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Marine debris ingestion by the South American Fur Seal from the Southwest Atlantic Ocean

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ABSTRACT

In this paper, we examined the ingestion of marine debris (MD) in South American fur seals (SAFS), *Arctocephalus australis*, found dead in coastal beaches of northern Argentina and southern Brazil. Seven percent of 133 SAFS analyzed presented marine debris in their stomach (n = 10), with no differences between sampling countries (Brazil n = 7, Argentina n = 3) and sexes (female = 3; male = 6). However, significant differences were observed between ages classes, with MD exclusively present in stomach contents of young specimens. Plastics represents 90% of MD ingested by the SAFS, whereas regarding the source, fishery-related items (e.g. monofilament lines) were the main MD (70%), with a lesser proportion of packaging (e.g. pieces of bags). Low numbers but large size pieces of MD were found in each stomach affected. Negative effects on the individuals could not be fully evaluated. Therefore, the potential impacts of the marine debris to the SAFS deserve further elucidation.

1. Introduction

Marine debris (MD), defined as solid materials of human origin discarded at sea or reaching the sea through other ways, is one of the most highly visible expressions of human impact on the marine environment (Ribic et al., 2010). Marine debris spoils the entire globe, from the poles to the equator and from shorelines, estuaries and the sea surface to the depths of the ocean (Thompson et al., 2009).

Every year, millions of tons of MD enter the ocean (Derraik, 2002) from a variety of pathways, including river and atmospheric transport, beach littering and directly at sea via aquaculture, shipping and fishing activities (GESAMP, 2016).

The global production of plastics increases annually (global production of plastics has increased from 5 million tons per year in the 1960s to 280 million tons per year in 2011; PlasticsEurope, 2012), a recent study estimated that around 2% to 5% of all plastic waste generated by the coastal countries (equivalent to 4.8 to 12.7 million tons) enters the ocean every year (Jambeck et al., 2015). Other study (Lebreton et al., 2017) estimated that between 2.8 and 18.6% of all plastic debris enter the ocean exclusively through rivers.

The detrimental consequences of debris contamination on marine organisms -including humans- that use the coastal zone have been broadly documented. Twenty years ago, at least 267 species have been quantified to be affected by this kind of marine pollutant, including 86% of all sea turtle species, 44% of all seabird species, and 43% of all marine mammal species (Laist, 1997). Furthermore, MD can cause problems to some human activities by fouling ship propellers or clogging intake filters of power plants or aquiculture systems (Sheavly and Register, 2007).

The impact of MD in marine animals is primarily mechanical due to

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ingestion and/or entanglement in synthetic ropes, lines or drift nets (Laist, 1987, 1997).The first reports on this issue were published in the 1960s (Gall and Thompson, 2015; and references therein) with fatalities being well documented mainly for birds, turtles, fish and marine mammals (Laist, 1997). The transference of contaminants from plastic debris to the environment and to wildlife has also been a cause of a growing concern (e.g. Teuten et al., 2007, 2009).Moreover, it has been reported that marine debris contributes to the rafting and transport of numerous marine organisms over long distances due to the debris' floating potential (Gall and Thompson, 2015).

The latest review on debris impacts on marine life, reporting almost 700 species affected by this anthropogenic pollutant (Gall and Thompson, 2015), which represents a nearly 2.5-fold increase over the species list reported by Laist in 1997.

In the Southwest Atlantic Ocean, the marine debris problem has been documented at least from the early 1970s and the exposed marine biota since the 1990s (see Ivar do Sul and Costa, 2007, for a historical overview). Particularly for the coast of Argentina, Uruguay and Brazil, marine debris ingestion was reported, at least, in seabirds (e.g. Copello and Quintana, 2003; Jiménez et al., 2015; Seco Pon and Denuncio, 2016), turtles (e.g. González Carman et al., 2014; Teryda, 2015) and marine mammals (e.g. Secchi and Zarzur, 1999; Oliveira et al., 2008; Denuncio et al., 2011; Milmann et al., 2016).

In this paper, we presented the first information on marine debris ingestion for one of the most numerous and widely distributed pinnipeds species along the coasts of South America, the South American Fur Seal *Arctocephalus australis*.

2. Materials and methods

A total of 133 South American Fur Seal (SAFS) found dead on the coast of northern Argentina and southern Brazil were studied. In Argentina, 48 SAFS were collected during systematic surveys carried out during 2015, between the localities of Mar del Plata and Villa Gesell, in the Buenos Aires Province (Fig. 1). In addition, 85 specimens were collected from systematic surveys (and few occasional sampling) along sandy beaches of Brazil between Torres and the Lagoa do Peixe National Park, in the northern coast of Rio Grande do Sul State, between 1994 and 2012 (Fig. 1).

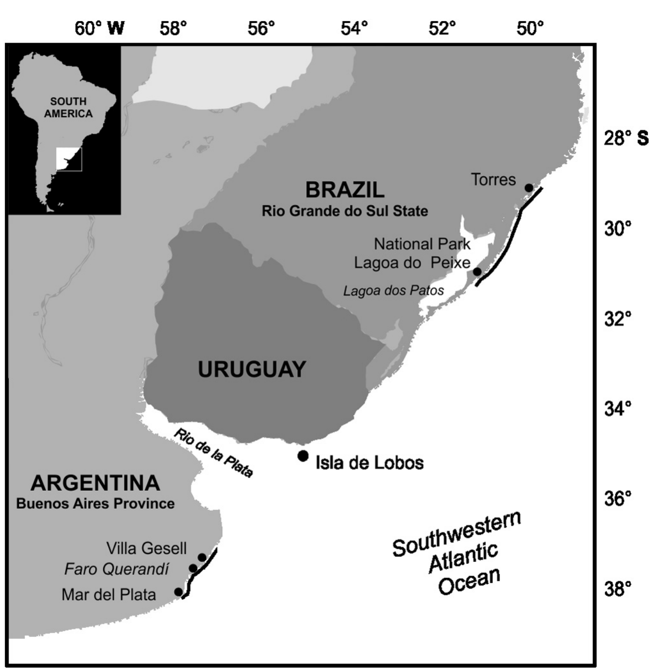

Fig. 1. Systematic survey areas carried out in Brazil and Argentina where were collected the South American Fur Seal stranded on beaches during 1994–2012 and 2015 respectively.

It is important to note that both study areas are approximately equidistant from the greatest concentration of SAFS at Isla de Lobos and other Uruguayan Islands, with an estimated population of 300,000 in the 1990s (Páez, 2006; Crespo et al., 2015) (Fig. 1).

SAFS stomachs were removed during necropsies in the field, or in a few cases in the laboratory in order to later filter and fix in formalin or ethanol the stomach contents for later diet analyses. Stomachs were fully inspected in order to detect MD, ulcerations and obstructions. All marine debris found were measured and classified by type (plastic, metal, wood, glass, etc.) and source (fishery-related items such as monofilament lines, ropes, net fragments; and packaging debris such as plastic rubber bands, cellophane, plastic bags, etc.) following Denuncio et al. (2011).

Data were expressed in relative frequency of occurrence (FO %),defined as the percentage number of SAFS stomach with MD. The occurrence of MD was analyzed by sex (female/male), sampling country (Argentina/Brazil) and age categories (yearling, juvenile, subadult, adult, following Borella et al., 2014).In this sense, yearlings were defined as individuals smaller than 89.75 and 93.62 cm of total length (TL) for females and males; juveniles were defined as individuals between 89.75 and 99.12 and between 93.62 and 135.80 cm of TL for females and males; sub-adults were defined as individuals between 99.12 and 129.36 and between 135.80 and 154.25 cm of TL for females and males and adults were defined as individuals larger than the last category.

In addition, presence-absence of MD in the SAFS was modeled using a binomial Generalized Linear Model GLM (logit-link distribution of errors; Crawley, 2005) as response of the above-mentioned explanatory variables (sex, country and age categories). A stepwise (backward/forward) procedure was applied to select the model that fitted the data best, in conjunction with AIC values (Akaike's Information Criterion; Akaike, 1973). The model having the lowest AIC was chosen.

The statistical analyses were performed in R 3.3.1 (R Development Core Team, 2015).

3. Results

3.1. Specimens affected by marine debris

The total length (TL) of the South American Fur Seals (SAFS) analyzed in this study ranged between 84 and 148 cm (107 ± 13.7 cm, n = 48) for Argentinean specimens and between 88.5 and 155 cm (113.2 ± 20.2 cm, n = 85) for Brazilian specimens. Previous the necropsies, the specimens were externally examined and no evidences of entanglement were found.

Seven percent (n = 10) of the 133 specimens analyzed in this study had ingested marine debris (MD). MD was found in 6.2% SAFS (n = 3) from Argentina and in the 8.0% of the specimens (n = 7) from Brazil. Within the SAFS affected by MD, 60% were males, 30% females and 10% of unknown sex.

Presence of MD was only significantly affected by the age classes (GLM, N = 133, null-deviance = 65.28, null-df = 54.74, p = 0.014). Only young specimens ingested MD: yearlings in Brazil and juveniles in Argentina. The smallest specimen was 84 cm TL female from Brazil, whereas the largest was 103 cm TL male juvenile from Argentina (Table 1). No sub-adult and adult age classes had ingested MD in the 133 SAFS analyzed.

3.2. Type and source of marine debris ingested

A total of 13 MD items were found in all stomach content analyzed, small number of MD items (1 to 2 items) was found per stomach content analyzed (Table 1). All MD ingested were conspicuous, from few centimeter pieces of fishing lines (e.g. specimen GEMARS 0283, Fig. 2A) to large pieces of plastic bags (e.g. specimen UNMDP-Aa41/15 with a

Table 1
Descriptive information of the specimens who ingest marine debris and marine debris information in the South American Fur Seal, *Arctocephalus australis*, stranded in southern Brazil and northern Argentina. TL: total length. N° items: number of marine debris per stomach. UNMDP: Universidad Nacional de Mar del Plata, GEMARS: Grupo de Estudos de Mamíferos Aquáticos do Rio Grande do Sul.

Collection	Specimen ID	Sex	TL (cm)	Country	N° items	Debris description	Source	Type	Food content
UNMDP	Aa49/15	Female	84	Argentina	1	Fishing hook	Fishing-related	Metal	Hard parts
UNMDP	Aa41/15	Female	87	Argentina	2	Plastic bag	Packaging	Plastic	Empty
UNMDP	AaR3	Female	94.5	Argentina	2	Plastic bag	Packaging	Plastic	Hard parts
GEMARS	GEMARS 0594	Unknown	88	Brazil	1	Bundle of fishing line	Fishing-related	Plastic	No data
GEMARS	GEMARS 1560	Male	88.5	Brazil	1	Plastic bag	Packaging	Plastic	Empty
GEMARS	GEMARS 0283	Male	89.5	Brazil	1	Fishing line	Fishing-related	Plastic	No data
GEMARS	GEMARS 0673	Male	92	Brazil	1	Bundle of fishing line	Fishing-related	Plastic	Empty
GEMARS	GEMARS 0669	Male	95	Brazil	1	Bundle of fishing line	Fishing-related	Plastic	Hard parts
GEMARS	GEMARS 0309	Male	102	Brazil	2	Fishing line	Fishing-related	Plastic	Hard parts
GEMARS	GEMARS 0657	Male	103	Brazil	1	Fishing line	Fishing-related	Plastic	No data

green plastic bag of maximum length of 26.11 cm and 246.57 cm^2 of surface area, Fig. 2B). No ulcerations were found in the inner stomach wall of the specimens.

The most frequent MD item were fishing lines followed by pieces of plastic bags (Table 1). Also, the fishery-related MD were the most frequent source of MD (70%). Moreover, except for the presence of a fishing hook (metal) in one stomach (specimen UNMDP-Aa49/15), the MD found in the SAFS analyzed in this paper were all plastics (Table 1).

4. Discussion

Marine debris, and in particular plastic debris, is a global problem with serious implications for the marine ecosystem and human health (Lebreton et al., 2017). The consequences of ingestion and entanglement are considered to be harmful for marine fauna. Several studies have quantified the occurrence of marine debris ingested by megafauna species in the Southwest Atlantic Ocean (e.g. Colabuono et al., 2009; Tourinho et al., 2010; Denuncio et al., 2011; Jiménez et al., 2015; Petry and Benemann, 2017). However, this is the first study to report the ingestion of marine debris (MD) by the South American Fur Seal, *Arctocephalus australis*.

Seven percent of 133 SAFS analyzed in the present study presented MD in their stomach. Plastic fragments were the predominant items found. Plastic items are consistently among the most numerically abundant and persistence types of marine debris in all ocean basins (OSPAR, 2007; UNEP, 2005, 2009). Previous studies demonstrate that between 50% and 80% of waste in the oceans is composed by plastics (Laist, 1987).

Following this global tendency, the area studied in this paper, comprising parts of the exclusive economic zones of Argentina, Uruguay and Brazil, is strongly affected by this kind of marine debris (Acha et al., 2003).

The same area was recognized as foraging grounds of the SAFS that breed in the Uruguayan rookeries span from central Argentina to southern Brazil (Pinedo, 1986, 1998; Dassis et al., 2012; Vales et al., 2014; González Carman et al., 2016). This area has high primary productivity provided by the confluence of cold austral waters, from the Malvinas/Falklands Current, and warm tropical waters, brought by the Brazil Current (Ciotti et al., 1995). This ocean patterns also promotes the refloating and accumulation of MD in the area (Acha et al., 2003; Eriksen et al., 2014).

The dominance of plastic as MD in the stomach content is not

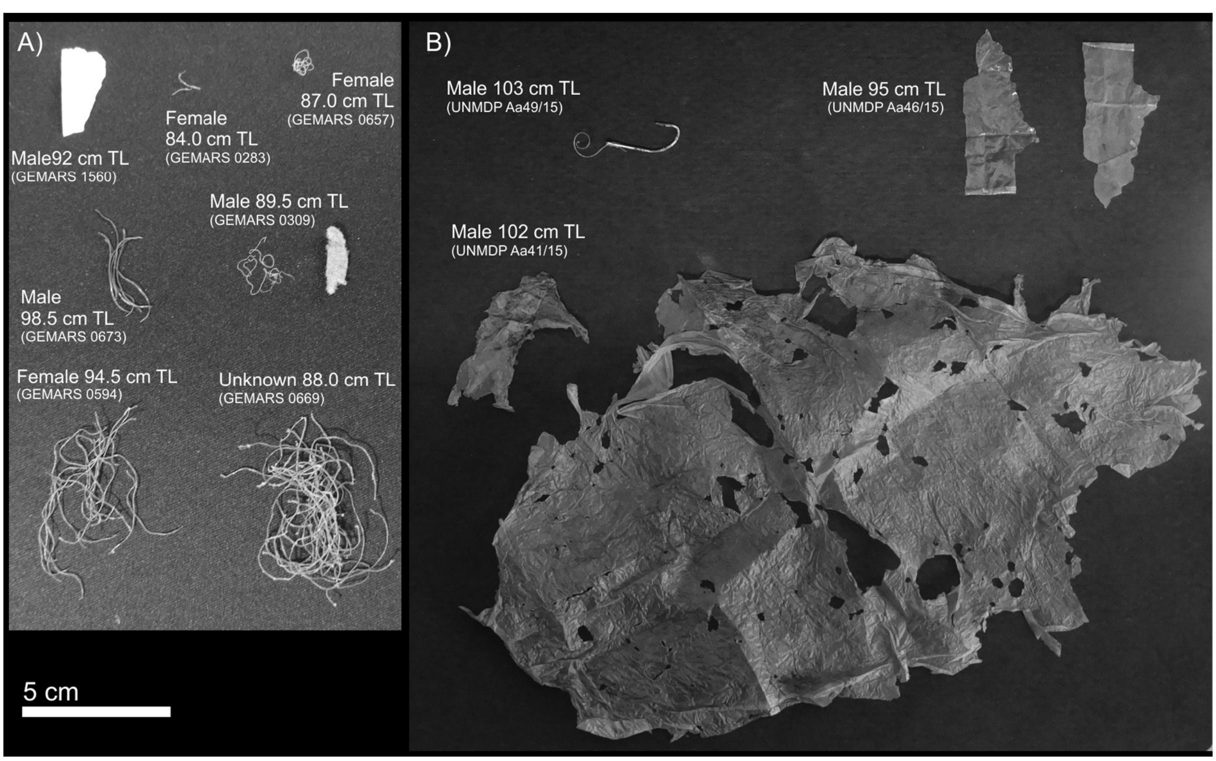

Fig. 2. Marine debris found in stomachs of South American Fur Seal *Arctocephalus australis* stranded in southern Brazil (A) and northern Argentina (B).

exclusive for the SAFS but also for other species of marine mammals of the Southwestern Atlantic Ocean. For instance, for the endangered Franciscana dolphin, the presence of plastic debris in stomach content was very important for individuals from Buenos Aires province and more plastic debris was found in individuals from inner estuarine waters of the Rio de la Plata than in specimen from marine areas (Denuncio et al., 2011). Along the Brazilian coast, the ingestion of plastic debris have also been reported for various marine mammals besides Franciscana, including the Guiana dolphin, *Sotalia fluviatilis* (Geise and Gomes, 1992; Di Beneditto and Ramos, 2014), rough-toothed dolphin, *Steno bredanensis* (Meirelles and do Rego Barros, 2007), common bottlenose dolphin, *Tursiops truncatus* (Milmann et al., 2016), short-finned pilot whale, *Globicephala macrorhynchus* (Barros et al., 1997), Blainville's beaked whale, *Mesoplodon densirostris* (Secchi and Zarzur, 1999) and South American sea lion, *Otaria flavescens* (Oliveira et al., 2008). Moreover, many species of seabirds and sea turtles are affected by this anthropogenic pollutant (e.g. Tourinho et al., 2010; González Carman et al., 2014; Teryda, 2015, Jiménez et al., 2015).

The major prey consumed by the SAFS in the area, are the principal species exploited by the fisheries (Oliveira et al., 2008; Vales et al., 2014) leading to interaction between SAFS and fishery fleets off South Brazil and Uruguay. The main source of MD we found was fishery-related items (monofilaments lines and a hook), represented the 70% of the total MD ingested. Although *A. australis* does not appear to be a species with serious by-catch problems, some authors have found occasional interaction between SAFS and fisheries, and occasionally they are incidentally captured for artisanal or industrial fisheries (Machado, unpublished results; Majluf et al., 2002; De María et al., 2012; Mandiola, unpublished results).

The literature shows that fishery-related MD largely contribute to overall MD ingestion in several marine organisms. Within marine mammals, 78% of the total MD ingested by stranded sperm whales along the North Sea were classified as fishing related (Unger et al., 2016). Also represented 35.7% of the total MD ingested in 106 Franciscana dolphins studied in Argentina (Denuncio et al., 2011). Fishery-related items were also found in occasional stranded of other marine mammals in the coast of Southern Brazil (same study area) such as the South American sea lion *Otaria flavescens* (a fishing hook), a Sub-Antarctic Fur Seal, *A. tropicalis* (a large fishing net). Besides, a fishing sinker was found in a juvenile South American Sea Lion at Isla de Lobos, Uruguay (Franco-Trecu et al., 2017).

Fishery related items had high prevalence in other marine species as sea birds (*Spheniscus magellanicus*, 42% of total MD; Brandão et al., 2011) and sea turtles (*Chelonia mydas*, 39.5% of green turtles, Bugoni et al., 2001) found dead in the coast of Brazil. Also several albatrosses species caught in Uruguayan shelf have ingested fishery-related debris items (Jiménez et al., 2015).

MD ingestion by young specimens is not only the case in SAFS. Young Franciscanas were also affected by MD (Denuncio et al., 2011; Di Beneditto and Ramos, 2014) in the Southwest Atlantic Ocean. Laist (1987) suggested that MD might represent an item of curiosity or an object of play for marine mammals, whereas Baird and Hooker (2000) suggested that particularly in cetaceans juveniles take up MD due to inexperience with regard to appropriate prey. By contrast, Walker and Coe (1990) suggested that mistaken ingestion of debris due to its resemblance to preferred prey is unlikely to occur in odontocete cetaceans because of their echolocation capabilities.

In addition, the possibility of indirect ingestion from prey cannot be ruled out. Denuncio (pers. obs.), found a cellophane piece in the digestive tract of an indigested teleost white croaker (*Micropogonias furnieri*) found in the stomach content of a Franciscana dolphin from Argentina by-caught in 2012 in the Rio de la Plata estuary. The cellophane was one of the main MD items found in Franciscana dolphins from Bahia Samborombón, Argentina (Denuncio et al., 2011), and this finding reinforces the hypothesis of indirect ingestion. The recent article published evidencing MD ingestion in a sciaenid teleost fish from northeast Brazil (Ferreira et al., 2016) also provide more support to this hypothesis.

Nowadays, information on MD ingestion based on a high sample number of marine mammals from the Southwest Atlantic Ocean are rare or unpublished. Only 7% of the SAFS studied in this paper ingested MD, a low number in comparison with the 28.1% of Franciscana dolphins affected by this kind of marine pollutant in the same area (Denuncio et al., 2011). Differences in feeding habits and behavior between the both top predator could drive their differences regarding size and number of MD ingested. For instance, Di Beneditto and Ramos (2014) found that dolphins with demersal-benthic feeding habits ingested more MD (Franciscana, 15.7%) than dolphins with pelagic habits (Guiana dolphins, 1.3%) in southeastern Brazil. The authors conclude that because of a lot of MD is found on the sea floor (buried or semi-buried), this can be easily re-suspended and accidentally ingested together with prey by Franciscanas. Following this interpretation, the low frequency of MD ingested by the SAFS (in comparison with other species) could be associated with the fact that the species mainly feeds on pelagic prey (Oliveira et al., 2008; Peres Salles, 2015; Vales et al., 2015). Nevertheless, a high incidence of plastics debris has also been found in the digestive tract of many seabirds species that forage and feed mainly in the water column in this region, as the Magellanic penguin, *Spheniscus magellanicus* (e.g. Mäder et al., 2010; Brandão et al., 2011). Therefore, other factors, possibly including behavioral and sensory mechanisms, contribute to marine debris uptake.

Marine debris ingestion in marine organisms was suggested to cause sub-lethal effects, such as partial obstruction of the gastrointestinal tract and reduction of feeding stimulus, compromising the energy consumption and the individuals's health (Bjorndal et al., 1994; Jacobsen et al., 2010; Meirelles and do Rego Barros, 2007; Secchi and Zarzur, 1999; Tourinho et al., 2010). Ingestion of MD may result in a false sensation of satiation for the animal, leading to reduced appetite and meal size (Bjorndal et al., 1994; Gregory, 1991; Ryan et al., 1988; Spear et al., 1995). Sub-lethal effects are particularly difficult to quantify. Most of the animals we found had empty stomachs or presented just hard remains in their digestive tracts, suggesting that they did not have ingested any food in the last 24 h before death. Also, the toxicological effects associated with plastic ingestion neither can be ruled out (see Teuten et al., 2007, 2009).

Finally, at present there is no clear evidence for the magnitude of consequences of the encounters between debris and marine life on population level. It is still very difficult to link such changes in natural populations to a single cause agent as MD (Gibbs et al., 1987). A lack of evidence does not therefore necessarily imply a lack of effect, and the significance and impact of MD in the SAFS deserves further elucidation.

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