The fate of rescued Manx Shearwaters following grounding

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Abstract

Manx Shearwaters *Puffinus puffinus*, like other procellariiform seabirds, spend most of their lives at sea and are encountered on land only when breeding at colonies or if they are grounded due to unfavourable weather conditions or exposure to artificial light. Here, we used historical ringing data to explore the age class structure and spatial patterns of Manx Shearwater groundings and examined ringing and recovery data to identify records of post-grounding survival for first-year and adult birds. We noted 35 cases, out of 6,381 ringed grounded shearwaters, where a bird went on to be recaptured, including two individuals that were later recorded as having successful breeding attempts. While this constitutes only a small number of birds confirmed to have survived following grounding, it is likely to be a considerable underestimate of survival considering the low probability of recapturing a surviving shearwater. Finally, we found that a greater proportion of grounded birds were first-years compared to adult shearwaters, and that adults were found to be grounded further away from colonies than first-year birds. This may be indicative of differential impacts of light pollution at different life stages.

Introduction

Procellariiform seabirds are one of the most threatened groups of birds. Major threats include invasive species, bycatch in fisheries, hunting and climate change (Dias *et al.* 2019). They spend most of their life at sea and, under normal circumstances, come to land only to breed at colonies located around coastlines or on offshore or oceanic islands (Warham 1990). Procellariiformes are, however, sometimes encountered on land away from their colonies after grounding, perhaps in association with light pollution, oil spills or unfavourable weather conditions such as storms (Telfer *et al.* 1987; Camphuysen *et al.* 1999, 2002; Rodríguez *et al.* 2017a). These 'groundings' peak shortly after the fledging period, when mostly juvenile shearwaters can become stranded in artificially lit towns, cities, ships and oil platforms near their nesting sites (Rodríguez *et al.* 2017a). In response, conservation organisations and local volunteers may deploy personnel to rescue, ring and release grounded shearwaters close to large colonies (e.g. Le Corre *et al.* 2002; Day *et al.* 2003; Rodríguez *et al.* 2017b).

Efforts have been made to monitor the body condition of grounded seabirds (Rodríguez *et al.* 2017b; Cuesta-García *et al.* 2022), as higher weight is an indication of higher probability of survival for juvenile seabirds (Perrins *et al.* 1973; Becker & Bradley 2007; Maness & Anderson 2013). For example, a study comparing the weight of juvenile Short-tailed Shearwaters *Puffinus tenuirostris* recovered at different locations indicated that birds grounded due to light pollution had lower body weights compared to near-fledging birds at the colony, while water-logged fledglings found washed up on beaches were in the poorest condition of the three groups (Rodríguez *et al.* 2017b). Whilst considerable effort is put into understanding the consequences of seabird grounding, little is known about survival to breeding age of rescued fledglings, which is important for estimating the impact of grounding casualties on seabird populations (Simons 1984; Fontaine *et al.* 2011; Griesemer & Holmes 2011; Gineste *et al.* 2017).

Our study species, the Manx Shearwater *P. puffinus*, breeds mainly on three islands in Great Britain (Fig. 1A). While the species' total population is estimated at 1.03–1.18 million individuals (Birdlife International 2015), a combination of hard-to-access breeding areas as well as nests located in burrow chambers, makes it difficult to accurately estimate the population size or its trend (Perrins *et al.* 2018). Like other procellariiform seabirds, Manx Shearwaters are affected by light pollution and unfavourable weather conditions, with grounding being reported mainly near colonies (Rodríguez *et al.* 2008; Miles *et al.* 2010; Syposz *et al.* 2018). Existing studies of grounding impacts, however, have mainly focused on a single location, failing to report the events at a larger scale.

Here, using ringing and recovery data, we investigated the age class structure and spatial distribution of Manx Shearwater groundings around Britain and Ireland, as well as records of confirmed survival of individuals following rescue. Adult Procellariiformes are thought to be less susceptible than juveniles to grounding caused by light pollution (Camphuysen *et al.* 1999; Troy *et al.* 2013; Rodríguez *et al.* 2015; Syposz *et al.* 2018), thus we expected to find differences in the frequency and distribution of grounding events depending on age class. Furthermore, survival rates of adult procellariform seabirds are higher than those of fledging juveniles (Perrins *et al.* 1973; Simons 1984; Jenouvrier *et al.* 2008), thus we expected that the probability of recapture after an initial grounding event would be higher in adults than juveniles.

Methods

We analysed Manx Shearwater ringing and recovery data provided by the British Trust for Ornithology (BTO) for the period between 1912 and 2019. We used these data to calculate the number of first-year and adult shearwaters that grounded (dead or alive) in Britain and Ireland. The context within which ringing and recovery of living birds took place was not always recorded, so we assumed that the occurrence of such events away from a breeding colony indicated that the bird had grounded on land. No instances of seabirds grounding on vessels or offshore oil platforms were recorded. Since shearwaters are occasionally lured to the coast for ringing, we excluded records where birds had been lured using a sound recording (EURING catching code F). We also excluded individuals that were grounded twice on the same day as we considered that this could be a result of specific release procedures at a given location; for example, seabirds released during the night or during unfavourable weather could be more likely to be recovered again.

First, to examine incidences of confirmed survival for each age class ('first-year' or 'adult') following grounding, we searched for subsequent recoveries of grounded birds. We classified a bird as 'surviving' the initial grounding event if the recoveries took place at least three months after the grounding and involved either a living bird or one that was freshly dead (i.e. all EURING condition codes except 0, 1 and 3), implying that it must have foraged successfully for at least some time following initial rescue. We then calculated the total number of alive grounded birds for each age class as the number of alive newly encountered birds plus alive recovered birds. Finally, we calculated a survival rate of adult and first-year birds, by dividing the number of surviving birds by the total number of alive grounded birds. We compared the survival rate between the age classes using a Chi-square test.

Next, we investigated whether the distance between an individual's colony and its grounding location varied with age class. For this analysis we compiled a dataset, searching for records of grounded Manx Shearwaters that were also encountered at a colony (either before or after the rescue). We assumed that, due to the strong philopatry of Manx Shearwaters (Brooke 1990; Wynn *et al.* 2020), they are likely to return to their natal colony each year once they reach breeding age. We limited our search for grounding events to those that occurred between August and October, corresponding to the autumn migration period when grounding in both adults and juveniles could occur (juveniles begin to fledge in August). We then calculated the distance between the colony and the grounding location for each bird. To test for differences in the colony-to-grounding distances, we first generated a null distribution by randomising the age class (first-year or adult) of a bird with respect to its distance 100,000 times and calculated a global difference between the means of the two groups for each run.

We then calculated the real difference in mean distance from colony to grounding location between first-year and adult birds and compared it to the null distribution.

Results

From the 1912 to 2019 ringing and recovery data (N = 194,960), we found 6,381 records of Manx Shearwater ringing or recovery events that occurred away from the colony, which were consistent with grounding. We noted 39 individuals that were recovered away from the colony on two occasions, having grounded twice, including 17 first-year birds (10 alive and seven dead) and 22 adults (six alive, 15 dead and one unknown). Most double-grounded birds (N = 20) were recovered within ten days from the first grounding event. The majority of all grounded birds were first-year birds (79.4%, Table 1, Figure 1b). Of these 5,069 first-year birds, 4,747 were found alive and 312 were found dead. Of the first-year birds found alive 4.7% had been ringed at their natal colony before grounding (marked as 'alive recoveries' in Table 1), and the remainder were newly encountered individuals ('alive new encounters'). For adults, 171 individuals were found alive (29.2% of these were birds that had been previously ringed at a breeding colony) and 827 were found dead (Figure 1c).

Over the entire dataset, we identified 35 recoveries that were confirmed to have survived more than three months following grounding (found alive or freshly dead more than three months after grounding, henceforth 'three-month survival'). Of these, 22 were recorded as first-year birds at the initial grounding, ten were adults and three were birds of unknown age (Table 1). We noted an additional three first-year birds (not included in the overall number used for the analysis) that grounded in Brazil within three months, suggesting that they survived migration from the UK to the South Atlantic. Adult shearwaters had a significantly higher chance of three-month survival than first-year birds ($X^2_{(1)} = 69.46$, $p < 0.001$). Live first-year birds comprised 91.2% of grounding records but made up only 63% of survivors. Considering that adults accounted only for 3.3% of birds found grounded live, it follows that estimated adult survival is 13 times greater than first years.

We collated data on how far groundings occurred from a colony. We considered those birds that were encountered at a colony before or after a grounding event (Figure 2). We found that first-year birds grounded 4.5–629.6 km away from their colony (N = 542, mean = 72 km, S.D. = 95 km), whereas adults were encountered 5.6–631 km away from their colony (N = 263, mean = 152 km, S.D. = 130 km). There was a significant difference in the colony-to-grounding distances between age class, with first-year birds being more likely to be found closer to the colony than adults (permutation test, N = 100,000, $P < 0.001$; Figure 3).

Table 1. Number and status (alive new encounters, alive recoveries, dead, unknown) of grounded Manx Shearwaters *Puffinus puffinus* in Britain and Ireland, split into age categories ('first-year' and 'adult'). 'Alive new encounters' refers to birds found at the grounding event that had not been previously ringed. 'Alive recoveries' indicates birds that were ringed previously and found alive at a grounding event. 'Recovery after three-month survival' indicates the number of seabirds that were found alive or freshly dead more than three months after the grounding event.

Age class	Status	Number	Recovery after three-month survival
First-year	Total	5,069	
	Alive new encounters	4,525	20
	Alive recoveries	222	2
	Dead	312	
	Unknown	10	
Adult	Total	1,017	
	Alive new encounters	121	7
	Alive recoveries	50	3
	Dead	827	
	Unknown	19	
Unknown	Total	295	
	Alive new encounters	283	3
	Alive recoveries	3	
	Dead	9	
All age classes	Total	6,381	35

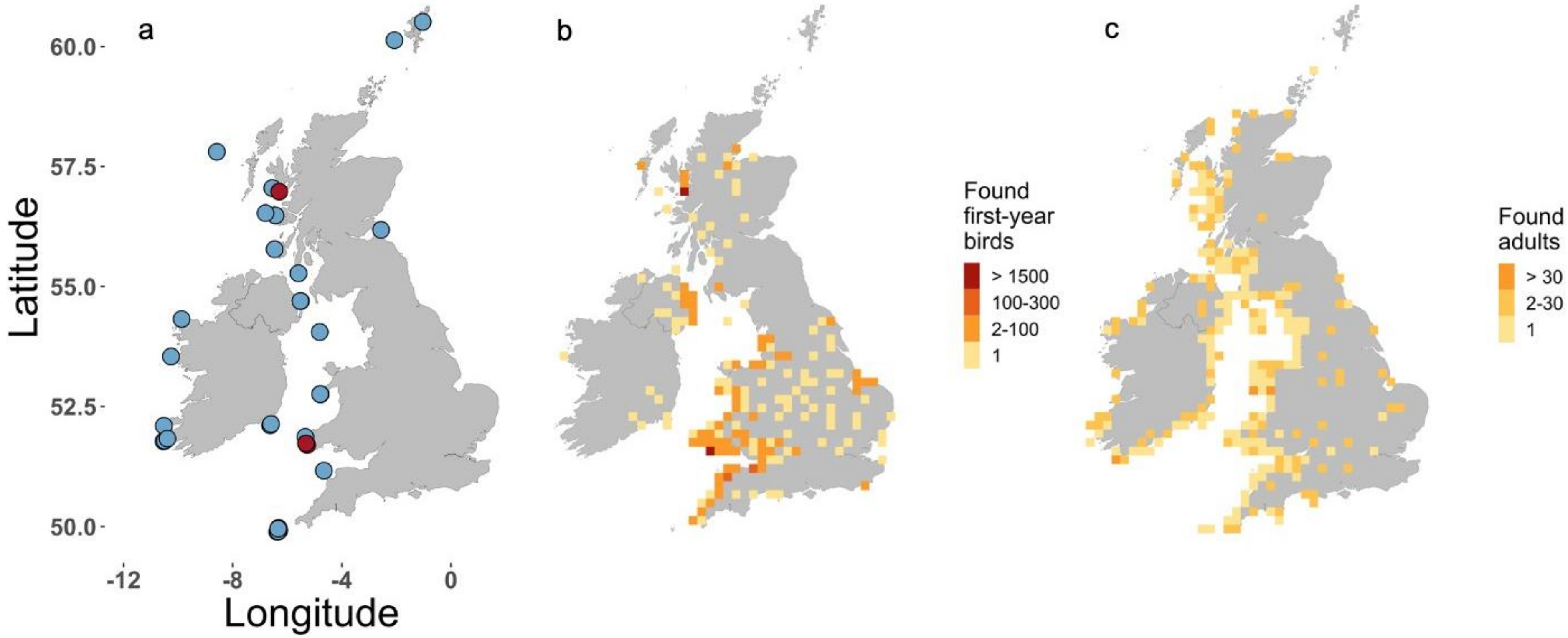

Figure 1 a) Map of Britain and Ireland with colonies of Manx Shearwaters *Puffinus puffinus* indicated with blue dots. Red dots indicate colonies on Skomer and Skokholm Islands (shared dot) and Rùm Island, where the majority of the population breeds. **b-c)** The distribution of grounded **b)** first-year and **c)** adult Manx Shearwaters. Darker colours indicate more grounding events.

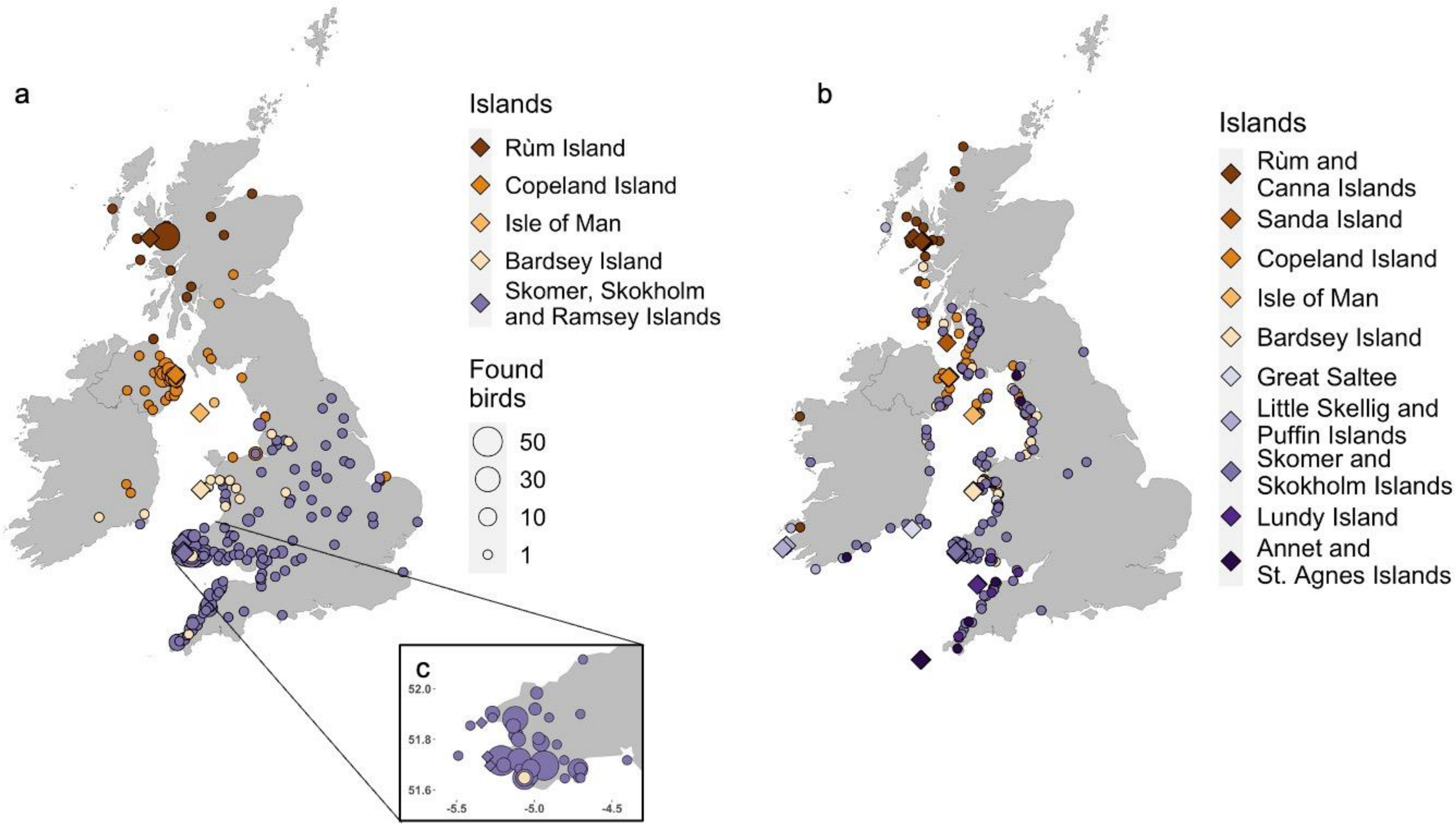

Figure 2. The distribution of grounded **a)** first-year and **b)** adult Manx Shearwaters *Puffinus puffinus* coloured by colony provenance and aggregated into 10 km square grids. The bird could be encountered at a colony either before or after the grounding event. We included birds that were found at grounding events that occurred between August and October. Panel **c)** presents the area near to Skomer, Skokholm and Ramsey Islands, with the cream dot indicating the two shearwaters rescued at Milford Haven Oil Refinery that were later encountered 120 km north, on Bardsey Island.

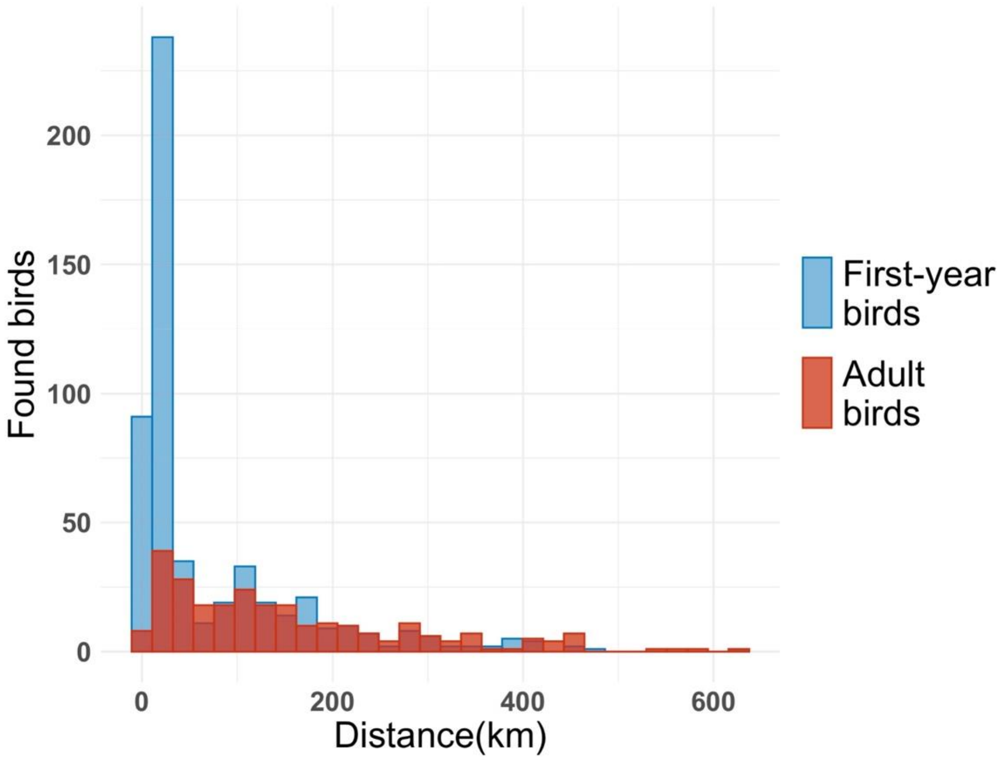

Figure 3. The distribution of distances between grounding location and the colony where the individual Manx Shearwater *Puffinus puffinus* was found before or after a grounding event. The distributions of distances for first-year birds (blue) and adults (red) were significantly different (permutation test, N = 100,000, $P < 0.001$); first-year birds were more likely to be found grounded closer to their colony than adults.

To gain a more complete picture of shearwater fate following grounding in areas with light pollution, we investigated the available recovery data for Manx Shearwaters ringed after grounding at Milford Haven Valero Oil Refinery, Pembrokeshire (Figure 2c) between 1992 and 2019. Of these records, 13 out of 1,576 birds were subsequently recovered (these data are included in the overall numbers above). Of these individuals, nine were subsequently found at breeding colonies between three and 20 years after grounding (two on Bardsey Island, four on Skomer Island and three on Skokholm Island). Breeding was confirmed in three consecutive years for one of the Skomer birds (successfully fledging one chick) and in two years for one of the birds on Skokholm (also fledging one chick).

Discussion

The ringing data collated here show that some Manx Shearwaters that ground after fledging, or as adults, go on to survive and even breed successfully. While only 35 of more than 6,000 grounded birds were recovered alive or freshly dead more than three months after grounding, the actual survival rate after grounding is likely to be considerably higher owing to the very small likelihood of recovery, even when birds go on to breed. The total population of Manx Shearwaters is estimated at 1.03–1.18 million (Birdlife International 2015) with 140,468 individuals ringed between 1912–2019 and ringing efforts over last 10 years (2010–19) being around 5,000 birds per year. Our collated grounding data are consistent with previous studies showing that first-year shearwaters have a greater tendency to ground than adults (Le Corre *et al.* 2002; Rodríguez *et al.* 2008; Rodríguez & Rodríguez 2009; Miles *et al.* 2010; Syposz *et al.* 2018). Grounding in response to light pollution represents a considerable conservation threat to shearwaters and other procellariform seabirds (Dias *et al.* 2019; Rodríguez *et al.* 2019). As such, rescue efforts could represent a valuable opportunity to mitigate against this threat since, as we showed in this study, rescued birds may go on to survive to adulthood and breed.

When considering all grounded birds, our results suggest that subsequent survival was higher for adult than first-year Manx Shearwaters. Indeed, adult shearwaters that grounded were 13 times more likely to survive and be recovered alive than first-year birds. This lower survival of juveniles in comparison to adults was expected (Simons 1984; Jenouvrier *et al.* 2008); survival of fledged Manx shearwaters to breeding age has been estimated at 30%, whereas adult annual survival is estimated at 80 –95% (Perrins *et al.* 1973). Since the data collated here were collected via grounding events rather than by effort at long-term study sites, it is not possible to infer a comparable survival rate of grounded birds from our data. It would therefore be difficult to compare our results with those from other rescue campaigns, such as a report of 15 re-encountered Newell's Shearwaters *P. auricularis newelli* out of 23,000 rescued fledglings from Kaua'i island in Hawaii (Ainley *et al.* 2001) or the low post-release survival rates of oiled seabirds (Sharp 2008). The very low probability of recovering birds ringed after grounding, however, means that the 'true' survival rate is almost certainly higher than that implied by the values that emerge from our analyses. Thus, efforts to rescue grounded shearwaters and other Procellariiformes are likely worthwhile (Ainley *et al.* 2001; Fontaine *et al.* 2011; Gineste *et al.* 2017). Whilst it would seem informative to compare our survival metrics with birds (both first-years and adults) ringed at colonies, survival rates of the latter are comparatively inflated by high survey effort at small subsections of shearwater colonies interacting with strong natal philopatry in Manx Shearwaters (Brooke 1990; Wynn *et al.* 2020). Any such comparison therefore yields little information about the relative survival rate of birds sampled through grounding and birds sampled through intensive ringing effort at colonies. Furthermore, high variability in efforts to capture Manx

Shearwaters between years and different locations, as well as the small sample size of recovered grounded birds, precludes us from comparisons between grounded and potentially non-grounded seabirds with use of capture-recapture methods (Otis *et al.* 1978; Fontaine *et al.* 2011). Future studies might consider examining the fate of grounded procellariiform seabirds in more detail by focusing on small colonies with the possibility of ringing and recovering the majority of the population.

After accounting for differences in the propensity of Manx Shearwaters to ground and be re-capture between life stages, we also note that adult birds were more likely to ground further away from their colony than first-year birds. The distribution of grounding event distances from the natal colony was similar for adult and juvenile shearwaters except for a distinct spike in groundings close to the colony for first-year birds. These numbers should be considered minimum estimates, since we could not distinguish between groundings that happen at the islands where Manx Shearwater breed and ringing efforts undertaken in the nesting areas (e.g. groundings known to occur on St Kilda (Miles *et al.* 2010) were not included). The high number of grounded juveniles near to the colony is consistent with the hypothesis that while both adult and juvenile seabirds are susceptible to grounding owing to storms, grounding close to natal colonies is a phenomenon largely limited to the fledging life stage in Manx shearwaters and is probably happening during the very first flight or soon after and exacerbated by anthropogenic light in coastal areas (Camphuysen *et al.* 1999; Troy *et al.* 2013; Rodríguez *et al.* 2015; Syposz *et al.* 2018). Nevertheless, when examining ringing and re-capture data, we found two shearwaters that grounded at Milford Haven Oil Refinery in Pembrokeshire later went on to breed 120 km north on Bardsey Island. While this could reflect normal natal dispersal in shearwaters it is also possible, owing to their strong natal philopatry (Brooke 1990; Wynn *et al.* 2020), that this may be indicative of fledgling birds grounding in areas with light pollution far further away from their natal colony than previously thought (Troy *et al.* 2013; Rodríguez *et al.* 2015, 2017a). Further research is necessary to confirm these possibilities by either greater effort in ringing juvenile shearwaters at colonies or use of biologging devices.

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