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Microplastics and other anthropogenic particles in Antarctica: Using penguins as biological samplers

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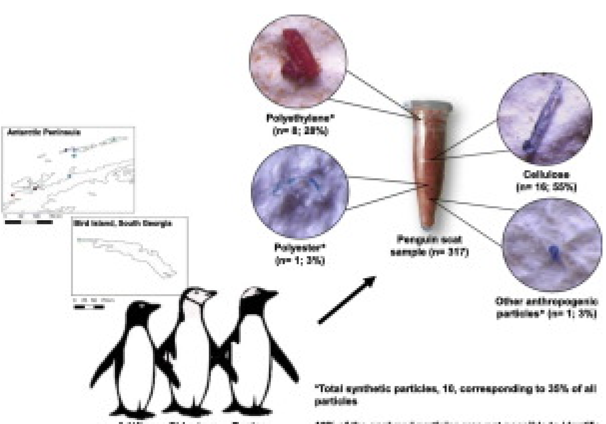
Highlights

- Anthropogenic particles were found in all three pygoscelid penguin species.
- Thirty-five percent were microplastics; these were found in all species.
- Fifty-five percent of the analysed particles were identified as cellulose fibres.
- Polyethylene were the most common synthetic polymer.
- Microplastics were widespread across years and colonies in Antarctic Peninsula.

Abstract

Microplastics (< 5 mm in size) are known to be widespread in the marine environment but are still poorly studied in Polar Regions, particularly in the Antarctic. As penguins have a wide distribution around Antarctica, three congeneric species: Adélie (Pygoscelis *adeliae*), chinstrap (*Pygoscelis antarcticus*) and gentoo penguins (*Pygoscelis papua*) were selected to evaluate the occurrence of microplastics across the Antarctic Peninsula and Scotia Sea. Scat samples (used as a proxy of ingestion), were collected from breeding colonies over seven seasons between 2006 and 2016. Antarctic krill (*Euphausia superba*), present in scat samples, contributed 85%, 66% and 54% of the diet in terms of frequency of occurrence to the diet of Adélie, gentoo and chinstrap penguins, respectively. Microplastics were found in 15%, 28% and 29% scats of Adélie, chinstrap and gentoo penguin respectively. A total of 92 particles were extracted from the scats (n = 317) and 32% (n = 29) were chemically identified via micro-Fourier Transform Infrared Spectroscopy (μ-FTIR). From all the particles extracted, 35% were identified as microplastics, particularly polyethylene (80%) and polyester (10%). It was not possible to ascertain the identification of the remaining 10% of samples. Other anthropogenic particles were identified in 55% of samples, identified as cellulose fibres. The results show a similar frequency of occurrence of particles across all colonies, suggesting there is no particular point source for microplastic pollution in the Scotia Sea. Additionally, no clear temporal variation in the number of microplastics in penguins was observed. Overall, this study reveals the presence of microplastics across Antarctica, in three penguin species and offers evidence of other anthropogenic particles in high numbers. Further research is needed to better understand the spatio-temporal dynamics, fate and effect of microplastics on these ecosystems, and improve plastic pollution policies in Antarctica.

Graphical abstract



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Introduction

Microplastic pollution, such as films, fragments or fibres less than 5 mm (Arthur and Baker, 2008; Thompson et al., 2004), has become an increasingly hot topic, since they are pervasive and persistent across global ocean ecosystems, from the tropics to the poles, including in the Southern Ocean (Fang et al., 2018; Waller et al., 2017). Most of the microplastics present in aquatic ecosystem come from secondary sources (i.e. plastic litter and debris which breaks down in the ocean) and are expected to continue to fragment until they reach nanometre sizes or mineralize into carbon dioxide and biomass (Dawson et al., 2018). The most abundant microplastic polymers in the marine ecosystem are polyethylene (PE) and polypropylene (PP), polyester (PET), polystyrene (PS), polyvinyl chloride (PVC) and polyamide (PA) (Andrady, 2011; Barboza and Gimenez, 2015). Although microplastics are the most abundant forms of plastic debris, elucidating their biological consequences are challenging and ecosystem-level impacts have not yet been assessed. Some studies already prove that microplastics are present in the waters in certain Antarctic regions, such as South Georgia, the Ross Sea, the Pacific Sector of the Southern Ocean (Lacerda et al., 2019; Reed et al., 2018) and the Weddell Sea (Waller et al., 2017). They have been reported in surface waters (Fang et al., 2018), in sediments (Barnes et al., 2010) and recently in biota, including in gentoo penguins *Pygoscelis papua* (Bessa et al., 2019b), king penguins *Aptenodytes patagonicus* (Le Guen et al., 2020), fur seals *Arctocephalus* spp. (Eriksson and Burton, 2003) and Antarctic toothfish *Dissostichus mawsoni* (Cannon et al., 2016). The presence of microplastics in other biota has not yet been verified in the Southern Ocean region, but microplastics can be easily accessible by a broad range of marine biota due to their small size and widespread occurrence (Fang et al., 2018). A recent laboratory study has proven that Antarctic krill *Euphausia superba* (hereafter krill) is able to ingest microplastic particles when exposed to them, and convert these particles into nanoplastics through digestive fragmentation (Bergami et al., 2020; Dawson et al., 2018).

Antarctica and the Southern Ocean have a relatively low volume of shipping traffic and a very small human presence, which indicates a potentially sparse local source of microplastics (Reed et al., 2018). The highest concentration of microplastic has been found in the Antarctic Peninsula/Scotia Sea region, where many scientific research stations are based, and there is a higher density of maritime traffic (Waller et al., 2017). This indicates that the potential main sources of microplastics are the scientific research stations, fishing vessels, tourist and research vessels. As well as these main sources of microplastics in Antarctica, other potential pathways and long-range sources have been described, such as sea ice melt, the presence and consequent degradation of macroplastics and the action of wind and ocean currents (Rowlands et al., 2020). Pollution by microplastics in the Southern Ocean may be significant on a local scale (Reed et al., 2018), and despite Antarctica being a fairly remote continent, it can be used as a reference for global microplastic pollution assessment and mitigation (Cincinelli et al., 2017).

To evaluate pollution and climate change effects in marine ecosystems, albatrosses (Phillips and Waluda, 2020), seals (Lehnert et al., 2017) and penguins (Bessa et al., 2019b) are commonly used as Antarctic bio-indicators to monitor changes, under the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) monitoring programs (Constable, 2011; Constable et al., 2000). These organisms are top Antarctic predators, and they can record perturbations in Antarctic ecosystems at the upper and lower levels of the food web (Xavier et al., 2016; Xavier and Peck, 2015). Also, top predators, are good for monitoring the health conditions of the marine environment (Clucas et al., 2014; Xavier and Trathan, 2020) through changes in population size, health or breeding success of top predators (Furness and Camphuysen, 1997; Trathan et al., 2015). For example, seabirds, including penguins, have been used to record (macro)plastic pollution for a number of years (Phillips et al., 2010; Phillips and Waluda, 2020).

Penguins from the Antarctic can be regarded as reliable plastic pollution bio-indicators, as they are widely distributed, easy to handle and their ecology (e.g. diet and foraging capacity) and life history are well documented (Furness and Camphuysen, 1997; Trathan et al., 2015). To date, only a small number of research studies have shown that microplastics have entered in the marine food web and are present in penguins. Bessa et al. (2019b) showed that 20% of gentoo penguin scat samples from two islands (South Georgia and Signy Island, Scotia Sea) included microplastics of different types, suggesting potential different contamination sources. Le Guen et al. (2020) also showed the presence of microplastics in king penguin scat samples obtained from Hound Bay, South Georgia. However, those studies did not infer the spatio-temporal dynamics of microplastics in top predators from Antarctica.

Given the important ecological role of Antarctica and the Southern Ocean, and implications for microplastics in ecosystems, this study aims to (1) assess the occurrence of microplastics in Adélie, chinstrap and gentoo penguins, using scat samples (as a proxy of ingestion), and examine the main diet components to assess the likely vectors of microplastics; (2) assess whether the number of microplastics ingested by these three penguin species vary between different colonies, according to their geographical distribution, and over multiple years; and (3) characterize and identify the particles in order to evaluate the potential source of contamination in these environment, contributing to review the present policy measures on plastic pollution under the Antarctic Treaty and to develop and propose potential mitigation measures for the areas where penguins live in the Antarctic Peninsula/Scotia Sea and to other regions.

Section snippets

Material and methods

This study took place across the Antarctic Peninsula and Scotia Sea region where Adélie, chinstrap and gentoo penguins breed sympatrically (Fig. 1). Scat (i.e. faecal) samples of penguins were collected from breeding colonies at Paradise Bay A (near Almirante Brown Station) (64°51′S, 62°54′W), Byers Peninsula (62°37′S, 61°04′W), Cierva Cove (64°09′S, 60°57′W), Deception Island (62°58′S, 60°39′W), Hannah Point (62°39′S, 60°36′W), King George Island (62°23′S, 58°27′W), Paradise Bay B (near…

Diet of Adélie, chinstrap and gentoo penguins

A total of 317 penguin scat samples, from Adélie, chinstrap and gentoo penguins were collected at ten different breeding sites across the Antarctic Peninsula and Scotia Sea (Fig. 1; Table 1), with all the three penguin species feeding mainly on sub-adult krill (Table 2). Krill was most frequently present in Adélie, followed by gentoo penguin diets, with chinstrap penguin diets having the lowest frequency of occurrence of krill.

In general, significant differences were found in the number of…

Discussion

This study revealed that the main particles found in Adélie, chinstrap and gentoo penguins were microplastics but also other anthropogenic particles were documented. Scat samples were used as a proxy of ingestion, to understand the route of these particles into the

Antarctic marine food chain. Our results show the presence of anthropogenic particles in Adélie, chinstrap and gentoo penguins, and that pollution by these particles is widespread throughout our study region. It is unlikely that the…

Ethical aprovement

The sampling methods used were under the recommendations from the Scientific Committee for Antarctic Research (SCAR) and the permission for sampling was issued by the Spanish Polar Committee and the Government of South Georgia and the South Sandwich Islands (GSGSSI).…

CRediT authorship contribution statement

Joana Fragão: Investigation, Writing – original draft, Writing – review & editing. **Filipa Bessa:** Supervision, Funding acquisition, Methodology, Writing – review & editing. **Vanessa Otero:** Investigation, Writing – review & editing. **Andrés Barbosa:** Funding acquisition, Writing – review & editing. **Paula Sobral:** Writing – review & editing. **Claire M. Waluda:** Resources, Writing – review & editing. **Hugo R. Guímaro:** Investigation, Writing – review & editing. **José C. Xavier:** Supervision, Writing – review …

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

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