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NESTING HABITAT SELECTION OF THE LEAST TERN ON THE GULF COAST OF FLORIDA

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Abstract.—Due to a decline in suitable coastal breeding habitat, the Coastal Least Tern (*Sterna antillarum antillarum*) has been listed as a threatened species by Florida. As available breeding habitat for this species continues to decline, the need to manage and protect existing habitat is crucial. To determine what constitutes suitable habitat for Least Tern populations on the Gulf coast of Florida, we surveyed six habitat variables at 11 occupied and 11 unoccupied sites and at an area recently restored for the species. On average, Least Tern colony sites were located on a sandy substrate made up mostly of sand-sized grains, mixed with gravel, shell, and a trace amount of silt. Vegetation was short with sparse coverage, which allowed chicks to find shelter from sun, wind, and rain. Dense patches of vegetation were located far enough from the colony to minimize their value as hiding places for potential egg or chick predators. The colonies were located on beaches where the slope, elevation, and distance from high tide were at levels unlikely to flood. Forward stepwise logistic regression analysis selected slope, elevation, and silt and shell content of the substrate as the most important variables associated with occupancy of a site by the Least Tern.

The Coastal Least Tern (*Sterna antillarum antillarum*) naturally nests on beaches along the Atlantic and Gulf coasts of the United States. Breeding colonies usually include from 3 to 300 pairs with an internest distance of about 1.5 m (Burger 1988). Historically beaches selected for nesting are >20 m in width (Gochfeld 1983). Substrate composition at these sites tends to include 80-90% sand, <20% shell fragments and gravel, and <10% silt (Thompson and Slack 1982, Gochfeld 1983, Kotliar and Burger 1986). Vegetation is typically short and sparse, ideally with <10% cover and usually <20% cover (Thompson and Slack 1982, Gochfeld 1983, Kotliar and Burger 1986). An elevation >2 m above high tide is important for breeding success (Thompson and Slack 1982, Gochfeld 1983) as is a slope of <10° (Gochfeld 1983).

Once the breeding season is complete in the United States, Least Terns migrate to the coasts of Mexico, Central and South America, Ar-

gentina, and Brazil for the winter (Thompson et al. 1997). Least Terns typically return to the same nesting site each breeding season; however, they will abandon sites that become physically unsuitable due to vegetation succession, flooding, habitat destruction, or human disturbance, or if they are consistently unproductive at that site (Kotliar and Burger 1986, Burger 1984, Gochfeld 1983, Downing 1973).

Due to the decline in their population in Florida, the Least Tern is listed by Florida as threatened (Wood 1994). This population decline began in the 1800s and early 1900s, when this seabird species was commercially hunted for use of its feathers on ladies' hats (Gore 1996). While this fashion trend ended, coastal recreation and development have increased. Current populations must compete with humans for diminishing habitats.

We attempted to further define the physical characteristics of beach nesting-sites used by the Least Tern. Our results also were considered in light of a need to develop plans for management and restoration of existing Least Tern breeding sites. We also compared habitat variable parameters of the breeding colonies with those of a nearby area that was restored to provide habitat for the Least Tern.

METHODS

Study Area.—We found 12 active Least Tern colony sites along the Gulf coast of Florida (from Hernando County south to Sarasota County) during the 2002 nesting season (Fig. 1). Nine sites, North Anclote Bar, Three Rooker Bar, Honeymoon Island State Park, Caladesi Island State Park, Clearwater Beach, Belleair Beach, Indian Shores, South Pasadena Park Habitat Extension, and Shell Key are located in Pinellas County. Two sites, Wolfbranch Creek and Egmont Key, are located in Hillsborough County, and the twelfth site, North Lido Beach, is in Sarasota County.

North Anclote Bar, Three Rooker Island, Honeymoon Island, Caladesi Island, and Shell Key are naturally formed barrier islands. Clearwater Beach, Belleair Beach, Indian Shores, and North Lido Beach are renourished beaches, backed by condominiums, houses, and hotels. Egmont Key is a naturally formed barrier island; however, the area where the Least Terns nested was renourished prior to their arrival in May 2002. Wolfbranch Creek, which is an ELAP (Environmental Land Acquisition Program) site that has been restored with native vegetation, tidal basins, and freshwater ponds, is located inland off of Tampa Bay.

South Pasadena Park Habitat Extension is a restored area that was built in 1997 and opened on 28 April 1998, with the primary purpose of providing nesting habitat for the Least Tern. The recreated beach habitat was built along a seawall in the city of South Pasadena, off the Intra-coastal Waterway. The colony observed during the 2002 breeding season was the first nesting colony to use the restored habitat.

Colony Census.—We censused each Least Tern colony once between 22 May and 29 June 2002 to confirm that there was breeding and to estimate colony size. During each site-census two observers independently counted the total number of adults, number of adults on a nest, chicks (not capable of flight), and fledglings (flight capable) within the vicinity of the colony. An adult was counted as nesting if its belly appeared to be resting in a scrape made for a nest versus resting on level sand. To avoid disturbance, each colony was observed from 30-200 m away using 10 × 50 binoculars or a 15-60× spotting scope. The two counts were averaged to calculate the mean number for each.

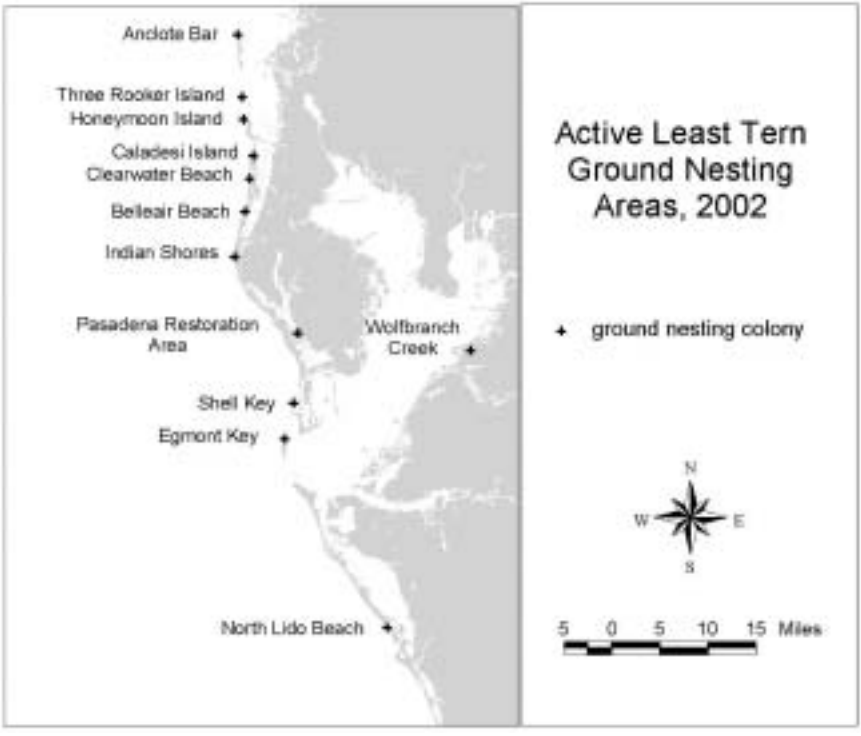

Figure 1. The 12 Least Tern breeding colony sites censused for this study. They are located on the Gulf coast of Florida, within Pinellas, Hillsborough, and Sarasota counties.

Habitat Survey.—We measured habitat characteristics for each colony site immediately after Least Tern chicks fledged and the birds were no longer congregating within the colony site. A transect was placed through the middle of the colony site, parallel with the water. Ten sampling points were evenly spaced along the transect. The length of the transect and space between sampling points varied among colony sites due to different colony sizes. A 1 m^2 quadrat was used as the sample area at each point. The bottom or top, right corner of the quadrat (depending upon the side of the transect) was placed at the point and the quadrat was laid on the sand toward the end of the transect. We altered the side of the transect on which the quadrat was placed for successive samples, first toward the dunes and then toward the water. The distance of the quadrat from the transect was randomly predetermined so that six quadrats were placed 2 m from the transect and four quadrats were placed 1 m from the transect. At each colony site we measured the following habitat variables: substrate composition, slope, vegetation cover, distance to dense vegetation, distance to high tide line and elevation.

We collected substrate and slope data at the center of each quadrat. For each sample, we sealed a one-cup sample of the substrate in a labeled plastic bag and dried it outside, in the sun, on a paper plate. We sifted 100 mL of the dried sample to measure the percentage of shell, gravel (>2 mm), sand (0.0625-2 mm), and silt (0.004-0.0625 mm) following the approach of Prothero and Schwab (1996). We measured slope by placing a

transit on a small piece of flat wood on the same plane as the water. A negative slope measurement indicated the beach was sloping down toward the water, while a positive slope measurement indicated that the beach was sloping down toward the dunes. We measured vegetation within the entire quadrat. Percent cover of vegetation (independent of species) was estimated visually and the tallest plant species was measured to determine maximum height of vegetation. Evidence of the presence of potential predators and disturbance were recorded as present or absent within each quadrat and within the colony when applicable.

We measured distance to densest vegetation, distance to high tide mark, and elevation from the center of the transect. Distance to dense vegetation was defined as the closest area of vegetation >1 m high. We chose this height because it would be high enough to provide cover to most potential predators (e.g., large wading birds, raccoons (*Procyon lotor*)).

Distance to high tide was the distance from the center of the transect to the line of dead, washed-up vegetation (i.e., the wrack line) present at the time of the habitat variable survey at each site. To measure elevation, a tape measure was kept level and extended from the higher elevation at the center of the transect to the lower wrack line.

We measured the width (distance parallel to the water) of the occupied colony and established the unoccupied sample site this width from the occupied colony. The same survey methods were used to measure habitat characteristics of an unoccupied site.

Data Analysis.—Habitat characteristics measured within each quadrat along the transects (e.g., substrate composition, amount of ground cover, height of ground cover, and slope) were averaged to determine the mean and standard error for each characteristic at each location. Each habitat characteristic was averaged among all locations to determine an overall mean for each variable. To increase the chance that the data were normally distributed, the mean results were then transformed using the arcsine square root transformation on percentage variables and logarithmic transformation on the remaining variables (Sokal and Rohlf 1969). The transformed variables were used to conduct t-tests, Pearson correlation, and forward stepwise logistic regression analyses (SPSS, Inc. 1997).

We used a t-test to determine which habitat characteristics were significantly different when comparing occupied sites to unoccupied sites. We used a Pearson correlation analysis to determine if there was a significant correlation between pairs of habitat variables across all sites. We used a forward stepwise logistic regression analysis to identify those habitat characteristics most associated with occupied or unoccupied sites. As suggested by Hosmer and Lemeshow (1989), the variables that were significant at the 0.10 level were included in the model.

RESULTS

Colony Establishment.—All 12 of our established colonies produced eggs; chicks were observed at all of the colonies except Belleair Beach (Table 1). These observations suggest that the habitat conditions of each colony were suitable for Least Tern nesting. We observed fledged juveniles at seven of the locations. At Belleair Beach and South Pasadena Park Habitat Extension, no chicks survived to fledge. At Three Rooker Bar, Clearwater Beach, and Shell Key, we observed no fledged juveniles, however, we cannot preclude the possibility of some fledging because our observations were either made before chicks reached juvenile stage or after the juveniles would have fledged.

Table 1. Estimated mean number of adults, nests, chicks, and juveniles observed on preliminary survey date (unless otherwise noted). Records of abandonment are also noted.

Beach (abandonment)	Date	# of Adults (Mean ± SE)	# of Nests (Mean ± SE)	Chicks (Mean ± SE)	Juveniles (Mean ± SE)
North Anclote Bar (no)	6/29/02	41.5 ± 0.50	21.5 ± 0.50	3.0 ± 0.00	3.5 ± 0.5
Three Rooker Bar (yes)	6/7/02	4.0 ± 0.00	1.0 ± 0.00[a]	2.0 ± 0.00[a]	0.0 ± 0.00
Honeymoon Island (no)	5/28/02	45.5 ± 2.50	20.5 ± 0.50	5.0 ± 0.50	1.5 ± 0.5
Caladesi Island (no)	6/21/02	52.0 ± 2.00	1.0 ± 0.00	0.0 ± 0.00	8.5 ± 0.5
Clearwater Beach[b] (yes)	6/9/02	8.0 ± 0.00	4.0 ± 0.00	2.0 ± 0.00	0.0 ± 0.00
Indian Shores (no)	6/10/02	34.5 ± 0.50	14.0 ± 0.00	0.0 ± 0.00	15.0 ± 0.00
Belleair Beach (yes)	6/10/02	0.0 ± 0.00[3]	0.0 ± 0.00[c]	0.0 ± 0.00	0.0 ± 0.00
Shell Key[b] (no)	6/11/02	18.0 ± 0.00	9.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.0
Egmont Key[d] (no)	8/9/02	0.0 ± 0.00[e]	0.0 ± 0.00	0.0 ± 0.00[e]	1.0 ± 0.0
North Lido Beach (no)	5/29/02	79.0 ± 2.00	18.0 ± 0.00	0.0 ± 0.00	18.0 ± 1.0
Wolfbranch Creek (no)	6/28/02	34.0 ± 1.00	9.0 ± 0.00	2.5 ± 0.50	2.0 ± 1.00
South Pasadena Park (yes)	5/22/02	49.5 ± 0.50	21.5 ± 0.50	0.0 ± 0.00[f]	0.0 ± 0.00

[a]Undetermined whether nest and chicks are from before abandonment or are renests.
[b]Observed colony was a renest colony.
[c]Two dozen adults and nests observed before abandonment (Jim Turner, pers. comm.).
[d]Observations made after the nesting season was completed.
[e]58 adults and 10, almost fledged, chicks observed at a point during the nesting season (Maureen Arnold, pers. comm.).
[f]Eggs and chicks observed, but chicks did not survive to juvenile stage (Doug Clark, pers. comm.).

Characteristics of Suitable Habitats.—Occupied sites varied widely in habitat characteristics. The average habitat was comprised of a sand substrate (mean = 91.49% ± 2.36) that was mixed with small pieces of gravel (including shell and limestone) (mean = 5.96% ± 1.90), larger pieces of shell (mean = 2.43% ± 0.50), and a minute amount of silt (mean = 0.04% ± 0.04) (Table 2). On average, there was little percent cover within the colony (mean = 1.87% ± 1.11) and vegetation was short (mean = 2.10 cm ± 0.69). Typically the slope was gradual (mean = 1.23° ± 0.16) and the elevation was high enough to avoid flooding due to high tide (mean = 0.76 m ± 0.53). The Least Tern colonies tended to be located a distance far from high tide (mean = 26.85 m ± 4.77) and dense vegetation (mean = 18.42 m ± 2.80).

Comparison Between Occupied and Unoccupied Sites.—The most significant habitat difference between occupied and the unoccupied sites was slope ($t = 3.916, p = 0.003$) (Table 2). At the occupied sites, the slope was more gradual (mean = 1.23° ± 0.16) than it was at the unoccupied sites (mean = 1.71° ± 0.19). Elevation also differed significantly between the areas ($t = 2.286, p = 0.045$). Occupied sites had a higher elevation (mean = 0.76 m ± 0.53) than unoccupied sites (mean = 0.19 m ± 0.07). All the other habitat characteristic comparisons were not sig-

Table 2. Mean results of habitat variable data collected at occupied and unoccupied sites of eleven beach locations sampled. The *t*-value and *p*-value were calculated from transformed habitat variable data. South Pasadena Park Habitat Extension data included for comparison.

Variable	Occupied (Mean ± SE)	Unoccupied (Mean ± SE)	*t*-value	*p*-value	South Pasadena Park (Mean ± SE)
Shell (%)	2.43 ± 0.50	1.93 ± 0.53	1.333	0.212	89.60 ± 1.76
Gravel (%)	5.96 ± 1.91	5.00 ± 2.00	1.352	0.206	5.20 ± 0.70
Sand (%)	91.49 ± 2.36	92.97 ± 2.44	1.332	0.213	5.20 ± 1.27
Silt (%)	0.04 ± 0.04	0.08 ± 0.06	1.228	0.248	0.06 ± 0.02
Cover (%)	1.87 ± 1.11	5.35 ± 4.36	0.656	0.527	21.50 ± 7.75
Height (cm)	2.10 ± 0.69	5.71 ± 4.03	0.682	0.510	11.88 ± 2.79
Slope (°)	1.23 ± 0.16	1.71 ± 0.19	3.916	0.003	2.35 ± 0.57
Dense Veg (m)	18.42 ± 2.79	19.07 ± 4.07	0.177	0.863	6.50
High Tide (m)	26.85 ± 4.77	23.47 ± 5.80	1.509	0.162	18.3
Elevation (m)	0.76 ± 0.53	0.19 ± 0.07	2.286	0.045	1.5

nificant ($p > 0.05$). Average percent cover and average maximum height at the occupied versus the unoccupied sites showed the greatest differences among all the habitat characteristics; however, these differences were not significant ($t = 0.656, p = 0.527; t = 0.682, p = 0.510$).

Results of the Pearson correlation analyses indicated that there were no significant correlations between pairs of variables ($p > 0.05$). Forward stepwise logistic regression analysis selected beach slope first, followed by elevation, silt, and shell as those variables that most likely determined whether an area had the potential to be occupied or unoccupied by a Least Tern colony (Table 3). This combination of habitat variables yielded the greatest percentage of correct predictions concerning whether the locations were occupied or unoccupied (occupied =

Table 3. Transformed habitat variables selected by forward stepwise logistic regression to determine the probability of an area being occupied or unoccupied.

Habitat variable	β ± SE[1]	Wald[2]	df	*p*-value[3]
Slope	5.278 ± 2.741	3.709	1	0.054
Elevation	-1.422 ± 0.708	4.030	1	0.045
Silt	130.676 ± 78.406	2.778	1	0.096
Shell	-28.755 ± 16.252	3.310	1	0.077

[1]β here refers to the estimated regression coefficient.
[2]The "Wald" is a statistic used in logistic regression to test the significance of individual independent variables. It is similar to t-test statistic.
[3]For logistic regression, a p value of <0.10 indicates that the variable significantly helps to discriminate between the groups (occupied and unoccupied beach sites).

9/11 correct, 81.8%; unoccupied = 10/11 correct, 90.9%; overall = 86.4%). When additional habitat variables were entered into the equation the percentage of correct predictions remained the same.

Comparison Between Occupied Sites and South Pasadena Park Habitat Extension.—Many of the habitat characteristics at the South Pasadena Park Habitat Extension differed greatly from the averages of those characteristics for the occupied sites (Table 2). The top 2.5 cm of substrate was dominated by heavy shell (mean = 89.60% ± 1.76). Sand substrate, which typically dominates Least Tern nesting habitat, was less dominant (mean = 5.20% ± 1.27). Percent cover and maximum height were also drastically different from the average Least Tern nesting habitat (mean = 21.50% ± 7.75; 11.88 cm ± 2.79, respectively). However, the habitat was free of vegetation when the Least Tern colony was established. While this is a critical observation it is also important to realize that the vegetation at the occupied sites was significantly less at the beginning of the nesting season as well, yet during the season, encroachment was not as great as it was at the restoration site. The seeds of the vegetation that overtook the restoration site were likely responsible for attracting other avian species, which may have been a cause for the abandonment by the Least Terns at this site. Slope, elevation, and distance to high tide were measured; however, they are not comparable because the restoration site was built up on property protected by a seawall.

DISCUSSION

On average, the Least Tern colony sites along the Gulf Coast of Florida were located on a sand substrate mixed with gravel, shell, and minimal silt. Vegetation was short and sparse, with dense vegetation far enough from the colony to avoid hiding places for predators. Colonies were at a high-enough elevation and distant-enough from the high tide mark to avoid flooding. Our results are similar to those found on the Atlantic Coast in New Jersey and the Gulf Coast in Texas (Thompson and Slack 1982, Gochfeld 1983, Kotliar and Burger 1986), with the exception that both our occupied and unoccupied beaches tended to have slightly more sand and less gravel than those other locations.

Slope and Elevation.—The significance of slope and elevation in the selection of a site and in determining the potential occupancy of an area were both supported by the statistical analyses. In addition to the need to avoid flooding, being on a slope up from the water provides the Least Terns with the visibility they need to easily detect approaching danger (Burger and Gochfeld 1990). The importance of these two variables was observed at Honeymoon Island State Park, where a flood high-tide stopped near the nesting colony. Had the colony not been es-

tablished at the peak slope and elevation the eggs and chicks would have been destroyed

Substrate.—Shell and silt seemed to be significant variables in determining the potential occupancy of an area. Mallach and Leberg (1999) found that the addition of shell to a dredged material island lacking this substrate resulted in attraction of Least Terns to the island, successful nesting, and reduced vegetation growth. Increased amount of shell substrate at the South Pasadena Park Habitat Extension did attract Least Terns to the area and provided a suitable habitat; however, it did not appear to reduce vegetation growth.

The presence of silt is an important variable to consider because substrate composition with greater than 40% silt can cause what is known as "egg-sticking" during wet periods (Thompson and Slack 1982). Deposition and fill sites tend to have a higher abundance of silt than do the natural sites. This is relevant to the colony sites used in this study because the presence of silt was only observed on renourished beaches and filled areas; however, we felt the abundance of silt was likely never enough to cause "egg-sticking."

Vegetation.—The significance of percent cover and maximum height was minimized by the statistical analysis due to great variation, although these variables showed the greatest difference between occupied and unoccupied sites. While vegetation was determined to be insignificant, other studies have found vegetation to be an important variable in the success of Coastal Least Tern colonies (Thompson and Slack 1982, Kotliar and Burger 1986). While some vegetation is needed to provide protection for chicks (Thompson and Slack 1982, Burger and Gochfeld 1990, Jackson 1976), too much vegetation hinders the ability of Least Terns to maneuver, provides cover for predators, and can inhibit the construction of nest scrapes (Kotliar and Burger 1986).

While we usually observed the positive effects of vegetation found in other studies at all the sites that had chicks, we also saw the negative effects. We observed a Yellow-crowned Night-Heron (*Nyctanassa violacea*) moving stealthily into the colony at Shell Key by hiding within the tall stands of sea oats (*Uniola paniculata*). Adult terns left their nests and attacked the night-heron while it ran between stands of sea oats and then ceased when they could no longer see it hidden in the sea oats.

An over-growth of vegetation may have played a major role in abandonment of the colony at South Pasadena Park Habitat Extension, which occurred after the chicks hatched. When the Least Terns established their nests, there was minimal vegetation within the colony. As the nesting season progressed, the vegetation ground cover grew to exceed 20% of the colony site. The vegetation began to seed, which attracted many other species of birds and caused some disturbance within the tern colony.

Management Recommendations.—Based upon results of this and similar studies, it seems important to ensure that the slope and elevation of the area are suitable to avoid flooding. Substrate should consist of a sand and shell mixture. If it is necessary to add fill to the site, it is important to keep silt composition minimal to avoid "egg-sticking." Vegetation should be reduced to <5% coverage, cut low to the ground before Least Terns arrive in spring, and then allowed to grow during the nesting season. Sparse vegetation can be removed manually; however rototillers, bulldozers, or tractors and plows may be needed to remove denser cover (O'Meara and Gore 1988, Burger 1989, Jackson 1976). Spraying vegetation with salt water or Ureabore®, or depositing dredge spoil, can be used to inhibit growth (Kotliar and Burger 1986).

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