

# PASSAGE PATTERNS OF SEABIRDS IN OCTOBER AT CABO CARVOEIRO, PORTUGAL, WITH SPECIAL REFERENCE TO THE BALEARIC SHEARWATER *Puffinus mauretanicus*

JOHAN ELMBERG<sup>1</sup>, ERIK HIRSCHFELD<sup>2</sup>, HELDER CARDOSO<sup>3</sup> & REBECCA HESSEL<sup>1</sup>

<sup>1</sup>Division of Natural Sciences, Kristianstad University, SE-29188 Kristianstad, Sweden (Johan.Elmberg@hkr.se)

<sup>2</sup>Köpenhamnsvägen 105D, SE-217 75 Malmö, Sweden

<sup>3</sup>Largo dos Camarnais, n° 3, 2540-479, Pó, Portugal

Received 9 February 2016, accepted 22 April 2016

## SUMMARY

ELMBERG, J., HIRSCHFELD, E., CARDOSO, H. & HESSEL, R. 2016. Passage patterns of seabirds in October at Cabo Carvoeiro, Portugal, with special reference to the Balearic Shearwater *Puffinus mauretanicus*. *Marine Ornithology* 44: 151–156.

Land-based counts of migrating seabirds remain essential to increase knowledge about their numbers and movements. To assess the value of Cabo Carvoeiro (Peniche, Portugal) as a monitoring site in the East Atlantic, we studied seabird species composition, passage patterns and flock size during mid-October 2014. During standardized counts, we observed nearly 8000 seabirds of 17 species. The ratio of individuals passing in a southerly to southwesterly direction was >96% in all species, showing that genuine migrants were counted. The passage rate (birds/hour) was higher for Northern Gannets *Morus bassanus* than for any other species, by a factor of approximately 50 (morning mean 906/h, afternoon mean 1153/h). The globally endangered Balearic Shearwaters *Puffinus mauretanicus*, Great Skuas *Stercorarius skua* and Pomarine Skuas *S. pomarinus* had passage rates of 10–25/h. Flock size distribution in the 11 most numerous species showed that most migrated singly or in groups of two. Flock size was larger in Balearic Shearwaters than in both Cory's *Calonectris borealis* and Manx Shearwaters *P. puffinus*. Among skuas, flock size was larger in Pomarine than in Great Skuas. The passage rate of Manx Shearwaters was positively correlated with that of Northern Gannets, Great Skuas and Sandwich Terns *Sterna sandvicensis*. Northern Gannets showed a positive co-variation with Pomarine Skuas. Balearic and Sooty Shearwaters *Ardenna griseus* were the only species that did not show any significant co-variation with another species. Morning and afternoon passage rates did not differ significantly in any of the six most numerous species (Northern Gannets, Cory's and Balearic Shearwaters, Great and Pomarine Skuas, and Sandwich Terns), or in Sooty Shearwaters (less numerous). Thus, the passage rates at Cabo Carvoeiro in October of Balearic Shearwaters and five other species were as high or higher than those reported from any other seawatch in Portugal, indicating the international value of seabird monitoring at Cabo Carvoeiro during the autumn migration.

**Key words:** gannet, seabird migration, seabird monitoring, seawatch, shearwater, skua, tern

## INTRODUCTION

Most seabirds are long-lived, but are also late and slow reproducers in the upper levels of marine food webs. This makes them vulnerable to environmental disturbances, especially in the current era of global change, pollution and increasing fisheries impact. As a result, the list of threats to seabirds is growing (Croxall *et al.* 2012). This is not the only reason seabirds are receiving increased attention from scientists and conservationists, though; differences in seabird distribution and abundance may help to explain links between components of marine ecosystems (Louzao *et al.* 2011).

Seabirds are inherently difficult to study, as much of their lives is spent in the open sea. Although satellite telemetry and geolocators have provided much new insight into their biology in recent years (e.g. Guilford *et al.* 2012, Péron & Grémillet 2013), it remains arduous to obtain large samples and hard to make population-level conclusions based on these methods. In addition, a recent modeling study of the Balearic Shearwater *Puffinus mauretanicus*, based on 13 environmental variables and ship transect data, highlighted the difficulties in predicting abundance as well as spatial patterns at sea (Oppel *et al.* 2012). In other words, for the foreseeable future, land-based (and at-sea) counts will remain important to better understand

spatial and temporal distribution of many seabird species (e.g. Jones *et al.* 2014). To this end, there have been recent methodological advances addressing some of the problems associated with land-based counts; for example, time gaps in count series (Mateo-Rodriguez *et al.* 2012).

In a first pilot study (Elmberg *et al.* 2013), we showed that the west coast of Portugal, notably the Peniche area, is potentially a strategic location along the East Atlantic Flyway to study migrating seabirds of many species. The volunteer-based RAM (Rede de observação de Aves e Mamíferos marinhos) initiative to count seabirds from land in the western Iberian Peninsula (Sengo *et al.* 2012, Oliveira *et al.* 2014) is much welcome and a source of valuable information, but has important limitations: 1) the low temporal resolution, i.e. monthly counts, provides only coarse annual patterns of occurrence; 2) counts are made only in the first three hours of the morning; 3) flock size data for most species are not provided in reports thus far; 4) passage rate data have been presented for nine species only, thus omitting several seabirds occurring in the region; and 5) data are not very accessible because reports are in Portuguese and not in indexed journals. Consequently, quantitative seabird-passage data with higher temporal resolution are needed from the western Iberian Peninsula, especially from the main migration months. Qualitative

data such as flight direction, flock size, age ratios and color morph ratios are also called for to aid conservation efforts and increase general ecological understanding. Cabo Carvoeiro, at Peniche, Portugal, may be a key site to provide such data, and studies following up Elmberg *et al.* (2013) are needed to determine this.

The waters off the Western Iberian Peninsula are of special interest because they are key in the life cycle of Europe's only endemic seabird, the Balearic Shearwater, which is regarded as Critically (globally) Endangered (Arcos 2011). It breeds only on small islets off the main Balearic Islands, the known breeding population amounting to a mere 3200 pairs (Arcos 2011). After nesting in March–July most of, or possibly all of, the population exits the Mediterranean and migrates to waters off Portugal, Spain and France, where it spends approximately three months or more (generally June to August; Mouriño *et al.* 2003, Arcos 2011, Guilford *et al.* 2012), during which the birds moult. Return migration to the Mediterranean takes place mainly in September–November, with stragglers through December (Mouriño *et al.* 2003, Arcos 2011, Oppel *et al.* 2011, Guilford *et al.* 2012). However, the temporal pattern of this return is imperfectly known. There is also a discrepancy between population estimates based on counts at nesting sites on the one hand, and net eastward migration totals at Gibraltar on the other, the latter indicating a larger breeding population (Arcos 2011 *versus* Mateos-Rodriguez *et al.* 2012). In comparison with other procellariiforms, Balearic Shearwaters exhibit low adult survival (0.78–0.81) and an alarmingly steep population decline (7.4% per year; Oro *et al.* 2003, Genovart *et al.* 2016). There are immediate concerns for the bird's future, as it seems to be particularly vulnerable as fisheries bycatch (Oliveira *et al.* 2015, Genovart *et al.* 2016). Previous studies (shipboard surveys [Oppel *et al.* 2011], isotopic analysis [Louzao *et al.* 2011] and telemetry [Guilford *et al.* 2012, Louzao *et al.* 2012]) all show that Balearic Shearwaters use mainly shallow near-coast waters throughout the year, including during the pre-breeding return migration (Mouriño *et al.* 2003, see also Jones *et al.* 2014). This suggests that Cabo Carvoeiro would be an excellent site to monitor the species and to gain a better understanding of its migration (cf. Oppel *et al.* 2011, pp. 100–101).

The aim of the present study was to provide a better understanding of species composition as well as between-day and within-day variation in seabird numbers passing Cabo Carvoeiro, Peniche, in October (cf. Sengo *et al.* 2012, Elmberg *et al.* 2013, Oliveira *et al.* 2014), the main month for return migration by Balearic Shearwaters. We address the following specific questions: 1) What is the relative proportion of southbound versus northbound seabirds? 2) What is the variation in net passage rate? 3) What is the frequency distribution of flock sizes?

## STUDY AREA AND METHODS

We undertook seabird counts at Cabo Carvoeiro on seven days (12–18 October 2014; Appendix 1, available on the website) from the sea cliffs west and south-southwest of Remédios (39°21'59"N, 9°24'12"W and 39°21'34"N, 9°24'31"W, respectively) in the western outskirts of the city of Peniche (see Fig. 1 in Elmberg *et al.* 2013 for a map of location and bathymetry of the adjacent sea). Both vantage points are 20–25 m above sea level, offering unobstructed views over the sea, backlit in the morning and sidelit in the evening. Large birds such as Northern Gannets *Morus bassanus* are easily identified at a distance of up to 10 km; for example, when passing

close to the Berlengas Islands situated to the west-northwest of Cabo Carvoeiro. We did seven morning counts (07:30–12:30) totaling 1057 min (mean = 151 min/d) and six afternoon counts (14:00–19:00) totaling 763 min (mean = 127 min/d) (Appendix 1). Morning counts started as soon as it was light enough to observe migrating birds, and afternoon counts stopped when it was too dark to do so. Counts were suspended during heavy precipitation and occurrence of clouds/fog that reduced visibility significantly. Mainly due to these reasons, observation effort varied among days (Appendix 1). We registered all seabirds moving over the sea, except the abundant resident Yellow-legged Gull *Larus michahellii*. The recently split Cory's *Calonectris (diomedea) borealis* and Scopoli's *C. (d.) diomedea* Shearwaters are both known to occur in Portuguese waters, but we chose to treat them together for the purpose of this study, as distance and time rarely permitted conclusive identification. Since thousands of Cory's Shearwaters nest on the nearby Berlengas Islands, we assumed that most were indeed this species, and therefore we used this name throughout this article.

Only birds passing Cabo Carvoeiro were counted. This was usually obvious from behavior, and, if not, ascertained by following the bird/flock until this could be determined. In other words, resident, swimming or rafting birds were omitted, as were those merely following fishing vessels, unless they changed behavior to adopt longer-range flight. Count procedures were as described in Elmberg *et al.* (2013), with the following modifications: a) flight direction was noted for all birds; b) flock size (a flock was defined as birds following the same flight trajectory and within ~50 m from each other) was noted for all birds except Northern Gannets, as it was often impossible to delineate flocks in this species; c) Northern Gannets were counted every 5 min per half-hour and all other species up to 30 min per half-hour, depending on passage strength and the number of observers present (Appendix 1). All counts were made by JE, EH and HC (1–3 observers on each occasion). We used 10× binoculars and 20–75× spotting scopes, scanning the sea and sky continuously. Wind and precipitation data for Peniche were obtained from Windguru (2014), and they corresponded very well to our own on-site estimates.

## RESULTS

The weather was unsettled. Winds were generally from the sector between south and west, stronger than 10 m/s on 12–13 and 15–17 October, with the most “onshore” conditions during 12–13 October (Appendix 1). Precipitation was >5 mm 12–13 October and 1–5 mm all other days. Overall, seabird passage activity was obviously related to weather, with the highest daily totals for Northern Gannets, Manx Shearwaters *Puffinus*, Balearic Shearwaters, Great Skuas *Stercorarius skua*, Pomarine Skuas *S. pomarinus*, and Parasitic Skuas *S. parasiticus* all occurring on 12 October. This day was characterized by overcast skies and strong onshore winds (west 12–14 m/s), with frequent periods of limited visibility (down to 1–2 km).

Nevertheless, seabird movement was strong throughout the study period, and dominated by Northern Gannets (Appendix 1), the unstandardized total count for which greatly outnumbered all other species, even though observation effort for Northern Gannets was much smaller. The next most numerous species were Balearic Shearwater, Great and Pomarine Skuas, and Sandwich Tern *Sterna sandvicensis*, all but the last being recorded every day (Appendix 1).

Cory's, Sooty *Adenna griseus* and Manx Shearwaters were seen on six of seven days. In these more numerous species there was a notable passage in the afternoon as well as in the morning. The numbers of birds passing in the opposite direction to the expected south-southwest migration sector were extremely few; in all species, 96% or more of the individuals flew south-southwest (Appendix 1).

Since count effort differed among days, between morning and afternoon, and between Northern Gannets and the other species, actual counts were standardized to express the number of southbound migrating birds per hour. Such passage rates for morning and afternoon counts, respectively, showed that Northern Gannets outnumbered all other species by a factor of ~50, with a mean of roughly 1000 birds/h in the morning as well as in the afternoon, with large variation among days (Appendix 1). Rates of Balearic Shearwaters and Great and Pomarine Skuas, averaged 10–25 birds/h, while Sandwich Terns and Cory's Shearwaters averaged 5–10 birds/h, again as weekly means for morning and afternoon (Appendix 1).

On a daily basis (morning and afternoon counts pooled), passage rate varied greatly within and among the six most numerous species (Table 1). Northern Gannets, Balearic Shearwaters, Great Skuas and Pomarine Skuas all had their highest value on 12 October, but the second highest passage rate in these four species was recorded on four different days. To explore the degree of synchrony in October passage rates among species at Cabo Carvoeiro at a more general level, data from 2014 were merged with those from 2012 (Table 1 in Elmberg *et al.* 2013) to provide 12 morning and nine afternoon passage rates per species for the period 1–18 October. Among the eight most numerous species in 2012 and 2014, only five of 28 cases of pairwise co-variation were statistically significant based on rank correlation (Table 2). Passage rate of Manx Shearwaters was positively correlated with that of Northern Gannets, Great Skuas and Sandwich Terns, and the passage of Northern Gannets also showed a strong positive co-variation with that of Pomarine

Skuas. However, there was a significant negative co-variation between Northern Gannets and Cory's Shearwaters. Balearic and Sooty Shearwaters were the only species not showing any significant co-variation in passage rate with another species.

On a weekly basis in 2014, four of the six most numerous species showed higher passage rates in the afternoon than in the morning (Appendix 1), calling for an analysis of diel patterns. Thus, count data were pooled over days, broken down into 30-min periods, and standardized by effort. The results indicate that the six most numerous species may have different diel patterns (Appendix 2, available on the website): Cory's Shearwater passage rates showed a peak in mid-morning, Balearic Shearwaters peaked in mid-morning and mid-afternoon, Great Skuas in early morning and late afternoon, whereas Pomarine Skuas peaked in late morning and early afternoon. Passage rates of Northern Gannets and Sandwich Terns showed no clear peaks. However, these diel patterns are based on counts from a limited part of the migration season, and the actual number of individuals involved is often low when broken down into 30-min periods. Accordingly, these patterns should be seen as hypotheses for further testing based on larger samples covering a longer part of the migration season and a wider range of weather conditions. Nevertheless, based on data from Cabo Carvoeiro in 2012 and 2014, general comparisons of passage rates between mornings and afternoons (Appendix 1 in the present study, and daily count and effort data in Table 1 in Elmberg *et al.* 2013) are useful. Mean passage rate data were available for seven mornings and six afternoons in 2014, and five mornings and three afternoons in 2012, together spanning the period 1–18 October. In this pooled data set, there was no statistically significant difference in passage rate between morning and afternoon in any of the six most numerous species, and the same was true for Sooty Shearwaters (Mann–Whitney U statistic ranging from 58 to 74, and *P* values, 0.15–0.78; *n* = 21 [12 morning and nine afternoon values per species]). However, the Manx Shearwater passage rate was significantly biased to mornings (Mann–Whitney U = 89, *P* < 0.01, *n* = 21).

**TABLE 1**  
Count effort and daily southbound passage rate of the six most numerous seabird species at Cabo Carvoeiro, Portugal, 12–18 October 2014

Date	12 Oct		13 Oct		14 Oct		15 Oct		16 Oct		17 Oct		18 Oct	
Effort Northern Gannet (min)	70		55		50		50		50		40		25	
Effort other species (min)	287		305		288		273		277		240		150	
	Individuals	Inds/h	Individuals	Inds/h	Individuals	Inds/h	Individuals	Inds/h	Individuals	Inds/h	Individuals	Inds/h	Individuals	Inds/h
Cory's Shearwater	61	12.8	10	2	84	17.5	22	4.8	3	0.6	1	0.3	0	0
Balearic Shearwater	218	45.6	28	5.5	47	9.8	95	20.9	137	29.7	49	12.3	70	28
Northern Gannet	2,871	2,460.9	800	872.7	441	529.2	352	422.4	366	439.2	296	444	585	1,404
Great Skua	261	54.6	114	22.4	59	12.3	11	2.4	9	1.9	5	1.3	11	4.4
Pomarine Skua	323	67.5	7	1.4	46	9.6	7	1.5	1	0.2	2	0.5	2	0.8
Sandwich Tern	48	10	86	16.9	20	4.2	0	0.0	82	17.8	13	3.3	14	5.6

Flock size distribution for the 11 most numerous species (excluding Northern Gannets, see Methods) showed that single birds were the most common in all species except Mediterranean Gulls *L. melanocephalus* and Common Terns *S. hirundo* (Appendix 3, available on the website). The proportion of all individuals passing singly ranged from 9% to 11% in gulls and terns to 78% in Manx Shearwaters and 83% in European Storm-petrels *Hydrobates pelagicus* (Appendix 3). Indeed, in most species most passing birds occurred either singly or in groups of two; 100% of European Storm-petrels, Sooty Shearwaters, Manx Shearwaters and Parasitic Skuas were single or groups of two. Among the shearwaters, Balearic Shearwaters occurred in flocks of three or more birds more often than the other species. Flock size in Balearic Shearwaters was significantly larger than in both Cory's and Manx Shearwaters (Mann–Whitney  $U = 36980$  [ $P < 0.001$ ] and  $9922.5$  [ $P < 0.02$ ], respectively; means and sample sizes in Appendix 3). Flock size did not differ significantly between Cory's and Manx Shearwaters, however (Mann–Whitney  $U = 2917.5$  [ $P = 0.80$ ]; sample sizes in Appendix 3). Among the skuas, Pomarine Skuas occurred in flocks of three or more birds more often than did Great and Parasitic Skuas, although Great Skuas were more numerous than Pomarine. Indeed, flock size in Pomarine Skuas was significantly larger than in Great Skuas (Mann–Whitney  $U = 23860$ ;  $P < 0.001$ ; sample sizes in Appendix 3). It was not meaningful to further explore variation in flock size (i.e. within and among days), as temporal variation was slight in all numerous species, and samples were small when broken down by day or hour.

## DISCUSSION

Unlike our pilot study at Cabo Carvoeiro in 2012 (Elmberg *et al.* 2013), the current study was characterized by unsettled weather and winds from the sector between south and west, that is, conditions usually regarded as more favorable for observing seabirds from land in this region. The 2014 study indeed recorded more species and higher numbers of most species, despite the fact that visibility, and hence detectability of far offshore migrants, was lower than in

2012. A striking difference between the two studies is that in 2014 virtually all birds were obvious southbound migrants, whereas in 2012 there was a notable proportion of northbound individuals of Shag *Phalacrocorax aristotelis* and Great Cormorants *Ph. carbo* as well as of Cory's, Manx and Balearic Shearwaters. Future study is needed to address whether the striking difference in the proportion of southbound migrants in these species merely reflects differences in wind conditions between the two studies, or if there is a shift from early to mid-October in the proportion of genuine migrants at Cabo Carvoeiro. In contrast, Iberian Peninsula seabird counts spanning longer annual periods than the present study often show rather “messy” patterns of birds moving in both directions (cf. Paterson 1997, Mouriño *et al.* 2003, Mateos-Rodriguez *et al.* 2012). To our knowledge, our daily totals for Great Skuas on 12 October (261 birds) and European Storm-petrels on 13 October (36 birds) are the highest published for Portugal. For the other species, the highest daily totals in 2014 were not extreme (cf. totals from Cabo Carvoeiro in Moore [2000] and maximum counts at Estaca de Bares, Galicia, Spain [Seawatching Estaca 2014]).

Passage rates showed that Sooty Shearwaters, Great and Pomarine Skuas, Sandwich Terns, and especially Northern Gannets had a stronger passage at Cabo Carvoeiro in 2014 (mid-October) than in 2012 (early October) (Appendix 1 in the present paper and Table 1 in Elmberg *et al.* 2013). However, the passage rate of Cory's Shearwaters was much lower in 2014 than in 2012, possibly because there was less movement by local breeders on Berlengas Islands at this time (Lecoq *et al.* 2011), or because they had left the colony for the year. Morning passage rates in 2014 can be compared to October means for 2009–2013 in the RAM counts from five other seawatch sites in southern Portugal (Oliveira *et al.* 2014; data collected 08:00–11:00 only, but flight direction not specified). Accordingly, the morning passage rates for Great Skuas at other RAM sites in 2009–2013 were much lower than that recorded at Cabo Carvoeiro in mid-October 2014 or early October 2012 (Elmberg *et al.* 2013). Similarly, the passage rate of Northern Gannets at Cabo Carvoeiro was three to 20 times higher than at other RAM sites in October. Balearic Shearwaters showed a higher, or equally high, passage rate

**TABLE 2**  
Co-variation in daily southbound passage rate among the eight most numerous seabird species at Cabo Carvoeiro, Portugal, 1–5 October 2012 and 12–18 October 2014<sup>a</sup>

	Northern Gannet	Cory's Shearwater	Sooty Shearwater	Manx Shearwater	Balearic Shearwater	Great Skua	Pomarine Skua	Sandwich Tern
Northern Gannet	1.000							
Cory's Shearwater	-0.438 <sup>b</sup>	1.000						
Sooty Shearwater	0.001	0.393	1.000					
Manx Shearwater	0.445 <sup>b</sup>	0.343	0.171	1.000				
Balearic Shearwater	0.008	-0.014	-0.201	0.061	1.000			
Great Skua	0.249	0.267	0.137	0.487 <sup>b</sup>	0.174	1.000		
Pomarine Skua	0.796 <sup>c</sup>	-0.292	0.246	0.332	-0.114	0.305	1.000	
Sandwich Tern	0.432	0.010	-0.099	0.465 <sup>c</sup>	-0.138	0.309	0.025	1.000

<sup>a</sup> For each species, there are data from 12 mornings (five in 2012 and seven in 2014) and nine afternoons (three in 2012 and six in 2014), for a total sample of 21 counts from 12 days. Cell values are Spearman rank correlation coefficients.

<sup>b</sup> Statistically significant,  $P = 0.05$  level.

<sup>c</sup> Statistically significant,  $P = 0.0005$  level. All probabilities are two-tailed.

at Cabo Carvoeiro than October values from four of five RAM sites (Oliveira *et al.* 2014). Although based on smaller samples in terms of counted birds (but neither days nor count effort), Mediterranean Gulls and Sandwich Terns also showed stronger October passage rates at Cabo Carvoeiro in both 2012 and 2014 than at other RAM sites in 2009–2013. Comparing the still-limited data from Cabo Carvoeiro with October counts in Galicia in 2008–2009 (Estaca de Bares), the maximum daily passage rate was twice as high in Northern Gannets and higher in Great and Pomarine Skuas at Cabo Carvoeiro (Table 1 versus Sandoval *et al.* 2009, 2010). However, higher rates for single days have been recorded at Estaca de Bares in earlier years: 360 birds/h on 22 October 1997 (Mouriño *et al.* 2003). Count totals, as well as hourly and daily passage rates in the present study, strengthen the suggestion in Elmberg *et al.* (2013) that Cabo Carvoeiro is a seawatch eminently suited to capturing the flux of an array of seabird species moving south in the Eastern Atlantic in autumn.

In a broad sense, the present study supports the notion that days with massive passage of one species often also have a strong passage of other species. This seems to be true at a general level (most correlation coefficients in Table 2 have a positive sign, whether significant or not), but also for the single days with the strongest migration (e.g. 12 October 2014, with the highest passage rate for four of the six most numerous species). Nevertheless, our prediction was rather that Table 2 would contain a higher number of statistically significant positive correlations, and we still assume this may be the case at larger sample sizes, at least for species with similar phenology. The Balearic Shearwater was the second most numerous species in our study, but interestingly its passage rate did not co-vary with that of any other species. This may indicate that the Balearic Shearwaters we observed may have spent the preceding day or days in a different area than Northern Gannets and Great Skuas, for example.

We do not see any obvious explanation why morning passage was significantly stronger than afternoon passage in Manx Shearwater. The fact that mean passage rate did not differ between morning and afternoon in the seven most numerous species passing Cabo Carvoeiro is a negative result and is interesting in at least two ways. First, it refutes the hypothesis in Elmberg *et al.* (2013) that morning passage at Cabo Carvoeiro is generally stronger than afternoon passage in Northern Gannet, and Balearic and Sooty Shearwaters. Second, it suggests that passage past Cabo Carvoeiro is rather even on a diel basis. If this suggestion can be corroborated, the data from this site would be of even greater value for extrapolation of passage rates to estimate the total number of passing birds of certain species, which would be of international significance. Consequently, we advise that future count efforts at Cabo Carvoeiro include days at regular intervals during which passing seabirds are counted throughout the day. This would allow the application of generalized additive modeling, which is a powerful analytical tool to produce estimates of total passage (Mateos-Rodriguez *et al.* 2012). Extrapolations based on available data from Cabo Carvoeiro remain speculative. Walker (1996) cautioned that morning count data for Northern Gannet at Cape St Vincent (Portugal) should not be used to extrapolate daily totals at this site, and two studies cited by Mateos-Rodriguez *et al.* (2012, p. 514) state that neither Northern Gannets nor Cory's and Balearic Shearwaters are known to migrate through the Strait of Gibraltar at night. In our 2014 data, Northern Gannets and Balearic Shearwaters exhibited a relatively even passage rate over the parts of the day when counts

were carried out. Assuming a passage rate of 1 000 and 20 birds/h (Appendices 1 and 2), and assuming that migration occurs only when it is light, approximately 75 000 Northern Gannets and 1 500 Balearic Shearwaters are estimated to have passed Cabo Carvoeiro during our week-long study in mid-October 2014, both of which are much higher estimates than in Elmberg *et al.* (2013). These 2014 estimates from Cabo Carvoeiro also compare very well to four-week (mid-October to mid-November) eastbound net totals at the Strait of Gibraltar in 2005–2007: 4 000–6 000 Northern Gannets and 1 000–7 000 Balearic Shearwaters (Mateos-Rodriguez *et al.* 2012).

These are the first published flock size data for seabirds at Cabo Carvoeiro, and there is little information of this kind available from other seawatches in the Western Iberian Peninsula for comparison. Hence, only some remarks are warranted at this time. First, observation conditions at Cabo Carvoeiro allow for very accurate data to be collected; with the exception of Northern Gannets, it was straightforward to determine flock size for all species in the vast majority of cases. Second, our data demonstrate statistically significant differences in flock size between some numerous species (Balearic versus Manx and Cory's Shearwaters, and Pomarine versus Great Skuas). However, the fact that these differences were small in sheer numbers suggests that differences in flock size distribution instead may have more biological meaning (e.g. Poisson-distributed data are often assumed in analyses of larger data sets of bird counts; Mateos-Rodriguez *et al.* 2012). Third, the small flock sizes of Balearic Shearwater are in stark contrast to the large flocks often observed in this species in moulting areas (e.g. Yésou 2003), but also in western Portugal earlier in the season (Poot 2005). Finally, based on geolocator data from the pre-nesting period off the Balearic breeding islets, Guilford *et al.* (2012) suggested that "mating synchrony in Balearic Shearwaters emerges as a consequence of the pair meeting at the colony." Yet, to our knowledge, it is not established when pairing in this species occurs, or if pair-bonds last for several years as in many other seabirds (Warham 1990, Swatschek *et al.* 1994). We note in our 2014 October data that shearwaters with a more imminent nesting period (October–March in Sooty Shearwaters and March–June in Balearic Shearwaters) have a higher fraction of passing birds occurring in groups of two (i.e. possible pairs) than do the species (Cory's and Manx Shearwaters) that have more time remaining to their nesting season (34% and 26% versus 14% and 22%). Consequently, we would like to see further tracking data to determine whether Balearic Shearwaters may pair before or during the pre-breeding migration.

The present study supports Opper *et al.* (2012), who found that the waters off central Portugal are an important area to study Balearic Shearwaters, and Elmberg *et al.* (2013), who found that Cabo Carvoeiro is an internationally promising site for land-based monitoring of seabirds. Data now available from two periods in October demonstrate that species richness is high and passage rates significant for several species, including the globally endangered Balearic Shearwater. We see great utility in an expanded scheme of annual seabird counts at Cabo Carvoeiro, running daily from August to November, with consistent methodology allowing for subsequent exploration of data by generalized additive modeling, as suggested by Mateo-Rodriguez *et al.* (2012). Such counts are likely to contribute significantly to information-gathering and conservation efforts for the Balearic Shearwater, in light of its precarious current status.

## ACKNOWLEDGEMENTS

We are grateful to Martin Heubeck and Pierre Yésou for constructive criticism of earlier versions of this manuscript.

## REFERENCES

- ARCOS, J.M. 2011. *International species action plan for the Balearic Shearwater, Puffinus mauretanicus*. SEO/BirdLife and BirdLife International.
- CROXALL, J.P., BUTCHART, S.H.M., LASCELLE, B., STATTERSFIELD, A.J., SULLIVAN, B., SYMES, A. & TAYLOR, P. 2012. Seabird conservation status, threats and priority actions: a global assessment. *Bird Conservation International* 22: 1-34.
- ELMBERG, J., HIRSCHFELD, E. & CARDOSO, H. 2013. Diurnal seabird movements at Cabo Carvoeiro (Peniche, Portugal): observations in early October 2012. *Seabird* 26: 24-30.
- GENOVART, M., ARCOS, J.M., ÁLVAREZ, D. ET AL. 2016. Demography of the critically endangered Balearic shearwater: the impact of fisheries and time to extinction. *Journal of Applied Ecology*. doi:10.1111/1365-2664.12622.
- GUILFORD, T., WYNN, R., McMINN, M. ET AL. 2012. Geolocators reveal migration and pre-breeding behaviour of the critically endangered Balearic Shearwater *Puffinus mauretanicus*. *PLoS ONE* 7(3): e33753.
- JONES, A.R., WYNN, R.B., YÉSOU, P. ET AL. 2014. Using integrated land- and boat-based surveys to inform conservation of the Critically Endangered Balearic shearwater *Puffinus mauretanicus* in northeast Atlantic waters. *Endangered Species Research* 25: 1-18. doi: 10.3354/esr00611.
- LECOQ, M., RAMIREZ, I., GERALDES, P. & ANDRADE, J. 2011. First complete census of Cory's Shearwaters *Calonectris diomedea borealis* breeding at Berlengas Islands (Portugal), including the small islets of the archipelago. *Airo* 21: 31-34.
- LOUZAO, M., DELORD, K., GARCIA, D., BOUÉ, A. & WEIMERSKIRCH, H. 2012. Protecting persistent dynamic oceanographic features: transboundary conservation efforts are needed for the critically endangered Balearic Shearwater. *PLoS ONE* 7(5): e35728.
- LOUZAO, M., NAVARRO, J., FORRERO, M.G., IGUAL, J.M., GENOVART, M., HOBSON, K.A. & ORO, D. 2011. Exploiting the closest production area: geographical segregation in foraging grounds in a critically endangered seabird. *Marine Ecology Progress Series* 429: 291-301.
- MATEOS-RODRIGUEZ, M., THOMAS, L. & ARROYO, G.M. 2012. The development and use of a method to fill time gaps in migration counts. *Condor* 114: 513-522.
- MOORE, C.C. 2000. Movimentações invulgares de aves marinhas junto ao Cabo Carvoeiro, Outono de 1999 – uma discussão. *Pardela* 13: 7-10.
- MOURIÑO, J., ARCOS, F., SALVADORES, R., SANDOVAL, A. & VIDAL, C. 2003. Status of the Balearic shearwater (*Puffinus mauretanicus*) on the Galician coast (NW Iberian Peninsula). *Scientia Marina* 67 (suppl. 2): 135-142.
- OLIVEIRA, N., BARROS, N., MERINHO, P., GERALDES, I., RAMIREZ, I. & ANDRADE, J. 2014. *Relatório RAM em Portugal Continental – 2013*. Lisbon, Portugal: Sociedade Portuguesa para o Estudo das Aves.
- OLIVEIRA, N., HENRIQUES, A., MIODONSKI, J. ET AL. 2015. Seabird bycatch in Portuguese mainland coastal fisheries: An assessment through on-board observations and fishermen interviews. *Global Ecology and Conservation* 3: 51-61.
- OPPEL, S., MERINHO, A., RAMIREZ, I., GARDNER, B., O'CONNELL, A.F., MILLER, P.I. & LOUZAO, M. 2011. Comparison of five modelling techniques to predict the spatial distribution and abundance of seabirds. *Biological Conservation* 156: 94-104.
- ORO, D., AGUILAR, J.S., IGUAL, J.M. & LOUZAO, M. 2003. Modelling demography and extinction risk in the endangered Balearic shearwater. *Biological Conservation* 116: 93-102.
- PATERSON, A.M. 1997. *Las aves marinas de España y Portugal*. Barcelona, Spain: Lynx Edicions.
- PÉRON, C. & GRÉMILLET, D. 2013. Tracking through life stages: adult, immature and juvenile autumn migration in a long-lived seabird. *PLoS ONE* 8(8): e72713.
- POOT, M. 2005. Large numbers of staging Balearic Shearwaters *Puffinus mauretanicus* along the Lisbon coast, Portugal, during the post-breeding period, June 2004. *Airo* 15: 43-50.
- SANDOVAL, R.A., HEVIA, B.R. & FERNÁNDEZ, M.D. 2009. *Boletín de la Estación Ornitológica de Estaca de Bares Numero 1 – Año 2008*. Dirección Xeral de Conservación da Natureza, Consellería de Medio Ambiente e Desenvolvemento Sostible da Xunta de Galicia / TERRANOVA Interpretación y Gestión Ambiental S.L.
- SANDOVAL, R.A., HEVIA, B.R. & FERNÁNDEZ, M.D. & VALDERAS, F.A. 2010. *Boletín de la Estación Ornitológica de Estaca de Bares Numero 2 – Año 2009*. Dirección Xeral de Conservación da Natureza, Consellería de Medio Ambiente e Desenvolvemento Sostible da Xunta de Galicia / TERRANOVA Interpretación y Gestión Ambiental S.L.
- Seawatching Estaca [Online]. Estaca de Bares, Spain: Seawatching Estaca [Available online at: <http://seawatchingestaca.com>. Accessed 7 June 2016.]
- SENGO, R., OLIVEIRA, N., ANDRADE, J., BARROS, N. & RAMIREZ, I. 2012. *Três anos de RAM em Portugal Continental (2009 – 2011)*. Lisbon, Portugal: Sociedade Portuguesa para o Estudo das Aves.
- SWATSCHEK, I., RISTOW, D. & WINK, M. 1994. Mate fidelity and parentage in Cory's shearwater *Calonectris diomedea* – field studies and DNA fingerprinting. *Molecular Ecology* 3: 259-262.
- WALKER, F.J. 1996. Observations of movements of North Atlantic Gannets *Morus bassanus* from Cape St Vincent, Portugal. *Seabird* 18: 44-48.
- WARHAM, J. 1990. *The Petrels. Their ecology and breeding systems*. London, UK: Academic Press.
- Windguru [Online]. Czech Republic: Windguru. [Available online at: <http://www.windguru.cz>. Accessed 7 June 2016.]
- YÉSOU, P. 2003. Recent changes in the summer distribution of the Balearic shearwater *Puffinus mauretanicus* off western France. *Scientia Marina* 67 (suppl. 2): 143-148.