THE POPULATION STATUS OF SOOTY TERNS *STERNA FUSCATA* ON ASCENSION ISLAND

DE STATUS VAN BONTE STERNS OP ASCENSION

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Feral cats were introduced to Ascension Island in the 1800s and extirpated all seabirds with the exception of Sooty Terns to inaccessible islets, stacks and cliffs. Sooty Terns continue to breed in reduced numbers on the south-west plains of the island and are still subject to cat predation, so monitoring of their population trends is important. Measuring the impact of cat predation upon seabird populations depends on having reliable baseline data; censuses of Sooty Terns on Ascension were conducted in 1990, 1996, 1997 and 1998 and involved sampling clutch densities in sub-colonies and then extrapolating to the total colony area. The population varied significantly over the study period, with 176 000 pairs in 1990, 202 000 pairs in 1996, 151 000 pairs in 1997 and 207 000 pairs in 1998. The 22% reduction in 1997 compared with 1996 and 1998 is thought to be due to a large proportion of mature birds deferring breeding because of reduced food availability induced by oceanographic perturbations. Such variability in breeding population size in relation to stochastic events means that censuses need to be undertaken frequently to ensure trends can be detected with confidence.

Ratcliffe N., J. Hughes & F.A. Roberts 1999. The population status of Sooty Terns *Sterna fuscata* on Ascension Island. Atlantic Seabirds 1(4): 159-168.

INTRODUCTION

Historic records, subfossil evidence and distribution of guano deposits indicate that large colonies of seabirds once nested on the coastal plains of Ascension Island (Stonehouse 1962; Ashmole 1963a; Olson 1977; Blair 1989). Black Rats *Rattus rattus* reached the island in 1701 (Stonehouse 1962) but it is thought that these had little effect on the seabirds, with the possible exception of Madeiran Storm-petrel *Oceanodroma castro* (Ashmole *et al.* 1994). Domestic cats *Felis catus* were introduced to the island in 1815 in the hope that they would control rats (Ashmole *et al.* 1994), but they preyed on seabirds and their population multiplied rapidly (Stonehouse 1962). By the middle of the nineteenth century, seabirds were almost entirely extirpated to the adjacent Boatswainbird Islet, inaccessible cliffs on the main island and 14 small stacks around the coast (Ashmole *et al.* 1994).

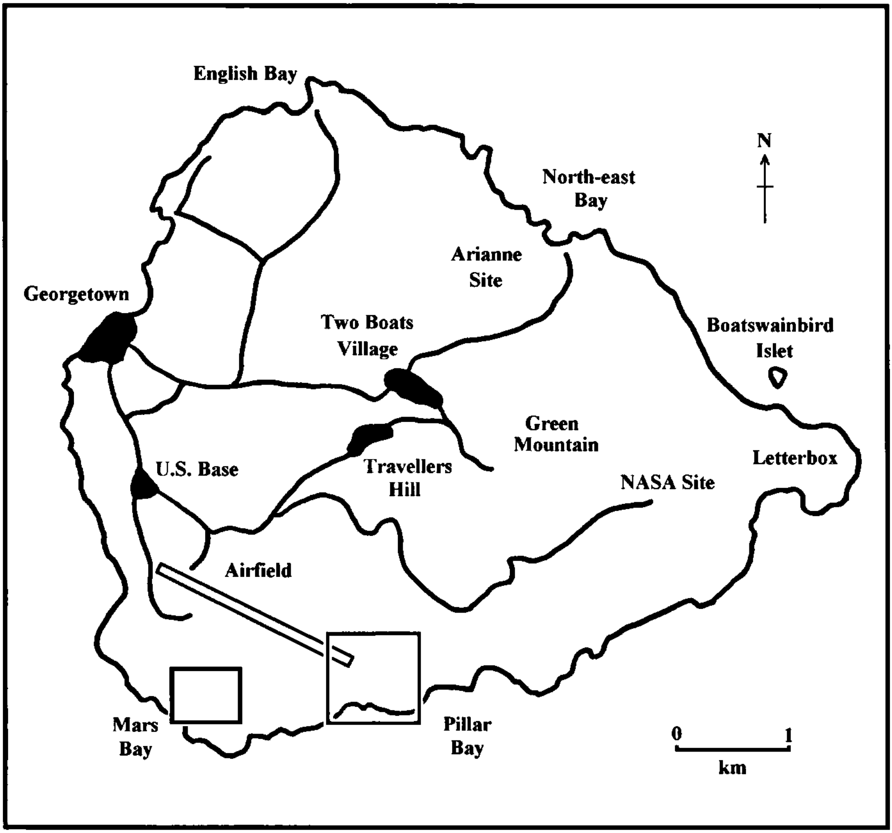

Figure 1. Map of Ascension Island, showing major geographical features, settlements and roads. The boxes in the south-west of the map indicate the areas in which Sooty Tern sub-colonies occur.

Figuur 1. Kaart van Ascension met plaatsnamen. De met vierkanten aangegeven gebieden in het zuidwesten zijn het deel van Ascension waar de in dit stuk besproken sub-kolonies zich bevinden.

Of the 11 breeding seabird species present on Ascension, only Sooty Terns *Sterna fuscata* continue to breed on the coastal plain (Ashmole *et al.* 1994), although it is believed that their numbers are greatly reduced (Ashmole 1963b). Sooty Terns survived on the mainland probably because their sub-annual breeding season is highly synchronised and they are completely absent from the island for 2-3 months of the year (Ashmole 1963b). Following the extirpation of alternative seabird prey, feral cats would have suffered a severe food shortage during this period and their population would consequently have declined to its current size of around 600-800 individuals (Bell & Ashmole 1995). Cat predation upon Sooty Terns still occurs and estimates suggest that approximately 1% of the population is killed every breeding season (Ashmole 1963b; Walmsley 1991, 1992, 1994). Rat predation on eggs or chicks is negligible, with most of the rat population being in vegetated areas well away from the breeding colonies (pers. obs.).

The eradication of feral cats would probably result in an increase in the Sooty Tern population by increasing adult survival rates and productivity, and also in the recolonisation of the mainland by other seabird species (Ashmole *et al.* 1994). A feasibility study for eradication of cats has been conducted by Bell & Ashmole (1995) who concluded that it would be possible to remove cats from the island altogether over a period of 3 years.

In order to investigate the effects of cat eradication on the Sooty Tern population it is important to have accurate baseline census data against which future trends can be judged. Even if eradication is not implemented, it is important to monitor population trends and predation rates so that appropriate action may be taken should Sooty Tern numbers decline. Such action could include intensive cat control around colonies prior to the breeding season. This paper describes the status and population trends of Sooty Terns on Ascension Island between 1990 and 1998 and considers whether the censuses provide adequate baselines for assessing future trends in response to cat eradication.

METHODS

The Sooty Tern population on Ascension was surveyed four times during the 1990s: in March 1990, October 1996, August and September 1997, and June and July 1998. The total population is very large (100 000s), so these censuses estimated mean clutch densities in sample quadrats and extrapolated these to the estimated area of the colony.

Sooty Terns breed relatively synchronously every 9.6 months, but there is still considerable spread in the timing of laying within a breeding season. There are often two or more asynchronous peak periods of nesting in a breeding season, resulting in breeders in some sub-colonies having chicks while others are still laying (pers obs). Timing of the surveys is crucial if the total number of nesting birds is to be estimated accurately. If the census is too early many birds will not have laid, resulting in underestimates of colony area and population size, and if it is too late then the chicks will have hatched, making quantitative estimation of clutch densities impossible.

Laying Sooty Terns nest at the highest density that the habitat will support, so that any expansion in numbers nesting at a sub-colony is always due to an increase in the area occupied rather than increased density due to pairs nesting among established breeders. Established areas of sub-colonies may therefore be surveyed without the risk of more birds nesting among them and thereby increasing clutch density.

Newly forming sub-colonies were distinguished from those where laying was complete by large numbers of adults circling overhead, calling and courting, but with few eggs present. In established sub-colonies, all adults had eggs and incubated quietly if left undisturbed. Sub-colonies were surveyed only when laying had been completed and before chicks hatched. An exception to this was in 1998, when surveying began in one large sub-colony after hatching.

Locating sub-colonies The breeding distribution of Sooty Terns on Ascension Island (7°57'S, 1°22'W) is entirely restricted to the coastal plain between Mars Bay and Pillar Bay (Fig. 1). During each expedition, a large proportion of the Ascension coastal plain was visited, but no Sooty Terns were ever found breeding outside the Mars Bay-Pillar Bay area. The only other colony in Ascension is a small one on Boatswain Bird Islet (Ashmole 1963b). Censuses of the coastal plain between Mars and Pillar Bays, therefore, may be regarded as population estimates for Ascension as a whole. During each census, the breeding area was searched systematically for Sooty Tern sub-colonies. A complete search is required as nesting habitat (typically mixed ash and basalt rubble) is extensive and the distribution, size and shape of sub-colonies changes during each breeding season. Sub-colonies are defined as spatially separate areas occupied by breeding birds.

Mapping subcolonies The sub-colonies were surveyed when all signs of birds establishing new nests had ceased. During the 1990, 1996 and 1998 surveys, cairns of rock (*c.* 0.6 m high) were built around each sub-colony perimeter every 20-30 m or at each change in direction of the sub-colony edge. A circular compass traverse was then conducted around the entire sub-colony perimeter (Hughes 1991). This involved measuring the distances between each cairn and the bearing of each cairn to its two neighbours using a prismatic compass. The distances and angles between each cairn were then plotted on 1 mm square graph paper at a scale of 1:1000. The total area of the sub-colony was deduced by counting the number of 1mm squares in each sub-colony plot and multiplying the total by 1 000 000.

In 1997 the sub-colonies were mapped using a different method. A central reference line (CRL, a string marked at 5 m intervals) was run through the middle of a sub-colony. At each 5 m interval and on each side, the distance from the CRL to the sub-colony edge was measured at 90° to the nearest 5 m. From this, a grid-map of the sub-colony was constructed on graph paper, each square of the grid representing a 5x5 m square on the ground. The number of squares in the grid was then counted and the area of the colony (in m^2) determined by multiplying the total by 25.

Estimating clutch densities In the 1990, 1996 and 1998 surveys, transects were placed at random through each sub-colony. At every 20 paces along the transect, a peg with a 1.784 m long string attached to it was used to describe a circle of area $10m^2$. The number of clutches within each circle was counted by two observers and the mean count adopted if the two counts differed. In the 1998 survey, eggs at one sub-colony had hatched before the survey began, so collection of nest density data was not possible. However, visual comparisons of incubating and brooding bird densities at two other sub-colonies in the same year suggested that nest density was similar to this sub-colony. Therefore, the mean density (2.12 clutches/m^2) of these was used in estimating the size of the sub-colony where eggs had already hatched.

In the 1997 survey, the density of clutches in each sub-colony was estimated using square 5x5 m quadrats. A rectangular grid was constructed for each sub-colony and the X-Y co-ordinates of every quadrat were written on pegs. In order to avoid any bias in estimating clutch density, sample quadrats for estimating clutch density were randomly selected by drawing pegs from a hat. Quadrat boundaries were marked out with string and all eggs within each quadrat were counted and marked with a spot of red permanent ink to avoid double counting. A second search of the entire quadrat was then made to ensure that no eggs were missed. In cases where the quadrat string straddled clutches, only those that had more than half of their volume in the quadrat were included in the count.

Analysis Clutch densities were calculated by dividing the number of clutches counted in each quadrat by its area in m^2. Clutch densities differed among sub-colonies and so simply multiplying the overall mean density by the total colony area would not produce precise population estimates. Calculating the population size within each sub-colony would also reduce the precision of the estimate due to sub-division of the sample size.

Variation in clutch densities among sub-colonies was tested using Analysis of Variance with Bonferroni Pairwise Comparisons (Winer *et al.* 1991). Sub-colonies were grouped together for further analysis if their clutch densities did not differ significantly. The frequency distribution of clutch densities in some sub-colonies was non-normal with a strong skew towards lower values. As this invalidates arithmetic calculation of means and confidence limits, a bootstrapping procedure was used to re-sample the data with replacement (Westfall & Young 1993). This procedure involves randomly drawing values from the observed data until the number of cases resampled is equal to the number actually sampled; some samples are drawn more than once and others not at all. The mean value of this re-sample was then calculated and the procedure repeated 999 times to produce a frequency distribution of possible mean values based on the raw data. The mean of this re-sampled clutch density data along with the 2.5 and 97.5 percentiles were then calculated and extrapolated by the total colony area to give a population estimate with confidence intervals.

The number of breeding pairs in each sub-colony group in each year was calculated by multiplying the nesting density by the total area occupied by that density. The estimated sizes of all sub-colony groups were then summed to give the overall population estimate. The upper and lower confidence limits of each bootstrapped mean were treated in the same manner to produce measures of precision for each population estimate.

RESULTS

Nesting density varied significantly among sub-colonies in all years (ANOVA 1990: $F_{4,229} = 23.20$, $P < 0.001$; 1996: $F_{3,461} = 57.46$, $P < 0.001$; 1997: $F_{7,536} = 11.94$, $P < 0.001$; 1998: $F_{2,304}=88.83$, $P < 0.001$). Sub-colonies with mean densities that did not differ significantly (as determined by Bonferroni tests) were pooled for further analysis in order to reduce the variance and improve precision of the population estimates. The mean bootstrapped nesting densities and 95% confidence limits for each of these groupings are shown in Table 1, along with the number of sub-colonies exhibiting that density and their total area.

The breeding population sizes of Sooty Terns on Ascension Island between 1990 and 1998 are shown in Table 2. Examination of the mean population estimates and their confidence intervals shows that the size of the breeding population has varied significantly during this period. The population sizes in 1996 and 1998 were similar and exceeded 200 000 pairs, but population size in 1997 was significantly lower, at 151 000 pairs, than all other years with. The population size in 1990, 176 000 pairs, was intermediate and differed significantly from all other years.

DISCUSSION

Sooty Terns have a minimum global population of 25 million pairs, making it one of the most common seabirds in the world (Gochfeld & Burger 1996). The major part of the population occurs in the tropical Pacific where some colonies exceed 1000 000 pairs (Gochfeld & Burger 1996). Compared with these

Table 1 Variation in Sooty Tern nesting density (clutches per m²) on Ascension Island among sub-colonies and years (with upper and lower 95% confidence limits, CI). The density values within each year are pooled for those sub-colonies that did not differ at the 0.05 significance level. The number of sub-colonies exhibiting each mean density and their total area are also presented.

Tabel 1. Variaties in dichtheden broedende Bonte Sterns op Ascension Island in verschillende subkolonies en in verschillende jaren.

Year	Density	Sample size	Lower 95% CI	Upper 95% CI	N°. Sub-colonies	Area (ha)
1990	0.51	78	0.34	0.67	1	5.46
1990	1.85	156	1.70	2.01	13	8.04
1996	1.93	118	1.72	2.14	2	3.21
1996	0.92	127	0.80	1.04	1	1.40
1996	2.52	219	2.41	2.62	1	5.06
1997	1.09	109	1.01	1.16	4	1.39
1997	1.74	434	1.69	1.79	4	7.73
1998	0.77	100	0.67	2.03	1	0.88
1998	2.12	307	0.87	2.23	3	9.45

Table 2: Population status of Sooty Terns at Ascension Island between 1990 and 1998 (values rounded to the nearest 1000 pairs).

Tabel 2. Populatieschattingen van Bonte Sterns op Ascension Island tussen 1990 en 1998 (afgerond op duizendtallen).

Year	Population size	Lower 95% CI	Upper 95% CI
1990	176 000	155 000	198 000
1996	202 000	188 000	216 000
1997	151 000	143 000	158 000
1998	207 000	197 000	219 000

colonies, the one on Ascension is relatively small, representing approximately 0.8% of the world population. However, it is certainly among the largest colonies in the Atlantic Ocean (Williams 1984) and as such, is an important component of the region's biodiversity. If cats were eradicated the number of Sooty Terns would probably increase dramatically, and the importance of the island for this species would increase further. This single conservation measure would probably also lead to the recolonisation of the main island by other seabird species, including the endemic Ascension Frigatebird *Fregata aquila* (Bell & Ashmole 1995).

The Sooty Tern population on Ascension probably declined from 1815 onwards following the introduction of feral cats, although the population status prior to this date is unknown. Ashmole (1963b) estimated that 500 000 pairs bred on Ascension in 1954 although this is speculative and does not allow formal comparison with the estimates presented here. The population increased from 176 000 in 1990 to 202 000 in 1996. It then declined sharply to 151 000 pairs in 1997 before recovering to 207 000 pairs in 1998. It appears that the Sooty Tern population on Ascension is on average stable and therefore in equilibrium with current rates of cat predation, although significant fluctuations do occur around the average population size.

The 22% reduction in population size in 1997 compared with 1996 and 1998 could not have resulted from a catastrophic mortality event since the recovery during the following year was far too rapid. Such a large difference is also unlikely to be an artefact of the minor methodological differences employed in the 1997 survey. The most likely explanation was that the 1997 season coincided with an El Niño event (National Oceanic and Atmospheric Association, unpublished data) that may have influenced oceanographic conditions in the equatorial Atlantic, causing a reduction in pelagic food availability. A large proportion of the sexually mature population may have deferred breeding in response to this reduced prey availability, as has been documented for Brown Booby *Sula leucogaster* on Ascension (Simmons 1967, 1970), Brandt's Cormorant *Phalacrocorax penicillatus* (Boekelheide & Ainley 1989) and Elegant Tern *Sterna elegans* (Schaffner 1986) in California, and several species of seabird in South Africa (Crawford & Dyer 1995).

A second expedition to Ascension several weeks after the August/September 1997 survey discovered that breeding success of Sooty Terns was very low, with only small numbers of fledged young and very large numbers of abandoned eggs (Simmons & Prytherch 1998). This supports the hypothesis that food availability was poor during 1997 and forced adults to abandon their eggs, as documented for Arctic terns *Sterna paradisaea* on Shetland during a period of poor sandeel *Ammodytes marinus* abundance (Monaghan *et al.* 1992). Mass desertions of eggs by Sooty Terns at Ascension was also documented during the October 1991 breeding season (Hughes 1992). Annual variability in the proportion of mature birds present, in response to stochastic fluctuations in food availability, makes accurate census and monitoring of population trends difficult. Single surveys risk coinciding with a period of low food availability, as seemed to happen in 1997, and so surveys in several successive breeding seasons are required to establish a suitable baseline, and surveys in ten or more seasons are required to obtain an accurate measure of population trends. We recommend, therefore, that monitoring of the Sooty Tern population on Ascension occurs on an annual or biennial basis.

ACKNOWLEDGEMENTS

We would like to thank Roger Huxley for permitting census work on Ascension Island and for logistic support. Hilary Nash and Roger Dickey led the expeditions during 1990 and 1996 & 1998 respectively. They and other members of the Army Ornithological Society, and John Walmsley provided invaluable assistance in mapping the colonies and collecting clutch density data during the 1990, 1996 and 1998 censuses, and Philip Ashmole kindly provided clutch density data from 1990. The Heritage Society kindly made contributions to our subsistence expenses during the 1997 survey. We are indebted to the RAF station commander Adrian Hayward and the SERCo staff on the base for allowing us to use the runway to access Sooty Tern sub-colonies.

SAMENVATTING

Zoals op zoveel afgelegen eilanden bleef ook voor de zeevogels van Ascension Island (Centrale Atlantische Oceaan, juist onder de evenaar) de komst van de mens niet onopgemerkt. In de 19e eeuw werden katten op het eiland geïntroduceerd en daardoor werden de zeevogels van het eiland uitgeroeid, of op zijn minst naar enkele afgelegen rotspunten en kliffen teruggedrongen. Alleen de Bonte Stern Sterna fuscata *wist zich (tot op de dag van vandaag) op het hoofdeiland te handhaven, ondanks de aanhoudende predatie door katten. Een populatie die zo sterk onder druk staat moet nauwkeurig gevolgd worden en in dit artikel worden de resultaten van tellingen in de jaren 1990, 1996, 1997 en 1998 gepresenteerd. De tellingen bestonden uit precieze tellingen van de aantallen legsels in vaste gedeeltes van de kolonies, gevolgd door extrapolatie van de dichtheden voor de totale met vergelijkbare dichtheden bezette oppervlakte. Het bleek dat de aantallen broedvogels enorm van jaar tot jaar verschilden: 176 000 in 1990, 202 000 in 1996, 151 000 in 1997 en 207 000 paar in 1998. Het kleine aantal broedvogels in 1997 werd vermoedelijk veroorzaakt doordat veel volwassen vogels dat jaar wegens slechte voedselomstandigheden van broeden hebben afgezien. Het voedselaanbod staat onder invloed van oceanografische fluctuaties. Indien de populatie zodanig kan variëren, is het aan de hand van een klein aantal tellingen onmogelijk om lange termijn op het spoor te komen. Een dergelijke populatie moet dan ook regelmatig geteld worden.*

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