Attempted re-establishment of a sooty tern *Onychoprion fuscatus* breeding colony on Denis Island, Seychelles

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SUMMARY

Seychelles supports around three million nesting pairs of sooty terns. However, there have been recent declines and the colonies continue to face ongoing threats from habitat change and excessive commercial harvesting of their eggs, as well as potential threats by commercial fishing and climate change. A possible method to counter these threats is to re-establish breeding colonies on islands from which they have disappeared. An attempt was made to attract birds to a previously occupied island through habitat management, decoy birds and playback of recorded sooty tern calls. Habitat preparation involved predator eradication and tree removal to provide open ground with bare sandy areas and low herb vegetation. Overflying birds were attracted by broadcast calls, with some circling over and landing among the decoys. Large three-dimensional plastic models were superior to other models presented. This study demonstrated that large numbers of birds can be attracted by these means and that the birds then undertook behaviour associated with breeding, including egg laying by a few birds. However, after five seasons a breeding colony has not yet been established; one possible cause is the emergence of unexpected egg predators, common moorhen *Gallinula chloropus* and common myna *Acridotheres tristis*.

BACKGROUND

Over six million pairs of sooty terns *Onychoprion fuscatus* are estimated to breed in the western Indian Ocean, about half of them on islands in the political Seychelles (comprising the Seychelles, Amirantes, Aldabras and Farquhar atoll situated at approximately 3°40'-10°30'S, 46°00'-56°00'E). Historical records indicate that some breeding colonies have been lost from Seychelles, probably representing a further 600,000 pairs (Feare *et al*. 2007). Habitat change, excessive human predation of eggs and possibly introduction of exotic predators have contributed to these colony extinctions (Ridley & Percy 1958, Feare 1976a,b).

Within Seychelles commercial egg harvesting continues, regulated by the government, and further habitat changes on islands in the Seychelles group have led to recent decreases in the two main colonies on Aride and Bird islands (Calabrese & Bullock 2012, per.obs.). In view of these continuing negative influences on the population, an attempt is being made to re-establish breeding sooty terns on an island where they have not bred for approximately 200 years.

Denis Island (3°48'S, 55°40'E) is a coralline island situated at the north of the Seychelles Group, approximately 30 km from Aride and 40 km from Bird Island, the nearest sooty tern colonies. When first described in 1773, Denis Island's habitats included woodland, probably dominated by *Pisonia grandis* (Stoddart & Fosberg 1981), and open fine grass prairies interspersed with dry sandy areas (de Trobriand 1777). It supported large numbers of breeding seabirds, with sooty terns likely to have been the most abundant species in the grassland areas (their preferred habitat on Bird Island, Feare *et al*. 1997). Subsequently, Denis Island became a coconut plantation with areas of dense woodland, thereby losing habitat for ground-nesting seabirds.

Denis Island is now privately owned and managed as a tourist resort. The dense woodland dominated by native broad-leaved trees was considered suitable habitat for some of Seychelles' threatened endemic birds. Cats *Felis catus* and black rats *Rattus rattus* were therefore eradicated from the island in 2000 and 2002 respectively. Subsequently, in 2004 and 2008 four endemic bird species were translocated to Denis Island to establish insurance populations.

This paper describes the first five years of a project to reintroduce sooty terns. The re-establishment attempt has taken place in three phases: habitat creation and attraction of birds (2008), intensive monitoring of settlement behaviour (2009 and 2010) and opportunistic monitoring of numbers (2011, 2012).

ACTION

Habitat preparation: An approximately 2 ha plot (160 x 50 m) on the south-west of the island was selected to create suitable habitat for sooty terns, The site was about 40 m from the beach crest and a break in the tall coastal vegetation offered a flyway for birds commuting between the proposed nesting site and the sea. In 2008 the selected area was cleared of most

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trees and bushes, largely the remains of an introduced coconut *Cocos nucifera* plantation with a ground layer of coconut seedlings, to allow a herb layer to develop. Towards the southern part of the plot five tall casuarina trees *Casuarina equisetifolia* were left standing. The resulting herb layer was dominated by various grasses and herbs, including pourpier *Portulaca oleracea*, a plant that creates nesting habitat favoured by sooty terns (Feare *et al*. 1997). Other herbs (*Amaranthus dubius*, *Sida acuta*, *Abutilon indicum*, *Stachytarpheta jamaicensis*, *Turnera angustifolia*, *Lippia nodiflora*), grasses (*Panicum maximum*, *Cenchrus echinatus*) and seedlings of cotton *Gossypium hirsutum*, passion flower *Passiflora suberosa* and papaya *Carica papaya* grew readily and required cutting and weeding prior to and during the birds' breeding season, from late May to October.

Before the start of the 2009 season, remaining coconut tree roots were removed and the casuarina trees in the southern part of the cleared area were felled. The cleared are was levelled and herb vegetation was cut. The area was weeded periodically during June and July 2009 and 2010 when sooty terns were absent, to remove rapidly growing herbs but leave *Portulaca oleracea* plants.

Models: Decoys have been used successfully to encourage other tern species to establish or re-establish breeding colonies (Veen 1977, Kress 1983, Kotliar & Burger 1984, Dunlop 1987, Burger 1988, Blokpoel *et al.* 1997, Jeffries & Brunton 2001).

Figure 1. Models of adult sooty terns. Above, two-dimensional models cut from plywood sheets; below, crow models painted to resemble adult sooty terns.

Jeffries and Brunton (2001) additionally used broadcast calls to attract fairy terns *Sterna nereis* but found no difference in the effectiveness of decoys and calls together and decoys alone. A combination of decoys and broadcast calls was used in attempts to establish new colonies of the Chinese crested tern *Thalasseus bernsteini* (BirdLife International 2013). Sooty terns are extremely vocal (Feare *et al*. 2003) and so broadcast calls were used along with models on Denis Island.

Three types of model were used as potential attractants. Two-dimensional models were cut from sheets of marine plywood into the shape of, but a little larger than, the dorsal view of an incubating adult sooty tern. The dorsal surfaces were painted black with white forehead markings, white leading edges to the closed wings and white outer tail margins, to resemble the signalling features of adult sooty terns (Figure 1). Forty three-dimensional models were prepared using plastic crow *Corvus corone* decoys (Sport Plast Decoy Company, Ferrara, Italy, www.sportplast-decoys.com). These were painted white below, with white foreheads and white leading edges to the closed wing, and strips of white plastic material were stapled to the outer edge of the tail to resemble the long white outer-tail streamers of adult sooty terns at the beginning of the breeding season (Figure 1). In addition, eight crow decoys were painted to resemble juvenile sooty terns by adding white spots to the backs of otherwise black crows; these models were deployed in the cleared area, among the adult models, in the first week of July to mimic the presence of juveniles. All models were removed from the site in September, when sooty terns begin to depart from other Seychelles colonies.

The plastic crow decoys were considerably larger than sooty terns (standing approximately 40 cm tall) and in 2009 and 2010 plastic decoy magpies *Pica pica* (Sport Plast Decoy Company), similar in size to sooty terns (approximately 20 cm tall), were painted as adults as described above and deployed among the crow models.

Sound generation: Recordings of the sounds of a large sooty tern colony on Bird Island were obtained by holding the microphone of a minidisc player at the edge of the breeding area, approximately 2 m from the nearest birds. Recording began once birds had stopped reacting to the presence of the person holding the recorder. Recordings were made during the day, when the colony is at its noisiest, and also four hours after dark, at 22:00 h, when the colony remains noisy but less so than during daytime.

The recorded calls were incorporated into the repertoire of a "One-shot" airfield bird scaring unit (Scarecrow Bioacoustic Systems Ltd, Uckfield, East Sussex, UK; www.scarecrow.eu). The unit was fitted with a light sensor that switched between daytime and night time recordings at dawn and dusk. The calls were broadcast in the 2 ha cleared area through four Scarecrow 1215/L 20 w re-entrant horn loudspeakers, each connected to the One-shot control unit by armoured cable. A Scarecrow Long-line transformer was incorporated into the One-shot control box to ensure adequate transmission through the cables. Feare *et al*. (2003) recorded sound levels up to 107 dBa approximately 1 m above the birds in the Bird Island colony. Speakers used on Denis Island were therefore set to produce sound levels of this intensity 1 m from the speakers. The unit was powered by a 12 V car battery that was recharged from a solar panel. During the initial trials in 2008, we found that the solar recharging was insufficient to fully recharge the battery, leading to periodic outages when the broadcasts ceased. After

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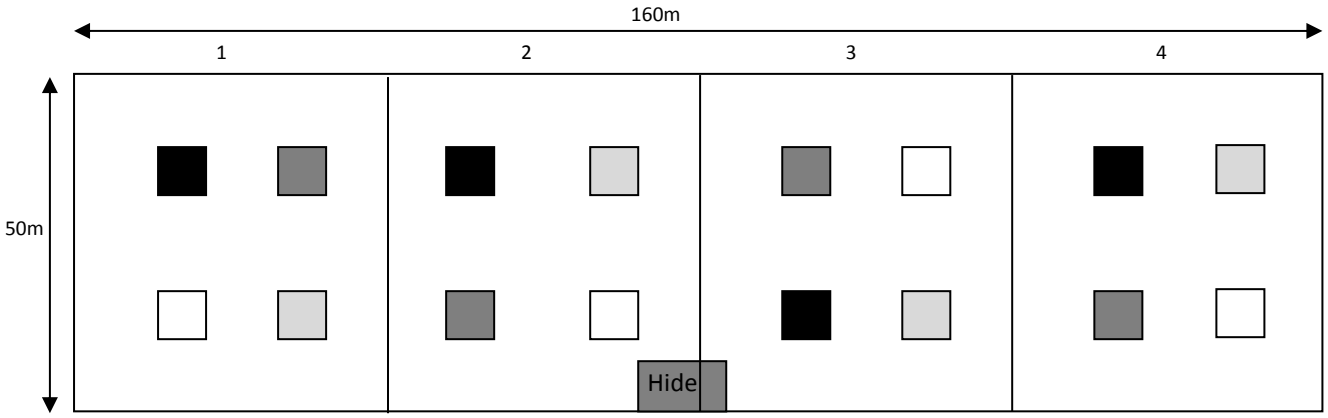

Figure 2. The layout of treatment plots within each treatment unit (1-4) of the area cleared for sooty terns in 2008. White plots: control; pale grey plots: two-dimensional models; dark grey plots: three-dimensional models; black plots: three-dimensional models + loudspeaker.

this the battery was replaced with a fully-charged unit every two days.

In 2009 and 2010 three loudspeakers were deployed around the area occupied by the models. In 2009, two were directed at the group of models and a third was angled upwards with the intention of attracting birds flying overhead, while in 2010 all three speakers were directed in towards the models. In both years the fourth loudspeaker was fixed approximately 10 m high to the trunk of a coconut tree on the edge of the flyway, directed towards the sea.

Experimental design: In 2008 the cleared area was divided into four 50 x 40 m "treatment units"; within each four presentations of attractants were placed at random in "treatment plots" (Figure 2). These treatments were: i) 20 two-dimensional sooty tern models, ii) 10 three-dimensional plastic models, iii) 10 three-dimensional plastic models plus a loudspeaker, and iv) no attractants. Decoys were placed within an area 5 m x 5 m, and where loudspeakers were used these were placed at the edge of the 5 m x 5 m treatment area, pointing towards the centre of it, and away from the other treatment areas in an attempt to reduce "contamination" of no-sound treatment plots with broadcasts. The three-dimensional decoy treatment involved four birds placed alone, plus three pairs of birds standing parallel to each other but facing in opposite directions; this was to simulate the "parade" display of adult courtship (Dinsmore 1972, Feare 1976a, Schreiber *et al*. 2002).

In 2009 and 2010 two-dimensional models were not used. Instead 40 magpie models were deployed among the crow models in the centre of the cleared area in order to be visible from the sea through the flyway. Models were deployed in mid-May in both years, in singles and pairs as above, and the eight juveniles were added among them in early July. The models were removed in early September.

Observations: Observations were made on the presence and behaviour of sooty terns at the cleared area from an elevated hide (observation platform 2 m above ground, with roof and side screens of coconut leaves) by volunteer graduate biologists. In 2008 field observations were made in June and July, the main months of arrival, egg laying and incubation on neighbouring Bird Island. The number of birds undertaking three activities i) flying over the cleared area, ii) dropping low and circling treatment units, and iii) landing in each of treatment plot was recorded during 1 h observation periods, beginning at 06:00, 09:00, 1200, 15:00, and 17:30 h local time. In addition, eight observation periods were undertaken after dark at 20:00 h, using Yukon Night Vision Binoculars 24022 WP. Observations were made on 26 alternate days from 4 June to 24 July. All counts undoubtedly included repeat visits by some individuals.

In 2009, numbers of sooty terns were recorded for approximately 4 h after dawn (06:30-10:30 h), for 1 h around midday (12:00-13:00 h) and for about 2 h in the late afternoon (16:30-18:30 h) on 18 days, 15 days and 20 days respectively between 4 June and 22 July. Two observers (GCAF, VSP-W) recorded behaviours as above but separated counts of birds circling high from birds circling low over the site. The presence or absence of birds on the ground performing behaviours associated with breeding was also recorded in two categories: nest territory acquisition (aggressive behaviours including bill stabbing, driving nearby birds away, fighting), and courtship (e.g. parade display, copulation); digging nest scrape and egg-laying have not so far been directly observed during this study.

Following the identification of morning as the most active period in 2009, in 2010 observations were made only from 06:00-09:00 h and survey data were collected as in 2009. Staffing constraints led to a shorter period of observation on nine days between 24 June and 26 July. In addition, the type of decoy (crow or magpie) closest to which sooty terns landed was recorded when possible.

In 2011 and 2012 models and loudspeakers were deployed as in 2009 but no staff were available to make systematic observations of sooty tern activity. In 2011, counts of sooty terns were only made during visits on 16 days in the second half of June. Twenty visits were made, 15 in the morning (between 06:30 and 09:00 h) and five in the evening (between 17:00 and 18:00 h). In 2012 the presence of birds was recorded opportunistically by conservation staff and visitors.

Statistical analysis: For analysis the counts were converted to number of birds per hour of observation. Most comparisons of the birds' responses to sound and models were made using χ^2 tests. A binary logistic regression with a logit link function was also used to analyse the effect of sound upon the probability of at least one bird circling the site (1 = at least one bird circling (n=17), 0 = no birds circling (n=25)). Data before 12 June 2008 and from the midday observation period were excluded due to small samples. Observation periods were collapsed into "morning" (06:00-07:00 h, 09:00-10:00 h) and "afternoon" (15:00-16:00 h, 17:30-18:30 h) observation blocks. As instances of entire mornings or afternoons with no playback

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were very few, a morning or afternoon which had at least one observation period without sound was coded as "sound off", while mornings and afternoons which had sound playing in both observation periods were coded as "sound on".

The full binary logistic regression model included the variables sound on/off, the number of birds flying over the site/h, observation period (morning/afternoon), and month (June/July). All interactions were modelled and a backwards stepwise elimination of variables conducted, based on a significance cut off value of 0.05, which eliminated "month". Preliminary scrutiny indicated that the number of birds circling in the "morning" and "afternoon" observation periods were correlated, precluding the inclusion of both variables in the logistic regression model. Consequently the pooled number of birds flying over the site per hour in both the morning and the afternoon was included, log-transformed to normalise distribution.

CONSEQUENCES

Responses of sooty terns to sound and models*:* In 2008 interruptions in the broadcasting of sooty tern calls allowed comparison of the number of visits by terns during periods when calls were being played and periods when they were not. In 48 one-hour observation periods when the broadcasting system failed, 71 sooty terns were recorded flying over the cleared area, whereas in the 93 observation periods in which sound was broadcast sooty terns flew over the area significantly more frequently (446 observations) ($\chi^2_1 = 28.12$, $p < 0.0001$). When no sound was being broadcast, no birds flew down to circle treatment plots and no birds landed, while during broadcasts 101 birds flew down to circle the treatment plots, with 23 birds landing.

The logistic regression model showed that the probability of at least one bird circling the site was 6.2 times greater with the sound turned on for the entire observation period compared to instances with the sound turned off for part or all of the period. Furthermore, for every additional individual that flew over the site per hour, the probability of at least one bird circling the site increased by over six-fold. The broadcasting of sooty terns calls thus encouraged more birds to fly over the prepared area, and was essential to stimulate birds to investigate and land in treatment plots.

In 2008 sooty terns circled over all treatment units, but preferentially over units 1 and 2 (Table 1), the units that lacked tall trees. All 23 observed landings were in units 1 and 2 (Table 1) and all were within treatment plots. No terns landed in control plots, one landed in a plot of two-dimensional models, one in a plot of three-dimensional models and 21 in plots containing three-dimensional models and sound; thus sooty terns demonstrated a significant preference for landing in plots with both three-dimensional models and sound ($\chi^2_3 = 54.04$, $p < 0.001$).

In the two observation periods in 2009 following the deployment of crow models painted as juvenile sooty terns, five birds landed nearest to a juvenile, six close to adult crow models and none closest to magpie models. In 2010, 173 sooty terns were recorded landing nearest to crow models but only one was observed landing nearest to a magpie model ($\chi^2_1 = 98.9$, $p < 0.0001$).

Table 1. The number of sooty terns that circled and landed in the treatment units in 2008.

Unit	1	2	3	4
No. circled	97	89	21	16
No. landed	19	4	0	0

Table 2. The total number of hours of observation of sooty terns at the cleared area in each year, with the hourly rate of each behaviour recorded.

Year	Hours of observation	Hourly rate			Total events
		Fly-overs	Low circling	Landing	
2008	120	4.39	0.82	0.19	648
2009	122	19.59	11.36	3.07	4148
2010	27	53.40	61.40	12.67	3442

In 2009 and 2010 with models and three speakers concentrated in the centre of the cleared area and one speaker directed out to sea, the frequencies of birds over-flying, circling low over the cleared area and landing within it were higher than in 2008 (Table 2).

In 2008 too few birds were attracted to the cleared area to determine if there was a seasonal trend in attendance. In 2009 and 2010 circling birds were recorded on every observation day, with consistently larger numbers later during the study period in mid-late July 2009, while peak numbers were recorded earlier, in late June and early July, in 2010. Outside the observation periods, at 0800 h on 3 July 2010, 875 sooty terns were recorded on the ground in the cleared area with > 1000 circling above (J van der Woude, pers. comm.).

In 2008 eight observation periods after dark (six with no sound, two with broadcasts functioning) revealed no birds on the ground or heard calling in the vicinity at 2000 h. In 2009 and 2010 no systematic observations were made during darkness but occasional visits in both years indicated that sooty terns did not remain at the cleared area after nightfall.

Territorial and courtship behaviour: Most of the birds that landed remained on the ground for only a short time (2 s – 20 min) before flying off. While on the ground the birds stood and looked around and frequently "bowed", a movement in which the bird looks downward, appearing to look at its feet; this behaviour appears to reflect anxiety or submission but may also have a physiological role in excretion of salt from the salt glands (CJF, pers. obs.). No behaviours related to territorial defence or courtship were observed in 2008.

In 2009 and 2010, both nest territory acquisition and courtship behaviours (including copulation) were observed. All of these behaviours were recorded later in the season (Figure 3) and most in the morning observation sessions (97.4 % of 533 territory acquisition events, 80.2 % of 270 courtship events). In 2010, territorial and courtship events were recorded but only in late June - early July, after which few sooty terns were recorded over the cleared area (Figure 4).

Following the departure of the volunteers on 23 July 2009, opportunistic visits to the area by island staff showed that sooty tern activity declined during August. However, during preparation of the site in May 2010 four sooty tern egg shells, with holes in them signifying predation, were discovered in the part of the cleared area where most birds had been seen on the ground in 2009. The damage to the egg shells was more extensive than that made by common mynas, which break into sooty tern eggs by making a hole in the shell (Hughes 2008) and the predators were assumed to have been indigenous common moorhens, which are frequent visitors to the cleared area.

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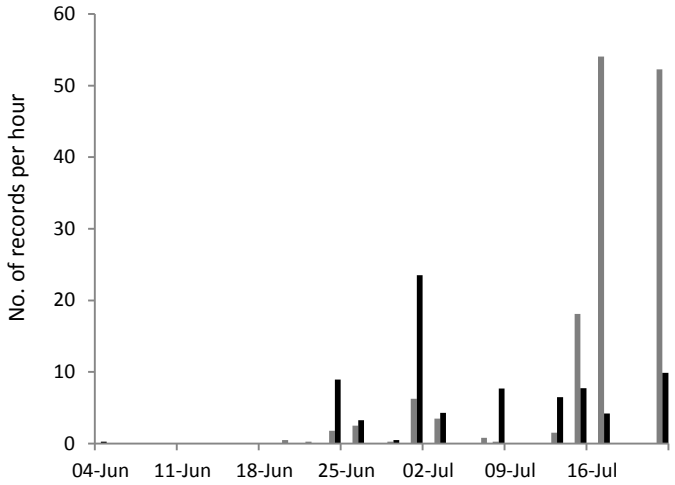

Figure 3. The frequency of territorial acquisition behaviours (grey bars) and courtship behaviours (black bars) during morning observations from 4 June to 22 July 2009.

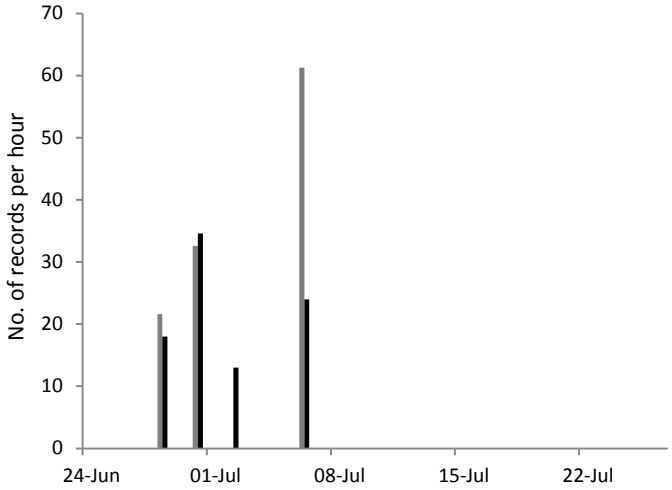

Figure 4. The frequency of territorial acquisition behaviours (grey bars) and courtship behaviours (black bars) during morning observations from 24 June to 26 July 2010.

In 2011 sooty terns were seen circling and landing during all but one (26 June) of the 16 late June visits. Numbers circling ranged from 4–40 and numbers on the ground from 1 to approximately 250. The higher numbers were all seen between 27 and 30 June. Less monitoring was undertaken in 2012 and the maximum number of birds recorded was approximately 200 on 4 July, including birds on the ground; sooty terns were observed in smaller numbers both in the air and on the ground throughout July 2012 but none were recorded at the area in August, despite birds being seen and heard near the island.

Observations on moult and voice of sooty terns attracted to the site: In 2009 and 2010, some (percentage not estimated) of the overflying birds had the innermost primary missing and towards the end of the observations in both years up to 12 birds were seen in adult plumage, but with pale margins to the otherwise black mantle feathers; the calls of at least some of these birds were noticeably higher-pitched than the majority of birds heard earlier in the season (and of breeding adults in established colonies – CJF pers. obs.). This raises the hypothesis that the sooty terns attracted to Denis Island were young birds, perhaps prospecting for nesting areas for use when the birds mature at 5-6 years old (Feare & Doherty 2011). If this is the case, establishment of a breeding colony on Denis Island may take several years.

DISCUSSION

In the first year of this attempt to re-establish sooty terns, preparation of suitable habitat and the presentation of attractants encouraged sooty terns to fly over the area, some to circle over the treatment plots, and a few birds to land for short periods. Both broadcast calls and three-dimensional models influenced the birds' choice of landing areas. These findings led to a more concentrated presentation of the most attractive stimuli in 2009, the broadcast calls and three-dimensional models. This resulted in much greater numbers of sooty terns being attracted to the site and this presentation has been repeated in subsequent years and continues to attract birds.

The sooty terns' preference to land closer to crow models, rather than magpie models that were closer to the size of sooty terns, suggests that large crow models presented the landing birds with a "superstimulus" (Tinbergen 1951). These should therefore remain the preferred models in this re-establishment attempt.

In this investigation, sooty terns visited the prepared site during the day but not at night, despite the 24-hour presence of the models and sound. At established breeding colonies, birds arriving at the start of each breeding season first land during the night, gradually extending their time on the ground until, just before laying commences, birds remain on the ground throughout the day (Ashmole 1963, Feare 1976a, Schreiber *et al*. 2002). The absence of nocturnal activity in the cleared area suggests that visits by sooty terns are exploratory, supporting the suggestion that these are young, rather than mature birds.

Critical to the success of the establishment attempt will be maintenance of the site in a suitable state for a breeding colony. The rapidity with which tall herb and bush vegetation grew both between and within breeding seasons, indicates that the soil has acquired a substantial seed bank. Vegetation will need continual management, especially through the wetter non-breeding period from November to April, but also during the breeding season in wetter years. With sooty tern activity concentrated in the mornings, vegetation management could be scheduled later in the day, but once egg-laying begins even this will be undesirable. The most desirable plant from the birds' point of view is *Portulaca oleracea*, a succulent tolerant of saline conditions. Many of the other plants are likely to be less tolerant of salt, and spraying the area with sea water might be a better longer-term management option.

Predation of the few eggs that have been laid so far is another concern. One potential predator, the exotic common myna, is being eradicated for broader conservation reasons (Feare 2010) and their numbers are already much reduced. Common moorhens, the birds suspected of taking the eggs laid to date, are indigenous to Seychelles and their numbers have increased dramatically on Denis and other small islands over recent years. They have no impact on the established sooty tern colony on Bird Island (CJF pers. obs.) but they could delay or perhaps even prevent the establishment of a new colony by young sooty terns on Denis Island unless some management of this species is implemented.

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