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Marine debris boost in juvenile Magellanic penguins stranded in south-eastern Brazil in less than a decade: Insights into feeding habits and habitat use

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ABSTRACT

The Magellanic penguin (*Spheniscus magellanicus*) is a marine sentinel for the southern Atlantic Ocean that is a proxy of environmental quality. The presence of marine debris (macro-debris) in the stomach contents of emaciated juvenile penguins stranded from 21°S to 23°S was compared at different times (2000 and 2008), and the debris ingestion pathway was determined. The frequency of marine debris in the stomachs doubled in less than a decade, and flexible plastics remained the main ingested item over time (68–70%). The pelagic octopus, *Argonauta nodosa*, which inhabits the sea surface, was the most important prey species recovered in the stomach contents. The poor physical condition of the penguins that reach the northern migration limit (study area) reduces the diving capacity of the animals and increases their vulnerability to debris ingestion. Considering their preferred prey and physical condition, we conclude that the penguins likely ingested the marine debris in surface waters.

1. Introduction

Marine debris or marine litter is any persistent, manufactured or processed solid material disposed of or abandoned in the marine environment (UNEP, 2005), and it enters this environment *via* land or marine-based sources, accumulating in estuaries, along coastlines and on the seabed or floating in the water column in both coastal and oceanic areas (Murray, 2009; Splenger and Costa, 2008; Gall and Thompson, 2015). This type of pollution includes materials such as plastic, rubber, paper, glass, metal and Styrofoam and has been increasing globally since the 1940s (UNEP, 2005). Plastic comprises up to 97% of marine debris, and its dominance in the environment is explained by its abundance, persistence and pervasiveness (Ivar do Sul and Costa, 2014; Ryan, 2014; Gall and Thompson, 2015).

Marine organisms are negatively impacted by marine debris both directly (through ingestion, entanglement, smothering and physical injuries) and indirectly (through the transference and accumulation of pollutants) (Rios et al., 2007; Hong et al., 2013; Di Beneditto and Awabdi, 2014), and the ingestion of such material can damage the gastrointestinal tract of vertebrates by causing ulcerations, perforations and obstructions (Jacobsen et al., 2010; Brandão et al., 2011; Awabdi et al., 2013) as well as reduce the feeding stimulus (Macedo et al., 2011). Debris ingestion, mainly of plastics, affects seabirds, and the degree of vulnerability differs among species (Ivar do Sul and Costa, 2007; Ryan, 2008; Tavares et al., 2017).

The Magellanic penguin (*Spheniscus magellanicus* Forster, 1781) is the most abundant penguin species on South America, and in the south-western Atlantic Ocean, the species breeds from 41°S to 55°S. After the breeding season, the penguins disperse northwards during the austral winter (June to September), usually reaching northern Argentina, Uruguay and southern Brazil (33°S-40°S) (Williams and Boersma, 1995), but some specimens can reach areas that are considered the northern migration limit of the species in south-eastern Brazil (20°S-24°S) (Dantas et al., 2013). Approximately 97% of the Magellanic penguins that reach the Brazilian coast during the winter migrations are juveniles, and a few to several hundred specimens are found drifting or stranded on beaches annually (García-Borboroglu et al., 2010; Mäder et al., 2010). In 2008, the highest mortality event in a wintering area along the Atlantic coast involved > 4000 specimens from 5°S to 33°S (García-Borboroglu et al., 2010; Di Beneditto et al., 2015).

Similar to other seabird species, the Magellanic penguin is susceptible to marine debris ingestion, which has been widely reported in the literature (*e.g.*, Mäder et al., 2010; Pinto et al., 2007; Tourinho et al., 2010; Brandão et al., 2011; Di Beneditto et al., 2015; Tavares et al.,

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2017). This species is recognized as a marine sentinel for the southern Atlantic Ocean, so changes in the status of its populations reflect changes in the state of the waters it inhabits (Boersma, 2008). Thus, Magellanic penguin carcasses stranded on beaches are a proxy for environment quality.

The aims of this study are to (a) evaluate the presence of marine debris in the stomach contents of juvenile Magellanic penguins stranded from 21°S at 23°S at different times (2000 and 2008) and (b) discuss the arguments proposed by Tavares et al. (2017) to explain the ingestion of marine debris by this penguin. Tavares et al. (2017) assessed the incidence of debris in the gastrointestinal tracts of 22 seabird species feeding at different depths and found stranded along the south-eastern Brazilian coast (18°S-23°S) from 2010 to 2013, and they explained the ingestion of marine debris by the Magellanic penguin as a consequence of its deep-diving feeding behaviour. Additionally, they postulated that it is unlikely that the octopus *Argonauta nodosa*, the main prey recovered in penguin stomach contents in this area (Pinto et al., 2007; Di Beneditto et al., 2015), is ingested in surface waters. However, the results of the present study disagree with those of Tavares et al. (2017) and provide new insights into the ingestion of marine debris by Magellanic penguins (juveniles) in a wintering area off the coast of Brazil.

2. Materials and methods

In September 2000, > 100 juvenile Magellanic penguins were stranded along south-eastern Brazil (approximately 23°S), and forty fresh carcasses were randomly selected for stomach content analysis. From July to September 2008, 776 specimens were stranded between 21°S and 23°S, of which 46 fresh carcasses were randomly selected for analysis. The fresh carcasses were intact specimens with no missing body parts or exposed skeletons (Tavares et al., 2016).

Data on the items recovered in the stomachs (food and marine debris) in 2000 and 2008 were previously described in Pinto et al. (2007) and Di Beneditto et al. (2015), respectively. The authors of the present study recovered the penguin carcasses and participated in these previous studies.

The marine debris > 5 mm in diameter (macro-debris - Ivar do Sul and Costa, 2014) recovered from the stomachs of the juvenile Magellanic penguins were classified as flexible plastic, rigid plastic, nylon yard, paper, rubber and styrofoam. The debris fragments in each stomach were counted, and their frequencies (%) were calculated relative to the total number of stomachs with debris. Differences in the proportions of marine debris between the sampling periods (2000 and 2008) were tested by a normal approximation of the Chi-square test using Statistica for Windows 12 ($p < 0.05$).

3. Results and discussion

3.1. Temporal analysis of the presence of marine debris in juvenile Magellanic penguins

During 2000 and 2008, the stranding period, maturity, size and physical condition of the specimens as well as the items recovered from the stomach contents were similar among the Magellanic penguins sampled between 21°S-23°S (Table 1; Pinto et al., 2007; Di Beneditto et al., 2015). The penguins were all emaciated juveniles that stranded during winter (July to September) with an average length of < 60 cm and an average weight of approximately 2.0 kg. Despite the poor physical condition of the penguins, there were food items in their stomach contents, especially cephalopods. The octopus *A. nodosa* was the most frequently observed prey species in the stomachs followed by squids of the genus *Dorytheutis*. Thus, the vulnerability of all penguin specimens to marine debris ingestion was similar regardless of sampling period.

The frequency of marine debris ingestion differed between the sampling periods ($p < 0.001$) with a > 100% increase (42.5% in 2000 and 89.1% in 2008) (Table 1). More than one type of debris was recorded in seven penguins in 2000 (41.2% of the total penguins with debris), but this was the case for 22 penguins in 2008 (53.6% of the total penguins with debris) ($p = 0.405$). Flexible plastic was the most frequent debris in both periods, and the average number of fragments recorded in each stomach content was similar. Meanwhile, the presence of rigid plastic and rubber fragments differed significantly between the sampling periods (Table 1).

The presence of marine debris in the stomach contents of juvenile Magellanic penguins that reach the Brazilian coast during winter was widely discussed in Brandão et al. (2011), and these authors estimated that approximately 36% of the penguins stranded along the Brazilian coast had ingested debris. Temporal and spatial differences in debris ingestion are noted when previous studies are compared, but there is no clear pattern (see details in Brandão et al., 2011). Indeed, when comparing the available information, there is no consensus, even for the study area. The present study showed an increase in debris ingestion with time (42.5% in 2000 to 89.1% in 2008), but these values were higher than those in Brandão et al. (2011) (14.8% in 2008 and 2010) and Tavares et al. (2017) (15.3% in 2010–2013), whose samplings were conducted more recently.

Such differences in the proportion of marine debris in the stomachs of Magellanic penguins in less than a decade could be attributed to an economic boom period in Brazil. As the Brazilian economy expanded significantly since 2000, proportionately more litter was produced and inadequately disposed, especially in the marine environment. Unfortunately, there is lack of monitoring and reporting of debris on beaches and in the adjacent marine environment in Brazil. In the study area, Oigman-Pszczol and Creed (2007) reported an alarming amount of litter on the beaches with plastics being the most abundant submerged marine debris observed. This could possibly be an important source of the debris ingested by juvenile Magellanic penguins in south-eastern Brazil.

Seabird species show temporal variations in debris ingestion, reflecting changes in the debris present in the environment (Tavares et al., 2017). Ontogenetic differences in feeding habits, as noted for the Magellanic penguin (Walker and Boersma, 2003; Di Beneditto et al., 2015), may influence the susceptibility of seabirds to debris ingestion. Meanwhile, studies that have analysed the presence of debris in the stomach contents of Magellanic penguin refer only to juvenile penguins (*e.g.*, Pinto et al., 2007; Tourinho et al., 2010; Brandão et al., 2011; Di Beneditto et al., 2015), which does not allow for comparisons between different age classes. Additionally, the lack of standardization in sampling procedures may be a source of variability among different studies including the number of carcasses analysed, the debris classification and the size of the debris to be counted (Provencher et al., 2017). Moreover, different researchers in a study group may be a source of variability, influencing data collection and interpretation.

Like other penguin species, Magellanic penguins are primarily visual predators that actively pursue their prey (mainly fish and cephalopods) (*e.g.*, Williams et al., 1992; Wilson et al., 1993; Cannel and Cullen, 1998; Walker and Boersma, 2003), so a low frequency of marine debris ingestion would be expected from this feeding behaviour (Di Beneditto and Awabdi, 2014). The poor physical condition of the juvenile Magellanic penguins that swim to the northern migration limit (the study area) probably increases their vulnerability to debris ingestion as previously discussed (Brandão et al., 2011; Di Beneditto et al., 2015). Despite differences among studies that address the amount of marine debris ingested by this species, the situation deserves further attention. This interaction (Magellanic penguins x marine debris) is an additional risk for the conservation of the species throughout its distribution, and our results showed a temporal increase in the frequency of marine debris ingestion that should be monitored over time.