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Plastic pollution in islands of the Atlantic Ocean☆

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ABSTRACT

Marine plastic pollution is present in all oceans, including remote oceanic islands. Despite the increasing number of articles on plastic pollution in the last years, there is still a lack of studies in islands, that are biodiversity hotspots when compared to the surrounding ocean, and even other recognized highly biodiverse marine environments. Articles published in the peer reviewed literature (N = 20) were analysed according to the presence of macro (>5 mm) and microplastics (<5 mm) on beaches and the marine habitats immediately adjacent to 31 islands of the Atlantic Ocean and Caribbean Sea. The first articles date from the 1980s, but most were published in the 2000s. Articles on macroplastics were predominant in this review (N = 12). Beaches were the most studied environment, possibly due to easy access. The main focus of most articles was the spatial distribution of plastics associated with variables such as position of the beach in relation to wind and currents. Very few studies have analysed plastics colonization by organisms or the identification of persistent organic pollutants (POPs). Islands of the North/South Atlantic and Caribbean Sea were influenced by different sources of macroplastics, being marine-based sources (i.e., fishing activities) predominant in the Atlantic Ocean basin. On the other hand, in the Caribbean Sea, land-based sources were more common.

1. Introduction

Plastics are diverse, versatile and practical, reasons why they have become indispensable in all aspects of modern life. However, the present consumption model of most plastic items also results in large amounts of waste with environmental, social and economic consequences (Debrot et al., 1999, 2013). Coastal environments are directly impacted by this form of pollution due to their proximity to every land-based source (Jambeck et al., 2015). However, the adjacent ocean is also vulnerable to land- and ocean-based sources of plastics due to *in situ* generation and long-range transport (e.g., Eriksen et al., 2013; Cózar et al., 2014). Oceanic insular environments are even more vulnerable to plastic pollution because populated islands are also potential sources of plastics; islands retain plastics from the adjacent sea by different meteoceanographic mechanisms; and, ecologically, they are unique ecosystems in terms of biodiversity and endemism (e.g., Ivar do Sul et al., 2013).

Oceanic islands are formed from the oceanic crust, usually as the result of volcanic action. In the Atlantic Ocean they are widespread, distributed along the whole basin, from North and South high latitudes to the Equator (http://www.iho.int/). Some of these territories are under the responsibility of states that protect them within different degrees and for historical and/or strategic reasons (e.g., Tristan da Cunha). Being territorial extensions of developed nations, they might (or not) share social and environmental policies with their head-administrators. Others are island-nations (e.g., Cape Verde) with very different management options (e.g., Mohee et al., 2015).

In the Atlantic Ocean, due to geologic, environmental and climatic diversity, some islands are uninhabited, while others are occupied by a few to thousands of people. The extreme scenery frequently make these islands tourism destinations, and the local economy grows heavily dependant on this income. However, often they have to face a limited number and reach of services and resources (water, space, locally produced food and wastes management options). This is particularly relevant in the Carribean Sea, where permanent and/or temporary occupation associated with high costs for waste disposal result in potential land-based sources of plastics to hundreds of insular environments and surrounding waters (e.g., Curaçao).

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On the other hand, the remoteness of many islands is no longer a guarantee of protection against ocean-based sources of plastic marine debris (i.e., fisheries; shipping). For instance, Lavers and Bond (2017) identified the "most polluted island in the world", with millions of plastic items stranded on beaches in relatively short time ranges. Henderson Island is directly influenced by marine current systems of the South Pacific Ocean, so floating plastics are mostly transported for long-distances by wind and superficial ocean currents (Eriksen et al., 2013) that hit the island.

In the Atlantic Ocean, several papers reported the distribution of pelagic plastics in large, oceanic basin scales (e.g., Thompson et al., 2004; Law et al., 2010; Cózar et al., 2014; Kanhai et al., 2017), revealing movement and accumulation patterns on the sea surface. Few articles have focused on insular environments, despite their propensity to, for instance, temporarily accumulate stranded plastics on its depositional habitats (i.e., beaches). These works are, however, important in recognizing oceanic islands as environments of special interest, following the example of upwelling areas (Kanhai et al., 2017), and describing their role in processes and status of plastics pollution of the World Ocean.

Therefore, our objective was to review the information available about plastics (macro and micro) contamination of island environments (beaches and immediately adjacent waters) of the Atlantic Ocean, in order to look for common patterns of pollution and risks. We then discuss both scales of basin-wide spatial distribution of plastic marine debris and the local factors possibly influencing plastic densities, sources and composition.

2. Data compilation and processing

Our literature survey aimed at works dealing with plastics contamination directly related to oceanic islands (deposited on beaches and/or in immedialtely surrounding waters) of the Atlantic, and did not include reports about plastics from the open ocean which sampling did not consider the islands environments. For the purpose of this work, macro and microplastics are items >5 and < 5 mm, respectively.

Combinations of the keywords "marine debris", "plastic", "microplastic", "island" and "beach" were used to retrieve papers published until April 2017. Articles were then sorted and analysed according to reporting the presence of macro and/or microplastics 1) on beaches and; 2) around islands.

Islands in the Atlantic Ocean were then treated into two groups – the Atlantic Ocean basin proper and the Caribbean Sea (http://www.iho.int/). Macroplastics were grouped into five categories according to size, most probable source and/or type of material: a) fragments, b) fishing materials (i.e., netting and floats), c) Single-use items (i.e., packaging, cups, caps and bottles), d) non-disposable user objects (i.e., gloves and shoes) and e) Styrofoam and foamed plastic. Macroplastic densities (items m^{-1}) were estimated multiplying the number of surveys (in days, months or years) and the length (m) of the beach (Table S1). For microplastics, however, it was not always possible to convert reported densities into items m^{-1}. Therefore, papers were only qualitatively compared (e.g., polymer types, size classes).

3. Results and discussion

Twenty papers, dating back to 1983, matched our search criteria (Tables S1 and S2); only one paper did not report comparable density units (Baztan et al., 2014). An increasing trend in the number of publications was observed, with 65% of the articles published in the last 15 years and 45% from 2010 onwards. Since 2012, new papers appeared every year. This pattern is also observed with other topics on marine plastic pollution, mainly microplastics, and reflect a progressive improvement of quality, diversity of studied environments and updated technologies employed on plastic pollution research. Geographically, articles used in our review covered the entire Atlantic Ocean basin (Fig. 1A).

Papers chosen for this review were published in eight peer-reviewed journals, especially *Marine Pollution Bulletin* (N = 12). This is an interesting trend, and suggests that researchers from a specific community are researching and reading about the subject. On the other hand, the works tend to be highly specialized and have high credibility. Other journals contained one publication each. The nature of these journals was both specific (N = 2 polar science; N = 2 marine science) and generalist (N = 1 environmental conservation; N = 3 environmental pollution). In general, journals have a reasonably high impact factor (mean = 2.76), and therefore works must have been subject to thorough competition for space and quality control by editors and peer reviewers.

Some studies included more than one island, or group of islands, of the Atlantic Ocean (e.g., Barnes and Milner, 2005). This is probably due to their sampling goals since plastics were often sampled as a supplementary variable during ecologic and/or geologic expeditions. Sampling one or more than one island or group of islands involves long-haul flights or cruises which increase research costs, so it is expected that a number of variables are observed at the same time. However, they need to be more often reported in integrated works.

Macroplastics were more studied (N = 12), frequently together with other marine debris categories (i.e., glass, paper, etc.). Five studies included both macro and microplastics. Studies on microplastics only (N = 6) are more recent (2000 onwards), except a pioneer study by Gregory (1983). A total of 31 islands were reported to be contaminated, most located in the open ocean ~50 km away from any continental land mass (Fig. 1).

Densities of stranded macro and microplastics were frequently reported, but using different units (i.e., total items m^{-1} and weight of items m^{-1}). This lack of consistency is recurrent in plastic literature reviews, and was already pointed in conferences, books and papers as an important barrier to be followed through the plastic scientific community (e.g., Arthur et al., 2009).

Generally, articles focused on macroplastics described their main characteristics such as type and size, their densities, and spatial distribution within/around islands for specific time ranges (months, years). In addition, some authors compared macroplastic densities with wind incidence on islands (e.g., Debrot et al., 1999). Few papers analyse the colonization of plastics by fouling organisms (Gregory, 1983; Barnes and Milner, 2005) or identified persistent organic pollutants (POPs) in plastic pellets (Heskett et al., 2012). Overall, the reviewed studies remain mostly in an inventory phase, and rarely approach processes that determine plastics sources, distribution, interactions with the biota and sinks (including fragmentation to microplastics).

3.1. Macroplastics

In general, marine-based sources are more important for macroplastic debris in islands of the Atlantic Ocean, mainly derelict fishing gear (>40%). This pattern is also observed in the Indian Ocean (Edyvane and Penny, 2017; Unger and Harrison, 2015), being fishing nets and floats commonly more sampled. Household items such as supermarket plastic bags, water bottles and food packaging may also be related to intentional illegal discard or accidental losses during fishery (Richardson et al., 2017). For instance, in the Falklands, 38 of the 40 types of plastics found on beaches were used aboard fishing vessels around the island. Moreover, 27 types seems to be directly discarded into the sea as reported by the Falkland Islands Government Fisheries Observers (Otley and Ingham, 2003).