SECOND INTERNATIONAL MANX SHEARWATER WORKSHOP: STUDIES ON THE MANX SHEARWATER *PUFFINUS PUFFINUS* AND RELATED PETREL SPECIES

INTRODUCTION

The Second International Manx Shearwater Workshop took place between the 2nd and 4th August 2005. It was hosted by Copeland Bird Observatory (CBO), was held at the Ulster Museum in Belfast, Northern Ireland, and was attended by 90 delegates from around the world.

The First International Manx Shearwater Workshop took place in Madeira in 2000 and attendees included an enthusiastic group from CBO who volunteered to host a second workshop. In planning the event, we aimed to attract a wide range of interests by extending the focus from Manx Shearwater *Puffinus puffinus* and related petrel species to include petrels breeding in the North Atlantic. We invited papers on four broad themes: populations and censusing; conservation issues (threats to breeding colonies and protection measures); activity at the colony (breeding behaviour and population ecology); and activity away from the colony (at-sea behaviour and censusing).

Each of the four themes is represented in the nine papers included in this volume, and I will use part of this introduction to complement these by summarising some of the material covered by all the presentations and posters.

The workshop was dedicated to the late Irynej Skira, who had died just a few months earlier. Irynej had been an enthusiastic supporter of the workshop and had planned to present a paper on his study of the Short-tailed Shearwater *P. tenuirostris.*

We began with **populations and censusing** – an appropriate beginning, coming after the publication of *Seabird Populations of Britain and Ireland*, at a time when we could consider the results of the surveys and discuss the value of the various census methods. Stephen Newton, Greg Robertson and Aevar Petersen set the scene describing previous and recent surveys and current understandings of population sizes and distributions of Manx Shearwater, Leach's *Oceanodroma leucorhoa* and European Storm-Petrels *Hydrobates pelagicus*. These papers were followed by others on speciation and on the effectiveness of some of the methods used in surveys, concentrating particularly on tape-playback methods where birds in breeding burrows are counted when they respond to pre-recorded calls played near the burrow entrance. It was apparent from the discussion session that there remains much work to be done on refining the methods used and the interpretation of results from all of the current survey techniques.

The section on **conservation** included talks on the impact of predators and on predator control, on (protected) site designations and on the potential impacts of climate change. Stephen Votier described the severe impact of Great Skuas *Catharacta skua* on St Kilda's Leach's Storm-Petrels and the dilemma arising because the skuas are arguably the more important species in global terms. There was much less sympathy for the rats which have been eradicated from Lundy and those to be removed from Canna, or the feral cats which threaten the endangered Townsend's Shearwaters *P. auricularis* breeding high in the hills on Socorro Island in the Pacific Ocean. The poor outlook for the Balearic Shearwater *P. mauretanicus*, with perhaps 2,000 breeding pairs, seems to be due to a more complex range of inter-acting factors including introduced predators, poor survival rates, low productivity, long-line fishing and changing food availability – with proposed new wind farms about to join the picture.

The identification and protection of key feeding and rafting areas was also covered with descriptions of ship-based surveys and the use of radio tracking and data loggers to follow the birds into these areas.

There was also a selection of papers on the potential **impacts of climate change**, especially changing sea surface temperatures and the connections with food availability, foraging success and the ability to raise chicks. There are observable changes in the condition of individuals and on the distribution at sea of affected species.

The theme of **breeding behaviour and population ecology** had papers ranging from flighting behaviour at colonies, to studies of colony and burrow location faithfulness, comparative survival rates, availability of food and competition from human fishing activities, impacts of the timing of snow cover, and the selection of the best nest sites.

Our last session was on **at-sea distributions and censusing**. It soon became apparent that some highly ingenious techniques covering a wide range of levels of technology are currently being applied in this difficult area. These studies are uncovering evidence of the adaptability and variability of the birds' survival strategies, when they react to seasonally changing conditions, perhaps modifying their migration and feeding strategies to take best advantage of wind patterns and food sources.

The workshop was held to be a great success by all of the participants who offered their feedback. This was not only due to the quality and interest of the papers and posters presented, but also because of the opportunity to network, to discuss current and future prospects and to socialise together in the evenings. One of the most popular aspects of the week was the opportunity for some of our delegates to visit the Observatory on Lighthouse Island, either before or after the workshop, to experience the Manx Shearwater colony and to take part in our Shearwater and Storm-petrel studies.

Of course such events require a great deal of organisation and significant funding to make them a success and I wish to acknowledge the major contributions made to our workshop. Funding and other support was provided by the JNCC, Atlantic Seabirds, the Quercus Centre at Queen's University Belfast, the Centre for Environmental Data and Recording (CEDaR) and the Ulster Museum, and particularly, our major sponsor, the Environment and Heritage Service of the Northern Ireland Department of the Environment.

There is also a long list of people who helped to make things go so well. Our thanks go to Stuart Bearhop (who acted as editor for this volume) and Robbie McDonald from Queen's University (SB is now at Exeter University), James Orr and his staff at the Wildfowl and Wetlands Trust, Angela Ross, Moira Concannon and their colleagues at the Ulster Museum. Thanks also to the many members of the Observatory who helped out in dozens of ways. Special mention is due to our boatman, Philip McNamara who ferried us all to and from the Island and to Pat McKee who organised all the food and catering for the visits.

The two other main organisers of the workshop were Fiona Maitland and Kerry Leonard, who were involved in almost every aspect of the event. The ultimate success of the workshop was due, in no small part, to their sustained efforts over a two-year period.

John Stewart

OBITUARY IRYNEJ SKIRA 1950-2005

Dr Irynej Skira was born in Tasmania in 1950. His scientific career spanned over 33 years working with the Tasmanian Government.

He was a pre-eminent Tasmanian researcher and, since 1978, had been carrying out population monitoring of the Short-tailed Shearwater *Puffinus tenuirostris*, a study which was begun on Fisher Island, Bass Strait, nearly 60 years ago by Dominic Serventy. This remains one of the world's longest systematic seabird studies. An internationally recognized scientist, Irynej was considered to be one of the architects of seabird research. He also worked on whales, gulls, pest control on sub-Antarctic Islands and a range of other wildlife issues including muttonbirding in Tasmania. He was strongly committed to the conservation of the Short-tailed Shearwater and to the protection of Tasmania's native wildlife.

He fell ill in January while on the tiny Snares Island, 222 km south of New Zealand, where he was helping three other researchers from the University of Otago who were studying the Sooty Shearwater *P. griseus*. Dramatically airlifted by rescue helicopter to Dunedin, he was then transferred to Hobart where he spent his last days. He died on the 18th February 2005.

John Stewart

MONITORING EUROPEAN STORM-PETRELS *HYDROBATES PELAGICUS*: A COMPARISON OF THE RESULTS PROVIDED BY MARK/RECAPTURE AND TAPE RESPONSE METHODS

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Hounsome, M.V., Insley, H., Elliott, S. Graham, K.L. & Mayhew, P. 2006. Monitoring European Storm-petrels *Hydrobates pelagicus*: a comparison of the results provided by mark/recapture and tape response methods. Atlantic Seabirds 8(1/2): 5-20. *Two techniques for estimating the size of breeding populations of European Storm-petrels* Hydrobates pelagicus *were carried out on two Scottish islands: the tape response method (in 1999 and 2004) and three types of mark/release/recapture method (in each year since 1998). The tape response method gave lower estimates than the MRR methods, raising questions about the assumptions and limitations of the techniques for monitoring European Storm-petrel populations. An apparent fall in population on Priest Island in 2004, indicated by the tape response method, is discussed.*

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INTRODUCTION

Breeding storm-petrels are difficult to census accurately (Ratcliffe *et al.* 1998) but the tape response method has become the accepted technique for censussing both storm-petrel species that breed in the British Isles (Gilbert *et al.* 1999). It is labour intensive and time consuming, requiring a minimum of seven days to calibrate the counts in each colony, making it expensive for frequent monitoring. Mark/recapture methods have been suggested as an alternative, but the results can be difficult to interpret, largely because of uncertainty about the origin and distribution of the population they are estimating.

Storm-petrels have been monitored on two small islands off the north and west coast of Scotland during the last nine years using two different methods (Hounsome *et al.* 2002, Hounsome *et al.* 2003, Insley *et al.* 2004a, 2004b). The work on Eilean Hoan started in 1996 and that on Priest Island in 1998. Both islands are Royal Society for the Protection of Birds (RSPB) reserves and Special Protection Areas designated under the European Union Natura 2000 programme, Priest being specifically designated for its European Storm-petrel breeding colony, which is thought to be the third biggest in Britain (Mitchell *et al* 2004).

METHODS

Mark/recapture Throughout the study European Storm-petrels have been caught after dark using mist nets. Tape-luring attracts non-breeders as well as breeders and Fowler & Hounsome (1998) have shown that very few non-breeders are present before the beginning of July so catches, without tape lures, have been taken in the second and third weeks of June. Both of these measures were a deliberate attempt to minimise the number of non-breeding wandering birds trapped and to focus the study on the breeding population at each colony. Captured birds were processed in the order in which they were caught and times were recorded in 10 minute intervals. The processing rate of up to three birds a minute on Priest precluded any close examination of the birds, but on Eilean Hoan there was time to assess the extent and vascularisation of the brood-patch and to measure the wing and weight of the birds.

After initial work to measure the extent of population mixing at sites across Priest Island (Hounsome *et al* 2002), from 2002 onwards catching efforts were focussed on one core site (labelled as MSS in this paper). Eilean Hoan is small enough for most if not all of the population to be caught at the main colony area in a ruined stone fank (sheep holding pen). Exploratory catching was done elsewhere on the island in 2003 and 2005 and this confirmed that birds from the core site were quickly being re-caught elsewhere and that the mixing assumption was reasonable.

Analysis of the mark/recapture results has been carried out using three separate statistical methods. The du Feu method (du Feu *et al* 1983) considers only the retraps caught within each yearly session so that each year's estimate is independent of all other years. The Fisher and Ford and Jolly methods (Fisher & Ford 1947, Jolly 1965) consider only year-to-year retraps ignoring any multiple recaptures within the yearly session. Thus, there are three methods using two completely independent types of mark/recapture analyses which use separate sets of recapture data.

Tape response survey The first full tape response survey at Priest Island was carried out in 1999 with a second in 2004. Both surveys were carried out in July to ensure that the work was done at the optimal period (Ratcliffe *et al.* 1998; Gilbert *et al.* 1999). The tape response survey was carried out and analysed using the methods described by Gilbert *et al.* (1999) and Mayhew *et al.* (2000). To calibrate response rates (i.e. establish what proportion of birds respond to the tape stimulus), a series of 'calibration plots' were repeatedly visited. Tape response surveys require a separate calibration plot for each season and habitat, and a separate calibration exercise for each survey year. Calibration requires repeat surveying and recording of response over the same plots for a minimum seven-day period.

On Priest Island four habitat types were recognised (boulder beach, stone walls, scree and heath/grassland). One calibration plot was established in each habitat and the same calibration plots for each type were used in 1999 and 2004 to determine the response rate of European Storm-petrels in each of these habitats (map and site descriptions in Mayhew *et al*. 2000). Over the seven visits to each calibration plot, an increasing number of responses occurred, with the cumulative number of burrows from which a response had been heard increasing with number of visits. A curve was fitted to the relationship between visit number and cumulative number of responses, and this was used to estimate (i) the eventual number of responses that would have occurred after a large number of visits; and (ii) the response rate on the first visit [a]. The results from all calibration plots in both years were further analysed using a single generalised linear model [b]. The aim of this was to test the degree of association between response rate, and the year, habitat and visit number.

Population estimation broadly followed the procedure used in Mayhew 2000. This was in two stages, firstly the extrapolated number of responses, had the whole island been surveyed, was estimated. Then the population was estimated, as the extrapolated number of responses, divided by the appropriate response rate.

For the boulder beach, scree and stone wall areas, the extrapolated number of responses was the same as the uncorrected number of responses, as these areas were surveyed in their entirety. However, the surveyed area in heath/grass habitats was only 20 quadrats, or 20ha out of a possible 94.68ha. So the extrapolated number of responses, had this whole area been surveyed, was estimated as 94.68/20 times the number of responses from the sampled quadrats. Confidence intervals of the extrapolated number of responses were estimated using bootstrapping [c] (Table 2).

To calculate the population estimates, the extrapolated number of responses in each habitat was divided by the habitat-specific response rate for that year (Table 3). For boulder beach, scree and stone wall habitats, the confidence intervals of the population were taken as the number of responses divided by the lower and upper confidence intervals of the response rate for that habitat in that year (Table 3). For heath/grass habitats, the lower confidence interval of the population was estimated as the lower confidence interval of the extrapolated number of responses, divided by the upper confidence interval of the response rate, and vice versa for the upper confidence interval. For the whole island population, the population estimates in the different habitats were summed. The confidence intervals were estimated using the confidence intervals of the global response rate across all habitats in that year [d]. Population estimates (number of birds) were calculated as twice the number of corrected responses, assuming one pair for each occupied burrow.

The significance of the difference in population estimates between the two years was tested using a resampling procedure used by Sim *et al*. (2005) [e]. Essentially this creates a distribution of differences under a null hypothesis that the years are equivalent, and compares this with the observed difference. Note that for this test, the data we used were the corrected responses, using the mean response estimate for each habitat. The uncertainty in the response rate was not modelled in the analysis.

RESULTS

Mark/recapture The du Feu population estimates (du Feu *et al*. 1983) from this survey are presented in Table 1. Comparison with the estimates presented in earlier years (Hounsome *et al* 2002 and 2003, Insley *et al* 2002, 2004a, 2004b) will show some minor differences. Both the Jolly and Fisher and Ford methods (Jolly 1965, Fisher & Ford 1947) incorporate data for birds caught in previous years. As the study progresses and more birds from earlier years are recaptured there is a progressive updating and improvement of population estimates by these year-to-year methods. On the other hand, the du Feu estimates are unaffected by captures in previous or subsequent years because the method considers only captures and recaptures within each year. The data sets have been cleaned several times over the course of the work so that there may be some small changes from previously published du Feu estimates.

The du Feu estimates for Eilean Hoan show the population fluctuating between about 250 to 800 birds, with an apparent fall in 2004 (Table 1). The estimates for the MSS site on Priest Island range from about 8,000 to about 12,000 but show little indication of a fall in 2004 (Table 1).

The Fisher & Ford method is an old deterministic approach (Fisher & Ford 1947) and assumes a constant survival rate; it consequently gives a smoothed series of population estimates. It is included here only because it can give estimates in the early stages of a study, which this is, considering that some of these birds live for thirty years. The accepted modern method is that of Jolly (1965) and its subsequent developments and the computer programs MARK and POPAN5 have been used to determine the optimal model for these data. Both programs agree that the general model is the best i.e. the model that assumes that both the survival rate and the probability of capture vary with time ($\Phi_t\ p_t$). For Priest this model was the most parsimonious, with an AICc weight of 0.99; it was also the best fit, with a deviance of 132.8. The next most parsimonious model was one in which the survival rate was constant but the probability of capture varies with time ($\Phi_{.}\ p_t$), with an AICc weight of 0.01; this was also the second best fit, with a deviance of 149.7. The same pattern was seen in the Eilean Hoan data, with the $\Phi_t\ p_t$ model being both the most parsimonious and the best fit (AICc weight = 0.85 and the deviance = 246.7); the next best model was again $\Phi_{.}\ p_t$. (AICc weight = 0.15 and deviance = 262.5). The program MARKREC (Hounsome 1978) was used to produce the population estimates (Table 1, and Figures 1 and 2).

Table 1. Summary of mark/recapture population estimates ± = standard error.
Tabel 1. Samenvatting van populatieschattingen met behulp van vangst/terugvangst. ± = standaardfout.

Island	Method	Survival	1998	1999	2000	2001	2002	2003	2004
Eilean Hoan									
	duFeu	-	-	-	-	464 ±73	391 ±80	775 ±210	267 ±39
	Jolly	0.7206 ±0.1294	296 ±74	308 ±51	621 ±109	474 ±77	362 ±63	685 ±168	454 ±129
	F&F	0.8386 ±0.0262	324	271	546	490	523	628	816
Priest MSS									
	duFeu	-	-	-	-	11,514 ±3,024	8,036 ±918	11,804 ±1,601	9,450 ±1,624
	Jolly	0.8484 ±0.0820	-	-	-	8,141 ±1,460	7,929 ±841	8,439 ±846	6,718 ±808
	F&F	0.8448 ±0.0158	-	-	-	11,638	8,500	7,477	7,279

The estimates of the overall survival rate are, with the exception of the Jolly estimate for Eilean Hoan, consistent both within themselves and with published estimates of 0.86 (Dagys 2001) and 0.87 (Scott 1970). Note that the standard error for the Jolly survival estimate for Eilean Hoan is very large; it is expected that in future years this estimate will come into line with the others. Most published survival estimates are derived from recoveries of dead birds, but mark/recapture estimates must necessarily include emigration so they are usually much lower than those derived from recoveries of dead birds only. The fact that our estimates are only slightly below those for dead birds indicates that there is little emigration from our breeding populations. This, together with the agreement of three mark/recapture methods gives us confidence that the population estimates are reasonable and that the captured birds are breeders not non-breeding birds. There is also some synchronicity between the estimates for the two islands which might reflect real natural processes and which add a degree of confidence to the population estimates.

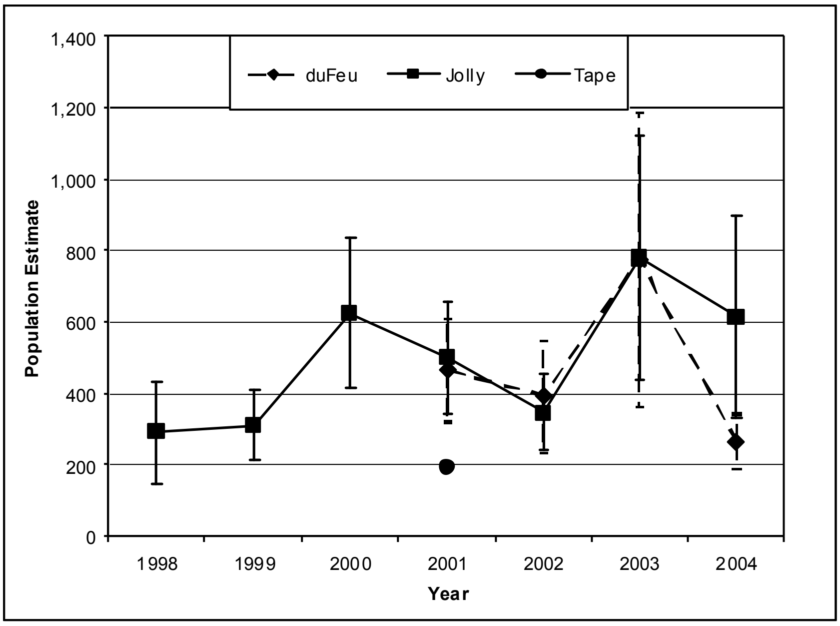

Figure 1. Eilean Hoan Storm Petrel population estimates for the period 1998-2004, with 95% confidence limits (the limits for the tape response estimate in 2004 are too small to show on this graph).
Figuur 1. Populatieschattingen van Stormvogeltjes op Eilean Hoan, 1998-2004, inclusief 95%-betrouwbaarheidsintervallen (resultaten van playback-methode in 2004 zijn te klein om in de grafiek zichtbaar te zijn).

Table 2. Response rate to taped call playback by European Storm-petrels in each of the habitat types surveyed on Priest Island in 1999 and 2004.
Tabel 2. Antwoordfrequentie van Stormvogeltjes bij playback-methode per habitattype, zoals onderzocht is op Priest Island in 1999 en 2004.

Habitat	1999		2004	
	Response rate	95% C.I.	Response rate	95% C.I.
Boulder Beach	0.47	0.40 - 0.54	0.21	0.17 - 0.27
Stone Walls	0.42	0.38 - 0.45	0.17	0.04 - 0.29
Scree	0.48	0.45 - 0.50	0.26	0.17 - 0.34
Heath/Grassland	0.36	0.27 - 0.44	0.21	0.10 - 0.31
All Habitats	0.41	0.24 - 0.59	0.27	0.21 - 0.34

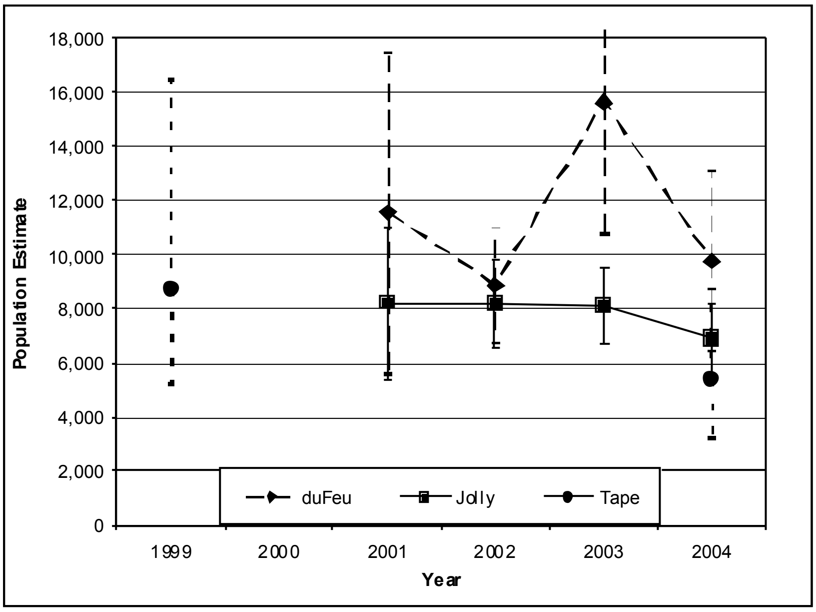

Figure 2. Priest Island European Storm-petrel population estimates for the period 1999-2004, with their 95% confidence limits. It is important to note that the tape response estimates are for the whole island, whereas those for Jolly and du Feu are for a single site (MSS). Also note the very large 95% limits of the tape response estimates compared with those for Eilean Hoan (fig.1).

Figuur 2. Populatieschattingen van Stormvogeltjes op Priest Island, 1999-2004, inclusief 95%-betrouwbaarheidsintervallen. Nota bene: de schattingen aan de hand van de playback-methode zijn voor het gehele eiland, terwijl die van Jolly en du Feu betrekking hebben op één (studie)gebied (MSS). Let ook op de zeer ruime 95%-marges van de playback-methode in vergelijking met die van Eilean Hoan (fig.1).

Tape response survey On Priest Island twenty 1ha plots of heath/grassland were surveyed, representing only 21% of the total area of this habitat type so this was extrapolated to give a total number of European Storm-petrels recorded in that habitat area, before the response rate was applied. All the areas of boulder beach, stone wall and scree were surveyed, so no extrapolation was needed.

Table 2 shows the response rates (with upper and lower 95% confidence intervals) for each habitat in each of the two years, 1999 and 2004, and the mean response rates across all habitats in the two years. Habitat specific estimates of response rate are taken from the curve-fitting as described in the Methods. The modelling analysis of response rate data from the calibration plots (see Methods) suggested that the difference in response rates between years was significant (p=0.03), and that the response rate in 1999 was about 1.5 times higher than that in 2004. The model simplified to one suggesting that only 'year' was significantly associated with response rate, implying that differences in response rate between habitats and visits were minor. The response rates for all habitats combined, in each year, and their confidence limits, were taken as the estimates for the two levels, 1999 and 2004, of the categorical variable 'year', in this model (Table 2).

Table 3. Tape response calculation of AOS by European Storm-petrels from the main survey for the four breeding habitats and the total population estimates for Priest Island in1999 and 2004.
Tabel 3. Berekening aan de hand van de playback-methode van het aantal AOS van de belangrijkste inventarisatie van de vier broedhabitats en populatieschattingen voor Priest Island in 1999 en 2004.

	Number of responses		Extrapolated responses		AOS (after correction for response rate)		95% confidence limits (after bootstrapping)		95% confidence limits of correction factors	
Habitat	1999	2004	1999	2004	1999	2004	1999	2004	1999	2004
Boulder Beach	25	24	(25)	(24)	53	112			47-63	88-144
Stone Wall	72	34	(72)	(34)	172	198			159-190	119-879
Scree	679	230	(679)	(230)	1,429	900			1,358-1,516	685-1,388
Heath/Grassland	206	64	975	303	2,716	1,458	2,149-3,270	819-2,139	1,774-4,300	555-4,684
All Habitats	982	352	1,751	591	4,370	2,670	3,800-4,920	2,030-3,350	2,610-8,220	1,590-4,370
Population Estimate					8,740	5,340	7,600-9,850	4,060-6,700	5,220-16,440	3,180-8,740

The responses and population estimates on Priest Island for 1999 and 2004 are shown in Table 3. It is clear that, with the exception of the boulder beach and walls, the responses to the taped calls were many fewer in 2004 than in 1999. Overall population estimates in the two years were 8,740 (95% cls: 5,220-16,440) birds in 1999 and 5,340 (95% cls: 3,180-8,740) birds in 2004.

The between years difference in corrected responses was strongly significant (*p*=0.006) using the randomisation test described in Methods. It must be emphasised that these are estimates for the whole island whereas the mark/recapture estimates are for only the MSS site.

A tape response survey has been carried out comprehensively on Eilean Hoan only once during the study period, in 2001, when the whole island was surveyed over a seven day period. The much smaller size of both the island and European Storm-petrel colony made this possible rather than having a sample and calibration survey as employed on Priest Island.

The tape response population estimate for Eilean Hoan in 2001 was 194 (95%CI 188-200) (Insley *et al* 2002). Note that this is much less than the mark/recapture estimates between 1998 and 2004; indeed, it is close to the numbers actually caught in each of these years. In 2001 the mark/recapture estimates were: du Feu, 464, Jolly, 474 and Fisher & Ford, 490, with 150 birds being caught (Figure 1). It is clear that there were many more birds present than would be expected from the tape response estimate.

DISCUSSION

There are two main questions raised by these results: why are the tape response estimates lower than the mark/ recapture ones, particularly for Priest Island where the latter measured only one section of the island? And, was there a genuine reduction in the breeding population in 2004? A subsidiary question might be: if there really was a reduction in 2004 does it represent a true reduction in the colony size, or just an exceptional bad year?

There are four possible answers to the first question:

1) mark/recapture is falsely high, possibly because it is including pre-breeders or because it includes birds that are alive but not actually breeding or because it is a flawed statistical method or at least, is not suited to these circumstances.

2) tape response is falsely low, possibly because it is not detecting all the occupied nests even after calibration or because of surveyor error or because it is a flawed method.

3) both methods are giving inaccurate estimates.

4) both methods are correct, but they are estimating different aspects of the population.

The fact that the two quite independent types of mark/recapture analysis give similar results and that the estimated survival rates are so close to the published ones means that the population estimates are not likely to be seriously biased. Also, the data are ideal for such analysis, with so many extensive individual recapture histories and such a high proportion of retraps (around 30%). So, answer 1) does not seem likely. The fact that tape lures were not used and that very few immatures are present in mid June means that these estimates are likely to be of adults only.

The tape response method has become the standard way of estimating apparently occupied sites and has been extensively used and refined. There is no reason to suspect that it is a flawed method. It is, however, more dependent upon the skill of the surveyors than is the mark/recapture method (although trained ringers are needed for mark/recapture projects), so it is just possible that the surveys themselves were flawed rather than the method itself. The teams on Priest and Eilean Hoan were experienced and dedicated, and the differences in response rate on Priest were so obvious that it is unlikely that this was significant observer error. So answer 2) does not seem likely. It is also unlikely that both well-tried and tested methods are giving wrong estimates.

So we are left with the possibility that the different methods are estimating different components of the population. The tape response method is explicitly estimating the number of apparently occupied sites, in a particular year. This estimate can be doubled to give an estimate of the number of birds occupying burrows. What does the Jolly mark/recapture method estimate? The answer is simple: it is the number of birds in the 'pool' from which the samples have been taken. In others words, it estimates the number of birds in the population, *whether they are present on the sampling nights or not*. It would include birds taking a year off and not present as well as birds present but not actually breeding in that year. So it is estimating the breeding population of the islands, not the numbers actually occupying burrows during the survey. As noted in the Methods section, it is thought that there are very few immature birds present at these colonies this early in the breeding season so the estimate is of the mature, potentially breeding, population. Later in the season up to half the birds in the burrows can be non-breeders (Cramp & Simmons 1977), and these birds are known to sing (*op. cit.*) and may respond to taped calls and thus be included in estimates made by the tape-response method.

The mark/recapture estimates show a modest fall in the population on both Eilean Hoan and Priest Island in 2004, but only as part of the normal fluctuations over the period (Figures 1 and 2). No tape response estimates were made on Eilean Hoan in 2004, but those for Priest Island show a considerable fall – from a population of 8,740 in 1999 to 5,340 in 2004. If the suggested reason for the differences between the estimates by the two methods, above, is correct then it could be said that, yes, there were fewer occupied burrows in 2004 than in 1999, but that does not necessarily mean that the breeding population had fallen. The birds could be alive but conditions were such that many of them chose not to breed or they were in too poor a condition to breed.

Another possibility might be that normal numbers were present early in the season when the mark/recapture estimate was made, but that conditions were such that many of them abandoned their breeding attempts. Thus, birds might have returned to the breeding colony but had either laid and failed, or were simply not in good enough condition on their return to lay and were therefore not occupying the nesting burrows later in July, when the tape response survey was carried out.

It is difficult to know whether the fall in the tape response estimates from 1999 to 2004 indicates a genuine decline in the breeding population of European Storm-petrels on Priest Island, or whether it is just a sign of a poor breeding season. It has been well documented that other seabirds around Scotland have had a generally poor breeding season in 2004 (Mavor *et al*. 2005). This may be related to the increased Atlantic inflow changing the species composition and timing of the bloom and/or to rising sea temperatures causing a shift northwards in plankton populations. On the other hand it might be that the surveys were conducted too early in 2004. We go on the dates recommended in Gilbert *et al.* (1999) which is based on the normal peak of responses, but if laying was delayed and all the birds were not yet on eggs when we carried out the survey it might result in an underestimate of the number of apparently occupied sites. Laying date has been shown to vary by up to a month in work done in Brittany (Cadiou, 2001) with the date by which 50% of eggs had been laid varying from mid May to mid July. So it is possible that the low population estimate in 2004 is because not all the birds were yet incubating. We propose to install nest boxes so that we can determine the breeding status of the colony on our visits; this will help us interpret future tape response estimates.

Continued monitoring over the next five years will answer some of these questions. Mark/recapture estimates can be made in every year and trends may become apparent. So far there have been only two tape response estimates on Priest Island and one on Eilean Hoan and it is impossible to identify trends from only two estimates. Even if the survey on Priest Island is repeated in another five years (2009) there will be only three points.

So, which method is best for monitoring European Storm-petrel populations? The tape response method has the advantage in that it is widely used and is standardised so that comparisons can be made not only within years on one island but among other islands. Other advantages are that it can be done in daylight, you don't need a ringing license or ringing equipment, it's spatially explicit which enables sampling, it can be applied irrespective of colony size and it can map breeding distribution within islands. It is also likely to give good estimates of the number and distribution of occupied sites, but these do not necessarily correspond to the number of birds available to breed. It also suffers from the fact that it is hard to calibrate for birds that don't respond and it can be very laborious for large islands/colonies. In most circumstances it is not practical to carry out a survey every year so that the normal annual fluctuation in the number of pairs attempting to breed will be obscured. In 2005 a trial was begun on Priest Island to assess whether annual monitoring of a sample of tape response plots can be used to assess annual population fluctuations on the island.

The mark/recapture estimates refer to a more nebulous concept of the population – the number of potential breeders in the wider population using each island. It has the advantage that it is less labour-intensive and so is practical to carry out annually. This is likely to give a better indication of the annual population fluctuations and will highlight trends with a finer resolution. The Jolly method also gives estimates of survival rate and, crucially, recruitment rate and it thus allows diagnosis of the aspects of the life history that are driving population change which has the potential to inform conservation management. The disadvantages are that personnel have to stay overnight, they need to be trained ringers and they need ringing equipment. It is worthwhile only for colonies over a certain size, the proportion of large colonies sampled is often unknown and there is a risk of including non-breeders if the visits are not correctly timed.

At present it is not possible to say which method is best for European Storm-petrel monitoring as they are estimating slightly different things. It could be said that it is best to continue using the tape response method because most other seabird populations are estimated on the basis of the number of occupied nests. On the other hand, mark/recapture methods give annual estimates not only of the population but of survival and recruitment. Another five years of mark/recapture estimates, annual tape response estimates for selected plots and another full tape response estimate in 2009 will go a long way towards resolving the issue and hopefully will lead to the development of more robust monitoring methods for these internationally important populations of European Storm-petrels.

ACKNOWLEDGEMENTS

We are grateful to all of the RSPB staff and volunteers who have worked with us at Priest Island and Eilean Hoan , and to SNH for their continued support of this work which is attempting to resolve the issues around using mark recapture techniques to find a time-efficient method for monitoring European Storm-petrel populations. Special thanks go to Norman Ratcliffe and Mark Hancock (RSPB) who carried out the statistical analysis for the tape response work.
Finally we acknowledge our gratitude to Hamish Sinclair of Achiltibuie and James and Michael Mather of Durness for taking us to and from the islands in their fishing boats. Their arrival to collect us after a hard few days when the weather has made a pickup look doubtful has always been a high point in our island going.

MONITORING VAN STORMVOGELTJES *HYDROBATES PELAGICUS*: EEN VERGELIJKING VAN DE RESULTATEN VAN VANGST/TERUGVANGST- EN PLAYBACK-METHODEN

Op twee Schotse eilanden werden twee technieken gebruikt om de grootte van de broedpopulatie van Stormvogeltje *Hydrobates pelagicus* te bepalen: de playback-methode (in 1999 en 2004) en drie typen van vang/terugvangmethoden (jaarlijks sinds 1998; vangen, merken, vrij laten en terug vangen). De playback-methode leverde lagere schattingen op dan de vang/terugvangmethode, hetgeen vragen oproept over de aannames en beperkingen van de technieken om Stormvogeltjes te monitoren. Een ogenschijnlijke afname in een populatie op Priest Island in 2004, aangetoond met de playback methode, wordt bediscussieerd.

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ENDNOTES

a. The formula used in the curve-fitting program was as Mayhew *et al*. (2000), i.e.:

$$CUMULA = a * (1 - exp (-1 * b * VISNUM))$$

where CUMULA is cumulative total number of responses and VISNUM is visit number to the calibration plot (1-7). The value 'a' estimates the asymptote - the 'true' total no. birds in the plot; while the value for 'b' estimates the shape of the curve. The 'visit 1 response rate' (v1rr) is estimated as the value of CUMULA for VISNUM=1, divided by the true total (a). This simplifies to:

$$v1rr = 1-exp(-1 * b)$$

From this equation, and the confidence intervals of the 'b' parameter from the curve-fitting, the confidence intervals of the response rate were calculated. The curve-fitting was carried out using the NLIN procedure in SAS version 8 which uses least squares to fit a curve to the function specified by the user. At one calibration plot in one year, it was impossible to fit a curve as there was a large jump in the cumulative number of responses between two visits. In this case, the cumulative total number of responses (12) after seven visits was used directly as the estimate of the 'true' total no. birds in the plot. The mean and 95% cls of the visit one response rate were estimated by bootstrapping: 1000 'bootstrap samples' each of seven values, were selected at random, with replacement, from the seven numbers representing the responses from the seven visits. The mean response rate of each sample was calculated, as the mean number of responses divided by 12. The mean and confidence intervals of these 1000 means was used as the mean and confidence intervals of the response rate for this habitat in this year.

b. The model fitted was a GLM with repeated measures (proc Genmod in SAS, using a GEE approach to model correlation between repeated measures), with (responses)/(estimated total no. occupied burrows (i.e. the parameter 'a' from curve-fitting exercise) as the y variable in a binomial model. Each trial (i.e. visit to a calibration plot) contributed a separate row of data, the repeated trials at each stratum in each year were modelled as correlated with each other using a repeated command which assumes that visits closer together were more strongly correlated than visits further apart. The explanatory variables were Year (1999 or 2004), Habitat (a four-level categorical variable representing boulder beach, scree etc), and TrialNumber (1-7), and all their interactions. Using backwards deletion and a threshold p value of 0.05, only 'year' remained in the model (p=0.03) suggesting that response rates differed between years but not between habitats or between trials at each stratum.

This involved selecting, at random, with replacement, 20 values from the list of observed responses for the 20 quadrats in this stratum, taking the mean of each sample, and multiplying up (by 94.68/20) to give an estimate for the whole heath/grass area. This was repeated 1,000 times and the 25th largest and 25th smallest values of the estimated number of responses for the whole area were taken as the 95% confidence intervals.

d. The total population estimate, calculated from the sum of estimates of the different habitats, was multiplied by the global mean response rate for that year, then divided by the upper confidence limit of this response rate to give the lower population confidence limit (and vice versa to calculate the upper confidence limit).

Briefly, this involves selecting, for each survey plot, one of the two year's data at random. The data for the other year is then placed beside this in a second column. This is done for all plots. The difference in population is then calculated for the two years. This process is repeated 1000 times and the resulting distribution (based on the null hypothesis that the years are equivalent) is compared with the observed difference. If differences as large as that observed, are rare within this distribution, then the observed difference is unlikely under the null hypothesis, with a level of significance which can be estimated from the distribution. Further details in Sim *et al*.

CENSUS OF EUROPEAN STORM-PETRELS *HYDROBATES PELAGICUS* ON SKOMER ISLAND

JUAN G. BROWN

Brown, J.G. 2006. Census of European Storm-petrels *Hydrobates pelagicus* on Skomer Island. Atlantic Seabirds 8(1/2): 21-30. *Comprehensive tape playback surveys were carried out in 2003 and 2004 in order to provide repeatable estimates of the number of European Storm-petrels* Hydrobates pelagicus *breeding on Skomer Island. This included the measurement of response-rates by repeated visits to two sub-colonies, one each year. In 2003, the cumulative number of Apparently Occupied Sites was still increasing on the 11th and final visit, and so the data were extrapolated to predict an asymptote. The 2004 calibration plot levelled out after the 7th visit (probably due to the consistent use of a more effective tape) but the discovery of a new site on the 13th visit resulted in a slightly higher predicted asymptote than that was found. The respective response-rates of 0.27 and 0.44 were significantly lower than previously thought, and thus give higher population estimates when responses were adjusted by the reciprocal correction factors. The Skomer European Storm-petrel population is now thought to be in excess of 300 AOS, and is becoming a significant component of the Skomer and Skokholm SPA (now the population on the latter is apparently declining). Tape quality has a significant effect on the number of responses elicited, which has important implications for future surveys.*

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INRODUCTION

The estimated number of European Storm-petrels *Hydrobates pelagicus* breeding on Skomer Island has ranged from 55 to 1200 pairs, using the two apparently incomparable methods of capture-mark-recapture and diurnal tape playback (see Brown 2005a and references therein). Population estimates using playback have previously involved multiplying the number of responses by a 'correction factor' of 1.37, based on the assumptions that 100% of males and 46% of females respond to playback (James 1984), and that both sexes share incubation equally (Scott 1970).

There has been concern raised in some quarters as to the effect of predation by the introduced Little Owl *Athene noctua* on the Storm-petrel population, but any evidence for a decline is inconclusive due to the inherent census difficulties.

In order to monitor the population dynamics of the Skomer Storm-petrel population (and the effects of any future experimental manipulation of the Little Owl population), a repeatable census technique must be developed.

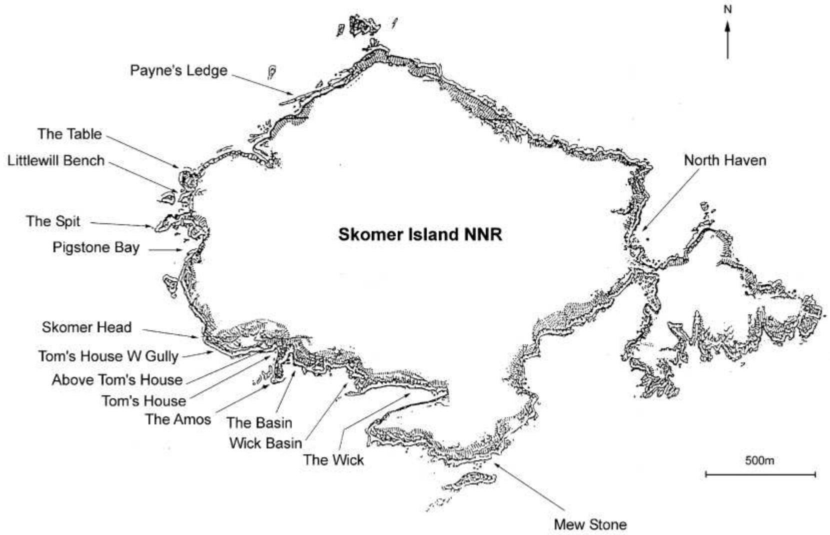

Figure 1. Location of European Storm-petrel sub-colonies on Skomer Island.
Figuur 1. Ligging van subkolonies van Stormvogeltje op Skomer.

In 2003 and 2004 all known sub-colonies and any other suspected areas were searched thoroughly using diurnal tape playback, and response-rates established from repeated visits to selected sub-colonies, with the aim of providing repeatable estimates of the number of European Storm-petrels nesting on Skomer Island (for more detailed reports see Brown 2005 a&b).

METHODS

All known Storm-petrel sub-colonies were visited, and carefully searched for likely nest site entrances. Smell was used to identify prospective nest holes in some instances, but by and large this was found to be very subtle and non-perceptible in many cases. A tape recording of a calling European Storm-petrel ('terr chick' and purring male) was played close to (generally within 10cm from) a prospective nest site entrance on a small Sony cassette recorder at near full volume (what was thought to be close to 'natural' volume) for roughly 30 seconds, and a reply listened for (either a creaky 'terr chick' call, the purring male 'song', or both). Nest-site entrances from which responses were elicited were individually marked (usually numbered) using paint or Tip-Ex ('correction fluid'). Some markings from previous years were still visible.

2003 In 2003, visits were carried out between 5 and 22 July between 08.30 and 20.00h, except for an early visit to the Mew Stone sub-colony on 23 June, and a repeat visit to North Haven on 14 August to test the effects of a late season visit on adult and chick responses. The Mew Stone sub-colony was visited twice, and Tom's House five times. The mean number of responses per visit was used in the calculation of apparently occupied sites (AOS) for these sub-colonies. Other potential sub-colonies (except North Haven) were visited just once.

2004 In 2004, the bulk of the work was carried out from 2-16 July, with three other potential sub-colonies ('Above Tom's House', Amos and 'Tom's House West Gully') checked on 26 and 31 July respectively. Two visits were made to the Mew Stone, and other sub-colonies (apart from Tom's House, see below) were visited once only.

Measurement of response-rates In 2003, the North Haven sub-colony was chosen as a calibration site, as it is a compact area of homogenous habitat which could be checked thoroughly and relatively quickly. Eleven visits were made between 5 and 22 July, with an additional visit on 14 August (see above). An effort was made to vary the time of day for each visit and the tape used. Nest-site entrances from which a response was obtained were numbered with Tip-Ex.

In 2004, the Tom's House sub-colony was selected, to provide a contrast in habitat (Tom's House is a natural boulder beach while North Haven is a man-made stone-clad bank) and geographical spread (the two sub-colonies are at opposite ends of the island to each other). Tom's House is also one of the sub-colonies where access is more straightforward. Fifteen visits were made between 2 and 16 July, between 10.35 and 18.50h.

Tapes In 2003 the following tapes were used, in the case of Tapes 1 and 2 because they were present on the island and had been used in previous playback. Tape 4 was only acquired in the third week in July:

- Tape 1: loop tape from Warden's office with quite loud, harsh, sharp, predominantly 'terr chick' with some purring. Source unknown.
- Tape 2: recording made from 'Bird Sounds' tape. Soft, somewhat muffled, purring.
- Tape 3: a hybrid of 1 and 2.
- Tape 4: loop recording from CD recorded on Skokholm in 1998. Predominantly purring. Relatively good quality.

In 2004 Tape 4 only was used.

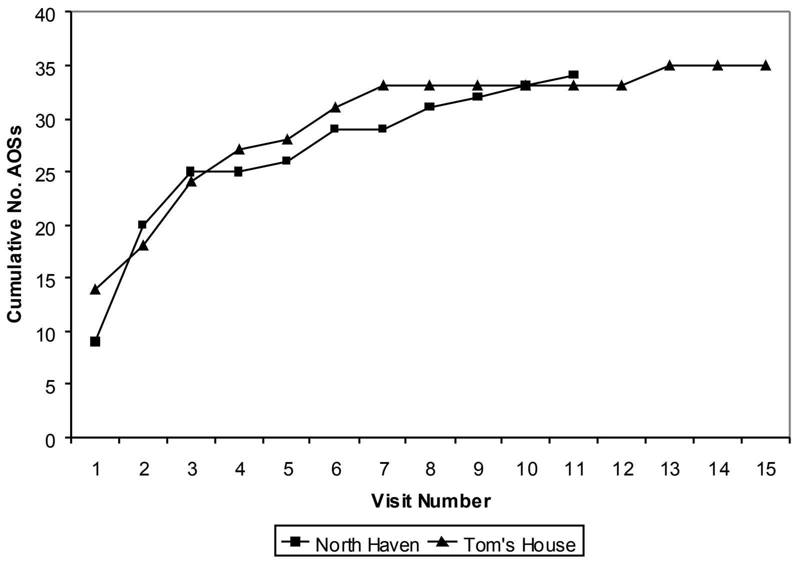

Figure 2. Cumulative increase in the number of Apparently Occupied Sites identified over 11 visits to the North Haven sub-colony in 2003, and 15 visits to the Tom's House colony in 2004.

Figure 2. Cumulatieve toename van het aantal 'schijnbaar bezette nesten' (AOS) tijdens 11 bezoeken aan de subkolonie North Haven in 2003 en tijdens 15 bezoeken aan de kolonie Tom's House in 2004.

RESULTS

Response-rates 34 AOS were found over 11 visits to North Haven, but a new site was still found on the eleventh visit (Fig 2), suggesting that even 11 visits was probably too few to find all occupied sites. In 2004, no new sites were found after the seventh visit (33 AOS in total), until the 13th visit, when two others were discovered (total 35 AOS) (Fig 2). In order to predict asymptotes, i.e. the total number of AOS at each sub-colony, Fowler's (2001) method was used, as recommended in App II of Mitchell *et al.* (2004). This involves the reciprocal transformation of both axes in Figure 2, with the reciprocal of the y intersect the predicted asymptote. (N.B. Mitchell *et al.* actually erroneously state that the y axis is 1 / number of responses, whereas it should be 1 / the cumulative number of responses). Thus, the predicted total numbers of AOS were 50.8 at North Haven in 2003, and 39.5 at Tom's House in 2004.

Table 1. Results from Storm-petrel tape playback studies on Skomer 1981-2004 (brackets denote most recent data where sites were not visited).
Tabel 1. Resultaten van playback-studies aan Stormvogeltjes op Skomer 1981-2004. (tussen haakjes staan de meest recente data indien een studiegebied niet was bezocht).

	2004	2003	2001	2000	1998	1997	1996	1993	1981-82[1]
North Haven	13	13.8 (*n*=11)	8	11	21	17	10	(10)	5
Mew Stone	23.0 (*n*=2)	24.5 (*n*=2)	38	11	9	12	17	10	40
The Wick	3	-	-	-	-	-	-	-	-
Wick Basin	12	5	10	4	2	2	3	8	10
The Basin	0	2	0	1	0	2	2	(2)	10
Tom's House	17.4 (*n*=15)	11.2 (*n*=5)	9	6	3	4	8	6	20 incl. Amos
Above Tom's Hse	1	-	-	-	-	-	-	-	See above
The Amos	4	-	-	0	(2)	(2)	2	(2)	See above
TH West Gully	1	-	-	-	-	-	-	-	-
Skomer Head	1	-	-	-	-	-	-	-	-
Pigstone Bay	3	2	1	1	0	1	3	(3)	Not visited
The Spit	5	4	6	3	1	(1)	(1)	(1)	10
Littlewill Be.	20	14	7	7	0	(0)	(0)	(0)	Not visited
The Table	7	6	2	2	2	(2)	(2)	(2)	5
Paynes Ledges	0	0	0	0	-	-	-	-	-
Total	110.4	82.5	81	46	40	43	48	44	-
No. pairs[2] (95% CL)	251 (219-295)	303 (258-375)	388 (331-468)	220 (188-266)	192 (164-231)	206 (176-249)	230 (196-277)	211 (180-254)	

N.B. figures expressed to decimal places in 2003 and 2004 are means of a number of visits, thus giving an overall number of responses per visit. In 1996-1998, the highest figures from two visits were used, which would actually produce overestimates when multiplied by the correction factor. [1] Pairs rounded up to nearest 5. [2] Number of pairs = responses x 2.27 in 2004, 3.67 in 2003, 4.79 rest

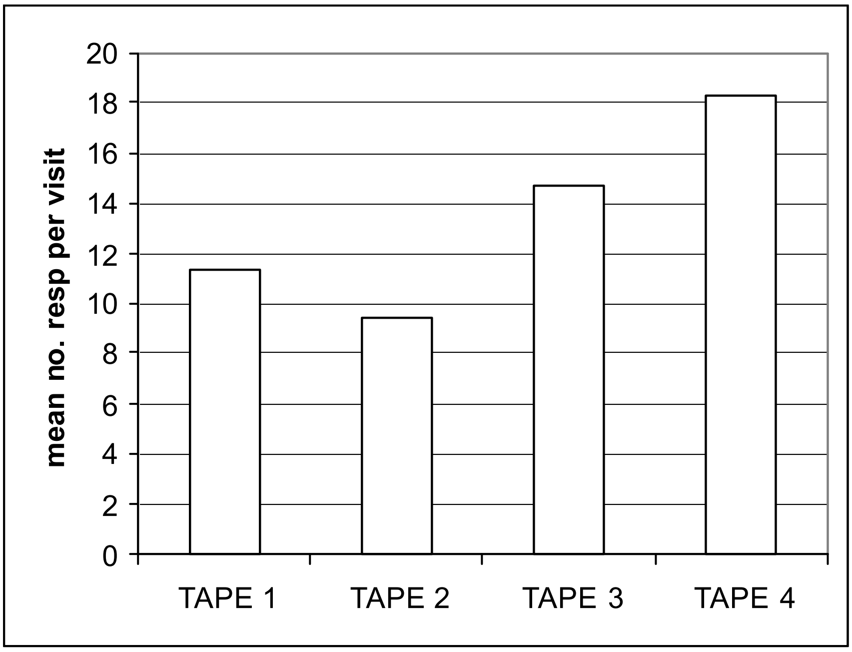

Figure 3. Effect of Tape Quality on Response-rate
Figuur 3. Effect van de kwaliteit van de geluidsopname op de antwoordfrequentie.

Replies from a mean of 13.8 nest sites were recorded per visit at North Haven (95% CL 11.4 - 16.2), giving a mean response-rate of 0.27 (95% CL 0.22 - 0.32). At Tom's House, a mean of 17.4 responses were elicited per visit (95% CL 14.8 – 20.0); a response-rate of 0.44 (95% CL 0.37 – 0.51).

Population estimates Responses were elicited from a mean of 82.5 sites in 2003 and 110.4 sites in 2004 (Table 1). The 2003 figure was just 1.5 up on 2001 overall (Table 1), but still the highest number of responses ever elicited on Skomer using this methodology. The 2004 figure was a further 33.8% rise.

Multiplying the mean number of responses by their respective correction factors (reciprocals of the response-rates i.e. 3.67 and 2.27) gives population estimates of 303 (95% CL 211-298) AOS in 2003 and 251 (95% CL 282 -398) AOS in 2004 (Table 1).

Effects of time of day, stage of survey period, and tape quality There was no effect of time of day on response-rate (ANOVA of response rate by 4-hour period [0800-1200 etc.]; $F_{2,8} = 0.14$, P=0.9), nor July date ($r^2 = 0.17$, $F_{1,9} = 1.82$, $P = 0.21$).

Tape quality had a significant effect on the number of responses elicited (ANOVA $F = 5.98$, $P = 0.02$). More birds responded to Tape 4 (mean 18.3 responses, se 1.67) than tapes 1, 2 and 3 (with means of 11.3 [se 1.45], 9.5 [se 2.85] and 14.7 [se 1.67] respectively) (Fig 3), although Tape 3 ('hybrid' of 1 and 2) was not significantly different to the others (using Tukey's pairwise comparisons). Tape 4 also yielded the highest number of responses at Tom's House in 2003, and was used on the penultimate visit.

Chick responses Chicks responded to tapes (peeping call) at seven sites at North Haven in 2003, the first on 20 July, and three sites at Tom's House in 2004, first on 14 July. (Where chick calls were not accompanied by an adult, they were not registered as responses in the response-rate calculation). North Haven was revisited on 14 August 2003 to test the effect of such a late visit on response-rate, and to establish whether chicks responded alone to tapes (which would have implications on productivity measurement). Only one response was elicited and no chicks were heard.

DISCUSSION

Skomer Storm-petrel population The revised population estimates are considerably greater than those from previous playback surveys, as a result of the application of significantly higher correction factors than the 1.37 previously used (based on James'[1984] assumptions). There has also been a big increase in the actual number of responses obtained since 2000. The further big jump in 2004 (an increase of 33.8% on 2003) can be largely attributable to the consistent use of the most effective tape (Tape 4) throughout the 2004 survey period. In fact, 76.3% of that increase can be attributed to use of a better tape (based on the fact that Tape 4 elicited 35.5% more responses than the mean of Tapes 1,2 and 3, and Tape 4 was only used 27.2% of the time in 2003). Other causes of the observed increase in the number of responses elicited by playback in recent years are the discovery of new sub-colonies, and the cumulative search effort of previous surveys (many Apparently Occupied Sites from previous surveys are still marked, thus increasing search efficiency).

The results from years prior to 2003 have been revised by multiplying the number of responses by a correction factor equalling the inverse of the mean response-rate of Tapes 1 and 2, as it is assumed that these tapes were the ones used in previous surveys (Table 1). As they were the least effective tapes, a rather large correction factor of 4.79 (95% CL 4.09-5.78) is derived. A larger potential for error must be borne in mind with these data, due to the smaller sample size and larger extrapolation.

Nevertheless, the estimated number of pairs of European Storm-petrel now breeding on Skomer is as high as 388, which could be regarded as a minimum as it is unlikely that all sites were found, and new sub-colonies continue to be discovered. With the population on Skokholm now thought to be as low as 1009 AOS (Thomson 2005), the Skomer Storm-petrel population is becoming a significant component of the Skomer and Skokholm SPA.

Chick responses and non-breeder bias The complete lack of chick responses on the mid-August visit suggests that chicks replied to tapes when newly hatched, but not when they were over seven days and no longer brooded by their parents. The reason for this may well be that a fidgeting parent, agitated by the intrusion of a tape played at the burrow entrance inadvertently wakes the chick and provokes begging. The chick would presumably only normally associate parental activity during 'changeover', when a feed would ensue. So, the chick is not responding directly to the tape, but to the tape-induced activity of the adult.

The mid-August visit showed a near-cessation of responding adults. While this demonstrates that this stage of the season is unsuitable for playback surveys, it also suggests that non-breeders occupying burrows at this time of year are not a significant bias. Ratcliffe *et al.* (1998) also found that non-breeding birds were unlikely to constitute a serious bias in estimation of breeding populations during diurnal playback surveys of European Storm-petrels.

Recommendations Tape quality is clearly highly important when conducting playback surveys. In order to provide as accurate an estimate as possible, the tape which is likely to produce the greatest number of responses should be consistently used. At the very least, response-rate measurement should be a part of every survey, to test tape efficiency and adjust the data accordingly.

North Haven and Tom's House are the most accessible large sub-colonies on Skomer, and their convenient contrasting habitat type and geographical locations render these sites suitable to test variations in response-rate further. The results from 2004 suggest that an asymptote may be reached as early as the seventh visit with the consistent use of a good quality tape (the two new sites discovered on the 13th visit may have been late pairs, non-breeders, or been overlooked on previous visits).

Once variations in response-rate (and their causes) are established, we will be closer to standardising the playback technique and hence repeatable censuses which will enable trends in the population to be monitored.

Results from tape playback surveys have contrasted strongly with ringing studies, with both techniques suffering from inherent biases. Further disadvantages of census by ringing include the necessity to access potentially dangerous areas at night, and disturbance of birds. Perhaps ringing should not be completely discounted, however, as a tool to compliment playback surveys, and provide data comparable with previous capture-mark-recapture studies.

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The 2003 and 2004 surveys were carried out by the Wildlife Trust of South and West Wales under contract by the Countryside Council for Wales. Thanks to Lizzie Wilberforce and Catherine Gray for processing some of the statistical analyses.

INVENTARISATIE VAN STORMVOGELTJE *HYDROBATES PELAGICUS* OP SKOMER

In 2003 en 2004 werden uitgebreide inventarisaties - met behulp van playback van geluidsopnames (playback-methode)- van Stormvogeltjes *Hydrobates pelagicus* uitgevoerd teneinde vergelijkbare schattingen te krijgen van het aantal broedpaar op Skomer. Het bepalen van de antwoordfrequentie door middel van meerdere herhaalde bezoeken aan twee subkolonies, elk in een jaar. In 2003 nam het cumulatieve aantal 'schijnbaar bezette nesten' (AOS) tijdens het elfde en laatste bezoek nog steeds toe. Derhalve werden de data geëxtrapoleerd om de asymptoot te berekenen. In 2004 vlakte de calibratieplot af na het 7^{e} bezoek (waarschijnlijk als gevolg van gebruik van een effectievere geluidsopname), maar de ontdekking van een nieuw nest tijdens het dertiende bezoek resulteerde in een iets hogere berekende asymptoot dan gevonden. De antwoordfrequenties van respectievelijk 0,27 en 0,44 waren significant lager dan voorheen werd gedacht, hetgeen leidt tot hogere populatieschattingen indien deze correctiefactoren worden toegepast. De populatie op Skomer wordt nu geschat op meer dan 300 AOS; waarmee Skomer een belangrijk onderdeel begint te worden van het Vogelrichtlijngebied (SPA) Skomer and Skokholm, zeker nu de populatie op het laatste eiland blijkbaar afneemt. De kwaliteit van de geluidsopname heeft een significant effect op het aantal 'uitgelokte' antwoorden, hetgeen belangrijke implicaties heeft voor toekomstige inventarisaties.

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COASTAL MEDITERRANEAN STORM-PETREL *HYDROBATES PELAGICUS* POPULATIONS: ISOLATED SMALL BREEDING SITES OR OUTLYING SUBCOLONIES OF LARGER BREEDING COLONIES?

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Gutiérrez, R., López, F., Ramal A. & Guinart, E. 2006. Coastal Mediterranean Storm-petrel *Hydrobates pelagicus* populations: isolated small breeding sites or outlying subcolonies of larger breeding colonies? Atlantic Seabirds 8(1/2): 31-40.
There are few known coastal breeding sites for the Mediterranean Storm-Petrel Hydrobates pelagicus melitensis *in Spain and France, apart from their core breeding areas in the Balearics and central Mediterranean. In spite of the difficulty of documenting breeding in this species, islands closer to core breeding areas have well-known breeding populations, whilst sites in NE Catalonia and France have not, despite thorough research. Ringing effort has provided a different approach to addressing the issue of determining breeding colonies; ringing results suggest the possibility of an irregular, opportunistic breeding at sites in NE Catalonia and France when habitat conditions are optimal. Of 27 birds trapped and ringed in NE Catalonia from 2003-2005, five were recaptures from the Balearics and Murcia, W Mediterranean Spain (15,62%). In contrast, only an average of 0,22% of total Spanish ringings 1969-2002 (*n*=10.997) were long-distance recaptures. These differences support the idea of a breeding distribution composed of core breeding areas and isolated small breeding sites such as those in NE Catalonia. Given habitat resource variability, such small peripheral area could act as either irregular breeding sites, as some past evidence and body condition of trapped birds suggest or, alternatively, as part of core areas feeding grounds for either adults or non-breeding birds.*

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INTRODUCTION

The estimated 8.500- 15.500 breeding pairs of the endangered Mediterranean Storm-petrel *Hydrobates pelagicus melitensis* (Cagnon *et al.* 2004, Martí & del Moral 2003) are mainly distributed on islands across the central and western Mediterranean, especially around Malta and the Balearic Islands (Massa & Merne 1987, Martí & del Moral 2003, Cadiou 2004, Brichetti & Fracasso 2004). Several coastal island breeding sites isolated from major colonies have been

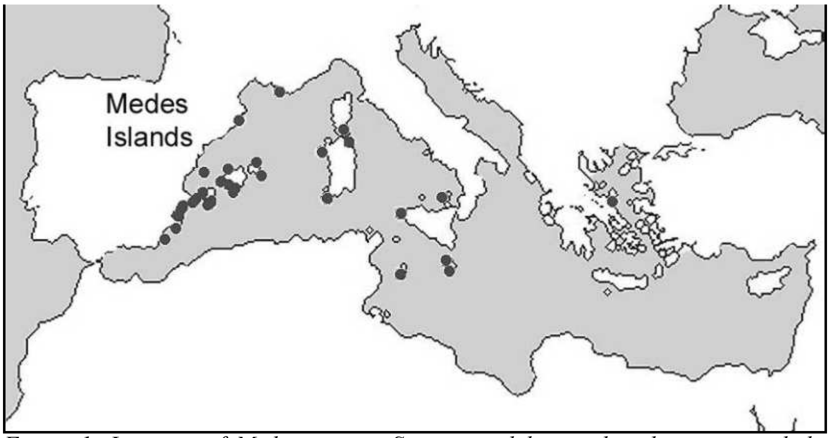

Figure 1. Location of Mediterranean Storm-petrel known breeding sites and the study area in the Spanish NE coast.
Figuur 1. Ligging van de bekende kolonies van het Mediterraan Stormvogeltje in de Middellandse Zee en het studiegebied bij de Spaanse noordoostkust.

documented in Spain (Mínguez 1994c) and France (Marseille islands, Cadiou 2004), but not in Italy (Brichetti & Fracasso 2003, figure 1).

The Spanish *melitensis* population is estimated to be 3830-5310 pairs, concentrated mostly in the Balearics (Catalonia 0-10 breeding pairs, Gutiérrez *et al.* 2004; Valencia 555-685, Balearic Islands 2912-4046, Murcia 360-544, and Andalucia 3-20 breeding pairs, Mínguez in Martí & del Moral 2003) but estimates are rough due to difficulties in censusing (González & Hernández 1989, Mínguez 1994a). To obtain accurate breeding counts, direct evidence of breeding, such as finding active nests, is necessary. Indirect methods like capture of adults with vascularized brood patches or the presence of individuals attracted through vocalizations are not definitive proof of breeding (Walmsley 1986, Nogales *et al.* 1993, Mínguez 1994b). The capability of flying long distances to feed (200 km in a night, Cadiou 2004), the existence of over-summering populations (Martí & Del Moral 2003), and the presence of non-breeding birds around colonies (Mínguez 1992) complicate efforts to estimate breeding Storm-petrel numbers.

In Spain, away from the Balearics, some of the coastal islets with proven breeding populations hold large suitable caves where counting is fairly straightforward and where breeding has been encouraged through the installation of nest-boxes (e.g. Benidorm, De León & Mínguez 2003). Populations off the regions of Murcia, Andalusia and Valencia are close enough to form an interrelated core area. All breeding sites are within 100 km of each other and Benidorm is only 137 km from Formentera in the Balearics, the stronghold for *melitensis* in Spain. Ringing recoveries support the hypothesis of a high interrelation between these SW Mediterranean breeding locations (Pinilla *et al* 2003).

The situation in N Catalonia and coastal France, however, appears to be different. The traditional breeding sites (Massa & Merne 1997) appear to be isolated from the main core populations in Corsica/Sardinia and the Balearics and contain lesser known breeding populations (Cadiou 2004, Gutiérrez *et al.* 2004). In Catalonia, unlike in the islands in southern Spain, research from 2001-2005 involving on-the-ground searches in suitable habitat plus ringing campaigns have not definitively proven breeding, despite having trapped and ringed 31 birds (Gutiérrez *et al.* 2004, this study). In the French islands of Hyeres and Marseille, recent evidence of breeding is also dubious because it was based on indirect methods (Cadiou 2004).

Given the negative results of the searches but the positive ringing results in NE Spain, an analysis of ringing effort and recoveries was carried out to determine if Spanish Storm-Petrel populations differed. Our primary goal was to attempt to establish the true status of what formerly have been considered firmly established colonies for the species (e.g. Massa & Merne 1997).

Results suggest that NE Catalonia locations, and possibly French sites as well, may have held local breeding populations but now seem to be opportunistic breeding sites, depending on factors such as food availability, presence of predators and site availability. Additionally, these sites may serve as dispersal areas for the core sites for both adults and non-breeding birds; in the case of Catalonia, the region would serve as a dispersal area for the Balearics. All in all supporting the threatened status of the taxon according to its breeding locations constraints (Mínguez 2000).

METHODS

During May 2001-July 2005, a total of 19 campaigns lasting 38 days were carried out in Catalonia, NE Spain. Of those 19, 3 were in 2001, 2 in 2002, 5 in 2003, 7 in 2004 and two in 2005. The studied areas covered the Montgrí coastal cliffs (4 campaigns), Medes islands (13 campaigns), Baix Empordà coast (one), Cap de Creus Natural Park (four) and Garraf coast (three). Activities included offshore bird counts (seven sessions), searches of potential habitat for breeding evidence (eight sessions), installation and monitoring of nest boxes (six sessions), recording of nocturnal vocalisations (eight sessions), and mist-net trapping and ringing during the night, aided by tape recordings (12 nights), see appendix.

Table 1. Proportion of ringings and long-distance retrappings of Storm-petrels in Spain.
Tabel 1. Aandeel van geringde en over grotere afstand terug gemelde Stormvogeltjes in Spanje.

Period	Area	Ringings	Retraps		Reference
			n	%	
1969-2002	Spain	10.997	25	0,22	Pinilla *et al.* 2003
1973-2003	Balearic Islands	7370	17	0,23	López-Jurado 2003
1986-1989	Catalonia	16	1	6,25	Gutiérrez *et al.* 2004
2003-2005	NE Catalonia	27	6	18,75	this study

The 12 ringing sessions were held from 2003-2005 between May-September, but primarily in June: May (2), June (6), July (1) August (2) and September (1). Except for two sessions on the Garraf coast in 2003 (no results) and one on the Montgrí coast (one capture), all sessions were held in the Medes Islands, L'Estartit, Torroella de Montgrí, Girona (42º 01,963 N, 3º 11,915' E). We used a battery of 3x18 m long mist-nets and a cd-player with 20W loudspeakers continuously playing vocalisations of *Hydrobates pelagicus ssp.* during the entire night-time period. Ageing of birds was carried out following Baker (1993) and measurements were taken after Svensson (1992) and Lalanne *et al* (2001) by a single observer. These included maximum chord (wing length), longest primary length (P3), tail length, tarsus length and five measurements of bill: bill tip to feather, height of bill including the tubular nostril, height of mandibles (bill without nostril), nostril width, and bill width at tubenose tip. Weight, moult stage and behavioural notes if any were also recorded.

RESULTS

No direct evidence of breeding was found at any of the surveyed sites. Thirty-two Storm-Petrels were trapped in the study period: 3 in 2003, 25 in 2004 and 4 in 2005. Of those birds, five were recaptures of birds already ringed, four in the Balearic Islands (two in 2004 and two in 2005) and a fifth in the Hormigas Islands, Murcia, a distance of 590 km. Additonally, there is one long distance recapture from a bird ringed in the study area: an adult ringed on 22 May 2003 at Cala Pedrosa, Torroella de Montgrí, was retrapped 13 days later, on 4 June 2003, at S'Algar, Felanitx, Mallorca, Balearic Islands becoming the first ever long-distance recapture of a Storm-Petrel ringed in Catalonia. Considering both birds trapped in Catalonia, either ringed or already ringed and the S'Algar bird, recaptures represent 18,75% of the trapping total, 85 times the recovery ratio for the whole of Spain (0,22%) or 81 times for the Balearics (0,23%) but only three times the ratio of previous studies in Catalonia (6,25%, table 1).

*Table 2. Biometrics of Storm-petrel in Medes Islands, Mediterranean Spain (*present study*) compared to those of* H.p. melitensis*: Lalanne* et al *2001 (Corsica,* n*=32 and Riou islands,* n*=4) and Amengual* et al *2000 (Cabrera, Balearic Islands,* n*>148). All measurements in millimetres except weight in grams.*

*Tabel 2. Biometrie van Stormvogetje op de Medes Eilanden, (*deze studie*) vergeleken met die van* H.p.melitensis*: Lalanne* et al *2001 (Corsica,* n*=32 en Riou Eilanden,* n*=4) en Amengual* et al *2000 (Cabrera, Balearen,* n*>148). Alle maten in millimeter, behalve het gewicht (gram).*

	Medes Islands				Corsica	Riou	Cabrera
	n	Mean	SD	Range			
Wing length	32	123,31	1,96	119,5-128	123,58 ±2,98	129,25 ±2,22	122,50 ±3,78
Bill height	32	5,22	0,28	4,7-5,8	5,56 ±0,22	5,75 ±0,24	
Mandible heigth	31	3,95	0,17	3,7-4,3	4,08 ±0,17	4,50 ±0,08	3,97 ±0,31
Bill length	32	12,38	0,41	11,4-13,4	11,99 ±0,71	12,25 ±0,29	12,32 ±1
Weight	32	25,87	2,06	22-31,4	28,94 ±2,97	28,25 ±1,89	27,60 ±2,74

Of the three birds caught in 2003, one was a first summer bird and the other two were adults. All but one bird (24 of 25) in 2004 were adults, 20 of them showing a different degree of development and vascularization of defeathered breeding patches. The twenty-fifth bird was a juvenile ringed in September. All four birds trapped in June-July 2005 were first summer, non-breeding birds.

All measurements fell within *melitensis* range (Lalanne *et al.* 2001, Amengual *et al* 2000), table 2.

DISCUSSION

In Catalonia, only one known, proven breeding record exists for the Storm-petrel (Raventos 1972). The species has been scarcely studied, except for a number of ringing campaigns from 1986-1990 which produced 16 ringings and, interestingly, a recapture of a bird trapped at the Balearics (Estrada 1988, 1989). The capture of a bird with an egg about to be laid on 12 June 1988, plus indirect evidence, led to the species being considered as a breeder in NE Spain (Estrada 1988). However, no direct supporting evidence was found during the 2001-2005 breeding seasons. However, ringing results during the breeding period overwhelmed previous trapping results in all of NE Spain. Anecdotal observations indicate that the species occurs regularly during the breeding season off NE Spain, particularly around the Medes Islands (*pers.obs.*).

Differences in ages of trapped birds between the 2004 and 2005 seasons may be influenced by local food availability. There have been strong fluctuations in fishing captures in the area in recent years, with an even stronger

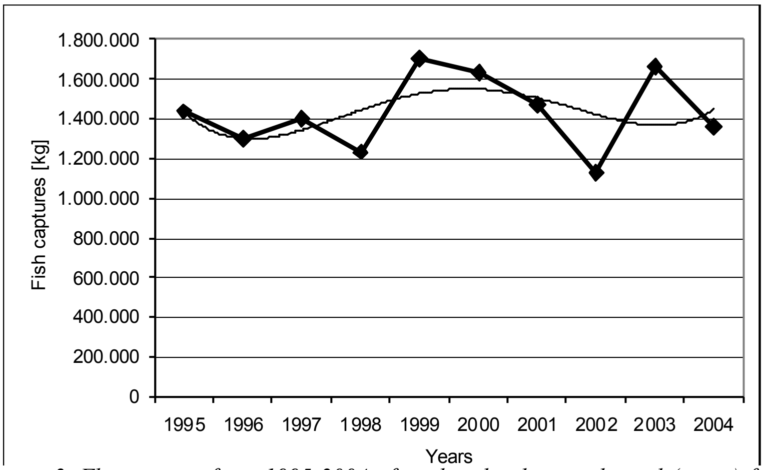

Figure 2. Fluctuations from 1995-2004 of total and polynomial trend (curve) fish captures [kg] landed at L'Escala Harbour, Girona, NE Spain (42º 07,711 N, 3º 08,220'E), the closest harbour to the study area. Between 2003 and 2004 a 18,19% decrease in fish captures was noted. No data are available for 2005, but trend is negative (Medes Islands Protected Area, pers.comm.*; DARP Marine Inspection Service* pers.comm.*).*

Figuur 2. Fluctuatie in totale visvangst [kg] en trend (polynoom) in 1995-2004 in L'Escala, Girona, NO-Spanje (42º 07,711 N, 3º 08,220'E), de haven die het dichtst bij het studiegebied ligt. Tussen 2003 en 2004 was er een afname in gevangen vis van 18,19%. Voor 2005 zijn geen data beschibaar, maar de trend is negatief (Medes Islands Protected Area, pers.comm.*; DARP Marine Inspection Service* pers.comm.*).*

decrease in 2005 than in 2004, which, in turn, showed a 18,19% decrease relative to 2003 (figure 2; Medes Islands Protected Area, *pers.comm.*; DARP Marine Inspection Service, *pers.comm.*). It is known that fluctuations in zooplankton and fish availability are factors contributing to intermittent Storm-Petrel reproduction and even to the decrease of populations in some colonies (Elbée & Hemery 1998), including the decrease of breeding success in Atlantic French colonies (Cadiou 2004). Therefore, it is possible that seasonal lack of food could make the Medes Islands area less attractive for adult breeding birds, with only non-breeding or nomadic birds present in poor years, as the 2005 ringing recaptures, only including subadults, might suggest.

Considerations such as lack of an attractive cave (e.g. Benidorm), the historical evidence of human disturbance, competition with Yellow-legged Gull *Larus michahellis* populations (one of the largest colonies of the species is at the

Medes Islands, currently >6300 pairs but with a maximum of 14.000 in the 1980s, Bosch & Carrera 2003), or even high densities of mice (*Mus musculus)*, could be additional factors explaining irregular breeding, something that regularly happens on the species on the other hand either naturally or induced by a previous breeding failure (Amengual *et al.* 2000).

The French populations off Marseille and Hyeres are largely unknown (Cadiou 2004), and their estimates are recently based on indirect evidence (Zotier & Vidal 1988). Ringing activities produced only four birds in May 2000 (Lalanne *et al.* 2001). This low capture rate suggests that this French region may function similarly to NE Catalonia areas, namely as a dispersal area with occasional breeding.

These sets of evidence bring out a new scenario. The relatively high proportion of ringing recaptures recorded in the Medes Islands (18,75% of trappings) suggests a close relationship with Balearic and even SE Spanish populations. This is particularly noteworthy when one considers that the 10.997 Storm-Petrels ringed in Spain from 1969-2002 and the 7370 ringed in the Balearics produced only 25 (0,22%) and 17 (0,23%) long-distance recaptures, respectively. The 6,25% recapture ratio of 1986-1989 campaigns in Catalonia matches this hypothesis of a relationship Balearics – Medes Islands. Compared with the current study, the eighties lower ratio might be explained by different local environmental conditions or sample size but is still well above Spanish or Balearic Islands average (table 1).

Estrada (1989) documented the first known long-distance recovery of a *melitensis* Storm-Petrel in the Mediterranean. The 241 km distance of that recapture could not eliminate the possibility of the bird being a local Medes breeder (it was an adult with brood patch) or a dispersive Balearic bird. In turn, none of the birds trapped in 2004-2005 was known to be an active breeder in those years in the Balearics (M.McMinn/Skua SL, *pers.comm.*). But the Murcia bird, mist-netted and ringed on 10.6.2003 in a colony of c.100 pairs without any tape-recording, could have been a local breeder there, as it was recaptured in the Medes Islands on 18 June 2004 showing a developed brood patch. Given the evidence of Storm-Petrels being capable of visiting sites more than 200 km apart in a single night (Cadiou 2004), the high ratio of recoveries in NE Spain both in the 1980s and in the current study suggests the possibility of a close relationship between the Balearic birds, and even beyond, and those off NE Spain. Thus, the coastal islets off NE Catalonia, as well as those off France, could be a foraging area for adults from well-established colonies and dispersal areas for subadults and non-breeders. It is even possible to reach NE Catalonia from the Balearics on a daily basis, as the distance, about 200 km, may well be within the flying range of the species. These coastal sites, depending on the year, might hold a breeding population, but different on-island factors discussed above could make consistent breeding difficult. These coastal islets perhaps function as irregular small breeding sites which would certainly be linked to larger breeding grounds, thus serving as a connected extension of the core breeding area.

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BROEDENDE STORMVOGELTJES *HYDROBATES PELAGICUS* LANGS DE MIDDELLANDSE ZEEKUST: KLEINE GEÏSOLEERDE BROEDPLAATSEN OF SUBKOLONIES VAN GROTERE KOLONIES?

Naast de kerngebieden op de Balearen en in de centrale Middellandse Zee zijn er weinig bekende broedplaatsen van het Mediterraan Stormvogeltje *Hydrobates pelagicus melitensis* aan de kust van Spanje en Frankrijk. Ondanks de problemen om het broeden van deze soort te documenteren is het duidelijk dat eilanden dichter bij het kerngebied bekende kolonies herbergen, terwijl ze in Noordoost-Catalonië en Frankrijk ontbreken, ondanks grondig onderzoek. Ringen van vogels heeft geleid tot een andere aanpak om broedkolonies vast te stellen; ringgegevens suggereren de mogelijkheid van onregelmatig, opportunistisch broeden in Noordoost-Catalonië en Frankrijk indien habitatcondities optimaal zijn. Van 27 terugvangsten van geringde vogels in Noordoost-Catalonië in 2003-2005, waren er vijf (15,62%) afkomstig van de Balearen en Murcia (westelijke Spaanse Middellandse Zee). Ter vergelijking; slechts 0,22% van het totaal aantal Spaanse terugmeldingen in 1969-2002 (*n*=10997) was afkomstig van (lange afstand)terugvangsten. Deze verschillen ondersteunen de idee dat de broedverspreiding bestaat uit kerngebieden en kleine geïsoleerde broedplaatsen zoals in Noordoost-Catalonië. Gezien de variatie in habitatkwaliteit zouden dergelijke kleine, perifere gebieden onregelmatige broedplaatsen kunnen zijn, zoals gesuggereerd wordt door resultaten uit het verleden en de conditie van gevangen vogels, of als deel van de belangrijkste foerageergebieden voor zowel adulte als niet-broedende vogels.

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Appendix
Survey data and methods used per field session (years 2001-2005)

			n days	Marine Survey	Terrestrial Survey	Ringing	Nest-boxes	Night calls	Montgrí	Medes	Baix Empordà	Cap de Creus	Garraf
1	2001	8-9.5.2001	2	x	x			x	x	x			
2		23-24.5.2001	2	x				x				x	
3		25-28.5.2001	4	x				x					x
4	2002	10-13.6.2001	4	x	x			x	x	x	x	x	
5		12.7.2002	1	x	x					x			
6	2003	21-22.5.2003	2			x		x	x				
7		29.5.2003	1			x		x					x
8		10-11.6.2003	2			x		x					x
9		19-20.6.2003	2			x		x		x			
10		7-8.8.2003	2			x		x		x			
11	2004	11.3.2004	1		x		x			x			
12		05.4.2004	1		x		x					x	
13		10-11.6.2004	2			x	x			x			
14		16-18.6.2004	3			x	x			x			
15		22-23.6.2004	2	x	x	x			x	x		x	
16		12-13.8.2004	2			x				x			
17		6-7.9.2004	2	x	x	x	x			x			
18	2005	15-16.6.2005	2		x	x	x			x			
19		4-5.7.2005	2			x				x			
n			39	7	8	12	6	9	4	13	1	4	3

SIZE AND TRENDS OF LEACH'S STORM-PETREL *OCEANODROMA LEUCORHOA* BREEDING POPULATIONS IN NEWFOUNDLAND

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Robertson, G.J., Russell, J., Bryant, R., Fifield, D.A. & Stenhouse, I.J. 2006. Size and trends of Leach's Storm-Petrel *Oceanodroma leucorhoa* breeding populations in Newfoundland. Atlantic Seabirds 8(1/2): 41-50. *The world's largest Leach's Storm-Petrel* Oceanodroma leucorhoa *colonies are in Newfoundland, Canada, with Baccalieu Island alone supporting over 3 million nesting pairs. Since 2001, an effort was made to re-census many of the larger colonies in Newfoundland and compare current population estimates with those from the 1970s and early 1980s. Surveys were undertaken by grubbing small plots, calculating occupied burrow densities and extrapolating these densities to the area occupied by petrels. Playback and burrow entrance monitoring proved to be less or equally effective as grubbing, but required much more time, possibly due to the high densities of occupied burrows. The larger colonies examined appeared to be stable between the 1970-80s and the early 2000s while the two smaller colonies examined, Middle Lawn Island and Small Island, showed declines. The establishment of large gull (both Great Black-backed Gull* Larus marinus *and Herring Gull* L. argentatus*) colonies close to these two islands in the 1970s may explain the population declines at these sites, although habitat quality differences among islands could not be ruled out. In contrast, massive predation (an estimated 49,000 adults killed/year) of Storm-Petrels on Great Island, Witless Bay by large gulls did not appear to have reduced the breeding Storm-Petrel population which remains around 270,000 breeding pairs. Although Leach's Storm-Petrel colonies in Newfoundland appear to be faring well in the last 2-3 decades, continued monitoring is warranted, given potential threats from large gull predation, contaminants, chronic oil pollution and offshore oil and gas production.*

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INTRODUCTION

The east coast of Newfoundland harbours some of the largest Leach's Storm-Petrel *Oceanodroma leucorhoa* colonies in the world (Sklepkovych & Montevecchi 1989). In spite of their global significance, by 2000 most major colonies had not been surveyed since the late 1970s or early 1980s (Cairns *et al.* 1989), so little data existed to assess current population trends in this species (but see Stenhouse *et al.* 2000). This was largely due to the extensive and time-consuming field work needed to effectively monitor this nocturnal, burrow-nesting seabird. To begin to fill this information gap, surveys of breeding populations of several important Leach's Storm-Petrel colonies were begun in the summer of 2001 and have continued annually since then.

This paper updates population size estimates of Leach's Storm-Petrel colonies in Newfoundland, assesses trends where historical data were available and discusses possible factors influencing the population size and trend of this species.

METHODS

Information from older surveys (pre-2001) was extracted from Cairns *et al.* (1989) and the associated Atlantic Seabird Colony Register, a database of seabird colony surveys maintained by the Canadian Wildlife Service. In addition, all available survey documentation was consulted directly, e.g. Sklepkovych & Montevecchi (1989) and Stenhouse *et al.* (2000). The methods used in older surveys were variable, and in some cases not known. For trend analysis, we included surveys that were based on quantitative estimates of colony size. Surveys since 2001 were conducted in a standardized manner, and details are presented in Robertson *et al.* (2001) and Robertson & Elliot (2002). Islands with larger populations (so that more of the global population could be sampled) accessible islands and islands with previous population estimates were selected for re-census. The methods used in recent surveys are outlined below.

As previous surveys did not always document the area used by breeding Leach's Storm-Petrels, island-wide grids were established to, 1) determine the limits and area of Leach's Storm-Petrel breeding habitat, and then, 2) determine occupied burrow densities. On maps of each island, a geo-referenced grid was laid out which included at least 100 intersection points. These grid lines ranged from 25-75m wide, depending on the size of the island. In the field, grid intersection points were located by a hand-held GPS, or with tape measures and compass. At the intersection of all grid lines, a 16 m^2 circular plot was established by placing a stake at the centre of the plot and marking a circle on the ground with a can of spray paint tied to a cord of appropriate length (2.26 m). All burrow entrances in the plot were counted, and the contents assessed. Burrow entrances were recorded as leading to either: a burrow too short to hold a pair of breeding petrels, an empty burrow, an occupied burrow (adult and/or egg present), a burrow for which the contents could not be assessed (unknown), or as an additional entrance to a burrow already recorded as falling into one of the above categories. Contents of each burrow were assessed by grubbing (reaching into the burrow by hand). In rare cases an access hatch was dug in the peat to assess the contents of longer burrows.

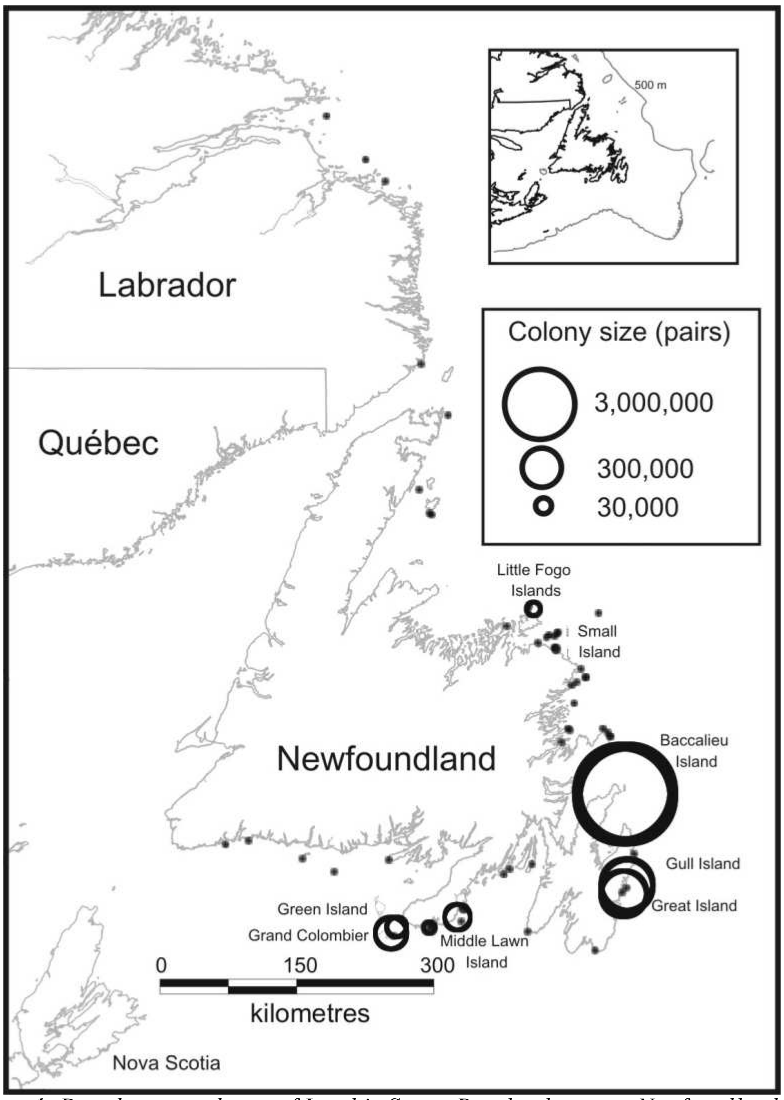

Figure 1. Distribution and size of Leach's Storm-Petrel colonies in Newfoundland and Labrador, Canada and St. Pierre and Miquelon, France. Inset map shows 500 m isobath.

Figuur 1. Verspreiding en grootte van kolonies van Vaal Stormvogeltje in Newfoundland en Labrador (Canada) en St. Pierre en Miquelon (Frankrijk). De inzet laat de 500 m isobath zien.

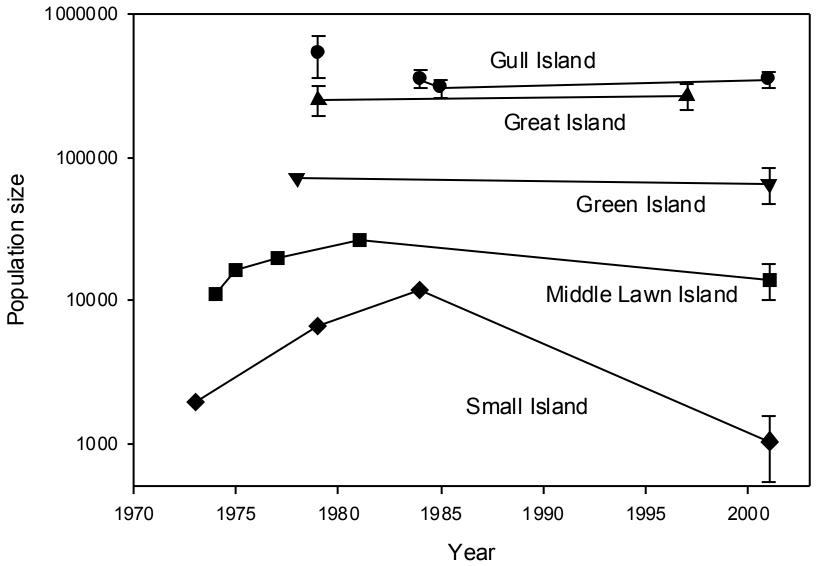

Figure 2. Population size (log 10) and trends of Leach's Storm-Petrel colonies monitored in Newfoundland, Canada. Data sources for older information can be found in Stenhouse et al. *(2000), Robertson* et al. *(2002) and Robertson & Elliot (2002) and 95% confidence are presented where available.*

Figuur 2. Populatiegrootte (log 10) en trends van gemonitorde kolonies van Vaal Stormvogeltje in Newfoundland (Canada). Bronnen van oudere data zijn te vinden in Stenhouse et al. *(2000), Robertson* et al. *(2002) en Robertson & Elliot (2002). Indien beschikbaar worden de 95%-betrouwbaarheidsintervallen gepresenteerd.*

For analysis, if a grid intersection had at least one burrow in the 16 m^2 plot then the surrounding area, specifically half the distance to the next grid line, was considered occupied habitat. Technically, plots without burrows could be included to calculate occupied burrow densities and then multiplied by total island area to obtain a population estimate. However, we chose not to include these unoccupied plots in the analysis, as it had the undesirable effect of skewing the distribution of occupied burrow densities due to the large number of 0s. Removing unoccupied habitat and 0 occupied burrow densities had two statistical advantages, firstly it allowed the standard error to be calculated on a distribution that approximated a normal distribution, and second, it effectively reduced the standard error of the estimate of population size. For islands with steep topography, the occupied area was further corrected by the mean angle of all plots, measured with a clinometer. Occupied burrow densities for each plot were calculated by multiplying occupancy rates (excluding unknown burrows as the contents of these burrows was not known) by the burrow density in each plot (including unknown burrows). Mean occupied burrow densities were then calculated from all plots which had burrows. Finally, the total corrected occupied area was multiplied by the mean occupied burrow density to obtain a final population estimate. Standard errors and 95% confidence intervals are available in the original reports.

Table 1. Estimated population sizes, most recent census year, occupancy rates, burrow densities and occupied burrow densities for the largest known Leach's Storm-Petrel colonies in Newfoundland and Labrador, Canada and St. Pierre and Miquelon, France.

Tabel 1. Geschatte populatiegrootte, meest recente inventarisatiejaar, bezettingsgraad, holendichtheid en dichtheid bezette holen voor de grootste bekende kolonies in Newfoundland en Labrador (Canada) en St. Pierre en Miquelon (Frankrijk) van Vaal Stormvogeltje.

Colony	Year	Size (pairs)	Occupancy rate	Burrow density (m^{-2})	Occupied burrow density (m^{-2})	Source
Baccalieu Island	1984	3,360,000	0.680	0.046-4.166	0.017-2.495	1
Gull Island (Witless Bay)	2001	351,866	0.722	1.070	0.772	2
Great Island (Witless Bay)	1997	269,765	0.659	1.870	1.233	3
Grand Colombier, St Pierre	2004	142,783	0.617	0.670	0.451	4
Corbin Island	1974	100,000				5
Green Island (Fortune Bay)	2001	65,280	0.747	0.874	0.653	2
Little Fogo Islands	1975	38,000				5
Middle Lawn Island	2001	13,879	0.709	0.666	0.472	2
Iron Island	1974	10,000				5
Small Island	2001	1,038	0.338	0.223	0.076	6

[1] Sklepkovych & Montevecchi 1989; [2] Robertson *et al.* 2002; [3] Stenhouse *et al.* 2000; [4] CWS, Alder Institute and Service D'Agriculture et de la Faune, and Le Centre Culturel, St. Pierre et Miquelon; [5] Cairns *et al.* 1989; [6] Robertson & Elliot 2002.

RESULTS

The distribution of Leach's Storm-Petrel breeding colonies in Newfoundland and Labrador is shown in Figure 1, with details for the larger colonies in Table 1. In addition to the colonies in Table 1, another 7 have population sizes in the 1,000-10,000 range, 12 are in 100-1,000 range and 32 have between 1-100 breeding pairs. The information available on trends for Newfoundland shows that most larger colonies appear stable, while two smaller colonies showed declines since the early 1980s (Figure 2). As the estimate of 533,186 pairs available for Gull Island in 1979 (Cairns & Verspoor 1980) was based on a single transect through habitat that had unrepresentatively high burrow densities, the apparent decline from 1979 to 1984 is a sampling artefact. Occupancy rates were relatively consistent among colonies, while burrow densities were much more variable (Table 1).

DISCUSSION

Newfoundland harbours some of the largest Leach's Storm-Petrel colonies in the world, totalling over 4 million breeding pairs. The distribution of colonies is highly skewed, with Baccalieu Island holding 3.36 million pairs (Sklepkovych & Montevecchi 1989), a few colonies harbouring 100s or 10s of thousands of pairs and a collection of smaller colonies of tens, hundreds or thousands of pairs. All large colonies have been surveyed at least once (although Corbin Island requires a thorough re-assessment) and are reasonably well known. On the other hand, most small colonies have only been visited once, have not had quantitative assessments of population size, and many more are likely to have gone unnoticed. The majority of the colonies occur in eastern Newfoundland, a distribution typical of most pelagic seabirds breeding in the province. This is likely a function of the proximity to appropriate foraging grounds near the continental shelf break. Labrador has a few known colonies, with numbers of pairs in the tens or hundreds, and represents the northern breeding limit of this species in the Northwest Atlantic. Québec has only a small population of Leach's Storm-Petrels, while Nova Scotia supports some larger colonies (tens of thousands) and may have over 100,000 breeding pairs (Huntingdon *et al.* 1996). New Brunswick and Maine support about 20,000 pairs, while Massachusetts represents the current southern breeding limit (Huntington *et al.* 1996).

Burrow occupancy rates did not vary greatly among colonies, ranging from 0.62-0.75, except for the sharply declining colony on Small Island (0.34). In contrast, excluding Baccalieu Island, burrow densities ranged from 0.22 to 1.87 burrows/m^2 across different islands; with Baccalieu Island itself showing an even greater range of 0.046-4.166 burrows/m^2. These ranges likely reflect habitat differences among islands, as burrow densities are related to habitat (Sklepkovych & Montevecchi 1989; Stenhouse & Montevecchi 2000). When used alone, the lack of range in occupancy rates, and the great range in burrow densities, make neither a suitable monitoring metric to assess population trends for this species in Newfoundland (except for crashing populations such as those on Small Island). Therefore, continued censuses to estimate island-wide breeding populations are recommended for future monitoring.

Both older and recent surveys used burrow grubbing to assess burrow contents. In other regions, the use of tape playbacks and/or video probes has been recommended (Ambagis 2004; Mitchell *et al.* 2004). These two methods were attempted during recent surveys in Newfoundland, but reports from field workers suggested that they proved to be more difficult and less efficient than burrow grubbing. Playbacks proved difficult to interpret due to the high density of burrows. In Newfoundland, Leach's Storm-Petrel burrows tend to be relatively short and straight holes in peaty soils, making grubbing relatively easy (the contents could not be assessed for about 10% of burrows), especially in contrast to European Storm-Petrels *Hydrobates pelagicus* which nest in crevices and in scree. However, further work will be conducted to investigate the value of these less invasive methods in assessing burrow occupancy.

Although the data on population trends for colonies in Newfoundland is somewhat sparse, a few patterns emerge from the available information. Firstly, between the 1970s-early 1980s to the late 1990s-early 2000s, there has been little change in the population size of the large colonies that have been monitored. On the other hand, the two smaller colonies that have been monitored have shown significant, and in the case of Small Island, precipitous, declines. Both these colonies share one feature; hundreds of pairs of Herring *Larus argentatus* and Great Black-backed Gulls *L. marinus* began nesting in the vicinity of these colonies since the 1970s (Robertson & Elliot 2002; Robertson *et al.* 2002).

It is not clear why these small colonies have declined in the face of gull predation, while the larger colonies appear stable. In the case of Green Island, light keepers are still present on the island, which keeps the island free of nesting gulls. Baccalieu Island is similarly gull free, due to the presence of red foxes *Vulpes vulpes* (Sklepkovych & Montevecchi 1989); although trend data for this island are not available. The large islands in Witless Bay support over 600,000 pairs of Leach's Storm-Petrels and harbour significant gull colonies, with approximately 2,900 pairs of large gulls on Gull Island and 1,700 pairs on Great Island (Robertson *et al.* 2001). Stenhouse *et al.* (2000) estimated that 49,000 Leach's Storm-Petrels were killed by gulls annually on Great Island alone, while Robertson *et al.* (2001) postulated that habitat-specific changes in gull nesting locations could lead to increasing predation pressure on Leach's Storm-Petrel. However, Leach's Storm-Petrel populations on Gull and Great Island appear to have been stable over the last 25 years. In general, breeding success of Leach's Storm-Petrel in Newfoundland is high and does not appear to vary greatly in response to ecosystem changes, as seen in other seabirds (Stenhouse & Montevecchi 2000; Regehr & Rodway 1999). Consistently high chick production, and the subsequent abundance of young pre-breeding cohorts, could explain how these mortality levels are maintained. Clearly, more work is needed to understand the degree to which Leach's Storm-Petrel populations are impacted by predation pressure from large gulls.

Additional threats to Leach's Storm-Petrel could include contaminants, as there are indications that Mercury (Hg) levels in the eggs of this species have risen from 1972-2000 in the Northwest Atlantic (Burgess & Braune 2001). Recent offshore oil and gas exploration and production on the Grand Banks and Scotian Shelf has increased the risk of Leach's Storm-Petrel colliding with offshore installations and being incinerated in gas flare booms (Wiese *et al.* 2001). Newfoundland has one on of the largest chronic ship-source (bilge dumping) oil pollution problems in the world (Wiese & Ryan 2003). As surface feeders, Storm-Petrels consume hydrocarbons while foraging (Boersma 1986), which can impact chick survival and the reproduction of breeding adults (Trivelpiece *et al.* 1984). Unlike most major seabird colonies in the world, there is one significant threat that Leach's Storm-Petrel (and other seabirds) in Newfoundland are not currently facing, that is the introduction of predatory mammals or other invasive species (e.g. rats or rabbits). However, monitoring will be required to ensure that this remains the case.

Given the extent of the current potential threats, and uncertainties surrounding the impact of gull depredation, continued monitoring of Leach's Storm-Petrel in Newfoundland is clearly warranted. A survey of the large colony on Baccalieu Island is particularly critical for any future assessment of this population.

ACKNOWLEDGEMENTS

We thank all who have contributed to monitoring Leach's Storm-Petrels in Newfoundland and Labrador. Recent surveys have been supported by the Canadian Wildlife Service of Environment Canada and the Alder Institute. We also thank Service D'Agriculture et de la Faune, Le Centre Culturel, and Animation St. Pierre for assistance with the survey on Grand Colombier in 2004. Richard Elliot, Jonathan Crane and Mike Hounsome provided very helpful comments on this paper.

OMVANG EN TRENDS VAN BROEDPOPULATIES VAN VAAL STORMVOGELTJE *OCEANODROMA LEUCORHOA* IN NEWFOUNDLAND

De grootste kolonies van Vaal Stormvogeltje Oceanodroma leucorhoa *ter wereld bevinden zich in Newfoundland, Canada, met alleen op Baccalieu Island al meer dan 3 miljoen paar. Sinds 2001 wordt inspanning verricht om de grotere kolonies in Newfoundland opnieuw te inventariseren teneinde huidige populatieschattingen te vergelijken met die van de jaren zeventig en begin jaren tachtig. Inventarisaties werden uitgevoerd door te 'graaien' in kleine plots (met de hand holen inspecteren), dichtheden van bezette holen te berekenen en deze dichtheden te extrapoleren naar het gebied dat door de stormvogeltjes wordt gebruikt. Playback van geluidsopnames en monitoring van ingangen van holen bleek minder of even efficiënt als graaien, maar vereiste veel meer tijd, mogelijk als gevolg van hogere dichtheden van bezette holen. De onderzochte grotere kolonies leken stabiel tussen de jaren zeventig/tachtig en begin 2000. De twee kleinere kolonies daarentegen Middle Lawn Island en Small Island vertoonden een afname. De vestiging in de jaren zeventig van grote meeuwenkolonies (bestaand uit Grote Mantelmeeuw* Larus marinus *en Zilvermeeuw* L. argentatus*)*

dichtbij deze twee eilanden kan de populatie-afname op deze eilanden verklaren. Verschillen in habitatkwaliteit tussen de eilanden kan echter niet uitgesloten worden. Aan de andere kant leek massale predatie (een geschatte 49000 adulte vogels per jaar) van stormvogeltjes op Great Island, Witless Bay door grote meeuwen de broedpopulatie, die nu nog bestaat uit 270000 broedpaar niet gereduceerd te hebben. Hoewel het kolonies van Vaal Stormvogeltje in Newfoundland de laatste twee à drie decades voor de wind gaat, is een voortgaande monitoring aanbevolen gezien de potentiële bedreigingen door predatie (door meeuwen), gifstoffen, chronische olievervuiling en offshore olie- en gasproductie.

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THE SEABIRD RECOVERY PROJECT: LUNDY ISLAND

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Appleton, D., Booker, H., Bullock, D.J., Cordrey, L. & Sampson, B. 2006. The Seabird recovery project: Lundy Island. Atlantic Seabirds 8(1/2): 51-60. *The UK holds 93% of the world's breeding populations of Manx Shearwater* Puffinus puffinus. *Lundy Island's populations of Manx Shearwater and Puffin* Fratercula arctica*, another burrow-nesting seabird, are currently much lower than those reported over 100 years ago. A major factor responsible for these declines was believed to be predation by rats. In 2002 a programme to eradicate rats to benefit these seabirds was started. Both the Black and Brown Rats* Rattus rattus *and* R. norvegicus *occurred on the island. The former is rare in the UK but both are globally widespread and abundant, and both are predators of seabirds. The two-year eradication programme was completed in March 2004, since which there has been no evidence of rats. Monitoring will now focus on the populations and productivity of the target seabirds although an increase in the breeding populations is not expected in the short term.*

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INTRODUCTION

Lundy Island (51°10'N, 04°40'W; 430 ha) lies 18 km off the north Devon coast in the Bristol Channel. Rising steeply to a plateau dominated by grassland and heath, it is a popular tourist destination with 23 holiday cottages, a working sheep farm and a small residential population. Traditionally, Lundy was known as a seabird island holding important populations of cliff and burrow-nesting species. These include the Manx Shearwater *Puffinus puffinus*, for which the UK holds 93% of the global breeding population (Stroud *et al.* 2001), and the Puffin *Fratercula arctica* from which Lundy gets its name ("lund" is Norse for Puffin).

In 2001 the first comprehensive survey of the Manx Shearwater on Lundy using tape-playback at burrows returned an estimate of 166 pairs (Price & Booker 2001). This is much lower than previous estimates from 1976 and 1985 of between 2,800 to 7,000 (Thomas 1981) and 1,200 pairs (Taylor 1985) respectively. However, these estimates were based largely on counts of birds in flight and may not be directly comparable with the more recent estimate.

For the Puffin a similar decline is evident: in 2000, only 13 individuals were counted compared with an estimated 3,500 pairs in 1939 (Perry 1940). Several factors could have caused the declines in these seabird species on Lundy of which predation by rats (Rattus *spp*.) on eggs and chicks was believed to be one of the most important. Lundy's Manx Shearwater and Puffin populations are significantly lower than those on nearby Welsh islands of Skomer and Skokholm both of which are rat free. Rats can devastate seabird populations on islands but recovery following rat removal is documented (Micol & Jouventin 2002; Stoneman & Zonfrillo 2005). In 2001 a feasibility study concluded that, with systematic and comprehensive use of poison bait, eradication of rats from Lundy was a realistic and achievable goal (Bell 2001). On this basis an eradication programme was initiated in 2002.

Unusually, two species of rat have been recorded on Lundy: the Brown Rat *Rattus norvegicus* which is ubiquitous in mainland Britain and the Black Rat *R. rattus* which is nationally rare. Historically the Black Rat was widespread in the UK and Ireland but is now largely confined to four island groups. It was probably replaced by the Brown Rat when it arrived in the mid-18th century. Both species are globally widespread and abundant (Corbet & Harris 1991) and known to kill and eat adult seabirds, or their eggs or young (Atkinson 1978; Micol & Jouventin 2002).

A description and appraisal of the eradication programme forms the basis of this report, together with some observations on the productivity of the target seabird species, the Manx Shearwater.

METHODS

The primary aim of the Seabird Recovery Project was to remove or reduce the factors preventing the populations of the Manx Shearwater (and Puffin) on Lundy from achieving their potential population sizes. The initial objective was to eradicate the island's rats to allow an immediate increase in the productivity of these two species. The decision to remove the rats was not taken lightly. The eradication programme was likely to be difficult given the terrain. It attracted many protests from people or groups objecting to the use of rodenticides to kill the rats, and the killing of the Black Rat which many considered to be "Britain's rarest mammal" (Appleton *et al.* 2002).

The eradication programme ran from November 2002 to March 2004 with effort concentrated in the two winter periods when the natural food supply for rats was low and take up of bait would be highest. Expert contractors, assisted by a total of 57 volunteers, conducted the fieldwork, totalling some 2,485 people days.

Rats were poisoned using cereal-based wax bait blocks, each weighing c. 24 g. Three to four of these were set in 2,100 bait stations in a 50 m grid that covered the entire island and offshore stacks; stations consisted of 0.75m long sections of plastic corrugated pipe with a diameter of 0.1m. Bait stations were also placed on the island ferry. All stations were regularly checked and maintained, bait take noted and replaced or changed to ensure a constant supply of intact blocks. Data were collated on a daily basis to track project progress.

The bait blocks contained 0.005% active ingredient difenacoum, a second generation anticoagulant that causes internal haemorrhage by inhibiting synthesis of Vitamin K. For a 400g Brown Rat, the LD50 for difenacoum was 18g of the wax bait block bait. On average two to four feeds are required for a lethal dose, after which death occurs within four to seven days. Difenacoum is a routinely used anticoagulant rodenticide throughout the UK (and the active ingredient in poison bait used for many years previously to control rats in buildings on Lundy).

Monitoring stations within the bait grid held "chewsticks" (wooden pegs soaked in oil) and candles or soap. Rats routinely gnaw on chewsticks etc revealing their characteristic incisor marks providing a further means of detecting their presence when no bait was being taken.

Quarantine measures to reduce risk of rat re-infestation and contingency procedures to remove rats if any were sighted were agreed and drawn up.

Full details of the poisoning programme are given in the unpublished final report (Bell 2004) which can be made available on request.

The likely trends of Manx shearwaters following rat eradication were investigated using difference equations (Croxall & Rothery 1991). The starting population size was taken as 166 pairs and the start date for modelling 2001 when this count was made. The productivity was assumed to be 0.1 chicks per pair prior to rat eradication in winter 2002 (based on data from rat predation years on Canna; A. Ramsay, *pers comm.*) and 0.7 chicks per pair afterwards (based on productivity at rat free islands; Mavor *et al.* 2005). Age of first breeding was assumed six years (Brooke 1990), survival from fledging to the first-year of life to be 44% (Brooke 1990, Perrins *pers. comm.*) and adult survival 93% (Richdale 1963, Bradley *et a*l. 1989, Cuthbert & Davis 2002, Perrins *pers. comm.*).

RESULTS

Over the winter of 2002/3 bait uptake, as indexed by the number of stations where bait was replaced, increased rapidly and then declined indicating by

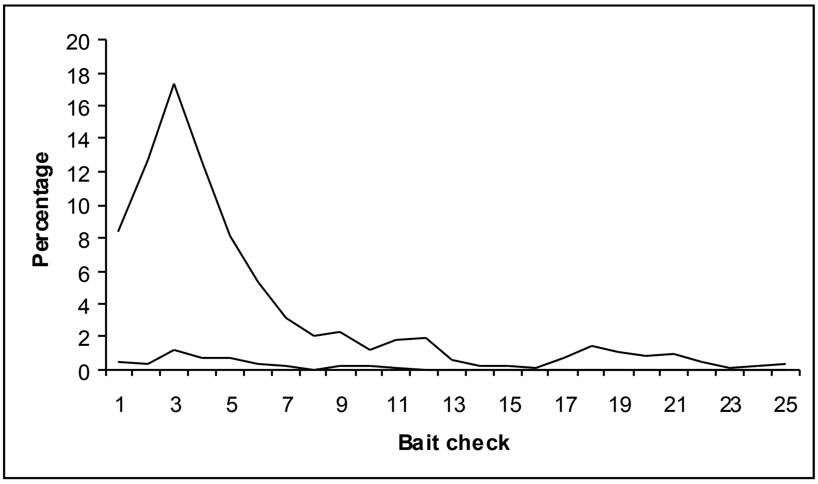

Figure 1. Temporal variation in uptake from bait stations during the poisoning programmes. Top line – from Bait check 1; first part of 2003 (4th January to 4th June), and bottom line – from Bait check; late 2003 to 2004 (9th December to 1st March). From: Bell, 2004.

Figuur 1. Variatie in 'verdwijnen' van aas op aasplekken gedurende het verdelgingsprogramma. Bovenste lijn: eerste helft van 2003 (4 januari tot 4 juni); onderste lijn: eind 2003 tot 2004 (9 december tot 1 maart). Naar: Bell, 2004.

March 2003 a significant decrease in the rat population (Fig 1). However, monitoring of chew sticks revealed that 'hot spots' of rat activity remained. With one exception, these were associated with human habitation and the farm. To target the remaining rats effort was intensified in these areas by using a smaller grid size (25 x 25 m) effectively tripling the density of stations.

By the end of May 2003 monitoring showed that rats where still being detected in the "hot spots". A combination of increased natural food sources, reducing the chance of rats eating bait, and increased visitor pressure meant that the baiting of stations was scaled down until the autumn. In November 2003 both the bait and monitoring grids were re-established over the entire island. Bait take occurred at a small number of locations during December 2003 and January 2004 (Fig 1). However no rat sign was detected on chew sticks at monitoring stations indicating that once bait take had stopped, the rats had been killed.

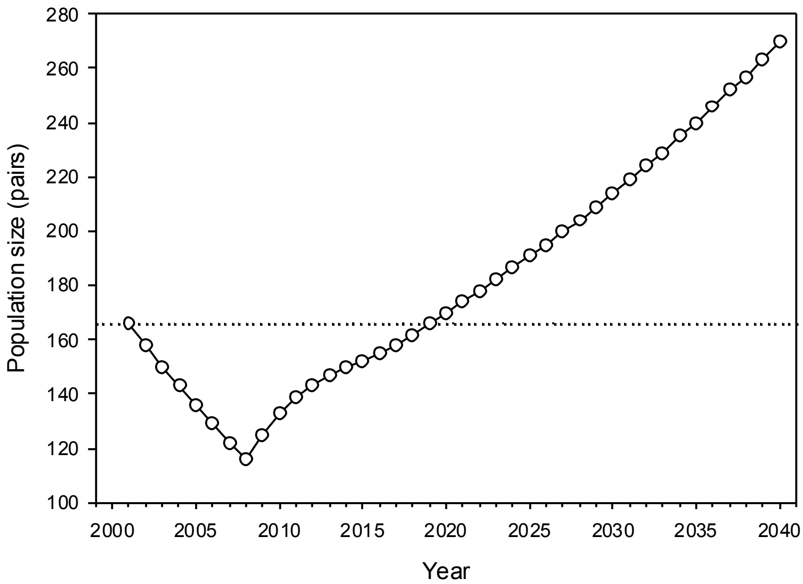

Figure 2. Predicted trend of the Lundy Manx Shearwater population to the eradication of rats in winter of 2002.
Figuur 2. Berekende populatietrend van de Noordse Pijlstormvogel op Lundy na het uitroeien van ratten in de winter van 2002.

The final bait take was noted during February 2004. For the rest of that year, weekly checks of bait stations (initially containing bait, and later candle/soap) located at previous "hot spots" were conducted followed by monthly checks in 2005. No evidence of rats has been recorded since February 2004. In the wild very few rats live for more than a year (Corbet & Harris 1991). A whole island final check in early 2006 confirmed the rat-free status of the island. Monitoring to detect rats will continue indefinitely at the island's jetty and associated buildings.

Quarantine measures have been implemented to prevent rodents reaching Lundy. Contingency procedures have also been drawn up should a rodent be detected on the island (Bell 2004). These have already been used to detect and remove a mouse or mice in the farm buildings where a 25 x 25 m bait station grid within a 50 m radius check of the sighting (of droppings) was installed.

Using the model and assuming a closed population the number of Manx Shearwaters is expected to continue to fall owing to poor productivity during years prior to rat removal (Fig 2). Six years on from rat eradication, the population should increase owing to higher productivity and hence recruitment. The trajectory of the increase is convex between 6 and 12 years following the eradication owing to the declining number of breeding pairs in previous years making the cohorts progressively smaller. Following this period, growth becomes exponential; a pattern that should continue until density dependent limitation causes growth rates to slow. Figure 2 also illustrates that counts prior to 2022 are unlikely to detect an increase in Manx Shearwater numbers, and those made earlier may indeed result in a decline being detected.

DISCUSSION

Eradication of rats from Lundy Island presented many challenges, from the logistical and technical difficulties of working on an inhabited and farmed island which is a tourist attraction, to opposition from animal rights campaigners wishing to conserve the Black Rat and prevent the use of poisons to kill rats (Meech 2005). The feasibility study (Bell 2001) did not take into account an unforeseen increase in visitor use of the island during the winter months. This resulted in additional food sources from the visitors, being available to rats reducing their bait uptake in the crucial winter period. Waste management procedures were significantly tightened during the course of the project to the point where scrap food and animal feedstuffs are now much less accessible to rodents.

In wet weather the bait blocks swelled and crumbled, leaving them unpalatable to rats and requiring frequent replacement. Bait stations, although designed to minimise access by non-target animals and birds, were sometimes damaged by livestock and ponies. Adaptations to stations and project design were generally successful in minimising interference by non-target animals although a small number of crows *Corvus corone corone* (8) and rabbits *Oryctolagus cuniculus* (7), were found to have been poisoned during the two year programme. The crow and rabbit carcasses for which we suspected non-target poisoning as the cause of death were sent to the Department of the Environment Food and Rural Affairs for autopsy and reporting. The post-mortem of one crow revealed traces of three second generation anticoagulants, difenacoum, flocoumafen and brodifacoum, the last two of which are banned for use outdoors in the UK. These incidents strongly suggested that the bait blocks, which should have contained only difenacoum as the active ingredient, also contained traces of more toxic anticoagulants, through contamination during manufacture. The bait manufacturers were immediately informed and contaminated bait removed and sent back to source. These unfortunate incidents highlighted the problem of the potential contamination of commonly available 'off the shelf' baits.

During the eradication programme on Lundy an attempt was made to collate details of similar projects on four other British Islands (Willcox 2000, 2001; Zonfrillo 2002a, 2002b., B. Zonfrillo *pers. comm.*; Ratcliffe & Sandison 2001, 2002; J. Ratcliffe *pers. comm.*; Bell *et al.* 2000). This was done for two reasons: first to identify common issues and second to compare costs. The islands, including Lundy, varied in size between 32ha and 424ha. Rat eradication cost/ha was however, much less variable: mean = £164/ha, S.E. = 47.67, range = £14-£191/ha. Thus the estimated cost/ha of rat eradication for these British Islands is comparable with area payments for farmland in agri-environment schemes. The success of two of these projects, (Handa and Ailsa Craig), based on an increase in seabird productivity, gave rise to an expectation of a similar result to occur on Lundy.

The eradication of rats from Lundy has been successful. Quarantine measures and a contingency plan are in place to prevent and remove any new invasion respectively. Monitoring will now focus on the breeding success of the burrow-nesting seabirds, and especially the Manx Shearwater. Survey techniques including burrow-scope observations and mark recapture of chicks have been trialled to investigate the productivity of shearwaters on the island. The steep slopes and deep, convoluted burrows make burrow-scopes and other underground studies impractical. Mark recapture will be favoured following observations of juveniles outside burrows at night which confirmed successful breeding in 2004 and 2005 (H Booker *pers. comm.*).

The Seabird Recovery Project cannot be considered a success until we record an increase in the number of breeding pairs of Manx Shearwater on Lundy. The model shows that the population will continue to decline for a further six years following rat eradication and that it is only likely to exceed the 2001 count after 2022. This assumes, however, that the population is closed. Brooke (1990) suggested that half the chicks fledging from Skokholm move to other colonies. Given that Lundy is only 60 km away, it is highly likely that it will receive immigrants from this and other Pembrokeshire colonies. Even if the proportion of Pembrokeshire fledglings emigrating to Lundy was small, this could generate a higher rate of increase than predicted by the closed population model owing to the relative sizes of the source and recipient colonies.

ACKNOWLEDGEMENTS

We thank the contractors Wildlife Management International Ltd for their expertise and hard work in conducting this project. They were supported by many volunteers whose work in (often arduous) conditions was vital to the project. We thank Martina Flynn and her colleagues at SOREX for donations of bait and their interest in the project and Dr Alan Buckle who kindly gave advice and support. We thank the Lundy islanders for their ongoing support of the project. We are grateful to Dr Norman Ratcliffe for running the population model and providing its interpretation and to Prof Chris Perrins for providing values of survival rates of Manx Shearwaters from an unpublished manuscript.

HET ZEEVOGELHERSTELPROJECT OP HET EILAND LUNDY

Groot-Brittannië herbergt 93% van 's werelds broedpopulatie van Noordse Pijlstormvogel *Puffinus puffinus.* De populatie van Noordse Pijlstormvogel en Papegaaiduiker *Fratercula arctica,* een andere in holen broedende zeevogel, is momenteel veel lager dan honderd jaar geleden werd gemeld. Predatie door ratten werd geacht een belangrijke factor voor deze afname te zijn. In 2002 werd een programma gestart om ratten uit te roeien, met als doel om de populaties van deze zeevogels te herstellen. Zowel de Zwarte, als de Bruine Rat *Rattus rattus* en *R. norvegivus* kwamen op het eiland voor. Eerstgenoemde soort is zeldzaam in Groot-Brittannië, maar beide komen wereldwijd voor, zijn algemeen én prederen zeevogels. De twee jaar durende uitroeiingscampagne werd maart 2004 afgesloten en sindsdien is geen bewijs voor hun aanwezigheid. Hoewel een toename in de broedpopulatie niet op de korte termijn verwacht wordt zal monitoring nu geconcentreerd worden op de populaties en productiviteit van de doelsoorten Noordse Pijlstormvogel en Papegaaiduiker.

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THE NATIONAL TRUST FOR SCOTLAND'S SEABIRD RECOVERY PROGRAMME: PROPOSED BROWN RAT ERADICATION FROM THE INNER HEBRIDEAN ISLANDS OF CANNA AND SANDAY

A.J. PATTERSON*

Patterson, A.J., 2006. The National Trust for Scotland's seabird recovery programme: proposed Brown Rat eradication from the Inner Hebridean Islands of Canna and Sanday. Atlantic Seabirds 8(1/2): 61-72. *The islands of Canna and Sanday are situated off the west coast of Scotland within the Inner Hebridean archipelago. The island of Canna is the largest being 5 mile long by 2 mile wide and Sanday 1½ mile long by ½ mile wide. The islands (excluding all inbye land) were designated an SSSI in 1987 and an SPA in 1997 for their seabird and raptor populations, particularly Manx Shearwater* Puffinus puffinus, *Shag* Phalacrocorax aristotelis *and White-tailed Eagle* Haliaetuus albicilla. *Studies carried out by The Highland Ringing Group have highlighted declines in several species of seabirds. The National Trust for Scotland in conjunction with the Highland Ringing Group investigated the cause of decline and brown rat was suspected to be the main cause. Some remedial work was carried out in 1997-1999 to prevent Manx Shearwater declining further but this species became extinct in 2000. Plans for a full rat eradication program were initiated in 1997 for the islands of Canna and Sanday and research into the environmental impact on other species for such a program were undertaken. A small mammal survey took place 1997-1999 since little was known on this group's status. Studies found that there were few species on the islands and that numbers were low. It was found that Wood Mouse* Apodemus sylvaticus *had an interesting physiology and that further work would be needed to establish if this was genetically different from mainland species. However, this added to the project where this species had to be protected and samples are now in quarantine in Edinburgh Zoo until the eradication program has been completed. A rat distribution survey was carried out in the winter of 2000-2001 to determine their location and rough densities. There are several raptor species on the island and most do scavenge rabbits and rats which will be affected by poisoning. Though secondary poisoning in raptors using a 1st generation poison is unlikely, these risks had to be reduced to an acceptable level. A steering group was set up in 2003 to carry the project forward. LIFE-Nature fund application was made to Brussels and the Trust has now received full funding for the project.*

*National Species Recovery Officer, The National Trust for Scotland

INTRODUCTION

The islands of Canna and Sanday are situated off the west coast of Scotland within the Inner Hebridean archipelago. A small farm, light crofting and tourism constitute the main livelihood of the 12 residents currently living on the islands, which are owned by The National Trust for Scotland (NTS). The islands (excluding all inbye land) were designated a Site of Special Scientific Interest (SSSI) in1987, for their biological and geological features, and a Special Protection Area (SPA) in 1997 for raptors and seabird populations, particularly Manx Shearwater *Puffinus puffinus* and European Shag *Phalacrocorax artistotelis*.

Over the past 30 years, The Highland Ringing Group has, on behalf of The Joint Nature Conservation Council (JNCC), collected data on seabird breeding success and numbers through the Seabird Monitoring Programme Canna Studies. These studies have highlighted a decline in seabird numbers between 1973 and 2004 with a steep decline from the nineties. Burrow-nesting birds such as Manx Shearwater showed a very dramatic decline. More recent declines have been noted in more robust species such as European Shag and Razorbill *Alca torda*. Predation by Brown Rats *Rattus norvegicus* has been identified as the cause of the decline, and a series of studies were initiated by The National Trust for Scotland to investigate the feasibility of setting up an eradication programme, with a future Brown Rat control programme, and to establish the impacts this may have on non-target species. This programme of eradicating Brown Rats began in September 2005.

SEABIRD DECLINE

Overall there has been a 49% decline in seabirds between 1995 and 2004, with Manx Shearwater showing the steepest decline, at 99% (Table 1). All species have exhibited marked declines, with the exception of Black-legged Kittiwake *Rissa tridactyla,* which has experienced a 44% increase in numbers (Table 1). Other seabird colonies within the archipelago have faired better and do not share Canna and Sanday's trends, suggesting that the problem of seabird decline is local.

The population of Manx Shearwaters was estimated as between 1000-1500 pairs in 1973, since when it has been monitored annually. This species has been decreasing since 1976, with a sharp decline in 1989 when only 15 out of 62 study burrows contained chicks, and only four chicks successfully reared (Swann, 2001). By 1998 productivity in the colony was too low to measure (Figure 1).

Table 1. Percentage change in numbers of breeding seabirds (individuals) for each species on Canna and Sanday 1995-2004.
Tabel 1. Procentuele verandering in aantallen broedende zeevogels (individuen) op Canna en Sanday 1995-2004.

Species	1995	2004	Increase (%)	Decrease (%)
Manx Shearwater	268	2		99
Northern Fulmar	1306	886		32
European Shag	2060	1080		48
Common Guillemot	7716	6243		19
Razorbill	2104	498		76
Atlantic Puffin	1225	740		40
Black Guillemot	85	44		48
Common Gull	34	12		65
Lesser Black-Backed Gull	78	26		67
Herring Gull	2652	744		72
Greater Black-Backed Gull	170	88		48
Black-legged Kittiwake	1864	2680	44	
Common Tern	6	2		67
			Overall decline 49%	

In May 2000 no responses were elicited when a tape was played to 240 burrows within the study area, though in 2001 a single bird responded (Swann *pers. comm.*). Historic nesting sites were checked in June and again in August 2001. Shearwaters were heard calling in flight at some of these locations at night and additional checks were made by day using tape playback. Although there was some physical evidence of burrow occupancy in terms of droppings at burrow entrances, no birds responded (Patterson 2003). The nearby Manx Shearwater colony on the island of Rum has not shown a decline, though data is inconclusive and cannot be used as a comparison. (Swann *pers. comm.*).

Northern Fulmar *Fulmaris glacialis* numbers have fluctuated since 1973, with a notable decline in apparently occupied sites (AOS) occurring between 1995 and 1999 (Figure 2).

It is difficult to draw any clear trends from this as different counting methods were used and the number of non-breeders occupying sites in mid-summer may vary (Swann *pers. comm.*). In one study site in 1997, out of 16 Northern Fulmar eggs laid only four chicks fledged, and in 1998 out of 12 eggs laid only one chick fledged. In 2004 breeding success was 0.56 for all study plots collectively. Sites on high inaccessible cliffs tended to be more successful, possibly because rats could not gain access.

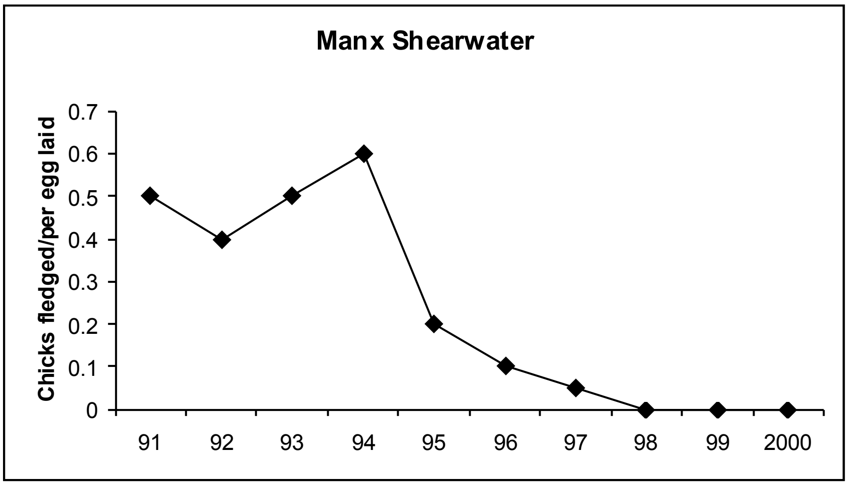

Figure 1. Manx Shearwater chicks fledged per egg laid within study plots where the species became extinct in 2000.
Figuur 1. Aantal uitgevlogen jongen per gelegd ei in studieplots, waar de Noordse Pijlstormvogel in 2000 was uitgestorven.

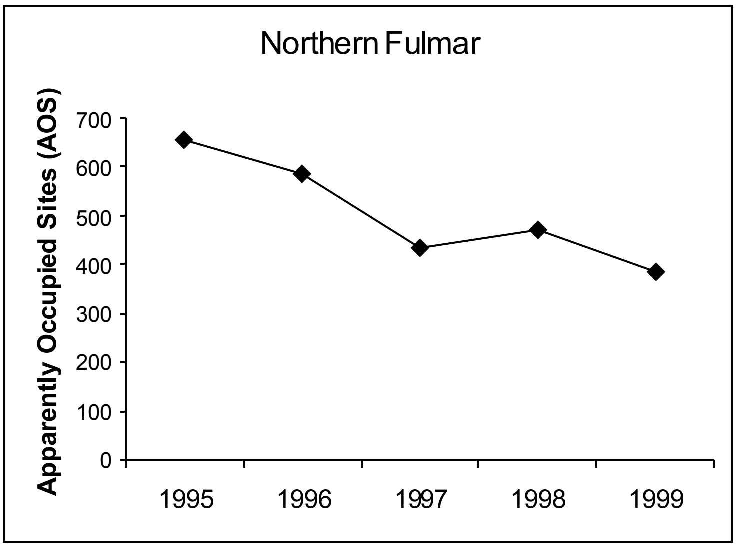

Figure 2. Declining trend off Northern Fulmar decline in Apparently Occupied Sites.
Figuur 2. Een afnemende trend in het aantal door Noordse Stormvogels bezette nestplaatsen (AOS).

The European Shag colony is located in a boulder field at the foot of cliffs at Garrisdale, in the west end of the island. There was a steady increase in the European Shag population throughout the 1970s to the 1980s; thereafter there has been a steady decline. The number of apparently occupied sites (AOS's) remained fairly constant during the 1990s followed by a decline from 2002. Up until 2000 there were increasing numbers of nest failures at the colonies at Garrisdale and Nunnery. There was an almost complete failure at the Nunnery and Lamasgor colonies in 2000 and 2001 (Swann 2001). Surviving nests were restricted to inaccessible cliff ledges or deep recesses under large boulders at the top of the colony furthest from the shore. At Garrisdale all nests failed except for a small section in the core of the colony where breeding success was normal. In contrast the large colony at Geugasgor had normal breeding success. Of the four, this colony is the most inaccessible to ground predators being on a raised wave-cut platform below high cliffs. In 2004 all nests failed at Garrisdale and the remains of predated eggs were found and strongly suggest that rats may be to blame. Overall at Garrisdale three nests produced chicks with a success rate of 0.1 chicks per nest and these were all on inaccessible cliffs (Swann 2004).

Between 1979 and 1996, 400 to 500 Razorbill AOS were counted at Geugasgor. Other sites have fluctuated above and below 100 AOS with a steady decline from 1995 to 2004 (Swann in press). The number of chicks produced declined over the period 1986-2000 from 550 to around 420. However, the study areas of the Nunnery and Garrisdale showed a particularly dramatic decline, and almost total breeding failure occurred in 2000. Geugasgor colony being less accessible was initially less affected but declined from 1995, and there is strong evidence indicating that ground predators may be responsible for this decline (Swann, 2001). There were signs of Brown Rat activity in these areas in the form of rat runs and droppings. In 2004 the total count for Canna was 169 nests with 162 of those at Geugasgor. Many previously occupied Razorbill sites, for example Garrisdale and the Nunnery, are now totally abandoned and large numbers of predated eggs were found in the Geugasgor colony.

BROWN RAT SURVEY

A survey was carried out in winter 2000-2001 to map the distribution of Brown Rats and to record rough densities throughout the islands (Patterson & Quinn, 2001). Winter was chosen because Brown Rats are at their weakest with relatively little food available and this time would coincide when an eradication programme would have the greatest chance of success (Zonfrillo *pers. comm.*). Survey points were made up of four chewsticks coated with lard and placed into the ground, the site marked with a bamboo cane for ease of locating and survey points placed in a 200 m² grid. Rats can detect food on average 300 m away and a 200 m grid should, given the right circumstances away from other competing food sources, attract Brown Rats (Taylor 1978). To check for movement between islands, survey points were placed on the pedestrian bridge linking Canna and Sanday, and also on small islets accessible at low tide. This survey pattern was detailed enough to monitor all Brown Rat activity on the islands (Figure 3). The presence of Brown Rats was determined by teeth marks on gnawed chewsticks.

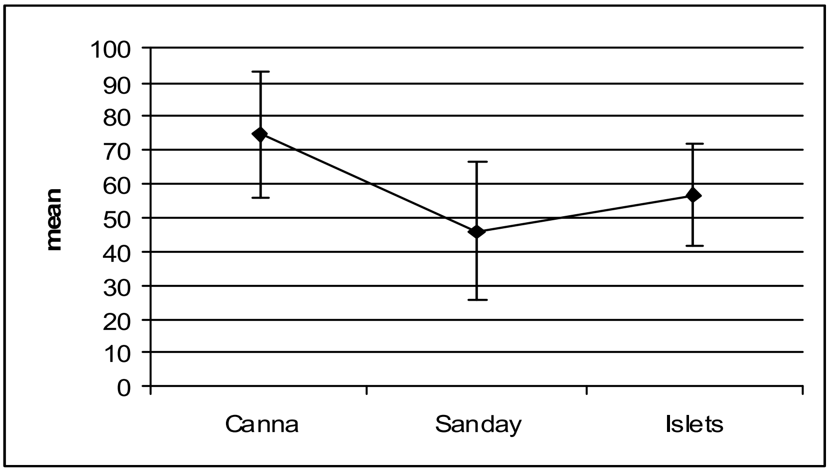

Figure 3. Mean (± SE) of chewstick activity on Canna and Sanday and small accessible islets.
Figuur 3. Gemiddelde 'kauwstok-activiteit' (± SD) op Canna, Sanday en kleine toegankelijke eilandjes.

Of a total of 434 chewstick stations, 343 were on Canna, 78 on Sanday, three on the footbridge that connects the islands, and a further 10 on small islets. Small offshore islands and sea stacks were not surveyed. Chewsticks were coated in lard as an attractant for rats and chew marks then recorded on a scale of 1-5 where 1=light chewing (low activity), and 5=heavy chewing (high activity). The highest level of rat activity was found around the coast reflecting the greater availability of food washed up. Brown Rat activity was also found on inland areas and correlated with watercourses and Rabbit *Oryctolagus cuniculus* colonies. Brown Rats coexist with Rabbits in their burrows and prey on sick or weak individuals as a food source. Myxomatosis was widespread on Canna and Sanday during the survey period and an abundance of carcasses and ailing

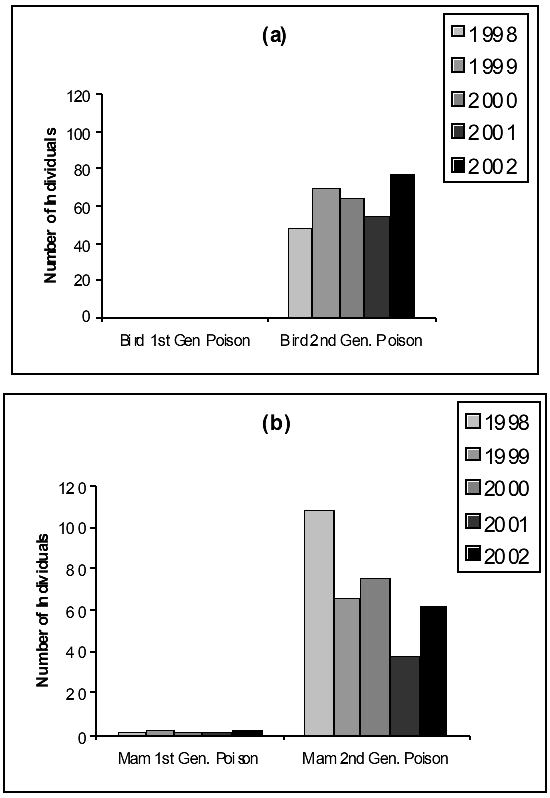

Figure 4. (a) Reported 1[st] and 2[nd] generation poisoning incidents in birds. (b) Reported 1[st] and 2[nd] generation poisoning incidents in mammals.
Figuur 4. (a) Gemelde eerste en tweede generatie vergiftigingen bij vogels. (b) Gemelde eerste en tweede generatie vergiftigingen bij zoogdieren.

individuals was available to rats. There are several islets adjacent to Canna and Sanday that can easily be accessed at low tide. Of the two islands and four islets included within the survey, only two of the smallest islets had no signs of rat activity. The presence of rats on the other larger islets highlights that Brown Rats will cross at low tide and access both Canna and Sanday. Chewstick stations on the footbridge showed no signs of Brown Rat activity indicating that they will not cross at this point.

NON-TARGET SPECIES

Diphacinone, a first generation anticoagulant rodenticide, will be the primary poison for the eradication programme. Diphacinone has limited, if any, secondary effects on raptors. Between 1998 and 2002 in the UK there were no incidents reported of birds being poisoned by a first generation rodenticide, whereas over the same period there have been incidents of poisoned birds by second generation rodenticides (DEFRA 1998 to 2003). Similarly, there are very few cases of first generation poisoning in non-target mammals, in contrast to a much larger number poisoned by second generation rodenticides (Figure 4 a & b). However, it could be hypothesised that there are more farmers/land-owners using second generation poisons than first generation poison and that this will skew the results.

Raptors are a priority when planning an eradication programme. It is important to maintain and increase productivity of White-tailed Eagles *Haliaeetus albicilla* as, the two pairs on Canna represent 6% of the UK population. All poison will be placed in bait stations designed to prevent access to species larger than rats and so inaccessible to raptors. Rats will die underground and therefore cannot be scavenged by raptors. Poison is contained in wax blocks and held in place with a metal pin within a plastic flexible tube, which is secured to the ground with metal pins and cannot be pulled out (Figure 5).

Figure 5. Poison bait dispenser made from drainage flexible plastic piping.
Figuur 5. Doseerbuis voor vergiftigd aas, gemaakt van een flexibele plastic afvoerbuis.

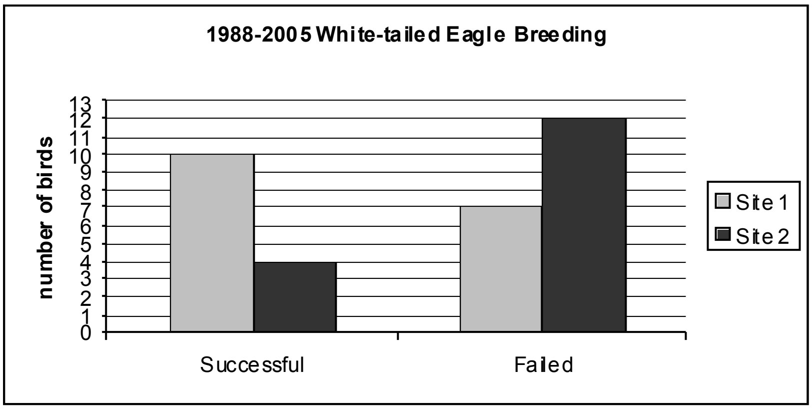

Figure 6. Breeding success of White-tailed Eagle at site 1 and 2.
Figuur 6. Broedsucces van Zeearend op 'site 1 en 2'.

The timing of the eradication (start September / October 2005) will also reduce the risk of disturbance to raptors and should be completed by May 2006. Raptor areas can be poisoned early in the season to prevent disturbance.

It is possible that rats may be causing problems to the breeding success of White-tailed Eagles, though no evidence exists. Of 13 breeding attempts at one site, ten were successful, while at another site chicks only fledged in 4 out of 16 attempts (Figure 6). The low success rate at Site 2 could be caused by many variables but rats have to be considered (Patterson 2003).

SMALL MAMMALS

Other than rats, the small mammal fauna of Canna and Sanday is limited to Wood Mouse *Apodemus sylvaticus* and (in smaller numbers) Pygmy Shrew *Sorex minutus* (Patterson & Brough 1999: Patterson & Lloyd 2000). Wood Mice on Canna and Sanday are apparently morphologically unique, being heavier than their mainland conspecifics (Table 2).

Small mammals are susceptible to Diphacinone poison and populations could be depleted during the eradication programme. The 50m grid is designed so that species with smaller home ranges will not always encounter bait stations, and so it is hoped that many Wood Mice and Pygmy Shrews will not be poisoned. In addition, samples of Wood Mouse will be kept in quarintine at Edinburgh Zoo and at Kincraig Wildlife Park. They will be allowed to breed in captivity and thereafter be released on Canna and Sanday.

Table 2. Weight (g) and home range of Wood Mouse from Canna and other areas.
Tabel 2. Gewicht (g) en homerange van Bosmuizen op Canna en andere gebieden

Location	Males			Females		
	Mean	Range m^2	*n*	Mean	Range m^2	*n*
Perthshire[a]	19.1	13-27	20	17.8	13-24	13
Muck[b]	19.0		3			
Rum[b]	30.6		19	31.7		6
Canna	28		11	23.5		5
Eigg[b]	27.4		4	30.3		5
Canna[c]	33.8	27-41	18	33.3	31-35	6

[a] Flowerdew 1991; [b] Berry, Evans & Sennitt 1967 & [c] Patterson & Lloyd 2000.

Baseline data from surveys carried in 1999-2000 will facilitate comparison with post-rat-eradication numbers. Densities of the two species are expected to increase in the absence of rats (from current low numbers), Brown Rats having been shown to suppress numbers of Wood Mice on Rum (Berry *et al.* 1967). Feral Cat *Felis catus* are common on Canna, however these predators may also play a role in regulating numbers of small mammals.

CONCLUSION

Seabirds have been declining steadily for 30 years with a more pronounced decline in the last 10 years. If left unchecked, further extinctions will occur, as seen recently with Manx Shearwater. There is strong evidence to suggest that rats are the main predator causing these declines. Rat eradication is the only answer to this problem and mitigation procedures have been put in place to safeguard small mammals and raptors. The consequences of the accidental mortality of raptors on Canna resulting from the eradication programme would be extremely serious both for the conservation of the species and the adverse publicity that it would generate. It must therefore be avoided at all costs. Nevertheless, it is concluded that the mitigation measures proposed are such that the residual risk to White-tailed Eagle are vanishingly small and, the risk to small mammals reduced to an acceptable low-level to prevent extinction from rat-eradication activities.

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DE ZEEVOGELHERSTELCAMPAGNE VAN THE NATIONAL TRUST FOR SCOTLAND: VOORSTEL TOT UITROEIÏNG VAN BRUINE RAT OP CANNA EN SANDAY

De eilanden Canna en Sanday liggen voor de westkust van Schotland, in de archipel van de Inner Hebrides. Met een lengte van 5 mijl en een breedte van 2 mijl is Canna het grootst; Sanday is 1½ bij ½ mijl groot. De eilanden kregen in 1987de status van Site of Special Scientific Interest (SSSI) en in 1997 de status van Special Protection Area (SPA, Vogelrichtlijngebied) vanwege de populaties van zeevogels en roofvogels, met name van Noordse Pijlstormvogel *Puffinus puffinus*, Kuifaalscholver *Phalacrocorax aristotelis* en Zeearend *Haliaetuus albicilla*. Onderzoek door The Highland Ringing Group toonde een afname van verschillende zeevogels aan. De National Trust for Scotland heeft, samen met The Highland Ringing Group, onderzocht wat de oorzaak van deze afname was; predatie door bruine ratten is waarschijnlijk de hoofdoorzaak. In 1997-1999 werden herstelmaatregelen genomen om verdere afname van Noordse Pijlstormvogel te stoppen, maar deze soort was in 2000 verdwenen.

Plannen voor een campagne om ratten op Canna en Sanday uit te roeien werden in 1997 geïnitieerd, terwijl onderzoek naar de invloed van een dergelijke campagne op andere soorten werd opgezet. Een inventarisatie van kleine zoogdieren vond in 1997-1990 plaats, omdat er weinig bekend was over de status van deze groep. De inventarisaties lieten zien dat er een klein aantal soorten in lage aantallen op de eilanden voorkwam. Er werd vastgesteld dat de Bosmuis *Apodemus sylvaticus* een interessante fysiologie had, en dat verder onderzoek nodig is om vast te stellen of deze genetisch verschilt van de Bosmuizen op het vasteland. Een inventarisatie van de verspreiding van ratten werd in de winter van 2000/2001 uitgevoerd. Op het eiland komen verschillende soorten roofvogels voor die foerageren op Konijnen en ratten en dientengevolge met gif in aanraking zullen komen. Hoewel secondaire vergiftiging van roofvogels bij een zogenoemd eerste generatie-gif onwaarschijnlijk wordt geacht, moeten de risico's tot een aanvaardbaar niveau beperkt worden. In 2003 werd een stuurgroep in het leven geroepen om de campagne te volbrengen. Na een subsidieaanvraag bij het LIFE-Naturefonds heeft de Trust nu volledige subsidie voor het project ontvangen.

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THE BALEARIC SHEARWATER *PUFFINUS MAURETANICUS*: A REVIEW OF FACTS AND QUESTIONS

PIERRE YÉSOU[1]

Yésou, P., 2006. The Balearic Shearwater *Puffinus mauretanicus*: a review of facts and questions. Atlantic Seabirds 8(1/2): 73-80. *The systematic relationships of* Puffinus mauretanicus, *which breeds in the Balearic Islands in the western Mediterranean, have been disputed since its initial description as a subspecies of the Manx Shearwater* P. puffinus. *It is presently considered a species of its own, slightly differentiated from Yelkouan Shearwater* P. yelkouan, *a 'sibling species' which breeds elsewhere in the Mediterranean. However, birds seemingly intermediate between these two forms are breeding in Menorca, and further research is needed to confirm whether the two taxa really are different species. Bearing its limited breeding range and population size in mind, it is rather odd that the Balearic Shearwater has not been classified as threatened by BirdLife International in its Threatened Birds of the World, 2000. Since then, population studies have sounded the alarm, suggesting that the species might disappear within a few decades, and the Balearic Shearwater is now categorized as 'Critically Endangered'. Published population estimates are not always reliable, however, and its population dynamics remains poorly understood. Threats are better known and include mammal predators at breeding sites, mortality induced by long-line fishing, and probably a greater difficulty to access food resources.*

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INTRODUCTION

The Balearic Shearwater *Puffinus mauretanicus* is endemic to the Balearic Islands, in the western Mediterranean. Although its distribution, including non-breeding dispersal, and its biology are relatively well known (Ruiz & Martí 2004), various points remain unclarified regarding its taxonomy, its population size, and its conservation status. These topics are reviewed here with the aim of highlighting what the priorities could be for further studies.

TAXONOMY

First described by Lowe in 1921, *mauretanicus* has long been considered a subspecies of the Manx Shearwater *P. puffinus* together with another Mediterranean taxa, *yelkouan*. When the morphological and behavioural differences between Manx and the two Mediterranean taxa became better understood, the latter duet was united into one species, the Yelkouan (or Levantine) Shearwater *P. yelkouan*, following Bourne *et al*. (1988). Reasons to split *P. yelkouan* into two species were therafter given by Sangster *et al*. (1997), who considered the two taxa as originating from different stocks. The latter assumption was contradicted by both bio-acoustics (Bretagnolle & Zotier 1998) and genetics (Heidrich *et al.* 1998, 2000; Austin *et al*. 2004), which both emphasized the sister relationships of *mauretanicus* and *yelkouan*, but the split of the two species became widely accepted (e.g. Sangster *et al*. 2002).

As usual nowadays when accepting changes in avian systematics, a high credential was given to genetic data (i.e., Heidrich *et al.* 1998, 2000). As a genetist, Petra Heidrich (pers. comm. 1998) was however unsure whether these taxa were to be regarded as different species, because of a relatively low divergence between them, and because she had compared *mauretanicus* to birds from eastern Mediterranean, not to the nearest *yelkouan* from southern France or Sardinia. She was prompted to split the taxa by her correspondants in the Balearic, who put forward both biological and osteological reasons. Unfortunately, the osteological approach is weakened as it forgot to take into account Mayaud's (1932) conclusions on a larger data set (Yésou & Paterson 1999), and it may even be flawed as the preparation technique affected the reference material (M. McMinn, pers. comm.). The biological support holds in differences in breeding calendar between the taxa and the fact that no 'intermediate' population was known, although overlap occurs in both biometry and overall appearance (Yésou & Paterson 1999).

During the first intensive survey of breeding sites all over the Balearic Islands in 1999-2001, observers realized that some breeders in Menorca exhibited a more contrasted plumage than is usually seen around the other islands, almost pure white below and thus resembling *yelkouan*, and so news was quickly released that Yelkouan Shearwater was breeding in Menorca (Martí & Ruiz 2001; Ruiz *et al*. 2003; Guttiérrez 2004). A more critical approach might have been preferred, particularly since pale individuals were already known to occur in Menorca (e.g., E.J. Mackrill in Yésou *et al*. 1990) which at the time have been identified as *mauretanicus* on characters such as size and structure.

Furthermore, some of the pale birds found in recent years were breeding in the same colony than undisputed *mauretanicus* (M. McMinn, pers. comm.; Genovart *et al*. 2005), a rather unexpected situation if they are not the same species. Although difference in breeding calendar has been put forward to support the split of *yelkouan* and *mauretanicus* in two species (e.g., Heidrich *et al.* 1998, 2000), no such difference has been reported between the Menorcan pale birds given as *yelkouan* and the *mauretanicus* breeding nearby; even, it has been suggested that they might interbreed (Genovart *et al*. 2005). The fact is that intergradation between the two taxa might have occurred, since genetic study of Menorcan pale birds showed a differentation of only 1.6% from *mauretanicus* (Genovart *et al*. 2005), which is lower than the 2.2-2.9% found between *mauretanicus* from Mallorca and undisputed *yelkouan* from eastern Mediterranean (Heidrich *et al*. 1998, 2000) and soutern France (Austin *et al*. 2004). A last point concerns the biometrics of the pale Menorcan birds, which are controversial: Genovart *et al*. (2005) assumed that they "showed phenotypic traits of Yelkouan shearwaters" but published no biometric data; this is particularly disappointing since measurements of the so-called *yelkouan* caught in Menorca in 2000 (S.E.O. unpublished, courtesy A.M. Paterson) differed markedly from those published for any undisputed *yelkouan* location, leading D. Oro and J.A. Alcover (in Ruiz & Martí 2004) to consider that either the variation between *yelkouan* and *mauretanicus* may be clinal, or the polymorphism of *mauretanicus* is higher than usually suspected.

To summarize, birds breeding in Menorca could be considered as 'intermediates' between *yelkouan* from other Mediterranean archipelagoes and the rest of the *mauretanicus* population, both in plumage and in measurements, questioning the phenotypical variability and relationships of these taxa. There is presently a wide agreement among scientists and conservationists in the Balearic that more research is needed (Ruiz & Martí 2004 ; J. Mayol, M. McMinn, J. Muntaner & D. Oro, *pers. comm*.).

POPULATION SIZE AND DYNAMICS

The Balearic Shearwater breeds in caves often situated in steep cliffs. Having difficult access to most colonies, the size of the breeding population has long remained a matter of guesswork, derived from both the number of pairs at surveyed sites and, e.g., the number of birds rafting off the cliffs. In 1984, J. Mayol (per J. Muntaner *in litt*.) considered that there were between 1,300 and 2,800 breeding pairs (bp). De Juana (1984) and Capella (1988) thereafter proposed 1,000-5,000 and 2,000-3,000 bp, respectively. A census organized in 1991 gave 2,127-4,475 bp (Aguilar 1991 in Govern Balear 1997). Pooled estimates for the period 1991-1998 led to 2,084-4,414 bp and the population was still estimated at 2,190-4,256 bp in 1999, again pooling precise censuses and estimates (Ruiz & Martí 2004). Figures given by other authors were derived from the above, e.g. c. 3,000 bp in 1998 (Mayol-Serra *et al.* 2000) or c. 3,300 bp (BirdLife International 2000). Another census was carried out in

2001, with a more restrictive approach than in earlier years (optimistic estimates being avoided for those sites which cannot be carefully surveyed), leading to an estimated 1,750-2,125 bp (Ruiz & Martí 2004), not 1,650-2,050 bp as given by BirdLife International (2004). The survey of many breeding sites has been improved in subsequent years, e.g.using mountain gear to visit inaccessible colonies, and in 2005 the population was estimated at 2,000-2,400 bp (Rodriguez-Molina & McMinn-Grivé 2005a).

The above figures do not indicate any clear trend, particularly because upper range values are now considered to have been overestimated. However, although new colonies have been discovered, a decline is apparent at various sites surveyed over the long term and a contraction of the breeding range is obvious (Rodriguez-Molina & McMinn-Grivé 2005a). Similarly, a decline is suggested by surveys carried out during the summer exodus of Balearic Shearwaters to the Atlantic: by the mid 1980s it was estimated that 8,000-10,000 individuals occurred in the French waters of Biscay alone (Yésou 2003), while in 2005 these 8,000-10,000 correspond to the estimated size of the whole population of Balearic Shearwater (Rodriguez-Molina & McMinn-Grivé 2005a). Moreover, demographic studies at predator-free colonies indicate a poor breeding success and a much lower adult survival than expected for a medium-sized shearwater, the calculated value of demographic parameters even leading to the prediction that the species might disappear within a few decades (Oro *et al*. 2004). This prediction of a fast decline is nevertheless at odds with the slower erosion suggested by population censuses. Obviously, demographic data are to be improved, particularly regarding adult survival and the frequency of sabbatical (D. Oro *pers. comm.*).

CONSERVATION STATUS

Despite its restricted range and limited number, the Balearic Shearwater was classified only as "lower risk / near threatened" by BirdLife International (2000), which is particularly surprising as the same publication quoted the Black-vented Shearwater *P. opisthomelas* as "vulnerable" –a less favourable status– although its estimated population size was more than twenty times higher than that of Balearic Shearwater. The situation was amended following the extensive field work carried out in 1999-2001 (Ruiz & Martí 2004) and the alarm bell rung by Oro *et al*. (2004), and the Balearic Shearwater is presently considered as "critically endangered" (BirdLife International 2004).

These birds are facing well identified problems at most breeding sites, particularly in the form of introduced mammal predators (Black Rat *Rattus*

rattus, Domestic Cat *Felix cattus* and Genet *Genetta genetta*). The poor breeding success and the apparent low survival of adults at predator-free sites further indicate that Balearic Shearwaters are also facing difficulties at sea. Indeed, fishing equipment is a source of mortality (Rodriguez-Molina & McMinn-Grivé 2005b). Lastly, it has been suggested that the food resources of these birds are under pressure; the distribution, abundance and availability of these resources are changing due to the evolution of fishery policies (including moratoria) and marked modifications in the marine environment. The effects of such changes remain unclear in the Mediterranean but have already led to a marked northward shift of the species range during its post-breeding dispersal in the Atlantic (Yésou 2003; Wynn 2005).

A conservation strategy is now under development in the Balearic Islands (Rodriguez-Molina & McMinn-Grivé 2005b) and this taxon has been given conservation priority all over its range unter the Convention on Migratory Species (UNEP 2005), but we still need to know more about the basic biology of the Balearic Shearwater in order to optimise our efforts to ensure its conservation.

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VALE PIJLSTORMVOGELS *PUFFINUS MAURETANICUS*: EEN OVERZICHT VAN VRAGEN EN FEITEN

De taxonomische status van de Vale Pijlstormvogel *Puffinus mauretanicus*, die op de Balearen in de westelijke Middellandse Zee broedt, is al onderwerp van discussie sinds dit taxon voor het eerst als ondersoort van de Noordse Pijlstormvogel *P. puffinus* werd beschreven. Tegenwoordig wordt dit taxon beschouwd als een soort, die weinig verschilt van Yelkouan Pijlstormvogel *P. yelkouan*, een 'zustersoort' die elders in de Middellandse Zee broedt. Op Menorca broeden echter vogels die schijnbaar intermediair zijn tussen beide taxa. Verder onderzoek is nodig om te bevestigen of het inderdaad verschillende soorten zijn. Gezien de beperkte broedverspreiding en populatiegrootte is het opmerkelijk dat de Vale Pijlstormvogel niet is geklassificeerd als bedreigd ("threatened") in *Threatened Birds of the World, 2000* van BirdLife International. Na deze publicatie werd de alarmbel geluid naar aanleiding van populatiestudies, die suggereerden dat deze soort binnen een paar decades zou kunnen uitsterven. Met als gevolg dat de Vale Pijlstormvogel nu in de categorie ernstig bedreigd ('critically endangered') valt. Gepubliceerde populatieschattingen blijken echter niet altijd betrouwbaar te zijn en over de populatiedynamica is weinig bekend. Er is meer bekend over bedreigingen, waaronder predatie door zoogdieren op broedplaatsen, sterfte door long-linevisserij en (mogelijk) grotere problemen om voedsel te vinden.

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PRE-BREEDING MIGRATION OF MANX SHEARWATER *PUFFINUS PUFFINUS* IN THE WESTERN ATLANTIC: NEW INSIGHT FROM A SURVEY IN GUADELOUPE, LESSER ANTILLES

A. LEVESQUE[1], & P. YÉSOU[2]

Levesque, A. & Yésou, P. 2006. Pre-breeding migration of Manx Shearwater *Puffinus puffinus* in the western Atlantic: new insight from a survey in Guadeloupe, Lesser Antilles. Atlantic Seabirds 8(1/2): 81-86. *A sea-watching routine set up from 2001 to 2004 in Guadeloupe, Lesser Antilles, showed that large numbers of Manx Shearwaters* Puffinus puffinus *regularly migrate through this area from February to May, peaking in March. It has been estimated that each year on average 26,000 (95% confidence interval: 17,000-38,100) individuals are passing within 4 nautical miles off the coast, while more birds could be passing further offshore. It is suggested that these birds follow a northwestward direction from northern Brazil, and probably continue following the Gulf Stream up to their main summer range in northwestern Europe.*

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INTRODUCTION

Little is known about the migration route followed by Manx Shearwaters *Puffinus puffinus* from their winter quaters off South America to their summer range in Europe. It is usually assumed that they follow a straight route, crossing the Atlantic Ocean from the northern coast of Brazil and flying straight to the Azores area, then continuing to NW Europe. Both the major handbooks (Cramp & Simmons 1977; del Hoyo *et al.* 1992) and the main monograph devoted to the Manx Shearwater (Brooke 1990) have mapped such a hypothetical route, which implies that the whole migration takes place east of 40°W (Figure 1).

In such a context, it was not surprising that Manx Shearwaters were rarely encountered in the West Indies (Raffaele *et al.* 1998). Moreover, although birds ringed in the British Isles had been recovered in Trinidad, Grenada and Guadeloupe, it was initially proposed that most records there should relate to migrants from the small population breeding in the NW Atlantic, particularly in Newfoundland (Keith & Keith 2003), as already suggested for Manx Shearwaters observed off southeastern USA (Lee 1995).

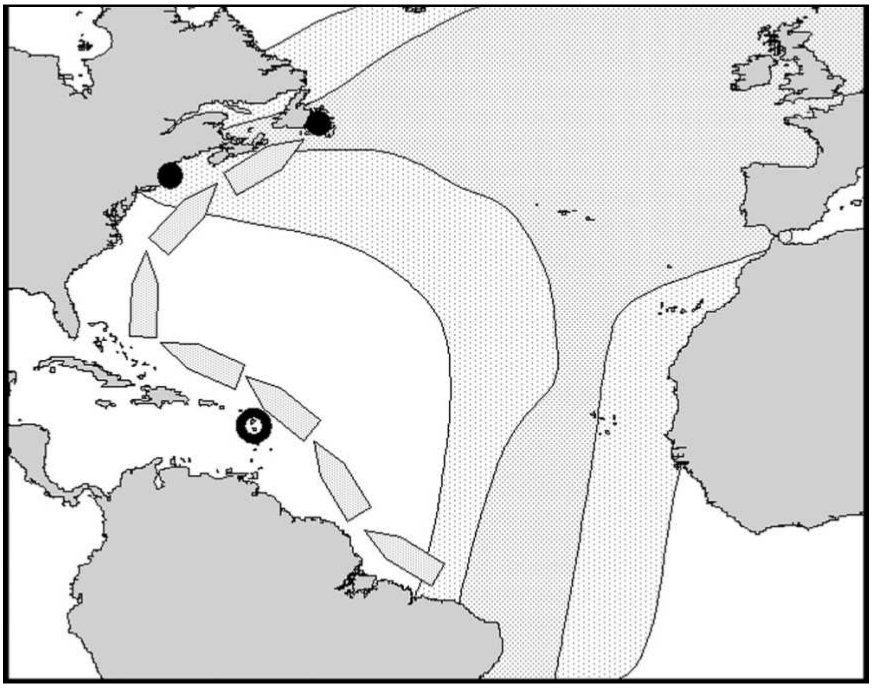

Figure 1. Distribution of Manx Shearwater as mapped by Cramp & Simmons (1977: darker grey shade) and del Hoyo et al. *(1992: paler grey shade). Filled circles: North American breeding localities. Open circle: study site in Guadeloupe. Line of arrows: western migration route as proposed in this paper.*

Figuur 1. Verspreiding van Noordse Pijlstormvogel volgens Cramp & Simmons (1977: donkergrijs) en del Hoyo et al. *(1992: lichtgrijs). Dichte cirkels: Noord-Amerikaanse broedlocaties. Open cirkel: studiegebied op Guadeloupe. Pijlen: westelijke trekroute zoals in dit artikel voorgesteld.*

STUDY AREA AND METHODS

The observations were carried out from 2001 to 2004 from Petite-Terre, in the Guadeloupe archipelago: at 16°15'N – 61°7'W is one of the easternmost islands in the Lesser Antilles and is bordered by a rather narrow Continental Shelf, with ocean sea-floor depths of 88 m, 376 m and 456 m at 2, 3 and 4 NM (nautical miles) respectively. Periods of 15 minutes non-stop observation were carried out from the top of a cliff (c. 7 m above sea level), looking through a tripod-mounted telescope (x20-60 zoom, lens used at x30 during search). A few minutes rest was systematically taken between two consecutive 15 min-periods, which were designed as to take place within each one-hour daylight period of each day (i.e. 6 to 7 am and so on, time zone UTC/GTM –4 hours). The distribution of observation effort was uneven, as the main passage periods received extra coverage to better document the birds' status at that time. Logistical reasons also resulted in higher observation effort at early and late hours of the day. Simultaneous, co-ordinated, observations from the study spot and from a boat using GPS positioning showed that large-sized birds such as Manx Shearwater were detected through the telescope when passing up to 4 NM off at sea, with much of the observed passage occurring between 1 NM and 3 NM from the islet. Data obtained during each 15 min-period (including 'zero' data) were pooled both per hour and per month, leading to the calculation of the mean number of individuals observed per hour during a given month. Multiplied by the number of hours with daylight and the number of days per month, this allows a rough estimate of the number of birds that have been passing through the study area over a given period. AL is responsible for most of the field work. PY, who has long experience with shearwaters and has been particularly involved in the study of taxa related to the Manx Shearwater, joined for ten days in April 2004, mostly to assist in checking the validity of identification characters used in the separation of Manx Shearwater from Audubon's Shearwater *Puffinus lherminieri*. Preliminary results relating to the nine species of Procellariiformes observed during this survey were given in Levesque & Yésou (2005), while here we discuss in more detail the observed status of the Manx Shearwater.

RESULTS

Out of 3330 small shearwaters (either Manx or Audubon's) seen during the four-year survey, only 6% were left unidentified. Most of the identified birds were Manx Shearwaters (N = 2543) which accounted for 34% of all tubenoses recorded, 40% of all shearwaters and 76% off all small shearwaters (81% of all identified small shearwaters).

Manx Shearwaters were recorded off the observation point, singly or in small flocks of up to 18 birds, from mid-Autumn (earliest date 5 November) through late-Spring (latest date 10 June), but remained scarce outside the Spring passage, which occurred from February to May, peaking in March (Fig. 2). The February-May passage has been observed each year, with 72% of the birds recorded in March. The highest count was on 3 March 2004, when 597 birds were recorded in 4 hours during strong north-easterlies (wind speed up to 80 kmph) which had begun the previous day.

From these observations, it can be estimated that on average an amazing 26,000 (95% confidence interval: 17,000-38,100) Manx Shearwaters are passing by the observation spot in February-May each year. There is much inter-year

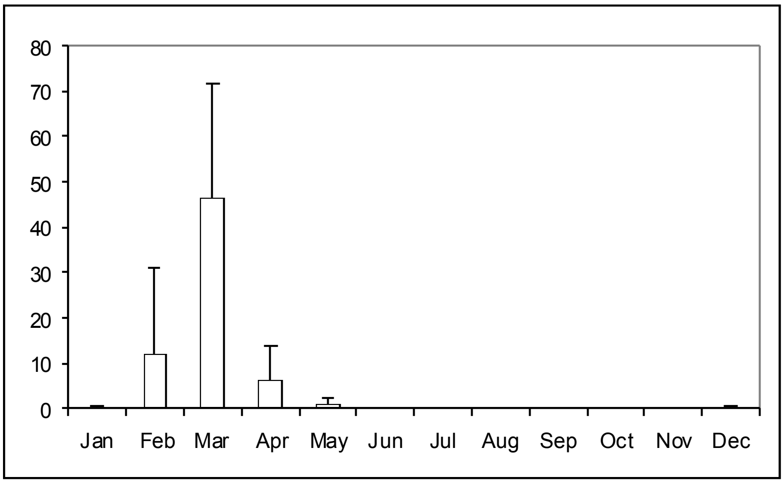

Figure 2. Mean numbers of Manx Shearwater recorded per hour from Petite-Terre, Guadeloupe, 2001-2004. The Standard Error illustrates the between-year variability.
Figuur 2. Gemiddeld aantal waargenomen Noordse Pijlstormvogels vanaf Petite-Terre, Guadeloupe, 2001-2004. De standaardfout is een maat voor de jaarlijkse variatie.

variation in the intensity of passage within sight of land, however, with an estimated passage of only c.18,000 (95% CI: 10,600-28,500) birds in 2002 but over 33,000 (95% CI: 22,700-46,300) in 2004.

DISCUSSION

The first record of Manx Shearwater for Guadeloupe was a corpse found washed ashore at Désirade island on 30 April 1997, which had been ringed in 1978 as a flying bird (born before that year) at a colony in Saint Kilda, Scotland (Keith & Keith 2003; J. Clark/BTO *pers. comm.*), and no bird was recorded alive in waters surrounding Guadeloupe until 2001 (Levesque & Jaffard 2002). Thus it was a great surprise when the Manx Shearwater proved to be the most abundant species of Procellariiformes, and probably the most abundant of all seabirds off Guadeloupe, although no systematiced counts of terns and noddies have been undertaken.

The above estimates can be disputed with regard to the fact that huge movements of Manx Shearwaters passing off the observation spot have occasionally been given extra coverage: this may lead to slightly higher estimates than in a case of a strict protocol where observation are conducted over pre-defined periods. Regardless of the precision of the estimates, this survey has clearly shown that Manx Shearwaters regularly migrate close to the Lesser Antilles by the thousands. In such a pelagic species, movements detected from land might be just one part of a wider context. Thus can we conceive that much higher numbers than those reported here are passing offshore in West Indian waters?

The observed and infered numbers are such that the presence of Manx Shearwaters off the Lesser Antilles can no longer be related to the very small population which breeds in the NW Atlantic (the tenuous breeding population in Newfoundland, which seems to have declined since the 1980s, has been estimated at only 55-170 individuals in 2004-2005: Robertson 2005). The numbers involved make it obvious that the spring movement observed each year off the Lesser Antilles is part of the return migration of the European population of Manx Shearwater. We suggest that these birds leave the South American waters in a northwest direction, following the nutrient-rich plumes of the Amazonian rivers off the Guyanas and the Antilles, to reach the Gulf Stream along which feeding conditions may be of importance to these birds during their return journey to Europe (the significance of the Gulf Stream as a feeding area is known for other seabirds species, including various shearwater species and other Procellariiformes: e.g. Brown *et al*. 1981; Haney 1986, 1987).

Which part of the population actually follow this western route and at which latitude do these birds turn eastward are questions still to be answered. Since breeders arrive at their colonies from late February to early April (Brooke 1990; C. Perrins *pers. comm.*), their pre-breeding migration must be earlier than observed here, suggesting that, at least, most of the Manx Shearwaters migrating off the Antilles are non-breeding birds. This agrees with the time schedule of the older immatures, which reach the breeding grounds as prospectors in May (C. Perrins *pers. comm.*), and with the fact that most recoveries of British Manx Shearwaters in the eastern coast of North America correspond to 2nd calendar year birds (Cramp & Simmons 1977); even recoveries of older birds (such as the first record for Guadeloupe –in late April) could correspond to non-breeders, e.g. birds having a sabbatical. Given the species' regular presence in spring further north off southeastern USA and Newfoundland (Lee 1995, Robertson 2005), it is entirely possible that this migration route follows the Gulf Stream all the way back to the Western Approaches.

ACKNOWLEDGEMENTS

The project was partly funded by Direction Régionale de l'Environnement de Guadeloupe and by ONCFS. We are grateful to Alain Saint-Auret and Maurice Dévarieux who have been very helpful in driving the boats during trips at sea. Professor Christopher Perrins kindly commented on our work during the conference: he has been helpful in improving our paper, as were the remarks from the referees. Jean-Sébastien Guitton's skills were much appreciated during the preparation of the map.

VOORJAARSTREK VAN NOORDSE PIJLSTORMVOGEL *PUFFINUS PUFFINUS* IN DE WESTELIJKE ATLANTISCHE OCEAAN: NIEUWE INZICHTEN DOOR ZEETREKTELLINGEN OP GUADELOUPE

Een zeetrektelprogramma dat van 2001 tot 2004 op Guadeloupe liep, liet zien dat grote aantallen Noordse Pijlstormvogels *Puffinus puffinus* van februari t/m mei, met een piek in maart, regelmatig door dit gebied trekken. Naar schatting passeren gemiddeld 26000 (95%-betrouwbaarheidsinterval 17000-38100) individuen binnen vier zeemijl van de kust, terwijl er meer vogels verder op zee kunnen passeren. Mogelijk volgen deze vogels een noordwestelijke koers vanaf Noord-Brazilië om vervolgens de Golfstroom te volgen naar hun belangrijkste zomergebieden in het noordwesten van Europa.

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EVIDENCE FOR NOCTURNAL INTER-TIDAL FORAGING BY EUROPEAN STORM-PETRELS *HYDROBATES PELAGICUS* DURING MIGRATION

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ALEXANDRA L. POLLARD[1]

Thomas, R.J., Medeiros, R.J. & Pollard, A.L. 2006. Evidence for nocturnal inter-tidal foraging by European Storm-petrels *Hydrobates pelagicus* during migration. Atlantic Seabirds 8(1/2): 87-96. *European Storm-petrels* Hydrobates pelagicus *have previously been assumed to be exclusively pelagic foragers during migration. However, in this paper we report evidence that migrating Storm-petrels also forage at night along beaches. We highlight the repeated occurrence of the inter-tidal crustaceans* Eurydice naylori *&* E. affinis *(Isopoda: Cirolanidae) in the regurgitated crop contents of European Storm-petrels captured for ringing during their northwards migration past SW Portugal. The combination of the fresh condition of these crustaceans, their habitat and limited inter-tidal distribution and their nocturnal pattern of activity, together indicate that the Storm-petrels which had eaten them had been foraging by night along the inter-tidal zone of sandy beaches. We also found subtidal* Eurydice *species in the regurgitated samples, including the offshore species* E. inermis *and* E. truncata *that are nocturnal vertical migrants to the sea surface, providing further clues as to the location and timing of Storm-petrel foraging. We highlight the insights into the foraging behaviour of migrating Storm-petrels that can be obtained from the study of their gut contents and the behaviour and ecology of their prey.*

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INTRODUCTION

Very little is known about the diet of seabirds during their long-distance migrations because of the difficulty of observing or catching birds on passage and of obtaining food samples from them. The Atlantic population of the British or European Storm-petrel *Hydrobates pelagicus* (henceforth "Storm-petrel") migrates between its breeding colonies on islands and promontories in the NE Atlantic and its wintering grounds in South Atlantic waters off southern Africa (Wernham *et al.* 2002). As with most seabird research, all systematic studies of Storm-petrel foraging ecology have focussed on the breeding colonies, where birds are accessible to researchers (Scott 1970, Cramp & Simmons 1977, D'Elbée & Hémery 1998). However, work by A Rocha Bird Observatory in SW Portugal has shown that Storm-petrels can be attracted to nocturnal shoreline tape-lures during their summer passage migration past the Portuguese coast, several hundred km from the nearest known breeding colonies. At this time, the birds are heading rapidly northwards, often at speeds of over 100km/day (Harris *et al.* 1993, Wernham *et al.* 2002, A Rocha Bird Observatory unpublished data). Mist-netting the birds attracted to these tape lures provides a valuable opportunity to study Storm-petrels during their long-distance migration. Most of the birds mist-netted in this way are thought to be wandering pre-breeders, in their second to fourth calendar years, which move into the NE Atlantic in mid-summer, prospecting for mates and future nest sites (Bolton & Thomas 2001, Wernham *et al.* 2002, Okill & Bolton 2005).

Storm-petrels are widely considered to be highly pelagic seabirds, and are generally thought to visit land only to breed, or when driven into inshore waters or even inland during storms (Cramp & Simmons 1977). During the season of northwards migration past Portugal (June), they are frequently observed during daylight by birdwatchers on pelagic boat trips several km off the southern Portuguese coast, with an apparent concentration of foraging birds seen at the edge of the continental shelf approx. 8-12 km offshore (pers. obs.), including in mixed species assemblages scavenging behind fishing boats (Valeiras 2003). Such observations, together with the lack of observations of Storm-petrels from shoreline vantage points have led to the assumption that Storm-petrels are exclusively pelagic foragers during migration.

A small proportion (<5%) of the Storm-petrels mist netted during migration past Portugal employ the anti-predator strategy of regurgitating a mixture of stomach oils and partly digested food from their proventriculus (crop), thereby providing a convenient opportunity to obtain information about the birds' diet during the migration journey. Visual identification of food items in Storm-petrel vomit samples is sometimes possible, though the vomit often contains prey material that is too well digested to be identified, or contains stomach oils only.

In this paper, we report evidence from a number of particularly revealing vomit samples, which suggest that Storm-petrels may forage at night along the intertidal zone of Portuguese sandy beaches during their northwards migration, rather than exclusively far offshore as has generally been assumed.

METHODS

We captured Storm-petrels in mist nets, to which they were attracted by playing tape-recordings of the species' "burrow call" (Cramp & Simmons 1977). These tape-lures were played throughout the night on a wave-cut platform at the base of a sea-cliff at Ponta da Almadena, on the south coast of the Algarve, Portugal (N 37º 04', W 8º 47'). We collected samples of regurgitated proventriculus/

stomach contents from the minority of birds which vomited during capture and handling. The regurgitated material was stored in 96% ethanol for subsequent identification and analysis.

Though the capture site is on a rocky shoreline, it is within approx. 1km of sandy beaches to the east and west. At the beach to the west of the capture site, we sampled potential Storm-petrel prey taxa in the surf zone at hourly intervals through the night, from 20:00 GMT (dusk) to 05:00 GMT (dawn), as well as additional samples during full daylight at approx. 06:00 GMT. We waded approx. 3m out from the shore into the surf (i.e. the exact position up the beach varying with the tide), and swept along a 1m line parallel with the shore, for 2 minutes using a long-handled hand net with 500µm mesh (Alana Ecology Ltd., Shropshire, UK). All live animals captured were fixed and stored in 96% ethanol, and were later visually identified to genus level (Jones & Pierpoint 1997).

To study the behaviour of stranded but living *Eurydice* isopods, we netted *Eurydice* individuals from the surf zone at night, and placed them immediately on damp sand just above the reach of the breaking waves, in order to observe their behaviour, including the time taken for them to bury themselves in the sand.

Tide times were calculated for Lagos, Portugal (10km east of the study site at 37.10°N, 8.67°W), using the Neptune Tides programme (v6.15, Neptune Navigation, Reading, UK).

RESULTS

Regurgitated samples We captured 116 and 436 Storm-petrels during late May–late June in 2004 and 2005 respectively. From these, we collected vomit samples from 32 birds. Eight of these 32 individuals regurgitated a total of 23 intact and apparently undigested small crustaceans of the Genus *Eurydice*. Figure 1 illustrates the intact nature of the specimens. The majority of the regurgitated specimens were subsequently identified to species level on the basis of skeletal morphology, by Prof. David Jones of Bangor University, UK (Jones & Pierpoint 1997). Table 1 shows the *Eurydice* species identified in each regurgitate sample, and the habitats of these species. The stage of the tidal cycle at which each *Eurydice* species was obtained in regurgitated samples is shown in Figure 2, and indicates that Storm-petrels forage on *Eurydice* throughout the tidal cycle. The graph also shows that the records of regurgitated isopods are clustered in the second half of the night, but this simply reflects the fact that the numbers of Storm-petrel arriving at the tape-lure peaks in the hours between 01:00 and 05:00 GMT (A Rocha Bird Observatory, unpublished data).

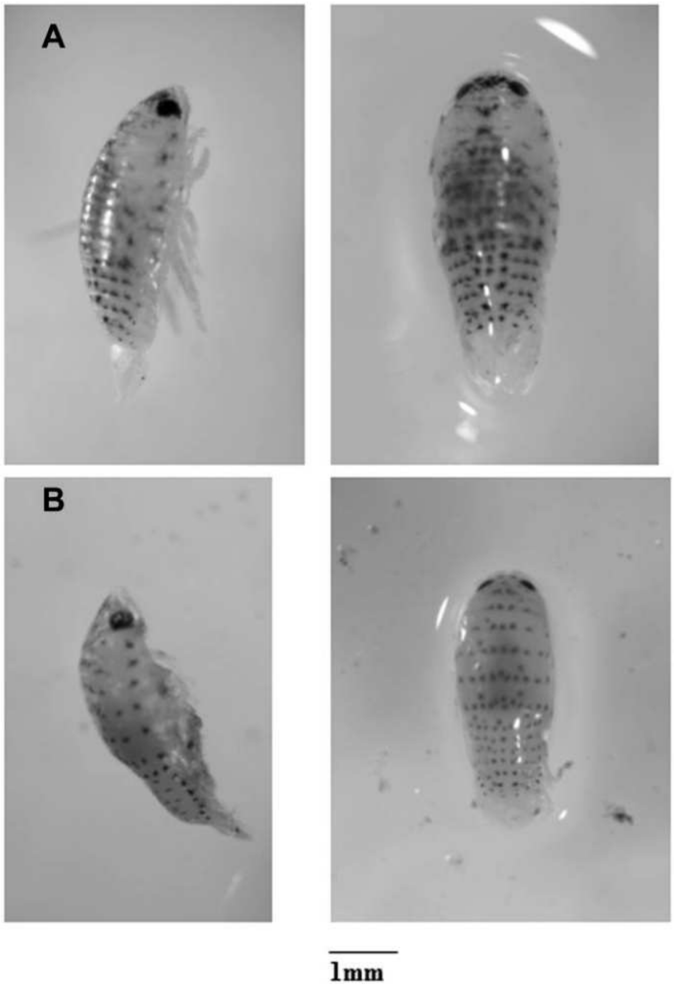

Figure 1: A) Fresh specimen of the intertidal isopod Eurydice affinis, *obtained by hand-netting in the surf zone of a Portuguese beach. B) Typical specimen of* Eurydice affinis, *obtained from the regurgitated stomach contents of Storm-petrels captured in Portugal during the June passage migration season. Photographs by Geoff Swann, Cardiff University.*

Figuur 1: A) 'Vers' exemlaar van de isopode Eurydice affinis *uit de intergetijdenzone, verzameld met behulp van een handnet in de branding van een Portugees strand. B) Karakteristiekexemplaar van* Eurydice affinis, *verkregen uit uitgebraakte maaginhouden van Stormvogeltjes die in juni in Portugal tijdens de trek zijn gevangen. Foto's Geoff Swann, Cardiff University.*

Table 1. Date and time of capture (GMT) of each Storm-petrel that regurgitated Eurydice *isopods. The habitat of each* Eurydice *species is indicated as follows: I = Intertidal, S = Subtidal, O = Offshore.*

Tabel 1. Datum en vangsttijd (GMT) van Stormvogeltjes die Eurydice*-isopoden opbraakten.. De habitat van de* Eurydice*-soorten is aangegeven met: I = Intergetijdezone, S = Sublitoraal, O = Offshore.*

Storm-petrel ring number	Night	Time of capture (GMT)	*Eurydice* species found in vomit sample	Habitat of *Eurydice* sp
N01950	7-8 June 04	00:10	4 x *Eurydice naylori*	I
N02370	2-3 June 05	01:18	1 x *Eurydice affinis*	I
			1 x *Eurydice truncata*	O
			1 x *Eurydice* sp.	-
N02379	2-3 June 05	01:59	4 x *Eurydice affinis*	I
N02386	2-3 June 05	02:20	2 x *Eurydice affinis*	I
			1 x *Eurydice truncata*	O
N02402	3-4 June 05	22:54	3 x *Eurydice spinigera*	S
N02547	5-6 June 05	02:28	1 x *Eurydice truncata*	O
			2 x *E inermis*	O
N02564	5-6 June 05	04:10	1 x *Eurydice affinis*	I
N03114	14-15 June 05	22:55	2 x *Eurydice* sp.	-

Many of the birds that we captured also regurgitated fish remains and clear “stomach oil”, along with other more digested material that could not be identified visually.

Behaviour & availability of live *Eurydice* isopods and other potential prey

Our hand-net sampling revealed that *Eurydice* isopods were almost totally absent from samples taken from the surf zone during full daylight, but they appeared in the water column as dusk approached. They were abundant in the surf throughout the night, and disappeared (presumably into the sand) soon after dawn. Our visual searching during daylight to find *Eurydice* isopods proved that they are extremely difficult for humans to find in sand, even during daylight, because of their small size and cryptic colouration.

We found that *Eurydice* isopods placed on damp sand just above the tide level at night immediately began to bury themselves, and disappeared from view into the sand within 2 minutes.

We observed that Sandhoppers (Amphipoda: Orchestiidae) and the small crustacean *Gastrosaccus spinifer* (Mysidacea: Mysidae) were even more abundant than *Eurydice* isopods at night on the exposed sand and in the water column of the intertidal zone, respectively. However, despite their apparent availability, these potential prey taxa were strikingly absent from any of the identifiable prey remains in any of the Storm-petrel vomit samples.

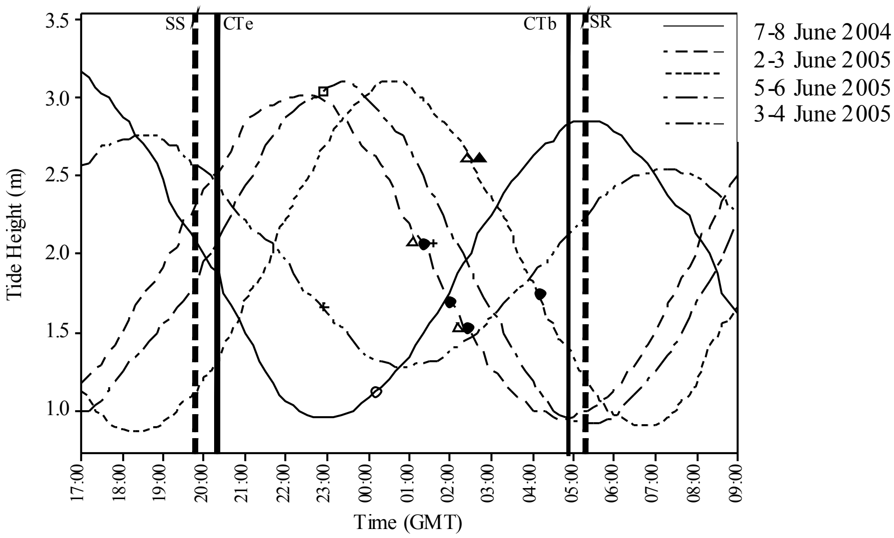

Figure 2. Tidal cycles on nights when mist-netted Storm-petrels regurgitated Eurydice isopods. SS = Sunset, SR = Sunrise, Cte = Civil twilight ends, CTb = Civil twilight begins. The following symbols indicate different species of isopod and their habitats: Intertidal species: ○ = E. naylori,● = E. affinis*; Subtidal species:* □ = E. spinigera*; Offshore species:* Δ = E. truncata, ▲ = E. inermis*; + = Unidentified* Eurydice *sp*

Figuur 2. Getijdencycli tijdens nachten dat gevangen Stormvogeltjes Eurydice *isopoden opbraakten. SS = zonsondergang, SR = zonsopkomst, Cte = begin schemering, CTb = einde schemering. Soorten van intergetijdezone: ○ = E. naylori, ●= E. affinis; Sublitorale soorten: □ = E. spinigera; Offshore soorten: Δ= E. truncata, ▲= E. inermis; + = Unidentified Eurydice sp*

DISCUSSION

We found a total of five *Eurydice* species in the gut contents regurgitated by mist-netted Storm-petrels (Table 1). Of these, two species have intertidal distributions (*E. naylori* & *E. affinis*), two are offshore species (*E. truncata* & *E. inermis*), and one species (*E. spinigera*) is largely subtidal but occurs in smaller numbers in the intertidal zone (Jones & Pierpoint 1997).

Eurydice naylori and *E. affinis* are restricted to the inter-tidal zone, with greatest concentrations in the upper half of the tidal range, i.e. the zone between Mean Tidal Level and High Water Neap Level (Jones & Pierpoint 1997). Thus, the occurrence of fresh specimens of these species in the vomit of five of the eight migrating Storm-petrels that regurgitated *Eurydice* isopods (Table 1) indicates that these individual birds had been foraging in the inter-tidal zone.

E. naylori and *E. affinis* are normally found in the top 10-15cm of sand, but at night they emerge into the water column of the surf zone as the tide comes in (Salvat 1966, Jones & Pierpoint 1997). Several pieces of evidence suggest that Storm-petrels obtain these intertidal *Eurydice* isopods from water, rather than land, during darkness: (i) *Eurydice* isopods are abundant in the surf zone, but are probably unavailable on shore because they bury themselves within just a few minutes of being stranded on exposed sand. It seems very unlikely that Storm-petrels would dig in the sand to search for such small and cryptic prey at night, and we do not find sand grains on the bill, legs or plumage of the Storm-petrels that we capture at our tape lures. Furthermore, the legs and bills of Storm-petrels do not seem to be well adapted for digging in the sand to search for prey. (ii) In the water column, *Eurydice* are abundant at night, but not during the day. (iii) The very fresh and undigested condition of the *Eurydice* specimens found in the vomit samples of nocturnally-captured Storm-petrels suggests that the birds had very recently ingested them.

We obtained live intertidal *Eurydice* sp. in our hand-netted surf samples throughout the nocturnal parts of the tidal cycle, and Figure 2 shows that the times at which Storm-petrels regurgitated undigested *E. naylori* and *E. affinis* in vomit are not restricted to the hours immediately around high tide.

Eurydice truncata and *E. inermis* are offshore species, found exclusively in the subtidal zone (Jones & Pierpoint 1997, Macquart-Moulin 1998). Both species bury themselves in the substrate on the sea floor during the day, and perform nocturnal vertical migrations of many metres, to forage at the sea surface by night (Jones & Naylor 1967, Macquart-Moulin 1998), when they may become available to foraging Storm-petrels. Thus, the occurrence of these species in the vomit of migrating Storm-petrels indicates that these individuals had been foraging offshore at night. It is noteworthy that some individual Storm-petrels had fed both on intertidal and offshore *Eurydice* species (see Table 1).

Studies at the breeding colonies indicate that Storm-petrels may regularly obtain food from the intertidal zone when they are anyway coming onshore to deliver food to their chicks. In a 5-year study of material regurgitated by Storm-petrels captured while attending two separate breeding colonies in the Bay of Biscay, 37% of identified prey items were inter-tidal taxa, including *Eurydice affinis* & *E. pulchra* (D'Elbée & Hémery 1998), showing that breeding Storm-petrels routinely forage in the inter-tidal zone during summer nights –at least at these particular colonies (but see Scott (1970) for an apparently more pelagic diet among Storm-petrels attending a colony on Skokholm Island, S. Wales). Other records of Storm-petrels feeding on terrestrial invertebrates refer to insects that had probably been blown out to sea before being picked up from the sea surface by the birds (Voous 1954, Cramp & Simmons 1977).

The ability of Storm-petrels to feed on very small (~3-5mm) non-bioluminescent *Eurydice* isopods during darkness raises the question of how they locate and capture their prey. The European Storm-petrel does not have particularly large eyes compared to birds of equivalent body mass, and it has a relatively low retinal image brightness compared to other nocturnal birds (Thomas *et al.* 2004, & unpublished data). Such data imply that, although this species forages during darkness, it may not have particularly good nocturnal vision –though retinal and neural specialisations may allow Storm-petrels to see more detail in low light conditions than their small eye size might suggest. It is also possible that Storm-petrels detect their prey by smell (Roper 1999) or touch as well as -or instead of- by sight. The striking absence of other abundant potential prey taxa of the intertidal zone from any of the Storm-petrel vomit samples (see results) suggests that some feature of *Eurydice* behaviour or ecology must make them relatively available to foraging Storm-petrels.

The presence of fish remains and subtidal and offshore *Eurydice* species in the vomit samples in our study shows that migrating Storm-petrels do not forage exclusively on intertidal *Eurydice* isopods, and indeed the diversity of prey taken near the breeding colonies show that they are often generalist foragers (Cramp & Simmons 1977, D'Elbée & Hémery 1998). However, our results indicate that at least some Storm-petrels do forage close to the shore by night during migration, at a time in their annual cycle when they have previously been assumed to be exclusively pelagic. We believe that our observations are the first evidence for inter-tidal foraging in migrating (rather than breeding) European Storm-petrels, and they illustrate the kind of detailed behavioural information that can be inferred from combining the study of gut contents of migrating seabirds with information about the behaviour and ecology of their prey.

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BEWIJS VOOR 'S NACHT IN DE GETIJDEZONE FOERAGEREN DOOR STORMVOGELTJES *HYDROBATES PELAGICUS* TIJDENS DE TREK

Vroeger werd gedacht dat Stormvogeltjes *Hydrobates pelagicus* tijdens de trek uitsluitend pelagische foerageerders waren. In dit artikel presenteren we echter bewijs dat trekkende Stormvogeltjes 's nachts ook bij het strand foerageren. We benadrukken het herhaaldelijk voorkomen van de intergetijden crustaceeën *Eurydice naylori* & *E. affinis* (Isopoda: Cirolanidae) in de uitgebraakte voedselresten van Stormvogeltjes die tijdens hun noordwaartse trek langs ZW-Portugal werden gevangen om geringd te worden. De combinatie van de 'verse' staat van deze crustaceeën, hun biotoop, hun beperkte verspreiding in de intergetijdezone en hun nachtelijke activiteitspatroon, indiceert dat de Stormvogeltjes die deze soorten hadden gegeten 's nachts in de intergetijdezone van zandstranden gefoerageerd hebben. We vonden ook *Eurydice*-soorten van de sublitorale zone in de uitgebraakte monsters, inclusief offshore-soorten *E. inermis* en *E. truncata* die beide 's nachts naar het zeeoppervlak migreren, hetgeen eveneens een aanwijzing is voor de plaats waar én het tijdstip waarop Stormvogeltjes foerageren. We benadrukken de nieuwe inzichten in het foerageergedrag van Stormvogeltjes, die verkregen kunnen worden door analyse van hun maaginhoud en het gedrag en de ecologie van hun prooisoorten.

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