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First data on productivity and reproductive parameters of tropical roseate terns breeding on St Joseph Atoll, Seychelles

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Abstract: Nest-site characteristics and reproductive parameters of tropical roseate terns *Sterna dougallii* breeding on St Joseph Atoll (Amirantes, Seychelles) were studied in June-August 2006. The total breeding population of *ca*300 pairs included 3 different colonies located on two islands (Pelican and Ressource islands). Roseate terns nested at sea-level on coral rubble on average 0.4 m from neighbors and selected nest sites that offered more concealment within the available habitat. First eggs were laid between 16-23 June (50 pairs, small colonies), with the peak of laying occurring during the first week of July (250 pairs, large colony). Mean clutch size was lower in early birds (1.1 eggs/clutch) compared to peak-laying birds (1.5 eggs/clutch). The former experienced a complete breeding failure at the egg stage presumably due to predation, but in the main colony 70 chicks were found to have fledged within the usual period of 25-30 days reported for the species. Overall, productivity was estimated at 0.23 chicks per pair. Although the recently-discovered colonies on St Joseph Atoll may be at risk due to the high number of potential predators (land crabs/herons/turnstones), these data are indicative of a productive population in the absence of food shortage periods recorded during the season. Our results are compared to the long-established population on Aride island (Central Seychelles), where productivity has been monitored annually since 1984. This paper highlights the importance of St Joseph Atoll for the conservation of roseate tern colonies in the western Indian Ocean, which could be partly achieved by including it as Important Bird Area (IBA) in the Seychelles.

Key-words: *Sterna dougallii*, St Joseph Atoll, Indian Ocean, Aride, Inter-colony comparison

Introduction

The roseate tern (*Sterna dougallii* Montagu, 1813) is a widely and sparsely distributed seabird with its world's stronghold lying in the Indian Ocean (Gochfeld 1983). The species was still considered globally near-threatened (*sensu* IUCN Red List) until fairly recently owing to a dramatic extinction of known colonies over the past

decades (Collar & Andrew 1988). Following a more recent update, population levels appeared to have stabilised and it was removed from the Red List in 2004 (BirdLife International 2004). The population of the Seychelles is one of the largest currently known in the western Indian Ocean (Tree 2005), making the identification of potential limiting factors of both regional and global importance for the conservation of the species. Aride island hosts the largest colonies in the Seychelles with its annual breeding population estimated between a low of 607 pairs in 2004 and a high of 1,276 pairs in 2002 (Ramos *et al.* 2002, Monticelli & Ramos 2004). Recent census elsewhere in the archipelago have also reported smaller colonies irregularly present at the uninhabited islands of Goëlettes (Farquhar Atoll; 15-20 pairs), African Banks, Etoile, and possibly Bancs du Providence (Rocamora & Skerrett 2001). On St Joseph Atoll, where roseate terns have been opportunistically reported in the past (e.g. Betts 1998), breeding activity was first confirmed in 2005 (Skerrett & Skerrett 2005). The size of this population was estimated at *ca*350 pairs, which suggests that St Joseph Atoll may host the second largest number of roseate terns breeding in the Seychelles.

Compared to their temperate counterparts, tropical roseate tern colonies show lower productivities, with frequent periods of food shortage causing complete breeding failures (Milton *et al.* 1996, Ramos *et al.* 2002). On Aride, long-term research on roseate tern breeding parameters (Ramos 2002; Ramos *et al.* 2002) suggests a strong selection for laying as early as possible (Ramos *et al.* 2002). In poor years, egg and/or clutch sizes is significantly smaller than in years of good food supply conditions, and productivity is low because only the earliest breeders have a reasonable chance to rear a single chick (Ramos 2001). Moreover, Aride-roseate terns seem to trade off clutch size/egg size for earliness of laying (Ramos 2001), which appears to be a strategy to overcome the often declining food supply conditions as the season progresses (Ramos & Monticelli 2007). To date, however, these patterns in productivity and reproductive parameters have not been compared with other tropical colonies in the western Indian Ocean, because other breeding sites were poorly studied. Published information suggests also that the impact of predation on productivity is relatively small in tropical populations (Milton *et al.* 1996, Ramos 2002), but data is only available for a limited number of sites.

In this paper, we studied nest-site selection and reproductive performance of roseate terns colonies on St Joseph Atoll, Seychelles during the 2006 breeding season. Data on the number of breeding pairs, breeding chronology, clutch/egg sizes, hatching success, and productivity (no. of fledged chicks per pair) was collected, and compared to the Aride colonies, where breeding success and other characteristics are annually monitored since 1984 (Ramos *et al.* 2002). Nest- site characteristics were also collected on St Joseph Atoll to evaluate the possible response of the species to predation pressure.

Methods

Study Area

Fieldwork was conducted on St Joseph Atoll (5°25'S, 53°20'E) in June-August 2006. The atoll (1.21km²) is part of the Amirantes group of Seychelles and consists of 14 flat, sandy coral islands (Fig. 1). The three largest (St Joseph, Ressource, Fouquet) are

covered with coconut plantations. A thorough search of the atoll by boat to locate colony sites was conducted several days after the first birds were seen flying in early June. Roseate terns breeding in open areas are susceptible to human disturbance (Gochfeld *et al.* 1998), hence precluding regular visits to the nesting area during the season. We thus opted to minimize the number of visits paid to the colonies, and monitored breeding parameters such as fledging success at reasonable distance from a boat with binoculars (counting fledglings).

Location of colonies and nest-site selection

Colonies were found at sea-level on coral rubble cays. One small colony was found on Pelican island (PI) and two were found on Ressource island (one small, RI1, and one large colony, RI2). Nest-site characteristics were recorded by using a method previously applied on Aride island (Ramos 1998). Five variables were measured at both nest-sites and random-points during two brief visits of 10-15 minutes each at the peak of laying to colonies on RI (21-22 June; Table1).

Population size and breeding parameters

The size of the small colonies was determined by direct counts of the number of nests during several brief visits (21, 22, 23 June & 8 July). The size of the large RI2 colony was estimated by counting the number of black heads of birds on a panorama picture of the colony taken in the late afternoon at close range from a boat (24 July; colony size = total no. of birds divided by two). Clutch size and egg volume were recorded accurately in the two small colonies, but in the large colony, a study quadrat at the edge of the colony was only visited once (5-10min) 16 days after the first egg was seen to obtain data on clutch size. We inferred egg external volume (V, cm^3) from egg length (L, cm) and breadth (B, cm), measured with calipers to the nearest 0.1mm by using $V=0.512*L*B^2$ (Stonehouse 1966). An egg shape index was also calculated as 100*B/L (Coulson 1963).

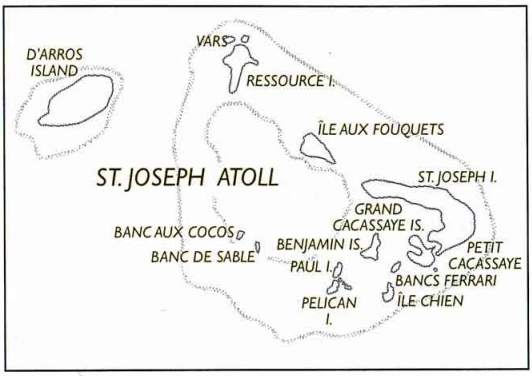

Fig. 1. Map of St Joseph Atoll (5°25'S, 53°20'E) showing the 14 flat, sandy coral islands. In 2005, roseate tern nested exclusively on Ile Chien (Skerrett & Skerrett 2005), in 2006 colonies were found on both Pelican and Ressource Islands (this study).

Table 1. Variables measured at roseate tern nest-sites and random-points on St Joseph Atoll during the 2006 breeding season.

Variable	Description (unit)
Object distance	Distance from the centre of the nest (egg) to the base of the nearest vertical object (log, coconut leaf, coral rubble) (cm).
Object height	Height of the nearest vertical object (cm).
Cover above nest	Object (log, coconut leaf) overhanging within a 30 cm radius from the centre of the nest (visual estimation, %).
Number of neighbour(s)	Number of neighbours counted within 1m radius around the nest.
Neighbour distance (NND)	Distance to the nearest neighbour nest (cm).

Table 2. Nest-site characteristics (mean ± SD) of roseate terns breeding on St Joseph Atoll, Seychelles, in 2006. nd = no data

Variable	Nests (N = 22)	Random-points (N = 7)	Mann-Whitney-*U* (*P*)
No. of neighbours	4.0 ± 2.0	nd	nd
Neighbour distance (cm)	38.4 ± 15.6	nd	nd
Object distance (cm)	15.4 ± 10.6	22.0 ± 12.6	47.0 (ns)
Object height (cm)	18.1 ± 13.6	4.1 ± 2.9	7.5 (*P < 0.001*)
Cover above nest (%)	11.1 ± 15.5	0	31.5 (*P < 0.05*)

Table 3. Summary of roseate tern breeding parameters and productivity (no. chicks fledged per pair) recorded at several colonies found on St Joseph Atoll and on Aride island, in 2006. Mean values are presented ± SD with sample size in parenthesis (nd = no data).

Variable	St Joseph Atoll		Aride island
	Small colonies (early birds)[1]	Large colony (peak of breeding)[2]	
Number of breeding pairs[1]	50	250	527
First egg-laying	16 June	1 July	1 June
Clutch size	1.1 ± 0.3 (58)	1.5 ± 0.5 (40)	1.1 ± 0.2 (470)
Egg volume (*a*-egg) (cm^3)	18.5 ± 2.2 (30)	nd	17.6 ± 1.3 (40)
Egg shape index (*a*-egg)	72.3 ± 3.1 (30)	nd	70.9 ± 3.0 (40)
First chick hatching	no hatching	22-23 July	23 June
Hatching success (*a*, *b*-eggs) (%)	0 (58)	nd	74 (43)
Productivity (*a*, *b*-chicks fledged/pair)	0 (50)	0.28 (250)	0.51 (527)

[1]Small colonies found on Pelican and Ressource islands. [2] Large colony found on Ressource island

Productivity

Productivity (chicks fledged per pair) was assessed in the small colonies by recording directly egg/chick fate in each nest during four visits (21, 22, 23 June & 8 July). For RI2, two visits were conducted within an interval of two weeks (24 July, 9 August) to record chick fate and their stages of development at several nests randomly selected at the edge of the colony. Around 25 to 30 days following the estimated date of peak-hatching, fledglings were very mobile and started to assemble in crèches at one edge of the colony along the coastline. The number of large chicks and fledged young present in the colony area was subsequently counted on 25-27 August with binoculars from the boat to minimize disturbance. Productivity was estimated as the number of large chicks/fledglings divided by the number of pairs. However, it should be acknowledged that this method is likely to underestimate productivity because fledglings may hide during the count.

Comparison with Aride

The main colonies found on Aride are monitored annually following a standardised protocol described in Ramos (2001) and Ramos *et al.* (2002). Birds are habituated to human presence and breeding parameters and colonial productivity are estimated from marked nests followed in two study quadrats along the season. In 2006, roseate terns breeding on Aride were studied in June-August (Monticelli & Ramos 2006, this study).

Statistical analysis

Nest-site variables were compared to random-points using non-parametric statistics (Mann-Whitney *U*-test). Egg volume and egg shape index were compared between Aride and St Joseph Atoll using *t*-tests (difference between means) after controlling for unequal variances between samples. We used Fisher Exact tests to compare clutch size and productivity with estimates available for Aride in 2006.

Results

Nest-site selection on St Joseph Atoll

The mean distance to the nearest roseate tern nest was about 0.4 m, and there was a mean of 4 neighbours (min = 1; max = 8) within a 1m radius from the centre of each nest (Table 2). Objects found around nests (logs, coral rubble) were taller than would have been expected by chance, and the percentage of cover (coconut leaf, logs, detritus) was higher than that found at random-points (Table 2). Altogether, this suggests that roseate terns selected nest sites that offered some concealment within the available habitat.

Population size and breeding chronology

A first wave of early birds appeared during the second half of June (Table 3), and 50 nests were counted on 2 islands *ca*1 km distant (PI = 15, RI1 = 35 nests). From our regular visits to the area, we estimated that the first clutch was initiated after 15 June, and that most clutches were laid between 16-23 June. The bulk of the roseate tern population arrived on St Joseph Atoll during the first week of July and egg-laying commenced almost immediately in a large newly formed colony (RI2) where a minimum of 250 pairs were estimated (500 birds on photographic document taken on 8 July).

Breeding parameters and productivity

Clutches laid between 16-22 June were significantly smaller than those laid in the peak laying period (after 1 July) at the RI2 colony (Fisher exact test $P < 0.001$; Table 3). Freshly broken eggs were found at the first visit to PI (8 out of 15 nests on 21 June) and subsequently during monitoring in June-July at PI and RI. A complete breeding failure of early birds was recorded at the egg stage due to heavy predation (PI, RI sites), presumably by land crabs (*Ocypode* sp.), turnstones (*Arenaria interpres*) and/or grey herons (*Ardea cinerea*) that were commonly seen in the immediate vicinity of the colonies. Because all eggs from early clutches laid on St Joseph Atoll failed, the first chick hatched around 23 July in the main RI2 colony (Table 3).

Despite the complete breeding failure recorded during the first half of the breeding season there was, however, no major predation event or food shortage period recorded at RI2 in August, with growing chicks at various stages of development observed during several visits (24 July-9 August). Chicks were successfully raised at RI2 throughout the month with a peak count of 70 fledglings at this site on 25-27 August. Overall, the productivity estimation was 0.23 chicks/pair.

Comparison with Aride in 2006

The 2006 Aride-population was estimated at 527 pairs with the first egg seen in the main hill woodland colony on 1 June, and the first chick hatching on 23 June (Table 3). The mean clutch size recorded for the whole population was similar to that of early birds laying in the small colonies on St Joseph Atoll. However, larger clutches were laid on St Joseph Atoll at the peak of breeding in the RI2 colony compared to the Aride value (Fisher exact test $P < 0.001$). Egg volume and egg shape index were smaller for Aride than for the two small colonies of St Joseph Atoll ($t_{68} = 2.2$; $P < 0.03$, and $t_{68} = 1.9$; $P = 0.059$, respectively). Overall, productivity on Aride was estimated at 0.5 chicks/pair (Table 3).

Discussion

Predation and location of colonies

Predation was responsible for most egg failure recorded early in the season in the small colonies located on Pelican and Ressource islands (St Joseph Atoll). The loss patterns of eggs suggested primary predation by land crabs and avian predators such as turnstones and/or grey herons which are widely present in the atoll and may predate on eggs and chicks (Nisbet & Spendelow 1999, Barbour *et al.* 2000). Despite the lack of detailed information on egg/chick predation at the main colony on Ressource island, chicks were successfully raised at this site during the season, which overall enhanced productivity to 0.23 chicks per pair. Large colonies are continuously attended by many adults compared to small colonies, which may be more effective to drive off aerial intruders (Hernandez-Matias *et al.* 2003), and possibly land crabs (Burger & Gochfeld 1988). This could contribute to explain the differential predation observed between early and peak-nesting birds on St Joseph Atoll. In 2005, the main roseate tern colony was found on the nearby Ile Chien (Fig. 1) by Skerrett & Skerrett (2005), but this breeding site was completely abandoned in 2006. Since predated colonies are also more likely to be abandoned in subsequent years (Nisbet & Spendelow 1999), the colony shifts observed in 2006 may reflect a predator avoidance response. Altogether, these observations suggest that the location of the St Joseph Atoll colonies may be fairly unpredictable from year to year. In the Great Barrier Reef, there are also frequent failures and colonies appear to change location frequently (Milton *et al.* 1996). In contrast, the main roseate tern colony found under woodland on Aride is well-established, presumably due to the virtual absence of ground and avian predators, except from two lizards (*Trachylepis wrightii* & *T. sechellensis*), that are passive egg predators (Ramos 2001), and introduced common barn-owls (*Tyto alba*) that sporadically take adult birds (authors' unpublished data).

Nest-site characteristics

Roseate terns nested in the open on coral rubble, a similar nesting habitat to that reported from other tropical colonies (e.g. Virgin Islands; Norton 1988, and Puerto Rico; Shealer 1995). The average distance of 0.4m between adjacent nests found on St Joseph Atoll is similar to values reported for Aride (0.5m; Ramos 1998). The study of nest-site characteristics revealed that roseate tern nests were not closer to vertical objects than were the random-points. However, objects found in the direct vicinity of the nests were taller and had a larger cover than expected by chance (e.g. log, coconut sapling). These features seem to be similar to nest-site selection at other tropical colonies within a similar open habitat (e.g. Culebra, Puerto Rico) where nests are usually placed far from vertical objects where crabs usually hide (Burger & Gochfeld 1988). There is also a preference for sites where cover is available at reasonable distance (0.5m) for shade and chick protection against bad weather or avian predators (Burger & Gochfeld 1988), which is consistent with our findings.

Breeding characteristics

The comparison between Aride and St Joseph Atoll suggests some differences during the 2006 season. The initiation of breeding differed by at least two weeks, with the earliest birds found on Aride (1 June). Over the last 15 years (1985-2001) laying on Aride has started as early as mid May (13 May), and as late as mid June (14 June), but usually fewer chicks fledged when laying started in June due to lack of food (Ramos *et al.* 2002). Mean clutch size recorded on Aride fluctuates between 1.03 eggs/clutch in poor years and 1.55 eggs/clutch in years of good food supply conditions (Ramos *et al.* 2002). In the arctic tern (*S. paradisaea*), egg production (clutch size and egg volume) has been found to be limited by food availability around the colonies, with a tendency to delay egg-laying in poor years (Suddaby & Ratcliffe 1997). Therefore, the fact that most clutches were laid on Aride in June 2006 and contained a single egg indicates that roseate terns laid under relatively poor food supply conditions in that year. On St. Joseph Atoll, where egg-laying was delayed compared to Aride, early birds laid mostly one egg (June), but those from the main laying period (July) laid larger clutches (mean of 1.5 eggs/clutch), which is indicative of presumably better food conditions during egg formation. The higher mean egg volume found on St Joseph Atoll (early birds) suggests also better food conditions when compared to the Aride situation.

Roseate terns breeding on St Joseph laid slightly longer, more pointed eggs compared to Aride which is consistent with a higher proportion of younger breeders (Coulson 1963), that usually initiate nests later in the season (Burger *et al.* 1996). The delayed laying dates on Ressource island in July (i.e., one month later than on Aride) raises also the possibility of earlier failure in the season at a different unknown site.

Altogether, these data are indicative of a productive population on St Joseph Atoll with absence of food shortage periods recorded during the season. This situation seems rather contrasting with Aride, where an acute food shortage in July-August limited productivity at 0.5 chicks per pair (Monticelli & Ramos 2006, this study). Extensive shallows in St Joseph Atoll are not available to Aride birds and could represent a more reliable feeding area with longer periods of food availability during the breeding season

(June-August). More years of data collection at both sites will help to further elucidate whether the 2006 situation represents a general pattern.

Conservation implications

Successful breeding on St Joseph Atoll may be at risk due to a high pressure by both avian and ground predators, but further research is needed to fully evaluate this aspect. Disturbance is also a serious concern. The owners of the atoll are very keen to preserve the natural fauna and are aware of the need to minimise disturbance but the lagoon is sometimes visited by others, including tourists (especially for fly-fishing) and poachers (for whom the main target may be wedge-tailed shearwaters *Puffinus pacificus*). Population estimates in 2005-2006 were fairly similar (Skerret & Skerrett 2005, this study) and suggest that St Joseph Atoll holds the largest known roseate tern breeding colony in the western Indian Ocean after Aride, which confers it the criteria to be included as an IBA in the Seychelles (Category *A4i*; Fishpool & Evans 2001). As further support for this inclusion, St Joseph Atoll also meets IBA criteria under category *A4i* in respect of black-naped tern *S. sumatrana*, *A4ii* for wedge-tailed shearwater, and *A4iii* for its overall seabird population (more than 10,000 pairs; Fishpool & Evans 2001).

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