Nest-Site Selection by Roseate Terns Breeding on Aride Island, Seychelles

JAIME A. RAMOS

Instituto Politécnico de Bragança, Escola Superior Agrária, Campus de Santa Apolónia,
5301-854 Bragança, Portugal
Internet: jramos@ipb.pt

Abstract.—Nest-site selection by tropical Roseate Terns (*Sterna dougallii*) was examined on Aride Island, Seychelles. Continuous variables reflecting concealment of the nest site, shelter, vegetation cover and intraspecific nest density were measured for nest-sites and random points. Seasonal variation in the initiation of nests with overhangs and their influence on hatching success and adult intraspecific aggression towards chicks were also examined. Roseate Terns selected nest-sites closer to taller vertical objects, and with a higher percentage of rocks, logs or branches overhanging the nest than occurred at random points. Nest-sites in small colonies differed more from the available habitat than did those in the main colony. Nesting density was positively correlated with the amount of rock cover. On Aride and other colonies in the tropics Roseate Terns breed at higher densities than their temperate counterparts and spacing between neighbors may be a main factor in the selection of nest-sites, especially for birds nesting at the peak of the breeding season. Nest-site characteristics, notably overhangs, had no influence on hatching success. However, the proportion of chicks that died from adult pecking was significantly lower in nests with overhangs. Concealment is a main factor of Roseate Tern nest-site selection throughout its breeding range, in both tropical and temperate areas, but the factors selecting for concealment seem to vary amongst colonies. On Aride concealment appeared to be advantageous in defending territories and protecting young chicks from attacks of adults. Artificial overhangs could be provided to enhance chick survival. *Received 26 June 1998, accepted 23 July 1998.*

Key words.—Roseate Tern, *Sterna dougallii*, nest-site selection, tropical terns, nesting density, Seychelles.

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The study of nest-site selection is important on theoretical and applied conservation grounds. Breeding birds are confined to the nest-site during incubation and the chick-rearing period, and the selection of an appropriate nest-site should allow birds to minimize the adverse effects of predation, inclement weather, or conspecific aggression, affecting reproductive fitness and survival (Partridge 1978). Nesting habitat may be artificially manipulated to enhance productivity of endangered species such as the Roseate Tern (*Sterna dougallii*). Nest-site selection has been quite well studied in terns, including Roseate Terns in temperate areas (Burger and Gochfeld 1988a; Gochfeld and Burger 1988; Ramos and del Nevo 1995). Tropical Roseate Tern populations have received much less attention (but see Burger and Gochfeld 1988b). This study examines nest-site selection by Roseate Terns on Aride Island (Seychelles), where this species nests under a tree (*Pisonia grandis*) canopy (Warman 1979).

Habitat variables apparently selected by temperate Roseate Terns for nesting vary among colonies, but a common pattern is the selection of certain characteristics; for example, proximity to an elevated item such as a rock or tall vegetation, that provides nest-site concealment (Burger and Gochfeld 1988a, 1988b; Gochfeld and Burger 1988; Ramos and del Nevo 1995). Nest-sites in tropical colonies such as on Culebra, Puerto Rico, seem to be more open. There, Roseate Terns nest closer to conspecifics, farther from vegetation and with greater visibility indices than do those nesting in temperate areas (Burger and Gochfeld 1988b). This pattern may in part be explained by the greater availability of open habitats in tropical areas, since Roseate Terns on Culebra also select concealed sites: their nests are closer to overhanging rocks and to taller vegetation than would be expected by chance. Concealment may be beneficial against avian predators (Burger and Gochfeld 1988b) and nest-site competitors (Ramos and del Nevo 1995).

Despite some plasticity in nesting habitat by Roseate Terns (Ramos and del Nevo 1995), previous studies suggest that primary features of nest-site selection may be common to both temperate and tropical Roseate Tern populations. Therefore, it is important to study nest-site selection in additional tropical populations to understand patterns of nest-site selection and their driving factors. On Aride Island, two lizards, Wright Skink (*Mabuya wrightii*) and Seychelles Skink (*Mabuya sechellensis*), are the main egg predators (Ayrton 1994; Maul 1996; Ramos 1998), taking only unattended eggs (Ramos 1998). Avian predators are not present. Therefore, Aride Roseate Terns should have less need to conceal their nests.

Nest-site characteristics of Roseate Terns on Aride Island are described in relation to available habitat, to compare nest-site selection between tropical and temperate populations and to suggest possible manipulations of the habitat that could enhance breeding success of this endangered species (Gochfeld 1983; Nisbet 1989). The Indian Ocean is the world's stronghold for this species (Gochfeld 1983), but very little is known about its ecology.

METHODS

Aride Island (4°10'S, 55°40'E), is a 73.2 ha Royal Society for Nature Conservation reserve rising to 151 m. It is a densely-vegetated granitic island, vegetated mainly with *Pisonia*, and has a few open glade areas. Open glades were originally dominated by a sedge (*Mariscus ligularis*) but recently have been invaded by an acanthaceous herb (*Asystasia* sp), which forms a dense mat of stems (Warman and Todd 1984). Open rocky areas are restricted to the seashore.

Tern populations in breeding pairs are estimated at 172,000 for Sooty Tern (*Sterna fuscata*), 8,500 for Fairy Tern (*Gygis alba*), 110,000 for Lesser Noddy (*Anous tenuirostris*), 5,600 for Brown Noddy (*Anous stolidus*), 70 for Bridled Tern (*Sterna anaethetus*) (Betts 1997) and 1,119 for Roseate Tern (Ramos 1998). The Lesser Noddy and Fairy Tern nest in trees throughout the island, including above the Roseate Tern colonies. The Sooty Tern nests in open glades and under the enclosed tree canopy (Feare *et al.* 1997) about 20-30 m from the Roseate Tern subcolonies, and the Brown Noddy nests on boulders and in palm trees. There are large numbers of Wright Skinks and Seychelles Skinks, which feed on feces, dropped fish and eggs of seabirds (Brooke and Houston 1983).

On Aride, Roseate Terns are known to nest in open glades and under the canopy of *Pisonia* (Warman 1979), although the former habitat has not been used since 1993 (Ayrton 1994; Maul 1996). Prior to 1993, the larger colony (the lodge glade) was an open area. This area was invaded by *Asystasia* and cleared in 1993 to encourage Roseate Terns to nest, but was instead colonized by Sooty Terns because *Asystasia* also inhibits Sooty Tern nesting (Feare *et al.* 1997). The remaining open glades are occupied by Sooty Terns, where their nesting densities are much higher than under the woodland canopy (Feare *et al.* 1997), so it is unlikely that Roseate Terns will re-nest in open glades.

This study was carried out from May to July 1997. Three colonies were located in 1997: "western woodlands" (a main colony and two sub-colonies), "bois tortue", and "western roosting rocks". The first two colonies were under a canopy of *Pisonia* and the third was in grass and open rock by the coast. Six clutches were found on the western roosting rocks but all eggs were abandoned soon after laying. The breeding population in the main colony of the western woodlands was estimated at 1,088 pairs (Ramos 1998). The two sub-colonies were small discrete groups about 30-50 m distant from the main colony, having six and 12 nests, respectively. Bois tortue, about 700 m from the western woodland colony, had seven nests. Apart from some tree stems, there was little ground vegetation within the woodland colonies; some fern patches adjoining the nesting area appeared too dense for terns to walk through. Thereafter I refer to the larger western woodlands colony as the main colony and the others as small colonies.

Three study groups were defined: (1) the small colonies, (2) two quadrats in the main colony, an edge quadrat with 49 m^2 and a center quadrat with 64 m^2, and (3) an area of about 180 m^2 around a blind in the main colony (blind area). Nests in the blind area were studied using low-disturbance methods. All nests were mapped at the time of egg-laying, from a permanent blind, erected on a tree trunk about one meter above the ground; and the fates of eggs and chicks were monitored daily. The two quadrats in the main colony were established with corner posts and string, 16 days after the first egg was seen (1 June). All nests in the quadrats and small colonies were marked with numbered pegs or wooden tongue-depressors. The two quadrats were visually isolated from each other and from the blind area by rocky barriers; only birds in the one study plot plus a few neighbors left their nests during the disturbance of each research visit.

Detailed nest-site characteristics were measured during 20-30 minute visits, between the 16th and 20th day after the first egg was seen, to minimize disturbance. This occurred about eight to ten days after the peak of egg-laying, but nest-mapping from the blind showed that only nine eggs were lost before 20 June, with one being relaid. Since 148 nests were mapped prior to 18 June, and assuming an equal proportion of egg loss in the blind area and quadrats plus small colonies, probably only about 5.4% of the nests were lost in the quadrats and the small colonies prior to nest-site characterization. This is a small error that would not have affected the study of nesting patterns.

For the small colonies and the edge quadrat, data were collected at all nests and at a similar number of random points. In the center quadrat, due to high nest density, nest-sites and random points were characterized only in the first 16 m^2 of the quadrat. For the edge and center quadrats of the main colony, the x coordinate of the random points were established systematically (every meter) and the y coordinate randomly, using a table of random numbers. For the small colonies, the random points were determined by using a table of random numbers to generate x and y coordinates for the

Table 1. Site variables recorded for nest sites and random points.

Site variable	Description
Object distance	Distance to the nearest vertical object (rock or log more than 4 cm high) from the edge of the nest to the base of the rock or log (cm).
Object height	Height of nearest elevated object (cm).
Vegetation cover	Vegetation cover within 1 m radius of nest (%, visual estimation).
Vertical object around nest	Vertical object around the nest within 30 cm (%, visual estimation).
Object overhanging	Object overhanging the nest (%, visual estimation).
Visibility from above	Nest-site visible from above (%, visual estimation).
Neighbor distance	Distance to nearest neighbor (cm).

points. This slight difference in sampling was used because the second technique should be more appropriate for sampling available habitat in an area where nests are more scattered. Seven continuous variables reflecting concealment of the nest-site, shelter, vegetation cover and intraspecific nest density were recorded (Table 1).

Characteristics of Roseate Tern nest-sites were compared against those of random points for the small colonies, the edge and the center quadrats, and characteristics of nests of the main colony against those of the small colonies, using Kruskal-Wallis H tests. Hatching success was registered for each nest-site and characteristics compared between successful and unsuccessful nests, using logistic regression.

In the blind area, the egg-laying season was divided into two periods (1-6 June and after 6 June). I noted whether or not each nest was placed under overhanging objects (rock or logs). Young chicks could be pecked by adults if they wandered from the territory or when left unguarded by their parents. Young chicks which were seen dead or which disappeared after being badly pecked when last observed were regarded as having died from pecking. Overhanging objects provide protection from inclement weather and should minimize the effects of adult aggression; therefore, nest-sites with overhanging objects may be preferred (i.e. selected by the earliest breeders). A chi-square analysis tested the null hypotheses that nest-sites initiated within each egg-laying period had an equal frequency of nest-sites with overhanging objects, and that overhangs had no influence on chick mortality from adult pecking. Chicks infested with ticks (birds observed standing on one foot only) in the blind area, quadrats and small colonies were noted also.

RESULTS

Nest-site characteristics on Aride

In the small colonies, nest sites differed from random points with respect to all characteristics measured, while in the edge quadrat, five of seven characteristics differed, and in the center quadrat only four characteristics were significantly different (Table 2). In all plots Object distance, Object height and Object overhanging were the main variables distinguishing nest sites from random points (Table 2). Roseate Terns selected nest-sites closer to taller vertical objects, and with a higher percentage of rocks, logs or branches overhanging the nest than were present at the random points. In small colonies, Roseate Terns selected nest-sites with a taller nearest vertical object, more vegetation cover, more vertical objects around the nest and more distant from the nearest neighbor than were present at nest-sites selected in the main colony.

The center quadrat had 1.23 nests m^{-2} and the edge quadrat 0.63 nests m^{-2}. Aride Roseate Terns kept, on average, a minimum distance of about 0.5 m from the nearest neighbor. Neighbor distance was significantly correlated with object height ($r_s = 0.27$, $P < 0.01$) and vertical object around the nest ($r_s = 0.22$, $P < 0.05$). Observations from the blind showed that Roseate Tern individuals built several trial nest-cups within the territory. Among other possible variables that may have influenced the exact location of the definitive nest-site, the nature of the substrate (it is probably easier to make a nest cup if the ground is soft) and the aggressiveness of neighbors (five pairs were seen changing nest-sites after much aggression from neighbors) seemed important. Several such trial nest-sites seemed to be closer to the nearest neighbor than were the eventual nest-sites.

Overall, nest-site characteristics had no influence on hatching success (logistic regression, $X^2_7 = 8.08$, $P = 0.33$). Hatching success in the small colonies (44.0%, N = 25) was lower than in the main colony (blind area, 56.7%, N = 171) but the difference was not significant ($X^2_1 = 2.21$, $P > 0.05$, Yates correction). Within the main colony, the hatch-

Table 2. Comparison of characteristics of nest-sites and random points at the three study sites on Aride Island (means ± SD and Kruskal-Wallis H values, with P values in parentheses).

	Western woodlands (main colony)									
	Edge			Center			Small colonies			Kruskal-wallis comparison of nests on the main colony and small colonies
	Nests	Random points	Kruskal-Wallis H (1, N=81) (P)	Nests	Random points	Kruskal-Wallis H (1, N=54) (P)	Nests	Random points	Kruskal-Wallis H (1, N=48) (P)	
Object distance (cm)	6.6 ± 3.7	16.2 ± 14.1	10.8 (0.001)	6.7 ± 5.2	21.0 ± 21.2	16.0 (0.001)	7.0 ± 3.3	19.0 ± 12.2	13.3 (0.001)	1.4 (ns)
Object height (cm)	17.4 ± 17.0	10.2 ± 8.3	7.8 (0.01)	18.8 ± 15.8	10.3 ± 7.8	7.7 (0.01)	23.6 ± 16.9	14.5 ± 10.9	4.8 (0.059)	4.1 (0.05)
Vegetation cover (%)	0.3 ± 1.7	0	0.3 (ns)	3.7 ± 6.7	1.5 ± 3.8	1.1 (ns)	7.9 ± 17.1	3.3 ± 12.7	3.9 (0.05)	4.7 (0.05)
Cover by vertical object (%)	31.7 ± 21.5	19.9 ± 20.6	8.4 (0.01)	32.7 ± 21.1	26.0 ± 21.5	1.4 (ns)	43.8 ± 21.5	18.3 ± 21.0	14.9 (0.001)	5.4 (0.05)
Object overhanging (%)	10.8 ± 18.4	2.1 ± 4.3	6.8 (0.01)	8.2 ± 12.8	1.3 ± 4.2	12.1 (0.001)	18.5 ± 30.2	4.8 ± 14.6	6.4 (0.01)	0.8 (ns)
Visibility from above (%)	86.3 ± 22.0	90.0 ± 25.8	3.0 (ns)	83.4 ± 24.5	97.3 ± 7.8	15.1 (0.001)	69.7 ± 38.0	93.5 ± 15.6	8.7 (0.01)	2.3 (ns)
Neighbor distance (cm)	61.6 ± 33.5	74.7 ± 33.9	3.9 (0.05)	46.2 ± 17.0	46.6 ± 19.4	0.0 (ns)	106.0 ± 84.6	200.0 ± 108.8	9.2 (0.01)	19.6 (0.001)

ing success of the center quadrat was significantly higher than that in the edge quadrat (73.8% and 51.1%, N = 84 and N = 45; $X^2_1 = 5.7$, $P < 0.05$, Yates correction), suggesting that factors other than physical characteristics of the nest-sites contributed to hatching success.

In the blind area, there was no difference in the frequency of nest-sites with overhang initiated between the periods 1-6 June and after 6 June ($X^2_1 = 3.0$, $P > 0.05$, Yates correction, Table 3). The presence of overhanging objects (rock or logs) did not have any significant effect on hatching success for both the periods 1-6 June ($X^2_1 = 0.63$, $P > 0.05$, Yates correction) and after 6 June ($X^2_1 = 1.9$, $P > 0.05$, Yates correction, Table 3), but it was significantly associated with the proportion of chicks that died from adult pecking (four chicks in nest-sites with overhang and 15 in nest-sites without overhang; $X^2_1 = 5.26$, $P < 0.05$, Yates correction). During this study virtually all chicks died from starvation, and there was extensive interference from neighbors and failed breeders during chick feeding (Ramos 1998). Some medium-sized chicks were seen hiding in overhangs or facing vertical rocks where they could swallow large prey without being robbed.

Chicks were also heavily infested with ticks (*Amblyomma loculosum*) in July. Of all marked nests, only two chicks fledged, from an isolated small colony without ticks.

Comparison with Other Colonies

In terms of physical features, nest-site characteristics on Aride were similar to that in the United States (Burger and Gochfeld 1988a; Gochfeld and Burger 1988), the Azores (Ramos and del Nevo 1995) and some colonies on Culebra, Caribbean (Burger and Gochfeld 1988b). Vegetation cover around the nest-site was a major difference between tropical Roseate Terns on Aride and those on Culebra. The beneficial effect of ground cover on Culebra was replaced by the tree canopy on Aride. Other tropical Roseate Tern populations seem to nest in more open areas: in the Virgin Islands on unvegetated ledges or sea-level coral rubble

(Norton 1988), in Parguera, Puerto Rico, on barren coral rubble cays (Shealer 1995), in Tanzania and South Africa on bare coral rock or on mats of detritus (Thomas and Elliot 1973; Randall and Randall 1981), and on the Great Barrier Reef, Australia, on flat cays of coralline sand covered with grass, which the birds prefer for nesting (Milton *et al.* 1996), on low vegetated cays with Black-naped Terns (*Sterna sumatrana*) (Smith 1991) and on bare sand near Black-naped Terns (Gochfeld, pers. comm.).

Mean nearest-neighbor distance found in this study is consistent with those found for other tropical colonies: 66 cm in South Africa (Randall and Randall 1981), 40-70 cm in Parguera (Shealer 1995) and 63-97 on Culebra (Burger and Gochfeld 1988b), but much smaller than those reported for temperate Roseate Tern populations: 80-126 cm in the Azores (Ramos 1990) and 143 cm in New York (Burger and Gochfeld 1988a).

DISCUSSION

Nest-site selection by Roseate Terns on Aride resembled that of temperate and some tropical counterparts. Tropical Roseate Terns seem to select concealed nest-sites if they are available, but are not constrained from nesting in open areas (Shealer 1995).

Social factors are important in the selection of nest-sites since Aride Roseate Terns nested, on average, as close as 0.5 m to neighbors, when many concealed sites were available around the colony. At high nest densities, fewer variables differed between nest-sites and available habitat, suggesting that peak-nesting birds were unable to select nest-sites differing in physical features from the available habitat, due to the proximity of neighbors.

Distance to the nearest neighbor was positively influenced by the amount of rock cover in the area, suggesting that a rugged terrain will accommodate more breeding birds. Tropical Roseate Terns are more aggressive than temperate counterparts (Burger and Gochfeld 1988c; Shealer 1995; pers. observations). This has been viewed as a reflection of the more exposed nesting habitats in tropical areas (Shealer 1995), but could simply be a reflection of higher nest densities in tropical areas. Higher nest densities may also make social stimulation more important for Roseate Terns breeding in the tropics.

Predation and inter-specific competition have been invoked to explain variability in nest-site selection by temperate and tropical Roseate Terns (Burger and Gochfeld 1988a,b; Ramos and del Nevo 1995). On Aride nest-site characteristics, notably overhangs, had no influence on hatching success and predation or inter-specific competition could not explain concealment. The higher hatching success in the center quadrat may be explained by older and more experienced birds presumably nesting in the center of the colony (Coulson 1968; Burger *et al* 1996). Ectoparasites were present on Aride and may also influence nest-site selection, but this needs evaluating.

Although the primary features of nest-site selection are common to both temperate and tropical Roseate Terns, the reasons behind nest-site selection may vary among colonies. If not for other reasons, concealment may be less stressful for breeding adults. The location of a nest-site should be viewed as a dynamic procedure depending on the aggressiveness of the neighbors, the softness of the ground to make a nest cup, and vegetation and rock cover. Finally, the benefits of nest-site selection to Roseate Terns may be

Table 3. Seasonal variation in the hatching success of Roseate Terns in relation to nests with and without overhang.

Nests initiated within	Number of nests	% with overhang	Hatching success and overhang (blind area)	
			% with overhang that hatched	% without overhang that hatched
1-6 June	79	34.2	59.3	76.9
After 6 June	77	22.1	64.7	50.0

difficult to quantify with conventional approaches like the one used in this study. It may be necessary to record adult and chick behaviors and relate them to nest-site features, to deepen our understanding of nest-site selection.

In practical terms this study suggests that partial overhangs may reduce chick mortality from adult aggression. Artificial shelters increased the reproductive success of temperate Roseate Terns (Spendelow 1982) and could be used in the tropics.

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