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# Nests of the brown booby (*Sula leucogaster*) as a potential indicator of tropical ocean pollution by marine debris

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ABSTRACT

Seabirds collect debris primarily nearby breeding sites, and thus they may be used to monitor these pollutants in the ocean. This study aimed to investigate the prevalence of marine debris used as nesting materials by the brown booby (*Sula leucogaster*) and to test the species selectivity to debris type and color in two coastal islands of Brazil. We found marine debris in 61% of the brown booby nests on both islands. Fishing gear and hard plastic were the most frequent types of debris. Higher prevalence of fishing gear was found on the island with greater fishery activity. Similarly, hard plastic was the most frequent type of debris in nests and adjacent beach environment. The frequency of debris in brown booby nests can be a potential indicator of the abundance of specific items in surrounding marine waters. Monitoring debris in brown booby nests in a long-term may provide a better understanding of the species' selectivity for specific debris. Furthermore, the impacts of debris in seabird nests at population level remain an overlooked threat that may reduce the quality of nesting habitats. We showed that brown booby nests are widely impacted by marine debris and that these organisms are exposed to this form of pollution from the beginning of their life.



## 1. Introduction

Marine debris is an increasing problem in oceans worldwide and poses several environmental, economic and health issues (Gregory, 2009; Hayes et al., 2015). As a result, there is a rising concern about the negative effects that this form of pollution may have on sea life (Thompson et al., 2004; Moore, 2015). The levels of vulnerability and exposure of organisms to debris have been poorly explored (Moore, 2015), especially in the tropical oceans (Di Beneditto and Awabdi, 2014). Entanglements and ingestions are well documented for marine vertebrates such as fish, sea turtles, cetaceans, and seabirds (Hammer et al., 2012). Seabirds are severely impacted, with 39% of 312 species ingesting marine debris (Gall and Thompson, 2015). Debris also impacts on seabird nests, but only a few studies have assessed the prevalence of this threat in specific localities in the North Atlantic and Oceania (Votier et al., 2011; Lavers et al., 2013; Verlis et al., 2014).

Seabirds collect different types of debris primarily on the sea surface and in areas nearby breeding sites (Votier et al., 2011; Lavers et al., 2013; Verlis et al., 2014). Nest surveys provide relatively easy, non-invasive, and rapid approach to quantify marine debris (Montevecchi, 1991; Provencher et al., 2015). However, some seabird species show some level of selectivity for type and color of debris, indicating that it might not be a good indicator for monitoring the abundance of these materials in the sea (Bond et al., 2012; Verlis et al., 2014; Lavers and Bond, 2016).

Marine debris in seabird nests increases the risk of plastic ingestion and the absorption of contaminants through the birds' digestive tract, with negative consequences for these organisms (Lavers et al., 2014; Tanaka et al., 2015). Sulidae species such as gannets (*Morus bassanus*) are the most negatively affected by nest debris (Montevecchi, 1991; Votier et al., 2011; Bond et al., 2012). The brown booby (*Sula leucogaster*) commonly occurs throughout the pantropical oceans but still there are few works dealing with the frequency of debris in their nests (Lavers et al., 2013; Verlis et al., 2014). The paucity of scientific papers provides limited comparative prognostic of the pervasiveness of debris use in breeding sites from different regions.

This study aimed to investigate the prevalence of marine debris used as nesting materials by brown boobies in two coastal islands of Brazil. In addition, we tested the selectivity of brown boobies to the type and color of debris as nesting materials. Our work-

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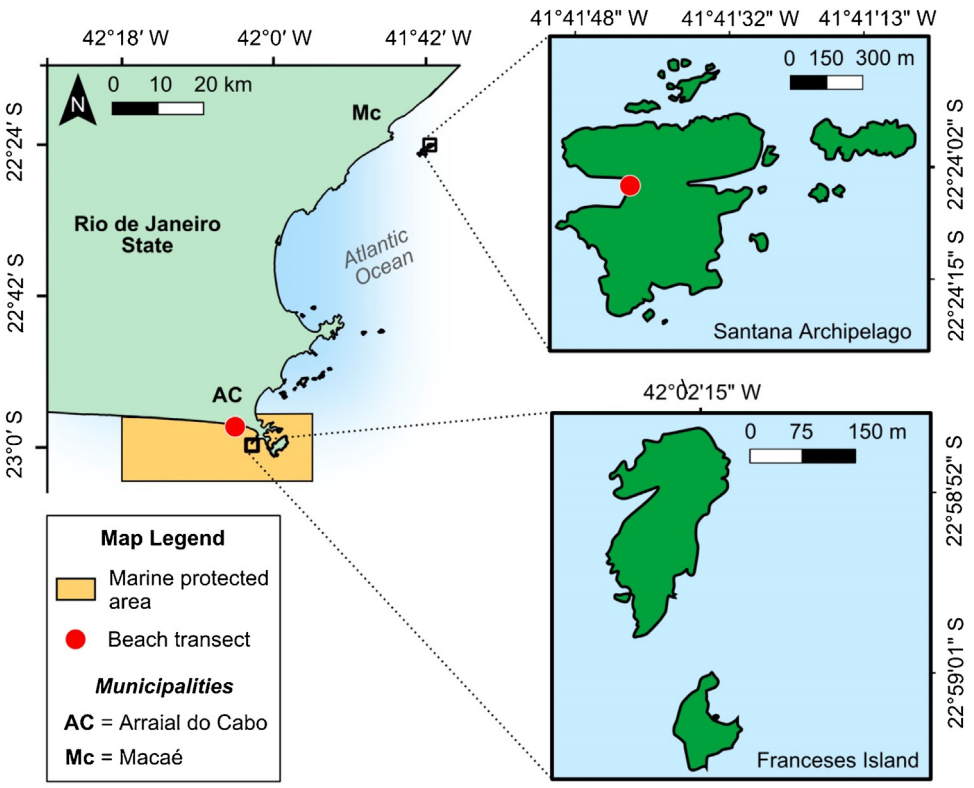


**Fig. 1.** Location of the islands surveyed to record brown booby nests with marine debris along the central-north coast of Rio de Janeiro state, Brazil, tropical Atlantic Ocean (22°23′ S–22°59′ S).

ing hypothesis is that brown boobies prefer to use fishing gear as nesting material more than other items, due to its similarity with elongated vegetation, which is used for building nests (Votier et al., 2011).

## 2. Material and methods

### 2.1. Study sites

We examined marine debris in brown booby active nests in both Santana Archipelago and Franceses Island in the central-north coast of Rio de Janeiro state, Brazil, Southwestern Atlantic Ocean (Fig. 1). Santana Archipelago is located in the Macaé municipality and constitutes an important breeding site for brown boobies (Alves et al., 2004). The Santana archipelago includes three small islands located at about 10 km from the coast: "Ilhote Sul", "Santana", and "Francês" Island (where the nests were surveyed). At least 200 trawling vessels operate year-round in the surrounding waters by artisanal fishermen. The other sampling site is located at "Franceses" Island, municipality of Arraial do Cabo, central coast of Rio de Janeiro state: an ecologically important area with threatened and rare marine species (Moura et al., 2009; Tavares and Siciliano, 2013; Moura et al., 2015). Franceses Island is a small rocky islet located 500 m from the edge of the continental shelf and is an important breeding ground for brown boobies (Coelho et al., 2004). Fishing activity in the surrounding area is negligible, particularly because the island is located within a marine protected area.

### 2.2. Data collection

We surveyed brown booby active nests in Santana Archipelago and Franceses Island in February and March 2016. To minimize any disturbance effect, we collected debris from nests in which adults had flushed out (Lavers et al., 2013). Based on previous studies (Bond et al., 2012; Lavers et al., 2013; Verlis et al., 2014), we classified marine debris into eleven categories: (1) hard plastic, (2) soft plastic, (3) foam, (4) fishing gear (i.e. rope, twine, monofilament line, netting), (5) glass, (6) sheet, (7) metal, (8) rubber, (9) wood, (10) textile, and (11) cigarette butt. Debris was also classified by color as (1) white, (2) green, (3) blue, (4) yellow, (5) red, and (6) black. Materials with more than one color were not considered in our analysis.

To estimate the availability of plastics in the surrounding coastal waters, we recorded all marine debris found in a 200-m transect along the high tide line in the nearest beaches (Fig. 1).

### 2.3. Data analysis

We investigated whether observed frequencies of type and color of marine debris differed between the nest and beach surveys using a Chi-square test. Significant differences indicate that brown boobies select specific debris ($p < 0.05$). We used the Chi-square standardized residuals to infer what type and color of debris significantly differed between nest and beach surveys. Residual values lower than −2 and greater than +2 were considered significantly large.

We also assessed the frequency of debris type and color in brown booby nests on both islands using the Conditional Inference Trees, which is a technique of unbiased recursive partitioning (Hothorn et al., 2006). This non-parametric regression analysis does not require any classical statistical assumptions and may be used to assess unbalanced data, that is, different numbers of nests among different categories of type and color of debris. We set the islands as a binary response variable and the type and color of items as predictive variables. The algorithm treats successive binary splits of the input variables using a minimum criterion of Bonferroni-adjusted $p$ values $< 0.05$ to test for independence between the predictive