Marine Pollution Bulletin 77 (2013) 220–226

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Plastic debris in Mediterranean seabirds

Marina Codina-García *, Teresa Militão, Javier Moreno, Jacob González-Solís

Institut de Recerca de la Biodiversitat (IRBio) and Departament de Biologia Animal, Universitat de Barcelona, Av. Diagonal 643, 08028 Barcelona, Spain

ARTICLE INFO

Keywords:
Plastic ingestion
Seabirds
Shearwaters
Mediterranean Sea

ABSTRACT

Plastic debris is often ingested by marine predators and can cause health disorders and even death. We present the first assessment of plastic ingestion in Mediterranean seabirds. We quantified and measured plastics accumulated in the stomach of 171 birds from 9 species accidentally caught by longliners in the western Mediterranean from 2003 to 2010. Cory's shearwaters (*Calonectris diomedea*) showed the highest occurrence (94%) and large numbers of small plastic particles per affected bird (on average $N = 15.3 \pm 24.4$ plastics and mass = 23.4 ± 49.6 mg), followed by Yelkouan shearwaters (*Puffinus yelkouan*, 70%, $N = 7.0 \pm 7.9$, 42.1 ± 100.0 mg), Balearic shearwaters (*Puffinus mauretanicus*, 70%, $N = 3.6 \pm 2.9$, 5.5 ± 9.7 mg) and the rest of species (below 33%, $N = 2.7$, 113.6 ± 128.4 mg). Plastic characteristics did not differ between sexes and were not related to the physical condition of the birds. Our results point out the three endemic and threatened shearwater species as being particularly exposed to plastic accumulation.

1. Introduction

Since 1970s the plastic pollution in oceanic waters has been detected and studied in several regions as a threat for human health and animal life. Floating plastic debris is usually ingested by marine animals by mistake or because plastic fragments resemble their natural food items (Cadée, 2002; Jackson et al., 2000; Mrosovsky and Sherry, 1980). Some plastics can release potentially toxic substances (Oehlmann et al., 2009; Teuten et al., 2009) or become vectors for dispersing harmful algae and alien species (Barnes, 2002; Masó et al., 2003). Moreover, plastics can produce entanglement, intoxication, internal wounds, digestive tract blockage and ulcers among other affections (Blais et al., 2005; Gregory, 2009; Ryan, 1987, 1988; Ryan et al., 1988). Therefore, there is an urgent need to assess the interactions between plastic debris and marine life.

Since 1960s, many studies have pointed out the problem in several oceans and seas (Barbieri, 2009). In this context, the Mediterranean Sea has been recognized as a singularly sensitive ecosystem because its coast is very industrialized and the shipping activity is intense (Galil et al., 1995). These traits, plus its small size and the enclosed situation can cause the accumulation of plastic debris (Barnes et al., 2009), in some cases even forming high density of floating plastic areas (Morris, 1980). In 1970, Mediterranean countries adopted the *Protocol for the Protection of the Mediterranean Sea against Pollution from Land-based Sources* in the framework of the *Convention for the Protection of the Mediterranean Sea against the pollution*. Although plastic litter was not directly mentioned, this convention gave rise to several protocols to regulate offshore activities, dumping from ships and aircrafts and waste water management among other activities to reduce pollution in Mediterranean waters. Despite this effort, the 2009 UNEP (UNEP, 2009) report revealed an overwhelming presence of plastic and identified shoreline recreational activities as one of the major pollution sources.

Although several litter monitoring projects have found substantial amounts of plastic in Mediterranean shorelines and deep waters, due to differences in sampling protocol it is not possible to compare their results to infer differences between areas or years at a Mediterranean scale (Table 1). In Europe, the Marine Strategy Framework Directive identifies the need of a marine litter descriptor to measure progress towards the target of a "Good Environmental Status" (GES). In this context, ingestion of litter by marine organisms has been recently proposed as an indicator for this descriptor. However, information on the incidence, time trends and effects of plastic ingestion on wildlife is still scarce. In loggerhead turtles (*Caretta caretta*) 71% of juveniles ingested human debris and again the most frequent item (75.9%) was plastic (Tomás et al., 2002). Plastic ingestion is also known to be common in stranded cetaceans in Mediterranean shores (Di Sciara and Gordon, 1996; Shoham-Frider et al., 2002). Seabirds are among the most affected animals by plastic contamination, especially those species that tend to accumulate plastic in their stomach (Day et al., 1985), however no attempt to quantify plastic ingestion in Mediterranean seabirds has been made so far. Indeed, due to their ability to accumulate plastics in their stomachs, seabirds have been suggested as good bioindicators for marine plastic pollution. Plastic

* Corresponding author. Tel.: +34 933296123.
E-mail address: marina.codinag@gmail.com (M. Codina-García).

0025-326X/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.marpolbul.2013.10.002

Table 1
Summary of surveys of marine plastic debris at sea or on beaches in the Mediterranean Basin showing the unavailability of comparable data. Plastic (%) indicates the proportion of plastic found among the debris load in each study.

Study area	Sampling year	Method	Debris load	Units	Plastic (%)	Data source
Balearic Islands	2005	Beach surveys	36	Item/m	36	Martinez-Ribes et al. (2007)
French coast	1994–1996	Depth trawl	0–78	Items/Ha	70	Galgani et al. (1996)
NW Mediterranean	1993–1994	Depth trawl	19.53 ± 6.30	Items/Ha	77	Galgani et al. (1995)
Gulf of Lion	1992–1998	Depth trawl	0.92 ± 0.12	Items/Ha	100	Galgani et al. (2000)
East Corsica	1992–1998	Depth trawl	1.05 ± 0.36	Items/Ha	100	Galgani et al. (2000)
Ligurian Sea	1997	Visual sightings	0.15–0.25	Items/Ha	100	Aliani et al. (2003)
Ligurian Sea	2000	Visual sightings	0.015–0.03	Items/Ha	100	Aliani et al. (2003)
Greece Gulfs	2000–2003	Depth trawl	0.72–4.37	Items/Ha	56	Koutsodendris et al. (2008)
Greece Gulfs	1997–1998	Depth trawl	0.89–2.40	Items/Ha	80	Stefatos et al. (1999)
Adriatic Sea	1992–1998	Depth trawl	2.63	Item/Ha	100	Galgani et al. (2000)
Israeli Mediterranean beaches	1990–1991	Beach survey	3–5 to13–32	Items/100m2 of beach front	70	Bowman et al. (1998)
East Mediterranean	1979	Visual sightings	20	Item/Ha	60–70	Morris (1980)
East Mediterranean	1986	Visual sightings	0.012	g/m^2	69	McCoy (1988)
East Mediterranean	1993	Depth trawl	277	Total items found	36	Galil et al. (1995)

stomach contents from those species feeding mostly or only on a pelagic environment are assumed to reflect the availability of ocean plastics at some degree. In this regard, regurgitations, seabirds stranded on beaches or those accidentally caught by fisheries, such as longliners, can be used as bioindicators to detect trends in the different types of marine litter over time (van Franeker, 2011).

In this study we attempt (1) to quantify and characterize the plastics accumulated in the stomachs of several Mediterranean seabird species accidentally caught by longliners in the Catalan Sea (NE Spain); (2) to understand the influence of the species, sex, migratory behavior, breeding area and condition of the birds on the type and quantity of ingested plastics.

2. Materials and methods

All birds included in this study were accidentally caught by longliners operating throughout the Catalan coast (Western Mediterranean Sea) from May 2003 to June 2010. Birds were voluntarily collected by fishermen and therefore sampling effort is irregular over time. In total, we collected 171 birds from 9 species: 49 Cory's (*Calonectris diomedea*), 46 Balearic (*Puffinus mauretanicus)* and 31 Yelkouan (*Puffinus yelkouan)* Shearwaters*;* 8 gannets (*Morus bassanus*); 15 Audouin's (*Ichthyaetus audouinii*), 4 Mediterranean (*Ichthyaetus. melanocephalus*) and 12 yellow-legged (*Larus michahellis)* gulls; 4 black-legged kittiwakes (*Rissa tridactyla*) and 2 great skuas (*Catharacta skua*). Cory's Shearwater individuals included in the study were all captured in the Mediterranean and they belong to the subspecies *C. d. diomedea.* Birds were stored frozen until dissection. After defrosting them, sex was determined by dissection. Age was determined by the presence of the bursa of Fabricius and also age-specific plumage variability whenever present in the species. As juveniles and immature birds of Procellariiformes do not have the opportunity to offload to their chicks, they may accumulate larger plastic loads in their stomachs, so we decided to only include birds with an adult plumage and/or absence of bursa de Fabricius. Although we understand that the comparison between different age classes would be very interesting it was not possible due to the small number of juveniles collected. Physical condition parameters were also recorded, including pectoral muscle condition, amount of subcutaneous fat and amount of intestinal fat by following standardized scoring codes (van Franeker, 2004). We added up the three scores to obtain a single value that we later used as an overall condition estimation.

During dissection, stomach and gizzard were removed and the contents were rinsed to tear them apart and poured into a 1 mm mesh sieve. Hard remains were spotted and classified as organic or non-organic items. Non-organic items included stones and plastic remains. The latter were classified according to their morphology as follows: filaments, industrial pellets, foamed plastic, laminar plastic, fragments and others. (van Franeker, 2011). Filaments refer to long and thin pieces of flexible plastic. Industrial pellets refer to small plastic spheres used as plastic major form for transport before it is shaped and used to manufacture any product. Foamed plastic refers to light weight pieces with spongy appearance and texture. Laminar plastic refers to thin and easy to fold and crumple pieces of plastics that most probably formed part of plastic bags and wrappings. Fragments refer to remains of post consumer plastic debris after being broken down into smaller pieces, if not included in the previous categories. Plastics that could not be classified in any of the previous categories were considered 'others'. All plastic items were individually weighted to the nearest 0.001 mg with a microbalance (Mettler Toledo MX5) and maximum length measured to the nearest 0.5 mm. In the case of laminar plastics and filaments maximum length was measured considering, whenever possible, their compression state inside the stomach. Plastic items were then classified by color 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).

To determine the migratory behavior of Balearic and Yelkouan shearwaters (resident versus migrant) and the breeding area of Cory's shearwaters caught by longliners we collected and analyzed the stable isotopic values of carbon (δ^{13}C) and nitrogen (δ^{15}N) of the first primary feather from 45 Balearic, 26 Yelkouan and 43 Cory's Shearwaters. Sample preparation and analysis was done following Militão et al. (2013). Stable isotope analyses on feathers can provide information from the areas where they grew (Bearhop et al., 2002; Ramos and González-Solís, 2012).

In the case of the Yelkouan and Balearic Shearwaters the first primary feather is known to be grown normally during the non-breeding period and its isotopic values can be used to determine whether a bird spent the non-breeding period on the western Mediterranean (resident) or migrated to another area (Militão et al., 2013). We used the discriminant function described in Militão et al. (2013) to determine the migratory behavior of Balearic and Yelkouan Shearwaters. In the case of Cory's shearwaters, the first primary feather is known to molt at the end of the breeding period, so the isotopic values of this feather can be used to infer their breeding colony.

To assign the breeding colony of bycaught birds we constructed a discriminant function based on the isotopic data of Cory's shearwaters of known breeding colony (Balearic Islands,Murcia, Tremiti, Crete) used in Gómez-Díaz and González-Solís (2007) as well as feathers of 20 Cory's shearwaters sampled in Zembra (Tunisia) in 2009 (Veronica Cortés unpublished data). This discriminant function analysis was performed assuming equal prior probabilities and using jackknife reclassification (leave-one-out cross validation).