SEABIRD ABUNDANCE AND DISTRIBUTION OFF WESTERN IBERIAN WATERS ESTIMATED THROUGH AERIAL SURVEYS

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ABSTRACT

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Western Iberian waters are important migratory flyways, stopover sites, and wintering areas for several of the world's seabird species. To describe seabird species composition, distribution, and abundance in these waters, we performed six aerial surveys in September and/or October of each year, 2010–2015, covering 74 840 km^2. Using line-transect methodology, 27 396 seabird sightings from 17 taxonomic groups were recorded along 10 496.3 nautical miles (19 433 km). Using the program "Distance," annual and overall abundance estimates were obtained for nine taxonomic groups: Balearic Shearwater *Puffinus mauretanicus*, Great Shearwater *Ardenna gravis*, Cory's Shearwater *Calonectris borealis*, shearwaters, Northern Gannet *Morus bassanus*, Sabine's Gull *Xema sabini*, Great Skua *Stercorarius skua*, storm petrels, and Red Phalarope *Phalaropus fulicarius*. For the six-year period, Northern Gannet was the most abundant species (89 630 individuals, coefficient of variation [CV] = 6.28%), followed by Cory's Shearwater (25 044 individuals, CV = 7.56%) and Balearic Shearwater (13 632 individuals, CV = 20.81%). The remaining taxonomic groups exhibited variable abundances. Results confirm that the study area is important to several seabird species, providing baseline estimates to inform conservation policies and instruments, such as the Birds Directive and the Marine Strategy Framework Directive.

Key words: aerial surveys, distance sampling, Galicia, marine birds, MSFD, Portugal, Spain

INTRODUCTION

Seabirds are widespread, occurring from coastal to pelagic areas (Oro & Martínez-Abraín 2004). However, they are among the most threatened bird groups due to depredation by invasive species on islands, incidental capture as fisheries bycatch, climate change (Dias *et al*. 2019), and food competition between seabirds and fisheries (Grémillet *et al*. 2018) in their reproduction and migration ranges. Their migratory behaviour varies across populations, and a recent study suggests individual-level variations in migratory behaviour across their migration range (Brown *et al*. 2021).

Western Iberian waters (hereafter WIW) are important migratory flyways, stopover sites, and wintering areas for almost one-fifth of the world's seabird species (de Jauna & Garcia 2015). This is mostly due to coastal upwelling and the high biological productivity in the area (Joint *et al*. 2002, Rossi *et al*. 2013, Ferreira Cordeiro *et al*. 2018). These waters are also important to pelagic and demersal fish, cetaceans, and turtles (Bañón *et al*. 2011, Nicolau *et al*. 2014, Vingada & Eira 2018). Some of these species are of conservation concern, such as the Critically Endangered Balearic Shearwater *Puffinus mauretanicus* (BirdLife International 2018a).

Portugal and Spain, as European Union member states, must provide information on seabird species distribution and abundance to meet international agreements, including the Marine Framework Strategy Directive (2008/56/EC) and the Birds Directive (2009/147/EC). Also, accurate and comparable population abundance estimates are needed to assess the impact of accidental or intentional removal of an individual from their respective population (Garthe & Hüppop 2004). Furthermore, understanding species distribution and abundance is essential when developing management actions and conservation programs. Finally, monitoring seabird abundance across migratory ranges is crucial for explaining potential variations in breeding populations (Lewison *et al*. 2012).

Some large-scale seabird surveys were conducted in WIW, mainly within the framework of the Special Protection Areas (SPAs) and Important Bird and Biodiversity Areas (IBA) designation programs (Ramírez *et al*. 2008, Arcos *et al*. 2009, Meirinho *et al*. 2014). These shipboard surveys were based on European Seabirds at Sea (ESAS) methodologies and provided valuable information about seabird distribution, habitat preferences, and phenology. However, ESAS assumes that all individuals are detected within a predetermined strip and disregards the effect of detection probabilities (Buckland *et al*. 2001, Camphuysen *et al*. 2004, Ronconi & Burger 2009, Winiarski *et al*. 2013). This can be addressed using methodologies such as "Distance Sampling," in which observers record the distance of each object from the track line rather than counting organisms within a predetermined transect width (strip). Although all objects on or near the track line are detected, this method allows for a proportion of objects to be missed by the observer within a given distance (Buckland *et al.* 2001, Camphuysen *et al*. 2004, Ranconi & Burger 2009). Finally, the use of Distance Sampling along predefined line transects provides abundance and density values, as well as their coefficients of variation and confidence intervals. This enables comparisons among surveys since detection functions may vary according to observers and periods (Bolduc & Fifield 2017).

Aerial surveys can cover large areas in a short period of time, allowing surveyors to take advantage of small weather windows and reducing the potential for under- or over-recording birds (Camphuysen *et al.* 2004). It is widely accepted that aerial surveys offer suitable data for long-term studies on population abundance trends (Dean *et al*. 2003, Bretagnolle *et al*. 2004, Camphuysen *et al*. 2004, Maclean *et al*. 2006, Certain & Bretagnolle 2008, Ridgway 2010, Buckland *et al*. 2012, Péron *et al*. 2013, Winiarski *et al*. 2013, Pettex *et al*. 2017, Merkel *et al*. 2019).

The main objective of this study was to report seabird species composition, as well as their late summer/early autumn distribution, abundance, and density in western Iberian waters between 2010 and 2015.

METHODS

Study area and data collection

The study area included a 50-nautical mile (nm; 93 km) buffer along the western Iberian coast from Vila Real de Sto. António to Caminha (Portugal) and between La Guardia and Cape Finisterre in Galicia (Spain) (latitude ranging from 36.5°N to 42.9°N) (Fig. 1).

Aerial surveys were conducted in the late summer/early autumn between 2010 and 2015. The methodology followed standard line-transect Distance Sampling (Buckland *et al*. 2001). To establish an optimal sampling design, we conducted a pilot study, the results from which showed that a parallel transect design was the most efficient (Santos *et al*. 2011). Flights were preformed along a systematic set of parallel 50 nm [92.6 km]-long transects (approximately) separated by a distance of 10 nm (18.5 km) and oriented perpendicular to the coast either in east–west (along the west coast) or north–south (along the south coast) directions (Fig. 1); the best direction was considered to be parallel to any hypothetical gradients (Buckland *et al*. 2001, Thomas *et al*. 2007).

All surveys were performed using a twin engine, high-wing aircraft equipped with two bubble windows to allow scanning directly underneath the plane. Transects were flown at a ground speed of 100 knots (kt; 185 km·h^{-1}) and an altitude of 500 feet (ft; 150.4 m). For each observation, we measured the perpendicular angle from the track line to the observed animals using a hand-held inclinometer. The survey team consisted of two trained observers, one data recorder, and the pilot (Trenkel *et al*. 1997, Noer *et al*. 2000, Perkins *et al*. 2005). The data recorder registered all location data with the help of a Global Positioning System with a 1-s data acquisition ratio. All transects' start and end positions, as well as seabird sighting positions, were recorded. Due to difficulties in the identification of some seabird species, unidentified individuals were pooled into groups according to morphological criteria (Pettex *et al*. 2017). Black-backed gulls (Great Black-backed Gull *Larus marinus* and Lesser Black-backed Gull *Larus fuscus*) and Yellow-legged Gulls (*Larus michahellis*) were not recorded. Data were collected under good survey conditions with Beaufort sea state ≤ 3 and good visibility (> 5 km).

Density and abundance

Abundance and density values were estimated using Conventional Distance Sampling (CDS) in the program "Distance 6.0" (Thomas *et al*. 2010), with a 5% standard truncation applied to sightings detected at the largest distances (Buckland *et al*. 2001). Coefficient of variation (CV) and 95% confidence interval (CI) were estimated by bootstrapping (999 replicates), using transects as sampling units (Buckland *et al*. 2001, Thomas *et al*. 2010). The group size bias effect on detection probability was tested by fitting a regression of group size (log-transformed) against the detection probability. We assumed that all individuals on the track line were detected [the detection probability is one at zero perpendicular distance, g(0) = 1] and that the probability of detection falls off smoothly from one as a function of distance from the track line. The abundance and density estimates were not corrected for possible perception bias (observers fail to detect available birds) and/or availability bias (birds are submerged and unavailable)

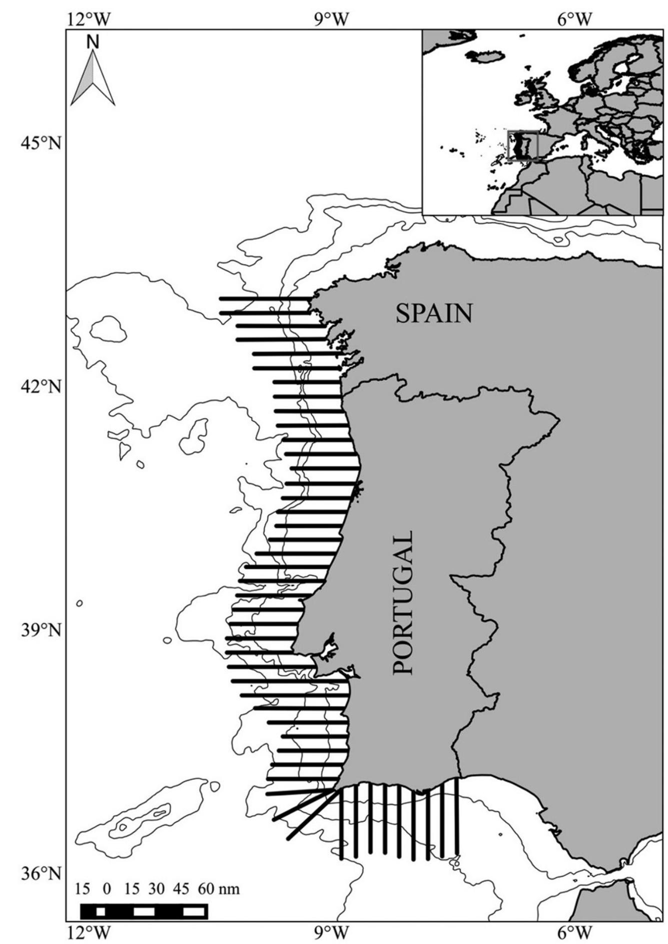

Fig. 1. Overview of the study area, which included a 50-nautical mile (93 km) buffer along the western Iberian coast from Vila Real de Sto. António to Caminha (Portugal) and between La Guardia and Cape Finisterre in Galicia (Spain), showing theoretical line transects (black continuous line). Bathymetric profile of the area shows the 200 m, 1 000 m and 3 000 m isobaths.

(Marsh & Sinclair 1989). It is likely that perception bias was significantly reduced by the use of experienced observers. Availability bias should be minimal for seabird species that spend most of their time on the surface (Ronconi & Burger 2009).

RESULTS

Airplane tracks covered a total of 10 496.3 nm (19 433 km) on 25 survey days. The Galicia area was surveyed only in 2011 and 2012 due to weather conditions and logistical constraints. As a result, an area of 62 716 km^2 was covered in 2010, 2013, 2014, and 2015, and an area of 74 870 km^2 was covered in 2011 and 2012 (Table 1). The survey effort amounted to 99 h and 31 min of flight.

In the study period, a total of 27 396 seabirds were recorded in 7 219 sightings. Although the identification was difficult or impossible for some species, 13 taxonomic groups were identified with accuracy to the species level (Table 2). The remaining sightings were pooled into the next possible groups, namely, shearwaters (unidentified *Puffinus* sp. and *Ardenna* sp.), cormorants (European Shag *Gulosus aristotelis* or Great Cormorant *Phalacrocorax carbo*), terns (unidentified individuals), and storm petrels (unidentified individuals) (Table 2).

It was possible to estimate abundance and density values, along with their confidence intervals and coefficients of variation, for seven species and two groups of species (Table 2, Fig. 2). Due to the low number of observations, no average flock size, abundance, or density estimates were possible for the remaining species/groups.

Balearic Shearwater

The Balearic Shearwater represented 11.8% of the total number of observed individuals (Table 2). The estimated abundance for the overall period was 13 632 individuals (CV = 20.81%) and density was 0.182 individuals km^{-2} (Table 2). Annual abundances varied between 7 690 individuals (CI = 4 910–14 674) in 2011 and 23 073 individuals (CI = 12 252–43 451) in 2012 (Fig. 2). The species' distribution includes the entire WIW coast where a strong concentration of individuals was registered in the central/north regions of Portugal, between Nazaré and Porto (Fig. 3A).

Great Shearwater

There were no Great Shearwater sightings in 2010 and 2011. The overall abundance estimate for the period 2012–2015 was 11 706 (CV = 40.85%), and the overall density was 0.156 individuals·km^{-2} (Table 2). The annual abundance varied between 1 412 individuals (CI = 247–8 067) in 2013 and 52 556 individuals (CI = 23 651–116 790) in 2012 (Fig. 2). Although some sightings were recorded in different parts of the study area, during the survey period there was a clear concentration of sightings in the southern region of Portugal (Fig. 3B).

Shearwaters

Puffinus and *Ardenna* shearwaters (other than those identified to species) represented 1.7% of the total number of observed individuals (Table 2). The overall abundance of these shearwaters was 6 758 individuals (CV = 21.39%), and the overall density was 0.090 individuals·km^{-2} in the study area (Table 2). The annual abundance estimates ranged from a minimum of 1 119 individuals (CI = 288–4350) in 2014 to 23 102 individuals (CI = 14 590–36 581) in 2011 (Fig. 2). The sightings of this group were spread along the entire study area (Fig. 3C).

Cory's Shearwater

After Northern Gannets, the Cory's Shearwater was the most often sighted seabird species, amounting to 22.4% of all observed individuals (Table 2). They exhibited a wide distribution along the entire WIW (Fig. 3D). The overall estimated abundance was 25 044 individuals (CV = 7.56%), and the overall density was 0.311 individuals·km^{-2} (Table 2). The annual abundance estimates varied from a minimum of 580 individuals (CI = 227–1 483) in 2010 to 57 216 individuals (CI = 44 357–73 803) in 2015 (Fig. 2).

Northern Gannet

The Northern Gannet sightings represent 50.3% of the total number of observed individuals (Table 2). For the six-year period, the abundance of the species was 89 930 (CV = 6.28%) individuals with a density of 1 201 individuals·km^{-2} (Table 2). The annual abundance values ranged from 58 010 individuals (CI = 44 894–74 958) in 2014 to 128 140 individuals (CI = 103 060–159 330) in 2015 (Fig. 2). Observation data shows that the Northern Gannet is widely distributed over the entire study area (Fig. 3E).

Sabine's Gull

The Sabine's Gull was not observed in either 2010 or 2012. For the remaining period, the overall estimated abundance was 2 390 individuals (CV = 23.24%) with a density of 0.032 individuals·km^{-2} (Table 2). The estimated annual abundance

Table 1
Aerial survey characterization

Campaign	Flight dates	Survey duration	Area (km^2)	Transect length (nm)	Number of transects	Average beaufort
2010	27, 28 September, 20, 21 October	12h38m	62 716	1 398.3	36	1.70
2011	21–24, 26–27 September	18h47m	74 870	1 972.2	46	2.03
2012	06–10 September	18h56m	74 870	2 000.4	47	1.32
2013	07–10 October	17h07m	62 716	1 793.9	42	2.07
2014	02–05 September	14h33m	62 716	1 546.2	41	2.09
2015	24–26, 28 September	17h03m	62 716	1 785.3	40	2.40

ranged from 265 individuals (CI = 89–794) in 2011 to 13 635 (CI = 8 364–22 228) in 2014 (Fig. 2). The species occurred along the entire coast, particularly along the continental slope (Fig. 3F).

Great Skua

The Great Skua was observed throughout the study area, mainly in waters shallower than 200 m, i.e., the shelf (Fig. 3G). For the six-year period, the abundance was 7 218 individuals (CV = 15.15%) with a density of 0.096 individuals·km^{-2} (Table 2). The annual abundance values varied from a minimum of 4 111 individuals (CI = 2 594–6 515) in 2014 to 10 538 in 2015 (CI = 6 819–16 284) (Fig. 2).

Storm Petrels

The observed storm petrels, all within the family Hydrobatidae, represent 5.7% of the total sighted seabirds (Table 2). The estimated

Table 2
Number of sightings and individuals per group observed in the aerial surveys for the period 2010–2015[a]

Species/Group	Sightings (*n*)	Individuals (*n*)	Relative importance (%)	Average flock size (CV%)	Abundance (95% CI)	Density (95% CI)	CV (%)
Balearic Shearwater *Puffinus mauretanicus*	299	3 236	11.8	2.86 (14.79)	13 632 (9 093–20 436)	0.182 (0.133–0.231)	20.81
Manx Shearwater[b] *Puffinus puffinus*	29	54	0.2	–	–	–	–
Great Shearwater *Ardenna gravis*	102	385	1.4	3.67 (28.88)	11 706 (5 399–25 379)	0.156 (0.072–0.339)	40.85
Shearwaters	129	462	1.7	3.71 (16.25)	6 758 (4 456–10 250)	0.090 (0.059–0.137)	21.39
Cory's Shearwater *Calonectris borealis*	1 568	6 149	22.4	1.22 (1.30)	25 044 (21 582–29 060)	0.335 (0.288–0.388)	7.56
Northern Gannet *Morus bassanus*	3 678	13 786	50.3	1.34 (0.90)	89 930 (79 518–101 700)	1.201 (1.062–1.358)	6.28
Phalacrocoracids[b] *Phalacrocoracidae*	8	48	0.2	–	–	–	–
Sabine's Gull *Xema sabini*	152	272	1.0	1.83 (14.43)	2 390 (727–3 356)	0.032 (0.020–0.050)	23.24
Black-legged Kittiwake[b] *Rissa tridactyla*	40	76	0.3	-	-	-	-
Mediterranean Gull[b] *Ichthyaetus melanocephalus*	6	27	0.1	-	-	-	-
Black-headed Gull[b] *Larus ridibundus*	40	72	0.3	-	-	-	-
Terns[b] *Sterninae*	342	456	1.7	-	-	-	-
Great Skua *Stercorarius skua*	310	384	1.4	1.25 (4.61)	7 218 (5 370–9 702)	0.096 (0.072–0.217)	15.15
Pomarine Jaeger[b] *Stercorarius pomarinus*	3	3	0.0	-	-	-	-
Arctic Jaeger[b] *Stercorarius parasiticus*	2	2	0.0	-	-	-	-
Storm Petrels *Hydrobatidae*	386	1 569	5.7	4.20 (16.09)	42 194 (28 852–61 703)	0.564 (0.385–0.824)	19.54
Red Phalarope *Phalaropus fulicarius*	125	415	1.5	2.86 (12.01)	5 067 (3 163–8117)	0.068 (0.042–0.108)	24.22
Total	**7 219**	**27 396**	100				

[a] Relative importance (%), proportion of the total number of observed individuals; average flock size, abundance (*n*) and density (*n*·km^{-2}) for each evaluated species or group. The coefficient of variation (CV) and the 95% abundance and density confidence intervals (CI) were calculated using bootstrapping (999 replicates) for each species or group for the overall study period (2010–2015).

[b] Average flock size, abundance, and density not estimated.

overall abundance was 42 194 birds (CV = 19.54%) with a density of 0.564 individuals·km^{-2} (Table 2). The annual abundance varied from 9 203 individuals (CI = 3 148–26 906) in 2011 to 99 831 individuals (CI = 63 812-156 180) in 2013 (Fig. 2). This group occurred throughout the study area, from coastal to deeper waters. However, there was a preference for areas closer to the continental slope (Fig. 3H).

Red Phalarope

The Red Phalarope was not observed in either 2010 or 2011. For the period 2012–2015, the estimated abundance was 5 067 individuals (CV = 24.22%) with a density of 0.068 individuals·km^{-2} (Table 2). Annual abundances varied from 559 individuals in 2013 (CI = 156–2 009) to 18 498 individuals (CI = 9 748–35 102) in 2014 (Fig. 2). The species occurred particularly along the continental slope although high concentrations were detected in waters of the Galician coast and the southeast coast of Portugal (Fig. 3I).

DISCUSSION

The present study produced the first absolute estimates of population abundance of several seabird species (Balearic Shearwater, Great Shearwater, Cory's Shearwater, Northern Gannet, Sabine's gull, Great Skua, and Red Phalarope) in western Iberian waters. These results are crucial for assessing possible changes in the conservation status of species listed under Annex I of the EU Birds Directive (79/409/EEC), such as the "Critically Endangered" Balearic Shearwater (BirdLife 2018a). Additionally, these estimates are needed to quantify potential biological removal limits with respect to fisheries bycatch (OSPAR Commission 2016), particularly when dealing with species with a sensitive conservation status.

Seabird distribution and abundance

It was possible to obtain information on 17 taxonomic seabird groups. Overall, the Northern Gannet was the most abundant

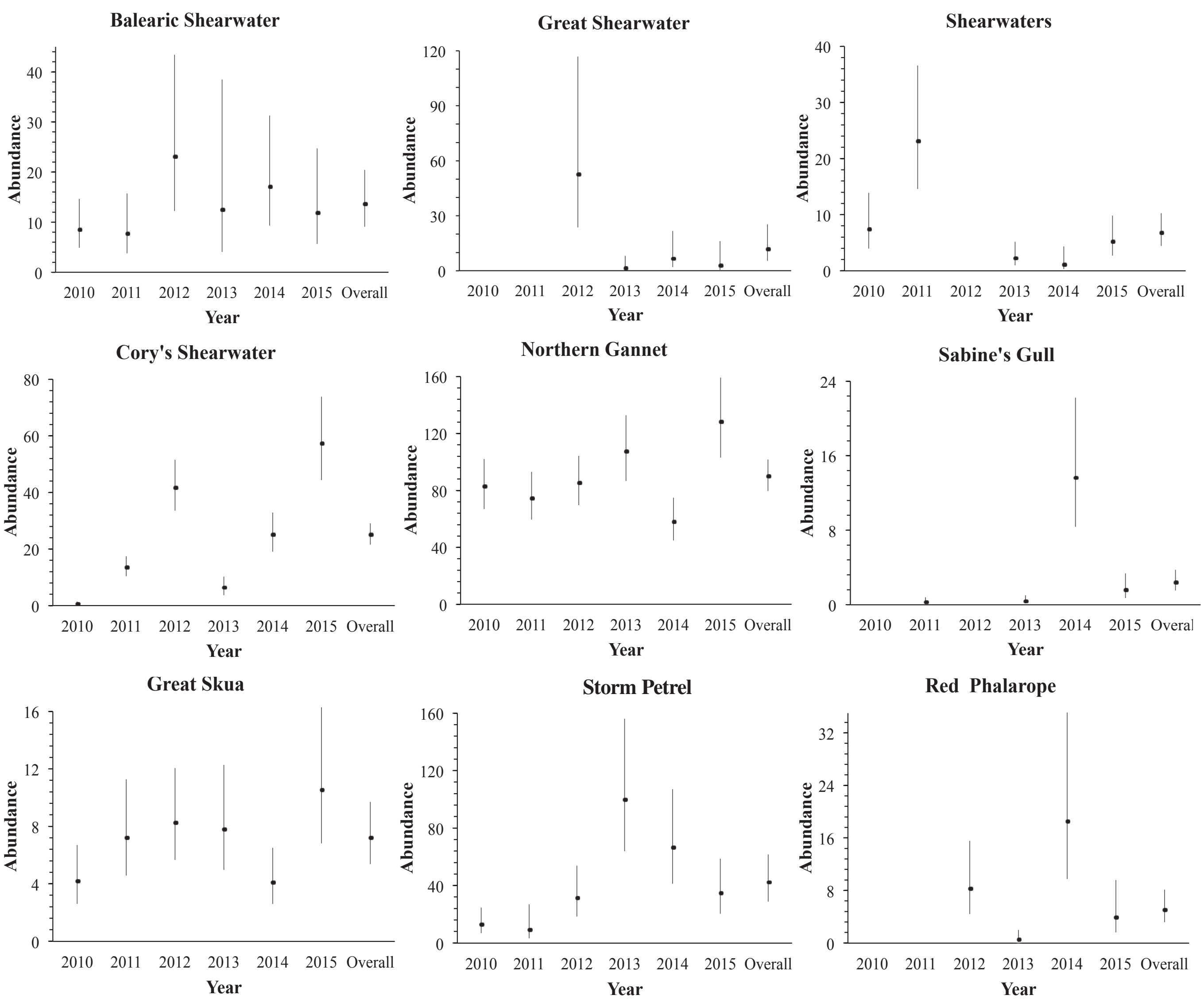

Fig. 2. Annual and overall survey abundance in thousands (bars represent low–high 95% confidence interval values) for the most abundant species and species group.

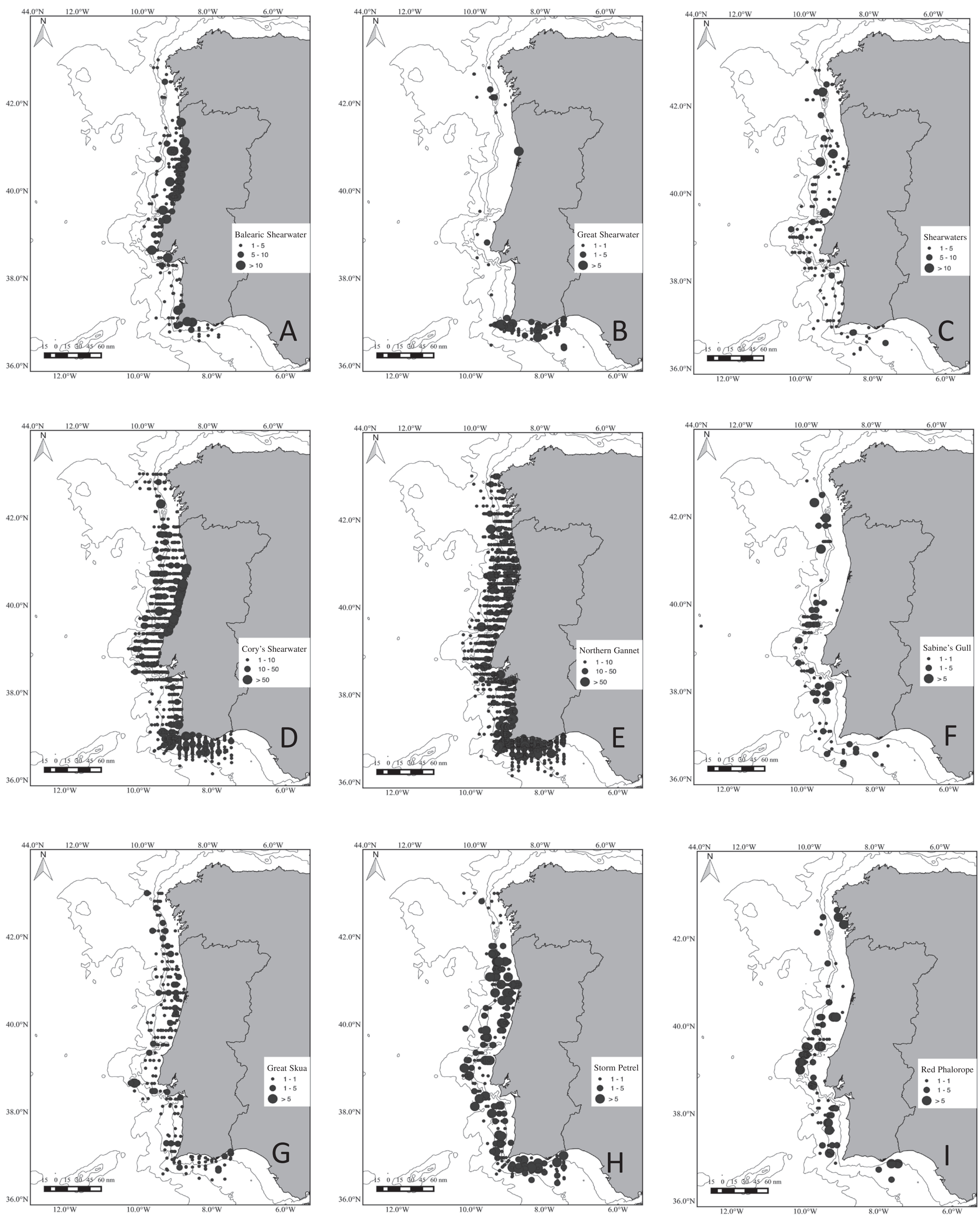

Fig. 3. Seabird sightings in the study area spanning 50 nautical miles (93 km) along with western Iberian coast from Portugal to Spain between 2010 and 2015. The circle size indicates the number of individuals per flock. Bathymetric profile of the area shows the 200 m, 1 000 m, and 3 000 m isobaths. (A) Balearic Shearwater *Puffinus mauretanicus*; (B) Great Shearwater *Ardenna gravis*; (C) shearwaters; (D) Cory's Shearwater *Calonectris borealis*; (E) Northern Gannet *Morus bassanus*; (F) Sabine's Gull *Xema sabini*; (G) Great Skua *Stercorarius skua*; (H) storm petrels; (I) Red Phalarope *Phalaropus fulicarius*.

species, followed by the Cory's Shearwater and the Balearic Shearwater. A similar study performed over the Bay of Biscay in 2011–2012 was able to obtain information on a comparable number of species or groups of species (19 taxonomic groups), including the Northern Gannet as the most abundant seabird species other than large-sized gulls (Pettex *et al*. 2017).

In the present study, variation in Northern Gannet abundance values (the lowest values were recorded in 2014) were in accord with the high bycatch rates reported earlier for this species in the study area (Oliveira *et al*. 2015). Annual abundances may also be related to mortality rates in waters off northwestern Africa where bycatch and intentional capture are more severe (Hagen & Wanless 2014, Grémillet *et al*. 2015). Weather conditions in breeding grounds and/or along migratory flyways may also affect inter-breeding movements (Kubetzki *et al*. 2009, Fifield *et al*. 2014) and may subsequently interfere with the period spent in WIW each year. In 2015, we recorded the highest annual Northern Gannet abundance in WIW, a figure that corresponded to 7.12% to 8.54% of the world's population (1 500 000–1 800 000 individuals, according to BirdLife International 2018b).

The Cory's Shearwater is one of the few seabird species breeding in WIW coastal areas. According to Oliveira *et al*. (2020), 800–975 breeding pairs nest in the Berlengas archipelago, Portugal. The species also nests at Coelleira, Sisargas, and Cies islands (off the Galician Coast, Spain), where the population is growing (Munilla *et al*. 2015). However, these colonies represent < 1% of the entire breeding population, estimated between 504 000 and 507 000 individuals (BirdLife International 2021a). In the present study, the overall Cory's Shearwater abundance (25 044 individuals) represented 5% of the global population. The highest annual estimate (57 217 individuals) was recorded in 2015 and corresponded to 11.3%–11.4% of the global population. These results show that individuals from the main breeding grounds in Macaronesia (Granadeiro *et al*. 2006, Derhé 2012) use WIW, apart from the Iberian breeding pairs. The important inter-annual abundance fluctuations detected may be associated with foraging movements towards more oceanic areas that were not included in our survey. Furthermore, since Cory's Shearwaters are more often sighted in WIW in June and July (Meirinho *et al*. 2014), our abundance estimates (surveys performed in September/October) probably represent underestimates.

Balearic Shearwaters use WIW as one of their main post-breeding grounds (Mouriño *et al*. 2003, Oppel *et al*. 2012, Meirinho *et al*. 2014). Our results revealed the crucial importance of the study area for the wintering population, in particular the central-north coastal region of Portugal (see also Araújo *et al*. 2017). The overall abundance estimated between 2010 and 2015 (13 632 individuals) represents 51.4%–56.8% of the global population (24 000–26 500 individuals according to Arroyo *et al*. 2014). The highest annual abundance in the WIW (obtained in 2012) was between 87.07% and 96.13% of the global population. The inter-annual abundance fluctuations were probably related to the individuals' progressive and periodic migratory fluxes either back to waters near breeding locations or farther north in the Atlantic. In fact, some individuals may stay in Portuguese continental waters during the post-breeding period (ICNF 2014), while others disperse northwards before returning to their breeding grounds (Guilford *et al*. 2012, Jones *et al*. 2014).

Great Shearwaters have an estimated global population of 15 000 000 individuals (Brooke 2004). They visit the WIW mainly in late summer/early autumn (Meirinho *et al*. 2014) before returning to their breeding area (mainly Tristan da Cunha) in the southern hemisphere (del Hoyo *et al*. 1992). During the six-year survey period, Great Shearwaters were not sighted in 2010 and 2011 and showed large abundance fluctuations in the remaining years. This fluctuation may be caused by the use of more offshore areas in some years, especially during the southbound migration period. In fact, that southbound movement can occur as far offshore as the Azores archipelago, where the species was commonly spotted (Moore 1994). In the present study, this species was more often detected in the southern part of the WIW, indicating that this area, in some years, is used as foraging or provisioning grounds before their southbound migration.

Sabine's Gulls use WIW in their southbound migratory movements during August–November and when returning to the Arctic during February–April (Catry *et al*. 2010). During the study period, the species was mainly sighted in more offshore waters. The highest abundance was recorded in 2014, amounting to 13 635 individuals, which represents 4% of the global population estimated at 340 000 individuals (Partners in Flight 2020).

For the six-year period, we estimated an overall abundance of 7 218 Great Skuas in WIW. The highest abundance was recorded in 2015, when 30.11%–35.12% of this species' global population (30 000–34 999 individuals, BirdLife International 2021b) was present in WIW. One of the species' migratory routes crosses WIW, thus explaining the high percentage of the global population detected in the present study. This is particularly true for individuals coming from Scotland, where the largest colonies of Great Skua are located (Magnusdottir *et al*. 2012). According to Meirinho *et al*. (2014), Great Skuas are more prevalent off Portugal between October and February. Therefore, our Great Skua abundance values are probably underestimates, since surveys were performed before their known highest occurrence periods in WIW. As a kleptoparasitic species, Great Skua annual abundances in WIW may be related to variations in the occurrence of the most commonly parasitized species, i.e., Lesser Black-backed and Yellow-legged gulls (Catry *et al*. 2010). Furthermore, these annual oscillations may also be related to a spatial discrepancy between the study area and the precise location of their migratory corridor (i.e., animals moving outside the study area, 50 nm [92.6 km] from shore).

As for the Red Phalarope, 18 498 individuals were estimated in 2014 (the highest annual abundance), indicating that 0.6%–1.4% of the global population was present in WIW during the 2014 survey period (1 300 000–2 999 999 individuals; BirdLife International 2021c). Red Phalaropes were mostly observed along the continental slope, in agreement with observations off Western Africa (del Hoyo *et al*. 1996).

Unidentified shearwaters were mostly sitting or flying at large distances from the airplane, and thus their size and shape could not be determined. Sooty Shearwater *Ardenna grisea* and Manx Shearwater *Puffinus puffinus* were reported to be common in the study area during their non-breeding periods, especially between August and October (Catry *et al*. 2010, Meirinho *et al*. 2014). Therefore, it is likely that unidentified shearwater sightings included both of these species, as well as unidentified Balearic and Great shearwaters.

Storm petrels were particularly abundant in 2013 (99 831 individuals). Due to their size and shape, hydrobatids are particularly difficult to identify from the air. However, considering their phenology and previous information about their distribution in WIW, most sightings probably referred to the Band-rumped Storm Petrel *Hydrobates castro*, European Storm Petrel *H. pelagicus*, and Wilson's Storm Petrel *Oceanites oceanicus* (Catry *et al*. 2010, Thomas & Medeiros 2010, Meirinho *et al*. 2014).

Monitoring strategy and limitations

Sampling seabirds during migration may be used efficiently to monitor their overall populations (Arroyo *et al*. 2014, Martín *et al*. 2019). Aerial surveys offer a cost-effective way to quantify abundance and to assess changes in the abundance and distribution of seabirds (Buckland *et al*. 2012). However, in the case of some taxa, species identification during aerial surveys may be difficult (Garthe 2019). In the present study, most difficulties were re-encountered with terns (Sterninae subfamily), shearwaters (*Puffinus* and *Ardenna*), and storm petrels. Also, due to variations in peak migratory periods over the study area across species, overall and annual abundances were not obtained for seabirds having a low number of sightings. In such cases, there was probably a mismatch between airplane survey dates and seabird phenology. For example, the Black-legged Kittiwake *Rissa tridactyla* and the Mediterranean Gull *Ichthyaetus melanocephalus* are known to be present in the study area mainly in late autumn and winter (Poot & Flamant 2006, Meirinho *et al*. 2014). Another possible limitation could be related to our assumption that all birds on the transect line were detected, $g(0) = 1$. Despite the use of trained observers, some seabird individuals might not have been recorded (uncorrected perception bias). This possibility would lead to an overestimation of the detection function and an underestimation of abundance values. However, in this study, the same airplane, observers, and protocol were used, making the perception bias low and constant throughout the whole survey (Panigada *et al*. 2011).

CONCLUSIONS

This study was conducted in the framework of a broad-scale marine megafauna survey, which was intended to provide comparable annual abundance estimates and a snap-shot picture for the overall study period. Our results will need updating, ideally conducting campaigns in the late winter/early spring in order to compare different abundances and use of space by seabirds in different seasons. In the future, our results may be used to inform environmental policies and provide a timely examination of the SPA's relevance within the study area. Our results confirmed the significant importance of WIW for several seabird species in their migratory corridors or as a wintering area. The WIW appeared to be particularly important for post-breeding Balearic Shearwaters, Cory's Shearwaters, Northern Gannets, and Great Skuas.

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