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Plastic ingestion in Franciscana dolphins, *Pontoporia blainvillei* (Gervais and d'Orbigny, 1844), from Argentina

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ABSTRACT

Plastic debris (PD) ingestion was examined in 106 Franciscana dolphins (*Pontoporia blainvillei*) incidentally captured in artisanal fisheries of the northern coast of Argentina. Twenty-eight percent of the dolphins presented PD in their stomach, but no ulcerations or obstructions were recorded in the digestive tracts. PD ingestion was more frequent in estuarine (34.6%) than in marine (19.2%) environments, but the type of debris was similar. Packaging debris (cellophane, bags, and bands) was found in 64.3% of the dolphins, with a lesser proportion (35.7%) ingesting fishery gear fragments (monofilament lines, ropes, and nets) or of unknown sources (25.0%). PD ingestion correlated with ontogenetic changes in feeding regimes, reaching maximum values in recently weaned dolphins. Because a simultaneous increase in gillnet entanglement and the bioaccumulation of heavy metals take place at this stage, the first months after trophic independence should be considered as a key phase for the conservation of Franciscana dolphin stocks in northern Argentina.

1. Introduction

Plastics are synthetic organic polymers, lightweight, strong, durable and inexpensive, properties that make it widely used (Laist, 1987). Considerable quantities of plastic debris (PD) can be found in coastal marine and estuarine ecosystems and millions of tons of these pollutants enter the ocean each year (Derraik, 2002). The increasing abundance of plastic debris in the marine environment and their threat to marine life was ignored for a long time (Shomura and Godfrey, 1990; Stefatos et al., 1999), although recently plastic impact on marine fauna, particularly marine turtles and birds, has been internationally recognized (Gregory, 2009; Pierce et al., 2004). The impact of PD to marine animals is primarily mechanical due to ingestion and/or entanglement in synthetic ropes, lines or drift nets (Laist, 1987, 1997; Quayle, 1992). Ingestion of PD has been reported for fishes, seabirds, turtles and marine mammals (Boerger et al., 2010; Bugoni et al., 2001; Derraik, 2002; Tourinho et al., 2010). A minimum of 267 species has been affected by this kind of marine pollution, including 86% of all sea turtle species, 44% of all seabird species, and 43% of all marine mammal species (Laist, 1997).

The debris ingested by marine mammals has been typically detected in necropsies of incidentally captured or stranded animals. The impact of the debris on the health of cetaceans is variable because the debris is diverse and often present in small amounts (Baird and Hooker, 2000; Laist, 1997; Meirelles and Barros, 2007; Walker and Coe, 1990). Nevertheless small amounts can have long term effects (Jacobsen et al., 2010) and can partially or totally block the digestive tract (Laist, 1987).

Among cetaceans, at least 26 species have been documented with PD in their stomachs or digestive system tracts (Baird and Hooker, 2000; Coleman and Wehle, 1984; Laist, 1987; Tarpley and Marwitz, 1993). In the Southwestern Atlantic Ocean, it has been rarely reported. Pinedo (1982) and Bassoi (1997) reported the presence of PD in Franciscana dolphins from Southern Brazil (Rio Grande do Sul), whereas there are occasional reports on Guiana dolphins (*Sotalia guianensis*; Geise and Gomes, 1992), rough-toothed dolphin (*Steno bredanensis*; Meirelles and Barros, 2007) and Blainville's beaked whale (*Mesoplodon densirostris*; Secchi and Zarzur, 1999) from Brazil. Stomach obstructions by plastic bags were recorded in stranded bottlenose dolphins (*Tursiops truncatus*) in Argentina (R. Bastida, unpublished information).

The Franciscana, *Pontoporia blainvillei*, is a small cetacean endemic to the Southwestern Atlantic Ocean, ranging from Itaúnas (18°25′ S, 30°42′ W, Brazil) to Golfo Nuevo (42°35′ S, 64°48′ W, Argentina) (Bastida et al., 2007; Crespo et al., 1998; Siciliano, 1994). Its distribution is restricted to coastal waters up to 30 m depth (Danilewicz et al., 2009; Pinedo et al., 1989), which makes it more vulnerable to anthropogenic activities.

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The main impact of anthropogenic activities affecting this species is the incidental captures in gillnet fisheries, which occurs all along its geographical distribution (Ott et al., 2002 and references therein). Between 2000 and 3000 Franciscana dolphins are incidentally caught each year, with more than 450 dolphins of these captures corresponding to the northern waters of Argentina (Bastida et al., 2007; Cappozzo et al., 2007). For this reason, the Franciscana has been recently classified as Vulnerable A3d by the IUCN along its whole distributional range (Reeves et al., 2008).

The aim of the present study was to analyze the presence of PD in digestive tracts of Franciscana dolphin (*P. blainvillei*) from waters of northern Argentina.

2. Materials and methods

The study was conducted along the coastal waters of northern Argentina, from Bahía Samborombón (36°26′ S, 57°07′ W) to Mar del Plata (38°00′ S, 57°33′ W), covering a total coastal front of ca. 350 km. Entangled dolphins were collected in cooperation with six local artisanal fishery communities (Fig. 1).

The northern coast of Argentina includes two main ecosystems, clearly different in its environmental parameters: an estuarine area and a marine coastal area. The northern ecosystem includes Bahía Samborombón, being the southern margin of the La Plata River Estuary (LPRE) and commonly characterized by shallow and brackish waters, with activities of both artisanal and commercial fisheries (Boschi, 1988; Guerrero et al., 1997). The marine coastal ecosystem extends south to Bahía Samborombón, and is characterized by extended sandy beaches where main human activity is tourism, and fisheries play a secondary role. Main touristic cities of Argentina are located in this area, with the consequent human disturbance during summer months (Fig. 1).

A total of 106 entangled dolphins were recovered from gillnet fisheries between 2007 and 2010 in both estuarine and coastal marine environments (Table 1). Body length ranged between 72 and 160 cm (118 ± 15.4 cm), with no differences in the length composition between estuarine and marine Franciscana dolphin groups ($Chi^2 = 13.34$; $df = 8$; $p = 0.11$). Most of dolphins (90%) were sexually immature, according to updated available information of sexual maturity of Franciscanas from the nearby area (Botta et al., 2010).

Fig. 1. Study area showing estuarine and marine ecosystems with artisanal fisheries communities where the dolphins were obtained (RS: Río Salado, SC: San Clemente del Tuyú, MA: Mar de Ajó, VG: Villa Gesell, MC: Mar Chiquita, MDP: Mar del Plata) and the biggest cities of Argentina (Buenos Aires and La Plata) and Uruguay (Montevideo).

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Table 1
Total number of Franciscana dolphins analyzed in the present study, discriminated by ecosystem and sex.

Area	Males	Females	Undetermined	Total
Estuarine	28	20	1	49
Marine	29	19	9	57
Total	57	39	10	106

Complete digestive tracts were removed during necropsies and the prey remains were immediately filtered and fixed (formalin or ethanol) for diet analyses. Esophagus, stomachs and intestines were fully inspected in order to detect PD, ulcerations and obstructions. Plastic debris found were counted, measured and classified by type and source. Two main sources of plastic debris were identified: *fishing-related* items (monofilament lines, ropes, net fragments) and *packaging* debris (plastic rubber bands, cellophane, plastic bags, etc.). Other remains (hard plastic fragments) were not assigned to these categories, and considered of *unknown source*.

Data was expressed in relative frequency of occurrence (FO%), defined as number of times PD occurs in dolphin digestive tracts. The occurrence of PD was analyzed by sex, total length categories (at 10 cm intervals, following Kasuya and Brownell, 1979) and different sampling areas (estuarine and marine environments) using Chi-square test of frequencies and log-linear analysis. One-way non-parametric permutation multivariate analysis of variance (PERMANOVA) was applied to test the differences in diet composition in dolphins with and without PD ingestion.

Table 2
Associations (likelihood-ratio) between habitat, sex and PD source. Statistical tests used were from a hierarchical log-linear analysis of a contingency table of habitat (two levels: estuarine and marine), sex (two levels: males and females) and PD source (three levels: packaging, fishing and unknown).

Effect	*df*	Chi^2	*p*
Habitat–sex	8	10.494	0.232
Habitat–PD source	6	4.136	0.658
Sex–PD source	6	8.599	0.197

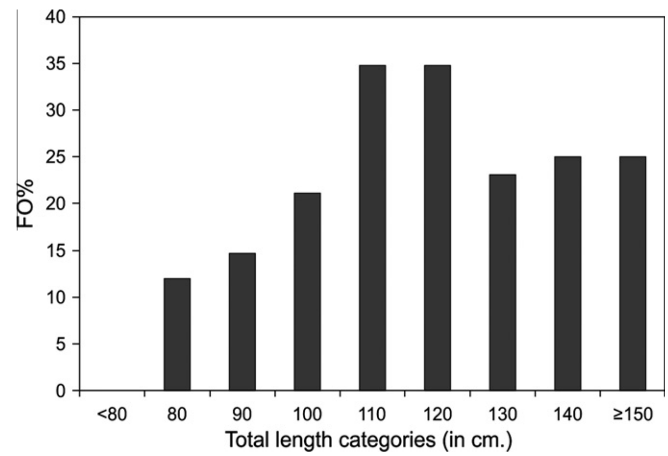

Fig. 2. Frequency of occurrence (FO%) of PD in different total length categories of *Pontoporia blainvillei*.

3. Results

A total of 28.1% of the dolphins analyzed presented PD in their stomach contents. PD was found only in stomachs, and no dolphins presented obstructions or ulcerations in the digestive tracts. Packaging debris was found in 64.3% of the dolphins, with a lesser proportion of dolphins ingesting fishery-related fragments (35.7%) and those of unknown source (25.0%). Packaging debris was constituted mainly by cellophane bands (52%), bags (11.4%) and plastic rubber bands (6.8%), whereas fragments of ropes (12.7%), monofilament lines (8.1%) and nets (4.5%) represent the fishery-related debris. A 4.5% of the fragments represent plastics of unknown source.

The 53.6% of the dolphins had only one plastic fragment in the stomach, whereas 46.4% had between 2 and 5 plastic items per stomach. The overall mean was 1.81 ± 1.05 items per stomach. In the 50% of the dolphins that had more than one fragment in their stomach, they were of a different source. The size of PD found were between 0.2 and 11.4 cm (7.45 ± 5.54 cm), with the cellophane bands of cigarette packages being the longest (11.4 cm). PD surface were less than 7.5 cm^2 (2.01 ± 3.46 cm^2) being the fragments of plastic bags the biggest. The hard plastic fragments were less than 0.6 cm in length and 0.2 cm^2 in surface.

Log-linear models revealed no association between sex, ecosystem and source of the PD (Table 2). The proportion of dolphins with PD was significantly dependent of total body length ($Chi^2 = 4.95$; $df = 8$; $p = 0.025$). The occurrence of PD rapidly increased in yearlings, reaching maximum occurrences between 110 and 130 cm of body length, with reduced smaller values in adult animals (>130 cm) (Fig. 2). Diet composition showed no significant differences between animals with and without PD in their stomachs (Table 3).

The proportion of dolphins ingesting PD was significantly higher in the estuarine ecosystem (34.6%) than in marine coastal areas (19.2%; $Chi^2 = 5.00$; $df = 1$; $p = 0.021$). With the exception of the lack of plastic rubber bands and a less abundance of monofilament lines in marine Franciscana dolphins, the type of PD recorded in estuarine and marine Franciscana dolphins was similar (Fig. 3).

4. Discussion

The absolute dominance of plastic in marine debris could be explained for its properties of resistance and abundance in all marine ecosystems (Derraik, 2002; Laist, 1987; Moore, 2008). Between 50% and 80% of anthropogenic debris in the ocean is composed by plastics (Derraik, 2002; Gregory and Ryan, 1997; Tourinho et al., 2010) and it constitutes the 44% (weight) of human debris in the LPRE (Acha et al., 2003).

The question about why marine organisms ingest debris was tried to explain by various authors. Some authors suggest that organism confuse the marine debris with prey (Carpenter et al., 1972; Derraik, 2002; Moore, 2008). 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. Then, in case of marine mammals, the marine debris might represent an item of curiosity or an object of play (Laist, 1987). Juvenile inexperience to eat the appropriate prey was also suggested for cetaceans (Baird and Hooker, 2000), whereas the possibility of indirect ingestion from prey cannot be ruled out. Our study confirms that a high proportion of the Franciscana dolphins inhabiting the La Plata River Estuary (LPRE) and the nearby marine area regularly ingest plastics. This fact also confirms that PD is commonly found and available to marine fauna in this South American region. The most important source of PD is packaging materials and discarded fishing gear, and it is directly related with human activities of the region. Urban areas of both Argentina and Uruguay are established in the LPRE, with three main cities being Buenos Aires, La Plata and Montevideo which concentrate about 12.2 million inhabitants. The marine

Table 3
Analysis of PERMANOVA testing differences in diet composition (absolute abundance of prey) according to presence/absence of PD. Prey presence was expressed as the mean ± SD number of pieces per stomach.

Factor	With plastic debris			Without plastic debris			*N*	*df*	*F*	*p*
	Fish	Cephalopods	Crustaceans	Fish	Cephalopods	Crustaceans				
Estuarine	46.82 ± 50.56	–	2.35 ± 4.80	32.95 ± 30.92	–	0.30 ± 0.63	49	1	0.235	0.899
Marine	45.00 ± 90.76	8.45 ± 14.76	0.36 ± 0.67	38.52 ± 76.68	15.62 ± 32.13	3.75 ± 20.68	57	1	1.965	0.111
Both	46.10 ± 67.38	3.32 ± 9.91	1.57 ± 3.85	42.13 ± 64.95	11.02 ± 27.22	2.75 ± 16.85	106	1	1.464	0.122

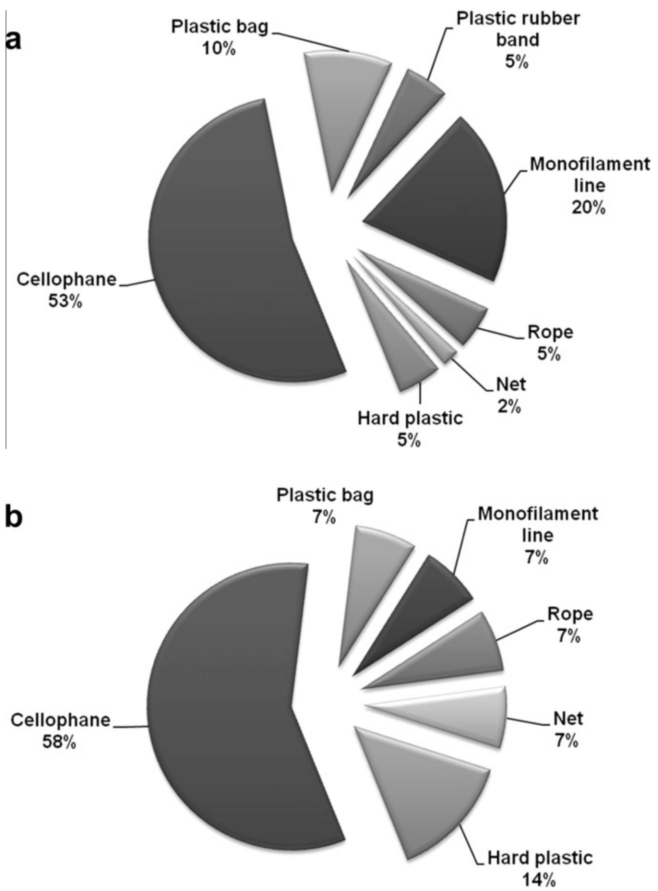

Fig. 3. Percentage of plastic debris types ingested by *Pontoporia blainvillei* in estuarine (a) and marine (b) ecosystems.

sector is characterized by the presence of the most important beach resorts of Argentina, with a summer population exceeding 2 million people and a permanent source of solid urban waste. Packaging debris constitute near 90% of the fragments found in marine beaches and are particularly frequent in Punta Rasa, the southernmost limit of the LPRE (SC in Fig. 1; Colombini et al., 2008).

La Plata River basin is the second largest of South America, draining ca. 4 million km^2 from Argentina, Bolivia, Paraguay, Brazil and Uruguay, with an average discharge of 20,000–25,000 m^{-3} s^{-1} (Urien, 1967). The packaging material ingested by the dolphins (cellophane bands, plastic bags) is easily transported by water and could be originated in other areas of the basin and drained into the estuary. The salt intrusion produce a great horizontal and vertical stratification, leading to the establishment of a bottom salinity front (Guerrero et al., 1997) and a zone of highest turbidity (Framiñan and Brown, 1996), particularly along Bahia Samborombon. This system was recognized as an efficient trap for plastic debris (Acha et al., 2003), and is a foraging habitat, because is also the spawning and nursery grounds of whitemouth croackers (*Micropogonias furnieri*; Acha et al., 1999; Jaureguizar et al., 2003), the main prey of Franciscanas in LPRE (Rodríguez et al., 2002). This fact arise the possibility not only of a direct ingestion of PD, but also by the indirect ingestion of small degraded fragments present in prey digestive tracts. A further analysis of the degree of degradation in ingested PD may enlighten this situation.

The northern waters of Argentina, both estuarine and marine, concentrate an intense artisanal and commercial coastal fisheries activity, and annual landings average ca. 68% of the total coastal catches of Argentina (Ministerio de Agricultura, Ganaderia y Pesca; http://www.minagri.gob.ar/SAGPyA/pesca/index.php). All the fishery gear debris were clearly identified as those regularly used by the local coastal fleets.

Both sexes in marine or estuarine habitats are impacted by plastics of similar source. The same types of PD seem to be available to all Franciscana dolphins, and no selection or differential impact was detected. This could be related with the similar habitat use in males and females of this species (Danilewicz et al., 2009). Franciscanas from marine areas of southern Brazil show similar occurrence of PD in stomach contents (17% of 36 stomachs; Bassoi, 1997; but with a predominance of fishing gear fragments).

The small number and size of the fragments found in healthy dolphins suggest that this material is not lethal. In fact, dolphins did not present ulcers along the digestive tract, or revealed relevant obstructions. Nevertheless the presence of bigger fragments and the effect of plastic digestion cannot be ruled out as a potential cause of death. Plastic 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 its health (Bjorndal et al., 1994; Jacobsen et al., 2010; Meirelles and Barros, 2007; Ryan, 1987; Secchi and Zarzur, 1999; Tourinho et al., 2010). Within these sublethal effects it should be considered those associated with the transfer of persistent organic pollutants (POPs) sorbed to surface of plastic (Rios et al., 2007). Moreover, our results showed that the presence of plastic does not affect the prey preferences of the Franciscana, because no differences in the absolute abundance of diet were detected with or without PD ingestion. In addition to this, no dolphin showed evident physical obstructions or ulcerations in the esophagus and/or intestines.

The occurrence of PD showed a clear relation with ontogenetic changes in feeding regimes. Franciscana dolphins of northern waters of Argentina have a gradual weaning process between 2 and 7 months of age, at a range of body lengths of ca. 80–100 cm (Rodríguez et al., 2002). The sharp increase of PD occurrence during the weaning phase could be a consequence of the learning process of young animals to catch the prey by themselves, and the possible misidentification or accidental ingestion during prey handling.

The end of the lactation period in Franciscanas is characterized by a series of simultaneous processes that can be relevant to the conservation of this vulnerable species. The increasing PD ingestion after the trophic independence could be a potential cause of death in juvenile dolphins, whereas this period also coincide with a sharp increase in gillnet entanglement (Rodríguez et al., 2002)

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and the beginning of the bioaccumulation of Mercury and Cadmium (Gerpe et al., 2002). Although is still not clear how these processes interact and impact in the dolphin populations, they should be considered as a threat to the Franciscana dolphin stocks in northern Argentina. The identification of synergic effects is important for management purposes, particularly in the presence of genetically isolated populations as was suggested to be the case of the stocks of *P. blainvillei* in northern Argentina (Mendez et al., 2008, 2010).

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