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Baseline

Plastic ingestion in aquatic birds in Portugal

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ABSTRACT

In modern society, plastic items have become indispensable. The rapid growth of plastic production has led to an increase in the concentration of plastic waste in the environment and, consequently, wildlife has been severely affected. As wide-ranging foragers and predators, aquatic birds are ideal sentinels for monitoring changes in their environment. Plastic found in stomach contents of stranded aquatic birds collected throughout Portugal was examined. Out of the 288 birds processed, 12.9% ingested plastics. Six of the 16 species assessed showed evidence of plastic ingestion. The Lesser Black-backed Gull (18.7%) had the highest incidence while, among those that did ingest plastics, the Northern Gannet (4.8%) had the lowest. User plastics were the most common type of plastic ingested, while microplastics and off/white-clear were the most common size and colour respectively of plastics found. This study sets a first multispecies baseline for incidence of plastic ingestion by aquatic birds in Portugal.

The accumulation of plastic waste at an uncontrollable rate and the expectation that the rate will increase (UNEP, 2016), has been recognised as a threat to the environment and to wildlife all around the world (Bergmann et al., 2015; Derraik, 2002; Gall and Thompson, 2015). In particular, aquatic birds are severely affected by the pervasive and increasing presence of plastic litter through both entanglement and ingestion (i.e., Boerger et al., 2010; Codina-García et al., 2013; Gregory, 2009; Laist, 1997; Sheavly and Register, 2007; Wilcox et al., 2015). Entanglement can cause injuries, drowning, suffocation, reduced ability to capture prey, while increasing the probability of being preyed upon in turn (Derraik, 2002; Gall and Thompson, 2015; Laist, 1997). Evidence of plastic litter, such as plastic bags, toys and caps, ingested by seabirds dates back to the 1960s (Harper and Fowler, 1987; Kenyon and Kridler, 1969). Once ingested, plastic litter may cause bleeding, blockage of the digestive tract, ulcers or perforations of the gut and can produce a deceptive feeling of satiation, causing the bird not to feed, and consequently leading to starvation (Derraik, 2002; Ryan, 1988a; Ryan, 1988b; Wright et al., 2013). Additionally, the ingested plastics may also expose the affected individuals to toxic compounds that were either added during production processes or absorbed from the surrounding environment (Koelmans, 2015; Tanaka et al., 2013, 2015).

The assessment of plastic ingested by birds does not necessarily reflect the abundance of plastic waste in the environment; however, it is a good proxy for spatio–temporal fluctuations and differences in the abundance of plastic litter (van Franeker et al., 2011; van Franeker and Law, 2015). For example, the Northern Fulmar (*Fulmarus glacialis*) is used by both OSPAR (Oslo/Paris Convention for the Protection of the Marine Environment of the North-East Atlantic) and the European MSFD (Marine Strategy Framework Directive) for monitoring plastic pollution in the North Sea (E.C, 2008, 2010; OSPAR, 2008).

Multispecies monitoring of the incidence and the types of plastic ingested is also crucial to understanding the pervasiveness of plastic ingestion, variation in its composition, amounts and trends among different species and, ultimately, to determining the usefulness of species for monitoring efforts (Acampora et al., 2016). Relative to northern Europe, in southern European countries, attempts to quantify plastic ingestion in aquatic birds have so far been limited (i.e., Codina-García et al., 2013). In Portugal, in particular, the only published information concerning plastic litter in aquatic birds, is restricted to the southern region, Algarve (Nicastro et al., 2018). Here, we set a baseline for incidence of plastic ingestion, and the types and amounts of plastic ingested in a variety of aquatic birds in Portugal.

The present study analysed 288 individual stomach contents from the following 16 species: *Larus michahellis* (Yellow-legged Gull; n = 124), *Larus fuscus* (Lesser Black-backed Gull; n = 107), *Morus bassanus* (Northern Gannet; n = 21), *Ardea cinerea* (Grey Heron;

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n = 17), *Bubulcus ibis* (Cattle Egret; n = 4), *Chroicocephalus ridibundus* (Black-headed Gull; n = 4), *Melanitta nigra* (Common Scoter; n = 2), *Phalacrocorax carbo* (Great Cormorant; n = 1), *Rissa tridactyla* (Black-legged Kittiwake; n = 1), *Egretta garzetta* (Little Egret; n = 1), *Gavia stellata* (Red-throated Loon; n = 1), *Ixobrychus minutus* (Common Little Bittern; n = 1), *Larus argentatus* (European Herring Gull; n = 1), *Larus audoinii* (Audouin's Gull; n = 1), *Larus melanocephalus* (Mediterranean Gull; n = 1) and *Platalea leucorodia* (Eurasian Spoonbill; n = 1). All individuals were collected between 2007 and 2017 by volunteers and brought to one of the following wildlife rescue centres located across Portugal: Parque Biológico de Gaia (PBGaia), Centro de Ecologia, Recuperação e Vigilângia de Animais Selvagens (CERVAS), Centro de Estudos e Recuperação de Animais Selvagens (CERAS), Centro de Recuperação de Animais Silvestres de Lisboa (LxCRAS), and Centro de Recuperação e Investigação de Animais Selvagens (RIAS; Fig. 1). All birds used in this study were found stranded (Fig. S1) as a result of injury, illness or exhaustion. They were either dead when admitted to the recovery facilities or died naturally during their stay. Each bird was labelled, weighed on an electronic balance to the nearest g and kept frozen at −20 °C until dissection.

Dissections were performed following the standard dissection methodology of van Franeker (2004). Whenever possible, data on origin, body condition, probable cause of death, age and gender were recorded for each species. Body condition was recorded based on the pectoral muscle condition, assessed by its palpation using a scale of 1 (lean) to 5 (obese; Carrega, 2016). Gender and age were determined based on the development of the sexual organs and plumage evaluation, respectively.

Stomachs were weighed using an electronic balance (Sartorius Advantage AW-224 Balance) to the nearest 0.0001 g. Stomach contents were examined for the presence of plastics or other foreign matter. The contents were carefully rinsed in a metal sieve with a 1 mm mesh, sieved items were transferred to a glass petri dish and then dried overnight in the oven at 40 °C.

Plastic items were counted and classified according to van Franeker et al. (2011) into industrial- or user-plastics, further subdivided into sheetlike (e.g., plastic bags), threadlike (e.g., fishing line and rope), foamed, fragments and others (e.g., rubber bands, elastics). Plastic items were also classified into the following colour categories (Provencher et al., 2017): off/white-clear, grey-silver, black, blue-purple, green, orange-brown, red-pink and yellow. Maximum length (± 1 mm) of each plastic item was recorded using a grid paper and items were sorted into the following size categories (Barnes et al., 2009): megaplastics (> 100 mm), macroplastics (> 20–100 mm), mesoplastics (> 5–20 mm) and microplastics (1–5 mm). Each plastic item was weighted to the nearest 0.0001 g.

Of the 288 birds collected, 37 individuals (12.9%) presented plastic litter in their stomach contents, representing six (37.5%) of the 16 species collected (Tables 1 to 6). Most of the items were categorised as user plastics. Industrial plastics were only found in two species: Lesser Black-backed Gull (n = 3) and in Black-legged Kittiwake (n = 1; Tables 2 and 6). The Lesser Black-backed Gull accumulated on average more plastic items and more plastic mass than the other species (Tables 1 to 6). Within user plastics, items belonging to the category foam were the most abundant followed by sheetlike, other, fragments and threadlike (Tables 1 to 6). Among species, different subtypes of user plastics were predominant. For example, the Yellow-legged Gull and the Northern Gannet mainly ingested foam while the sheetlike category was the most abundant in the Lesser Back-backed Gull.

Microplastic was the most common size category in all species followed by meso-, macro-, and megaplastics (Table 7), indicating that smaller plastic particles are more bioavailable and have a higher chance of being accidentally or selectively ingested than larger items (Lusher, 2015).

Interspecific differences were observed also in terms of colour; off/white-clear coloured items were the most common in the Yellow-legged Gull stomachs, while black and green plastics were the predominant colours ingested by the Lesser Black-backed Gull and Black-headed Gull, respectively. The Northern Gannet, Great Cormorant and Black-legged Kittiwake ingested off/white-clear coloured plastics.

Our results show that the frequency of plastic occurrence in Laridae are similar to those reported for Northern and Southern Europe (i.e., Acampora et al., 2016; Codina-García et al., 2013). In contrast to other works that reported comparatively high frequencies of plastic occurrence in the Northern Gannet (Acampora et al., 2016; Codina-García et al., 2013; Kühn et al., 2015), of the 21 individuals processed in this study only one had ingested plastic debris.

Several studies have shown that the propensity of a species to ingest plastic is expected to vary according to foraging strategy (i.e., Azzarello and Van Vleet, 1987; Ryan, 1988a; Ryan, 1988b; Shephard et al., 2015). For example, several gull species are particularly exposed to the risk of ingesting plastic waste because, in addition to foraging in marine habitats, they feed from land-based sources including general public litter, industry, harbours and unprotected landfills and dumps located near the coast (Belant et al., 1998; Duhem et al., 2003; Lindborg et al., 2012; Seif et al., 2017). In fact, it has been shown that some gulls may specialise on landfills (Bond, 2016; Weiser and Powell, 2011).

It is important to note that gulls regurgitate large quantities of the debris ingested, thus the assessment of stomach contents only represent a snapshot of ingestion. However, even if gulls are able to regurgitate indigestible items, the release of chemical contaminants from ingested plastic may have sublethal effects on physiology and behaviour (i.e.,

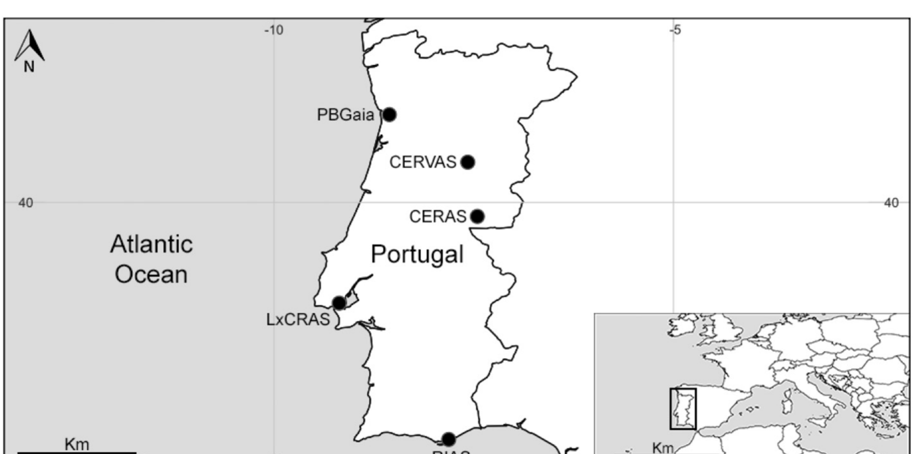

Fig. 1. Wildlife rescue centres that collaborated in this study.

Table 1
Data on the plastics ingested by *Larus michahellis* (n = 124) based on plastic categories. Frequency of occurrence of plastics (with Jeffery's nominal 95% confidence intervals – CI) and plastic litter abundance. Abundance was calculated including all individuals sampled (affected and non-affected).

	Frequency of occurrence (%; 95% CI)	Number of plastic items			Mass of plastic items		
		Mean (n; ± sd; ± se)	Median	Range	Mean (g; ± sd; ± se)	Median	Range
Global	10.48 (0.06–0.17)	0.80 (± 7.11; ± 0.64)	0	0–79	0.0053 (± 0.04; ± 0.004)	0	0–0.4614
Industrial	0 (0–0.02)	0	0	0	0	0	0
User	10.48 (0.06–0.17)	0.80 (± 7.11; ± 0.64)	0	0–79	0.0010 (± 0.01; ± 0.001)	0	0–0.2861
Sheetlike	4.84 (0.02–0.10)	0.13 (± 1.00; ± 0.09)	0	0–11	0.0004 (± 0.003; ± 0.0003)	0	0–0.0317
Threadlike	2.42 (0.01–0.06)	0.04 (± 0.30; ± 0.03)	0	0–3	0.00003 (± 0.0002; ± 0.00004)	0	0–0.0016
Foam	1.61 (0.003–0.05)	0.53 (± 5.84; ± 0.52)	0	0–65	0.0023 (± 0.03; ± 0.002)	0	0–0.2861
Fragments	4.03 (0.02–0.09)	0.08 (± 0.56; ± 0.05)	0	0–6	0.0017 (± 0.01; ± 0.001)	0	0–0.1300
Other	1.61 (0.003–0.05)	0.02 (± 0.13; ± 0.01)	0	0–1	0.0008 (± 0.01; ± 0.001)	0	0–0.0766

Table 2
Data on the plastics ingested by *Larus fuscus* (n = 107) based on plastic categories. Frequency of occurrence of plastics (with Jeffery's nominal 95% confidence intervals – CI) and plastic litter abundance. Abundance was calculated including all individuals sampled (affected and non-affected).

	Frequency of occurrence (%; 95% CI)	Number of plastic items			Mass of plastic items		
		Mean (n; ± sd; ± se)	Median	Range	Mean (g; ± sd; ± se)	Median	Range
Global	18.69 (0.12–0.27)	1.85 (± 9.63; ± 0.93)	0	0–91	0.0781 (± 0.48; ± 0.05)	0	0–4.0969
Industrial	2.80 (0.01–0.07)	0.87 (± 8.70; ± 0.84)	0	0–90	0.0311 (± 0.32; ± 0.03)	0	0–3.2657
User	16.82 (0.11–0.25)	0.98 (± 4.14; ± 0.40)	0	0–32	0.0071 (± 0.12; ± 0.01)	0	0–2.7455
Sheetlike	7.48 (0.04–0.14)	0.51 (± 2.71; ± 0.26)	0	0–20	0.0283 (± 0.27; ± 0.03)	0	0–2.7455
Threadlike	2.80 (0.01–0.07)	0.06 (± 0.36; ± 0.03)	0	0–3	0.0001 (± 0.0004; ± 0.00004)	0	0–0.0030
Foam	1.87 (0.004–0.06)	0.11 (± 1.07; ± 0.10)	0	0–11	0.0001 (± 0.001; ± 0.0001)	0	0–0.0094
Fragments	4.67 (0.02–0.10)	0.09 (± 0.54; ± 0.05)	0	0–5	0.0009 (± 0.01; ± 0.001)	0	0–0.0610
Other	6.54 (0.03–0.12)	0.21 (± 1.47; ± 0.14)	0	0–15	0.0059 (± 0.04; ± 0.004)	0	0–0.3252

Table 3
Data on the plastics ingested by *Morus bassanus* (n = 21) based on plastic categories. Frequency of occurrence of plastics (with Jeffery's nominal 95% confidence intervals – CI) and plastic litter abundance. Abundance was calculated including all individuals sampled (affected and non-affected).

	Frequency of occurrence (%; 95% CI)	Number of plastic items			Mass of plastic items		
		Mean (n; ± sd; ± se)	Median	Range	Mean (g; ± sd; ± se)	Median	Range
Global	4.76 (0.01–0.20)	5.81 (± 26.62; ± 5.81)	0	0–122	0.0032 (± 0.01; ± 0.003)	0	0–0.0676
Industrial	0 (0–0.11)	0	0	0	0	0	0
User	4.76 (0.01–0.20)	5.81 (± 26.62; ± 5.81)	0	0–122	0.0006 (± 0.01; ± 0.001)	0	0–0.0676
Sheetlike	0 (0–0.11)	0	0	0	0	0	0
Threadlike	0 (0–0.11)	0	0	0	0	0	0
Foam	4.76 (0.01–0.20)	5.81 (± 26.62; ± 5.81)	0	0–122	0.0032 (± 0.01; ± 0.003)	0	0–0.0676
Fragments	0 (0–0.11)	0	0	0	0	0	0
Other	0 (0–0.11)	0	0	0	0	0	0

Table 4
Data on the plastics ingested by *Chroicocephalus ridibundus* (n = 4) based on plastic categories. Frequency of occurrence of plastics (with Jeffery's nominal 95% confidence intervals – CI) and plastic litter abundance. Abundance was calculated including all individuals sampled (affected and non-affected).

	Frequency of occurrence (%; 95% CI)	Number of plastic items			Mass of plastic items		
		Mean (n; ± sd; ± se)	Median	Range	Mean (g; ± sd; ± se)	Median	Range
Global	25 (± 0.03; ± 0.72)	0.25 (± 0.50; ± 0.25)	0	0–1	0.0050 (± 0.01; ± 0.01)	0	0–0.0201
Industrial	0 (0.0001–0.44)	0	0	0	0	0	0
User	25 (± 0.03; ± 0.72)	0.25 (± 0.50; ± 0.25)	0	0–1	0.0010 (± 0.004; ± 0.002)	0	0–0.0201
Sheetlike	0 (0.0001–0.44)	0	0	0	0	0	0
Threadlike	0 (0.0001–0.44)	0	0	0	0	0	0
Foam	0 (0.0001–0.44)	0	0	0	0	0	0
Fragments	25 (± 0.03; ± 0.72)	0.25 (± 0.50; ± 0.25)	0	0–1	0.0050 (± 0.01; ± 0.01)	0	0–0.0201
Other	0 (0.0001–0.44)	0	0	0	0	0	0

Table 5
Data on the plastics ingested by *Phalacrocorax carbo* (n = 1) based on plastic categories. Frequency of occurrence of plastics (with Jeffery's nominal 95% confidence intervals – CI) and plastic litter abundance. Abundance was calculated including all individuals sampled (affected and non-affected).

	Frequency of occurrence (%; 95% CI)	Number of plastic items			Mass of plastic items		
		Mean (n; ± sd; ± se)	Median	Range	Mean (g; ± sd; ± se)	Median	Range
Global	100 (0.15–1)	2	2	2	0.0766	0.0766	0.0766
Industrial	0 (0.0004–0.85)	0	0	0	0	0	0
User	100 (0.15–1)	2	2	2	0.0766	0.0766	0.0766
Sheetlike	0 (0.0004–0.85)	0	0	0	0	0	0
Threadlike	0 (0.0004–0.85)	0	0	0	0	0	0
Foam	0 (0.0004–0.85)	0	0	0	0	0	0
Fragments	100 (0.15–1)	2	2	2	0.0766	0.0766	0.0766
Other	0 (0.0004–0.85)	0	0	0	0	0	0

Table 6
Data on the plastics ingested by *Rissa tridactyla* (n = 1) based on plastic categories. Frequency of occurrence of plastics (with Jeffery's nominal 95% confidence intervals – CI) and plastic litter abundance. Abundance was calculated including all individuals sampled (affected and non-affected).

	Frequency of occurrence (%; 95% CI)	Number of plastic items			Mass of plastic items		
		Mean (n; ± sd; ± se)	Median	Range	Mean (g; ± sd; ± se)	Median	Range
Global	100 (0.15–1)	1	1	1	0.0269	0.0269	0.0269
Industrial	100 (0.15–1)	1	1	1	0.0269	0.0269	0.0269
User	0 (0.0004–0.85)	0	0	0	0	0	0
Sheetlike	0 (0.0004–0.85)	0	0	0	0	0	0
Threadlike	0 (0.0004–0.85)	0	0	0	0	0	0
Foam	0 (0.0004–0.85)	0	0	0	0	0	0
Fragments	0 (0.0004–0.85)	0	0	0	0	0	0
Other	0 (0.0004–0.85)	0	0	0	0	0	0

Table 7
Characterization by size and colour of the plastics found in seven species in the study.

Species	Plastic size category (%)				Plastic colour (%)							
	Microplastic (1–5 mm)	Mesoplastic (> 5–20 mm)	Macroplastic (> 20–100 mm)	Megaplastic (> 100 mm)	Off/White–clear	Grey–silver	Black	Blue–purple	Green	Orange–brown	Red–pink	Yellow
Larus michahellis	69.70	27.27	3.03	0	87.88	0	2.02	3.03	4.04	0	3.03	0
Larus fuscus	66.67	26.77	6.06	0.51	45.96	0	47.98	2.53	1.01	0	1.01	1.52
Morus bassanus	100	0	0	0	100	0	0	0	0	0	0	0
Chroicocephalus ridibundus	100	0	0	0	0	0	0	0	100	0	0	0
Phalacrocorax carbo	0	100	0	0	100	0	0	0	0	0	0	0
Rissa tridactyla	100	0	0	0	100	0	0	0	0	0	0	0

Henriksen et al., 2000; Sagerup et al., 2009).

The European Union Landfill Directive (1993/31/EC) set a target to gradually reduce the volume of biodegradable municipal waste entering landfills starting 2016, by replacing open-air landfills by covered waist facilities of difficult access to birds (Gilbert et al., 2016). Presently, in Portugal more than one third of plastic waste ends up in landfills (PlasticsEurope, 2016), thus it is likely that, in the near future, the European Union Landfill Directive will have important consequences for aquatic birds in Portugal.

As the presence of plastics continues to increase in coastal and aquatic environments, our data will provide a solid record of affected species and a basis from which to track longer-term trends in plastic ingestion, particularly for Portuguese and southern Europe monitoring programs for which information is scarce or non-existent. Furthermore, by adopting the newest recommendations for standardization of plastic quantification in megafauna (i.e., Provencher et al., 2017; van Franeker et al., 2011), we hope to emphasise the importance of implementing these accepted protocols and standardized metrics when reporting plastic ingestion in affected organisms so to provide means of comparison among studies.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.marpolbul.2018.11.024.

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