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Nesting success of White Terns and White-tailed Tropicbirds on Cousine Island, Seychelles

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This study investigates the breeding success of two tropical seabirds that exploit dissimilar nesting habitats on Cousine Island in the Seychelles archipelago, the White Tern *Gygis alba* and the White-tailed Tropicbird *Phaethon lepturus*, which nest in trees and in crevices on the ground, respectively. Both species have a clutch of one egg. Over a 23-month study period, the outcomes of 134 nesting attempts by White Terns and 285 by White-tailed Tropicbirds were followed. White Terns produced an average of 0.4 chicks per attempt, significantly more than that of White-tailed Tropicbirds (0.25). Hatching success did not differ between the two species, but fledging success of White Terns (62%) was significantly higher than that of White-tailed Tropicbirds (43%). Nesting success of White-tailed Tropicbirds may be less successful than White Terns because their ground nests are at risk to purely terrestrial predators, in addition to predators that are both terrestrial and arboreal. Many nests of White-tailed Tropicbirds failed during the first two weeks of the incubation and nestling periods, but the reasons for this are unclear. Food availability may influence the reproductive success of both species.

Introduction

Seabird life history strategies are often characterised by high adult survival, delayed maturity at breeding, low clutch sizes and variable reproductive output (Schaffner 1990, Bowler et al. 2002, Hockey and Wilson 2003, Ramos et al. 2005). At low latitudes seabirds have small clutches, large eggs and long incubation and fledging periods (Hockey and Wilson 2003), and clutch size has been related to food availability and predation risk (Shea and Ricklefs 1996).

Primary production in tropical marine ecosystems is generally considered to be low and seasonal, and food may be scarce, especially at oceanic islands (Hockey and Wilson 2003). Avian predators on small islands are generally few, but predators may be attracted to seabird eggs and chicks when large numbers of seabirds are breeding at high densities (Schaffner 1991, Hockey and Wilson 2003). Although most tropical islands are free of large indigenous mammalian predators, predation by smaller terrestrial predators like crabs and skinks occurs (Schaffner 1991, Ramos et al. 2005). Intra- and interspecific competition between breeding birds may also lower breeding success (Bowler et al. 2002, Ramos et al. 2005).

Cousine Island is one of the smallest islands in the Seychelles archipelago. Seven tropical seabirds breed at the island; two of the least common are the White Tern *Gygis alba* and the White-tailed Tropicbird *Phaethon lepturus*. An estimated 1 000–1 500 pairs of White Terns and 450–850 pairs of White-tailed Tropicbirds breed on this island (Skerret et al. 2001). White Terns are tree-nesting birds that lay a single egg on an exposed fork or in an artificial structure, whereas White-tailed Tropicbirds are ground nesters that breed in a shady and sheltered crevice (Schaffner 1991, del Hoyo et al. 1996, Bowler and Pillay 2000). The incubation period of White Terns is 34–36 d (five weeks) and the nestling period 68 d (seven weeks), whereas the incubation period of the White-tailed Tropicbird is 40–42 d (six weeks) and the nestling period 77–85 d or 11–12 weeks (del Hoyo et al. 1996, Higgins and Davies 1996). Both species exhibit life-history traits specific to tropical island breeding. Each species has a clutch size of one and nesting success is generally low, from 30–50% for White-tailed Tropicbirds (Schaffner 1991, Ramos and Pacheco 2003) and 29–40% for White Terns (Vanderwerf 2003).

The aim of this study was to compare the reproductive parameters of White Terns and White-tailed Tropicbirds on Cousine Island and investigate if egg or chick failures were associated with different stages of the incubation and nestling periods. The study also examined the associations between reproductive parameters and nest types (White Terns), the two monsoon seasons and nest reuse. We postulate reasons for observed differences in the measured parameters between the two species.

Methods

Study area

The Seychelles archipelago consists of 116 islands. One of the smallest granitic islands is Cousine (04°20′ S, 55°38′ E), which is privately owned and where natural resources are conserved. It is 24.6 ha in size (excluding the beach), approximately 400 m wide (at its widest point) and 1 000 m long, with its highest point 70 m above sea level. The vegetation of Cousine Island consists of natural woodland found between the island's granitic boulders and is dominated by *Pisonia grandis*, *Scaevola taccada* (along the coast) and *Morinda citrifolia* trees.

The climate of the Seychelles is tropical: hot and humid all year round with low annual and diurnal ranges in temperature. The annual rainfall ranges between 1 400 and 2 000 mm per annum. The climate is influenced by two wind systems, each of which dominates for roughly half the year. The South-East (S-E) Monsoon is prevalent from May to October and the North-West (N-W) Monsoon from November to April (Skerret et al. 2001).

Nesting success

To study the nesting success of the two species, 25 nests of White Terns were located in September 2003 and their breeding status monitored until May 2004, after which another 25 nests were added (June 2004–June 2005) to double the sample size. For White-tailed Tropicbirds, 103 nests were followed from August 2003–June 2005. Nests were not selected randomly but, to ease monitoring, chosen along set routes such as trails or transect lines. Along these routes, all rocks, shrubs and forest patches were searched for nests and, once found, nests were mapped and marked with long-lasting tags (Phillips 1987). For the benefit of ecotourism on Cousine Island, halved coconut husks are placed in trees to function as artificial White Tern nests.

Each nest was examined once a week, and the presence or absence of an egg or chick recorded. Age classes of eggs and chicks were assigned to the weeks of the respective incubation and nestling periods. If an egg was present in the nest for longer than the documented incubation period (see above), it was assumed to be addled and recorded as a failure. The nesting attempts of two White-tailed Tropicbirds that fledged chicks two weeks later than the 12-week norm were recorded as being successful. We recorded how many times a particular nest site was used during the study period. To limit our disturbance of breeding birds, the nest contents were checked by carefully raising the adult with a cane (1 m in length) held at arm's length. This rarely caused the breeding bird to vacate the nest (Bowler et al. 2002). Nests were checked before 10:00 or between 14:00 and 16:00 to avoid the peak feeding times.

Three indices were used to measure nesting success: (1) hatching success as the percentage of the eggs laid that hatched, (2) fledging success as the percentage of eggs hatched that fledged, and (3) breeding success as the percentage of the eggs laid that fledged. For White Terns, we examined whether there was a relationship between success and the location of nests (tree branches versus coconut husks). For both species, we investigated the association between egg failure and age of the egg, between chick mortality and age of chick, between hatching and fledging success, and the two monsoon seasons. Finally, we examined if nests that were reused more often were more successful in fledging young from eggs laid.

Analyses

Chi-square analyses were used to compare breeding, hatching and fledging success between and within species, and to search for associations between egg or chick failures and age classes, nesting success and the two monsoon seasons, and nest reuse and breeding success. Pearson's correlation coefficient was employed to measure the linear association between the number of eggs laid per month by the two study species for the first (September 2003–May 2004) and second (June 2004–June 2005) study periods, and regression analysis to measure the relationship between nest reuse and breeding success (Fowler et al. 1998). Data were analysed using the Statistica software package (StatSoft, Tulsa).

Results

Hatching success for White Terns on Cousine Island was 64% (n = 134). Of the 86 chicks that hatched, 53 fledged (62%). Hence, breeding success was 0.40 chicks per pair per nesting attempt (53 of 134). Hatching success for White-tailed Tropicbirds was 58% (n = 285). Of the 166 hatchlings, only 43% fledged giving a breeding success of 0.25 chicks per pair per nesting attempt (71 of 285).

Hatching success did not differ between the two species (χ^2_c = 1.1, P = 0.29, n = 419). However, fledging success of White Terns (62%) was significantly higher than that of White-tailed Tropicbirds (43%; χ^2_c = 7.3, P < 0.01, n = 252). The overall breeding success of White Terns (40%) was significantly higher than that of White-tailed Tropicbirds (25%; χ^2_c = 8.7, P < 0.01, n = 419).

For White Terns, hatching success did not differ between nests located on tree branches (65%; n = 100) and those in coconut husks (63%; n = 34, χ^2_c = 0.040, P = 0.83). Similarly, fledging success did not differ between branch (62%; n = 65) and husk (62%; n = 21) nests (χ^2_c = 0.002, P = 0.97).

For White Terns, the number of eggs laid per month was highly variable during both the first (September 2003–May 2004, coefficient of variation [CV] = 67%) and second study periods (June 2004–June 2005, CV = 82%, Figure 1). For White-tailed Tropicbirds (measured over the entire study period), the number of eggs laid per month was less variable (CV = 35%). The number of eggs each species laid per month was not correlated for both the first (R = 0.40, t = 1.15, P = 0.29) and second study periods (R = –0.18, t = 0.62, P = 0.55).

For White Terns, there was no association between egg failure and age class of the eggs (χ^2_4 = 3.62, P = 0.46, n = 26), with egg abandonment averaging 5.2 eggs per week over the five-week incubation period. Similarly, there was no association between fledging success and age of the young (χ^2_6 = 3.69, P = 0.72, n = 13). An estimated 1.9 offspring per week died over the seven-week nestling period.

Hatching success of White-tailed Tropicbirds was related to egg age classes of (χ^2_5 = 32.6, P < 0.001; n = 116). Eggs that

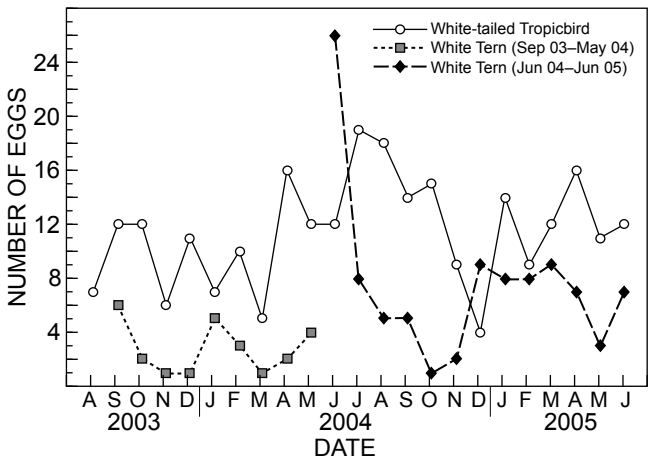

Figure 1: The number of eggs laid per month by White-tailed Tropicbirds and White Terns during the 23-month study period. For White Terns, 25 nests were studied from September 2003 to May 2004, and 50 nests from June 2004 to June 2005. For White-tailed Tropicbirds, 103 nests were followed throughout the study period

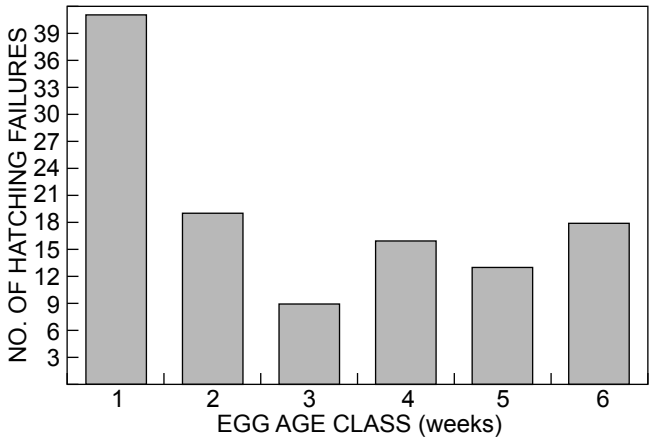

Figure 2: The egg failure rate of White-tailed Tropicbirds during the six-week incubation period

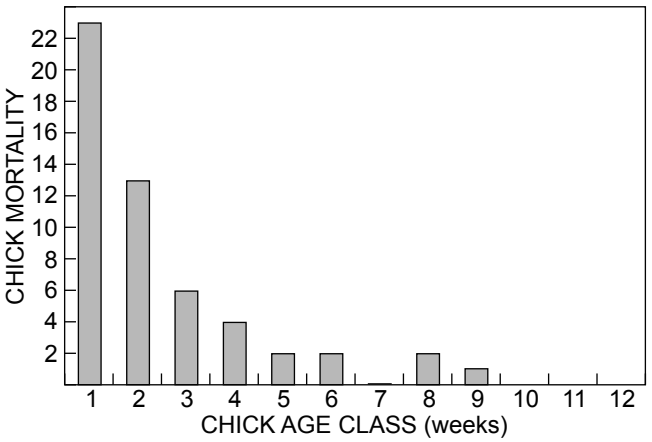

Figure 3: The chick failure rate of White-tailed Tropicbirds during the 12-week fledgling period

failed to hatch were mainly abandoned during the first (35%) and second (16%) incubation weeks (Figure 2). Similarly, chick mortality was associated with chick age (χ^2_{11} = 127.5, $P < 0.001$, n = 53). Most White-tailed Tropicbird chicks died during the first (43%) and second (25%) weeks (Figure 3).

There was no significant association found between White Tern hatching success and the monsoon seasons (χ^2_c = 2.21, P = 0.14), with a hatching success of 70% recorded (n = 77) during the S-E Monsoon and of 56% (n = 57) during the N-W Monsoon. There was no association found between fledging success of White Terns and the monsoon seasons (χ^2_c = 0.13, P = 0.72, 59% of 54 in S-E Monsoon, 66% of 32 in N-W Monsoon).

Similarly, there was no association found between hatching success of White-tailed Tropicbirds and the monsoon seasons (χ^2_c = 0.88, P = 0.35, 56% of 162 in S-E Monsoon, 63% of 123 in N-W Monsoon). There was also no association found between fledging success of White-tailed Tropicbirds and the monsoon season (χ^2_c = 3.58, P = 0.06, 50% of 90 in S-E Monsoon, 34% of 76 in N-W Monsoon).

For White Terns, there was a weak relationship found between the number of times the nest was used and breeding success (R^2 = 0.07, $F_{1,48}$ = 3.37, P = 0.07). For White-tailed Tropicbirds, there was no relationship found between nest reuse and breeding success (R^2 = 0.03, $F_{1,103}$ = 2.69, P = 0.10). The maximum numbers of times nests were reused in the study period were six for White Terns (mode = 2) and seven for White-tailed Tropicbirds (mode = 4).

Discussion

The breeding success recorded for White Terns at Cousine Island (40%) was higher than that recorded for this species at Ascension (Atlantic Ocean) and Tern (Pacific Ocean) islands (29–30%; Dorward 1963, Niethammer and Patrick-Castilaw 1998), but lower than that recorded for a very small population nesting on Oahu Island, Hawaii (74%; Vanderwerf 2003). The breeding success of White-tailed Tropicbirds on Cousine Island (25%) was lower than that recorded at Aldabra Atoll (43–50%; Diamond 1975) and at Ascension Island (30%), indicating that breeding success is variable between colonies (Stonehouse 1962). At Cousine Island, for White Terns and White-tailed Tropicbirds the fate of the fledglings was not known, nor was the size of the breeding population or the number of breeding attempts per pair per year (Vanderwerf 2003).

The fledging success of White Terns (62%) was significantly higher than that of White-tailed Tropicbirds (43%). Mortality of White-tailed Tropicbirds chicks may have resulted from intra- and interspecific competition for nest crevices, as adults were frequently observed fighting for nesting sites and occasionally competed with Wedge-tailed Shearwaters *Puffinus pacificus* for nests (QAH pers. obs.). It is also possible that the lower breeding success of White-tailed Tropicbirds resulted from a higher rate of predation. Chicks of White-tailed Tropicbirds are at risk to predation by four species of crabs found on Cousine Island,

namely pink ghost crab *Ocypode ryderi* and three *Coenobita* species (Schaffner 1991, Ramos et al. 2005), which do not gain access to tree nests. Hard tick *Amblyomma loculosum* infestations found on ground-nesting birds may also cause their deaths (Ramos et al. 2005).

For both species, nest failure may result from predation of eggs by the Seychelles skink *Trachylepis seychellensis,* Wright's skink *T. wrightii* and Seychelles Fody *Foudia sechellarum*, which are abundant on the island (Bowler et al. 2002). However, there may have been different rates of predation at ground and tree nests. White Terns normally nest at densities of an order of magnitude lower than other oceanic ground-nesting birds, principally because tree sites are less abundant (Houston 1979). However, at Cousine Island White Tern nests outnumbered those of White-tailed Tropicbirds by 2:1 (Skerret et al. 2001), White Terns nests having densities of 40–60 per hectare aided by the provision of artificial nests. Additionally, up to 60 000 pairs of Lesser Noddy *Anous tenuirostris* nest in trees at Cousine Island from May to August. White-tailed Tropicbird pairs compete with an estimated 15 000 Wedge-tailed Shearwater pairs for nest crevices (QAH unpublished data) on the ground. The greater supply of tree than ground nests at certain times and fewer arboreal than terrestrial predators are likely to reduce predation rates at tree nests.

White-tailed Tropicbirds suffered most losses during the first two weeks of the incubation and nestling periods. This trend has also been observed on neighbouring Aride Island (Ramos et al. 2005) and on Cayo Luis Pena in Puerto Rico (Schaffner 1991). Early losses of eggs and chicks may be caused by ground predators. During their first two weeks post-hatch, White-tailed Tropicbirds are small enough to be preyed on by crabs and skinks. However, these predators would be able to take eggs throughout the incubation period.

The mortality of eggs and chicks of White-tailed Tropicbirds during the early incubation and nestling periods may also have resulted from weather conditions or environmentally driven changes in prey abundance and availability (Schaffner 1990, Shea and Ricklefs 1996, Bowler et al. 2002, Ramos and Pacheco 2003), although in this study the different monsoon seasons had no measurable effect on nesting success. White Terns and White-tailed Tropicbirds share a diet of flying fish and squid (Schaffner 1990, Shea and Ricklefs 1996), but employ different methods to maximise payload mass: regurgitation by White-tailed Tropicbirds and multiple loading by White Terns (Schaffner 1990, Hockey and Wilson 2003). White Terns feed in close proximity to the islands, a foraging strategy contrasting that of White-tailed Tropicbirds, which can be found >200 km from their breeding grounds (Ashmole and Ashmole 1967, Schaffner 1990, Ramos and Pacheco 2003).

White-tailed Tropicbirds have double the mass of White Terns (del Hoyo et al. 1996). Their larger energetic requirement, coupled with long foraging periods (Ashmole 1963), may force them intermittently to abandon newly laid eggs to forage. Once a pair has succeeded in hatching the egg, they may abandon the hatchling if they cannot sustain a sufficient feeding frequency (Ramos and Pacheco 2003). In tropical marine environments, prey abundance is highly variable in time and space (Hockey and Wilson 2003).

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