Ecological Indicators 70 (2016) 10–14

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

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

Davi Castro Tavares[a,*], Leonardo Lopes da Costa[a], Danilo Freitas Rangel[a], Jailson Fulgencio de Moura[b], Ilana Rosental Zalmon[a], Salvatore Siciliano[c]

[a] Laboratório de Ciências Ambientais, Universidade Estadual do Norte Fluminense, Campos dos Goytacazes, RJ, Brazil
[b] Systems Ecology Group, Leibniz Center for Tropical Marine Ecology, Bremen, Germany
[c] Instituto Oswaldo Cruz, Fundação Oswaldo Cruz – Fiocruz, RJ, Brazil

ARTICLE INFO

*Article history:*
Received 20 April 2016
Received in revised form 30 May 2016
Accepted 3 June 2016
Available online 14 June 2016

*Keywords:*
Brazil
Fishing gear
Marine birds
Nesting material
Plastic
Seabird

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-

* Corresponding author.
*E-mail address:* wetlandbirdsbrazil@gmail.com (D.C. Tavares).

http://dx.doi.org/10.1016/j.ecolind.2016.06.005

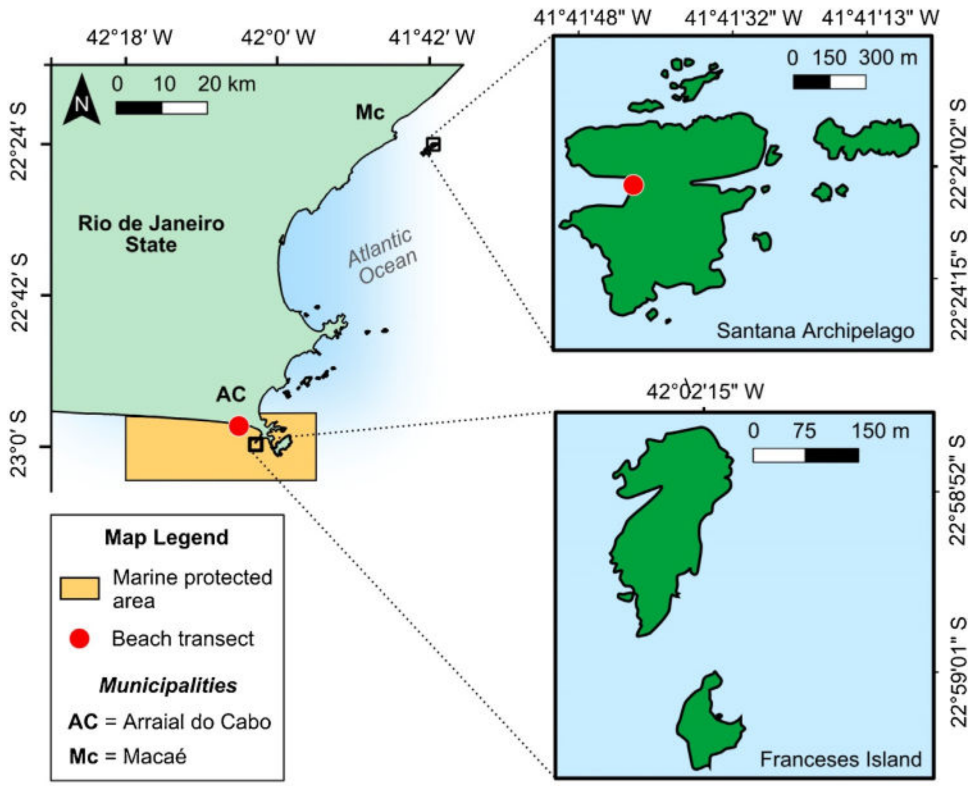


**Fig. 1.** Location of the islands surveyed to record brown booby nests with marine debris along the central-north coast of Rio de Janeiro state, Brazil, tropical Atlantic Ocean (22°23″ S–22°59″ S).

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

**Table 1**
Percent frequencies of type and color of marine debris recorded in brown booby nests and adjacent beaches along the central-north coast of Rio de Janeiro state, Brazil, tropical Atlantic Ocean (22°23″ S–22°59″ S).

| | Franceses Island | | Santana Archipeplago | |
|---|---|---|---|---|
| | Nests with debris (n = 50) | Beach debris (n = 71) | Nests with debris (n = 73) | Beach debris (n = 197) |
| Debris type | | | | |
| Hard plastic | 56 | 25 | 37 | 24 |
| Soft plastic | 32 | 24 | 18 | 12 |
| Foam | 6 | 8 | 11 | 4 |
| Fishing gear | 30 | 3 | 58 | 20 |
| Glass | 0 | 0 | 1 | 0 |
| Sheet | 0 | 14 | 4 | 0 |
| Metal | 0 | 0 | 11 | 4 |
| Rubber | 0 | 0 | 11 | 2 |
| Wood | 0 | 0 | 8 | 6 |
| Textile | 0 | 0 | 8 | 2 |
| Cigarette butt | 0 | 25 | 1 | 28 |
| Debris Color | | | | |
| White | 52 | 72 | 52 | 45 |
| Green | 6 | 1 | 3 | 9 |
| Blue | 10 | 6 | 14 | 28 |
| Yellow | 16 | 18 | 10 | 1 |
| Red | 22 | 3 | 18 | 3 |
| Black | 18 | 0 | 37 | 1 |
| Multicolored | 6 | 0 | 36 | 13 |

Values do not sum to 1 since a number of nests contained more than one type and color of debris.

and response variables. The split process proceeds until no further significant divisions is possible at $p$ values < 0.05.

## 2.4. Literature search

We searched the Web of Science database for studies that assessed the frequency of marine debris in seabird nests in order to provide data to be compared with our results. We performed the search using the following key terms: (1) seabird + nest + debris; and (2) seabird + nesting material + debris.

# 3. Results

## 3.1. Nest debris

We examined 203 brown booby nests: 118 at Santana Archipelago and 85 at Franceses Island (Table S1). We found marine debris in 61% of the active nests examined in the study sites. Overall, fishing gear and hard plastic were the most frequent debris items, present in 57% and 55% of the nests examined, respectively (Table 1). Values do not sum to 100% because 21% of the nests contained more than one type of debris. In Santana Archipelago, 62% of nests contained debris and the most common types were fishing

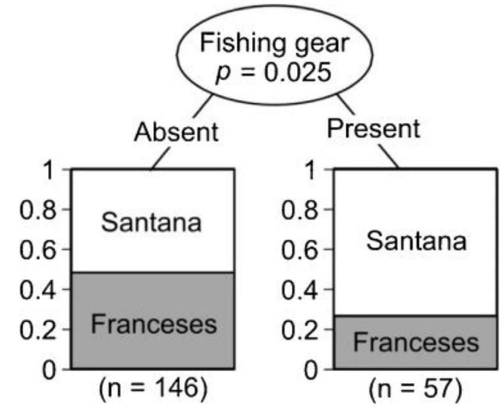


**Fig. 2.** Conditional Inference Tee (CIT) partitioning for predicting the frequency of debris types and colors across the two islands along the central-north coast of Rio de Janeiro, Brazil, tropical Atlantic Ocean. The barplot at each terminal node indicates the relative frequency of fishing gear debris per island. The tree indicates that only the proportion of fishing gear debris is significantly different between the two islands.

gear (58%) and hard plastic (37%). In Franceses Island, 59% of nests contained debris, with hard plastic being the most frequent item (58%), followed by soft plastic (32%) and fishing gear (30%).

The conditional inference tree revealed a higher proportion of nests with fishing gear items in Santana Archipelago than in Franceses Island (Bonferroni-adjusted $p = 0.03$) (Fig. 2).

The most common color of debris found in brown booby nests in both islands was white (52%), followed by black (29%) and red (20%). The average weight of marine debris per nest was 2.39 g (standard deviation = 5.92) in Franceses Island and 8.94 g (standard deviation = 30.88) in Santana Archipelago. As an outlying result, we recorded two nests including 284 g and 138 g of marine debris in Santana Archipelago. Fig. 3 shows examples of marine debris found in brown booby nests.

## 3.2. Beach debris

In the Santana Archipelago, we found 127 debris items: the most common types were cigarette butts (28%), hard plastics (24%), and fishing gear (20%). In the Franceses Island, we found 71 debris items: the most common types were hard plastic (25%), cigarette butts (25%), and soft plastics (24%). The most common color of debris items was white in both beaches (Santana Archipelago: 52%; Franceses Island: 45%).

The debris frequency in the beaches and in the nests differed in both type and color (type: chi-square = 70.27, $p < 0.01$; color: chi-square = 96.06, $p < 0.01$). Fishing gear items, such as twines and ropes, were more common in nests than in beaches (Table 1). Similarly, black and red items were relatively more frequent in nests than in beaches (Table 1).

**Table 2**
Studies that assessed the frequency of debris in seabird nests across the world. N: number of nests. ND: Percent of nests containing debris.

| Common species names | Country | N | ND (%) | References |
|---|---|---|---|---|
| Gannet[a] | Wales | 6 | 100 | Votier et al. (2011) |
| Gannet[a] | Canada | 741 | 97 | Montevecchi (1991) |
| Gannet[a] | Canada | 1080 | 31 | Bond et al. (2012) |
| Kittiwake[b] | Denmark | 466 | 39 | Clemens and Hartwig (1993) |
| Kittiwake[b] | Denmark | 311 | 57 | Hartwig et al. (2007) |
| Double-Crested Cormorant[c] | USA | 497 | 37 | Podolsky and Kress (1989) |
| Sooty tern[d] | Brazil | 1800 | 3 | Petersen et al. (2016) |
| Brown booby[e] | Australia | 96 | 58 | Verlis et al. (2014) |
| Brown booby[e] | Australia | 435 | 12 | Lavers et al. (2013) |
| Brown booby[e] | Brazil | 203 | 61 | Present study |

Scientific species names: *Morus bassanus* (a), *Rissa tridactyla* (b), *Phalacrocorax auritus* (c), *Onychoprion fuscatus* (d) and *Sula leucogaster* (e).


**Fig. 3.** Marine debris found in brown booby nests in two coastal islands off central-northern Rio de Janeiro state, Brazil, tropical Atlantic Ocean. Juvenile in a nest built mainly with debris (a); male in a nest with plastic (b); high amounts of fishing gear in a nest (c); and the diversity of debris collected in a single nest (d).

The literature search revealed nine studies assessing debris frequency in seabird nests across the world (Table 2). Only one study assessed seabird nests in South Atlantic Ocean. The frequency of debris we found in brown booby nests is only lower than the value reported for gannets in Wales and Canada (Table 2).

## 4. Discussion

Our data support that marine debris is widely used as nesting materials by brown boobies in the tropical Atlantic Ocean. Monitoring marine debris in brown booby nests has been proposed as a rapid and reasonable method to quantifying the magnitude of debris in marine waters (Ryan et al., 2009; Lavers et al., 2013), but our data showed, brown booby displays some selectivity about specific debris. Nevertheless, the highest prevalence of fishing gear was recorded in Santana Archipelago, where trawl fishing activity is remarkably greater than in Franceses Island. Hard plastics were the most frequent type of debris found in nests and beach transects in Franceses Island. These findings indicate that brown booby nests may reflect ocean pollution by specific debris at a local scale, and thus constitute a potential indicator of these items in the ocean.

Brown boobies may collect fishing gear items (i.e. ropes and twines) due to the similarity in shape with elongated vegetation items (Votier et al., 2011). The presence of fishing gear in nests increases the risk of mortality, since both adults and juveniles may get entangled (Votier et al., 2011). Our results indicate that fishing activities are the main source of nest debris in Santana Archipelago, where fishery activity is intense. Trawling boats may increase the availability of debris for brown boobies by dredging and scraping the sea bottom. A strict control of waste disposed of by boats coupled to efforts to increase fishermen's awareness regarding the impact of commercial fishing pollution may mitigate the impact of debris in brown booby nests.

The high prevalence of plastics in both brown booby nests and beaches demonstrates how ubiquitous this threat is in the ocean (Wilcox et al., 2015). Adults may feed their chicks with plastics collected in the ocean (Ryan et al., 1988), or these items may be accidentally ingested by birds in the nests (Podolsky and Kress, 1989). Seabirds do not usually die directly from plastic ingestion, but they often experience sublethal effects leading to different forms of physiological impairments (Browne et al., 2015). Plastic ingestion effect on chicks' survival needs further investigations.

Brown boobies may use marine debris as nesting material at greater frequencies in environments characterized by scarce vegetation (Lavers et al., 2013). However, we found a high prevalence of debris in the nests from both islands surveyed, even where vegetation was available to be used as nesting material. The presence of vegetation does not seem to be an important factor affecting the use of debris by brown boobies. Also, the vegetation may trap blown debris, instead, making them more easily available for the building of nests located in nearby areas (Verlis et al., 2014).

The choice of the color of the debris used by these birds is likely to be associated with its availability in the surrounding environment. We found that brown boobies seem to select black and red debris. Previous studies argue that the species selects debris that look similar to blackish natural nesting materials like wood and feathers (Lavers et al., 2013; Verlis et al., 2014). Surprisingly, brown boobies express some preference for red items. The debris color choice can be associated with mating interactions, as males offer items to the females as tokens, to strengthen the relationship with their mate (Nelson and Baird, 2002).

Our literature search revealed that marine debris in nests might affect seabird species at a global scale. However, data from 346 living seabird species (Croxall et al., 2012) show that debris frequency in nests are available only for five species: *Morus bassanus*, *Rissa tridactyla*, *Phalacrocorax auritus*, *Onychoprion fuscatus*, and *Sula leucogaster* (Table 2). Our study shows a greater frequency of debris use in the nests of brown boobies than had been previously described in Australia in the same species (Lavers et al., 2013; Verlis et al., 2014). In Brazil, between 0.25 and 1.0 million metric tons of mismanaged waste are chunked out in the ocean per year, as long as Australia contributes with 0.01–0.25 million metric tons (Jambeck et al., 2015). The high frequency of debris found in brown booby nests in Brazil reflects the greater concentration of waste on the coasts and in the ocean. Such scenario advocates, brown booby nests can be used as a rapid method to monitor the degree of ocean pollution by marine debris. In contrast with the high frequency of debris we found in brown booby nests, only 3% of the nests of the sooty tern (*O. fuscatus*) included debris in Trindade Island, which is located about 1000 km off the islands surveyed in our study (Petersen et al., 2016). Interspecific comparisons of debris in nests at a regional scale may provide insights on the effectiveness to use different species for monitoring specific types of debris in ocean waters.

In summary, we found a high prevalence of marine debris in brown booby nests in two coastal Brazilian islands here studied. Although these sea birds seem to select specific types and colors of debris, this preference might reflect the abundance of some items at local scale, such as fishing gear, which was most frequent in Santana Archipelago, where fishing activity is high. The frequency of debris in nests reflected the high availability of these pollutants on Brazilian marine waters in comparison to other regions, such as Australia (as previously discussed). According to our results, we shall conclude, brown boobies' nests can be used as indicators of the abundance of specific debris in the ocean. Monitoring marine debris in brown booby nests in the long term may provide a better understanding of the selectivity level for specific items.

## Conflict of interest

The authors declare that they have no conflict of interest.

## Acknowledgements

We gratefully acknowledge Vicente Klonowski and the local fishermen who cooperated during field surveys; *Secretaria de Meio Ambiente de Macaé* and *Prefeitura de Arraial do Cabo* for providing logistical support during field work. We also thank Andrea Lafisca and two anonymous reviewers for their helpful comments. Davi Castro Tavares is supported by Coordenação de Aperfeiçoamento de Pessoal de Nível Superior-CAPES.

## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.ecolind.2016.06.005.

## References


Alves, V.S., Soares, A.B.A., Couto, G.S., 2004. Aves marinhas e aquáticas das ilhas do estado do Rio de Janeiro. In: Branco, J.O. (Ed.), Aves marinhas e insulares brasileiras: biologia e conservação. Editora da Univali, Itajaí, pp. 83–100.

Bond, A.L., Montevecchi, W.A., Guse, N., Regular, P.M., Garthe, S., Rail, J., 2012. Prevalence and composition of fishing gear debris in the nests of northern gannets (*Morus bassanus*) are related to fishing effort. Mar. Pollut. Bull. 64, 907–911.

Browne, M.A., Underwood, A.J., Chapman, M.G., Willians, R., Thompson, R.C., van Franeker, J.A., 2015. Linking effects of anthropogenic debris to ecological impacts. Proc. Biol. Sci. 282, 1–10.

Clemens, T., Hartwig, E., 1993. Müll als Nistmaterial von Dreizehenmöwen (*Rissa tridactyla*)-Untersuchung einer Brutkolonie an der Jammerbucht, Dänemark. Seevögel 14, 6–7.

Coelho, E.P., Alves, V.S., Soares, A.B.A., Couto, G.S., Efe, M.A., Ribeiro, A.B.B., Vielliard, J., Gonzaga, L.P., 2004. O atobá-marrom (*Sula leucogaster*) na Ilha de Cabo Frio, Arraial do Cabo, Rio de Janeiro, Brasil. In: Branco, J.O. (Ed.), Aves marinhas e insulares brasileiras. Univali Editora, Itajaí, pp. 233–254.

Croxall, J.P., Butchart, S.H.M., Laslecelles, B., Stattersfield, A.J., Sullivan, B., Symes, A., Taylor, P., 2012. Seabird conservation status, threats and priority actions: a global assessment. Bird Conserv. Int. 22, 1–34.

Di Beneditto, A.P.M., Awabdi, D.R., 2014. How marine debris ingestion differs among megafauna species in a tropical coastal area. Mar. Pollut. Bull. 88, 86–90.

Gall, S.C., Thompson, R.C., 2015. The impact of debris on marine life. Mar. Pollut. Bull. 92, 170–179.

Gregory, M.R., 2009. Environmental implications of plastic debris in marine settings – entanglement ingestion, smothering, hangers-on, hitch-hiking and alien invasions. Philos. Trans. R. Soc. B 364, 2013–2025.

Hammer, J., Kraak, M.H.S., Parsons, J.R., 2012. Plastics in the marine environment: the dark side of a modern gift. Rev. Environ. Contam. Toxicol. 220, 1–39.

Hartwig, E., Clemens, T., Heckroth, M., 2007. Plastic debris as nesting material in a Kittiwake (*Rissa tridactyla*) colony at the Jammerbugt, Northwest Denmark. Mar. Pollut. Bull. 54, 595–597.

Hayes, K.R., Dambacher, J.M., Hosack, G.R., Bax, N.J., Dunstan, P.K., Fulton, E.A., Thompson, P.A., Hartog, J.R., Hobday, A.J., Bradford, R., Foster, S.D., Hedge, P., Smith, D.C., Marshall, C.J., 2015. Identifying indicators and essential variables for marine ecosystems. Ecol. Indic. 57, 409–419.

Hothorn, T., Homik, K., Zeileis, A., 2006. Unbiased recursive partitioning: a conditional inference framework. J. Comput. Graphic Stat. 15, 651–674.

Jambeck, J.R., Geyer, R., Wilcox, C., Siegler, R., Perryman, M., Andrady, A., Narayan, R., Law, K.L., 2015. Plastic waste inputs from land into the ocean. Science 347, 768–771.

Lavers, J.L., Bond, A.L., 2016. Selectivity of flesh-footed shearwaters for plastic colour: evidence for differential provisioning in adults and fledglings. Mar. Environ. Res. 113, 1–6.

Lavers, J.L., Hodgson, J.C., Clarke, R.H., 2013. Prevalence and composition of marine debris in Brown Booby (*Sula leucogaster*) nests at Ashmore Reef. Mar. Pollut. Bull. 77, 320–324.

Lavers, J.L., Bond, A.L., Hutton, I., 2014. Plastic ingestion by flesh-footed shearwaters (*Puffinus carneipes*): implications for fledgling body condition and the accumulation of plastic-derived chemicals. Environ. Pollut. 187, 124–129.

Montevecchi, W.A., 1991. Incidence and types of plastic in gannets' nests in the northwest Atlantic. Can. J. Zool. 69, 295–297.

Moore, C.J., 2015. How much plastic is in the ocean? You tell me! Mar. Pollut. Bull. 92, 1–3.

Moura, J.F., Rodrigues, E.S., Sholl, T.G.C., Siciliano, S., 2009. Franciscana dolphin (*Pontoporia blainvillei*) on the north-east coast of Rio de Janeiro State, Brazil, recorded during a long term monitoring programme. Mar. Biodivers. Rec. 2, 1–4.

Moura, J.F., Merico, A., Montone, R.C., Silva, J.A., Seixas, T.G., Godoy, J.M., Saint'Pierre, T.D., Houser-Davis, R.A., Di Beneditto, A.P.M., Reis, E.C., Tavares, D.C., Lemos, L.S., Siciliano, S., 2015. Assessment of trace elements, POPs, $^{210}$Po and stable isotopes ($^{15}$N and $^{13}$C) in a rare filter-feeding shark: the megamouth. Mar. Pollut. Bull. 95, 402–406.

Nelson, J.B., Baird, P.H., 2002. Seabird communication and displays. In: Schreiber, E.A., Burger, J. (Eds.), Biology of Marine Birds. CRC Press, Florida, pp. 307–357.

Petersen, E.S., Kruger, L., Dezevieski, A., Petry, M.V., Montone, R.C., 2016. Incidence of plastic debris in sooty tern nests: a preliminary study on Trindande Island, a remote area of Brazil. Mar. Pollut. Bull. 105, 373–376.

Podolsky, R.H., Kress, S.W., 1989. Plastic debris incorporated into double-crested cormorant nests in the Gulf of Maine. J. Field Ornithol. 60, 248–250.

Provencher, J.F., Bond, A.L., Mallory, M.L., 2015. Marine birds and plastic debris in Canada: a national synthesis and a way forward. Environ. Rev. 23, 1–13.

Ryan, P.G., Connell, A.D., Gardner, B.D., 1988. Plastic ingestion and PCBs in seabirds: is there a relationship? Mar. Pollut. Bull. 19, 174–176.

Ryan, P.G., Moore, C.J., van Franeker, J.A., Moloney, C.L., 2009. Monitoring the abundance of plastic in the marine environment. Philos. Trans. R. Soc. B 364, 1999–2012.

Tanaka, K., Takada, H., Yamashita, R., Mizukawa, K., Fukuwaka, M., Watanuki, Y., 2015. Facilitated leaching of additive-derived PBDEs from plastic by seabirds' stomach oil and accumulation in tissues. Environ. Sci. Technol. 49, 11799–11807.

Tavares, D.C., Siciliano, S., 2013. An inventory of wetland non-passerine birds along a southeastern Brazilian coastal area. J. Threat. Taxa 5, 4586–4597.

Thompson, R.C., Olsen, Y., Mitchell, R.P., Davis, A., Rowland, S.J., John, A.W.G., McGonigle, D., Russell, A., 2004. Lost at sea: where is all the plastic? Science 304, 838.

Verlis, K.M., Campbell, M.L., Wilson, S.P., 2014. Marine debris is selected as nesting material by the brown booby (*Sula leucogaster*) within the Swain Reefs, Great Barrier Reef, Australia. Mar. Pollut. Bull. 87, 180–190.

Votier, S.C., Archibald, K., Morgan, G., Morgan, L., 2011. The use of plastic debris as nesting material by a colonial seabird and associated entanglement mortality. Mar. Pollut. Bull. 62, 168–172.

Wilcox, C., Van Sebille, E., Hardesty, B.D., 2015. Threat of plastic pollution to seabirds is a global, pervasive and increasing. PNAS 112, 11899–11904.