INJURIES SUSTAINED BY BEACHED ADULT SOOTY TERNS *ONYCHOPRION FUSCATUS* ON BIRD ISLAND, SEYCHELLES, DURING THE BREEDING SEASON

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SUMMARY

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On Bird Island, Seychelles, adult Sooty Terns are frequently found injured on the beach, usually with dislocated or broken wings, during the breeding season. By ruling out other possibilities we hypothesized that the injuries were caused by frigatebirds, and therefore predicted that (1) most attacks would take place in the late afternoon, when adult Sooty Terns normally return to the colony after feeding during the day; (2) most injuries would be inflicted during the late afternoon and so injured birds are most likely to be found on the beach the following morning, after they have swum ashore; and (3) frigatebird *Fregata* spp. attacks would be more frequent during chick rearing, when adults carry fish and/or squid for their chicks, than during incubation, when they carry only the food required for their own maintenance. At two-week intervals during the 2014 breeding season we undertook early morning and late evening 5-d surveys of the number of beached Sooty Terns, of frigatebirds chasing seabirds visible from the beach, and of frigatebirds in the communal roost. The first two predictions were supported by the data but the third was not; this failure was considered to be due to frigatebirds parasitizing other species, especially Lesser Noddies *Anous tenuirostris*, when these were more profitable sources of regurgitates. Overall, we conclude that frigatebirds are responsible for the injuries that cause Sooty Terns to be found on the beach, and that the number found on the beach is probably only a small proportion of the mortality inflicted on the Bird Island colony.

Key words: Sooty Tern, *Onychoprion fuscatus*, frigatebird, *Fregata* spp., injury, Lesser Noddy, *Anous tenuirostris*, kleptoparasitism, Bird Island Seychelles

INTRODUCTION

A common, and the most conspicuous, evidence of mortality of adult Sooty Terns *Onychoprion fuscatus* at Bird Island, Seychelles, (3°43′S, 55°12′E) is birds found injured or dead on the beach adjacent to the nesting area, usually with a dislocated or broken wing. One of us (Feare 1976) noted that birds in this condition were found only on the beach, not in the colony, and assumed that they had been damaged at sea and come ashore. (Some birds are found dead in the colony, usually as a result of entanglement in vegetation, especially the parasitic vine *Cassytha filiformis*, and more rarely as a result of fights between birds competing for space.) In this study, Feare speculated that the damage was caused by birds colliding with other Sooty Terns or with waves. Collisions, sometimes fatal, have been recorded between feeding Australasian Gannets *Sula serrator* (Machovsky *et al*. 2011), and diving birds are also vulnerable to injuries or predation from predatory fish while they are submerged (Zavalaga *et al*. 2012), but Sooty Terns do not dive or sit on the water (Schreiber *et al*. 2002).

If Sooty Terns sustained dislocations and breakages through collisions with others, we would expect most injured or dead birds to be found in the colony, over which birds fly at high densities and in multiple directions, rather than on the beach, where the density of birds flying to and from the water is much lower than over the colony. (There are no predators or scavengers on Bird Island that could have quickly removed corpses from within the colony.) Similarly, it seems unlikely that injuries result from collisions with waves. Close to shore, Sooty Terns dip to the surface to drink or wet feet and plumage (Schreiber *et al*. 2002), but they do this beyond the zone where waves break, and it is unlikely that they would injure themselves in areas where swells, rather than breaking waves, predominate.

Another possibility, not considered earlier, is that the damage might be inflicted by frigatebirds, of which hundreds roost on the island by day and night during the Sooty Tern breeding season, Lesser Frigatebirds *Fregata ariel* heavily outnumbering Greater Frigatebirds *F. minor*. Frigatebirds are well-known as kleptoparasites (Gilardi 1994, Vickery & Brooke 1994, Le Corre & Jouventin 1997), and on Bird Island Sooty Terns and Lesser Noddies *Anous tenuirostris* are frequent targets. Both species are chased aerobatically, and on occasions frigatebirds have been seen to grasp Sooty Terns by the tail or by one wing during the chase. On Midway Atoll, Gilardi (1994) found Sooty Terns with broken or severed wings, which he concluded "could only have been caused by frigatebirds," although he had no direct evidence.

The hypothesis that frigatebirds are responsible for injuries resulting in incapacitation on Bird Island leads to predictions that (1) most frigatebird attacks would take place in the late afternoon, when adult Sooty Terns normally return to the colony after feeding during the day; (2) most injuries would be inflicted during the late afternoon and so injured birds are most likely to be found on the beach the following morning, after they have swum ashore; and (3) frigatebird attacks should be more frequent during chick rearing, when adults carry fish and/or squid for their chicks, than during incubation, when they carry only the food required for their own maintenance. Inherent in these predictions is the assumption that food regurgitated by Sooty Terns forms an important part of the diet of frigatebirds that roost on Bird Island during the Sooty Tern breeding season.

This study aimed to test these predictions by monitoring the occurrence of incapacitated Sooty Terns on the beach and frigatebird feeding behaviour during the Sooty Tern breeding season in June–August 2014.

METHODS

Beach surveys

The 0.95 km of beach adjacent to the Bird Island Sooty Tern colony was surveyed on five consecutive days, with 10-d intervals between surveys, from mid-June to mid-August 2014, and then a 6-d interval before the last survey, which commenced 22 August. On the evening preceding each 5-d survey, the beach was inspected for existing injured or dead birds, and these were removed; the birds were examined and any injuries were recorded. During the 5-d surveys, the beach was patrolled at 09h00 and 17h45 each day by two to four people. All incapacitated or dead birds were examined for injuries and humanely killed if severely injured but still alive. The type and position of injury, if any, was recorded. Freshly dead and killed birds were weighed to the nearest 5 g using a Pesola balance. The location of the bird on the beach was also recorded as: in water or at water's edge, beach slope, mid-beach or colony edge. The bodies were buried in the beach but, before burial, the primaries of one wing were cut off to distinguish them from birds found during later surveys. Corpses so buried were eventually taken by Ghost Crabs *Ocypode ceratophthalma* and Land Crabs *Ocypode cordimana.*

Frigatebird feeding activity

From a point on the beach where the largest section of the nearby sea was visible, the area was scanned using 8 × 30 binoculars. All of the frigatebirds seen quartering the ocean surface or actively chasing seabirds were counted. Frigatebirds that were seen circling high above the water were not counted; these birds were assumed to be soaring on thermals rather than actively feeding, their lack of flapping distinguishing them from feeding birds, which frequently use flapping flight while searching for potential targets. These counts of frigatebirds were undertaken during the course of the beach surveys, at about 09h15 and 18h00, and were effectively instantaneous counts.

Frigatebird population on Bird Island

Frigatebirds roosted at night in the tops of tall Casuarina *Casuarina equisetifolia* trees at the southern end of the Sooty Tern colony. Many birds also roosted there during the day, sitting, resting, preening and sometimes sun-bathing with wings extended and twisted to expose the ventral surface to the sun. During the beach surveys, the roosting birds were counted from suitable vantage points near the roosts.

Stage of parental care in the Sooty Tern colony

On Bird Island, Sooty Terns breed between late May and October, and egg laying is synchronous (Feare 1976a), usually beginning in early June, which was the case in 2014. The progress of laying, hatching and chick growth in the reserve was being monitored during the 2014 season for purposes of other research. This enabled us to ascribe the beach surveys and associated monitoring to different phases of the breeding season as follows: 13–17 June, arrival and laying; 28 June–2 July, incubation; 13–17 July, main hatching period; 28 July–1 August, hatching and feeding of chicks; 12–16 August and 22–26 August, feeding of chicks.

Frequency of regurgitation and weight of regurgitated food

During the course of other studies being undertaken in 2014, incubating birds that were disturbed by us sometimes regurgitated food as we walked through the colony. Any regurgitates found were collected and weighed to the nearest gram, using a 100 g Pesola balance. Regurgitation was not stimulated deliberately, and thus the collections were not systematic, nor could the number of disturbed birds be estimated. Thirty regurgitates were recovered from incubating adults from 13 June to 6 July but none were seen from 7 to 28 July; this latter period was a time of food shortage for Bird Island Sooty Terns in 2014 (confirmed by increased duration of foraging trips and distance travelled by GPS-tagged non-incubating birds; Feare & Larose, unpublished data).

From 15 to 25 August, 50 adults incubating eggs laid very late in the breeding season and 71 adults standing next to their chicks were caught for weighing and measuring. Some of these birds regurgitated, and all regurgitates were collected and weighed.

These data provided information on meal sizes when adults were feeding only themselves (arrival, laying and incubation) and when they were bringing food back for the growing chicks.

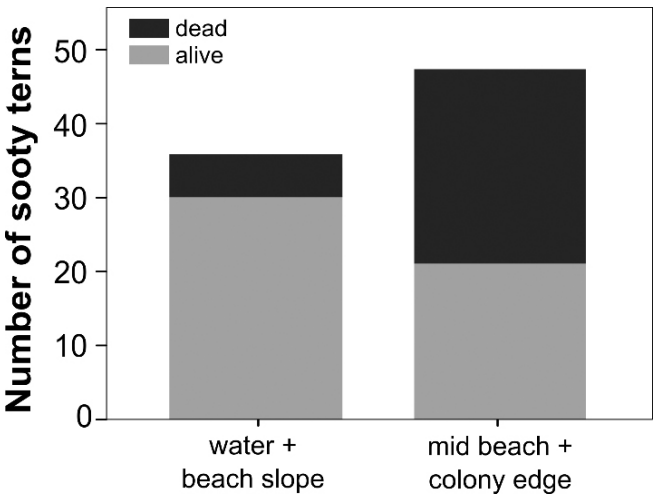

Fig. 1. Number of Sooty Terns found alive or dead at different beach levels (one additional living injured bird was reported by a tourist, but its location was not given).

RESULTS

Number of incapacitated birds

Between 13 June and 26 August, 84 Sooty Terns, three Lesser Noddies and one Brown Noddy *Anous stolidus* were found incapacitated or dead on the beach. Sixty-nine of the Sooty Terns were found during the 5-d beach surveys; the remaining 15 were found on the beach outside these dates. Of the 84 Sooty Terns, 57 (67.9%) were alive when discovered and 27 were already dead. Three birds were found in the surf, with the remainder at different levels on the beach. The proportion of birds alive or dead was significantly dependent on the levels of the beach ($\chi^2_1 = 6.918$, $P = 0.009$, Fig. 1). On the lower part of the beach (water and beach slope), most of the birds were found alive. In contrast, most of the birds found on the upper part of the beach closer to the colony were dead.

Among the 69 birds found during the beach surveys, 75.3% were found during the morning beach survey, significantly more than found in the evenings (Fig. 2A; F = 6.203, $P = 0.016$), and the numbers found significantly varied between the 5-d beach surveys, with most recorded during incubation (Fig. 2B; F = 6.168, $P < 0.001$). The number of counted birds was not affected by the number of counters (F = 1.477, $P = 0.239$).

Injuries

Of the 69 birds found on the beach during the survey, two were found with one wing drooping but with no apparent injury, and 15 birds had no sign of injury. Injuries were mainly to one wing and included dislocations of joints and breakages as follows: broken humerus 10; broken radius 2; dislocated humerus-radius 40; dislocated carpal 10. Five birds had cuts and bruising to skin and muscle on the breast and back but did not appear to have wing injuries.

Bone breakages were accompanied by localized bleeding, and sometimes the broken bone protruded through the skin; dislocations were usually accompanied by cuts or tears and limited bleeding at the site of injury. Two birds, each with a drooping wing but with no other apparent injury, were incapable of flight and assumed to have sustained some internal damage.

In addition to these wing and body injuries, one bird was found with an egg protruding from its bleeding cloaca and another with facial bleeding, as seen following nest territory disputes in the colony; these injuries were believed to have been sustained in the colony rather than as a result of events at sea. The cause of beaching and inability to fly of the remaining apparently uninjured birds was uncertain. As most beached birds had injuries of varying severity, it is possible that birds that showed no outward signs of injury or poor condition could have experienced muscle or joint strain that rendered them flightless.

There was no difference in body mass of injured and uninjured birds (injured: 161.8 g SE 3.77 g, n = 52; uninjured: 157.7 g SE 9.83 g, n = 12; $t_{62} = 0.45$, $P = 0.65$), but beached birds were significantly lighter than breeding adults caught in the colony (beached birds: 161.0 g SE 3.5 g, n = 64; breeding: 191.1 g SE 1.2 g, n = 225; $t_{77} = 8.08$, $P < 0.001$).

Frigatebird feeding behaviour

The morning and evening counts of frigatebirds parasitizing seabirds offshore showed that significantly more interactions

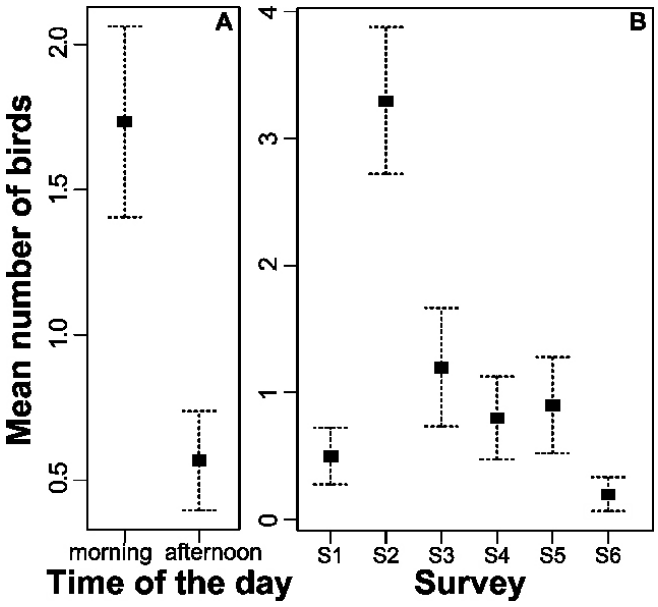

Fig. 2. Mean number of Sooty Terns found on the beach (standard error bars) in relation to (A) time of the day and (B) sequence of beach surveys. S1–S6 refer to the beach surveys and correspond to stages in the breeding season as follows: S1 = 13–17 June, arrival and laying; S2 = 28 June–2 July, incubation; S3 = 13–17 July, main hatching period; S4 = 28 July–1 August, hatching and feeding of chicks; S5 and S6 = 12–16 August and 22–26 August, feeding of chicks.

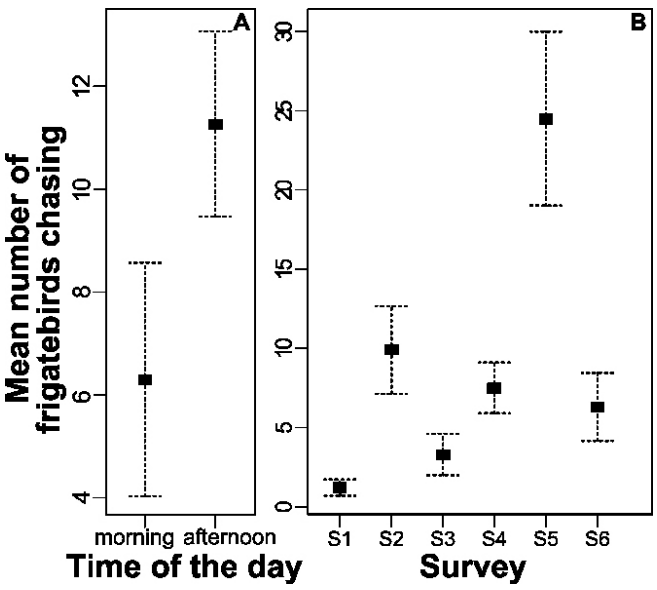

Fig. 3. Mean number of frigatebirds parasitizing seabirds (standard error bars) in relation to (A) time of the day and (B) sequence of beach surveys. S1–S6 refer to the beach surveys and correspond to stages in the breeding season as follows: S1 = 13–17 June, arrival and laying; S2 = 28 June–2 July, incubation; S3 = 13–17 July, main hatching period; S4 = 28 July–1 August, hatching and feeding of chicks; S5 and S6 = 12–16 August and 22–26 August, feeding of chicks.

occurred in the evenings (Fig. 3A; F = 4.773, P = 0.033). The number of interactions varied among the beach surveys (Fig. 3B; F = 8.867, P < 0.001), with most being observed during the 28 June–2 July (incubation) and 12–16 August (chick-feeding) surveys (F = 8.78, P < 0.001).

Overall, there was no correlation between the number of frigatebirds observed in the instantaneous afternoon counts of chasing birds and the number of incapacitated Sooty Terns recorded during the following morning's beach survey (R_s = 0.260, P = 0.220). Nor was there any correlation between frigatebird numbers counted in the roost and the number of incapacitated Sooty Terns the following morning in any of the separate beach survey periods (R_{s4} = 0.098–0.870, P > 0.130).

The number of day-roosting frigatebirds varied between the beach surveys (F = 13.696, P < 0.001) and also between morning and late afternoon counts (F = 40.944, P < 0.001), with an interaction between these two variables (F = 12.568, P < 0.001; Fig. 4). More birds were observed in the evening during the 13–17 June survey and in the mornings during the 13–17 July, 28 July–1 August and 12–16 August surveys (Fig. 4). These figures did not, however, reflect the total number of frigatebirds roosting on the island, many of which arrived after dark and some of which left before dawn. Furthermore, absence from the roost during the day did not provide an indication of the proportion of birds that were feeding, since throughout the day, and especially in the afternoons, large numbers of birds soared above the island, remaining almost stationary in the southerly winds, presumably using up-currents to maintain position and possibly to aid in thermoregulation by exposing maximal body surface area to the wind.

Direct observation of feeding frigatebirds showed that they did not restrict their targeting to Sooty Terns and that Lesser Noddies were also frequently harassed. The latter were targeted especially during the Lesser Noddy hatching period (28 June–2 July) and during their fledging period (22–26 August). On rare occasions, Brown Noddies were targeted, and once a Red-footed Booby *Sula sula* was chased. Frigatebirds were sometimes seen chasing other frigatebirds; on one occasion the targeted bird regurgitated and its food was eaten by the chasing bird.

Chases of both Sooty Terns and Lesser Noddies involved one to six frigatebirds, but the relative success of different group sizes in stimulating regurgitation by the target birds, and the ages and sexes of the chasing frigatebirds, were not investigated. Chases did not always involve contact with the target birds, but frigatebirds were seen to grasp Sooty Terns by a wing with their bills and force them down to the water surface. Where chases were seen close to the shore, on two occasions the Sooty Terns were seen to fly off, but on a third instance the Sooty Tern was not observed flying away (its reaction was obscured by water movement in choppy sea). Most encounters could not be seen as they took place too far from the observers. In most instances when regurgitation by the target Sooty Tern or Lesser Noddy was observed, the chasing frigatebird took the regurgitate from the sea surface rather than catching it in the air.

Frequency of regurgitation and weight of regurgitated food

We obtained 30 regurgitates from disturbed incubating Sooty Terns between 13 June and 6 July, with an average mass of 7.55 g SE 0.96 g (range 1–29.5 g). These samples were significantly lighter than the 21 regurgitates from 71 adults attending chicks on 16–25 August, which averaged 16.07 g SE 1.86 g (range 2.5–40 g; t_{27} = 3.51, P = 0.002).During the latter sampling period, 50 adult Sooty Terns that were incubating late-laid eggs were also handled, but none of them regurgitated.

DISCUSSION

The predictions that more frigatebirds would be observed parasitizing seabirds in the evening surveys and that beached Sooty Terns would be found more frequently in morning beach surveys were supported by our data, suggesting a link between frigatebird kleptoparasitism and the injury and beaching of Sooty Terns. The third prediction, that frigatebird attacks and consequent injuries to Sooty Terns would be more frequent during chick rearing than during incubation, appeared to be supported by data from the 28 June–2 July (incubation) and 12–16 August (early chick rearing) surveys but not by data from the 22–26 August (later chick-rearing) survey, although this association is spurious due to the frigatebirds' targeting of Lesser Noddies during the June–July survey (see below). The third prediction was based on the assumption that during chick-rearing adult Sooty Terns would carry a greater mass of food than when incubating; this was verified by the masses of regurgitates weighed during incubation and chick-rearing. However, the chick-rearing period was not accompanied by an increase in the number of injured Sooty Terns found on the beach.

Three confounding factors could have contributed to the absence of a closer association between the number of injured Sooty Terns found and the recorded frigatebird feeding activity.

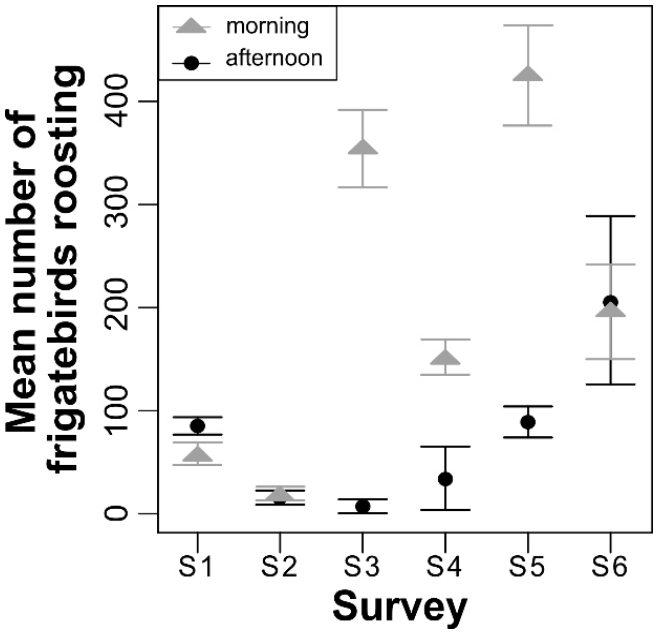

Fig. 4. Mean number of frigatebirds roosting (standard error bars) in the morning (grey triangles) and evening (black circles) during beach surveys S1–S6, which correspond to stages in the breeding season as follows: S1 = 13–17 June, arrival and laying; S2 = 28 June–2 July, incubation; S3 = 13–17 July, main hatching period; S4 = 28 July–1 August, hatching and feeding of chicks; S5 and S6 = 12–16 August and 22–26 August, feeding of chicks.

First, our assumption that Sooty Tern regurgitates were an important source of food for frigatebirds underestimated the contribution of regurgitates from Lesser Noddies. During the handling of incubating Lesser Noddies, it was readily apparent that these regurgitated much more freely than incubating Sooty Terns when similarly handled (but this was not quantified). The beach surveys of 28 June–2 July and 22–26 August coincided with Lesser Noddy hatching and fledging, respectively. Feeding flocks of Lesser Noddies formed close to the island, and birds commuted between nest sites and feeding areas throughout the day during both periods. Chasing frigatebirds targeted Lesser Noddies close inshore, while returning Sooty Terns were parasitized in the afternoons and further out to sea. The availability of Lesser Noddies throughout the day appeared to influence frigatebirds: during both periods there was no significant difference in the number of frigatebirds recorded chasing between morning and evening counts (Fig. 4). During observations of chasing frigatebirds, contact between frigatebirds and Lesser Noddies was seen infrequently, whereas frigatebirds were more persistent in chasing Sooty Terns, commonly grasping them by the wing or tail and driving them down to the water surface.

Second, comparing the number of frigatebirds chasing in the evening with the number of incapacitated Sooty Terns found the following morning may be unrealistic. Indeed, the instantaneous counts of frigatebirds may not be representative of their afternoon foraging pressure near the colony. Moreover, the number of injured birds that manage to swim ashore may be influenced by the distance offshore that they are injured, the severity of the injury (especially in terms of blood loss), and the direction of wind and surface currents that could render access to the island difficult. During the Sooty Tern breeding season, the winds are predominantly southeast and attain maximum strength in August, which could drift birds away from the island's west coast. The lower body mass of beached birds, compared with the body mass of healthy adults in the colony, might reflect the energetic costs of swimming ashore and of thermoregulation when birds were immersed. It is also likely that drifting birds could be taken by predatory fish, but the extent of this predation is unknown. It is possible that the mortality inflicted by frigatebirds is far greater than suggested by the number of beached birds.

Third, although the regurgitates of adult Sooty Terns are larger during chick feeding than during incubation, the greater propensity for adults with young to regurgitate when handled by us might translate to a greater likelihood of regurgitation when chased by frigatebirds. If this is so, Sooty Terns returning with food destined to be regurgitated for chicks might give up their food more readily when chased by frigatebirds, obviating the need for the frigatebirds to grasp their targets and thus reducing the tendency to injure Sooty Terns later in their breeding season.

Further evidence in support of the role of frigatebirds in injuries to Sooty Terns came from a severe food shortage from mid-July to early August. As mentioned above, birds in the colony did not regurgitate when disturbed by us 7–28 July. Other indicators of food shortage included foraging trip duration (determined from daily observation of incubating adults in which one member of the pair was ringed), which increased from 1–2 d (median 1 d) before the shortage to 4–13 d (median 7 d) during the shortage, and foraging round-trip distances (determined from GPS tracks of marked birds), which increased from 100–200 km to >2 000 km during the respective periods (Feare & Larose, unpublished data). This led to the abandonment of large numbers of eggs by the birds left incubating. During the beach surveys spanning the main hatching period and the early feeding of chicks, which was the main period of the food shortage, markedly fewer beached birds were found than during incubation (Fig. 2), when food was abundant. This would be expected if frigatebirds found Sooty Terns an unreliable source of food at this time, as suggested by the switch to Lesser Noddies as targets.

Despite the lack of an increase in incapacitated Sooty Terns during the chick-feeding period, we believe our observations support the hypothesis that frigatebird kleptoparasitism is a likely cause of the injury and beaching recorded.

ACKNOWLEDGEMENTS

This study was undertaken as part of a long-term investigation of Sooty Terns and other seabirds in Seychelles. The two components of these studies in 2014 were to investigate foraging movements of breeding Sooty Terns and to identify pathogens in Sooty Terns, Brown Noddies and Lesser Noddies; we are grateful to the Seychelles Bureau of Standards for approving these. We also thank Bird Island and its owner, Guy Savy, for continued support of these studies.

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