SEABIRD MIGRATION AT CABO CARVOEIRO (PENICHE, PORTUGAL) IN AUTUMN 2015

JOHAN ELMBERG[1*], ERIK HIRSCHFELD[2], HELDER CARDOSO[3] & REBECCA HESSEL[1]

[1]*Department of Environmental Science and Bioscience, Kristianstad University, SE-291 88 Kristianstad, Sweden* [*]*(Johan.Elmberg@hkr.se)*
[2]*Vikingagatan 100B, SE-217 75 Malmö, Sweden*
[3]*Largo dos Camarnais, nº 3, 2540-479, Pó, Portugal*

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ABSTRACT

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Land-based counts at Cabo Carvoeiro (Peniche, Portugal), made between 15 August and 15 November 2015 (effort 90 d, 517 h), tallied 302 469 birds, most of which (99.98%) were southbound. Although 65 species were observed, four species contributed to 91% of the total: 207 608 Northern Gannet *Morus bassanus*, 32 281 Cory's Shearwater *Calonectris borealis*, 16 086 Manx Shearwater *Puffinus puffinus*, and 15 222 Balearic Shearwater *Puffinus mauretanicus*. Passage as a whole increased throughout the period, mainly due to a gradual intensification of Northern Gannet migration. More than 67 000 southbound procellariforms of 12 species were recorded, as were 6183 Stercorariidae of four species. Daily passage rates of species recorded on more than 68 d were positively correlated in 22 of 36 cases. For Northern Gannet and Mediterranean Gull *Ichthyaetus melanocephalus*, the proportion of adult birds increased steadily, outnumbering younger birds. Extrapolation based on counted versus uncounted daylight hours suggests that at least 415 000 Northern Gannets, 65 000 Cory's Shearwaters, and 30 000 Balearic Shearwaters passed south at Cabo Carvoeiro in autumn 2015. Clearly, a very large share of the global population of the endangered Balearic Shearwater can be monitored at Cabo Carvoeiro. Based on generally unidirectional passage patterns, high species diversity, as well as high season totals and daily passage rates of several species, Cabo Carvoeiro is one of the most promising mainland sites in the eastern North Atlantic to monitor a wide range of seabirds.

Key words: migration, monitoring, passage rate, *Puffinus mauretanicus*, season total, seawatch, species richness

INTRODUCTION

Petrels, shearwaters, and other procellariforms are inherently vulnerable to environmental change due to a combination of factors, such as their protracted life histories, their localized breeding sites, and their position as apex predators in marine food webs. On a planet with an ever-growing anthropogenic footprint, issues such as climate change, pollution, and offshore fisheries are all sources of concern for these birds (Luczak *et al*. 2011, Oliveira *et al*. 2015). At present, an alarmingly large share of the world's procellariform species is in decline (Croxall *et al*. 2012).

Procellariforms, however, are not the only birds that spend most of their annual cycle at sea. Divers, gannets, cormorants, terns, gulls, skuas, and some shorebirds also share this lifestyle. Because of these shared traits, species in this extended group of seabirds are challenging to study and monitor. Despite recent advances in geolocator and satellite technologies, and in the face of less than successful spatial modeling attempts, land-based counts from seawatches remain an important method for obtaining quantitative data about migration and population trajectories of these birds (Oppel *et al*. 2011, Cook *et al*. 2012, Jones *et al*. 2014).

Systematic counts from seawatches have a long history in the Northeast Atlantic, notably in Ireland, Great Britain, and France (e.g., Cook *et al*. 2012, Caloin *et al*. 2015, further examples at www.trektellen.nl). In contrast, regular counts farther south in this flyway are much rarer; two exceptions include Estaca de Bares in Galicia, Spain, and the Rede de observação de Aves e Mamiferos marinhos (RAM) initiative in Portugal (Sandoval Rey *et al*. 2009, 2010, Sengo *et al*. 2012, Oliveira *et al*. 2014). However, the count methodologies of the two latter initiatives have usually left large time gaps between counts in any given year. The sparse seawatch coverage in western Iberia is unfortunate for several reasons, one being that its coastal waters host most of the world's population of the globally endangered Balearic Shearwater *Puffinus mauretanicus* for a large part of the year (Arcos 2011). In addition, during autumn migration, more species and greater numbers of birds typically use areas further downstream in any northern hemisphere flyway compared to areas further north, increasing the value of downstream monitoring schemes.

Previous intermittent counts (e.g., Moore 2000, Sengo *et al*. 2012, Oliveira *et al*. 2014), as well as brief but more intensive studies (Elmberg *et al*. 2013, 2016), suggest that Cabo Carvoeiro at Peniche, Portugal, is potentially one of the best mainland sites in the eastern North Atlantic to study migrating seabirds. Here, we present the first full autumn season count effort from this site. Using standardized methodology, we set out to describe: (1) the relative proportion of southbound versus northbound birds, (2) species composition, (3) species richness, (4) within-season patterns in passage rate, (5) correlations in daily passage rates among species, and (6) the proportion of age classes and color morphs in selected species. Building on these aims, auxiliary objectives were to estimate the total passage of some species and to assess Cabo Carvoeiro's overall value for monitoring seabirds in the eastern North Atlantic. The last two objectives are of special interest because Cabo Carvoeiro could be a key site for monitoring population numbers of the globally endangered Balearic Shearwater (Guilford *et al*. 2012, Elmberg *et al*. 2016).

STUDY AREA AND METHODS

Study site, season, and daily routine

This study was designed to cover the autumn migration of seabirds by daily counts 15 August 2015–15 November 2015, carried out from the seashore between Remédios (39°21′59″N, 009°24′11″W) and Cabo Carvoeiro (39°21′35″N, 009°24′31″W), in the western extremity of the city of Peniche, Portugal. The Peniche headland juts out several kilometers into the Atlantic Ocean, and it is the westernmost point on the European mainland next to Cabo da Roca west of Lisboa. A map of the location and bathymetry of the adjacent sea can be found in Elmberg *et al*. (2013). The seawatch site comprises steep cliffs bordered inland by a level plateau covered by sparse, low, open, brushy vegetation. All vantage points from the cliffs are 20–25 m above sea level, offering unobstructed views of the sea, as well as providing shelter from wind from different directions depending on the exact watch position. When looking west over the Atlantic, migrating birds are backlit in the morning and sidelit in the evening. Most birds pass within 3 km of land. Large birds (e.g., Northern Gannet *Morus bassanus* and Great Skuas *Stercorarius skua*) are readily identified at a distance of up to 10 km, such as when they pass just east of the Berlengas Islands situated to the west-northwest of Cabo Carvoeiro. Heat shimmer over the ocean is rarely a problem at this site, as hot winds from the east are infrequent.

Each day, there was a morning count and an afternoon count. Morning counts started at sunrise and lasted three hours, whilst afternoon counts started three hours before sunset and ended at sunset. On 15 August, sunrise was at 06h50 and sunset at 20h32 (Greenwich Daylight Savings Time). On 15 November, sunrise was at 07h21 and sunset at 17h22 (Greenwich Normal Time). Roughly every seventh day, there was a full-day count covering the light part of the day regardless of seabird passage strength. These dates were pre-chosen to occur on a regular basis, but some had to be postponed or were inhibited due to inclement weather or a shortage of observers. On these days, the morning and afternoon counts were carried out as on other days, and in the intervening time, counts were made for at least 30 min every full hour.

Weather during the count period was characterized by a positive North Atlantic Oscillation (NAO) from mid-September and onwards, pushing most cyclonic activity on a northerly track over the eastern North Atlantic. Air temperatures in central Portugal were above normal in August, October, and November but were somewhat below normal in September. The start and the end of the count period were drier than normal, whereas September and October saw above normal precipitation.

In August, skies were generally lightly cloudy or clear, with some periods of increased cloudiness and fog until late morning. Winds were weak-to-moderate, predominantly from the west quadrant, but some afternoons saw stronger but still moderate winds from the northwest. September was mainly characterized by lightly cloudy skies and often wind from the east quadrant. However, on 09–17 September, several fronts passed from the west, causing increased cloudiness, humidity, and precipitation. On these days, the wind came from the south quadrant and was strong, with gusts near 90 km/h. In October, cyclonic conditions prevailed to the west of the continent, with the passing of lines of instability through the area on 04–06, 09–15, and 26–31 October. Anticyclonic conditions with influence from the mainland occurred only during the first three days of the month. Winds came from the west quadrant in the first week and from 26 October onwards. On 17 October, a depression of about 988 hPa caused great variation in atmospheric pressure and increasing winds and precipitation. High rainfall values were recorded on 17–18 October, and winds averaged 90 km/h with gusts greater than 130 km/h. The rest of the month was dominated by moderate winds, mainly from the east quadrant. In November, the weather was characterized by anticyclonic systems associated with high pressure centers over the Iberian Peninsula, France, or north/northeast of the Azores. However, due to the passage of frontal undulations on 03–06 November, moderate precipitation occurred, and winds were weak-to-moderate from the south quadrant, but temporarily moderate-to-strong, with gusts up to 80 km/h on 03–04 November. The last part of the count period was under anticyclonic influence, with clear skies and weak-to-moderate winds from the east, sometimes turning northwest in the afternoon.

Indices based on a wide array of seabird species breeding in the eastern North Atlantic region show that 2015, in general terms, was neither a poor nor an exceptionally good year with respect to breeding success when compared to the 1992–2015 time period (OSPAR Commission 2015–2020; https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/biodiversity-status/marine-birds/marine-bird-breeding-success-failure/).

Species included in study

All migrating birds of all orders were included in the original counts (including passerines and migrants over land). The only exception was the Yellow-legged Gull *Larus michahellis* because it was difficult to separate true migration from local movements in this locally abundant and resident species. We defined "migrating birds" as all birds with a determined, consistent flight direction, and which did not follow boats, swim, congregate in rafts, or otherwise land on water or on land. Data are presented and analyzed for species in the following orders: Anseriformes, Gaviiformes, Podicipediformes, Procellariformes, Phaethontiformes, Suliformes, and Charadriiformes.

Count procedures

From the vantage point of the day, which was selected to obtain shelter from any wind and rain, we scanned the sea and the sky continuously using 8–12× binoculars and 20–75× spotting scopes. We noted species, migration direction, flock size, color morph (jaegers), as well as age and sex when possible. We defined a "flock" as birds of the same species following the same flight path in a formation in which no individual was more than 50 m from its nearest conspecific. Northern Gannets often pass in very long, loose bands; accordingly, it was frequently not possible to delineate flocks of this species.

All observers used the same manual to count and record birds, as well as to collect on-site basic weather data (Appendix 1, available on the website). The full data set from the autumn 2015 counts is open access (Appendices 2 & 3, downloadable from the website).

RESULTS

Observation effort and data filtering

In total, 25 observers took part in the counts (1–6 observers/d, mean 3.2; see Acknowledgements). The majority of the observers were experienced birders with a special interest in seabird identification. There were only eight days with a single observer, all before 07 September (i.e., before the main migration passage took place).

On three days (03, 04, and 06 September), counts were made impossible by heavy precipitation or fog that drastically reduced visibility. Also, on a few days, observation effort was less than the stipulated minimum of 6 h/d, either because of reduced visibility or a lack of availability of observers. The total observation effort summed over the 90 d was 517 h, and the total morning count effort was comparable to the total afternoon count effort (Table 1). On a weekly basis, count effort was not constant due to the three days in September with bad weather (Kruskal-Wallis test statistic = 33.56, $df = 12$, $P < 0.001$), but count effort did not have any seasonal trend or bias (mean daily count effort by month: August 5 h 32 min, September 4 h 56 min, October 5 h 54 min, November 6 h 7 min).

For the analyses in the present paper, we excluded observations of birds identified to the genus level only (i.e., 4 *Puffinus* sp., 3 *Oceanodroma/Oceanites* sp., 45 *Calidris* sp., 23 *Stercorarius* sp., and 86 *Sterna* sp.), which together made up a mere 0.05% of the total sample. The only cases of birds not identified to the species level, possibly causing a bias, were Common Terns *Sterna hirundo* versus Arctic Terns *S. paradisaea*. Consequently, 522 individuals of Common/Arctic terns were omitted from the present study and thus not included in the totals presented in Table 2. Based on extensive white coloring on the underside of the primaries, 153 birds were recorded as Scopoli's Shearwater *Calonectris diomedea* (Table 2), a taxon whose field identification criteria are still debated. We conservatively regard these birds as "Scopoli type shearwater" *Calonectris cf. diomedea*, and although they are listed in Table 2 for completeness, we excluded them from further analyses in this paper. Similarly, 13 birds matching the identification field marks of Yelkouan Shearwater *Puffinus yelkouan* were observed in August–September. These are listed in Table 2 but were not included in any further analyses. We refer to them as "Yelkouan type shearwater" pending further analysis of the occurrence of this taxon in Portugal.

Subsequent to these taxonomic and identification restrictions, the remaining data set comprised more than 300000 birds of 65 species, of which *ca*. 70000 were procellariforms, 208000 were Northern Gannets, and more than 6200 were skuas/jaegers (Table 2).

Relative proportion of southbound versus northbound birds

In most species, 95% or more of the observed individuals were in southerly migration (Table 2). A few species exhibiting a lower proportion of southbound birds were either local residents or had already reached their wintering grounds (e.g., Northern Pintail *Anas acuta*, Great Northern Diver *Gavia immer*, European Shag *Phalacrocorax aristotelis*, and Great Cormorant *Phalacrocorax corbo*). Hereafter, we use data for southbound individuals only, encompassing 297851 birds. This accounts for 99.98% of the total bird count in Table 2.

TABLE 1
Weekly observation effort (in days and minutes) at the Cabo Carvoeiro seawatch (Peniche, Portugal) in autumn 2015

Period (week)	Days with count	Full-day counts[a]	Effort (min) sunrise ≥ 10.00	Effort (min) 10.00 ≥ 14.30	Effort (min) 14.30 ≥ sunset	Total effort (min)
15–21 Aug	7	1	1111	120	1242	2473
22–28 Aug	7	0	1201	0	992	2193
29 Aug–04 Sep	5	0	642	135	574	1351
05–11 Sep	6	1	705	180	927	1812
12–18 Sep	7	2	1185	500	1570	3255
19–25 Sep	7	1	1120	225	1160	2505
26 Sep–02 Oct	7	0	540	0	950	1490
03–09 Oct	7	0	1020	180	1190	2390
10–16 Oct	7	0	1005	315	1271	2591
17–23 Oct	7	1	937	405	1215	2557
24–30 Oct	7	1	1187	150	1052	2389
31 Oct–06 Nov	7	2	1200	420	1140	2760
07–13 Nov	7	1	1080	90	1260	2430
14–15 Nov[b]	2	1	340	120	360	820
TOTAL	90	11	13273	2840	14903	31016

[a] 'Full-day counts' consisted of counts carried out each day for three hours starting at sunrise and three hours before sunset, but also at least 30 min of counting every hour in the intervening period. See methods for further details about count procedures for 'full-day counts'.

[b] Note the truncated last period, which was only two days.

TABLE 2
Migration totals at Cabo Carvoeiro (Peniche, Portugal) by month and migratory direction in autumn 2015

Order/ scientific name	15–31 August		September		October		01–15 November		Season total		
	S-bound	N-bound	S-bound	N-bound	S-bound	N-bound	S-bound	N-bound	S-bound	N-bound	S-bound %
Anseriformes											
Anas acuta	0	0	0	0	63	26	54	0	117	26	82
Anas crecca	0	0	0	0	0	0	7	0	7	0	100
Anas platyrhynchos	2	0	0	0	13	0	4	0	17	0	100
Mareca penelope	0	0	0	0	10	0	25	0	35	0	100
Mareca strepera	0	0	0	0	3	0	2	0	5	0	100
Spatula clypeata	0	0	4	0	17	0	63	0	84	0	100
Melanitta nigra	437	62	1129	76	3182	165	1598	68	6346	371	94
Gaviiformes											
Gavia immer	0	0	0	0	0	0	1	1	1	1	50
Gavia stellata	0	0	0	0	0	0	1	0	1	0	100
Podicipediformes											
Podiceps cristatus	0	0	0	0	0	0	2	0	2	0	100
Procellariformes											
Fulmarus glacialis	0	0	3	0	0	0	0	0	3	0	100
Calonectris borealis	1661	596	6133	415	13 524	215	10 963	2	32 281	1228	96
Calonectris cf. diomedea	12	13	28	2	113	0	0	0	153	15	91
Ardenna gravis	0	3	81	3	46	0	23	0	150	6	96
Ardenna griseus	26	1	2049	0	699	3	100	0	2874	4	100
Puffinus mauretanicus	1024	640	4637	594	6561	336	3000	13	15 222	1583	91
Puffinus puffinus	312	3	15 648	0	97	0	29	0	16 086	3	100
Puffinus cf. yelkouan	4	1	8	0	0	0	0	0	12	1	92
Pterodroma feae/deserta	0	0	2	0	0	0	0	0	2	0	100
Hydrobates pelagicus	4	1	16	0	2	0	1	0	23	1	96
Oceanites oceanicus	1	0	1	0	0	0	0	0	2	0	100
Oceanodroma castro	0	0	0	0	3	0	0	0	3	0	100
Phaethontiformes											
Phaethon aethereus	0	0	1	0	0	0	0	0	1	0	100
Suliformes											
Morus bassanus	3830	342	20 490	475	103 576	127	79 712	149	207 608	1093	99
Phalacrocorax aristotelis	41	18	2	2	0	0	0	0	43	20	68
Phalacrocorax carbo	22	14	14	20	0	0	0	0	36	34	51
Charadriiformes											
Actitis hypoleucos	1	0	0	0	0	0	0	0	1	0	100
Arenaria interpres	1	0	5	3	3	0	0	0	9	3	75
Calidris alba	16	2	23	3	0	0	0	0	39	5	89
Calidris alpina	67	0	14	16	1	0	0	0	82	16	84
Calidris canutus	65	0	2	0	0	0	0	0	67	0	100
Calidris maritima	0	0	0	0	0	0	2	0	2	0	100
Charadrius hiaticula	12	0	0	0	2	0	2	0	16	0	100

Table 2 continued from previous page

	15–31 August		**September**		**October**		**01–15 November**		**Season total**		
Order/ scientific name	**S-bound**	**N-bound**	**S-bound**	**N-bound**	**S-bound**	**N-bound**	**S-bound**	**N-bound**	**S-bound**	**N-bound**	**S-bound %**
Charadriiformes continued											
Haematopus ostralegus	6	0	2	0	11	1	0	0	19	1	95
Limosa lapponica	5	0	0	0	1	0	0	0	6	0	100
Limosa limosa	0	0	7	0	0	0	0	0	7	0	100
Numenius arquata	0	0	0	0	1	0	0	0	1	0	100
Numenius phaeopus	54	2	59	0	14	0	2	0	129	2	98
Phalaropus fulicarius	0	0	145	10	143	0	2	1	290	11	96
Philomachus pugnax	0	0	4	0	0	0	0	0	4	0	100
Pluvialis squatarola	59	2	1	0	130	0	7	0	197	2	99
Tringa ochropus	0	0	0	0	1	0	0	0	1	0	100
Tringa totanus	1	0	0	0	10	0	0	0	11	0	100
Chroiocephalus ridibundus	0	0	0	0	0	0	4	1	4	1	80
Larus canus	0	0	0	0	1	0	1	0	2	0	100
Larus fuscus	149	15	85	1	532	6	44	5	810	27	97
Larus fuscus graellsii	0	0	0	0	17	0	0	0	17	0	100
Larus f. intermedius	0	0	0	0	2	0	0	0	2	0	100
Larus marinus	0	0	0	0	1	0	0	0	1	0	100
Ichthyaetus melanocephalus	3	3	21	0	413	11	428	5	865	19	98
Rissa tridactyla	1	0	2	0	9	0	2	0	14	0	100
Xema sabini	1	0	2	0	0	0	0	0	3	0	100
Chlidonias niger	53	0	127	0	3	0	0	0	183	0	100
Sterna dougalli	0	0	6	0	0	0	0	0	6	0	100
Sterna hirundo	510	0	165	0	25	0	0	0	700	0	100
Sterna paradisaea	141	0	799	0	60	1	3	0	1003	1	100
Thalasseus sandvicensis	831	13	4045	11	760	36	25	16	5661	76	99
Sternula albifrons	3	1	13	0	0	0	0	0	16	1	94
Stercorarius longicaudus	7	0	27	0	2	0	0	0	36	0	100
Stercorarius parasiticus	232	0	811	1	79	0	24	0	1146	1	100
Stercorarius pomarinus	245	0	459	0	349	2	71	0	1124	2	100
Stercorarius skua	124	6	1181	4	1627	32	945	17	3877	59	99
Alca torda	0	0	0	0	83	1	301	4	384	5	99
Cepphus grylle	0	0	0	0	0	0	1	0	1	0	100
Fratercula arctica	0	0	0	0	0	0	1	0	1	0	100
TOTAL[a]	9951	1738	58 258	1636	132 177	962	97 451	282	297 851	4618	
Percent of grand total									99.98	0.02	

[a] Total and percent of grand total values are totals for all species listed in Table 2.

General patterns in species composition, abundance, and species richness

The southbound seabird migration as a whole (all species pooled) became more intensive as the autumn season progressed; on average, 586 birds/d passed in August, 2157 in September, 4264 in October, and 6497 in November. The total number of species recorded did not differ much among months, despite the fact that there were fewer count days in the first and last months: 36 species in August, 40 in September, 42 in October, and 35 in November.

Over the autumn season as a whole, the southbound migration at Cabo Carvoeiro was dominated by four species that together made up 91% of the total: Northern Gannet 69.7%, Cory's Shearwater

TABLE 3
Highest daily totals (individuals) and highest daily passage rates (mean number of individuals per hour of counting) for southbound migrants of selected species at Cabo Carvoeiro (Peniche, Portugal) 15 August–15 November 2015

Order/scientific name	Number of days observed[a]	Highest total[b]	Second highest total	Third highest total	Highest passage rate (ind./hr)	Second highest passage rate (ind./hr)	Third highest passage rate (ind./hr)
Anseriformes							
Melanitta nigra	62	991 (01 Nov)	932 (21 Oct)	708 (13 Oct)	155.3 (21 Oct)	118.0 (13 Oct)	109.3 (01 Oct)
Procellariformes							
Calonectris borealis	90	5988 (06 Nov)	3327 (27 Oct)	3081 (07 Nov)	1041.4 (06 Nov)	627.7 (27 Oct)	410.8 (07 Nov)
Ardenna gravis	17	42 (16 Sep)	28 (26 Oct)	19 (13 Nov)	5.5 (26 Oct)	3.3 (16 Sep)	3.2 (13 Nov)
Ardenna griseus	71	1515 (16 Sep)	327 (17 Sep)	165 (06 Oct)	118.8 (16 Sep)	54.5 (17 Sep)	27.5 (06 Oct)
Puffinus mauretanicus	89	1450 (16 Sep)	817 (01 Nov)	592 (13 Oct)	113.8 (16 Sep)	99.7 (27 Sep)	98.7 (13 Oct)
Puffinus puffinus	68	13 285 (16 Sep)	812 (17 Sep)	387 (14 Sep)	1042.0 (16 Sep)	135.3 (17 Sep)	64.5 (14 Sep)
Suliformes							
Morus bassanus	90	22 114 (01 Nov)	12 868 (13 Nov)	11 873 (27 Oct)	2240.2 (27 Oct)	2144.7 (13 Nov)	2106.1 (01 Nov)
Charadriiformes							
Ichthyaetus melanocephalus	54	123 (01 Nov)	66 (20 Oct)	58 (03 Nov)	11.7 (01 Nov)	11.0 (20 Oct)	10.1 (03 Nov)
Sterna hirundo	47	152 (28 Aug)	57 (15 Aug)	47 (29 Aug)	24.6 (28 Aug)	15.6 (16 Aug)	10.1 (15 Aug)
Sterna paradisaea	43	534 (16 Sep)	184 (17 Sep)	30 (16 Aug)	41.9 (16 Sep)	30.7 (17 Sep)	11.2 (16 Aug)
Thalasseus sandvicensis	74	867 (12 Sep)	388 (20 Sep)	368 (26 Sep)	86.7 (12 Sep)	81.8 (26 Sep)	74.8 (28 Sep)
Stercorarius longicaudus	14	16 (16 Sep)	5 (28 Aug)	2 (07, 10, 12 Sep)	1.2 (16 Sep)	0.8 (28 Aug)	0.5 (07, 29 Sep)
Stercorarius parasiticus	70	414 (16 Sep)	79 (28 Aug)	61 (17 Sep)	32.5 (16 Sep)	12.8 (28 Aug)	12.3 (02 Sep)
Stercorarius pomarinus	76	248 (16 Sep)	110 (06 Oct)	78 (12 Oct)	19.4 (16 Sep)	18.3 (06 Oct)	13.0 (12 Oct)
Stercorarius skua	87	261 (16 Sep)	237 (27 Oct)	156 (06 Oct)	44.7 (27 Oct)	26.0 (06 Oct)	23.1 (03 Nov)
Alca torda	29	70 (13 Nov)	39 (11 Nov)	37 (15 Nov)	11.7 (13 Nov)	6.5 (11 Nov)	6.2 (15 Nov)

[a] The maximum possible number of days with observations of any species is 90 d (see Methods).
[b] Due to variation in observation effort among days, dates with the highest totals are not necessarily the same as those with the highest passage rates.

Calonectris borealis 10.8%, Manx Shearwater *Puffinus puffinus* 5.4%, and Balearic Shearwater 5.1% (see Table 2 for monthly and season totals). However, the relative dominance of these species varied among months; for example, in September, Manx Shearwater made up 26.9% of the total southbound count, whereas in November, Northern Gannet made up 81.8% of the count. The overall pattern of a few species being abundant and many species being much scarcer is further illustrated by the fact that less than 100 individuals were seen in 43 of the 65 species that were observed. Two taxa that are extremely rare in European waters were recorded: Red-billed Tropicbird *Phaethon aetherus* (22 September) and Fea's/Desertas Petrel *Pterodroma feae/deserta* (02 September). The former is currently being considered by the Portuguese rarities' committee, whilst the latter has been accepted by it, but is not yet published (H. Cardoso, pers. comm.).

A total of 12 procellariform species were recorded; species richness peaked in September (11 species; Table 2). Most of the procellariforms were shearwaters (*Calonectris, Ardenna, Puffinus*). Seven shearwater species were recorded, not counting the observations of likely Scopoli's and Yelkouan shearwaters. The most numerous was Cory's Shearwater, of which the total count was roughly twice that of each of Manx and Balearic shearwaters (Table 2). Procellariforms made up 22.4% (66 801 birds) of the southbound total, Stercorariidae species 2.1% (6189 birds), ducks 2.2% (6599 birds, most of which were Common Scoters *Melanitta nigra*), and terns 2.5% (7569 birds). The passage of dabbling ducks was concentrated in October and November, which was also true for overall numbers and species richness in this group (Table 2).

Many species were seen on a highly regular basis: Northern Gannet and Cory's Shearwater were observed on all 90 d that counts were carried out, Balearic Shearwater was seen on 89 d, and Great Skua was seen on 87 d. Sooty Shearwater, Parasitic Jaeger *Stercorarius parasiticus*, Pomarine Jaeger *Stercorarius pomarinus*, and Sandwich Tern *Thalasseus sandvicensis* were seen on 70 d or more (Table 3).

Within-season patterns in passage rate

Northern Gannet was the most numerous species in all months. Passage rate of this species increased steadily through autumn and did not show any sign of abating when counts were terminated in mid-November (Fig. 1). Although Cory's, Manx, and Balearic shearwater each had a distinct passage peak during a few days in mid-September (Figs. 2, 3, and 4), the overall passage pattern differed among these species. In Manx Shearwater, 94% of the season total passed during these few days, and much of the remainder was spread out over just a few weeks before and after (Fig. 4). Balearic and Cory's shearwaters, on the other hand, showed migration activity throughout the entire study period, with a second passage peak in mid-October (Balearic Shearwater) and 24 October–06 November (Cory's Shearwater), respectively. Sooty Shearwater was also observed throughout the study period but was most numerous and was observed most frequently in September, a month accounting for 71.3 % of its total. Almost all Great Shearwaters *Ardenna gravis* passed during two restricted periods more than a month apart: 08–18 September and 26 October–13 November. All of the few Yelkouan type shearwaters were seen in the first four weeks of the study.

All four Stercorariidae species showed a passage peak in mid-September (Figs. 5, 6, and 7; Table 2). Nevertheless, the migration

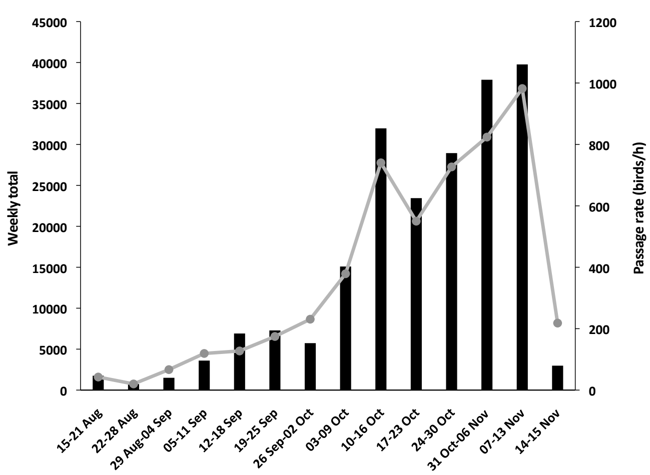

Fig. 1. Weekly totals (black bars, left axis) and passage rate (grey dots, right axis) of Northern Gannet *Morus bassanus* at Cabo Carvoeiro (Peniche, Portugal) in autumn 2015. Note that the last bar is a truncated week consisting of two days.

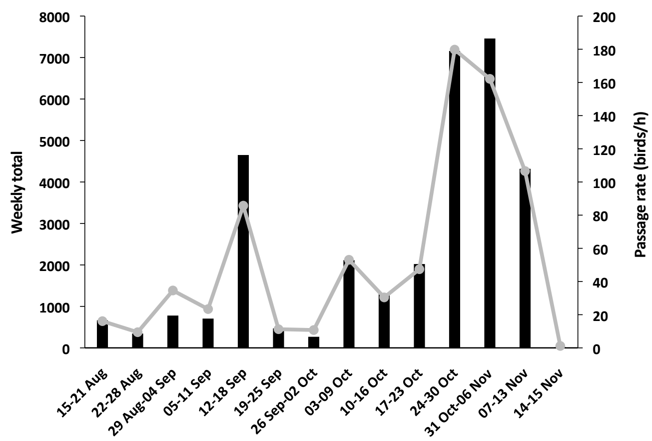

Fig. 2. Weekly totals (black bars, left axis) and passage rate (grey dots, right axis) of Cory's Shearwater *Calonectris borealis* in autumn 2015 at Cabo Carvoeiro (Peniche, Portugal).

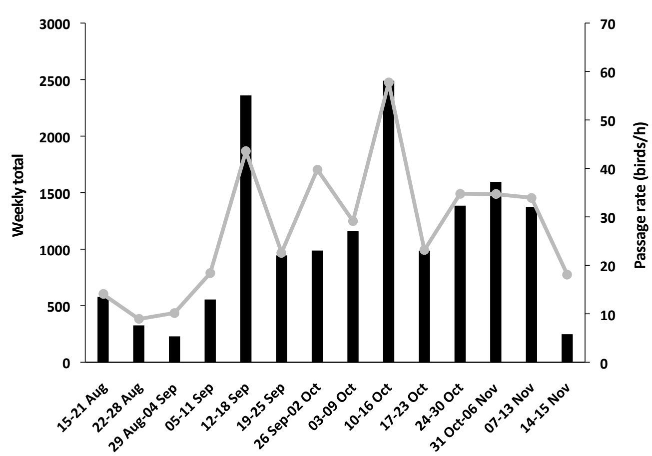

Fig. 3. Weekly totals (black bars, left axis) and passage rate (grey dots, right axis) of Balearic Shearwater *Puffinus mauretanicus* in autumn 2015 at Cabo Carvoeiro (Peniche, Portugal).

periods of Great Skua, and Pomarine and Parasitic jaegers, were protracted; passage rate was variable but significant throughout the study period in the former two species (Figs. 5, 6). Passage of Parasitic Jaeger, and especially of Long-tailed Jaeger *Stercrorarius longicaudus*, was more concentrated, occurring only in August and September (Table 2, Fig. 7).

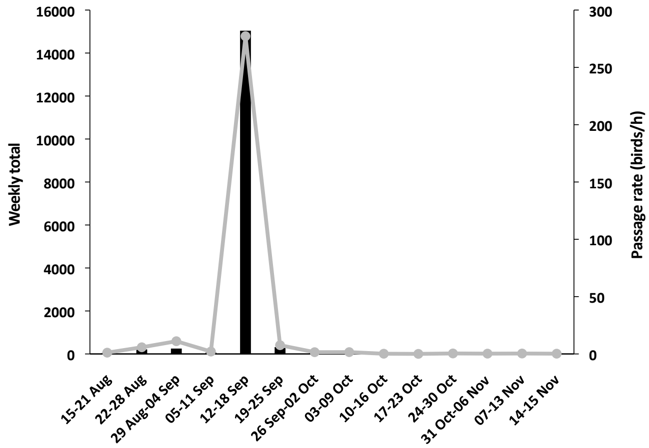

Fig. 4. Weekly totals (black bars, left axis) and passage rate (grey dots, right axis) of Manx Shearwater *Puffinus puffinus* in autumn 2015 at Cabo Carvoeiro (Peniche, Portugal).

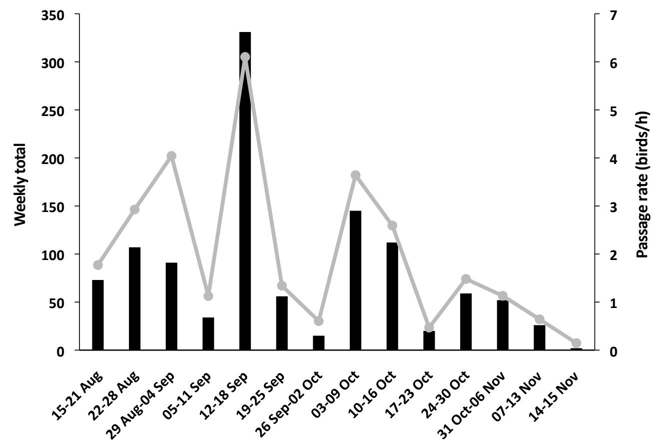

Fig. 6. Weekly totals (black bars, left axis) and passage rate (grey dots, right axis) of Pomarine Jaeger *Stercorarius pomarinus* in autumn 2015 at Cabo Carvoeiro (Peniche, Portugal).

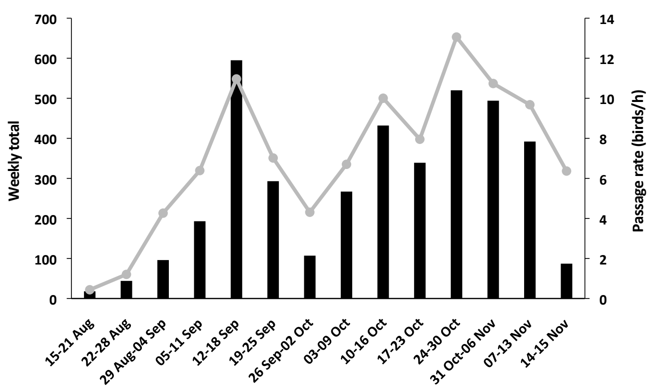

Fig. 5. Weekly totals (black bars, left axis) and passage rate (grey dots, right axis) of Great Skua *Stercorarius skua* in autumn 2015 at Cabo Carvoeiro (Peniche, Portugal).

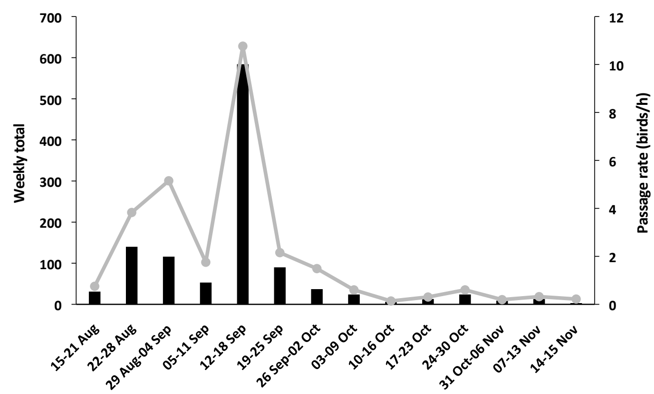

Fig. 7. Weekly totals (black bars, left axis) and passage rate (grey dots, right axis) of Parasitic Jaeger *Stercorarius parasiticus* in autumn 2015 at Cabo Carvoeiro (Peniche, Portugal).

TABLE 4
Pairwise Spearman rank correlation coefficients[a] of daily southbound count totals at Cabo Carvoeiro (Peniche, Portugal) in autumn 2015 of species observed on 68 d or more and in all four months[b]

	Calonectris borealis	*Ardenna griseus*	*Puffinus mauretanicus*	*Puffinus puffinus*	*Morus bassanus*	*Thalasseus sandvicensis*	*Stercorarius parasiticus*	*Stercorarius pomarinus*
Ardenna griseus	0.457****							
Puffinus mauretanicus	0.501****	0.490****						
Puffinus puffinus	0.112, NS	0.185*	-0.063, NS					
Morus bassanus	0.527****	0.514****	0.727****	-0.345****				
Thalasseus sandvicensis	-0.090, NS	-0.014, NS	-0.063, NS	0.529****	-0.391****			
Stercorarius parasiticus	0.166, NS	0.236*	-0.020, NS	0.712****	-0.251**	0.519****		
Stercorarius pomarinus	0.479****	0.348****	0.243*	0.510****	0.066, NS	0.284**	0.602****	
Stercorarius skua	0.596****	0.509****	0.664****	0.057, NS	0.743****	-0.173, NS	0.144, NS	0.369****

[a] Significance levels: * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$, **** = $P < 0.0005$; probabilities are two-tailed.
[b] Days with zero counts were included; sample size is 90 d in all species.

Daily totals and passage rates indicate that much of the seabird total passed through Cabo Carvoeiro during limited periods; on a day-by-day basis, nine of 16 species showed their highest daily total on the same date (16 September), a day when seven of the same 16 species also had their highest passage rate of the autumn (Table 3). Although October was the month with the highest total number of southbound migrants (Table 2), five species showed their highest daily totals in November (Common Scoter, Cory's Shearwater, Northern Gannet, Mediterranean Gull *Ichthyaetus melanocephalus*, and Razorbill *Alca torda*; Table 3). Three of these species (Cory's Shearwater, Mediterranean Gull, and Razorbill) also showed their highest daily passage rate of the autumn in November (Table 3).

Correlation of daily passage among species

As is obvious from Table 3, peak numbers of several species occurred on the same few days, mainly in September. However, a more consistent co-occurrence of high and low passage rates among species over longer time periods is more important in order to understand migration dynamics and its causality at a certain seawatch. To address this, we performed pairwise rank correlations of daily count totals of species that were observed on 68 d or more and in all four months. These restrictions reduce the probability of obtaining spurious negative correlations due to some species having many dates with a zero count.

Twenty-five of 36 correlations in the resulting matrix were significant (Table 4; 20 of these at $P < 0.0005$). The extremely low P values indicate that patterns are real and consistent; in other words, the risk of committing a type 1 statistical error is negligible even without correcting significance levels for using multiple tests. As anticipated, 22 of the significant correlations were positive, showing that days of strong versus weak passage were the same in many species. Three of the four most numerous species showed a very strong correlation in passage rate (all combinations of Northern Gannet, Balearic Shearwater, and Cory's Shearwater were significant at $P < 0.0005$). Passage of the fourth in the quartet of the most numerous species, Manx Shearwater, did not correlate with that of Balearic or Cory's shearwaters, but strongly and negatively correlated with the passage of Northern Gannet. Interestingly, Northern Gannet was also part of the only other two examples of a significantly negative correlation in passage rate, namely with Sandwich Tern and Parasitic Jaeger. The strongest correlation in the data set occurred between Great Skua and Northern Gannet (positive sign, Table 4, Fig. 8). It is also worth noting that the passage of Pomarine Jaeger correlated significantly and positively with all other nine species tested, except Northern Gannet (although the sign of the correlation coefficient was positive in this case, too).

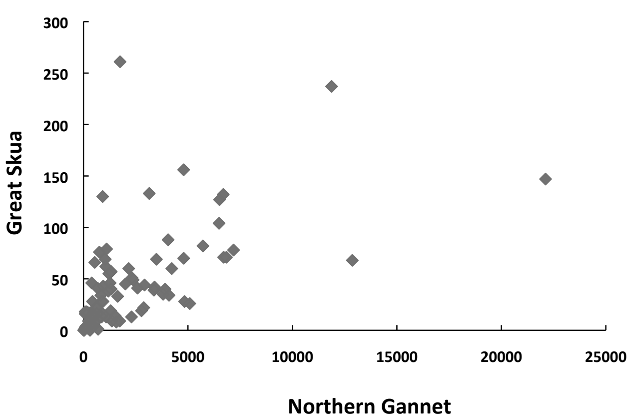

Fig. 8. Daily totals of southbound migrating Northern Gannets *Morus bassanus* and Great Skuas *Stercorarius skua* were strongly and positively correlated at Cabo Carvoeiro (Peniche, Portugal) in autumn 2015 (Spearman rank correlation: $r_s = 0.743$, $P < 0.0005$, $n = 90$ d).

Flock size, age classes, and color morphs

When overall migration intensity permitted (i.e., from August to September), flock size was noted in 3710 of the southbound Balearic Shearwaters at Cabo Carvoeiro, in other words individuals on their return, pre-breeding migration to nesting islands in the western Mediterranean. The increasing migration of Northern Gannet that occurred later in the study period did not allow for detailed flock counts of Balearic Shearwater. The flock size distribution in this sub-sample of Balearic Shearwaters was dominated by single birds, which made up 69.3% of the total. Mean flock size was 1.26 birds. Flocks of five or fewer birds contributed 92.9% of the total, demonstrating that very few Balearic Shearwaters migrate in larger flocks (Table 5).

Out of the 207 608 southbound Northern Gannets, 98.9% (205 239) were aged. Most were adults (75.4%), and the age classes showed distinctly different temporal patterns during the course of autumn. Immature birds (2nd and 3rd calendar year birds, 14.2% of the species' total) dominated early in the season and decreased in share steadily thereafter, whilst adults made up an increasing proportion of the passage as the season progressed (Fig. 9). The passage rate of juveniles (10.4% of the species total) showed a distinct peak in mid-autumn (Fig. 9).

Out of the 865 southbound Mediterranean Gulls, 787 were aged. Just as for Northern Gannet, the proportion of adult Mediterranean Gulls

TABLE 5
Flock size distribution of a sub-sample of southbound Balearic Shearwaters *Puffinus mauretanicus* at Cabo Carvoeiro (Peniche, Portugal) in autumn 2015

Flock size	Number of flocks
1	2570
2	223
3	75
4	28
5	19
6	5
7	1
8	3
9	3
10	4
12	2
13	1
14	1
20	1
63	1

increased steadily during the course of autumn (Table 6), and there were more adults tallied than the two younger age classes combined.

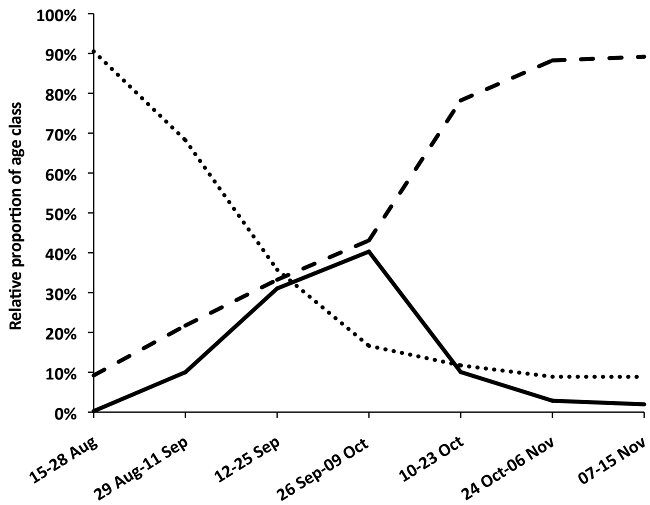

Fig. 9. Relative proportion of age classes in southbound Northern Gannet *Morus bassanus* in autumn 2015 at Cabo Carvoeiro (Peniche, Portugal). Age classes are "juvenile"' (1st calendar year; *n* = 21 382, dotted line), "immature birds" (2nd to 3rd calendar year; *n* = 29 137, solid line), and "adults" (4th calendar year or older; *n* = 154 720, dashed line).

TABLE 6
Monthly proportion of age classes in southbound Mediterranean Gulls *Ichthyaetus melanocephalus* at Cabo Carvoeiro (Peniche, Portugal) in autumn 2015

Time period Age class	Number of birds	Age class proportion per time period
15–31 August		
1st calendar year	2	66%
2nd calendar year	1	33%
3rd calendar year or older	0	0%
September		
1st calendar year	12	70%
2nd calendar year	2	12%
3rd calendar year or older	3	18%
October		
1st calendar year	165	48%
2nd calendar year	37	11%
3rd calendar year or older	144	41%
01–15 November		
1st calendar year	135	32%
2nd calendar year	26	6%
3rd calendar year or older	260	62%
Season total		
1st calendar year	314	40%
2nd calendar year	66	8%
3rd calendar year or older	407	52%

We set out to note color morph in the jaeger species, but this was not possible at times due to intensive migration or poor light. However, 90% of the Parasitic Jaegers and 86% of the Pomarine Jaegers were assigned to color morph and age (adult versus non-adult [immature birds and juveniles]). In both age classes, pale morph birds were notably more common than dark birds in Pomarine Jaeger, whereas the opposite was true in Parasitic Jaeger (Table 7). Intermediate morph birds were rare in both species and age classes (< 6%). The proportion of non-adults among the aged birds differed strongly between these two species and were much higher in Parasitic Jaeger compared to Pomarine Jaeger (Table 7).

DISCUSSION

Relative proportion of southbound versus northbound birds

As is evident from Table 2, a mere 0.02% of the recorded birds were northbound, corroborating the migration pattern found at this site in October 2014 (Elmberg *et al*. 2016), but opposing the less clear-cut pattern observed in some species in a much shorter study at the same site in 2012 (Elmberg *et al*. 2013). The near-complete unidirectional passage at Cabo Carvoeiro makes it an ideal site to survey southbound seabirds in autumn. In a practical sense, this near-complete unidirectional passage also makes counts easier to carry out, and it minimizes the risk of counting the same bird more than once, which is an important consideration when assessing migration totals of, for example, Balearic Shearwater. We further argue that Cabo Carvoeiro's location, which falls on a fairly straight north-south oriented coastline, minimizes the risk of including local movements in count data, as is witnessed by the high share of southbound Cory's Shearwaters (96%). This is despite the fact that the nearby Berlengas Islands host a colony of ~1000 breeding pairs of this species (Lecoq *et al*. 2011). Many other established European seawatches are located on coastlines less fortunate in this respect (e.g., Cook *et al*. 2012, p. 76; Table 3 in Mateos-Rodriguez *et al*. 2012). The latter is also true for other main Iberian seawatches (e.g., Gibraltar and Estaca de Bares, where significant movements in both directions are common;

TABLE 7
Proportion of color morphs by age class in southbound jaegers at Cabo Carvoeiro (Peniche, Portugal) in autumn 2015

Species	*Stercorarius parasiticus*	*Stercorarius pomarinus*
Age class and color morph[a]		
Adult, dark	66%	20%
Adult, intermediate	6%	1%
Adults, pale	28%	79%
Sample size	*n* = 377	*n* = 598
Non-adult, dark	73%	31%
Non-adult, intermediate	4%	3%
Non-adult, pale	23%	66%
Sample size	*n* = 660	*n* = 377
Proportion of aged birds that were adults	36%	61%

[a] Color morph distribution differed significantly between species (χ^2 test, $P < 0.00001$, $df = 2$).

Huyskens & Maes 1971, Paterson 1997, Mouriño *et al.* 2003, Mateos-Rodriguez *et al.* 2012).

Patterns in species composition, abundance, and species richness

We note that the daily observance of species richness of procellariforms was high for most of the autumn at Cabo Carvoeiro in 2015. Although species richness of procellariforms and Stercorariidae species did not show any consistent trend during the course of the season, the overall daily passage rate of seabirds increased steadily. This was mainly due to Northern Gannet becoming more abundant as autumn progressed. The four most numerous species (Northern Gannet, Cory's Shearwater, Manx Shearwater, and Balearic Shearwater) together made up 91% of the southbound season total. The relative dominance of the first three species in this quartet compares well with data from Estaca de Bares in 2008, where the trio collectively made up 75% of the annual total (Sandoval Rey *et al.* 2009). Taking into account that the observation effort at Cabo Carvoeiro in 2015 (90 d, 517 h) was higher than for published data from this Galician seawatch (46–113 d, 158–410 observation h/yr from 2004–2008; Sandoval Rey *et al.* 2010), species totals at Cabo Carvoeiro in autumn 2015 were higher than the five-year annual means at Estaca de Bares for at least 11 out of 14 species. The autumn southbound total of Balearic Shearwater in 2015 (15 222 birds) is noteworthy considering that some population estimates for this taxon are < 3500 breeding pairs in total (Arcos 2011, Birdlife International 2018).

Compared to other seawatches in the eastern North Atlantic, several of the species totals in autumn 2015 at Cabo Carvoeiro stand out as high, especially considering that they are based on southbound birds only. The value of the north-south coastline orientation at Cabo Carvoeiro has already been mentioned, and we also believe that the location farther south in the flyway is a reason why migration totals are high in autumn compared to more upstream sites.

The numbers of some species were unexpectedly low. Only three Sabine's Gulls *Xema sabinii* were seen. Considering that this species is regular in the Bay of Biscay and Galicia from August to October (Sandoval Rey *et al.* 2010, de Juana & Garcia 2015, p. 366), we think it either takes a more westerly route after exiting the Bay of Biscay, or that there were too few days with strong westerly winds in 2015 to make the migration of this species visible from Cabo Carvoeiro. Similarly, only 14 Black-legged Kittiwakes *Rissa tridactyla* were tallied. Because this is an abundant species in the North Atlantic, we believe the low total numbers at Cabo Carvoeiro resulted from a lack of periods of strong westerly winds (*cf.* de Juana & Garcia 2015, p. 364). Another possibility is that the bulk of the passage occurred after we ended our counts (i.e., after 15 November, such as in 2003 when 2500 birds were recorded flying south at Cabo Carvoeiro; de Juana & Garcia 2015, p. 364). Finally, the total lack of observations of Little Gull *Hydrocoloeus minutus* is worth noting. This is also a numerous species in October–November in the eastern North Atlantic, including at seawatches (Sandoval Rey *et al.* 2010, Caloin 2015), but its occurrence in Iberian waters is incompletely understood, with most high totals recorded in the second half of November (de Juana & Garcia 2015, p. 367). We speculate that the passage of Little Gull in 2015 either occurred after our counts were terminated, or that movements were more offshore and westerly.

Passage rate patterns across the autumn season

The temporal passage patterns for the more common species at Cabo Carvoeiro in autumn 2015 (Table 3) correspond well to those documented for the same species at upstream sites, albeit with a slightly later passage in some species at Cabo Carvoeiro (Cook *et al.* 2012, Caloin 2015). Accordingly, some species exhibited a protracted autumn passage (e.g., Common Scoter, Northern Gannet, Balearic Shearwater, Great Skua, and Pomarine Jaeger), whilst others had a pronounced passage peak with the bulk of individuals passing during a few weeks (Manx Shearwater, Sandwich Tern, and Long-tailed Jaeger). The migration time windows identified at Cabo Carvoeiro embrace those documented for the same species at upstream seawatches (Mouriño *et al.* 2003, Sandoval Rey *et al.* 2009, Cook *et al.* 2012, Caloin 2015) and thus imply that data from Cabo Carvoeiro are generally representative of the East Atlantic flyway.

Although single higher daily totals than those recorded in autumn 2015 are known from Cabo Carvoeiro (e.g., Table 3 versus 12 000 Cory's Shearwaters, 3450 Balearic Shearwaters, and 1350 Parasitic Jaegers in Moore (2000)), it is notable that daily coverage during one autumn, which was characterized by few days with strong westerly winds, nevertheless produced notably high daily totals for several species. This is true despite the fact that we were not able to count all daylight hours on some of the best migration days, such as on 27 October and 06 November.

Maximum hourly passage rates can serve as an indicator of the potential of a seawatch to reflect concentrated migration events, and for this purpose this measure is widely used in the literature. For several species, the highest hourly passage rates recorded at Cabo Carvoeiro in autumn 2015 (Table 3) are remarkably high compared with data previously published from Portugal: Common Scoter, Cory's Shearwater, Northern Gannet, Mediterranean Gull, Sandwich Tern, and Great Skua (*cf.* Walker 1996, Sengo *et al.* 2012, Oliveira *et al.* 2014). Although our data are derived from a single autumn, many of the passage rate peaks at Cabo Carvoeiro in 2015 are generally higher compared to data sets from more upstream seawatches that have been in operation for several years (e.g., Mouriño *et al.* 2003, Cook *et al.* 2012, Caloin *et al.* 2015). However, not surprisingly, the long-standing seawatch effort at Estaca de Bares in Galicia has seen single days with even higher passage rates for all species recorded at Cabo Carvoeiro in autumn 2015 (Huyskens & Maes 1971, Mouriño *et al.* 2003, Sandoval Rey *et al.* 2009, 2010).

Correlation among species in daily passage

The present study strongly supports the notion that passage strength is positively correlated among many seabird species (Table 4). In other words, good migration days are the same in many species, and so are days of weak migration. This finding corroborates and strengthens the conclusions of two earlier studies at Cabo Carvoeiro that covered much shorter time windows and smaller samples (Elmberg *et al.* 2013, 2016). The fact that so many species had their strongest passage on the same days, as well as the large proportion of highly significant positive correlations (Table 4), are reasons to argue that most species react similarly to different weather situations, especially to winds from the west and northwest in connection with passing cold fronts.

Given these insights, and the large sample size, it may seem puzzling that Table 4 also includes examples where correlations are lacking, and also a few negative correlations. However, the temporally very concentrated passage of Manx Shearwater may explain its lack of correlation with the passage of Cory's and Balearic Shearwaters. That is, many good migration days for the latter two species were outside the main passage time window of Manx Shearwater (days with counts of zero). All three instances of a negative pairwise correlation involved Northern Gannet (Table 4). The likely reason for this is that its passage increased throughout the count period, long after most Manx Shearwater, Sandwich Terns, and Arctic Jaegers had passed. In other words, these negative correlations likely resulted from partly non-overlapping migration periods rather than from differing responses to weather conditions.

Flock size, age classes, and color morphs

Elmberg *et al*. (2016) noted that flock size in migrating Balearic Shearwaters at Cabo Carvoeiro in October stood in stark contrast to this species' habit of forming large flocks earlier in the season in the Bay of Biscay and off Portugal (Yésou 2003, Mouriño *et al*. 2003, Poot 2005). Data from Cabo Carvoeiro in 2015 (mainly in August and September) yielded a small mean flock size (1.26 individuals), which is close to the flock size of 1.53 recorded there in October 2014 (Elmberg *et al*. 2016). These observations indicate that this species breaks up from big rafts into small parties when the return migration starts. Also, in 2015, there was not any indication that Balearic Shearwaters were performing their pre-breeding migration in pairs. If this were the case, we might have expected that even-numbered flocks would have been over-represented (Table 5; see also Elmberg *et al*. 2016).

The fact that adult birds outnumbered younger age classes among Northern Gannets and Mediterranean Gulls (Table 6, Fig. 9) is not surprising considering that both are relatively long-lived species. Clearly, age classes in these species have different timetables for their autumn migration (see Veron & Lawlor 2009 for Northern Gannet), and their respective temporal passage pattern corresponds well to those documented at Cape Griz-Nez in France (Caloin 2015). In the case of Northern Gannet, our data also corroborate temporal migration patterns found by Walker (1996) at Cape St Vincent farther south in Portugal.

We propose that seabird monitoring at Cabo Carvoeiro can be used to gauge between-year variation in breeding success in the upstream breeding areas of Northern Gannet and Mediterranean Gull. This may also be true for tundra-nesting species such as Parasitic and Pomarine jaegers; it is noteworthy that the ratio of adults versus younger birds was quite different between the latter two species in autumn 2015. This could indicate that these species were recruited from different source areas that were associated with different breeding success in this year. The difference in proportions of color morphs in adult Parasitic versus Pomarine jaegers in 2015 (dark dominate in the former, pale in the latter) corresponds well to compilations of morph ratios in seabird identification guides (e.g., Harrison 1985, Blomdahl *et al*. 2003), possibly with the exception that dark morph adult Pomarine Jaegers were unusually common at Cabo Carvoeiro in 2015 (i.e., 20%, compared to 5–10% in Harrison 1985 and Blomdahl *et al*. 2003).

Extrapolation to season totals

Based on the continuous period of daily standardized counts at Cabo Carvoeiro in autumn 2015, we argue that it is feasible to make crude extrapolations to estimate the true number of birds that passed, especially for the more common species that have a protracted migration period. We acknowledge that diel pattern analyses were outside the scope of the present study. Nevertheless, counts were carried out over 517 h, which is 49% of the possible 1062 h of daylight during the study period. It is likely that assuming that passage was as strong during mid-day (less coverage in 2015) as in morning and evening (almost total coverage) is incorrect, leading to an overestimation of the actual total. It is also likely incorrect to assume that that no significant migration took place between sunset and sunrise, which would lead to an underestimation of totals (*cf*. Elmberg *et al*. 2013). If we combine these biases and simply assume that we have counted 50% of the true totals, *ca*. 65 000 Cory's and 30 000 Balearic shearwaters would have passed Cabo Carvoeiro between 15 August and 15 November 2015. For Northern Gannet, the corresponding estimate is 415 000 birds, although the true total for the entire autumn season was likely much higher in this species, as its migration was still increasing when counts were terminated in mid-November.

Sandoval Rey *et al*. (2010) provided annual and five-year mean estimates for the number of seabirds passing Estaca de Bares in Galicia. According to these authors, the five-year annual mean at Estaca de Bares was much higher than the 2015 estimate for Cabo Carvoeiro for Cory's Shearwater and Northern Gannet, but somewhat lower for Balearic Shearwater. However, the estimates from Estaca de Bares were based on extrapolation of passage rates (rather than season totals) and on much fewer observation hours per year, which might lead to overestimations if days with strong passage are overrepresented and days with weaker passage are underrepresented in the sample.

Mateos-Rodriguez *et al*. (2012) presented count totals as well as estimates for three years from the Strait of Gibraltar. Their estimated annual net flow for Northern Gannet is only *ca*. 5% of ours for Cabo Carvoeiro in 2015, whilst that for Cory's Shearwater is two to three times higher than ours. Interestingly, their estimates for Balearic Shearwater, of which most of the world's population is supposed to pass Gibraltar annually, span 6000 to 23 000 individuals per year; for some years, this was less than the actual 2015 count at Cabo Carvoeiro, and much less than our southbound extrapolated season estimate. Instead, the latter falls well in line with recent studies suggesting that the total population of this endangered taxon is larger than previously thought (e.g., Mateos-Rodriguez *et al*. 2012, Arroyo *et al*. 2016). Regardless, a very large share of the world's entire population of this globally endangered species can be counted at Cabo Carvoeiro (*cf*. Arcos 2011), not least because it is known to occur primarily in near-shore areas during its presence off western Iberia, including the pre-breeding migration in autumn (Jones *et al*. 2014, Meirinho *et al*. 2014).

CONCLUSIONS

The autumn counts at Cabo Carvoeiro in 2015 produced consistently high passage rates for several seabird species as well as high species diversity. The tally of 300 000 southbound seabirds in 517 h of counting corresponds to an average of 10 birds/min. The ratio of southbound versus northbound individuals was remarkably high in most species, demonstrating that Cabo Carvoeiro is very well suited for monitoring migrating seabirds because local movements and double counts are unlikely to create bias. Moreover, most of the migrating birds pass at close range, leaving rather few unidentified to the level of species.

Although the 2015 autumn count effort did not include any days of extremely strong seabird passage, as have been recorded at Cabo Carvoeiro before (e.g., Moore 2000), autumn totals as well as daily highs were remarkably high for several species. In this context, it should be noted that counts were carried out on all days, whilst count activity at many other Atlantic seawatches has historically been concentrated to days with favorable winds to obtain high totals. This makes comparison between sites difficult. However, based on the autumn 2015 counts and previously published data (Sengo *et al*. 2012, Elmberg *et al*. 2013, 2016, Oliveira *et al*. 2014), we argue that Cabo Carvoeiro is likely one of the very best sites in the eastern North Atlantic to monitor the migration of many seabird species. This is true not only for Balearic Shearwater, but also for other species that primarily occur in nearshore areas off western Iberia in autumn, such as Sandwich Tern and Great Skua (Meirinho *et al*. 2014). The analyses carried out in this paper are just the beginning of what could be accomplished if a more permanent count scheme were established on the Peniche headland, and if similar long-term counts were combined with weather data. Indeed, the world and its seas are changing faster than we can carry out research focusing on every species in isolation, making monitoring crucial at key sites that provide data for many species. Not only can such efforts at Cabo Carvoeiro aid in conservation of the Balearic Shearwater, they will also serve to describe changes in abundance and annual reproduction in several species from a large upstream area.

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