

TRACKING THE MIGRATION AND FORAGING DYNAMICS OF LUNDY'S MANX SHEARWATERS

by

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INTRODUCTION

Discovering the details of animal movements during foraging and migration is critical in finding out which areas are important for conservation and protection. New technologies are now able to record in great detail the short-range movements of individual animals during foraging and, at larger scales, the overall patterns of migratory routes and overwintering sites. The use of such technologies has led to new insights into the spatial behaviour of animals in the wild (Dean *et al.* 2012), the interaction between individuals and their environment (Phillips *et al.* 2006; Shaffer *et al.* 2006; Felicísimo *et al.* 2008; Weimerskirch *et al.* 2012; Freeman *et al.* 2013) and their navigational behaviour (Guilford *et al.* 2011).

Over the last four years, we have established a comprehensive tracking programme on Lundy to understand the migratory and foraging behaviour of Manx Shearwater *Puffinus puffinus*. This study is part of a network of sister projects at sites across the British Isles, including Skomer (Guilford *et al.* 2008; Guilford *et al.* 2009), Ramsey, Copeland (Freeman *et al.* 2013) and Rum. The Manx Shearwater is a medium-sized seabird that migrates to waters off the eastern coasts of South America during the northern winter, returning the following spring. The majority of Manx Shearwaters breed in the UK and Ireland (93%, Mitchell *et al.* 2004). The species is listed as Amber on the list of UK Birds of Conservation Concern (Eaton *et al.* 2009) and is a species of European Conservation Concern (Burfield, I. & van Bommel, 2004).

Lundy lies approximately 20 km off the northern coast of Devon in the Bristol Channel. It is the largest island within the Bristol Channel and is an important home to a variety of seabird species. Manx Shearwaters have been found in increasing numbers on the island, particularly in recent years, almost certainly due to a rat eradication programme completed in 2004 (Brown *et al.* 2011).

We report here on our successful tracking of the migration and foraging routes of individual Manx Shearwaters during summer breeding on Lundy. We also extend our previous reports on migratory routes, overwintering habitats and summer foraging of shearwaters from Lundy (Dean *et al.* 2011; Freeman *et al.* 2012), and we also highlight a new way of studying the flight dynamics of individuals during foraging trips.

METHODS

Study birds

Previously identified and marked burrows were used at the established study colony near the Old Light on the west coast of Lundy. Study burrows were pegged and covered with purse nets to capture birds on departure and arrival during the hours of darkness. Netted burrows were

inspected every 15 minutes during the night. Unmarked birds were fitted with a metal BTO ring and released on the surface. Known residents (from previous studies) and birds that had appropriately disturbed the marker pegs (inwards from attempted entrance or outwards from departure) were assumed to be resident in the burrow and selected for detailed study.

During the period 12-25 August 2012, previously marked burrows were relocated and investigated for signs of use. New marker pegs were set out to ensure ease of identification during night work. Individuals caught with geolocation devices already attached either had the data downloaded on the spot, or the devices were removed and replaced with a new one. Only birds that were heavy enough were chosen to carry GPS devices. The GPS devices weighed less than 17 g and made up 3.5-4.6% of the total body weight.

GPS deployments

A total of 27 lightweight GPS devices were deployed. These were of two types: iGot-U-120 devices (Mobile Action Technology Inc.) and our own custom GPS loggers (able to record at up to 10Hz). The complete mass of both devices including attachment materials was kept below 17 g. Birds selected for deployments were initially weighed to assess suitability (here deployments covered 3.5-4.6% body weight). To fit the devices to individual birds, small strips of Tesa tape (Tesa 4651) were used to attach the device to small bundles of back feathers so that the device was above the bird's centre of mass (see Guilford *et al.* 2008 for details). On recovery, the attachment tapes were carefully peeled away from the feathers, the device removed and the bird weighed to see if its mass had changed during tracking.

GLS deployments

Geolocation devices (2.5 g Mk15 and Mk19; British Antarctic Survey, Cambridge, Biotrack Mk4083, Biotrack) were attached to elliptical Darvic rings with miniature cable-ties and fitted to the birds' legs. On recovery, devices were either removed or downloaded on the spot so that recording could continue.

Devices and data

Two kinds of devices were used throughout the research: GPS trackers and geolocators. GPS trackers allow position to be estimated from a constellation of satellites using the relative timing of signals arriving from those satellites (in combination with very accurate clocks). This allows the devices to record position very accurately (to within around 2.5 m). The calculations of these GPS devices however consume considerable battery power and are therefore usually used only for short durations.

Geolocators, on the other hand, use very little power as they only record the maximum levels of light every ten minutes. This allows levels of light throughout the day and night to be recorded for long periods in a simple, lightweight device. The resulting periods of light and dark can then be analysed and the timings of dawn, dusk, midnight and midday can be estimated. These timings then allow us to roughly estimate the location of the device (to within approximately 185 km). While this gives a less accurate estimate of position, and only twice a day, it allows locations to be recorded year-round, enabling us to explore the migration and overwintering behaviour of the birds.

RESULTS

GPS tracking of foraging trips

A total of 13 foraging trips were successfully recorded. Of these, seven were recorded using high-frequency tracking and seven with the previously established tracking mode (every five

minutes). Recorded foraging trips lasted from one to six days (Table 1). Mass changes during foraging trips were largely within the range of a single meal (some positive, some negative).

The majority of foraging was close to the island (Figures 1 & 2 – see colour plates 11 and 12). This follows the pattern observed in previous years (although more local than in 2011, when foraging also extended westwards along the northern coast of Cornwall as far as St Ives). In 2012, by contrast, one or two individuals foraged near Bideford, somewhat to the east. While some individuals travelled north towards the south Pembrokeshire coast, we did not record any individuals visiting the colonies at Skomer or beyond. The individual routes in Figure 2 show how variable foraging locations are, with some individuals travelling south or north-west during their trips.

Figure 3 (colour plate 13) shows the individual foraging trips recorded using high-frequency tracking. Each plotted location here comprises a burst of high-frequency track data (recording at ten times a second) for up to 60 seconds. The overall pattern of movement is the same as the tracking data shown using the normal tracking technique. However, Figure 4 (colour plate 14) shows three example 'bursts' revealing the dynamic movement of individuals at each location. Here, individuals appear to engage in sinusoidal movements both horizontally and vertically.

Tracking during migration and the non-breeding season

Thirteen successful geolocators were recovered covering 2011-2012. Figure 5 (colour plate 15) shows the estimated locations for each individual's migratory route. The pattern of movement

Table 1. GPS deployment summaries for each bird showing dates of deployment and recovery of devices, and mass changes. Device names ('GPS deployed') that start with 'L' are IGotU-120 devices; those that start with 'A' are our own design

Ring no.	Burrow	Deployment date (Aug 2012)	Mass at deployment (g)	Duration (days)	Mass at recovery (g)	GPS deployed	Mass change (g)
FC27340	7	12th	470	6	420	L42	-50
EW87540	6	13th	470	5	480	L52	10
EF98338	3	13th	400	1	405	L39	5
EW87543	–	13th	460	4	440	L60	-20
EW87542	8	13th	410	3	460	L57	50
EF98338	3	13th	440	2	455	A26	15
EW87539	10	13th	441	5	430	L34	-11
EX74098	10	13th	465	2	445	A31	-20
EW87554	10 Dec	14th	400	3	395	L36	-5
EX74098	near 7	14th	445	4	445	A11	0
EW87543	9	15th	440	4	445	A32	5
EW87539	7	16th	430	4	415	A23	-15
EW87524	16	17th	470	1	450	A26	-20

during migration is much the same as that seen in previous years and at other colonies (Guilford *et al.* 2009; Freeman *et al.* 2010; Freeman *et al.* 2013). Individuals depart in September and travel south along the western coast of Africa. They then cross the Atlantic to Brazil and continue down the eastern coast of South America. During February and March, northbound movements are also similar to those seen in previous years. Birds return to the UK by first heading north to the Caribbean before turning east across the North Atlantic to return to UK waters and Lundy itself.

The non-breeding distribution again shows two distinct zones. Figure 6 (colour plate 16) shows the occupancy contours that indicate where individuals appear to have spent 50% of their time. Five individuals first spent about a month in the northern zone before continuing southwards into the main, shared area. Even within this shared area there is much individual variation, with some individuals spending the bulk of their time at particular ends of the distribution.

DISCUSSION

The variable foraging patterns of Manx Shearwaters breeding on Lundy demonstrate how these oceanic predators exploit constantly moving food resources. In previous years foraging trips have extended north into the Irish Sea (Dean *et al.* 2011) and south towards the western tip of Cornwall (Freeman *et al.* 2012). In 2012, foraging (and therefore, presumably, food) was in waters much closer to the island. Some birds did forage north towards Pembrokeshire, further than recorded in 2011. Such changing foraging patterns can make it difficult to identify key areas for conservation and protection. However, it is clear that the waters surrounding Lundy are crucial. Here, birds are consistently present at high densities as individuals raft before coming to land and staging further foraging trips, sometimes without making landfall. The variation in foraging areas between years makes it important to continue these studies, as individual years may give a misleading impression of the long-term pattern.

We also highlighted here a new technique to explore the dynamic behaviour of individuals at sea. Shearwaters (like albatrosses and petrels) engage in complex dynamic soaring behaviours that have important implications for their ability to remain in flight for long periods with minimal energetic cost. Figure 4 shows three example recordings where individuals appear to engage in sinusoidal movements, perhaps using the wind to reduce energy expenditure during flight. As we develop this technique further, we hope to explore the relationship between these movements, their energetic cost, and the wind (recorded by remote sensing).

As observed previously, individuals consistently migrate to the same area off the Patagonian shelf (Figure 5). However, this apparent consistency is more complex when viewed at finer scale (Figure 6). Some individuals remain slightly to the north of the wintering area for extended periods before moving south. Even within the core wintering area, different birds do different things; individuals may be selecting specific areas to overwinter (and perhaps to moult). We have recently found that the behaviour of individuals during winter involves significantly less flight than in their summer movements, which would support this (Freeman *et al.* 2013).

New technology allows us ever greater insights into the complex and variable behaviour of highly pelagic species such as the Manx Shearwater. We have found that foraging and migration are flexible, changing from year to year in response to the distribution of prey and to weather conditions, and we need to find out exactly what controls these changes in behaviour. Such understanding may help us in making predictions for the future, particularly if and when climatic change alters the birds' environment. Such predictions will help us to understand how our changing environment will affect the distribution and behaviour of this fascinating species.

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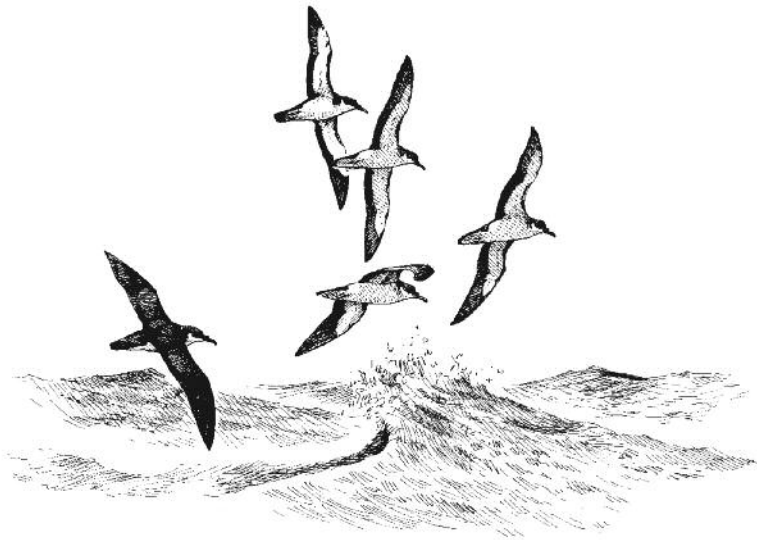
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Manx Shearwaters by Mike Langman from 'The Birds of Lundy'