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NEST-SITE SELECTION BY ROSEATE TERNS IN TWO TROPICAL COLONIES ON CULEBRA, PUERTO RICO[1]

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Abstract. We studied nest-site selection in Roseate Terns (*Sterna dougallii*) nesting on Cayo Raton and Cayo Molinos at Culebra, Puerto Rico to determine how nest sites differed from the available habitat. On both islands Roseate Tern nests differed from random points in being on flatter terrain and closer to other tern nests. On Molinos nests were significantly closer to the colony edge, farther from clearings, closer to taller vegetation, closer to overhanging rocks and had rounder rock platforms than the random points. On Raton, terns nested in three subcolonies that had similar distances to clearings, slopes of the nests, heights of the nearest vegetation, indices of visibility, and distances to nearest neighbors. Thus, regardless of the range of available habitats at these three sites, terns chose similar characteristics. Overall, tern nest sites on Molinos and Raton indicate a preference for flat places near clearings that offer about 25–40% cover within 0.5 m of the nest for shade or protection from inclement weather and concealment from predators, and were close to vegetation. On Molinos terns nested closer to vertical rocks, and on Raton they nested farther from vertical rocks than the random points. We attribute this difference to the presence of predatory land crabs (*Geocarcinus ruricola*) that hide under rocks on Raton. In comparing nest-site selection in the Puerto Rican colonies with that in New York, Roseate Terns in Puerto Rico nested closer to conspecifics, farther from vegetation which was shorter, with less cover around their nests, and with greater visibility indices than those nesting in New York. We attribute these differences to the kind and nature of predators present at the two sites, and the absence of Common Terns (*S. hirundo*) to provide early warning and antipredator defense in Puerto Rico.

Key words: Roseate Tern; Sterna dougallii; *nest-site selection; Puerto Rico; tropical biology.*

INTRODUCTION

Nest-site selection is critical for birds during the breeding season because eggs remain in the nest during incubation, and most chicks remain in or near the nest until fledging. Variations in habitat make selection possible, allowing birds to minimize the adverse effects of conspecific aggression, predation, or inclement weather (Partridge 1978). Species with broad geographical ranges are often faced with diverse habitats throughout their range, requiring plasticity in habitat use (Cody 1985). A species' nest-site preferences may shift in response to changes in physical or social factors. Studies of nest-site selection have usually focused on one geographical area rather than making comparisons among geographical areas. Comparisons among studies are difficult because the same aspects or features of the environment are not measured. Further, critical features of nest-site selection may involve gestalt factors rather than specific physical variables (Burger 1985, 1986). That is, visibility from the nest site may be a critical feature of nest-site selection rather than the height or density of the vegetation, rocks, or other objects surrounding the nest.

In this paper we examine nest-site selection in two Roseate Tern (*Sterna dougallii*) colonies in Culebra, Puerto Rico to determine if their choice of nest sites differs from the available habitat, and to compare their choices with those of Roseate Terns nesting on Long Island, New York (Burger and Gochfeld 1988a). We selected the Culebra colonies because they are tropical, and the Caribbean population is disjunct from that of the northeastern United States (Gochfeld 1983).

The Roseate Tern is nearly cosmopolitan, although most breeding populations are small and disjunct (Gochfeld 1983). Populations in Europe

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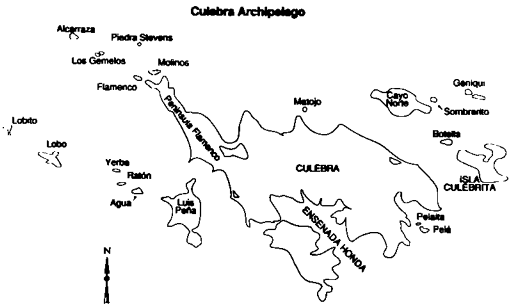

FIGURE 1. Map showing location of islands near Culebra, Puerto Rico.

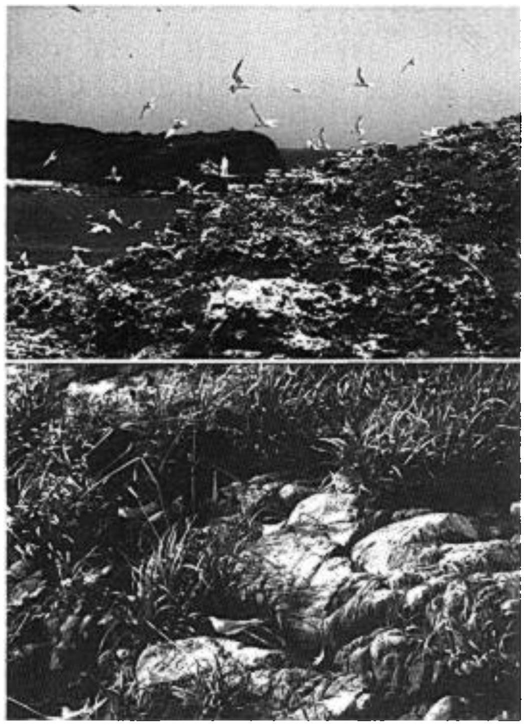

FIGURE 2. Photographs of Molinos (top) and Raton.

and North America have decreased markedly (Buckley and Buckley 1981, Gochfeld 1983), and in 1987 the Roseate Tern was listed as endangered in the northeastern United States and threatened in the Caribbean (Federal Register 1987). In the northeastern United States Roseate Terns usually nest under rocks, boards, or vegetation, or in sparse vegetation, although a few pairs may nest in open places (Nisbet 1980, 1981; Spendelow 1982; Gochfeld 1983; Burger and Gochfeld 1988a). Tropical populations often nest in open, unvegetated habitats (Hulsman 1977, Robertson 1978), but these descriptions do not include comparisons with available habitat. We were particularly interested in the difference between the concealed nests of temperate Roseate Terns contrasted with open nests in tropical colonies, and whether the terns selected open sites if sites near vegetation were available.

METHODS AND STUDY AREAS

Preliminary observations were made on nest-site selection on Molinos in 1983. We recorded percent cover within 0.5 and 1 m of the nest and nearest neighbor distance. We also made general observations and took photographs to design our data collection in 1986 and 1987.

We examined nest-site characteristics in detail on Cayo Molinos in 1986 and Cayo Raton in 1987 (Figs. 1, 2). Molinos (1.1 ha) is a small rocky island 150 m from the tip of Flamenco Point on Culebra. Most of the island is cliffs, and barren, jagged rocks. Sooty Terns (*S. fuscata*) nest under sea grape (*Coccoloba uvifera*), Brown Noddys (*Anous stolidus*) nest on the rock cliffs, and Roseate Terns nest on the rocky, jagged slope (Burger and Gochfeld 1986). Cayo Raton (0.8 ha) is 2.5 km from Culebra, and has both steep cliffs and a gently sloping rocky surface, with a flat top covered with bushes (Kepler and Kepler 1978). In 1987, 120 pairs of Roseate Terns nested on the rocky slopes just below the sea grape. The colony was divided into three subcolonies, isolated visually by rocky barriers from terns standing on the ground. With minimal disturbance only birds in the one subcolony that we were working in left their nests. Roseate Terns nested on Molinos for several years, but abandoned their breeding efforts late in incubation in 1986 after severe egging. When they returned in 1987 presumably the same birds moved to Cayo Raton, 4.2 km away. Roseate Terns nested on Raton in the 1970s (Kepler and Kepler 1978), but they had not nested there since at least 1981 (Furniss 1978, pers. comm.), although a few nested in 1986.

In 1986 we collected data on 57 nests of Roseate Terns on the jagged rock, SSW face of Molinos (all nests were on this side of the island). In 1987 we collected data on 120 nests in all three subcolonies on Raton: N Slope (n = 42), NW Slope (n = 55), and Top (n = 23). Data were collected at all nests, and at an equal number of random points within the colony, determined by using a table of random numbers to generate x and y coordinates for the points.

Data collected at nests and random points in both years included: distance to closest edge of colony, distance to clearing (from which a bird could take flight), maximum slope at nest (in degrees), slope in the 2-m section around the nest, substrate (soil, rock, vegetation), percent cover within 1 m of nest (visual estimation), species of nearest vegetation, distance to nearest vegetation, height of nearest vegetation (herb or other vegetation), vertical rock height, percent visibility from above and within 1 m and 2 m of the nest (visual estimation), clutch size, and distance to nearest neighbor's nest. Vertical rock refers to rock more than 3 cm high that is adjacent to the nest, and might provide shade during some of the day. Overhanging rock not only provides shade, but can provide cover from aerial predators. Distance to vertical rock was measured from the edge of the nest to the base of the nearest vertical rock.

Because physiognomy differed among colonies, we recorded some additional characteristics for the nests and random points in each colony. On Molinos we also recorded distance to vertical rock, percent rock overhanging the nest, distance to the upright rock, direction of the rock, and platform characteristics (maximum length, maximum width, and depth). On Raton we also recorded percent vegetation cover within 0.5 and 5 m of the nest (visual estimation), height of nearest herb (low ground cover), percent vertical rock around the nest (within 20 cm), and percent ground cover (visual estimation). Figure 3 diagrammatically represents some of the features measured.

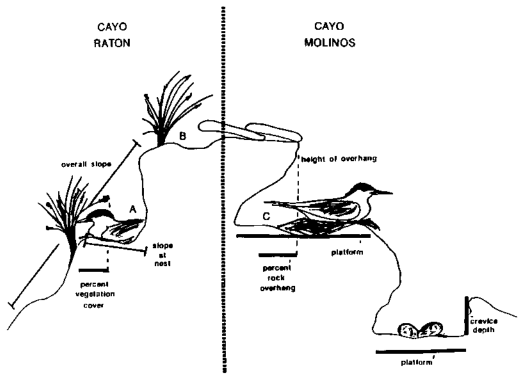

FIGURE 3. Schematic of habitat physiognomy on Cayo Molinos and Cayo Raton with some of the characteristics we measured.

In 1983 and 1986 peak afternoon temperature data were taken at several locations on Molinos

TABLE 1. Comparison of characteristics of nests and random points at the colony on Molinos (1986). Given are means ± standard errors.

	Molinos		Kruskal-Wallis χ^2 comparisons of nests on Molinos with	
	Nests	Random points	Random points on Molinos	Nests on Raton
Distance to colony edge (cm)	642 ± 116	762 ± 80	5.32 (0.02)	52.8 (0.0001)
to clearing (cm)	27 ± 2	12 ± 0.9	3.96 (0.05)	52.5 (0.0001)
to cliff (cm)	30.3 ± 4	30.9 ± 5	ns	—[a]
Slope of nest (°)	1.2 ± 0.6	18.4 ± 2	39.1 (0.0001)	5.76 (0.01)
of 2-m area of nest (°)	19.6 ± 0.7	30 ± 1.5	28.4 (0.0001)	22.0 (0.0001)
Vegetation cover within 1 m (%)	3.5 ± 0.7	2.4 ± 0.9	3.81 (0.05)	101.7 (0.0001)
Vertical rock—height (cm)	16.7 ± 2	15.2 ± 1.0	ns	ns
Percent overhang	3.7 ± 0.5	1.1 ± 0.2	25.5 (0.0001)	—
Distance to upright rock (cm)	5.4 ± 2.1	36 ± 4.7	54.3 (0.0001)	—
Direction of rock (°)	258 ± 14	230 ± 15	4.97 (0.03)	—
Height of nearest vegetation (cm)	8.9 ± 0.7	8.4 ± 0.7	ns	90.3 (0.0001)
Distance to nearest vegetation (cm)	1.6 ± 0.5	5.6 ± 1.2	7.22 (0.007)	8.65 (0.003)
Visibility from above	98 ± 0.6	96 ± 2.0	ns	83.0 (0.0001)
1 m	98 ± 0.5	97 ± 1.5	ns	77.7 (0.0001)
2 m	99 ± 0.4	98 ± 0.9	ns	67.7 (0.0001)
Nearest neighbor distance (cm)	63 ± 4	105 ± 12	3.98 (0.05)	ns
Nest platform				
Length (cm)	21.9 ± 1.6	25.6 ± 4.4	6.28 (0.01)	—
Width (cm)	21.4 ± 1.3	20.9 ± 3.3	6.36 (0.02)	—
Depth (cm)	1.5 ± 0.2	1.3 ± 0.3	ns	—

[a] Characteristic not recorded on Raton.

TABLE 2. Comparison of characteristics at nests and random points at the three study plots on Raton. Given are means ± standard error and Kruskal-Wallis chi square values.

	North			Northwest
	Nest	Random	χ^2 (P)	Nests
Distance to colony edge (cm)	140 ± 23	88.6 ± 25	ns	198 ± 19
to clearing (cm)	30 ± 4	58 ± 8	7.10 (0.007)	23 ± 3
Slope of nest (°)	4 ± 1	25 ± 2	42.0 (0.0001)	2 ± 1
of 2-m area by nest	35 ± 3	30 ± 2	ns	44 ± 2
Percent vegetation cover within 0.5 m	41 ± 3	47 ± 5	ns	35 ± 3
1 m around nest	42 ± 3	48 ± 5	ns	33 ± 3
5 m around nest	45 ± 2	54 ± 4	ns	29 ± 2
Percent grass cover within 0.5 m	29 ± 3	20 ± 4	4.62 (0.03)	22 ± 2
Percent rock cover	56 ± 3	38 ± 5	7.47 (0.006)	60 ± 4
Vertical rock height (cm)	14 ± 2	10 ± 1	ns	17 ± 3
Percent around nest	27 ± 4	13 ± 3	10.8 (0.001)	20 ± 2
Height (cm) of herbs	16 ± 1	21 ± 2	4.45 (0.03)	15 ± 2
nearest vegetation	35 ± 4	38 ± 4	ns	33 ± 2
Distance to nearest vegetation (cm)	5 ± 1	10 ± 3	ns	3 ± 1
Percent visibility from above	58	62 ± 6	ns	57 ± 4
1 m	72 ± 4	61 ± 6	ns	69 ± 5
2 m	69 ± 5	61 ± 6	ns	74 ± 4
Nearest neighbor distance (cm)	68 ± 9	126 ± 18	4.30 (0.03)	67 ± 4
Second nearest neighbor distance (cm)	115 ± 19	162 ± 19	4.24 (0.03)	97 ± 6

where Roseate Terns nested, as well as on parts of the island where they did not nest. With little vegetation cover, Molinos was expected to be a more stressful environment than Raton. Temperatures were taken with a black globe thermometer in several different places on the rock and in vegetation.

We used Kruskal-Wallis χ^2 tests to determine difference between characteristics at nests and random points. Although some characteristics measured may covary i.e., percent cover and visibility of nest from above, both such characteristics might be related to nest-site selection.

RESULTS

MOLINOS

Roseate Terns on Molinos nested on the south-facing slope, facing towards Flamenco Point of Culebra Island. The habitat was jagged rock, with small pits and fissures throughout. The nesting area was devoid of any tall or dense vegetation, and only small ground-cover plants grew amid the rocks. Only Roseate Terns nested in this section although other species nested in the *Coccoloba* nearby. The terns nested on the small flat platforms in the rocks (Fig. 3), usually with vertical rock partially surrounding the nests.

In 1983 mean nearest neighbor distance was 99.7 ± 11 cm, percent cover within 0.5 m was 43 ± 4%, and within 1 m it was 9 ± 2%. Thus percent cover immediately around the nest was significantly higher than in the general area around the nest ($\chi^2 = 63.2$, $P < 0.001$).

Nest sites in 1986 differed from random points with respect to several features. Nests were significantly closer to the colony edge and to vegetation, farther from clearings, on flatter slopes, had more vegetation cover, with a higher percentage of close, overhanging rocks, and were closer to nearest neighbors than were the random points (Table 1). Further, nests were on rock platforms that were shorter than those of the random points (Table 1).

RATON

The rocks of Raton generally were gently sloping with few jagged edges or overhanging ledges. Vegetation was taller and denser in some places where the Roseate Terns nested. Each of the three nesting areas differed, and will be discussed separately.

The North-facing slope was gentle, nonetheless terns selected the flatter areas on this slope (Table 2). Terns selected sites that had significantly more vertical rocks around the nest, shorter herbs, and more grass cover than the random sites. Otherwise vegetation cover and visibility did not differ between the nests and random points.

The Northwest nesting area was steeper (overall slope = 45 to 50°) than the North slope and

TABLE 2. Extended.

Northwest		Top			Comparison among Roseate nests χ^2 (P)
Random	χ^2 (P)	Nests	Random	χ^2 (P)	
90 ± 34	ns	437 ± 48	447 ± 45	ns	27.1 (0.0001)
48 ± 9	6.52 (0.01)	16 ± 3	9 ± 4	5.74 (0.01)	ns
30 ± 4	52.2 (0.0001)	4 ± 1	29 ± 6	18.6 (0.0001)	ns
46 ± 2	ns	17 ± 3	25 ± 2	3.72 (0.05)	16.1 (0.0003)
51 ± 6	4.32 (0.03)	27 ± 3	24 ± 5	ns	6.26 (0.04)
49 ± 5	4.29 (0.03)	29 ± 3	26 ± 4	ns	5.88 (0.05)
55 ± 5	14.3 (0.0002)	37 ± 2	38 ± 2	ns	23.12 (0.0001)
11 ± 2	11.4 (0.0007)	10 ± 2	2 ± 2	4.67 (0.02)	12.08 (0.0002)
37 ± 5	10.35 (0.001)	55 ± 4	64 ± 5	ns	ns
8 ± 2	11.9 (0.0006)	30 ± 6	23 ± 7	2.81 (0.09)	7.94 (0.02)
12 ± 3	5.9 (0.01)	33 ± 5	18 ± 4	4.57 (0.03)	4.97 (0.08)
18 ± 2	ns	29 ± 4	17 ± 3	4.69 (0.03)	10.34 (0.005)
31 ± 4	ns	35 ± 3	21 ± 4	7.18 (0.007)	ns
9 ± 3	ns	7 ± 2	13 ± 3	ns	6.79 (0.03)
54 ± 7	ns	70 ± 7	86 ± 5	4.97 (0.02)	ns
64 ± 7	ns	85 ± 5	90 ± 4	ns	ns
65 ± 7	ns	88 ± 5	91 ± 4	ns	ns
113 ± 17	0.2 (0.005)	97 ± 13	118 ± 14	1.23 (ns)	ns
180 ± 20	14.5 (0.001)	121 ± 12	191 ± 10	16.2 (0.0006)	ns

the terns nested in the flatter parts (slopes around nests averaged 30°). Again, terns selected flat ledges for nest sites even though the surrounding area was not flat (Table 2). Terns selected nest sites that had significantly less cover within 0.5, 1, and 5 m of the nest, taller vertical rocks, more vertical rocks around the nest, and significantly more grass cover than the random points (Table 2). Nests and random points were equally visible. In this subcolony significantly more terns nested close to *Cyperus planifolius* than to any other species of vegetation compared to the random points ($\chi^2 = 17.5$, df = 2, $P < 0.004$).

The Top nesting area was flatter overall, with large boulders and flat piles of rocks. Roseate Terns nested on the flattest part of the Top area. Nest sites had significantly more vertical rocks around the nest, with taller herbs, taller grass, more grass cover, and less visibility than the random points (Table 2). Vegetation cover (ground herbs, grass, and other vegetation) did not differ between nests and random points.

Taken separately, the three nesting areas provide an overall picture of nest-site selection. By comparing the three sites it is possible to determine which characteristics seem to be important to the birds. If nest-site characteristics do not differ among the areas, but within each area nest-site characteristics differ from random sites, then we suggest that the characteristic is important in nest-site selection. Table 2 indicates which nest-site characteristics differed among the nesting areas. There were no significant nest-site differences in distance to clearing, slope at nest, and distance to nearest neighbor, yet within each nesting area there were significant differences. This pattern was not repeated for any other characteristic (Table 2). Nest-site characteristics differed among nesting areas with respect to distance to colony edge, overall slope, vegetation cover within 0.5, 1, and 5 m of the nest, vertical rock height, percent vertical rock, herb height, distance to nearest vegetation and percent grass cover (Table 2). However, in each site Roseate Terns nested in places with significantly more and taller rocks, and significantly more grass cover than the random points, indicating that the birds used spots with more rocks and grass cover.

COMPARISON OF RATON AND MOLINOS

Nest sites on Molinos and Raton differed with respect to several characteristics (Table 1). Nests on Molinos were farther from the colony edge, farther from clearings, on flatter places, with less cover within 1 m, with closer and shorter vegetation, and with more visibility than the nests on Raton. Mean nearest neighbor distance was similar on the two islands.

TABLE 3. Peak afternoon temperatures (°C) on Molinos where Roseate Terns nested. Given are means ± standard error.

	Roseate Tern area	Under *Coccoloba*	North side (no vegetation)
Air (50 cm above ground level)	31.8 ± 0.3	31.6 ± 0.3	33.0 ± 0.4
5 cm above rocks	35.7 ± 0.7	—	39.6 ± 1.3
Rock crevice	31.8 ± 0.5	—	35.9 ± 0.9
Under vegetation			
Edge	33.3 ± 0.6	28.6 ± 0.5[b]	—[c]
Interior	—[a]	28.3 ± 0.6[b]	—

[a] No vegetation patches.
[b] No rock crevice.
[c] No vegetation present.

TEMPERATURE AND WIND STRESS

Roseate Terns nesting on offshore islands near Culebra are exposed to potential stress from heat and wind. To examine the possible advantage of nest-site choices we recorded temperatures on Molinos in different possible nest sites (Table 3). Temperatures differed as a function of location (site and height above rocks: $F = 8.31$, df $= 3, 75$, $P < 0.01$), with temperatures being lower under *Coccoloba* sp. than on the open rock, intermediate in the Roseate Tern nesting area, and highest on the North-facing slope. In the Roseate Tern nesting area temperatures were lowest in the rock crevices.

DISCUSSION

NEST-SITE SELECTION ON CAYOS MOLINOS AND RATON

The physiognomy of Molinos and Raton differed in that Raton had gently sloping, smooth rocks with moderate vegetation whereas Molinos had jagged rock crevices with very small and sparse vegetation. However in colonies and subcolonies Roseate Terns nested 15–30 cm from clearings where they could take flight, and they nested on places with slopes of less than 5°. Given the overall steep slopes of the domed islands (averaging about 20–45°), and that Roseate Terns did not make a nest from vegetation, it was essential for their nests to be on relatively flat rocks to prevent eggs from rolling off. It is advantageous to maintain a short distance to clearings because that is the distance a tern walks before being able to fly from the nest. This distance should be short enough to reduce the time to take flight to avoid predators, but large enough so that there is room for both parents to land and remain at the nest; sufficient space is also required for growing chicks to move about. Most nest platforms on Molinos had a rock lip around them (platform depth) which prevented eggs or chicks from rolling off.

On both Molinos and Raton nests had vertical rocks adjacent to them that were equal to or taller than those at the random points, and there was more rock around the nest or more overhanging rock than for the random points. Vertical rocks provided some protection from high winds and intense solar radiation. Indeed temperatures were less in the crevices than on the rock platforms at Molinos. The rock structure, however, varied on the two islands (Fig. 3). Molinos had jagged rocks that provided overhangs above the nest (or crevices beside the nest), whereas Raton had smooth rocks that were vertical with few crevices and overhangs. Indeed on Raton most terns avoided nesting near crevices and overhangs. We attribute this difference to the presence of large populations of land crabs (*Geocarcinus ruricola*) on Raton, but not on Molinos. Molinos had marine crabs but they only came to the edges of the Roseate Tern colony to drag dead chicks into the water to eat, and we never saw them within the colony or dragging live chicks. We observed land crabs on Raton dragging away two live Roseate Tern chicks (1–2 days old), and we found seven chicks already dragged into crevices by crabs which had already eaten the legs and feet of some. The crabs came out from under piles of rocks, and dragged the squeaking chicks under the rocks with them. We had expected that parents could defend their chicks against such attacks, but six of 15 banded 1- to 3-day-old chicks disappeared overnight in one plot heavily infested with the crabs. Thus nesting more in the open with nearby vegetation and vertical rocks (without crevices and overhangs, Fig. 3A) may reduce land crab predation while still providing some protection from solar radiation and aerial predators such as Laughing Gulls (*Larus atricilla*). Roseate Terns selected nest sites with some vegetation cover, no doubt to provide additional shade or predator protection for young chicks.

Nearest neighbor distances in all colonies and subcolonies were significantly less (under 1 m) than for the random points (over 1 m) indicating that the terns were clustered. Such close nesting may be advantageous for early warning and antipredator defense against aerial predators. Having many close neighbors to mob a Laughing Gull or other predator would be beneficial. Further, many terns in a small area may deter land crabs because some adults may always be present to attack crabs, although this requires careful study.

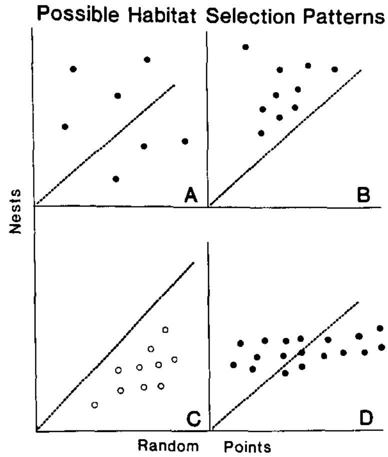

FIGURE 4. Schematic of possible relationships of mean characteristics at nests and random points.

COMPARISONS WITH OTHER COLONIES

Few data are available on nest-site selection in tropical terns, although descriptions of nest sites exist (Hulsman 1977, Tyzack and Volcere 1986). Most nest-site studies have dealt with temperate ecosystems (see Cody 1985), as is generally true with avian research. This inequity is being addressed in many areas of biology as we acknowledge the importance of tropical ecosystems to the Earth's biosphere. Nonetheless, Sooty Terns also nest on Culebra, and they generally nest under dense vegetation that also provides protection from thermal stress and concealment from predators (Burger and Gochfeld 1986).

Roseate Terns have a nearly world-wide nesting distribution, although they are uncommon over much of their range (Gochfeld 1983). In temperate colonies Roseate Terns generally nest under cover, whereas in the tropics they often nest in the open. In Scotland they nest near grass tussocks (Campbell 1947). In the northeastern United States they nest under rocks (Great Gull Island, H. Hays, pers. comm.), in sparse vegetation (Nisbet 1981, Spendelow 1982, Gochfeld 1983), or occasionally in the open (Spendelow, pers. comm.). In the Seychelles, Roseate Terns nest in a variety of habitats including under a canopy of *Pisonia* trees (Warman 1979, Tyzack and Volcere 1986). In South Africa they nest between rocks with most nests in the open or on bare coral (Thomas and Elliot 1973, Randall and Randall 1981). Tropical populations often nest in open, unvegetated habitats (Hulsman 1977, Robertson 1978). On the Great Barrier Reef, Australia, Roseate Terns nest entirely in the open on isolated islands more than 20 km from the mainland (Burger and Gochfeld, unpubl. data).

Although nest sites have been generally described by these authors, specific characteristics of nest sites and available habitat have not been described. Thus our detailed examination of nest-site characteristics at Cedar Beach, New York (Burger and Gochfeld 1988a) and at Culebra, Puerto Rico (this paper) allows for the first detailed comparison of nest-site selection in tropical and temperate populations of Roseate Terns. The overall habitat at Cedar Beach and in Culebra differed in that Cedar Beach is sand with scattered seaside goldenrod (*Solidago sempervirens*) and *Ammophila breviligulata* grass while the Culebra colonies are on uneven or jagged rock with sparse, smaller vegetation. By plotting the mean for a nest-site characteristic against the mean for random points for each colony (or subcolony), it is possible to examine whether birds are consistently selecting a particular range of values for a characteristic, or are maximizing the characteristic, or minimizing the characteristic (Fig. 4, see Burger and Gochfeld 1986 for further details).

Features measured at all three colonies include vegetation height, distance to vegetation, percent cover within 1 m of the nest, visibility from above, distance to clearing, and nearest neighbor distance. Roseate Terns at all colonies (and subcolonies) nested closer to vegetation than were the random points (Fig. 5A), and they generally selected vegetation that was taller than that near the random points (Fig. 5B). Although there was

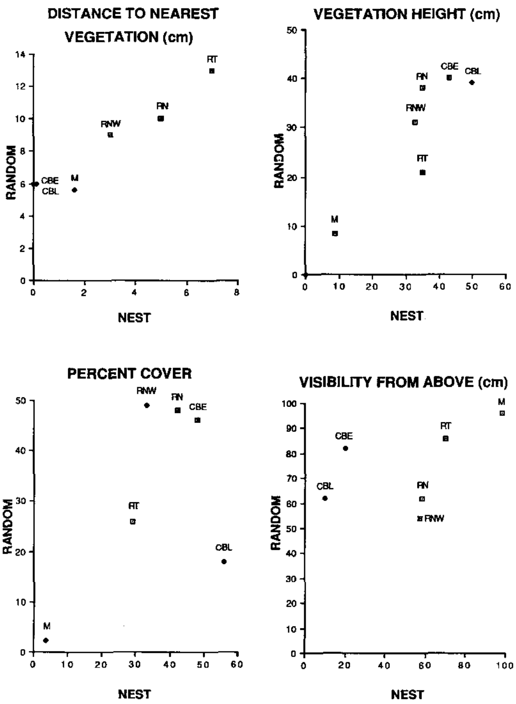

FIGURE 5. Relationship of distance to nearest vegetation, vegetation height, percent cover, and visibility from above for several Roseate Tern colonies. Given are mean values for nests and random points for the following Roseate Tern colonies and subcolonies: CBE = early-nesting Roseate Terns and CBL = late-nesting Roseate Terns at Cedar Beach, New York (after Burger and Gochfeld 1988a), M = Molinos, RT = Raton Top, RNW = Raton Northwest, and RN = Raton North. Closed square = significant differences between nest and random points. Box with dot = no significant difference.

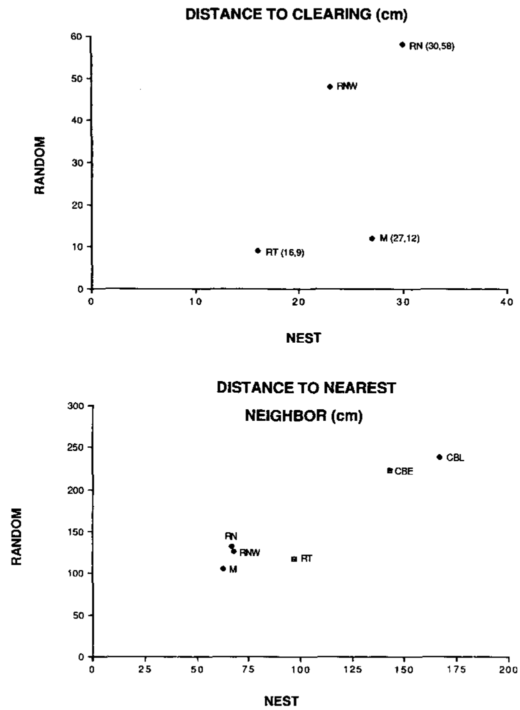

FIGURE 6. Relationship for nearest neighbor distance and distance to nearest clearing of mean values for nests and random points for Roseate Tern colonies (symbols as in Fig. 3).

no clear overall pattern for cover within 1 m around the nest (Fig. 5C), visibility of the nest from above was less than at random points (Fig. 5D). Distance to clearings was similar at nests in these colonies regardless of the wide range in these values at the random points (Fig. 6A). Overall, Roseate Terns nested closer to nearest neighbors than were the random points (Fig. 6B).

Taken altogether these data indicate that Roseate Terns in the tropical and temperate colonies placed nests close to tall vegetation that provides cover over the nest, reducing its visibility. Nonetheless, the birds nesting in the more open Cedar Beach colony are in denser cover and are less visible than those nesting on Molinos and Raton. The apparent tendency for nesting in the open in the tropics seems paradoxical since the tropical populations are faced by a greater solar radiation load and would appear to benefit most from the ameliorating effects of vegetation. This suggests that predation pressure may be an important factor influencing Roseate Tern nest concealment in the northeast colonies. Predation is now the major cause of mortality for Roseate Terns in Massachusetts (Nisbet in Kress et al. 1983). Roseate Terns in Massachusetts (Nisbet and Drury 1972) and on Long Island (Gochfeld, Safina, and Burger, unpubl. data) tend to raise more young per pair in a given season than Common Terns (*S. hirundo*), suggesting that the use of concealed sites is advantageous at these colonies. Hulsman (1977) noted that the unconcealed nests of Roseate Terns suffer much greater gull predation than the nearby concealed nests of Bridled Terns (*S. anaethetus*), raising the question of why Roseate Terns on the Great Barrier Reef do not conceal their nests. On Raton, Roseate Terns clearly avoid concealed sites among the rocks because such sites harbor land crabs that are all over the island (see above). Thus nesting in the open may reduce crab predation on young chicks. These variations in overall habitats selected for nest sites (open sand, sparse cover, rocks, dense vegetation) corroborate the suggestion that scale affects habitat choice (Burger 1985, Klopfer and Ganshorn 1985). Habitat physiognomy or configuration may affect general habitat selection, but the within-habitat responses may be more strongly associated with details of specific vegetation types or growth form (for predator or thermal avoidance).

Further, Roseate Terns nest with Common Terns in the northeastern United States and in Europe (Cramp et al. 1974) and derive antipredator advantages from them (Burger and Gochfeld 1988b). Common Terns gather in a large flock over a potential predator and make many dives, often hitting the intruder. Common Terns in the New York colony made an average of 86 dives per minute while Roseate Terns in that colony averaged only four dives per minute (Burger and Gochfeld 1988b). By their alarm calls, Common Terns also warn Roseate Terns of the presence of predators. However, in Culebra the Roseate Terns nest in monospecific subcolonies, and rely on each other for early warning and antipredator defense. Thus it may be more advantageous to nest in the open for a clear view of approaching avian predators.

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