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Prevalence and composition of marine debris in Brown Booby (*Sula leucogaster*) nests at Ashmore Reef

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ABSTRACT

Anthropogenic debris is ubiquitous in the marine environment and has been reported to negatively impact hundreds of species globally. Seabirds are particularly at risk from entanglement in debris due to their habit of collecting food and, in many cases, nesting material off the ocean's surface. We compared the prevalence and composition of debris in nests and along the beach at two Brown Booby (*Sula leucogaster*) colonies on Ashmore Reef, Timor Sea, a remote area known to contain high densities of debris transported by ocean currents. The proportion of nests with debris varied across islands (range 3–31%), likely in response to the availability of natural nesting materials. Boobies exhibited a preference for debris colour (white and black), but not type. The ephemeral nature of Brown Booby nests on Ashmore Reef may limit their utility as indicators of marine pollution, however monitoring is recommended in light of increasing demand for plastic products.

1. Introduction

Plastics and other anthropogenic debris (hereafter referred to as marine debris, or simply debris), much of it originating from fishing activities and run-off from rivers, are increasing rapidly in the world's oceans (Ribic et al., 1997; Gregory, 2009; Ryan et al., 2009). While ubiquitous in the marine environment, debris tends to concentrate at oceanographic sites where marine animals aggregate to feed (Laist, 1987; Pichel et al., 2007; Howell et al., 2012). Consequently, the ingestion of, or entanglement in, debris has been reported in more than 265 species of birds, fish, turtles, and whales (Laist, 1997; Derraik, 2002).

In the Sulidae (gannets and boobies), adult males collect debris, primarily at sea, during courtship and incorporate it rather conspicuously into their nests (Moore and Wodzicki, 1950; Nelson, 1978). This behaviour, along with the ingestion of debris by seabirds, can provide information on temporal changes in the type, quantity, and source of debris present in the marine environment (Ryan, 2008; van Franeker et al., 2011; Bond et al., 2012). However, it also increases the risk of entanglement of both juveniles and adults and therefore poses a conservation concern (Laist, 1997; Parker and Blomme, 2007; Votier et al., 2011).

Marine debris is prevalent in the nests of gannets (*Morus* sp.) and has been the focus of numerous studies (Schrey and Vauk, 1987; Montevecchi, 1991; Schneider, 1991; Norman et al., 1994; Cooper and Petersen, 2009; Bond et al., 2012). In contrast, only one study briefly mentions debris in booby (*Sula* sp.) nests (Ostrowski et al., 2005). In order to provide insight into the frequency of this behaviour in boobies, we assessed (1) the type, colour, and mass of marine debris incorporated into Brown Booby (*Sula leucogaster*) nests on breeding islands in the Timor Sea, and (2) the capacity of nest debris to act as an indicator of the amount and type of debris in marine environments where direct, quantitative data are not available. We also briefly discuss the extent to which nest debris poses an entanglement risk for this declining species.

2. Methods

2.1. Study sites

Ashmore Reef Commonwealth Marine Reserve (12°20′S, 123°0′E) lies within Australian Commonwealth waters, approximately 630 km north of Broome, Western Australia (Fig. 1). The reef contains four lightly vegetated islands (East, Middle, and West Islands and Splittgerber Cay; total land area ~54 ha) and is home to some of the most important seabird rookeries on the North West Shelf (Clarke et al., 2011). It is recognised as a Ramsar wetland of international importance (Ramsar Convention Bureau, 2013) and is designated as an Important Bird Area (BirdLife International, 2013). The Brown Booby is the most abundant of the three species of Sulidae breeding at Ashmore Reef with an estimated 2632 and 3453 pairs breeding on East and Middle Islands in April 2013, respectively (Clarke and Herrod, 2013).

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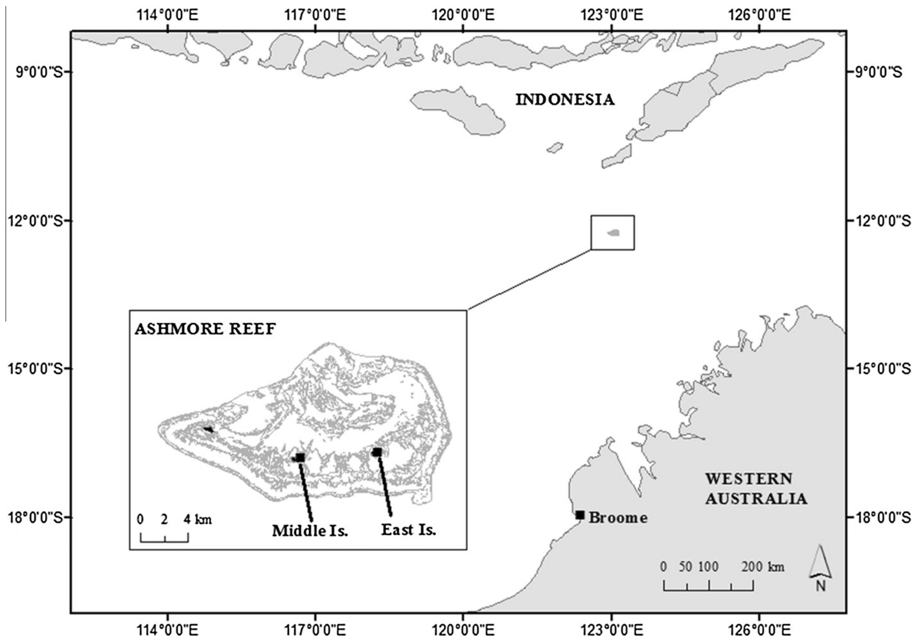

Fig. 1. Marine debris in Brown Booby nests was recorded at East and Middle Islands, Ashmore Reef, during April 2013.

2.2. Nest debris surveys

The number of Brown Booby nests containing marine debris was recorded on Middle and East Islands during 11–16 April 2013. Nests were located at least 5 m from the high tide mark. The type and colour of debris in each nest was visually recorded using binoculars from a distance of around 5 m. In order to minimise disturbance, marine debris was only collected from nests where the adult bird had flushed. Debris was collected, weighed to the nearest 1 g, and sorted into the following categories: foam (e.g., footwear, polystyrene), glass, hard plastic (e.g., bottle cap), rope, soft plastic (e.g., bag, balloon), and twine.

2.3. Beach debris surveys

Marine debris was collected from a single beach transect (2 m $\times$ 200 m) along the high tide mark on the eastern side of Middle Island on 15 April 2013. Items were sorted into the same categories outlined above. The provenance of items was recorded when manufacturing credentials were legible.

2.4. Statistical methods

We tested for differences in the proportion of booby nests with debris on East and Middle Islands using a general linear model (GLM) with a binomial distribution in SPSS 20 (Redmond, Washington, USA). Differences in the type and colour of debris in nests across islands were assessed using multivariate GLM with a Poisson distribution. Differences in the mass of debris items in nests on each island were assessed using ANOVA.

We also examined whether the type and colour of debris in nests on Middle Island differed from the debris found on the beach using Chi-square analysis. Values are reported as mean ± SD and differences are considered significant when $p < 0.05$.

3. Results

3.1. Nest debris

Significantly fewer nests contained debris on East Island (3.5%, $n = 313$; Wald chi-square = 51.32, $p < 0.01$; Table 1) than Middle Island (31.1%, $n = 122$). With the exception of one nest on Middle Island that contained two debris items (yellow and green), nests contained only a single piece of debris. Of nests with debris, white (13.2–42.0%, $n = 10$), black (26.3–33.0%, $n = 14$), and green (8.0–31.6%, $n = 13$) items were the most common numerically (Table 1). Hard plastic items (e.g., bottle caps) were the most frequent form of nest debris on both East (50.0%) and Middle Islands (48.7%), followed by rope and foam (Table 1). Nest debris colour and type did not differ significantly across the two islands (colour: Wald chi-square = 0.42, $p = 0.81$; type: Wald chi-square = 2.42, $p = 0.30$).

Average dry weight of marine debris incorporated into individual nests on East (13.3 ± 15.5 g, $n = 11$) and Middle Islands (8.8 ± 14.3 g, $n = 26$) did not differ significantly ($F_{2,37} = 0.45$, $p = 0.64$). Assuming nests with debris are a representative sample of the population (by mass and number of debris items), and using the most recent population estimates for East and Middle Islands, we estimate 92 and 1074 pieces of marine debris (weighing 1.2 kg and 9.5 kg, respectively) are incorporated into booby nests on each island, respectively.

3.2. Beach debris

Beach debris observed on Middle Island ($n = 34$) was comprised mainly of hard plastic (91.2%; Table 1). Debris found on the beach differed in colour, but not type, from debris found in booby nests on Middle Island (colour: Pearson chi-square = 11.97, $p = 0.04$; type: Pearson chi-square = 2.33, $p = 0.80$). A shoe and plastic water bottle manufactured in Indonesia and a plastic bottle containing body wash manufactured in Germany were recorded on Middle Island.

Table 1
Frequency of marine debris type and colour varied among Brown Booby nests on East and Middle Islands on Ashmore Reef and differed significantly from the type and colour of debris recorded on beaches during April 2013.

	East Island	Middle Island	
	Nest debris ($n = 12$)	Nest debris* ($n = 38$)	Beach debris ($n = 34$)
Debris type			
Hard plastic	0.363	0.487	0.912
Plastic bag	0.000	0.077	0.000
Rope	0.272	0.077	0.059
Twine	0.091	0.205	0.000
Foam	0.272	0.128	0.029
Glass	0.000	0.026	0.000
Debris colour			
Blue	0.000	0.184	0.559
White	0.420	0.132	0.265
Green	0.080	0.316	0.088
Yellow	0.000	0.158	0.029
Black	0.330	0.263	0.029
Red	0.170	0.105	0.029

* Values do not sum to 1 since one nest contained two items of debris.

4. Discussion

Entanglement in rope and other forms of marine debris is a significant source of mortality and morbidity for seabirds, particularly for species that incorporate debris into their nests (Podolsky and Kress, 1989; Votier et al., 2011). In Australia, entanglement in marine debris is listed as a Key Threatening Process for marine vertebrates, including seabirds (DEWHA, 2009). However, increasing recognition of the problem and introduction of regulations aimed at preventing debris from entering the world's oceans (e.g., MARPOL Annex 5) have not reduced the risk of entanglement for some marine species (Henderson, 2001; Page et al., 2004). While the source of Brown Booby nest debris on Ashmore Reef is not known, rope and twine in seabird nests have been linked to fishing activities adjacent to seabird colonies (Montevecchi, 1991; Hartwig et al., 2007; Votier et al., 2011; Bond et al., 2012). Fishing and other debris found on East and Middle Islands may have also originated from Southeast Asia and was transported to Ashmore Reef via the Indonesian Throughflow (Gordon and Fine, 1996; Qiu et al., 1999). We estimate the current amount of debris in booby nests on East and Middle Islands to be 1166 pieces, with rope and other fishing-related items that pose an entanglement risk to the birds accounting for around 30% (Table 1). On Middle Island, a young booby nestling was found entangled after the parent bird placed a large piece of green rope over its neck. While this is likely only a minor source of injury and mortality for Brown Boobies at the population level, the long term persistence of marine debris means the quantity in the ocean, and corresponding risk of entanglement at breeding colonies, will likely increase in the Browse Basin over time.

Previous studies on gannets suggest almost all nesting material is collected at sea (Moore and Wodzicki, 1950; Bourne, 1976; Nelson, 1978; Matthews et al., 2008), therefore the amount of anthropogenic debris in nests is thought to provide an indication of the level of pollution in the surrounding ocean (Montevecchi, 1991; Furness and Camphuysen, 1997; Hartwig et al., 2007). In boobies, the majority of nesting material is collected from nearby shrubs (Nelson, 1969), although Masked Boobies (*Sula dactylatra*) may occasionally return to breeding islands with rope after becoming entangled (Conant, 1984). On Ashmore Reef, Brown Boobies were frequently observed collecting vegetation within a 1 m radius of their nest and were only rarely observed flying back with nesting materials. The difference in the frequency of debris in Brown Booby nests on East (3.5%) and Middle Islands (31.1%) may therefore be due to differences in vegetation cover. During this study, East Island supported an extensive cover of annual vegetation (Fig. 2b) and nesting material may have been easier to locate. On Middle Island, observations were made in a sandy, open area (Fig. 2c) where nesting material of a vegetative origin is scarce and birds may rely more heavily on marine debris. However, on the Umm al-Qamari Islands in the Red Sea, only 8.8% ($n = 34$) of Brown Booby nests surveyed (July 2003) contained debris on an un-vegetated sandbank compared with 7.1% of nests ($n = 28$) on the vegetated island of al-Foganiah (Ostrowski pers. comm.; Ostrowski et al., 2005). This suggests factors other than proximity to vegetation may also influence nesting material selection.

Intraspecific differences in nesting and breeding behaviour have been reported in boobies (Simmons, 1973), therefore the behaviour of collecting marine debris as nesting material may be specific to certain individuals, or locations. For example, theft of nesting material from neighbouring conspecifics is commonly reported on un-vegetated islands (Marchant and Higgins, 1990), but was not observed on East or Middle Islands during this study. Despite an apparent shortage of nesting material on parts of Middle Island, Brown Boobies typically constructed well-defined nests (Fig. 2c), a behaviour that is not observed on other sandy cays (Hindwood et al., 1963; Ostrowski et al., 2005).

Selection for different coloured debris items ingested by Procellariform seabirds has been linked to the degree of similarity to potential prey items and conspicuousness at sea (Ryan, 1987). While our results suggest boobies in the Timor Sea exhibit colour selection (Table 1), this is unlikely to be influenced by prey colour or visibility on the ocean surface since the collection of nesting materials by Brown Boobies appears to be predominantly land-based. Male Brown Boobies exhibit a blue facial patch that varies in intensity based on breeding condition (Simmons, 1967), however the lack of blue debris in nests in the Browse Basin (Table 1) suggests female Brown Boobies are not selecting for debris that corresponds with indicators of mate condition. Instead, Brown Boobies on East and Middle Islands may exhibit a preference for debris items that resemble organic nesting material (e.g., driftwood and feathers in the white and black spectra; Table 1, Fig. 2a). Debris items recorded in Brown Booby nests on the Umm al-Qamari Islands (plastic bottle, black plastic sheet, fishing line, white plastic bag, two nests containing plastic bags, white bottle cap, brown cardboard; Ostrowski pers. comm.) were also primarily in the white and black spectra. While male boobies collect the vast majority of nesting materials (Simmons, 1970), females may shape the selection of debris colour and type since mate choice is influenced by the ability of the male to present the female with appropriate nesting materials (Simmons, 1967).

In Northern Gannet (*Morus bassanus*) colonies, the proportion of nests containing marine debris and mass of debris per nest is higher (around 50–90% and 470 g, respectively; Votier et al., 2011; Bond et al., 2012) than in Brown Boobies (3–30% and 10.1 ± 14.4 g, respectively). This is likely due to the accumulation of debris in nest pedestals that are re-used by Gannets each year (Nelson, 1978; Norman et al., 1994). Brown Boobies do not appear to re-use their nests and some of the nesting materials on Ashmore Reef are thought to be re-distributed by weather across the island during the dry season (June–November) when the herbaceous vegetation on East and Middle Islands dies and largely disappears. While this may benefit boobies by preventing the build-up of debris that may contribute to entanglement, it likely precludes the use of nest debris as an indicator of pollution in the marine environment. Despite this, monitoring of marine debris in booby nests remains of value as significant quantities of anthropogenic debris are now present in all major ocean basins (Thompson et al., 2004;

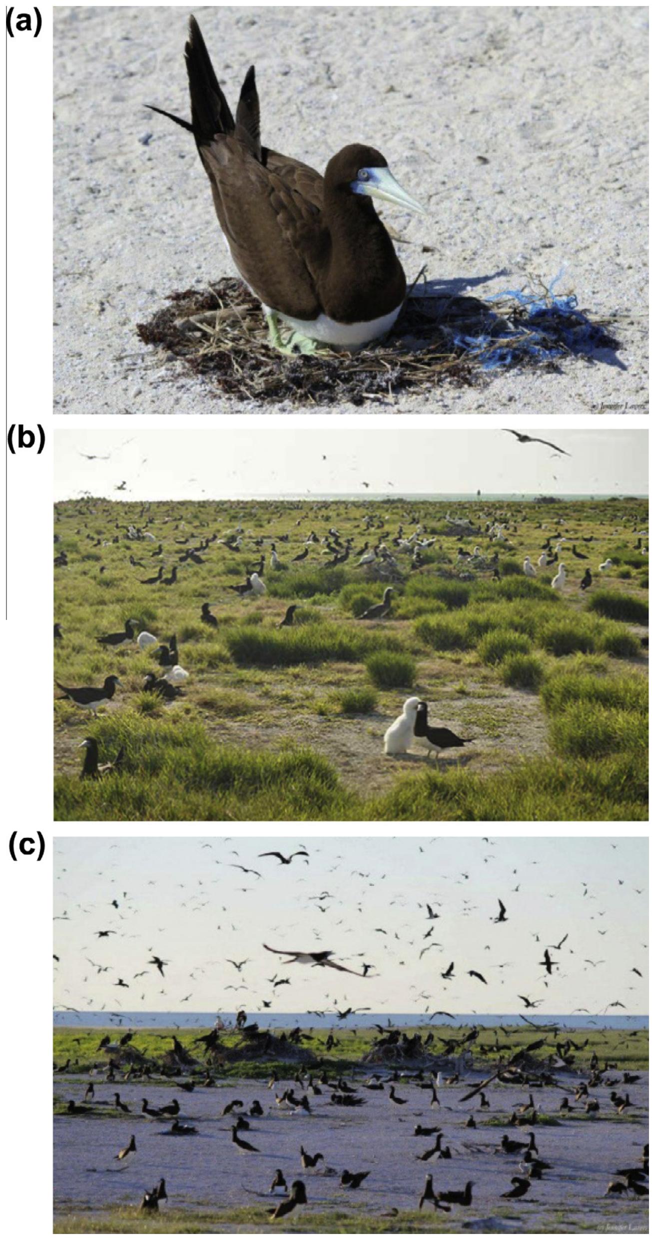

Fig. 2. An example of marine debris used as nesting material by Brown Boobies (a) and nesting colonies on East (b), and Middle (b) Islands.

Barnes et al., 2009; Gregory, 2009; Howell et al., 2012), including the Timor Sea (Morrison and Delaney, 1996), and global plastic production is predicted to increase by more than 10% per year over coming decades (PlasticsEurope, 2012; ACC, 2013).

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