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Protecting Damara Terns *Sterna balaenarum* from recreational disturbance in the Namib Desert increases breeding density and overall success

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Because resources and funds available for the conservation management of many threatened species are limited, it is important to determine the effectiveness of different conservation measures aimed at protecting threatened species. The globally Near Threatened Damara Tern *Sterna balaenarum* breeds on anthropogenically disturbed beaches on the central coast of Namibia. We assessed the effectiveness of conservation measures on the breeding numbers, densities and success of Damara Terns in a loose colony among small barchan dunes on the central Namibian coast. Nests were monitored daily during the 2001/02 and 2002/03 breeding seasons. Information notices were erected during the 2001/02 breeding season and vehicle access was restricted to prevent human disturbance in the colony during the 2002/03 season. Nest numbers and density doubled in the second season, but breeding success decreased significantly from 83% to 67%. This unexpected result probably arose from increased densities attracting more predators. Despite this decrease the protection measures increased the number of chicks hatching from the area by 71%. In conjunction with two previous studies of protection from off-road vehicles we conclude that Damara Terns benefit from reduced disturbance and prefer to nest on undisturbed beaches.

Introduction

The Damara Tern, one of the smallest members of the Sternidae, is a breeding endemic to Namibia. Only 2% of the global population breed outside the country, along the coastlines of South Africa and Angola (Crawford and Simmons 1997). The strip of coastline between Swakopmund and Walvis Bay, two coastal towns in central Namibia c. 40 km apart, has the greatest density of sea- and shorebirds roosting and feeding in southern Africa (Simmons et al. 1998a). The Damara Tern *Sterna balaenarum* nests adjacent to this strip, on the gravel plains that run parallel to the coast (Simmons et al. 1998b, Simmons 2005). The Damara Tern typically lays one egg in a small nondescript scrape on the ground, although two-egg clutches have been recorded on rare occasions (de Villiers and Simmons 1997, S Braby pers. obs.). Unlike other terns, Damara Terns breed in loose colonies with an average density of 1–8 nests per km^2 (Crawford and Simmons 1997). Damara Terns are mainland coastal breeders and prefer non-vegetated gravel or sandy plains in north-central regions and salt pans in southern regions (Simmons et al. 1998b, Simmons 2005). They often breed up to 5 km inland, but have been found to breed up to 11.5 km inland (Braby et al. 2001, Simmons 2005). The main breeding season starts in September and ends in April (JB pers. obs.), but nests with eggs occur as late as June (RJB pers. obs.) indicating that breeding extends over nine months. During non-breeding Damara Terns migrate to West Africa (Elgood 1982), but little is known about their exact non-breeding distribution and habitats. Three decades ago, the Damara Tern was listed as one of the 20 bird species breeding in South Africa most in need of conservation action (Siegfried et al. 1976). Subsequently, its threat status has varied between Globally Threatened to Near Threatened, its status in 2007 (BirdLife International 2007). In Namibia the species is listed as locally Near Threatened (Simmons and Brown in press).

Breeding Damara Terns are particularly vulnerable to human disturbance and conservation measures have been implemented to ensure their continued survival. Human disturbance in the Namib Desert is associated with recreational activities only, such as off-road vehicles (ORVs), quad-bikes, horse-riding and hiking. The densest population of breeding terns is found on the central Namibian coast during the austral summer, at the same time as the number of visitors to the area is greatest. Damara Terns have been subject to excessive disturbance and increased mortality during the breeding season in this area owing to off-road driving and quad-bike activity (Braby et al. 2001).

During November 2000, cable barriers were erected at a Damara Tern breeding colony at Caution Reef to prevent off-road vehicles (ORVs) from travelling across the sand and gravel plains where terns bred (Braby et al. 2001). However, it subsequently became apparent that large numbers of Damara Terns were breeding east of Caution Reef (Braby 1995) in an area known as the Horses Graveyard. Here terns were found breeding in gravel plains situated between dunes in an area popular with quad-bikers.

To determine the effectiveness of conservation measures, and to compare their success with that at the Caution Reef colony (Braby et al. 2001), the Horses Graveyard colony

was monitored during the 2001/02 breeding season, when it was subjected to a high level of quad-bike traffic. The colony was again monitored during the following breeding season (2002/03) after interpretative sign boards had been erected and strict access restrictions had been enforced. This paper compares Damara Tern nest numbers and densities, breeding success, and causes of mortalities before and after these conservation measures were implemented.

Study area

The main study area at the Horses Graveyard colony covered 2.5 km^2 and occurred in the hyper-arid Namib Desert with rainfall of less than 15 mm per year (Günster 1995, Mendelsohn et al. 2003). It was located 4 km south of Swakopmund, on the central Namibian coast, and was centred on 22°42.500′ S, 14°32.300′ E (Figures 1 and 2). The study area was 3.7 km NNE of the Caution Reef colony and comprised a series of barchan, linear and crescent dunes separated by gravel plains in which the terns breed (Braby et al. 2001). Gravel plains were comprised of approximately 3 mm diameter, grey-coloured substrate, with little wind-blown material. By contrast the dunes had a much smaller sand particle diameter and sand transport during prevailing south-westerly winds could be high. The area was situated just south of a disused railway line, 3 km east of the sea, and runs parallel to the coast. The areas used by the breeding terns were devoid of vegetation.

Methods

The study was conducted between November and March over two breeding seasons, 2001/02 and 2002/03. One (or sometimes two) observers searched the study area on a quad-bike and recorded Damara Tern eggs and chicks and all vehicles or new tracks crossing the area. These searches were done daily; time of day varied from early morning to late afternoon. A record was kept of the date, time and location of all tracks and vehicles in the study area in December 2001. One route was followed through the study area to monitor breeding activities, but on occasion we explored new plains in search of potential nesting sites. A Global Positioning System (Garmin II) was used to record the exact location of each nest to an accuracy of c. 10 m. New nests were included into daily visit routines until the chick successfully hatched and was ringed or until nest failure. Breeding success was defined as the emergence and survival of a chick that moved away from its nest aged 3–4 d – a combination of hatch success and early survival. Thereafter we could not easily follow the cryptic chicks and be certain that they had perished if they were not subsequently found. The presence of potential predators such as Kelp Gulls *Larus dominicanus*, Rock Kestrels *Falco rupicolus* and black-backed jackals *Canis mesomalis* was recorded and failed nests were carefully examined for signs of predators, such as jackal tracks leading to empty nests. When known, the cause of nest failure was noted.

Information and interpretation sign boards were erected on 21 December 2001, in the middle of the 2001/02 breeding season. Signs of human disturbance continued to be monitored. Prior to the start of the 2002/03 breeding season, cable barriers were set up at entry points to the study area

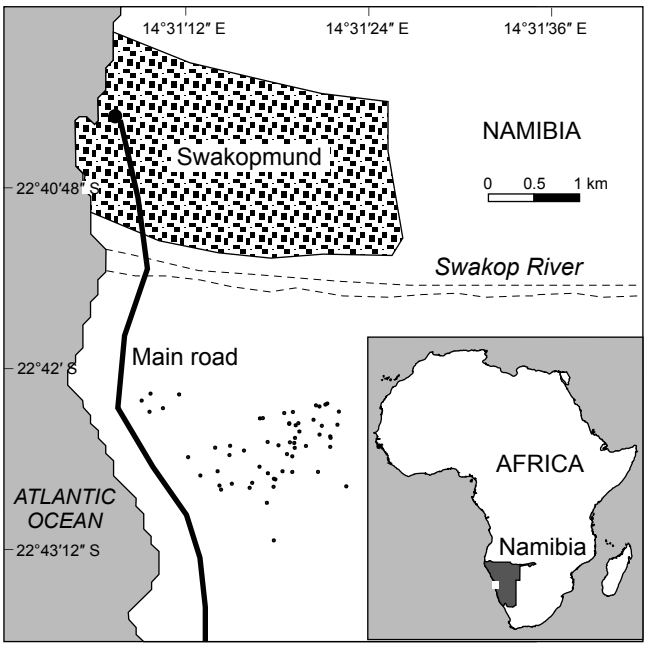

Figure 1: Damara Tern nesting distribution during the 2001/02 breeding season at the Horses Graveyard colony, central Namibia

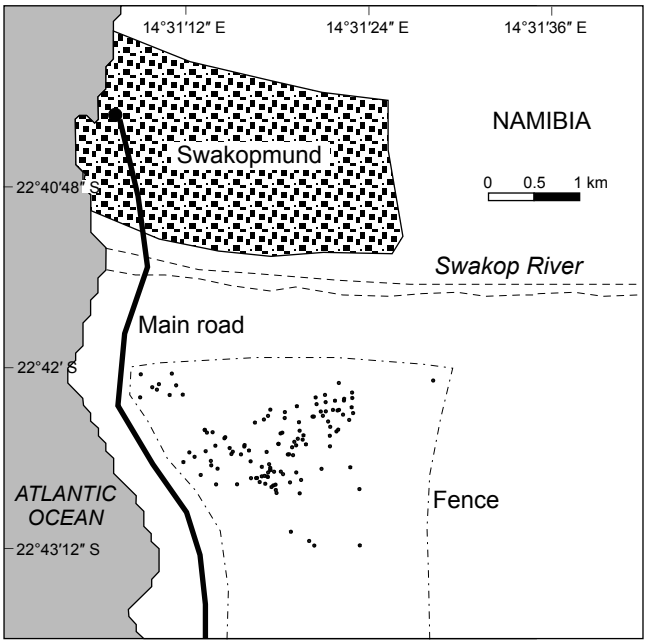

Figure 2: Damara Tern nest distribution during the 2002/03 breeding season at the Horses Graveyard colony, central Namibia, after the colony was fenced

that were typically used by quad-bikes. Quad-bike tour companies were limited to one designated route and private bike enthusiasts were warned off the gravel plain areas. Information sheets highlighting the vulnerability of Damara Terns and the position of the breeding site were handed out to private quad-bikers and other tourists.

Results

Nest abundance and density

All nests found over the study period contained one egg. In the 2001/02 breeding season, the first nest was found on 2 November and, in total, 58 nests with eggs were found over a period of two and a half months (Figure 1). The breeding season ended on 23 January 2002, with no more eggs or chicks seen after this date. During the 2002/03 breeding season, 122 nests with eggs were found over a four-month period, with the first egg appearing on 24 October 2002 and breeding activity recorded until 23 February 2003 (Figure 2). Field work occurred before these dates and until March to ensure no further egg-laying. Nest abundance more than doubled from the 2001/02 season to the 2002/03 season. The density of nests in the 2.5 km^2 study area increased from 23 nests km^{-2} to 49 nests km^{-2}, indicating a 2.1-fold increase in breeding density following reduction in disturbance to the area. A possibility exists that nest density was larger in 2002/03 because of the longer season. We controlled for this by examining the same two-and-a-half month period (2 November to 23 January) in both seasons, when the relative densities were 23 nests km^{-2} in 2001/02 and 34 nests km^{-2} in 2002/03 indicating a 1.5-fold increase. There was no increase in the area occupied by the breeding terns. Assuming that each nest represented a different breeding pair, the number of nests in 2002/03 was significantly larger than in 2001/02 (comparison of two counts, $z = 4.78$, $P < 0.001$; Zar 1999). There were, in fact, at most 15 pairs that re-laid in 2002/03, so that at least 107 pairs bred that year. The breeding population was significantly larger in 2002/03 than in 2001/02 ($z = 3.81$, $P < 0.001$).

Human disturbance

In the 2001/02 season, new vehicle tracks were seen on a daily basis and sometimes more frequently. Vehicles were common on both the gravel plains and the dunes. Quad-bike tracks were most common. In November 2001, nine ORVs were observed driving through the study area at the start of the Damara Tern breeding season. During December 2001, 27 new sets of quad-bike tracks, five ORVs or their tracks and one set of horse tracks (which passed within 2 m of an active nest) were encountered during a 30-day period. About 30% of the quad-bike tracks were multiple tracks made by up to seven quad-bikes at a time. Tracks frequently passed within metres of nests with eggs, indicating that the bikers were unaware or uninterested in the tern nests. In six cases vehicle tracks were found within 5 m of an active nest, but no nests were destroyed by vehicles. There was no apparent decrease in vehicle disturbance after conspicuously placed information boards were erected along all borders of the study area on 21 December 2001.

During the 2002/03 season, after additional conservation measures had been implemented, quad-bike tours were only seen following the routes allocated to them. With one exception, tourists in ORVs drove only on dunes and always at safe distances from the nests. Only human or horse tracks were found in the vicinity of nests. There were no quad-bike tracks through the nesting area. Human disturbance was only witnessed on two occasions: two tourists walking through the gravel plains and an ORV vehicle driving through one breeding plain where a small colony of Damara Terns nested.

Table 1: The outcomes of Damara Tern nesting attempts during the 2001/02 and 2002/03 breeding seasons at the Horses Graveyard colony

Fate	2001/02	2002/03
Jackal predation	5 (8.6%)	20 (16.4%)
Egg addled	0 (0%)	2 (1.6%)
Chick found dead	0 (0%)	2 (1.6%)
Egg abandoned	2 (3.4%)	1 (0.8%)
Unknown fate[1]	3 (5.2%)	15 (12.3%)
Successful	48 (82.8%)	82 (67.2%)
Total nests with eggs	58	122

[1] 'Unknown fate' is defined by an egg or chick that was not found again but the cause of disappearance was unknown

Breeding attempts and overall breeding success

The number of successful breeding attempts increased from 48 nests in 2001/02 to 82 nests in 2002/03, a 71% increase (Table 1). However, as a percentage of nests initiated, successful nests decreased significantly from 83% (48 of 58) in 2001/02 to 67% (82 of 122) in 2002/03 ($\chi^2_1 = 4.1$, $P = 0.043$) (Table 1). Despite the significant decrease in the proportion of nests successful before and after protection, the increased number of nests in the second year resulted in 34 more chicks surviving until 4 d of age following the implementation of protective measures.

The reduced proportion of successful nests in 2002/03 was attributable to predation by black-backed jackals, as determined by tracks at failed nests. The number of nests failing from jackal predation increased four-fold from five nests in the 2001/02 season to 20 nests in 2002/03. In addition, a Rock Kestrel was periodically seen flying over the area during the 2002/03 breeding season; this species had not been observed during the previous season. A pair of Rock Kestrels was known to have bred in the vicinity of the study area in 2002/03, but had not been observed the previous year. Subsequently, in 2005, a Rock Kestrel was observed to take a Damara Tern chick (RJB pers. obs.). It is thus likely that a substantial proportion of the losses attributed to 'unknown fate' (Table 1) involved predation by this Rock Kestrel. Nest abandonment due to direct human disturbance decreased from two nests (3%) in the 2001/02 breeding season to one nest (0.8%) in 2002/03 (Table 1).

Discussion

Our results show that conservation interventions can be audited, and their benefits quantified, by measuring a number of biological parameters, such as breeding numbers, density and success of breeding, and intensity of disturbance before and after implementation of the interventions. In this study, there was a large increase in the number of Damara Terns breeding in the season following the exclusion of ORVs from the breeding area and the

limitation of quad-bikes to fixed routes through it. Similarly, Braby et al. (2001) showed that nest density increased by 25% and that hatching success increased from 56% to 80% at the Caution Reef colony in the breeding season following exclusion of ORVs. At the southern limit of the species' breeding range, near Cape Agulhas, South Africa, all 11 pairs in the study area raised a chick to fledging in the year immediately following the ban on ORVs from beaches in South Africa (Williams et al. 2004). In the previous five years many pairs lost eggs or chicks during the midsummer holiday period due to disturbance attributable to ORVs. The similar results obtained in each of these three studies suggest that the protective measures played an important role in improving breeding participation and success. Non-breeding coastal seabirds also increased in number in study areas around the South African coast following the ban on ORVs (Williams et al. 2004).

In this study, once conservation measures were implemented, the breeding season lengthened from two-and-a-half to four months. There may be several reasons for the lengthening of the breeding season. Increased food resources to adults and chicks, known to be critical in tern breeding ecology (Nisbet 1978, Monaghan et al. 1989), could account for this change. At both De Mond and in this study, the breeding season started earlier after disturbance was eliminated, so that protection may have contributed to the lengthening of the season. Breeding earlier provides fledglings with a longer period of preparation for migration (Williams et al. 2004).

Once vehicle disturbance was eliminated, it was found that predation was an unexpected determinant of breeding success. The reduced breeding success in the second year was attributable to increased levels of predation by jackals and probably by the arrival of a new predator, the Rock Kestrel. Ecological factors such as these could not have been addressed through these conservation measures, but in hindsight may be expected for a ground-nesting species reliant on cryptic, well-spaced nests. Predation levels can increase naturally as nest density increases (Newton 1998), so it is useful to examine how much higher these densities were than typically encountered on the Nambian coast.

Nest densities in both seasons (23–49 nests km^{-2}) were higher than previously recorded along Namibia's coast (1–15 nests km^{-2}) (Simmons et al. 1998b) and at the nearby Caution Reef colony (12–15 nests km^{-2}) (Braby et al. 2001). The high densities at Horses Graveyard cannot be attributed to breeding habitat limitation, as there are vast areas of gravel plains available, nor can it be an anti-predator strategy as predation increased with higher tern densities.

Measuring the effectiveness of conservation measures is an essential but often untested step in the protection of any threatened biome, habitat or species. Managers should not simply assume that conservation efforts will be successful or that testing the effectiveness of measures is unnecessary, even if managers fear this will reveal that resources used and expenses incurred were not justified. We recommend that funders of conservation projects set aside a portion of the funding for auditing the effectiveness of conservation interventions. In this case we demonstrated that the conservation measures enacted were effective, a result consistent with observations at two other sites in Namibia and South Africa.

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