TRACKING A SMALL SEABIRD: FIRST RECORDS OF FORAGING MOVEMENTS IN THE SOOTY TERN *ONYCHOPRION FUSCATUS*

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SUMMARY

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Over the last 12 years, the use of global positioning system (GPS) technology to track the movements of seabirds has revealed important information on their behaviour and ecology that has greatly aided in their conservation. To date, the main limiting factor in the tracking of seabirds has been the size of loggers, restricting their use to medium-sized or larger seabird species only. This study reports on the GPS tracking of a small seabird, the Sooty Tern *Onychoprion fuscatus*, from the globally important population breeding on Dog Island, Anguilla. The eight Sooty Terns tracked in this preliminary study foraged a mean maximum distance of 94 (SE 12) km from the breeding colony, with a mean trip duration of 12 h 35 min, and mean travel speed of 14.8 (SE 1.2) km/h. While our study was limited in scope, it showed that small loggers such as the ones used present new opportunities for accurately tracking the short-term movements of small seabird species, thus providing huge potential to advance our understanding of seabird behaviour and conservation. Indeed, all study birds foraged in waters outside of Anguilla's Exclusive Economic Zone near the neighbouring islands of Saint Martin, Saint Barthelemy, Saint Eustatius, and St Kitts and Nevis, with 50% of birds commuting along the same route, thus demonstrating that the conservation of this population, with further study, will have geopolitical complexities.

Key words: Anguilla, Caribbean, GPS tracking, Lesser Antilles, tropical seabird, Sooty Tern

INTRODUCTION

Global positioning system (GPS) data loggers have become an essential tool for tracking the local foraging movements of individual breeding seabirds, given the relatively low cost and high spatial resolution provided (Soanes *et al.* 2014a). Since the first reported tracking of a seabird using GPS technology in 2001 (Weimerskirch *et al.* 2002), over 150 GPS tracking studies of seabirds have been published. Nevertheless, the use of this technology is constrained by the size of the loggers, such that, with a few exceptions (i.e. the ~150 g Little Auk *Alle alle* [Jakubas *et al.* 2012, 2014] and the ~330 g Wedge-Tailed Shearwater *Puffinus pacificus* [Cecere *et al.* 2013]), few studies have been conducted on small seabird species. This is driven in part by previous studies (Phillips *et al.* 2003, Heggøy *et al*. 2015), which reported that devices weighing more than 3% of a seabird's body weight had negative impacts on behaviour. This 3% convention is now used as the standard to determine whether the attachment of tracking devices is appropriate. Thus, with devices commonly weighing 15–20 g, medium-sized and large seabird species have predominantly been the focus of seabird tracking studies. However, many families of seabird such as terns (Sternidae), auks (Alcidae), storm petrels (Hydrobatidae) and diving petrels (Pelecanoididae) weigh under 330 g and to date have been too small for GPS logger attachment. In total, 135 species of the 322 recognised seabird species (42%) weigh <330g (Riddick *et al*. 2012). Some of these species form very large populations (e.g. >20 million birds) (BirdLife International 2014), and include colonies classified as endangered, threatened and globally important. Thus, as with all seabirds, there is a need to understand their foraging movements for conservation management purposes.

The Sooty Tern is one of the most abundant seabird species in the world and is widespread throughout the tropics (Birdlife International 2012). This species is known to nest in large colonies, typically numbering hundreds of thousands of birds, with some colonies reaching over 1 million (Feare *et al.* 2007). The Sooty Tern's small size (approximately 175 g) has meant that its foraging locations during the breeding season have previously been limited to observations from boat surveys (Surman & Wooler 2003, Jaquemet *et al.* 2005). As a result, we know very little about the individual aspects of foraging movement in this species, including the link between breeding colonies and foraging areas.

The Lesser Antillean chain of over 200 islands and cays are home to 183 054 breeding pairs of Sooty Tern (Lowrie *et al.* 2012), with the highest breeding number recorded on the Important Bird Area (IBA) of Dog Island, Anguilla, which is home to 64% of the region's breeding population (Wilkinson *et al.* 2012). Here we present one of the first GPS tracking studies of a small seabird, collected from this globally important population of Sooty Terns.

STUDY AREA AND METHODS

Sooty Terns breeding on Dog Island, (18°16′42N, 63°15′12W) were GPS-tracked over a 5-d period during June 2014. Nanofix

GPS loggers (Pathtrack Ltd. UK) were deployed on 20 individuals. A few days after hatching, Sooty Tern chicks become highly mobile and are likely to move from their nest site, and therefore we deployed loggers only on birds that were brooding a 1–3 d old chick. To reduce the risk of negative effects of logger deployment on birds, we attempted to recapture birds 24 h after deployment. Birds were caught while at the nest either by hand or with a hand net, and loggers were attached to the middle two tail feathers with waterproof Tesa tape (Wilson *et al.* 1997). This attachment method was used to ensure that the logger would fall off the bird within a week of attachment if retrieval was not possible. The processes of logger deployment and retrieval took no longer than 10 min per bird. Nest content was recorded on recapture and compared with a sample of 30 control nests at the end of the 5-d tracking period. Adult birds were weighed upon deployment and recapture, and these masses compared (using a two-tailed *t*-test). The occurrence and approximate contents of any spontaneous prey regurgitates were recorded.

Loggers weighed 2.0 g when waterproofed in epoxy, representing <1.2% of the bird's body weight. The loggers were specified for short-term deployment, using internal battery power alone with no solar panel to save weight. Logger dimensions were 24 × 11 × 7 mm, plus a thin whip antenna ~ 50 mm long. In ideal signal conditions the devices have the ability to take more than 300 GPS locations on a single battery charge. However, as GPS performance is heavily dependent on the environment in which the device operates, the typical capacity was specified at 160 location attempts, equivalent to recording a position at 20-min intervals.

Foraging tracks were plotted in ArcMap.10 (ESRI computing, Vienna) and overlaid with boundaries of the Exclusive Economic Zones (EEZ) of Anguilla and its neighbouring islands (downloaded from Maritime Boundaries Geodatabase, version 8, http://www.marineregions.org/). Foraging trip duration, maximum distance from the colony and total trip distance were calculated. Travel speed between GPS locations were calculated using the R software package *trip* function *tripdistance* (Sumner 2012) to determine Euclidean distance travelled between consecutive GPS points. While this approach is likely to underestimate travel speed due to the tortuosity of flight, it still allows for an evaluation of the distribution of speeds for each individual. Travel speeds were plotted as a histogram to allow easy visualisation and interpretation of data. Given the small sample size in this preliminary study we decided that it would be premature to attempt to relate the foraging areas of the terns to oceanographic features (e.g. bathymetry and sea surface temperatures).

RESULTS

Of 20 loggers deployed, 11 were retrieved within one or two days. Two additional adults were re-captured at their nest sites five days later, but loggers had already fallen off (and the tail feathers had been lost). The remaining seven birds were not recaptured or re-sighted at their nesting sites or flying above the colony during the visits to check nests within five days of deployment. Because of the large number of nesting birds in close proximity, re-sighting proved difficult once adults were in flight above the colony. It was also impossible to spend much time within the colony to observe birds returning to nests because our presence caused significant disturbance. While the attachment method used in this study apparently caused the loss of feathers of two birds (and subsequent loss of the logger) after five days of deployment, this attachment method was preferred to more permanent methods (e.g. harnesses or leg loops). It was important for this preliminary study to ensure that any potential detrimental effects of attachment of loggers were kept to a minimum. This objective precluded longer-term attachments, since we could not be sure that we could recapture the birds.

Chicks were present at all 20 nests where loggers had been deployed when nests were checked two days after deployment. Six out of the eight recaptured adults that left the colony, and still had loggers attached, regurgitated fry and squid on recapture, indicating that successful foraging trips had been made while the loggers were deployed. Checks of nests five days after deployment revealed chicks in the close proximity of five out of the 20 nests at which loggers were deployed. No dead chicks were recorded in the remaining nests, indicating that older and therefore highly mobile chicks had moved location, rather than that the nests had failed. Of the 30 control nests, 28 had chicks still present after two days. A re-visit to all control nests seven days after tracking had commenced revealed very mobile chicks, making it too difficult to assign chicks to individual nest sites. The mass of the 13 tracked birds that were recaptured did not differ significantly between logger deployment and retrieval (t = 0.75, df = 24, P = 0.458). However, it should be noted that the time spent at the colony before the bird was weighed, and whether the bird regurgitated prey on capture could potentially mask or falsely represent actual logger impacts on affect weight.

TABLE 1
Foraging trip characteristics of Sooty Terns tracked on Dog Island, Anguilla

Individual	Trip duration (h:min)	Trip distance (km)	Max. distance from colony (km)	Average travel speed (km/h)	Max. travel speed (km/h)
1	7:59	109	40	12.9	33.3
2	10:59	298	139	21.6	49.5
3	7:16	186	89	18.3	40.4
4	14:19	236	108	13.9	42.0
5	4:59	83	36	13.0	33.0
6	15:39	291	115	15.3	44.5
7	16:06	289	105	11.5	28.5
8	14:44	253	116	12.3	41.8
Mean (±SE)	12:35 (± 1:51)	218 (± 28)	94 (± 12)	14.8 (± 1.2)	39.1 (± 2.5)

Of the 11 loggers retrieved, eight contained one complete foraging trip, two birds did not travel anywhere during the tracking period, and one logger failed to record data due to erroneous instrument configuration. Foraging trip duration ranged from 4 h to 19 h, the maximum distance travelled from the colony ranged from 35 h 145 km and total trip distance from 83 km to 298 km (Table 1). Foraging trips were characterised by direct flights predominantly in a southeast direction from the colony towards presumed foraging areas where GPS fixes were clustered together (Fig. 1). Four of the eight birds used an apparent "corridor" to the southeast of Anguilla between the islands of the Lesser Antilles during both outbound and inbound flights. The distribution of travelling speeds (Fig. 2) showed two peaks, presumably reflecting, first, foraging and plunge diving at the water surface at speeds <7.5 km/h and, second, travel speeds during commuting flight around 20 km/h (Guilford *et al.* 2008) but with maximum speeds of up to 49.5 km/h. In seven of the eight foraging trips, birds left the breeding colony between 05h30 and 09h30 (with the eighth trip starting at 12h50), with four trips returning during daylight (between 12h50 and 16h30) and four returning to the colony at night (between 20h30 and 02h30).

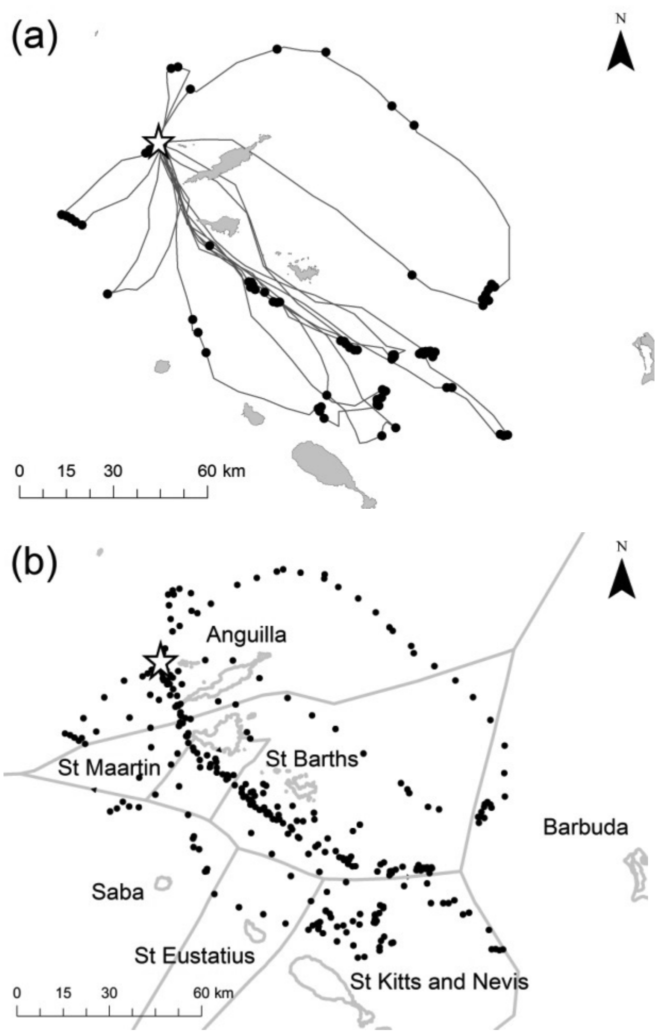

Fig. 1. (a) Foraging tracks of eight Sooty Terns breeding on Dog Island, Anguilla. Black circles represent travel speeds <7.5 km/h; (b) GPS locations recorded every 20 mins from Sooty Terns over-laid with Exclusive Economic Zones. Star represents breeding colony.

DISCUSSION

Before the development of miniature GPS devices such as the one used in this study, studies of small seabirds such as terns relied on visual observations and radio-tracking with pursuit using aircraft or boats (Rock *et al*. 2007, Perrow *et al*. 2011). While these approaches can yield important data, they are extremely labour-intensive, with the possibility that birds can still fly outside of the typical 15–20 km range of tracking equipment (Burger & Shaffer 2008). As a result, relatively little is known about the individual foraging movements of most small seabirds, a situation that affects our efforts to include them in marine planning and conservation strategies with respect to specific geographic areas. On the other hand, advancement in technology has allowed progressively smaller seabird species to be tracked effectively (e.g. Jakubas *et al.* 2012, 2014) and has informed the conservation of wide-ranging seabird species through the identification/confirmation of foraging hotspots (Trebilco *et al.* 2008, Le Corre *et al.* 2012) and threats (Torres *et al.* 2011) and has similarly informed assessment of the effectiveness of marine protected areas (Trebilco *et al*. 2008).

While Sooty Tern movements recorded during the breeding season in this study may not be as dramatic as those recorded during migration among other species (e.g. Arctic Terns *Sterna paradisaea*; Egevang *et al.* 2012), individuals travelled up to 298 km in a single day and had travel speeds reaching 49.5 km/h. Two previous studies that recorded the presence of feeding flocks from boat transects around Sooty Tern breeding colonies reported maximum foraging distances of up to 480–600 km from a colony of 260 000 pairs (Surman & Wooler 2003) and 250 km from a colony of 500 000+ pairs (Jaquemet *et al*. 2005). These distances travelled from the breeding colony are larger than those recorded from the Dog Island colony of approximately 113 000 breeding pairs, although this may be due to differences in the timing of tracking, the relatively low sample size in the current study (Soanes *et al*. 2013), differences in colony size leading to intraspecific competition (Wakefield *et al*. 2013), and/or interspecific competition effects from similar breeding species. However, despite our small sample size, it is interesting to note that all of the Sooty Tern foraging trips in this study travelled into neighbouring Caribbean Island's EEZs (Sint

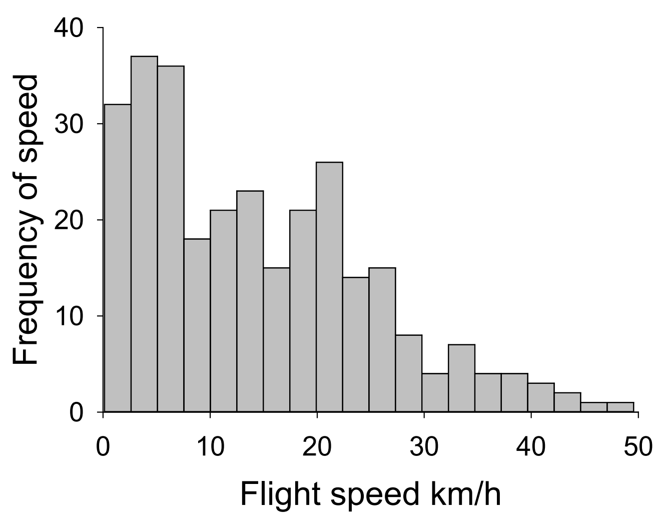

Fig. 2. Histogram of the frequency of flight speeds (x-axis) of Sooty Terns recorded between 20-min GPS fixes.

Maartin/Saint Martin, Saint Barthélemy, Saint Eustatius and St Kitts and Nevis), and the apparent "corridor" commuting route used by 50% of the birds ran across and alongside these territorial boundaries. While the importance of this area and any underlying biological factors that cause Sooty Terns to use it should be confirmed and investigated with a larger sample size, this already highlights the importance of regional cooperation when protecting and conserving seabird populations in the Lesser Antilles (Soanes *et al*. 2014b, Jodice & Suryan 2010).

The logger attachment method used in this study resulted in loggers falling off birds after 2–3 d of deployment, thus reducing the potential negative impact of long-term logger attachment. We suggest that short-term and/or non-permanent methods of attachment may be preferable for study species and locations where logistical challenges and species characteristics limit recapture rates. Given that micro data loggers of this type are limited in their data recording and storage capacity, there would have been no particular advantage in any case of a more permanent attachment method. During this study we found that birds with loggers were foraging and returning to the colony with prey. Despite the logistical difficulties of re-sighting and recapturing birds and chicks in a crowded tern colony, 65% of the tracked birds were re-sighted within five days of logger deployment, and there were no dramatic impacts on chick survival. Thus, we cautiously suggest that this short-term logger deployment did not have cause severe detrimental effects to Sooty Tern survival or ability to provision chicks, nor did it significantly alter foraging behaviour as far as we know. However, further studies (currently underway, C. Feare pers. comm.) on the impacts of short and longer-term deployment of devices on this and other small seabird species, and specifically on behaviour and breeding success will be valuable.

The availability of the logger used in the present study presents new opportunities for accurately tracking the short-term movements of small seabird species. Following the 3% of body weight convention, this means species as light as 70 g (representing 93% of all seabird species; Riddick *et al*. 2012) could be tracked, thus providing a huge potential to advance our understanding of seabird behaviour in general.

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