

Introduction

Massive mortality of seabirds are often associated to obvious anthropogenic causes, such as oil spills or bycatch in fisheries, as well as food shortages or extreme weather conditions (Camphuysen et al. 1999). These massive mortality events, depending on their spatial scale and frequency, can have a significant impact on the demography of seabird populations (Camphuysen et al. 1999). The documentation of these events is challenging, considering their unpredictability and magnitude, but is crucial for a better understanding of marine threats and their impact on seabird conservation. The Atlantic puffin *Fratercula arctica* is a long-lived seabird that lays a single-egg clutch and rarely breeds before the five years of age (Harris & Wanless 2011). This species is now classified as Vulnerable by the IUCN due to significant population declines and has been affected by significant mortality events in the northeast Atlantic (e.g., Harris & Wanless 2011, Morley et al. 2016, Anker-Nilssen et al. 2017). In the non-breeding period the Atlantic puffin has a pelagic and disperse distribution. The species winters off the Portuguese coast, being less common close to shore. In this work we report and characterize a massive wreck of Atlantic puffins in the Portuguese coast in the winter of 2022-23, documenting the extension and numbers involved, as well as the age and condition of beached birds, and also excluding possible causes.

Methods

In the 2nd week of January 2023 a large number of dead and live seabirds started to wash up along the mainland coast of Portugal, particularly Atlantic puffins in the Peniche area, being reported by citizens and local NGOs. The national institute for nature conservation (ICNF), SPEA, DGAV, CRAM and many local NGOs and volunteers joined efforts to implement a rescue campaign to take live birds to a wildlife recovery centre, while collecting information on this seabird wreck. From the 15th January and during the following two weeks, the beaches located between Santa Cruz and Foz do Arelho were surveyed daily and repeatedly, in order to rescue as many birds as possible. Additionally, from 1 to 3 February, a large extension of the central Portuguese coast was almost completely surveyed, namely the sand beaches from Esmoriz (40.9812, -8.6488) to Grândola (38.2514, -8.7739), an initiative coordinated by the ICNF. Whenever possible, photos of the beak and wing of individual birds were taken. All birds were collected and inspected for rings, dead birds were delivered to local authorities or DGAV for further analysis (including avian flu) while live birds were taken to CRAM. Complementary information was collected through a SPEA citizen science project – which collects information of stranded seabirds through a google form (date of the observation, species, number of birds, location, coordinates, photos and signs of fishery entanglement or oil). SPEA also encouraged citizens and local NGOs to report dead or live stranded seabirds found elsewhere along the Portuguese coastline and to take photographs of the puffin's beaks. Photographs of the beaks were used to age the birds (see Harris 2014), while the moult status of the flight feathers was assessed through wing photos. The estimation of the number and distribution of stranded birds was based on the information collected during the rescue campaigns, complemented with the information collected through SPEA's citizen science project, and information provided by other entities (Mar à Deriva, Brigada do Mar, Charcos & CIA, RIAS, CRASSA and RALVT) or through indirect sources (e.g., Biodiversity4all), whenever there was enough information to validate the observation and avoid duplications (date of observation, location, photos).

Results

From early December to early March, we recorded 2151 stranded seabirds of 20 different species, 80% of which were Atlantic puffins *Fratercula arctica* (n=1723) and 8% (n=165) were razorbills *Alca torda* (table 1). The peak of this seabird wreck was the 2nd fortnight of January 2023, when nearly 90% of all stranded birds were reported, and it was spatially concentrated in the area around Peniche, where 81% of birds were washed ashore (figure 1). The participation of citizens was also significant, by reporting 181 observations of 722 individuals along the Portuguese coast, mostly through the reporting tool made available by SPEA. Noteworthy was also the involvement of many local NGOs, who contributed with many of these observations. Most puffins were adult birds (78% of 311 birds, aged > 3 years), 14% were immature (2-3 years) and only 8% were first winter birds. Six ringed puffins were all adult birds from UK breeding colonies (5 from Orkney islands, 1 from Shiant islands), including two birds > 23 years old. The majority of the puffins (98% of 229 birds) were not moulting their flight feathers and, were in condition to fly. A total of 227 puffins were rescued alive and transported to a wildlife recovery centre (CRAM) but the survival rate was low (21% did not survive transportation and 71% died at CRAM). Necropsies of the birds were inconclusive regarding the cause of death but most birds were emaciated, showing gastrointestinal vacuity and atrophy of internal organs. Eight puffins were tested for H5N1, with negative results.

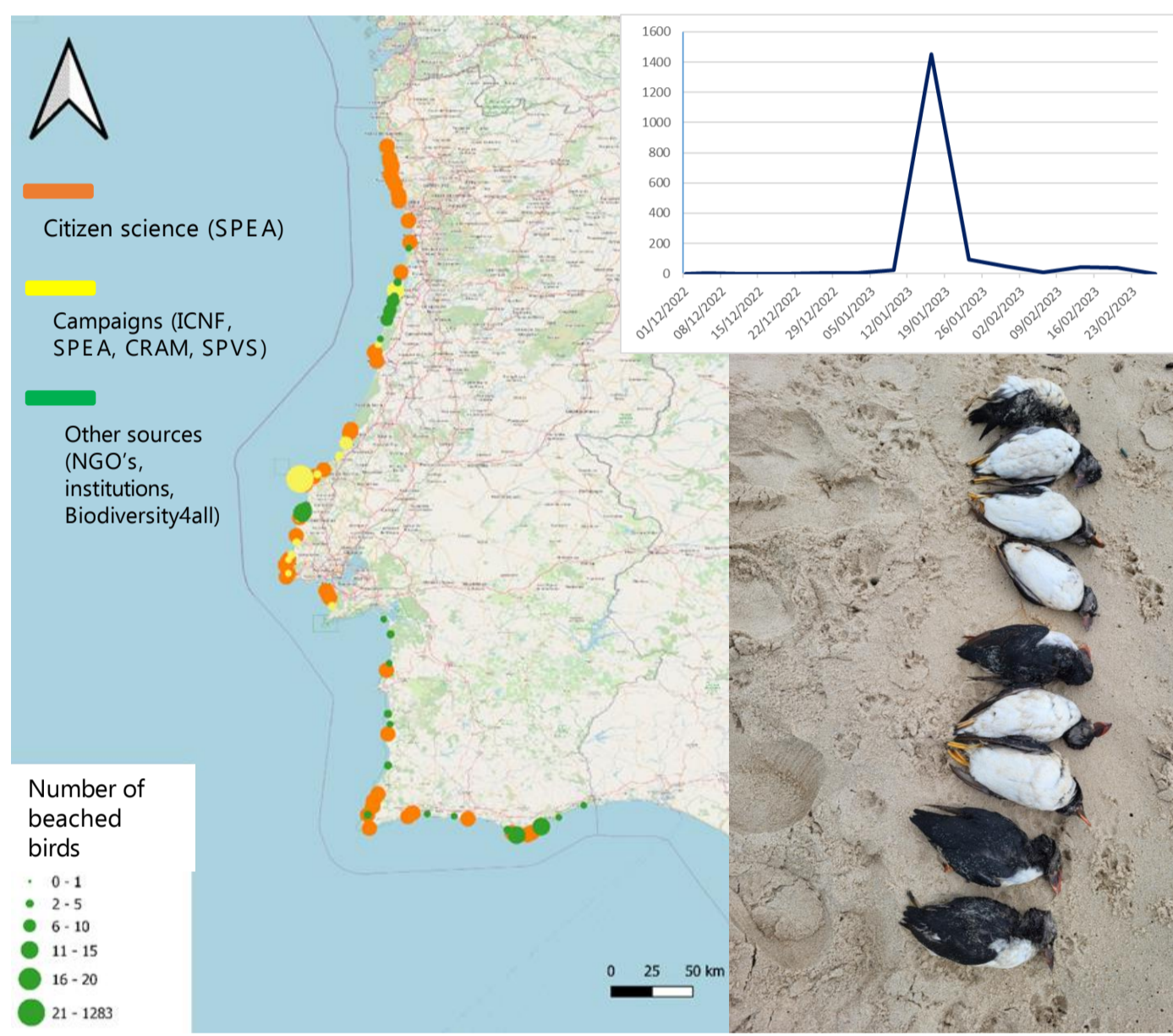


Figure 1 | Numbers, spatial and temporal distribution of beached birds along the Portuguese coast between early December 2022 and early March 2023, collected from different sources.

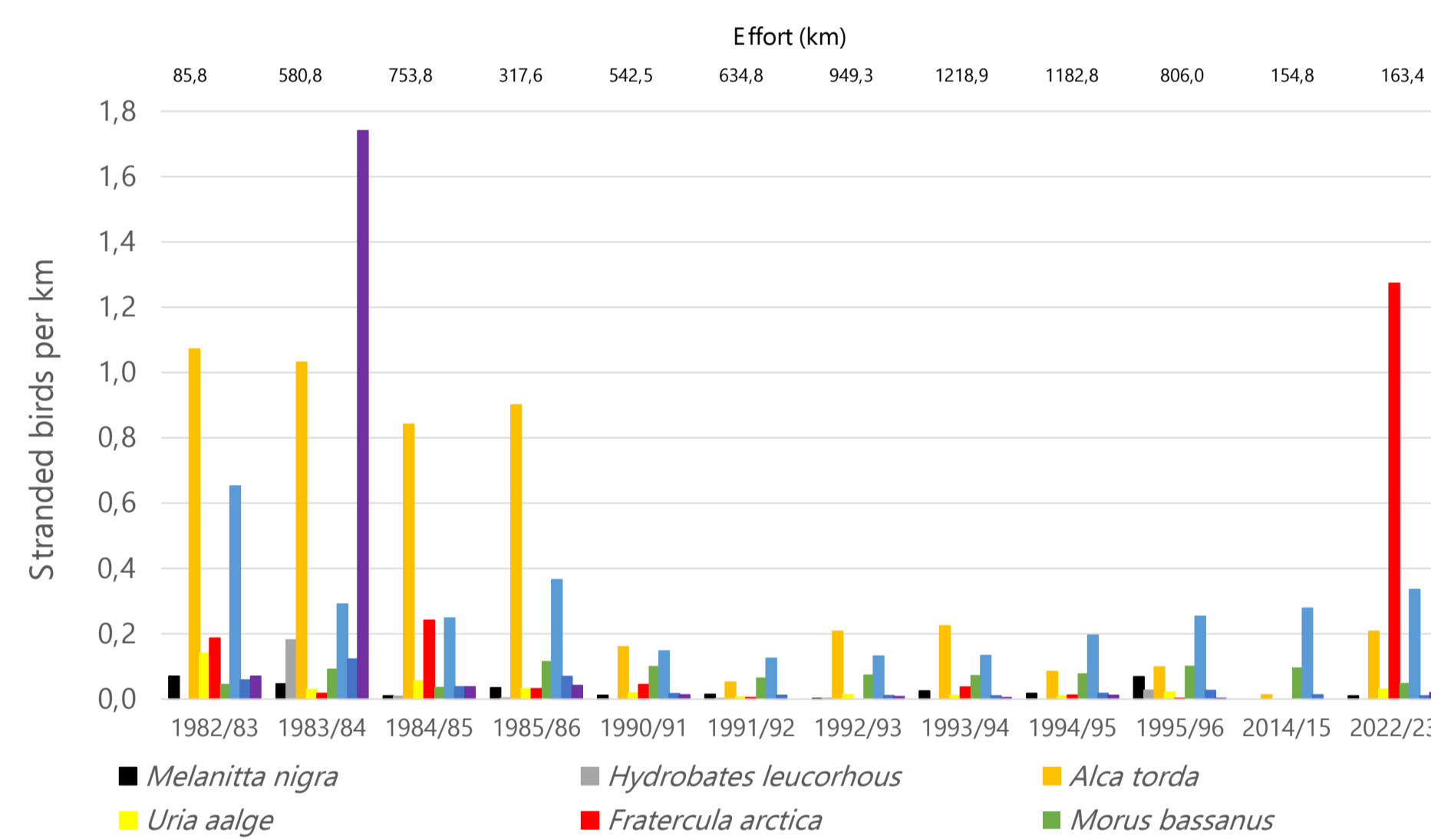


Figure 3 | Densities of stranded seabirds (birds per km) in the winter along the years in the Portuguese coast. The graphic only includes data for the most abundant species recorded in beached bird surveys. Data source: Teixeira 1986, Granadeiro et al. 1997, Fernandes 2016, This study

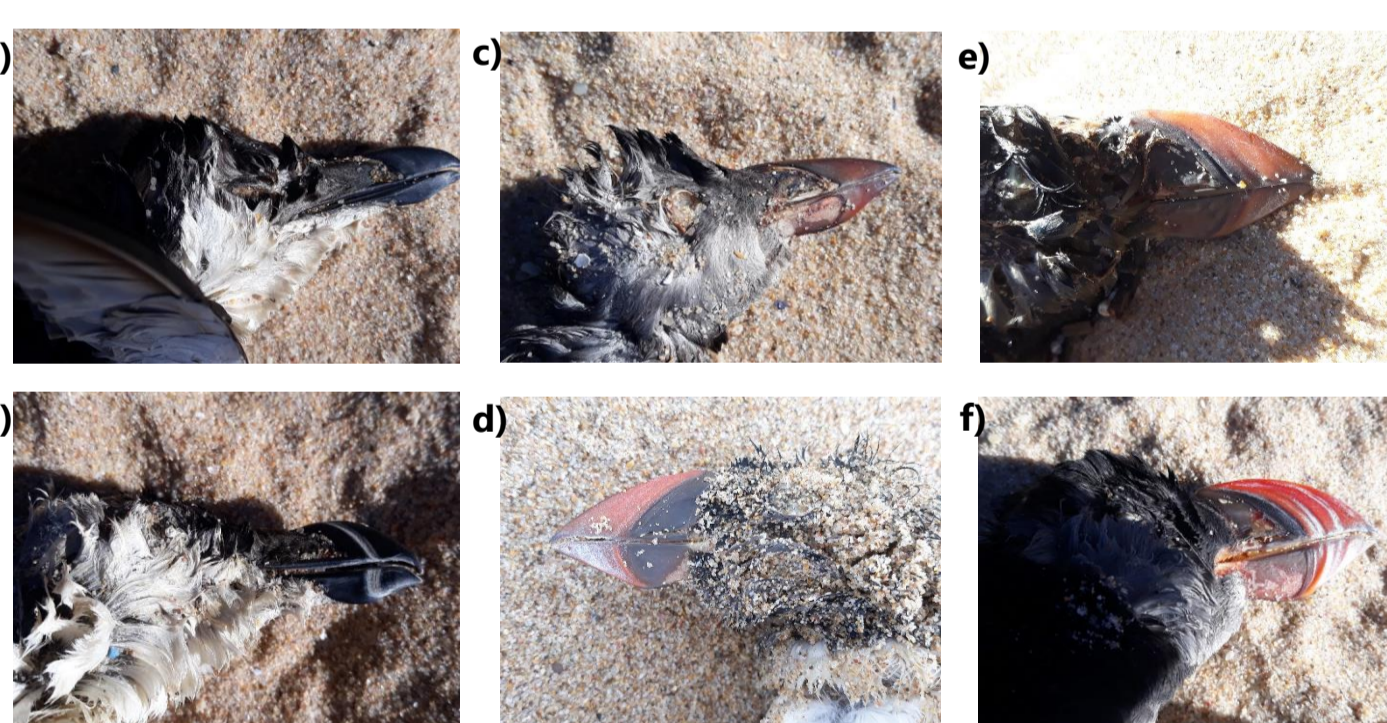


Figure 2 | Photos of different age classes of razorbills and Atlantic puffins. *Alca torda* – 1st winter (a) and adult (b); *Fratercula arctica* – 1st winter (c), 2nd winter (d), 3rd winter (e), adult (f). The identification of age classes of puffins was based on the beak grooves according to Harris (2014)



Figure 4 | Examples of the number of Atlantic puffins and razorbills found in single beached bird surveys during the campaigns to rescue in beaches of the Peniche region.

Table 1 | Total number of stranded individuals per species recorded in mainland Portugal between early December 2022 and early March 2023

Species	Number of birds
<i>Melanitta nigra</i>	1
<i>Fulmarus glacialis</i>	14
<i>Puffinus mauretanicus</i>	1
<i>Hydrobates pelagicus</i>	9
<i>Hydrobates sp.</i>	2
<i>Morus bassanus</i>	65
<i>Phalacrocorax carbo</i>	8
<i>Gulosus aristotelis</i>	1
<i>Fratercula arctica</i>	1723
<i>Alca torda</i>	165
<i>Uria aalge</i>	9
<i>Alle alle</i>	6
<i>Larus michahellis</i>	52
<i>Larus fuscus</i>	47
<i>Larus sp.</i>	20
<i>Larus ridibundus</i>	1
<i>Rissa tridactyla</i>	17
<i>Thalasseus sandvicensis</i>	2
<i>Gelochelidon nilotica</i>	1
<i>Arenaria interpres</i>	3
<i>Calidris alba</i>	1
<i>Phalaropus fulicarius</i>	2

Final considerations

In the winter of 2022-23, a massive wreck of Atlantic puffins took place along the Portuguese coast, with high incidence in the central region of the country (Peniche) and a clear peak in the 2nd fortnight of January. These high numbers of stranded puffins, composed mostly by adult birds, are unusual in the Portuguese coast (Teixeira 1986, Granadeiro et al. 1997, Barros et al. 2013, Fernandes 2016, but see van Nus & Moreira 2014, Morley et al. 2016) and this wreck could not be associated to avian flu, pollution or any bycatch event. These puffins were not flightless due to moult and their physical condition suggest that birds were not been able to feed normally, which could be linked to continuous extreme weather conditions at sea. More work is needed to investigate the causes of this wreck and assess the potential impact of weather/sea conditions at different spatial scales. Citizen science played an important role in signaling this seabird wreck and provided complementary information crucial to understand the spatial and temporal extent of this wreck.

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