A survey of Leach's Petrel *Oceanodroma leucorhoa* on North Rona, Western Isles, Scotland in 2015

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Abstract
Comparable surveys have been made of the Leach's Storm-petrel *Oceanodroma leucorhoa* colony on North Rona, Western Isles, Scotland in 2001, 2009 and 2015 using responses to tape recordings played at burrow entrances. Response rates estimated from a calibration plot were used to correct the total number of responses to tape playback from an island-wide survey. A 'simple arithmetic' method of calculating the population estimate suggested 606 apparently occupied burrows (AOB) for 2015, which is the lowest number to date and represents a c.15% decline since the last survey in 2009, when 713 AOB were estimated. In 2001 there were 1,084 AOB, giving an overall decline of 44% since this first survey. The 'first response' method, which only makes use of the first response from each burrow in the calibration plot, is designed to avoid potential bias, caused either by habituation or by very vocal individuals. As this suggests a population of 805 AOB there is a need to be cautious about inferring a further island wide decline since 2009.

Introduction
Leach's Storm-petrel *Oceanodroma leucorhoa* (hereafter Leach's Petrel) breeds on both sides of the North Atlantic, with some the world's largest colonies in Newfoundland, Canada (Robertson *et al*. 2006). Here, Baccalieu Island alone holds c. 3.4 million pairs (Sklepkovych & Montevecchi 1989) out of a global population of 9–10.6 million pairs (Mitchell *et al*. 2004). The northeast Atlantic colonies are much smaller, the largest, on the Westmann Islands, Iceland, holding 80–150,000 pairs (Icelandic Institute of Natural History 2000).

In Britain and Ireland, in 1999–2002, the largest colonies were 45,433 apparently occupied burrows (AOB) on St Kilda (94% of the total population), 1,425 on the Flannan Isles and 1,084 on North Rona; the remaining five confirmed colonies held a total of 367 AOB (Mitchell *et al*. 2004). Population trends on these islands are poorly known. On Dun, St Kilda, numbers declined by 54% between 1999 and 2006, while on North Rona they decreased by 34% between 2001 and 2009. Predation by Great Skuas *Stercorarius skua* is thought to be responsible for the decline on St Kilda, and perhaps on North Rona, although this is still unproven (Votier *et al*. 2006; Newson *et al*. 2008; Murray *et al*. 2010). This paper reports on

a further assessment of the numbers breeding on North Rona and compares the results with those from similar surveys made in 2001 and 2009.

North Rona (59°08'N 5°50'W) lies 70 km north of the Butt of Lewis in the Western Isles of Scotland. It is uninhabited, about 122 ha in extent and reaches 108 m at the highest point. There are no secure landing sites or anchorages and the island is exposed to the full force of Atlantic weather systems, which can make landings difficult to impossible, even in summer conditions. The island was declared a National Nature Reserve in 1956; classified as a Special Protection Area (SPA) under Article 4 of the European Birds Directive in 2001 and in 2005 as a Special Area of Conservation (SAC) under the European Habitats and Species Directive. Leach's Petrel is one of the designated features under both designations.

Methods

For census purposes North Rona is divided into 16 sections (Figure 1), designated by clearly defined natural or man-made boundaries (Murray *et al*. 2008). All sections can be accessed easily except sections O and P, where a combination of difficult access on steep ground close to cliff edges and high densities of Atlantic Puffin *Fratercula arctica* burrows requires careful footwork and in places rope protection.

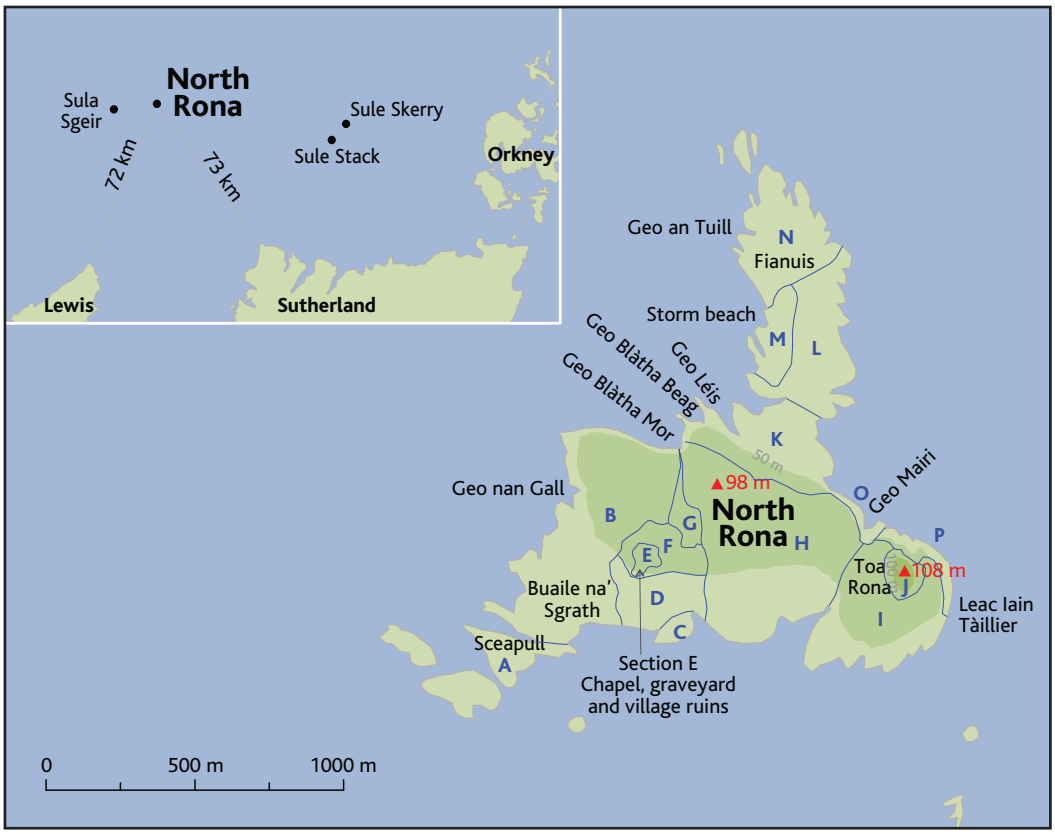

Figure 1. North Rona location map and island survey sections A to P. Courtesy of the Scottish Ornithologists' Club.

Timing of visits: The 2015 survey was conducted between 20 June and 4 July with the aim of carrying out the work as closely as possible to the first hatching date, assumed to be similar to Leach's Petrel on St Kilda, i.e. mid to late July (Money *et al*. 2008). Previous surveys had been carried out slightly later, in 2001 between 29 June and 8 July and in 2009 between 28 June and 7 July.

Playback and calibration: The tape playback technique of Ratcliffe *et al*. (1998) was used in all three surveys. This involves playing recordings of the chatter call of the male Leach's Petrel, which only responds to chatter calls of the same sex (Taoka *et al*. 1989). Not all incubating individuals respond to the taped calls at a given time, even during peak to late incubation, so a count of responses greatly underestimates the total number of AOB at a colony. Therefore, it is necessary to measure what proportion of birds are present in burrows and responding to the taped calls. This was achieved by setting up a calibration plot to calculate a colony-specific correction factor, by repeatedly visiting a delimited section of the colony on successive days and each time marking new responding AOB. Incubating females within the plot will not respond to the male calls, but should be replaced by males after three to four days (Watanuki 1985).

The calibration plot was set up at the village graveyard wall and adjacent ruins (Section E), the same sites used in the previous surveys (Figure 2). Sufficient burrows were included to ensure that at least 20 responded on the first visit, and on each day thereafter when new responding burrows were located they were marked and numbered with flagged canes. The plot was visited between 09.00 and 11.00 BST each day from 22 June to 1 July 2015 (Table 1).

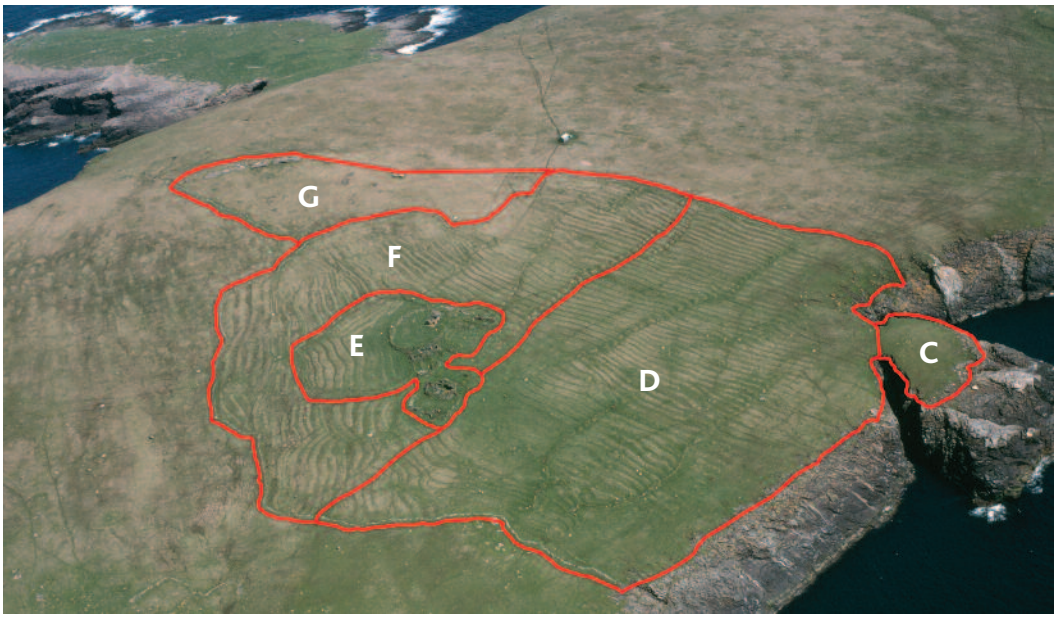

Figure 2. North Rona showing five (C to G) of the 16 sections (A to P) sub-dividing the island to standardise and improve survey efficiency. © *Stuart Murray*.

Table 1. Leach's Storm-petrel *Oceanodroma leucorhoa* 2015 calibration plot results.

Dates in June and July	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**1**	**Total**
Number of new AOB found per visit	20	12	10	7	5	2	1	4	1	0	62
Cumulative total of AOB	20	32	42	49	54	56	57	61	62	62	62
Number of responses per visit	20	26	32	33	29	24	21	29	27	29	270

Once daily calibration was complete, four surveyors used hand-held tape cassette players (Gilbert *et al*. 1999) to systematically survey all potential nesting habitat across the island, counting and mapping all responses. The total number of AOB for the island was estimated by dividing counts of responding birds by the response rate derived from the calibration plot (see below). Dividing the number of responses by the confidence intervals for the response rates also enabled confidence intervals for the number of AOB to be calculated.

Response rate: Response rates were estimated using two distinct methods. The standard or 'simple arithmetic' method was calculated as:

(1) Total number of responses/total AOB in the plot x number of visits.

This method is appropriate when one can be reasonably confident that all AOB within the plot have been located and the likelihood of a response from each occupied burrow is reasonably constant over the period of the study. However, if there is evidence that the likelihood of a response does vary during the study then an alternative such as the 'first response' method should be considered, which only uses the number of new responses found per visit (Murray *et al*. 2010; Table 1). For each visit this could be calculated as:

(2) Number of first responses/the number of possible first responses (i.e. excluding burrows already shown to be occupied).

In the current survey there were 62 occupied burrows within the plot. The first response rates for the first two visits were as follows:

Visit 1: there were 20 first responses out of a possible 62. Response rate = 20/62.

Visit 2: there were 12 first responses out of a possible 42 (62–20). Response rate = 12/42.

The overall initial response rate could be calculated as the average of these individual response rates. However, this is very sensitive to the values for the later visits, where there are relatively few possible new responses. A more robust estimate is provided by:

(3) Sum of the first responses/sum of the possible first responses where the sum is over the visits.

In practice it is sensible to exclude the last few visits where the number of possible new burrows is small e.g. the last two visits in 2001 and 2015 and the last three in 2009, since the overall response rate is largely determined by what happens in the first 3–4 visits.

The 95% confidence intervals (CI) were estimated by bootstrapping the AOB in the calibration plot (Efron 1979) and generating 9,999 re-samples with 2.5% and 97.5% percentiles. The calibration plot data, rather than the bootstrap means, were used to estimate the response rate as the two were very similar after 9,999 re-samples. Such intervals only take account of uncertainty in the response rate. Uncertainty due to other factors, such as differences in the completeness of the surveys for example, is harder to assess. For comparative purposes the calibration data collected during the two previous surveys were re-analysed in the same way.

Results

In the 2015 whole island survey conducted between 20 June and 4 July, 264 birds responded to the taped calls. The simple arithmetic method gave a response rate of 0.435 (95% CI: 0.381–0.490; Table 2) resulting in a population estimate of 606 AOB (95% CI: 538–694). The first response method gave a rate of 0.328 (95% CI: 0.274–0.397; Table 2) and consequently a higher population estimate of 805 AOB (95% CI: 664–962).

The first survey on North Rona in 2001 reported 1,084 AOB of Leach's Petrel but by the second survey in 2009 there had been a 34% decline to 713 AOB (Murray *et al*. 2010). These surveys used the simple arithmetic method of calculating the response rate, which suggested a further 15% decline to 606 AOB in 2015 (Table 2). The overall island losses of 107 AOB are not evenly distributed across the 16 colony sections, with 86 AOB lost in Section E, the ruined village. Elsewhere five sections, B, D, G, I and L have increased slightly, and these gains largely balance out the small losses in the other six sections active in both years (Table 3).

Table 2. Estimates of response rates and Apparently Occupied Burrows (AOB) in 2001, 2009 and 2015. Calculated by the 'simple arithmetic' method (top) and the 'first response' method (bottom).

Arithmetic method Year	Response rate Estimate	95% CI	AOB Estimate	95% CI	Change	95% CI
2001	0.452	0.402–0.503	1,084	974–1,219		
2009	0.355	0.320–0.391	713	647–791	-371	-519 – -237
2015	0.435	0.381–0.490	606	538–694	-107	-207 – +2
First response method	**Response rate**		**AOB Year**	**Estimate 95% CI**	**Estimate**	**95% CI Change 95% CI**
2001	0.362	0.297–0.439	1,270	1,048–1,550		
2009	0.338	0.292–0.394	748	643–867	-522	-819 – -268
2015	0.328	0.274–0.397	805	664–962	+57	-130 – +249

Table 3. Number of Leach's Storm-petrel *Oceanodroma leucorhoa* Apparently Occupied Burrows (AOB) on North Rona in 2001, 2009 and 2015 and the percentage change between years. Calculated by the simple arithmetic method.

Section	2001	2009	% change from 2001	2015	% change from 2009
A	0	0	0	0	0
B	62	45	-27	46	+2
C	0	0	0	0	0
D	12	8	-33	14	+75
E	314	235	-25	149	-37
F	5	8	+60	2	-75
G	22	11	-50	21	+91
H	29	22	-24	14	-36
I	81	48	-41	64	+33
J	93	45	-52	39	-13
K	152	65	-57	55	-15
L	177	161	-9	168	+4
M	27	14	-48	0	-100
N	48	51	+6	34	-33
O	20	0	-100	0	0
P	42	0	-100	0	0
Totals	*1084*	*713*	*-34*	*606*	*-15*

In 2009 the response rate was somewhat lower than in 2001 and 2015. In part this is because some burrows always, or almost always responded in 2001 and 2015, whereas this did not happen in 2009 (Table 2). The response rates in 2001 and 2015 appear to be higher after the first response although the pattern of re-response is different. The reasons for this apparent 'reverse-habituation' are not entirely clear. It may in part be due to a small number of very vocal individuals, possibly non-breeding adults, or immature birds prospecting for a burrow. Alternatively, this increase in the response rate would arise if some burrows were unoccupied for the first few days of the study. As any variation in response rates over the study may give rise to bias in the arithmetic method response rates, an alternative method, 'first response', was implemented for comparison (Table 2).

The first response method gives response rates consistent across the three surveys whereas the simple arithmetic method does not, the 2009 rate being lower than 2001 and 2015 (Table 2). If 2009 is anomalous with its rather low response rate, or there is some reverse-habituation in 2001 and 2015, but not in 2009, then the first response method is one way of removing the potentially spurious variation in response rates across the three surveys. If the true response rates were very similar for all three surveys, as the first response method suggests, then the analysis would still suggest a significant decline between 2001 and 2009. However, there would then be no evidence of a further decline between 2009 and 2015.

Discussion

The surveys of Leach's Petrel on North Rona in 2001, 2009 and 2015 covered all suitable breeding habitat on the island. The same person oversaw the work in all three years and the same tape cassette players were used throughout, playing recordings of the same male petrels. Weather, especially strong winds and rain might affect the survey, but 2015, although not as calm and sunny as 2009, was largely dry, although unseasonably cold. In both 2009 and 2015, calibration plots were checked daily for 10 days, always between 09.00 and 11.00 BST. The main difference between the three years was the earlier start date of the ground survey in 2015, but there is no evidence from the calibration plot or the wider survey that this affected response rates. On Gruney in Shetland, playback surveys were made of the Leach's Petrel colony in five summers between 1991 and 1995 and burrow attendance and response rates were found to be at their highest in mid June (Ellis *et al*. 1998). It is therefore unlikely that the timing of the survey on North Rona in 2015 resulted in reduced probability of a bird responding to playback. It would be unrealistic to attempt to standardise these counts further.

There are no repeat studies of Leach's Petrel at other large Scottish colonies where response rates have been measured in different years and could be compared with the North Rona results. On Dun, St Kilda large-scale surveys were undertaken in 1999, 2003 and 2006 but in the latter year calibration data were too limited to determine a correction factor, so the 2003 response rate (0.386) was used to calculate an island population total (Newson *et al*. 2008). For the first census on Dun in 1999, (Mitchell *et al*. 2004) the response rate (0.382) was calculated in 2000 on a different island in the group, Boreray, 9 km north of Dun, and applied retrospectively. These two response rates, although lower than the rates found on North Rona are within the confidence intervals for both arithmetic and first response methods in 2009 and 2015 (Table 2).

Whilst the first response method is useful when there are concerns that behaviour changes after the first response, it has two potential disadvantages. Firstly, it is not making use of all of the data from the calibration plot and so will give rise to wider confidence intervals for the number of AOB (Table 2). Secondly, it is particularly sensitive to the assumption that the AOB are occupied throughout the 10 days of the study. Given the sensitivity of the results to the choice of analysis method, further review of the calibration method would be desirable, to check the appropriateness of the assumptions made by both methods, and to ascertain the source of the discrepancy between them.

Treating the data as captures and re-captures (re-responses) provides another useful way of summarising the differences between years. Figure 3 shows the re-response rates by day for the three surveys, that is, the response rates among those AOB that already responded on a previous day. It suggests that 2015 is quite different to the earlier years, with the rate dropping markedly after the first few days and responders becoming rather less likely to respond again. Thus, although the overall arithmetic response rate is higher after the first response, this

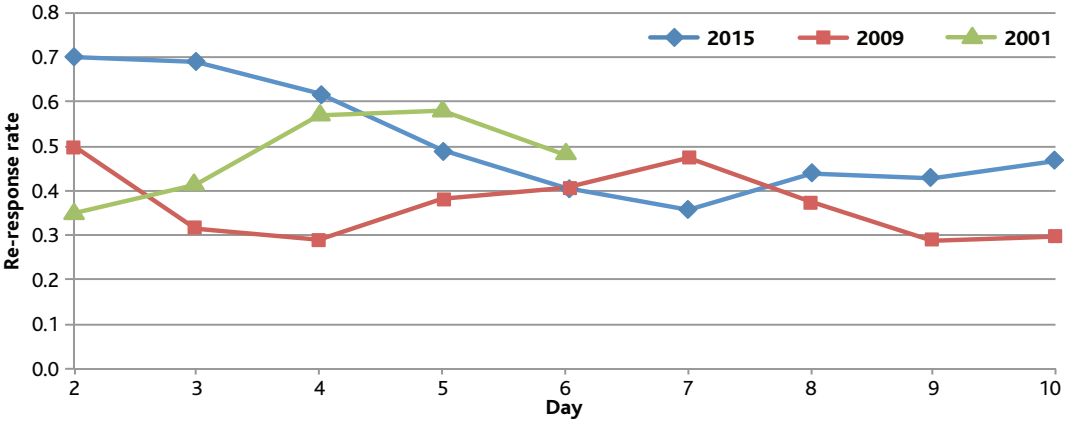

Figure 3. Differences in the re-response rate between 2001, 2009 and 2015. Showing response rates among AOB that have previously responded, with 2015 clearly different from 2001 and 2009 - responders become less likely to respond again.

is either because the early responders were particularly good re-responders or because some burrows were unoccupied in the early days of the study. In contrast, 2001 provides clearer evidence for reverse-habituation, although with just six days of data it is difficult to be certain of the response trend, while 2009 shows what appears to be random variation with broadly consistent responses over the 10 days (Figure 3).

Without being able to verify burrow occupancy with, for example, the use of an endoscope, the calibration plots will continue to be limited to tape response and will likely include an unknown proportion of non-breeding birds, which may not be consistent in their response to playbacks. Nearly 50% of North Rona Leach's Petrels nest in man-made structures and this use of ruined buildings and walls, where burrow entrances are often not obvious, would likely make the use of an endoscope challenging. Money (2008) in a pilot study using an endoscope on St Kilda, recommended using grass slope habitat and avoiding stone cavities when setting up a monitoring plot for Leach's Petrel. The calibration plot on North Rona has used the walls and ruins of the village because they hold c. 25% of the breeding population in a small area, making it relatively simple to find responding burrows and to monitor them efficiently. If there is a possibility of variation in response due to habitat (Mayhew *et al*. 2000) and the village is not typical, then an additional calibration plot could be set up away from the village, e.g. in Section L where burrows are in largely natural situations, generally under embedded boulders set in shallow soil.

Despite the ambiguity of the 2015 North Rona survey results, due to the differences found between the two different response rate methods, it appears that the overall rate of loss between 2001 and 2009 has at least slowed. However, the reasons behind the decline remain unknown. Predation by Great Skuas, and possibly Great Black-backed Gulls *Larus marinus*, may have had a detrimental impact on the colony, as has been shown on St Kilda (Phillips *et al*. 1999a,b). However, evidence is lacking to support predation as wholly responsible for the

Figure 4. Leach's Petrel after ringing, North Rona village, 3 July 2015. © *Steph Elliott*.

decline on North Rona. Other possible causes are poor productivity and low survival to breeding age, with subsequent poor recruitment of potential breeding birds. Given its remoteness and the expense of working on North Rona, it is unlikely that these issues can be easily investigated. Even a repeat tape-playback survey, although relatively simple to undertake, is costly and labour intensive, taking up to two weeks to complete.

In the present study, our population estimates include an unknown number of non-breeders, which recent, albeit numerically small studies, suggest could account for 15–29% of responses (Money *et al*. 2008; Miles *et al*. 2012). Despite this limitation a whole island survey using tape-playback, with a concurrent ten-day calibration exercise, offers the most accurate method of estimating colony size and distribution. The results of the 2015 survey suggest that Leach's Petrel is not so severely threatened across North Rona as once thought, although continuing losses in the ruined village (Section E) are concerning.

Acknowledgements

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