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Baseline

Plastic ingestion in aquatic-associated bird species in southern Portugal

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ABSTRACT

Excessive use of plastics in daily life and the inappropriate disposal of plastic products are severely affecting wildlife species in both coastal and aquatic environments. Birds are top-predators, exposed to all threats affecting their environments, making them ideal sentinel organisms for monitoring ecosystems change. We set a baseline assessment of the prevalence of marine plastic litter affecting multi-species populations of aquatic birds in southern Portugal. By examining 160 stomach contents from 8 species of aquatic birds, we show that 22.5% were affected by plastic debris. Plastic was found in *Ciconia ciconia*, *Larus fuscus* and L. *michahellis*. *Ciconia ciconia* ingested the highest amount (number of items and total mass) of plastic debris. Polydimethylsiloxane (PDMS, silicones) was the most abundant polymer and was recorded only in *C. ciconia*. Plastic ingestion baseline data are of crucial importance to evaluate changes through time and among regions and to define management and conservation strategies.

Since the mass production of plastics started in the 1950s, pollution of this inexpensive and long-lasting material has rapidly emerged as a global environmental concern (Barnes et al., 2009). The rapid and significant accumulation of plastic debris is pervasive and is affecting marine and terrestrial ecosystems virtually everywhere on the planet, far beyond areas of high human population density (e.g., Browne et al., 2011; Duis and Coors, 2016; Thompson et al., 2009). The drawbacks of plastic waste are not limited to aesthetic values; there is now clear and increasing evidence that it represents a major threat to wildlife (Barnes et al., 2009). The number of potentially detrimental consequences of plastic debris has escalated in terms of effects and taxa affected (Bergmann et al., 2015).

Aquatic birds are especially susceptible to the ubiquitous and increasing presence of plastic contamination (e.g., Acampora et al., 2017; Wilcox et al., 2015). Indeed, some of the earliest reports of plastic litter in the marine environment are of plastic caps, toys and bags ingested by seabirds in the 1960s (Harper and Fowler, 1987; Kenyon and Kridler, 1969).

Plastic pollution has a wide range of negative effects on aquatic birds. These include entanglement in multi-pack beverage rings, plastic bags and other plastic items (Bond et al., 2012; Gregory, 2009; Laist, 1997; Udyawer et al., 2013; Votier et al., 2011); smaller plastic debris can be ingested by mistake or because they resemble natural food items (Cadée, 2002; Jackson et al., 2000) causing internal wounds and ulcers, gastrointestinal obstruction and poisoning from exposure to plastic fragments and the organic pollutants associated with them.

In Europe, the Marine Strategy Framework Directive (MSFD) has proposed ingestion of debris by marine organisms as a marine litter indicator to quantify progress towards a "Good Environmental Status" (GES). In particular, due to their susceptibility to plastic debris ingestion, aquatic birds have been considered as good bioindicators for plastic pollution. Of all the seabird species, the Northern Fulmar (*Fulmarus glacialis*) is probably the most well-known bioindicator. Since 2009, monitoring ingestion of plastic litter in beached specimens of *F. glacialis* has been adopted by the Oslo-Paris Convention (OSPAR, 2010) and MSFD (Directive, 2008) as a marine environment quality indicator in the southern North Sea.

The selection of an individual species as an indicator is crucial for analyses of spatial and temporal trends in plastic pollution (Avery-Gomm et al., 2012; Kühn and van Franeker, 2012; Mallory et al., 2006; Provencher et al., 2009; Van Franeker et al., 2011). At the same time, surveys for a wide array of species (including non-indicator species) are also important to understanding the pervasiveness of plastic ingestion and identifying factors that account for differences in the quantities and qualities of plastic ingested by different species (Avery-Gomm et al., 2013; Provencher et al., 2014; Roman et al., 2016). Additionally,

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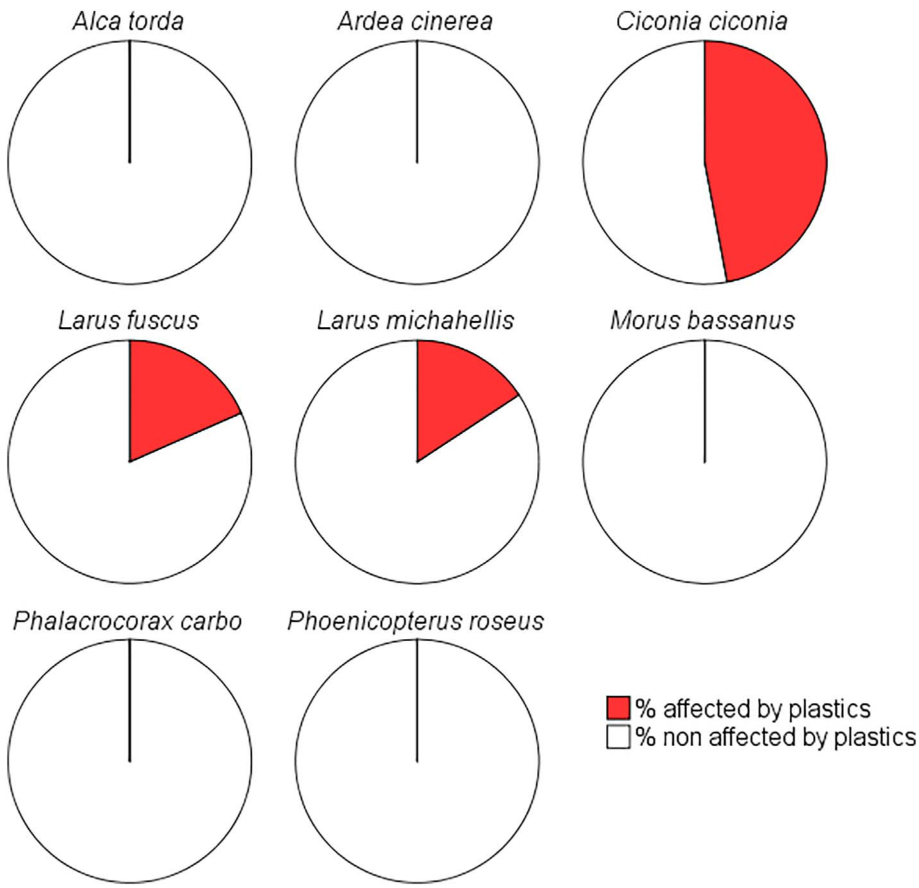

Fig. 1. Plastic litter occurrence (%) in the stomach of eight aquatic species in southern Portugal: *Alca torda* (n = 2), *Ardea cinerea* (n = 1), *Larus michahellis* (n = 75), *Ciconia ciconia* (n = 9) *Larus fuscus* (n = 62), *Morus bassanus* (n = 8), *Phalacrocorax carbo* (n = 1) *Phoenicopterus roseus* (n = 2).

comprehensive multi-species investigations may also be valuable in detecting alternative species for use in monitoring programmes (e.g. Acampora et al., 2016).

Plastic ingestion data are of particular value in regions where baseline studies are not yet available; not only they are important for assessing changes through time and differences among regions, they are also fundamental to a functional definition of management and conservation efforts (Avery-Gomm et al., 2013). While there is little information on the abundance, distribution and fluctuations (spatial and temporal) of plastic litter in Portuguese waters and shores (e.g., Antunes et al., 2013; Martins and Sobral, 2011; Oliveira et al., 2015), there is no published information concerning marine litter in aquatic birds in Portugal. A quantitative assessment that includes both numerical and mass trends is critical. In fact, number and mass of plastic items do not always match and plastic abundance evaluated in terms of mass is considered to be ecologically more relevant (Provencher et al., 2017; van Franeker and Law, 2015). Additionally, recent studies have stressed the importance of spectroscopic techniques in plastic monitoring schemes; these are critical to avoid misidentification of natural items for synthetic polymers (e.g., Wesch et al., 2016). Moreover, knowledge of the composition of plastic debris could lead to more effective mitigation measures (Ryan et al., 2009).

The south of Portugal is characterized by several lagoons near the coastline some of which are referred as areas of high diversity of wildlife including the presence of more than a 100 aquatic bird species. Here, we provide a first quantitative (number of items and total mass of litter) and qualitative (visual and spectroscopic assessment) baseline data on plastic ingestion by multi-species populations of aquatic birds in southern Portugal.

Sampling took place between June 2014 and June 2016 and comprised aquatic birds that had been brought to the wildlife recovery center RIAS in Olhão, southern Portugal. Birds were collected by volunteers along southern Portugal by locals and therefore sampling was irregular over time, space and species. The birds used in this study were either dead when they were admitted to the recovery facility or died during their stay. A total of 160 individuals belonging to 8 species were investigated: two razorbills (*Alca torda*), one grey heron (*Ardea cinerea*), nine white storks (*Ciconia ciconia*), 62 lesser black-backed (*Larus fuscus*) and 75 yellow-legged gulls (*L. michahellis*), eight northern gannets (*Morus bassanus*), one great cormorant (*Phalacrocorax carbo*) and two greater flamingos (*Phoenicopterus roseus*). Birds were labelled and frozen at −20 °C for later necropsy.

Dissections were performed following van Franeker (2004). For each sample and when available, data on age (juvenile or adult), gender, probable cause of death and body condition were recorded. Gender and age were derived from development stage of sexual organs and plumage evaluation. Body condition scoring (0–4) was evaluated following (Pinilla and Català, 2000). The gastrointestinal tract (esophagus, stomach and intestines) was collected and stored at −20 °C. Stomach contents were rinsed and sieved through a 1 mm mesh, retained in a petri dish and air dried for at least 2 days (Van Franeker et al., 2011).

Contents were examined under a stereomicroscope (SteREO Discovery V8 1x-8x). Plastic items were counted and individually weighted (Sartorius advantage AW-224 Balance) to the nearest 0.0001 g. These items were then classified in three different ways: (a) by categories as industrial or user and, within user, in sheetlike, fragment, threadlike, foamed or other (as in Van Franeker et al., 2011); (b) by colour, as dark (i.e., black, dark brown and dark blue), light (i.e., white and yellow), warm (i.e., orange, red and pink) or cold colors (i.e., pale blue and green; as in Codina-García et al., 2013) and (c) by polymer, as polyacrylamide (PAM), polydimethylsiloxane (PDMS), polyethylene (PE), polystyrene (PS), polytetrafluoroethylene (PTFE). To obtain information on their resin or polymer composition, Raman