Marine debris ingestion by albatrosses in the southwest Atlantic Ocean

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ABSTRACT

Plastics and other marine debris affect wildlife through entanglement and by ingestion. We assessed the ingestion of marine debris by seven albatross species in the southwest Atlantic by analysing stomach contents of birds killed in fisheries. Of the 128 specimens examined, including four *Diomedea* species (n=78) and three *Thalassarche* species (n=50), 21 (16.4%) contained 1-4 debris items, mainly in the ventriculus. The most common type was plastic fragments. Debris was most frequent in *Diomedea* species (25.6%) and, particularly, *D. sanfordi* (38.9%) and very rare in *Thalassarche* species (2.0%), presumably reflecting differences in foraging behavior or distribution. Frequency of occurrence was significantly higher in male than female *Diomedea* albatrosses (39.3% vs. 18.0%). Although levels of accumulated debris were relatively low overall, and unlikely to result in gut blockage, associated toxins might nevertheless represent a health risk for *Diomedea* albatrosses, compounding the negative impact of other human activities on these threatened species.

Keywords: Seabirds, Procellariiformes, Pollution, Plastics

1. Introduction

Plastics and other marine debris are increasing in the oceans worldwide and can be found even in the most remote and isolated regions (Barnes et al. 2009; Cózar et al. 2014). Plastic pollution affects marine wildlife by entanglements and ingestion. The latter can result in digestive tract blockage or ulceration, or poisoning from toxins adsorbed onto the debris surface or released after digestion, leading to reduced body condition and even to death (Azzarello and Van Vleet 1987; Ryan 1988; Ryan et al. 1988; Teuten et al. 2009; Tanaka et al. 2013).

There are many published studies on the ingestion of marine debris by seabirds (Ryan 1987; Colabuono et al. 2009; Codina-García et al. 2013), and very often these species are used as indicators of marine pollution (Robards et al. 1995; Ryan 2008; Ryan et al. 2009; Bond et al. 2013; Elliott and Elliott 2013). Among seabirds, species in the order Procellariiformes (albatrosses and petrels) seem to be the most vulnerable to effects of plastic ingestion (Ryan 1987). This is due to their smaller ventriculus (gizzard), and often a limited ability to regurgitate ingested plastics (Azzarello and Van Vleet 1987). The latter is a particular problem for most petrels (except giant petrels *Macronectes* spp.), as the narrow, angled junction between the proventriculus and ventriculus prevents the passage of material back up to the mouth (Furness 1985b; Ryan 1987; Spear et al. 1995). To some extent, this must also be an issue for albatrosses; although they do regurgitate plastic and other debris (Huin and Croxall 1996; Imber 1999; Phillips et al. 2010), there is a higher frequency of plastics in the ventriculus than proventriculus (Colabuono et al. 2009).

Albatrosses are among the seabirds that are most susceptible to bycatch in fisheries, and some face other major threats at breeding sites, including predation by alien invasive mammals (Croxall et al. 2012). Given their status as the most threatened of any bird family according to the World Conservation Union (IUCN), it is important to assess the relative risk from plastic ingestion for different species. In this study, we assess the ingestion of marine debris by seven species of albatrosses in the southwest Atlantic, through the analysis of stomach contents from carcasses recovered as fisheries bycatch.

2. Methods

Samples were obtained from albatross carcasses collected on pelagic longline vessels. These specimens were caught incidentally by Uruguayan commercial and research vessels in 2005-12, and 2009-13, respectively, and Japanese commercial vessels in 2009-11 operating off Uruguay under an experimental fishing license (Jiménez et al. 2010, 2014, 2015). All vessels fished in shelf break, slope and deeper

waters off Uruguay, and Uruguayan commercial vessels also operated in international waters (Jiménez et al. 2014).

The digestive tract (esophagus, proventriculus and ventriculus) of 128 specimens of seven species of albatrosses were examined (Table 1). These were of two genera; four species of great albatrosses (*Diomedea* spp.) and three species of mollymawks (*Thalassarche* spp.). Species of great albatrosses were identified in the laboratory; Northern royal *Diomedea sanfordi* and Southern royal *D. epomophora* albatrosses were distinguished by their plumage, and Wandering albatrosses *D. exulans* were separated from Tristan albatrosses *D. dabbenena* by a morphometric discriminant function (Cuthbert et al. 2003). White-capped albatrosses *Thalassarche steadi* were identified by molecular analysis (Jiménez et al. 2015). The sex was determined by examining the gonads. Both royal albatross species (Jiménez et al. 2014) and White-capped albatrosses (Jiménez et al. 2015) were captured on the shelf break off Uruguay. Black-browed *T. melanophris* and Wandering albatrosses were captured on the shelf break and deeper waters off Uruguay (34°–36° S, 51°–53°W) and in adjacent international waters (35°-38° S, 48°-50°W). Two of the Tristan albatrosses were captured in deep waters off Uruguay (35°28'S–51°20'W and 37°29'S–51°57'W), two others in international waters off Brazil (28°38'S–42°41'W and 30°25'S–43°47'W) and two breeding birds (with unfeathered brood patches) were captured at 35°28'S–29°30'W. The only Atlantic yellow-nosed albatross *T. chlororhynchos* was caught in Uruguayan waters (35°41'S–51°25'W) (Fig. 1).

All debris items found in each part of the digestive tract were counted and categorized as follows: plastic fragments (rigid plastics, usually pieces of larger objects); plastic pellets (raw material); nylon line; hooks; and wood. For each species, the relative frequency of occurrence (FO%) of each plastic category was estimated. Because almost all debris were found in great albatrosses, and mainly Northern royal albatrosses (see Results), we first used a $\chi 2$ test to evaluate whether there was an effect of sex on plastic incidence in these species. Subsequently, a generalized linear model (GLM), using a binomial error distribution and the log link function, was fitted to the data for Northern royal albatross; sex was included as a categorical variable and its significance examined using a Likelihood Ratio Test (LRT). Analyses were conducted in R (http://www.r-project.org/).

3. Results

Of the 128 albatross specimens analyzed, 21 (FO%=16.4) had one to four items of marine debris in their digestive tracts. Almost all debris items were located in the ventriculus; only two birds also had debris in

their proventriculus (Table 1). Debris types were dominated by plastic fragments (Fig. 2). Fisheries-related items were also found, including a hook and pieces of nylon line. There was a single debris item (a small white plastic pellet) in the stomach of only one of the 50 mollymawks examined, a Black-browed albatross (overall FO%=2.0). The great majority of the debris items were found in great albatrosses (FO%=25.6). Plastics were found mainly in the two royal albatross species, with a higher FO% in Northern royal albatross (Table 1). No plastic or other marine debris were found in the Wandering albatrosses.

The presence of debris varied significantly between sexes in the great albatrosses ($\chi^2 = 4.27$, d.f. = 1, $P < 0.05$); the FO% was significantly higher in males (39.3% of 28 birds examined) than females (18.0% of 50 birds examined). This was also the case in the analyses restricted to Northern royal albatrosses (binomial GLM; LRT, $\chi 2 = 4.39$, d.f.= 1, $p<0.05$), with a higher incidence of debris in males. Based on the rate of change in odds, the probability of occurrence of debris was 4.5 times higher (453%, 95% confidence limit = 104–1970%) in males than females.

4. Discussion

Previous studies have quantified the occurrence of marine debris ingested by albatrosses in the southwest Atlantic, including Wandering, Black-browed and Grey-headed (*Thalassarche chrysostoma*) albatrosses breeding at South Georgia (Huin and Croxall 1996), Atlantic yellow-nosed, Sooty (*Phoebetria fusca*) and Tristan albatrosses breeding at Gough Island (Furness 1985a), and Black-browed and Atlantic yellow-nosed albatrosses wintering off southern Brazil (Petry et al. 2007; Barbieri 2009; Colabuono et al. 2009; Tourinho et al. 2010). Presence of plastic particles has also been noted for two Southern royal albatrosses found dead in Brazil (Petry et al. 2001). In addition, there is a study on the incidence of plastics in Northern and Southern royal albatrosses breeding at New Zealand colonies (Imber 1999). Plastics were common in the breeding birds sampled at South Georgia and New Zealand, but absent at Gough Island. The numbers of birds examined at Gough Island were small, however, and so our study provides a robust quantification of the occurrence of plastic and other debris in a wide range of albatross species in the southwest Atlantic, including, for the first time, wintering birds from the New Zealand region (White-capped, Northern royal and Southern royal albatrosses).

Almost all plastic items found were in the ventriculus, as in previous studies (Colabuono et al. 2009). This suggests that most ingested debris, including large items such as the hook and line that were found in one proventriculus (Fig. 2), or smaller items that do not enter a full ventriculus, tend to be

regurgitated. Indeed, the relatively small ventriculus (mean values and range in mm; this study) of great albatrosses (length = 35.5, 27.3-43.0; width = 26.6, 19.9-34.3; n=69 birds) and mollymawks (length = 29.3, 20.2-40.2; width = 20.6, 13.7-33.6; n=46 birds) probably limits the number of plastic fragments that are retained, and explains the lower number of items found in comparison with medium-sized petrels and shearwaters in other studies (Furness 1983; Furness 1985a; Ryan 2008; Colabuono et al. 2009). The latter often accumulate smaller items than those reported in our study (Ryan 1987; Colabuono et al. 2009), which may reflect a ventriculus (mean length x mean width = 29.7 x 21.8 mm in *Procellaria* petrels, n=26; 36.5 x 24.6 mm in great shearwater *Puffinus gravis*, n=1; unpublished data) that is relatively large given their markedly smaller body size.

The previous studies in southern Brazil were of Black-browed and Atlantic yellow-nosed albatrosses incidentally caught in fisheries (Colabuono et al. 2009) and beach-stranded birds collected from the mid 1990s to mid 2000s (Petry et al. 2007; Barbieri 2009; Colabuono et al. 2009; Tourinho et al. 2010). The reported frequency of occurrence of marine debris in Black-browed albatrosses was between 12% and 73% (sample size range: 26-59 birds), excluding a study of only two birds which both had debris (Tourinho et al. 2010). As in our study, plastics always accounted for the majority of the ingested debris, followed by fishing-related items, such as nylon lines and hooks. The type and number of plastics varied, but plastic fragments were the most common, followed by nylon lines and plastic pellets (Petry et al. 2007; Barbieri 2009; Colabuono et al. 2009; Tourinho et al. 2010). For Atlantic yellow nosed albatrosses, the frequency of occurrence of marine debris in previous studies was 7% (Colabuono et al. 2009) and 44% (Barbieri 2009), with sample sizes of 29 and 9 birds, respectively. Similar to Black-browed albatross, the plastics were mainly fragments, and fishing lines and plastic pellets were recorded infrequently. In the present study we found a low frequency of plastic in Black-browed albatross (FO% = 3.1). For Atlantic yellow-nosed albatross, we had only one sampled individual, precluding interpretation, but we also analyzed 17 White-capped albatrosses and failed to find any plastic item. It is important to note that most studies of plastic ingestion by mollymawk species in the southwest Atlantic are of beach-stranded birds (see references above), which have often starved and are in poor body condition compared with birds incidentally caught in fisheries (Colabuono et al. 2012). A proportion of the beached birds may have died due to complications associated with plastic ingestion, and if so, would provide a biased representation of plastic retention by the wider population (Ryan 1987; Codina-García et al. 2013). Although a study in southern Brazil found no significant differences between the number of plastic items in bycaught and beach-stranded Procellariiformes (Colabuono et al. 2009), the sampling included several species of petrel which are well known to ingest and retain plastics at higher

frequencies than albatrosses. As birds caught incidentally in fisheries are more likely to provide a random sample, the low frequency of plastics found in mollymawks in our study indicates a lower rate of plastic retention than that suggested by previous studies of beach-stranded albatrosses, which seem likely to have been overestimates.

Contrasting with the mollymawks, a higher frequency of plastics was found in great albatrosses in our study, although varying among species; FO% ranged from 0 in Wandering albatrosses to 38.9% in Northern royal albatrosses. The greater incidence in wintering royal albatrosses is consistent with the large number of plastic items found regurgitated on the ground near nests at breeding sites of this species in New Zealand; 16 and 72 plastic items were found in 34 and 151 samples from Northern royal albatrosses at Chatham Islands and Taiaroa Head, respectively, and 81 plastic items were found in 79 samples from Southern royal albatrosses at Campbell Island (Imber 1999). Although we found no marine debris in the Wandering albatrosses, studies at Bird Island, South Georgia, have reported plastic and fishing-related items (including rubber, hooks and line) in diet samples and regurgitated on the ground by both adults and chicks (Huin and Croxall 1996; Phillips et al. 2010). However, these are often large items and for example, during 1993/1994 the reported incidence of plastics was low; 11 items at 1329 nests checked (Huin and Croxall 1996). Together, these results can be explained if Wandering albatrosses do ingest marine debris but these tend to be large items that are later regurgitated, and hence it would be rare for small plastic items to be retained in the ventriculus. In contrast, possibly because of differences in diet and foraging strategies, the two royal albatrosses, and potentially Tristan albatross (33% of the six birds sampled had ingested plastic fragments, nylon lines or wood) may have a greater tendency to ingest and retain small plastic items. However, some caution should be exercised in interpreting our results from Wandering, and particularly Tristan albatrosses due to low sample size, and so this hypothesis would need to be tested further.

Differences in densities of floating plastic in the main foraging areas of great albatrosses could also explain the variability in plastic incidence between species and sexes. Wandering and Tristan albatrosses breed in South Georgia and Tristan da Cunha, respectively, and both breeding and nonbreeding birds use the southwest Atlantic; Wandering albatrosses forage over an extensive region from oceanic waters to the shelf break, whereas Tristan albatrosses forage almost exclusively in oceanic waters in the subtropical region (Nicholls et al. 2002; Cuthbert et al. 2005; Reid et al. 2013). The reported plastic accumulation area for the subtropical south Atlantic gyre (Cózar et al. 2014; Ryan 2014) matches very well with the distribution of Tristan albatross, at least during breeding, suggesting a greater

susceptibility in this species to plastic ingestion. On the other hand, plastic also tends to accumulate over the shelf-break and continental shelf areas of the southwest Atlantic because of the density of fishing vessels, the main source of marine debris for seabirds in the region (Copello and Quintana 2003, 2008), and the occurrence of numerous oceanographic fronts (Acha et al. 2004). This may at least partially explain the greater frequency of plastic in royal albatrosses, which forage extensively over the continental shelf and shelf-slope (Nicholls et al. 2002; Jiménez et al. 2014) and interact with large number of fishing vessels, including trawlers, longliners and others, mainly off Uruguay and Argentina (Favero et al. 2011; Jiménez et al. 2014). However, it is also probable that some of birds sampled in our study had retained plastic particles in their ventriculus from the Pacific Ocean. Differences in at-sea distribution in relation to sex have also been noted in great albatrosses, with females foraging in more northern areas than males (Prince et al. 1998). The significantly higher frequency of plastic in male Northern royal albatrosses could indicate greater availability of floating plastics in their foraging areas in the southern continental shelf of South America.

The striking differences among great albatross and mollymawk species in the incidence of plastic debris seem likely to also reflect differences in distribution or foraging behavior. Similar to royal albatrosses, White-capped and Black-browed albatrosses are also distributed over shelf areas and the shelf-break (but the latter also in coastal and oceanic waters) (Phillips et al. 2005; Jiménez et al. 2010, 2015; Copello et al. 2013). A plausible explanation is that individual royal albatrosses spend a higher proportion of the time in frontal zones in these areas where there is more floating plastic, or following vessels (picking up the rubbish thrown overboard) than mollymawks. Alternatively, most plastic ingestion by royal albatrosses could be in areas other than Uruguay; again, the southern shelf of South America or around breeding colonies in the Pacific Ocean.

Given their small breeding populations and low productivity, great albatrosses are likely to be the species most affected by pelagic longline fisheries in the southwest Atlantic Ocean (Jiménez et al. 2012), with royal albatrosses probably also killed in small numbers by trawlers (Favero et al. 2011). Recently, high levels of bycatch in the pelagic longline fishery were reported for both royal albatross species in Uruguayan and adjacent waters (Jiménez et al. 2014). We have found evidence that Northern royal albatrosses also interact with demersal longliners, as a hook often used in fisheries for Patagonian toothfish *Dissostichus eleginoides* or other demersal target species was found in the proventriculus of a male. In addition, our study showed that royal albatrosses accumulated plastic in their digestive tract at a higher frequency than other common albatross species occurring in the southwest Atlantic. Although

overall, levels of accumulated debris were relatively low and unlikely to result in digestive tract blockage, the associated toxins might nevertheless represent a health risk for the great albatrosses. This may compound the negative impact of other human activities, including fishing, on these threatened species.

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Table 1. Sample size, sex ratio (F: females; M: males), relative frequency of occurrence (FO%) and types of marine debris found in the digestive tract of albatrosses caught in the southwest Atlantic Ocean.

Species	Sampled stomachs		Stomachs with debris			Number of debris items					
	N	F / M	N	F / M	FO%	Plastic fragments	Pellet	Nylon Line	Hook	Wood	Total
Great Albatrosses											
Tristan Albatross *Diomedea dabbenena*	6	5 / 1	2	1 / 1	33.3	4	0	2	0	1	7
Wandering Albatross *Diomedea exulans*	12	8 / 4	0	-	0.0	0	0	0	0	0	0
Northern Royal Albatross *Diomedea sanfordi*	36	23 / 13	14	6 / 8	38.9	25	0	0	1	0	26
Southern Royal Albatross *Diomedea epomophora*	23	13 / 10	4	2 / 2	17.4	5	0	0	0	0	5
Royal *Diomedea spp.*	1	1 / 0	0	-	0.0	0	0	0	0	0	0
Mollymawks											
White-capped Albatross *Thalassarche steadi*	17	9 / 8	0	-	0.0	0	0	0	0	0	0
Black-browed Albatross *Thalassarche melanophris*	32	20 / 11 *	1	0 / 0 *	3.1	0	1	0	0	0	1
Atlantic yellow-nosed Albatross *Thalassarche chlororhynchos*	1	0 / 1	0	-	0.0	0	0	0	0	0	0
All Species	**128**	**79 / 48 ***	**21**	**9 / 11 ***	**16.4**	**34**	**1**	**2**	**1**	**1**	**39**

* The sex of one bird was unknown.

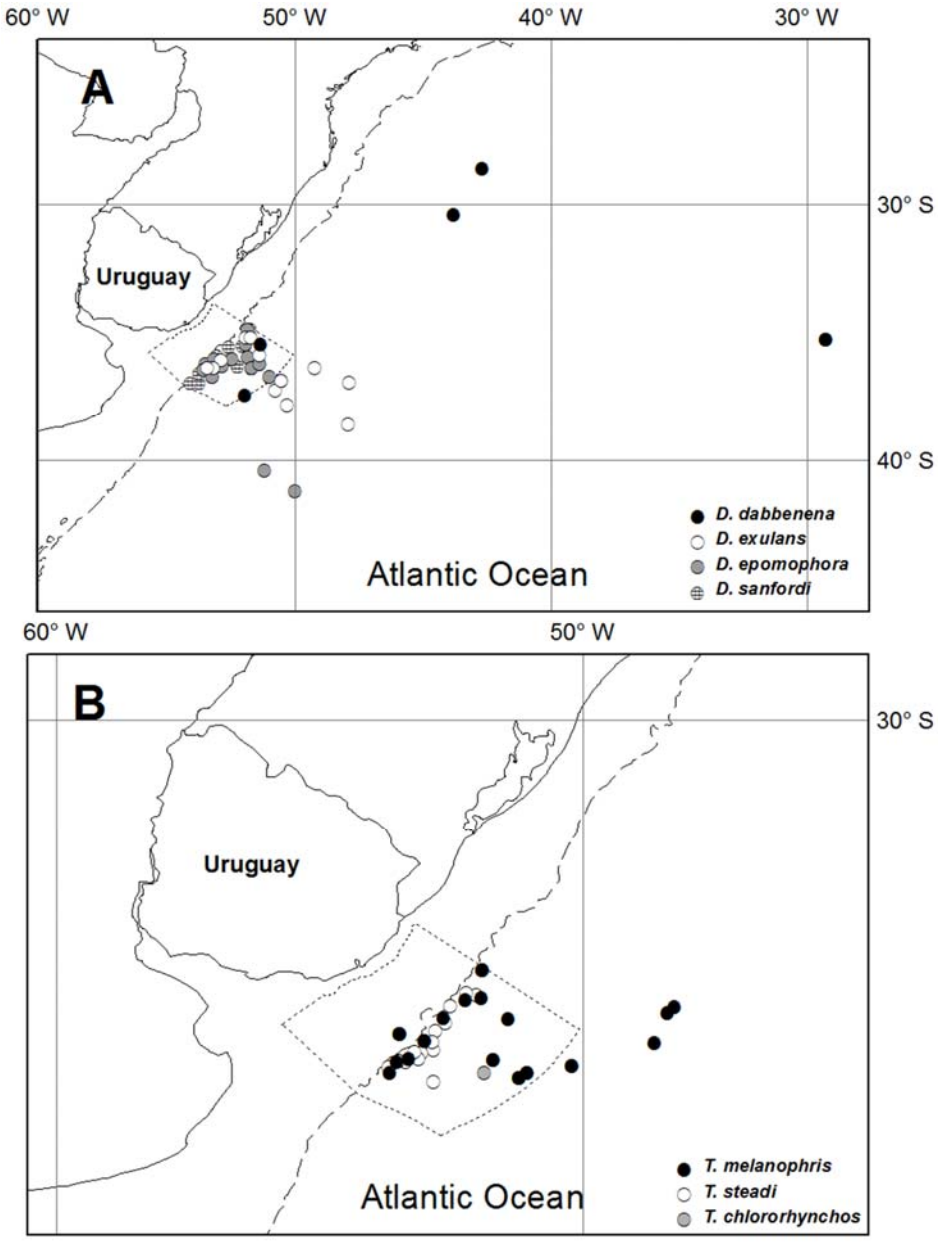

Figure 1. Distribution of the sampled bycaught *Diomedea* (A) and *Thalassarche* (B) albatrosses. The Uruguayan Economic Exclusive Zone (EEZ; dotted line) and the 200 m isobath (dashed line) are represented.

Figure 2. Marine debris found in great albatrosses (southwest Atlantic). The codes are the species [Dd=*Diomedea dabbenena* (first row); De= *D. epomophora* (second row); Ds= *D. sanfordi* (remaining rows)] plus the reference number. There are two samples from a small number of individuals. All items were from the ventriculus, except for two individuals where those from the pro-ventriculus (p) and ventriculus (v), are labelled accordingly. Db 413: nylon lines, Db413: wood; Ds543 hook with multifilament line; remaining items are plastic fragments. Black line = 1cm scale.