach colonies. Savereno and Murphy (1995) observed nesting success on roofs to be as high or higher than that on beaches. The roof colonies we observed were poor to moderately successful compared with Least Tern colonies elsewhere (Massey and Atwood 1981; Burger 1984; Burger and Gochfeld 1990).

Our finding of no significant differences in the mean proportion of eggs hatched among habitat types contradicts previous findings. Earlier studies indicated significantly greater reproductive success in roof versus ground colonies (Roche 1977; Fisk

1978a,b; Gore and Kinnison 1991). However, Gore and Kinnison (1991) only saw a significant difference when their data were pooled by habitat type; the proportion of eggs that hatched in roof colonies (29%) was significantly higher than in beach colonies (10%). Their study also had high within-habitat variability and small sample sizes ($n < 5$) that may have masked real differences in the proportion of eggs hatched among habitat types (Gore and Kinnison 1991).

Mortality Factors

Physiological and behavioral adaptations of Least Terns allow them to reproduce despite high ambient temperature (> 50°C). The colony with the greatest hatching success (53%), Glynn County Mall in 1997, also experienced the highest (67°C) and the lowest (2°C) temperatures. Cimbaro (1993) reported similar results among Florida ground and roof colonies. While eggs at Dixie Crystals continued to hatch in July, the hottest month of the year, chicks hatched from these eggs were unable to cope with the extreme temperatures. All dead chicks found in July were less than 1.5 days old. Although young terns regulate body temperature better at higher than lower temperatures, and chicks under severe heat stress (> 45°C) are able to regulate body temperatures sufficiently for up to 38 min (Howell 1959), even brief exposure to ground temperatures > 41°C is lethal to Charadriiform eggs and likely decreases chick survival (Purdue 1976).

Importance of Artificial Habitats

Human disturbance and flooding on natural beaches, predation on dredged-material sites, and greater relative reproductive success on roofs may explain why so many terns select gravel roofs, rather than natural beach and dredged-material sites. Unfortunately, new buildings are being covered with a gravel-free roofing material which the terns do not use for nesting (Gore and Kinnison 1991; Cimbaro 1993). Cooperation between planning agencies, developers, and wildlife agencies in the early stages of building design could help create suitable Least Tern nesting habitat on new roofs. Our experiences suggest that building owners are tolerant of roof colonies and would be willing to make some structural modifications to assist with conservation efforts.

Dredged-material islands are also very important nesting habitat for Least Terns and other colonial waterbirds in the southeastern U.S. (Parnell 1987; Parnell *et al.* 1988; Harris and Goodloe 1995). Dredged-material areas in Georgia supported as many as 38% of colonies and 39% of nests. More than 71% of North Carolina's Least Tern colonies were on dredged-material and such colonies are larger in size than those on natural beaches (Jernigan *et al.* 1978). While barrier island beaches are preferred Least Tern habitats, dredged-material islands act as refugia from human disturbances on beaches (Erwin 1980). In addition, dredged-material islands have the advantage of not being as susceptible to flooding as are beach sites. Isolated dredged-material islands are especially suitable because of the lack of mammalian predators.

Management Recommendations

Flat, gravel roofs with parapets ~30 cm high should be encouraged in local building codes. Parapets and screened drains prevent chicks from falling off roofs. Roof repairs should not include bare vinyl or rubber materials. Several Least Tern colonies in Florida have abandoned sites when gravel roofs were replaced with plastic. A thin layer of gravel spread over these materials might attract nesting terns. Maintenance work should not be performed from 15 April to 1 August. Roof maintenance during the nesting season should be completed within one h and should be performed before 1000 h or after 1700 h.

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