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Baseline

Marine debris in Trindade Island, a remote island of the South Atlantic

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ABSTRACT

Marine debris is widespread in oceans worldwide, including the most remote locations. Here, for the first time, we report macro-debris accumulation on beaches of Trindade Island, a remote island 1160 km from mainland Brazil. High debris density was recorded on windward, east-coast beaches, which are exposed to wind-driven currents. Small-sized plastic fragments were the most abundant debris. Polyethylene (67%), polypropylene (30%) and polyamide (3%) were the most prevalent polymeric materials identified by ATR-FTIR. Identified debris show that interaction with Trindade fauna, mainly with seabirds and endangered terrestrial crabs, exists and already has some impact. This study provides baseline information on Trindade macro-debris demonstrating that the island, located on the edge of the South Atlantic Gyre, acts as a sink for gyre debris, exposing the island fauna to the threats related to plastic contamination.

Marine debris pollution has emerged in the 21th century as one of the main concerns on ecological perturbations produced by human-made impacts (Barnes et al., 2009; Ryan, 2015). The major component of marine anthropogenic litter are plastics (Galgani et al., 2015), which have been extensively and intensively used by society during the last decades because of their physical characteristics and relatively low production cost (Andrady and Neal, 2009). Although society has rapidly embraced plastics for everyday use, the benefits of this use have been questioned (Hopewell et al., 2009; Rochman et al., 2013; Meyer-Rochow et al., 2015). As awareness of their multiple impacts on human health and wildlife increases, plastics are starting to play a villain role that has been hypothesized for a long time (Kenyon and Kridler, 1969; Bean, 1987).

Currently, the ubiquitous presence of plastic debris in the ocean sheds light not only on the large accumulations of debris on continental beaches but also in areas of ocean gyres and island beaches, endangering the status of the few near-pristine oceanic areas that remain (Galgani et al., 2015). The incidence and concerns over beach debris accumulation in oceanic islands were first raised by Merrell (1980). In his study on Amchitka Island beaches (Alaska) he linked the accumulation of stranded debris to the potential risks of entanglement and ingestion by marine fauna. However, risk to island faunas are not limited to physical or physiological effects as debris can, among others, function as a pathway to invasion of non-native fauna and flora through rafting (Barnes, 2002; Kiessling et al., 2015).

The movement and accumulation of debris in the open ocean and, consequently, its stranding on oceanic island beaches depends upon several complex factors (e.g., proximity to pollution source, oceanographic drivers); however, wind-driven surface currents play a key role in debris accumulation in oceanic zones, including island beaches and their nearshore habitats (Maximenko et al., 2012; Baztan et al., 2014; Monteiro et al., 2018). Island exposure to wind and current flows are the main factors involved in transportation and deposition of massive debris on remote islands such as Azores, Seychelles and Henderson islands (Duhec et al., 2015; Pieper et al., 2015; Lavers and Bond, 2017). This explains the greater amounts of debris recorded on Easter Island and Midway Atoll beaches than on more urbanized beaches of the Chilean coast (Hidalgo-Ruz and Thiel, 2013) and Hawai'i (McDermid and McMullen, 2004).

Beach debris survey is a low-cost and effective tool for measuring composition, contaminants and pollution sources in coastal and remote areas (Ashton et al., 2010; Bergmann et al., 2015; Andrades et al., 2016). In addition, beach debris is a reasonable proxy for ocean debris availability used to clarify what factors may be involved in debris

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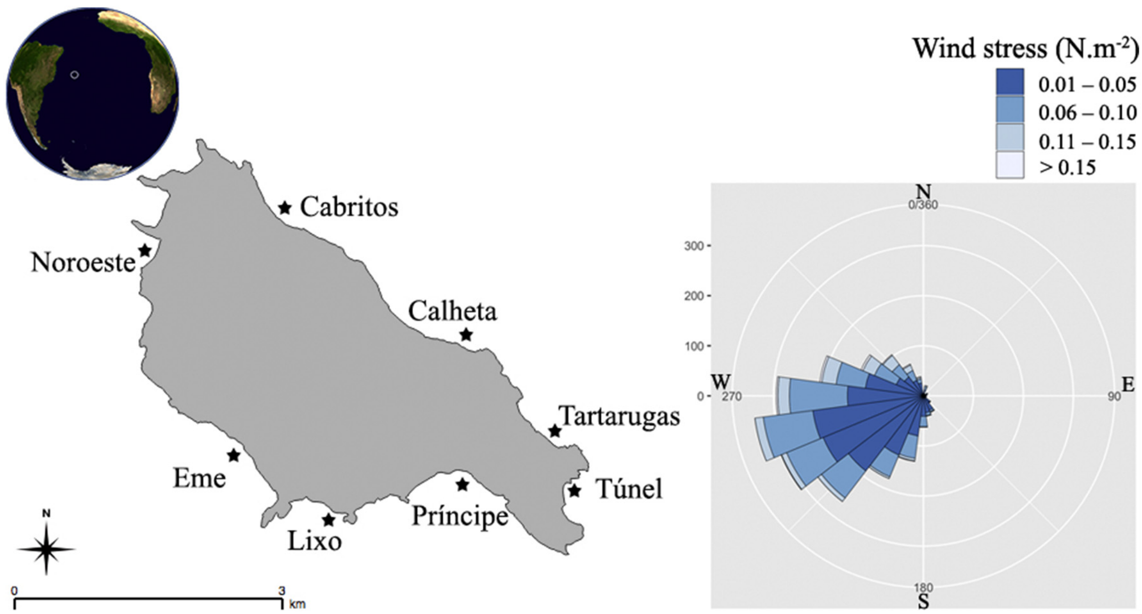

Fig. 1. Beaches (stars) and predominant wind direction and stress (N·m^{-2}) over Trindade Island region. Wind stress was computed daily from wind measures between March 2008 and March 2018 by a PIRATA mooring (Prediction and Research Moored Array in the Tropical Atlantic; NOAA, 2018) positioned at 19°S-34°W.

ingestion and marine contamination (Schuyler et al., 2012; Santos et al., 2016). Our study focuses on the distribution, density, type of material, size, color and polymeric composition of beach anthropogenic debris in Trindade Island, a remote tropical island located in the South Atlantic ca. 1160 and 3860 km from South-American and African mainlands, respectively.

The study was carried out on eight beaches (Fig. 1) in Trindade Island (20°30′ S; 29°20′ W), which bears ca. 22 km of coastline. East coast (windward) beaches Cabritos, Calheta, Tartarugas and Túnel are primarily sandy beaches dominated by sand and gravel. On the west coast (leeward), Noroeste, Eme, Lixo and Príncipe beaches are mostly composed by small pebbles and sand, except for Príncipe beach where sand and gravel are the main substrate types. All beaches also present biogenic calcareous material originated from intertidal and subtidal reefs. Wind direction and stress (N·m^{-2}; shear stress by wind over water body) are predominantly from NE to E quadrants, leading to high exposure of the eastern side to surface winds and water currents (Fig. 1). Climate is primarily tropical with annual mean temperature 25.3 °C, ranging from 22.9 to 27.7 °C; mean wave height varies from 1 to 2 m (Pedrosa et al., 2017). Trindade is uninhabited except for ca. 40 militaries manning a Brazilian Navy oceanographic station (POIT – Posto Oceanográfico da Ilha da Trindade). Visitation is restricted to research and military purposes.

Macro-debris items (i.e. > 0.5 cm) were surveyed through visual censuses between October and December 2017. The censuses consisted of 30 m transects of fixed width (2 m) performed at low tide along the sandy portion of the beach, from sea edge to supralittoral. Five transects were performed at each beach. In some cases, the surveyed area (sandy portion) was < 30 m long. Thus, density of debris items was estimated as items·m^{-2} based upon the length of each transect. All censuses were made by one observer (R. Andrades) in order to avoid bias in relation to visual accuracy.

All debris items visually apparent without digging, sand shuffling or seaving were collected and, in the laboratory, categorized according to material (hard plastic, flexible plastic, glass, nylon, cotton, rubber and other), size (maximum dimension in 5 cm size classes, except for the first, 0.5–5 cm, and the last, above 30 cm) and original use (fishery, food, medical, household and other). Also, debris items were categorized in function of color and color tonality (dark and light). Color and tonality were determined using a color- and gray-scale professional calibration card. In order to compare the influence of beach exposure we tested debris density between east and west Trindade coasts ($N = 20$ transects per coast) using Mann-Whitney U test performed in R environment (R Core Team, 2017).

As plastic was the most abundant material in all beaches surveyed, fifty-four samples of plastic debris were haphazardly collected, in four beaches, to determine polymer composition: Calheta ($N = 15$), Tartarugas ($N = 15$), Túnel ($N = 14$) and Príncipe ($N = 10$). We applied the most reliable method to identify the composition of marine plastic debris, Fourier Transform Infrared (FTIR) spectroscopy, which is tipically carried out using either single-element or Focal Plane Array (FPA) detectors (Reddy et al., 2006; Mecozzi et al., 2016; Cincinelli et al., 2017). In this study, FTIR spectra were collected in Attenuated Total Reflectance (ATR) mode, using a single-element MCT detector, which was deemed as the optimal set up, given the type and morphology of the plastic debris samples. The ATR-FTIR analysis of the samples was carried out using a Thermo Nicolet Nexus 870 FTIR spectrometer, equipped with a Golden Gate diamond cell. The spectra were recorded directly on the samples with a spectral resolution of 8 cm^{-1}, acquiring 128 scans for each spectrum in the 4000–650 cm^{-1} spectral range.

A total of 1057 debris items (mean 0.5 items·m^{-2}) were found on the eight Trindade beaches. Eastern beaches showed higher densities (mean 1.1 items·m^{-2}) than western beaches (mean 0.1 items·m^{-2}) ($p < 0.05$, Mann-Whitney U test). In average, most-polluted beaches were the windward beaches, Túnel (2.2 items·m^{-2}), Tartarugas (1.2 items·m^{-2}), Calheta (0.7 items·m^{-2}), Cabritas (0.2 items·m^{-2}) and Lixo (0.2 items·m^{-2}). The other beaches (Noroeste, Eme and Príncipe) recorded < 0.05 items·m^{-2} (Fig. 2). Fifteen material types of debris were recorded (Table 1), of which hard plastic was the most abundant (818 items), followed by glass (119 items) and cotton rope (51 items). Smaller fragments (0.5–5 cm size class) were the most abundant, followed by those in the 5–10 cm size classes (Fig. 3).

Prevalent colors of debris were blue (29.2%), white (26.2%), green (20.0%), black (7.1%) and transparent (5.2%). In respect to tonality of colors, light colors were observed in 57.2% of items and dark colors in 41.8%. Most debris consisted of small-sized fragments (smaller than 5 cm) and the use of the majority of debris (84.8%) could not be identified due to the absence of visual characteristics.

ATR-FTIR allowed the clear identification of all the different plastic