Population decline of Leach's Storm-petrel *Oceanodroma leucorhoa* within the largest colony in Britain and Ireland

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Abstract

This study used diurnal playback of vocalisations to examine the abundance of breeding Leach's Storm-petrel *Oceanodroma leucorhoa* on Dun, St Kilda in 2003 and 2006 in relation to the only previous survey conducted using similar methodology in 1999. The number of Apparently Occupied Sites in 2006 was 12,770, not significantly different to the 14,490 found in 2003, but significantly lower than the 27,811 found in 1999, by 54%. The magnitude and rate of the decline are of major conservation concern. Great Skua *Stercorarius skua* predation is thought the most likely cause but other factors such as poor food supply cannot be ruled out. The importance of continued monitoring of Leach's Storm-petrel and Great Skua is discussed.

Introduction

The Leach's Storm-petrel *Oceanodroma leucorhoa* has a highly localised distribution in the east Atlantic, with breeding confirmed on only about 13 remote islands and archipelagos off the coasts of the Republic of Ireland, Scotland, Faeroes, Iceland and Norway (Mitchell 2004). One of the largest of these is on the St Kilda archipelago off northwest Scotland, probably second only in size to the colony on the Westmann Islands off southern Iceland that is estimated to hold 80,000–150,000 pairs (Icelandic Institute of Natural History 2000). During 1999, the Seabird 2000 survey (Mitchell 2004) estimated that St Kilda held about 94% of the British and Irish population (45,433 Apparently Occupied Sites, AOS) of which 27,811 were in a single subcolony on the island of Dun. The lack of accurate population estimates for this species in Britain and Ireland before this time makes it impossible to assess whether there has been a significant long-term change in the status of this species.

On Dun and other islands of St Kilda, predation by Great Skuas *Stercorarius skua* is thought to pose a serious threat to Leach's Storm-petrel (Phillips *et al*. 1997, 1999a; Votier *et al*. 2006). Great Skuas have increased dramatically on St Kilda, with the

population rising from about 42 pairs in 1986 to a peak of 240 pairs in 2000 (Furness & Ratcliffe 2004). Based on their numbers in 1996, it has been estimated that Great Skuas predate approximately 14,850 Leach's Storm-petrel on St Kilda each year (Phillips *et al*. 1999b). Although there has been a small decline in the proportion of Leach's Storm-petrel in the diet of Great Skua since 1996, the level of predation appears to have remained high (Votier *et al*. 2006). With declines in the availability of offal and discards from commercial fishing boats predicted due to changes in fisheries management, Great Skuas may increase their reliance on seabird prey (Votier *et al*. 2004). Because of the importance of Dun for Leach's Storm-petrel in Britain and Ireland, there was a need to provide reliable monitoring data for this population. Here we report on two subsequent surveys of Leach's Storm-petrel on Dun conducted in 2003 and 2006, and examine whether the size of the population has changed since the first survey in 1999.

Methods

Survey methods: A playback survey was carried out on Dun, St Kilda (57°47'N, 08°33'W; Figure 1) on 4–5 and 7–10 July 2003 and 17–20 June 2006 using the methods developed by Ratcliffe *et al*. (1998) that were used previously on Dun in 1999 and throughout the rest of Britain and Ireland during Seabird 2000 (Mitchell 2004). Both surveys were conducted between 09.00–18.30 BST, since response rate is known to increase significantly towards dusk (Mitchell 2004). Leach's Storm-petrel burrows on Dun are virtually invisible, hidden in a thick sward on unconsolidated ground, which is broken by boulders and by Atlantic Puffin *Fratercula arctica* burrows. Transect lines running the width of the island (southwest to northeast; Figure 1) were positioned at 10 m intervals along the northwest side of the island and at larger 25 m intervals on the southeast side to minimise disturbance of breeding Atlantic Puffins in this part of the island. A Global Positioning System (GPS) was used to ensure that the positions of transects were similar (± 5 m) during the 2003 and 2006 surveys. At randomly selected points along these transects, a total of 331 and 303 5 m x 5 m quadrats were laid out in 2003 and 2006 respectively, which for each year is about 5% of the total area of Dun (147,396 m^2). Each quadrat was then surveyed by a single observer playing a recorded call on a dictaphone at approximately 1 m intervals and the number of responses was recorded. The tape playback used a male Leach's Storm-petrel chatter call recorded on St Kilda. The same recording was used in 1999, 2003 and 2006.

Data analysis: As only a proportion of birds will respond to tape playback, it is necessary to apply a response rate correction to any estimate. Such a correction factor is normally calculated by repeatedly sampling a calibration plot (Ratcliffe *et al*. 1998; Mayhew *et al*. 2000). On the first day of the survey in 2003, a calibration plot was established on the northwest end of Dun (chosen to avoid disturbance to the dense Atlantic Puffin colony on the southeast end). The plot yielded 25 responses from Leach's Storm-petrel on the first visit. The plot was subsequently visited on each day of the survey (except on 9 July, when deteriorating sea conditions dictated a premature departure from the island). Tape playback in the calibration plot was made at various times of day, but always within the same time period as the survey. Unfortunately, during the 2006 survey deteriorating sea conditions again necessitated a premature departure from the island and calibration data for 2006 were too limited

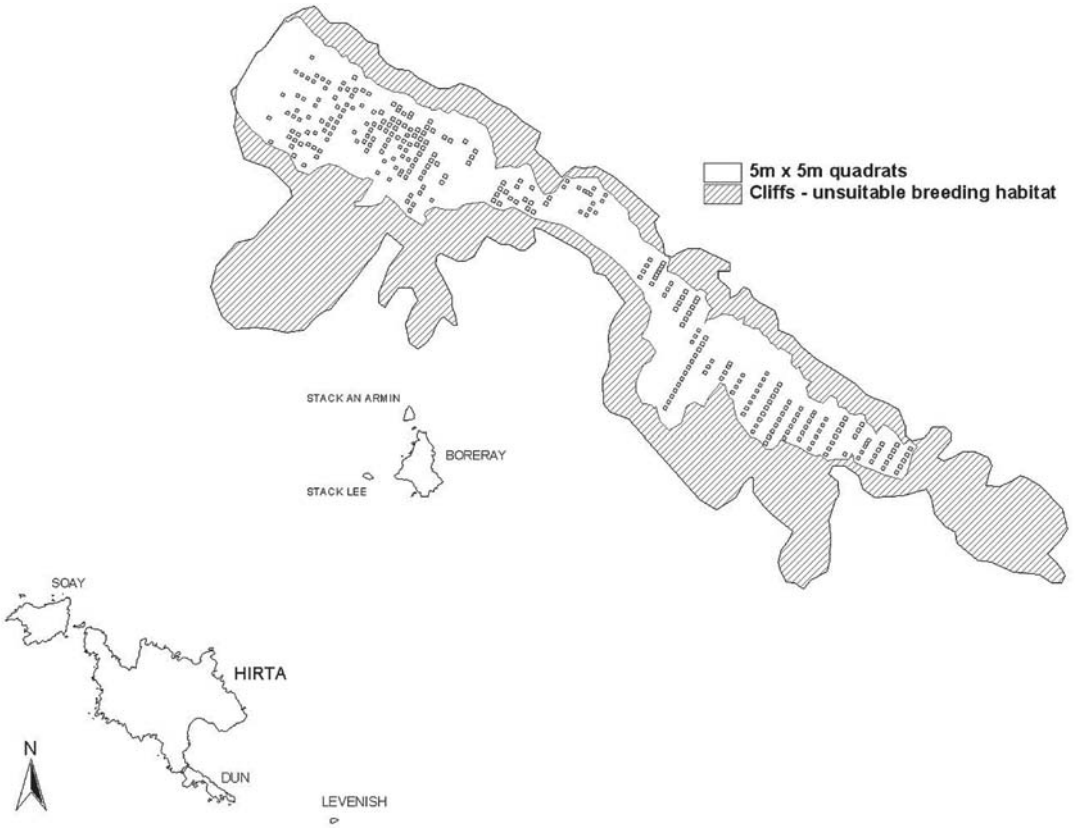


Figure 1. Map showing the location of Dun, St Kilda and surveyed quadrats.

to determine a correction. Therefore, we applied the same correction factor estimated from the calibration plot in 2003 to the survey data from 2006.

The population size (number of Apparently Occupied Sites, AOS_t), of Leach's Storm-petrel on Dun for each year was estimated as:

$$\hat{AOS}_t = \sum\sum AOS_s + \frac{\sum AOS_s}{(N \times A_q)} \times (A_t - A_q \times N)$$

Where AOS_s is the number of birds counted in each surveyed quadrat, N is the number of quadrats surveyed, A_t is the total area of Dun and A_q is the area of a quadrat.

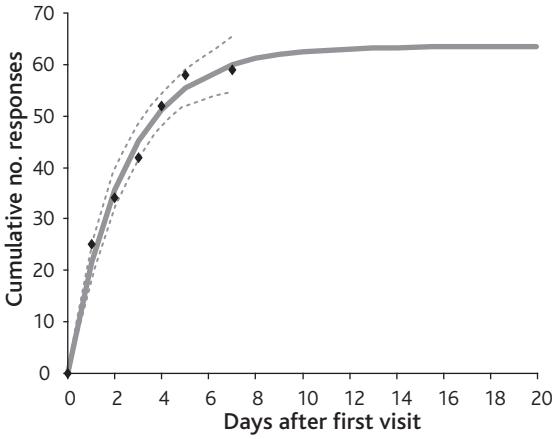
To produce confidence intervals we used a bootstrap resampling procedure of 10,000 iterations (Crowley 1992). For each iteration, AOS_s were randomly resampled with replacement, the sample drawn equal to the number of quadrats surveyed. The response rate correction factor was included within the above analyses, by dividing $\sum AOS_s$ across quadrats from each bootstrap iteration by the mean response rate. The errors around the response rate were incorporated by specifying a mean and standard deviation for each value and randomly selecting response rate values from a binomial

distribution defined by these values and constrained to remain between 0 and 1. By doing this 10,000 estimates of population size were produced. The 250th and 9,750th ordered bootstrap values across iterations were taken to give the lower and upper 95% confidence limits of the estimates respectively. Bootstrap *t*-tests were used to test for a significant difference in population estimates between years (Manly 1998).

Results

Calibration: The results of tape playback at the calibration plot on Dun in 2003 gave a mean response rate of 0.386 (Table 1 & Figure 2), very similar to that obtained in 2000 on Boreray, St Kilda (0.382, 95% CL 0.338–9.422) and applied to the 1999 census of Dun (Mitchell 2004).

Population size: As in 1999, there was no significant difference in 2003 between the mean number of responses per quadrat obtained on the northwest side of the island (0.945, 95% CL 0.776–1.132) compared to the southeast side (0.955, 95% CL



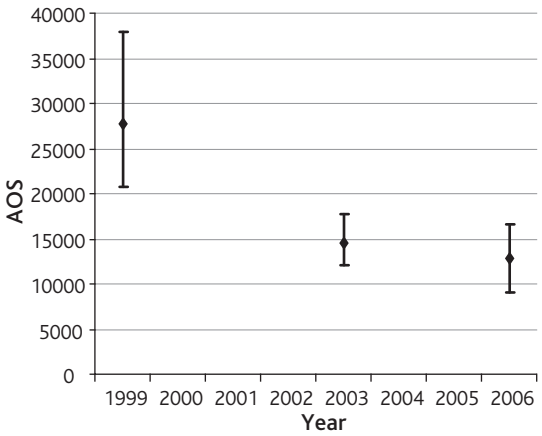


Figure 2 (left). Plot of cumulative number of responses to tape playback against days after first visit at the calibration plot on Dun, 4–10 July 2003. The solid line represents line of best fit from the observed responses (diamonds) and the broken lines represent the lower and upper 95% confidence limits of the line. **Figure 3 (right).** Estimated population size (AOS with 95% confidence intervals) of Leach's Storm-petrel *Oceanodroma leucorhoa* on Dun, St Kilda in 2003 and 2006 in relation to a previous survey carried out in 1999.

Table 1. Response rate of Leach's Storm-petrel *Oceanodroma leucorhoa* to tape playback, estimated from the calibration plot on Dun, 4–10 July 2003.

Date in July	**4**	**5**	**6**	**7**	**8**	**10**		
No. responses	25	25	29	25	25	17		
New responses	25	9	8	10	6	1		
Cumulative no. responses	25	34	42	52	58	59		
Response rate[1]	0.397	0.397	0.460	0.397	0.397	0.270	0.386	MEAN
							0.336	LCL
							0.436	UCL

[1]The plot of the cumulative number of responses against days after first visit (Figure 2) gave an asymptote of 63, which was taken to be the total number of birds present in the calibration plot.

0.754–1.159, t_{329} = 0.04, n.s.). Thus the data from both sides of the island were pooled in order to calculate a mean density of responses across the whole island. However in 2006, there were a significantly greater number of responses per quadrat on the northwest side of the island (1.08, CL 0.842–1.34) than on the southeast side (0.611; CL 0.45–0.77, t_{301} = 3.03, P < 0.01). For this reason, data were resampled separately for each side of the island and treated as if they were two separate populations to produce a separate population estimate for each. Population estimates produced from each iteration for each side of the island were then summed to produce 10,000 estimates for the whole of Dun and 95% confidence intervals taken as before.

With the application of the response rate, the total population of Leach's Storm-petrel on Dun was estimated as 14,490 AOS (95% CL 12,110–17,439) in 2003 and 12,770 AOS (95% CL 10,046–17,086) in 2006. This represents a significant decrease of 48% between 1999 and 2003 (t_{435} = 2.95, P < 0.01) but a non-significant 12% decrease from 2003 to 2006 (t_{632} = 0.19, n.s.; Figure 3).

Discussion

The estimate of 12,770 AOS in 2006 represents a decrease of approximately 15,000 AOS since 1999 and 1,700 AOS since 2003. The scale of decline since 1999 is a major concern, particularly if the other subcolonies within the archipelago have also decreased by a similar proportion (i.e. 54%), which would have reduced total numbers breeding on St Kilda from 45,433 AOS in 1999 to 20,899 AOS in 2006, a loss of about 49,000 breeding birds. Because estimates of population size of Leach's Storm-petrel on Dun prior to 1999 are qualitative, it is not possible to interpret this finding in relation to longer-term trends for this species.

Before exploring possible ecological or environmental causes of the decline, it is important to rule out the possibility that it was an artefact of the playback method used during each of the three surveys. The largest error in estimating the number of AOS would arise from using an inaccurate estimate of response rate to adjust the number of responses obtained during the playback survey. In theory, the decline in numbers between 1999 and 2003 could have arisen if: a) in 2003, the response rate used was too high and therefore underestimated the number of AOS; and/or b) in 1999, the response rate was too low and therefore overestimated the number of AOS. It is unlikely that the response rate used in 2003 was inaccurate, since this was measured on Dun at exactly the same time as the playback survey was carried out. Furthermore the response rate measured in 2003 on Dun was very similar to that measured at other subcolonies within St Kilda and at other colonies in the British Isles (Mitchell 2004). In contrast, in 1999, no simultaneous measurement of response rate was conducted on Dun during the survey and instead, a response rate was used that had been measured the following year on the neighbouring island of Boreray. This response rate was almost identical to that recorded on Dun in 2003. If the number of AOS in 1999 were in fact similar to that in 2003, such that there was no decline, the number of responses obtained in 1999 – 10,574 – would need to be corrected by a factor of 1.36 rather than 2.62, which was based on a response rate of 0.38 (correction factor = 1 / response rate). However, a correction factor of 1.36 would only have been

derived if the response rate in 1999 was 0.74. Response rates to a male chatter call of more than 0.52 have yet to be recorded at a Leach's Storm-petrel colony (Mitchell 2004) and are unlikely to be achieved since only the incubating males are thought to respond to recorded male chatter calls (Taoka *et al*. 1989). There is no reason to suggest that a higher proportion of males than females should be incubating at any one time, with sexes sharing incubation equally with a 3-day changeover time (Wilbur 1969; Watanuki 1985). On Boreray in 2000, the response rate of Leach's Storm-petrel did increase significantly towards dusk from a mean of 0.38 (95% CL 0.34–0.42) between 07.10 and 17.15 to 0.52 (95% CL 0.45–0.58) between 20.00 and 22.00, but the survey in 1999 was conducted no later than 17.00.

The response rate to playback by Leach's Storm-petrel will vary during the breeding season, with the highest and most consistent response rates obtained during the peak of incubation when the highest number of burrows will be occupied by an adult (Ellis *et al*. 1998). In the UK, peak incubation occurs around mid June to early July and each egg is incubated for 41–42 days (Cramp & Simmons 1977). As chicks start to hatch, daytime occupancy rates and hence response rates will decrease as adults spend days away from the burrow foraging, leaving young unattended (Ellis *et al*. 1998). The survey in 1999 was conducted on 30 June and 1 July, and on 4–10 July in 2003, but around two weeks earlier in 2006 on 17–20 June. The surveys in 1999 and 2003 were conducted towards the very end of incubation. However, of nine burrows examined on neighbouring Hirta in 2003 at the same time as the survey of Dun, the first chick hatched on 9 July, the day before the survey on Dun was completed. Furthermore, there is no evidence of a decrease in response rate during the course of the survey (Table 1), suggesting that the majority of birds during both the 1999 and 2003 surveys were still incubating or brooding small chicks, but nevertheless still occupying burrows during the day (Leach's Storm-petrel chicks are brooded continuously for five days after hatching (Cramp & Simmons 1977)). It is thus unlikely that the decline in AOS that occurred between 1999 and 2003 and 2006 was an artefact of the difference in timing of the three surveys, and is more likely to represent a real decline in the population on Dun.

One potential cause of the observed decline in Leach's Storm-petrels is predation by Great Skuas, which had increased in number exponentially on St Kilda prior to the 1999 survey of Leach's Storm-petrel (see above). A study on the neighbouring island of Hirta found that the diet of Great Skuas was dominated by Leach's Storm-petrel, and that they hunted during the night when Leach's Storm-petrels were returning to their colonies (Votier *et al*. 2006). Phillips *et al*. (1999b) estimated that the total Great Skua population on St Kilda in 1996 consumed approximately 15,000 Leach's Storm-petrels per year. Given that between 1996 and 2004, the proportion of Leach's Storm-petrels in the diet of Great Skuas remained relatively constant (Votier *et al*. 2006), around 60,000 Leach's Storm-petrels would have been killed on the archipelago during the period between the surveys in 1999 and 2003, assuming that the model of Phillips *et al*. (1999b) is correct and that the Great Skua population has not changed substantially since 1998. Whilst this is more than the 45,000 breeding Leach's Storm-petrels we estimate may have been lost from the archipelago, it is likely that recruitment will offset some of the losses due to predation mortality. In addition it is also likely that

non-breeding adult Leach's Storm-petrels that also visit colonies at night are being predated by Great Skuas, but the age or breeding status of Leach's Storm-petrel remains could not be determined from skua pellet analysis. Furthermore, it is possible that there may have been greater declines in the Leach's Storm-petrel populations on the other islands than there were on Dun.

Whilst the Leach's Storm-petrel is not rare in an international context, with an estimated 9,000,000–10,600,000 pairs worldwide (Mitchell 2004), the Great Skua, with just 16,000 pairs is scarce globally (Furness & Ratcliffe 2004). As St Kilda is a Special Protection Area (SPA) under the European Commission's Birds Directive, with both Leach's Storm-petrel and Great Skua listed as qualifying species, if it were thought necessary to devise a management solution, it would not be straightforward (Phillips *et al*. 1999a).

The question as to whether Great Skuas are the main cause of the decline remains unproven. Unfortunately there are no other demographic data available for Leach's Storm-petrel on St Kilda or any other colony in the northeast Atlantic that could be used to identify other causes. In fact St Kilda is the only colony of Leach's Storm-petrel in the northeast Atlantic where trends in population size have been accurately measured.

Recent steps have been taken on St Kilda to initiate monitoring of productivity and adult survival of Leach's Storm-petrel. In 2004, JNCC installed 25 nest boxes on Hirta and set up a constant effort mist-netting site for ringing. By attracting Leach's Storm-petrels to nest in the boxes it is hoped that monitoring of productivity (including hatching rates, chick growth rates and fledging success) could be carried out more easily than in natural nest cavities that have proved extremely difficult to investigate. While low productivity, perhaps related to poor food supply, may have contributed to the decline in the breeding population, it was most unlikely to have been the sole cause of such a steep decline. However, monitoring productivity could give an indication of the state of feeding conditions during the breeding season and the potential for the population to recover. The main aim of ringing Leach's Storm-petrel is to gain estimates of annual survival rates of adults to determine whether high mortality is indeed the main driver of the decline in the breeding population. However, simultaneous monitoring of predation rates by skuas is required to determine if observed levels of mortality are likely to have resulted from predation at the colony or from some other factor, e.g. in the non-breeding areas in the southeast Atlantic. Monitoring changes in the numbers of Leach's Storm-petrel breeding at other colonies in the British Isles and elsewhere in the northeast Atlantic would be useful to determine whether the decline is restricted to St Kilda or represents a more widespread phenomenon.

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