Nest Site Selection in Least Terns (*Sterna antillarum*) in New Jersey and New York

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Abstract.—East Coast Least Terns (*Sterna antillarum*) generally nest in relatively barren, homogeneous habitats of broad sandy beaches on barrier islands or on spoil deposition sites. We studied Least Terns at several New York (N=4) and New Jersey colonies. About 300 pairs of Least Terns nested along 2 km of beach on Brigantine Beach, NJ in 1983. The New York colonies contained from 20-300 pairs estimated from single visits in 1971, 1974 and 1977. At most sites choice of nest sites differed from random with respect to position on the beach, elevation and slope, shell cover, vegetation cover, and distance to vegetation. Terns preferred to nest in the middle third of the beach, on areas with shell cover, and on ridges and slopes. On sparsely vegetated beaches, nests were closer to vegetation than were the random points; on heavily vegetated areas, nests were further from vegetation than were the random points. At Brigantine, fox and cats entered the colony from the dunes and preyed heavily on nests closest to the dunes. Terns nesting during the peak of the nesting season fledged the most young and suffered the fewest losses to predators. At Brigantine, disturbance was less at the ends of the colony, resulting in higher reproductive success in these sections. In the Long Island colonies beach vehicles, humans, and cats were the main causes of egg and clutch mortality. *Received 28 November 1988, accepted 29 June 1989.*
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Nest site selection in birds involves the choice of a particular location among the available habitats and sites (Partridge 1978), usually resulting in a non-random spatial distribution of nests. Nest site selection is the final stage in a series of habitat choices, including colony, general habitat and territory selection (Gochfeld 1978, Burger 1985). In colonial species these three choices are not necessarily made at the same time, nor even by the same member of the pair (Burger 1985).

General nest site requirements of larids have been examined in detail, particularly in marsh-nesting species (Bongiorno 1970, Montevecchi 1978, Burger and Shisler 1978, Storey 1987a,b). However, factors affecting nest site selection in ground-nesting larids have not been as extensively studied, except for Laughing (*Larus atricilla*, Montevecchi 1978), Kelp (Burger and Gochfeld 1981) and Mew (*L. canus*, Burger and Gochfeld 1987) Gulls. Blokpoel *et al.* (1978) reported that Common Terns (*Sterna hirundo*) prefer nesting on vegetated versus bare ground, and Burger and Lesser (1978) showed a preference for mats and high-elevation nest sites for Common Terns nesting in salt marshes. Storey (1987a) reported that successful nests of marsh-nesting Common Terns were on high ground, in tall grass, or on large mats to avoid tidal flooding. Roseate Tern (*S. dougallii*, Gochfeld and Burger 1988, Burger and Gochfeld 1988) nest under vegetation. Sandwich Terns (*S. sandvicensis*) select nest sites that have uniform vetegation and substrate (Veen 1977). Most authors have not examined spatial features of nest site selection such as proximity to colony edges.

Several authors have examined the factors involved in colony site selection in Least Terns (*S. antillarum*, Veen 1977, Goodrich 1982, Thompson and Slack 1982, Burger 1984, Gochfeld 1984, Kotliar and Burger 1986, Minsky 1987). In this study we examine the physical, spatial and temporal aspects of nest site selection in Least Terns nesting on Brigantine Beach, NJ, and at several colonies on Long Island, NY to delineate nest site preferences with respect to location relative to the dunes, elevation, shell cover, and vegetation, and to relate these differences to reproduction success at Brigantine Beach. The number of chicks hatching and fledging per nest could be determined with a minimum of human disturbance by checking nests when chicks were young and using binoculars when chicks were older.

Least Terns are well suited to such a study because they traditionally nest along beaches and on spoil islands in relatively homogeneous habitats. They usually nest on sand-shell beaches relatively free of vegetation (Downing 1973, Massey 1974, Wolk 1974, Minsky 1987), although they have been known to nest on rooftops (Fisk 1975). Minsky (1987) reported that California Least Terns avoided vegetation, but preferred debris near their nests. Minsky (1987) and Burger (1988) also postulated that social factors are important in nest site selection.

STUDY SITES

We studied nest site selection at Brigantine Beach, Atlantic County, New Jersey; and at Meadow Island, Gilgo Beach, Short Beach and Fire Island on the south shore of Long Island, New York. The New York colonies were within a 30 km stretch of barrier beaches in east Nassau and Suffolk counties. At Brigantine Beach in 1983; 300 pairs of terns nested along a 200 m wide and 2 km long stretch of flat, sparsely vegetated, shell covered beach. In most places the beach had a 100-200 m wide strip of shallow dunes between it and houses and condominiums. Access to the tern colony was blocked by signs and wire fence, and people used narrow corridors to walk through the colony to the beach.

In New York we studied a 300-pair colony of Least Terns at Gilgo Beach in 1977; a 20-pair colony at Meadow Island in 1974; a 21-pair colony at Fire Island in 1974, and a 24-pair colony at Short Beach in 1971. At Gilgo Beach the terns nested linearly along the berm on a 25 m wide by 650 m long section of beach. The vegetation cover was sparse (< 5%) in the middle, ranging to 40% Beach Grass (*Ammophila breviligulata*) on the slope of the outer dune. At Short Beach, terns nested in a circular colony on berm 120 m wide by 80 m wide. The colony had 2% cover of Beach Grass and 3% cover of *Cakile edentula* (estimated from random points). At Meadow Island terns nested in a circular colony (40 m by 75 m) on fill with no vegetation within 30 m. At Fire Island terns occupied a circular area on a spoil site recently planted with Beach Grass to achieve stabilization (60 m x 90 m).

METHODS

Terns at Brigantine Beach were studied 5 to 7 days a week from 15 April to the end of July 1983. The beach was arbitrarily divided into quadrats 150 m wide and 100 m deep. During the egg-laying period the beach was censused every day for nests. New nests were marked and numbered and the following data were recorded: quadrat number, date, linear distance from ocean, elevation, % shell cover around the nest, and distance to nearest nest. Shell and vegetation cover were estimated by placing a 1-m diameter wooden circle partitioned into sections over the nest. The beach was partitioned longitudinally into thirds where 1 = near dunes, 2 = middle, and 3 = near ocean. The relative elevation of the nests ranged from level sandy areas, to depressions or troughs, to slopes and ridges. Elevation differences were minor (mostly < 1m), but were discernible. The distances to tracks of people and off-road vehicles were recorded weekly. The same data were collected at 100 random points within the tern colony (hereinafter referred to as "available habitat"). Distances between random points (a measure of random nearest neighbor distances) were determined by placing a number of points equal to the number of tern nests on a map of the colony that was gridded, and measuring the distance from each random point to its closest random point. Nest site characteristics were compared with those of the random points with Kruskal-Wallis X^2 tests. We also used Kruskal-Wallis X^2 tests to determine differences among the distributions of the variables with respect to hatching rates. Unless otherwise noted, means ± SD are given in the text.

At Brigantine Beach nests and nest contents were checked at least every other day until the young were fledged. Nest contents, broken or preyed upon egg shells, and any other evidence of predation were recorded during nest checks. Hatching and fledging success were computed for each nest. As chicks began to wander they were checked from the edge of the colony with binoculars. At the Short Beach, Meadow Island, and Fire Island colonies, nest site characteristics and proportions of habitats available to the terns were determined on single visits. At Gilgo the nest site characteristics were compared with random points. Two follow up visits were made at Gilgo to determine the number of chicks greater than 10 days of age per established nest. No further attempts were made to monitor productivity.

RESULTS

Temporal pattern

During the 1983 breeding season there were 424 nests initiated at Brigantine Beach, although only about 300 pairs were ever present at any time. The egg-laying period extended from 26 May until 20 July, with approximately 40% of the nests initiated in the first two weeks of the egg-laying period.

Environmental aspects of nest site selection

At Brigantine Beach, Least Terns nested on an open expanse along a 2 km stretch of beach. Most terns (N = 424, 47%) nested in the middle third of the beach while 34% nested near the dunes and 19% nested near the ocean (Fig. 1, X^2 = 10.4 df = 2, $P < 0.01$).

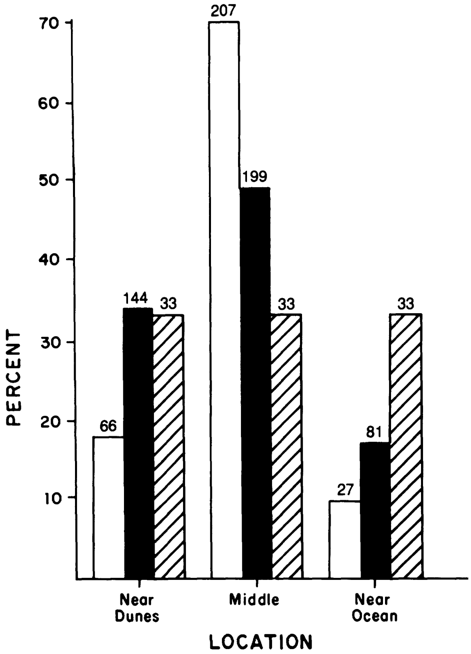

Figure 1. Location of nest sites relative to the ocean at Brigantine Beach (solid bar) and Gilgo (open bar) partitioned longitudinally in thirds, each third was 30 m in width (random, dashed bar).

At Gilgo Beach, a colony similar physiognomically to Brigantine Beach, an even higher percent nested in the middle third of the beach ($X^2 = 98.6$, df = 2, $P < 0.001$, Fig. 1). We did not examine this factor at the other colonies because they were not linear colonies along beaches.

Although the beach at Brigantine was generally flat, there were differences in elevation. Over 60% of the available habitat was flat but less than 40% of the terns nested on flat areas, most nested on ridges and slopes ($X^2 = 26.0$, df = 2, $P < 0.001$, Fig. 2). At Gilgo terns nested on the few available ridges, but ridges were scarce and no significant preference was demonstrated.

Vegetation on Brigantine Beach was sparse (less than 1%), although the dunes adjacent to the beach had about 40% coverage with Beach Grass and other vegetation. Whenever terns nested within 20 m of vegetation, we recorded the species and distance to the vegetation. Of the 152 nests that were within 20 m of vegetation, 70 (46%) were closest to Beach Grass and 27 (18%) were closest to Goldenrod (*Sol-*

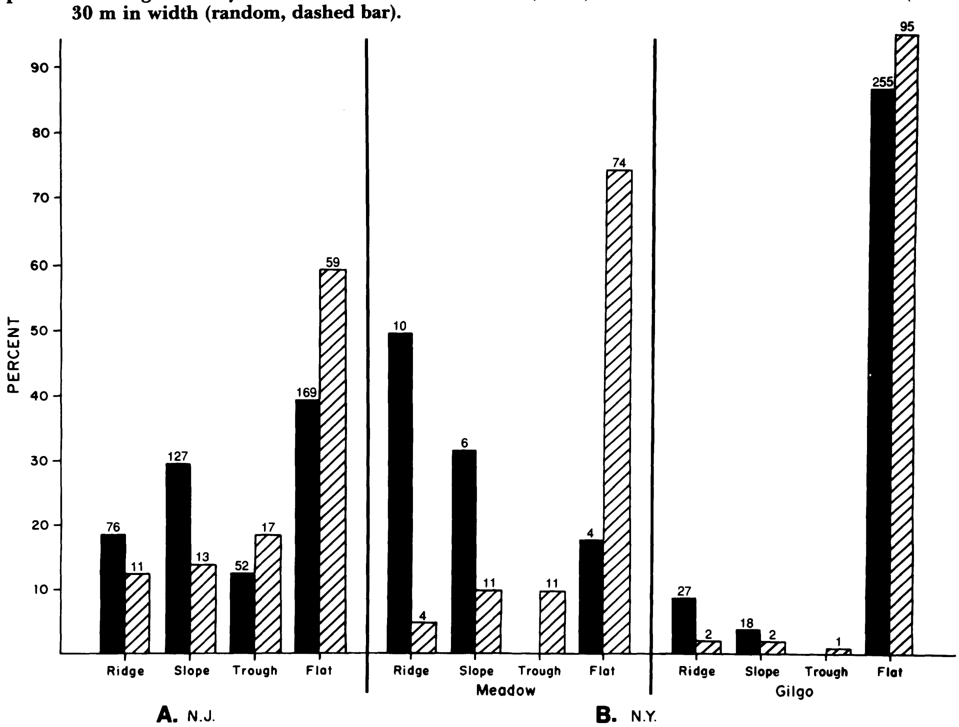

Figure 2. Location of Least Tern nests relative to slope for New York and New Jersey colonies. Solid bar equals nest, dashed bar equals random points.

idago). Of the 152 nests, 62 were within 3 m of vegetation. Those nests that were within 20 m of vegetation were closer to the vegetation than were the random points that were within 20 m of vegetation (X^2 = 101.3, df = 1, P <0.001, Fig. 3). At Gilgo Beach only 210 nests were within 20 m of vegetation and most of these (N = 109) were 6-9 m from the vegetation whereas the random points were over 9 m from vegetation.

At Short Beach there were irregular flat-topped tables of sand and broken clam shells elevated about 10-20 cm above the main beach. Whereas the beach sand was fine and subject to drifting, the tables had a mixture of tiny shell fragments (< 1 cm) and larger shells, and showed greater stabilization. All Least Tern nests were found on these tables although they represented less than 8% of the area available in the 20 m wide band along the upper beach (X^2 = 264, df = 1, P < 0.001, Fig. 4). In 1984 a brief visit to a large Least Tern colony near Fire Island inlet (Sore Thumb colony) again revealed this preference for stabilized sand and shell tables.

At Fire Island tern nests were found in an area stabilized with a regular pattern of Beach Grass. The grass stems were planted with "two foot centers" forming a square grid 60 cm apart. If one draws concentric circles of varying diameter around each grass stem, the available area within each band is proportional to its radius minus the area of the smaller circles. Although terns continued to nest in this area, they avoided the grass stems. In this grid, terns appeared to maximize the distance between their nests and grass stems (Table 1; P < 0.01).

The small colony at Meadow Island represented still a different situation. The island has been repeatedly topped with dredge spoil, presenting a rolling and undulating surface surrounded by *Phragmites*, but in many seasons it also provides nearly a dozen hectares of barren, fine sandy surface. In this colony the topography varied by an elevation of 160 cm,

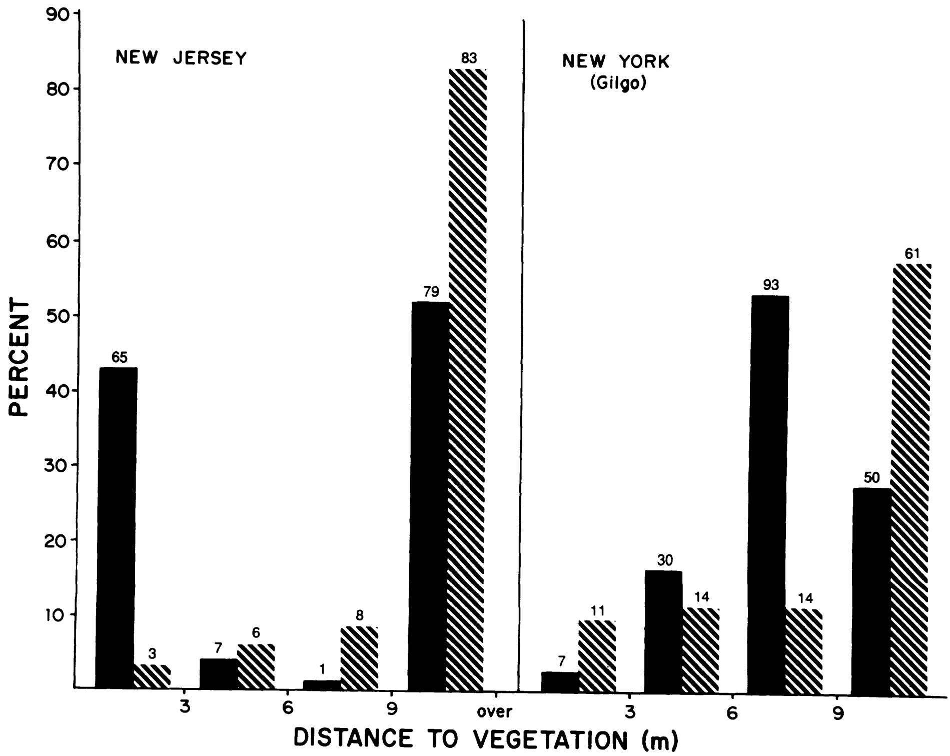

Figure 3. Distance of nests from closest vegetation for Brigantine and Gilgo Beaches. Solid bar equals nests, dashed bar equals random points.

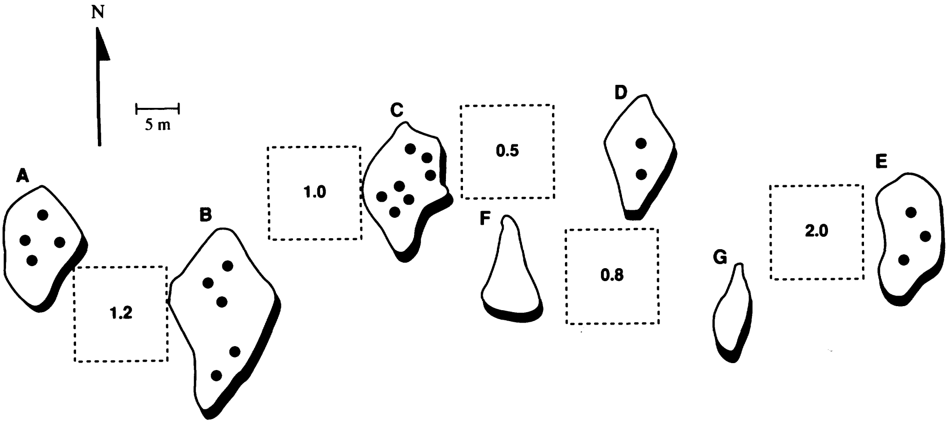

Figure 4. Schematic diagram of preference for Least Terns to nest on elevated tables with shells (lettered polygons A-E) at Short Beach. Dots indicate sites of Least Tern nests. Squares indicate the mean density of nests/10[2] expected on the basis of the number of nests in the quadrat.

and tern nests were found on the crest of small dunes and on their slopes, but seldom on the flats or depression. Their nest sites differed significantly from random points (Fig. 2).

Social and spatial aspects of nest site selection

At Brigantine, Least Terns formed 14 subcolonies each separated by a space of 50 m with no nests. Each quadrat contained from 18 to 47 ($\bar{X}$ = 31 ± 10) pairs. Internest distance ranged from 2 - 66 m initially (at the time of egg-laying, N = 424, $\bar{X}$ = 13.9 ± 10.1m), and ranged from 1-60 m at the end of incubation (N = 300, $\bar{X}$ = 9.2 ± 7.4m). Terns nested closer to conspecifics than expected from the distribution of random points (X^2 = 17.9, df = 4, P < 0.005). The mean date of egg-laying for the subcolonies varied, and ranged from 7 - 27 June ($\bar{X}$ = 14 June ± 12 days).

Table 1. Distance of 21 Least Tern nests from grass (*Ammophila breviligulata*) in the Fire Island Colony.

Distance to grass (cm)	% of Area in each category	Number of nests		Chi square[1]
		Expected	Observed	
0 - 10	8.3	1.7	0	1.7
11 - 20	25.1	5.3	1	3.5
21 - 20	41.9	8.8	5	1.6
31 - 44	24.5	5.1	15	19.0

[1]Overall X^2 = 25.8, df = 3, P < 0.001

In general, subcolonies were more synchronous than the entire colony (had lower standard deviations of 2 to 6 days).

Human disturbance factors

Human disturbance varied greatly, depending on whether the sites were fenced or had a tern warden. At Brigantine Beach the Least Tern nesting area was fenced off, but some people walked through the area during the day, and some entered with off-road vehicles. Over 50% (N = 233) of the tern nests were less than 20 m from off-road vehicle tracks made during the breeding season, whereas less than 20% of the tern nests were closer than 20 m to human tracks (Fig. 5). There were no instances of eggs stepped on by people but 12 nests were run over by ORV's, and a few parents led chicks upon hatching away from the nests to dune areas.

At Gilgo Beach the colony was posted but was not fenced. The beach was narrow and the colony was subject to frequent intrusions. Consequently, all nests had footprints and off-road vehicle tracks within 10 m. Indeed, most (86%) nests had tracks within 5 m. Meadow Island was not fenced, but was in an area not used for extensive recreation. The Short Beach colony had extensive human disturbance throughout; although no vehicles were within the colony, most nests had vehicle tracks within 20 m. Neither vehicles nor people entered the Fire Island colony.

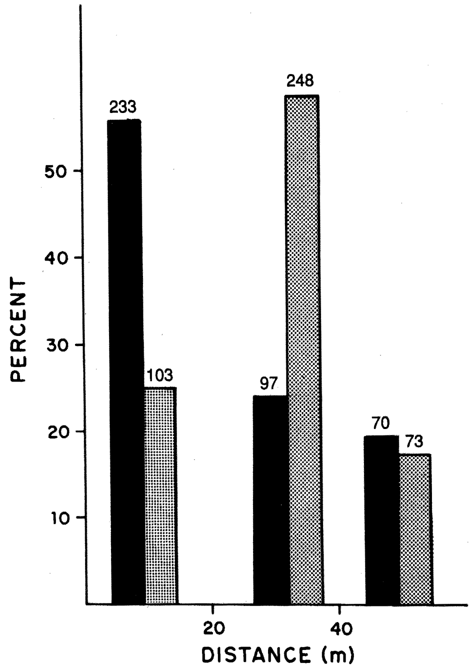

Figure 5. Distance of tern nests at Brigantine Beach from off road vehicle (ORV, solid bar) and human tracks (light bar).

Nest site selection and reproductive success at Brigantine Beach

Least Terns hatched 56% of their eggs at Brigantine Beach. Of the factors examined, location, date of egg-laying, ORV tracks, and density pattern affected hatching success (Tables 2,3). Least Terns nesting nearest the ocean were more successful than those nesting near the dunes, and pairs nesting at the peak of the egg-laying period were more successful than early or late nests (Table 3-5). The spatial pattern affected hatching success. Subcolonies at both ends of the beach were more successful than most subcolonies in the central sections of the beach. Nests that were farther from ORV tracks hatched more young than those near them (Table 3).

Fledging success was correlated with the number of nests in quadrats, breeding synchrony, and date of egg-laying (Table 5). Overall, parents that initiated nests during the peak of egg-laying fledged more young per nest than others. Predation accounted for most losses, thus predation rates were lowest on terns that nested during the peak of egg-laying (Table 5).

Table 2. Effect of physical, temporal and social characteristics on percent of eggs hatching in nests of Least Terns at Brigantine Beach.

Characteristic	Mean ± 1SD	Comparison among classes of percent hatched Kruskal-Wallis X^2	P
Physical Characteristics			
Location (to dunes)[1]	1.9 ± 0.7	14.53	0.005
Microhabitat[2]	2.8 ± 3.5	3.21	NS[3]
Vegetation species[4]		5.37	NS
Distance to vegetation (m)[4]	1.7 ± 1.8	7.81	NS
Percent shell	11.7 ± 14.2	8.25	NS
Temporal			
Date of egg-laying	15 June ± 16.3	58.9	0.001
Special Pattern	14 subcolonies	63.3	0.0001
Social Factors			
Number of neighbors within 5 m	0.3 ± 0.5	2.04	NS
Number of neighbors within 10 m	0.8 ± 0.7	3.88	NS
Nearest neighbor distance (m)			
at initiation	13.9 ± 10.1	3.29	NS
at hatching	9.2 ± 7.4	3.01	NS
Distance to off-road-vehicle tracks (m)	16.2 ± 0.8	12.22	0.01

[1] 1 = by dunes, 2 = middle 3 = by ocean (3x3 Contingency Table)
[2] 1 = ridge, 2 = slope, 3 = trough, 4 = flat sand area (3x4 Contingency table)
[3] NS = not significant
[4] Beach grass, Goldenrod and other beach vegetation.

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Table 3. Differences in percent of eggs hatched at Brigantine as a function of nest site characteristics. Statistical significance shown in Table 2. Percents are means from the 14 quadrats located in a line along the beach.

	N	Percent eggs to hatch (± 1SD)
Location on beach		
by Dune	144	20 ± 4
middle of Beach	199	88 ± 12
by Ocean	81	41 ± 6
Date of Egg-laying (1983)		
early (before 8 June	186	41 ± 6
peak (8-30 June)	147	78 ± 8
late (after 30 June)	72	46 ± 11
Spatial pattern		
ends of colony	141	89 ± 11
middle section	141	58 ± 14
center of colony	141	21 ± 5
Distance of off-road vehicle tracks		
less than 20 m	233	51 ± 6
20-40 m	97	58 ± 11
Over 40 m	70	89 ± 6

DISCUSSION

Environmental aspects

Compared to other seabirds, Least Terns appear to nest in generally homogenous habitats: flat, open, unvegetated beaches. However within such habitats, Least Tern nest sites differ from random points with respect to spatial location, slope, shell cover, and vetetation.

At both Brigantine and Gilgo, Least Terns nested in the center of the beach rather than near the dunes or ocean. Minsky (1987) also found that California Least Terns avoided the peripheries of colonies. The adaptive significance of central-nesting has been widely discussed in colonial birds (Darling 1938, Patterson 1965, Coulson 1968, Harris 1978), and usually relates to the ease with which mammalian predators can enter from the edge of the colony (Tinbergen *et al.* 1967, see review in Burger 1981). Nonetheless, some authors have found that reproductive success may not show a center versus edge difference, particularly where avian predation is important (Burger and Lesser 1978). Jenks-Jay (1980) found that by providing shelters for chicks, predation rates were reduced since predators could not find chicks.

For Least Terns, however, nest location relative to edge can be extremely important where cats, rats and fox are the pri-

Table 4. Kendall tau correlation of variables for all quadrats at Brigantine.

		With percent hatched		With percent preyed upon		With percent abandoned	
	N	tau	P	tau	P	tau	P
Date of egg-laying	214	0.26	0.0007	–0.31	0.0001	–0.09	ND[2]
Percent shell on substrate	214	–0.18	0.02	0.19	0.01	–0.14	ND
Number of neighbors within 10 m	214	–0.16	0.04	0.17	0.07	0.07	NS
Number of dives at intruders[1]	132	0.38	0.004	–0.38	0.004	–0.20	NS
Location (edge vs center)[3]	167	0.26	0.0007	–0.26	0.002	–0.30	0.006

[1]Not measured for all nests. Refers to dives made by nest owner.
[2]Not significant.
[3]Center = 1; edge = 7.

Table 5. Kendall tau correlation of fledging success and percent predation rates with number of nests, density, synchrony for subcolonies of Least Terns.

	Fledging success		Percent preyed upon	
	tau	P	tau	P
Number of nests in subcolonies	0.60	0.02	–0.79	0.0006
Synchrony[1]	0.59	0.03	–0.74	0.002
Mean date of initiation[2]	0.59	0.02	–0.74	0.002
Mean nearest neighbor distance	–0.56	0.03	0.04	NS

[1]Standard deviation of mean date of egg-laying[2] (see Gochfeld 1979).
[2]Squared, thus nests in the middle of egg-laying are the most successful.

mary predators (Burger 1984). Such predators usually live in the dunes and enter the colony from there. Extensive fox tracks were observed near the nests along the dunes at Brigantine but not in the New York colonies. Other predators such as dogs and cats usually entered from the densely vegetated dunes or the ocean side, but did not usually reach the middle of the colony. Least Terns nesting on the beach are also exposed to flooding (Burger 1984). Flooding usually originates from the ocean side, although lateral flooding and even backwash-flooding can occur. Later nesting pairs nested at the edge of the subcolonies often in places closer to the ocean or dunes. Our prediction that terns would select the middle sections of the colony was borne out. Least Terns nested principally in the center of colonies, although more nested near the dunes than the ocean even though those nesting near the dunes were less successful. We attribute this to the fact that tidal floods occur every year, and predation occurs only in some years. Thus, on average, it might be adaptive to nest closer to dunes to avoid high tides.

Least Terns preferred to nest on the ridges and slopes rather than in the troughs and flat sections of the beach. Choice of elevation was significantly different from the random points even though the elevation differences were slight. Thompson and Slack (1982) also reported that Least Terns in Texas nest on the high end of the available elevations. An incubating Least Tern on a ridge or slope can more easily detect approaching danger (people, predators) than one in a trough. With binoculars we could see birds nesting on ridges but often did not see birds incubating in the troughs until we were close. Since about 18 Least Tern adults were killed by predators, visibility may be an important factor in nest site selection. Additionally, nests in troughs and some flat sections may be more vulnerable to flooding during storm tides. When it was possible to do so (e.g., Short Beach), Least Terns nested on small mounds or tables of stabilized sand. Where shells or other objects were available, chicks could gain protection from wind or sun. Nesting close to vegetation may also function to provide chicks with protection from heat stress and cold, rainy weather. Tern chicks are particularly vulnerable to heat stress (Austin 1933) and cold flood tides (Storey 1987a). However, if there is excessive vegetation, Least Terns may avoid it (Minsky 1987). Nesting in the open likely allows incubating birds to see approaching predators. Having vegetation nearby, however, allows chicks to seek cover once they hatch.

Social Aspects of Nest-site selection

The presence of conspecifics affects nesting dispersion since Least Terns nest in colonies and avoid areas of the habitat without nesting birds. In a study of 11 colonies in California, Minsky (1987) reported that mean nearest neighbor distances ranged from 5.9 to 22.8 meters, and density varied up to 42% from year to year in any given colony. Further the amount of total available area for the colony was not correlated with nearest neighbor distance. We noted similar variation. Thus, factors other than social interactions influence the choice of particular nest sites.

In Brigantine Beach, a linear colony with several discrete subcolonies, we found that subcolonies were more synchronous with respect to egg-laying than the entire colony. Minsky (1987) also found synchrony in neighbors of Least Terns in California, and reproductive success varied as a function of synchrony whereas it did not vary with respect to density. This suggests that synchrony rather than density per se affects nesting success. Synchrony should be greater in subcolonies with more nests (Darling 1938). In this study both synchrony and nearest neighbor distance affected fledging success.

Spatial aspects of nest-site selection

At Brigantine Beach, predation was the primary cause of nest failure, and distance from the dunes played the critical role in egg and chick survival. Least Terns at Brigantine nested in subcolonies along the beach and not all subcolonies were equally successful. The terns nesting at the ends of the beach hatched more young than central-nesting subcolonies. Although one might predict that central nesting subcolonies should be more successful, in linear (rather than circular) colonies, the end represents only a small part of the edge where terrestrial predators can enter. In this case predators entered from the dunes and not from the ends or ocean-side. Also, human disturbances was less at the ends of the colony because people had to walk further from parking lots to get there. Thus, being at the end of the colony was not a disadvantage.

The Long Island data provide no clear evidence for spatial effects, perhaps because of smaller sample size. No data on predation were available from the New York colonies. Although specific nest site features were not recorded in previous years, nesting Least Terns were recorded in the same sections of the beach at Brigantine in successive years. Moreover, the same nest sites were used from year to year, as indicated by the location of nest markers. But without marked birds, it is impossible to say that particular pairs were site tenacious. The continued use of Fire Island despite vegetation encroachment further suggests site tenacity.

Diversity of nesting

The few colonies examined in this paper do not represent all of the habitats occupied by Least Terns in New Jersey and New York (Burger 1984, Gochfeld 1984, Kotliar and Burger 1986). Nonetheless, they show substantial microhabitat diversity. Brigantine and Short Beach represent broad natural beaches while Gilgo is a relatively narrow beach. Meadow and Fire Island represents spoil sites, the former barren, the latter rather heavily vegetated. The potential for human disturbance and types of predation likewise varied among colonies. Nontheless, tern nest sites shared characteristics of slope, substrate, vegetation and location. At Brigantine, at least, there is evidence that the chosen sites are advantageous.

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