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Marine debris: a proximate threat to marine sustainability in Bootless Bay, Papua New Guinea

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Abstract

Surveys of stranded marine debris around Motupore Island, a small island in Bootless Bay, Papua New Guinea, revealed exceptionally high loads (up to 78.3 items m^{-2}), with major concentrations in mangrove-dominated, depositional areas. The worst affected, 50-m stretch of shore was estimated to contain >37,000 items with a combined weight of 889 kg. Consistent with studies elsewhere, plastics comprised by far the majority of debris across all sites (89.7%). The lack of centralised waste collection and limited village-based resources, coupled with an increasing population, suggests that this issue is a long way from solution. High debris loads thwart attempts to rehabilitate depleted mangrove forests through smothering of seedlings, perpetuating run-off and water quality issues in the bay. Addressing marine debris is thus of fundamental importance for the sustainability of Bootless Bay and its resources, and a critical step in promoting ecosystem resilience.

Introduction

Marine debris is recognised worldwide as a threat to marine organisms, ecological processes and marine economies (for reviews see Derraik, 2002; Gregory, 2009; Katsanevakis, 2008; McIlgorm et al., 2008). As such, many nations have attempted to reduce the transport of litter into waterways. As evidenced by the remarkable debris loads reported in remote areas of the world's oceans in the recent past (e.g. Moore et al., 2001), there is clearly a long way to go. Although yet to be adequately quantified at a global scale, marine debris loads are likely to be highest in the coastal environments of developing countries (Todd et al., 2010), many of which are in the most biodiverse regions of the planet (Roberts et al., 2002). Marine debris is thus one of the many threats that leads to an over-representation of marine biodiversity hotspots (areas of high endemicity and diversity that are also at high risk) in the coral triangle of South-east Asia/Western Pacific.

There are several primary impediments to managing litter in the Pacific region. Population densities in urban areas are often large, and the centralised litter-disposal and recycling services provided in most developed countries are often rudimentary at best, and may be totally lacking. In Papua New Guinea, recent migration rates to coastal areas have been high, especially to the nation's capital, Port Moresby. While potentially leading to conflict over limited resources (Cinner, 2009), this also places enormous pressure on centralised services to deal with the associated waste, especially in informal settlements and outside the city boundaries. This is exacerbated by the system of customary ownership of land (>90% of all land in PNG has traditional land tenure) and the consequent lack of revenue from land taxes to enable governments to provide comprehensive waste services. In 2009, recognising the problem of plastic waste in the environment, the PNG government took an important step towards waste reduction by banning the sale and import of non-biodegradable plastic bags. In the same year, the Secretariat of the Pacific Community (SPC) highlighted the implications of marine debris on the environment and for constraining tourism development in coastal areas, recommending widespread awareness programs.

However, whilst litter and marine debris are prevalent in PNG and widely acknowledged as an issue, there have been few attempts to quantify the scale of the problem both in terms of debris loads and impacts on habitats, biodiversity and ecological processes. This study, therefore, represents a first attempt to quantify marine debris load on a single island close to the nation's capital, Port Moresby, and the location of the University of Papua New Guinea's (UPNG) marine research facility, Motupore Island Research Centre (MIRC).

Material and methods

Site description

Motupore Island is a small (~900 x 350 m) island 15 km south-east of Port Moresby (Fig. 1). Lying within the Papuan Barrier Reef in Bootless Bay, the island is surrounded by fringing reefs and seagrass beds: the intertidal areas of the adjacent mainland are dominated by mangrove forests although large tracts of mature trees have been removed for both construction and firewood (T. Maniwavie, pers. comm.). The waters of Bootless Bay are renowned for their high diversity (e.g. Baine and Harasti, 2007) and provide important resources for subsistence fishing by local people

(Cinner and McClanahan, 2006). The adjacent Loloata Island is the location of a resort and dive business that attracts divers from around the world. The UPNG established MIRC in 1970: since then, it has been the primary focus for marine teaching and an important base for local and international researchers. The primary settlement along the shores of Bootless Bay is Tubusereia, a village of ~5,000 residents to the south-east of Motupore Island (Fig. 1), in which most dwellings are constructed on stilted platforms over the sea.

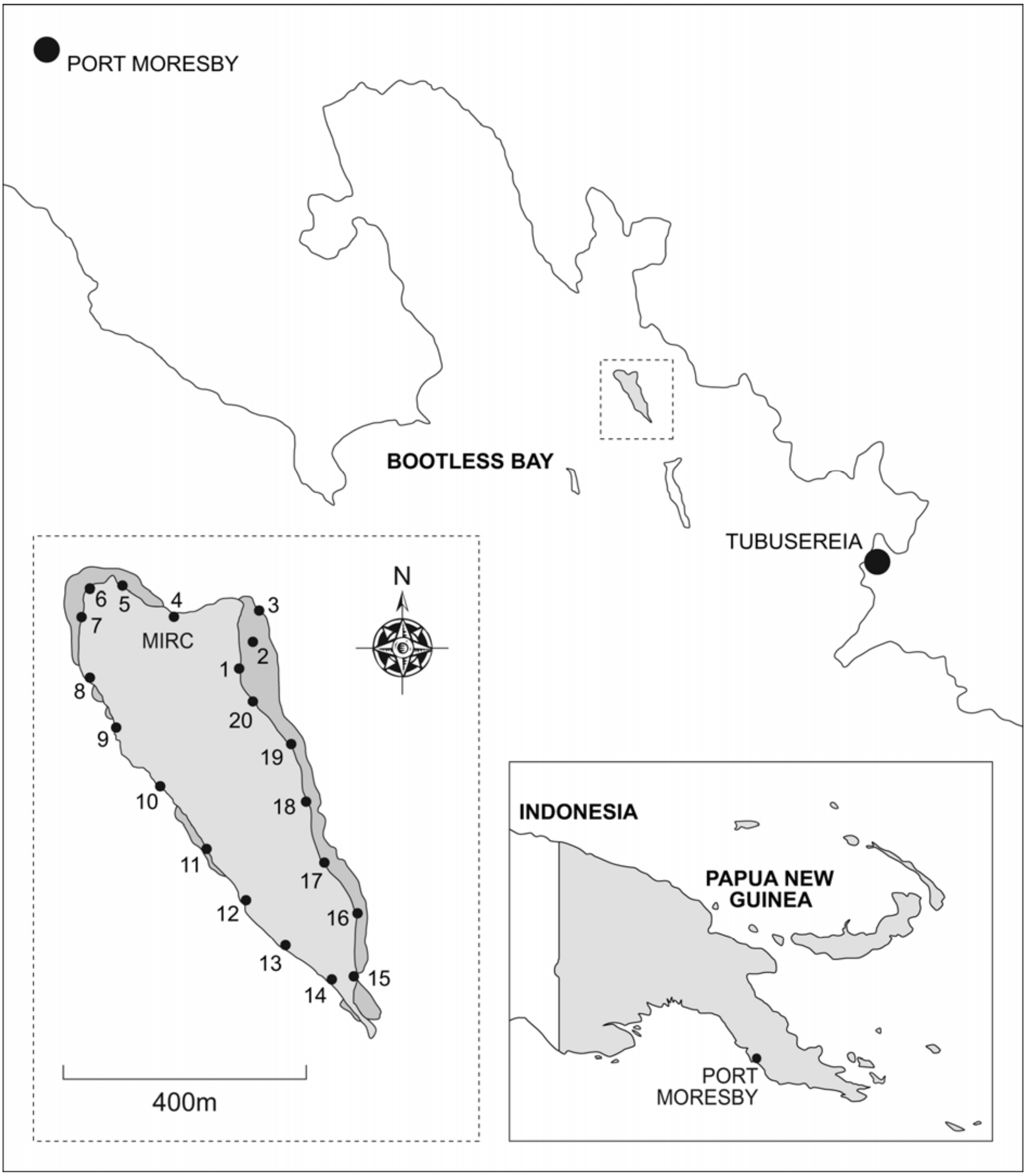

Fig. 1. Motupore Island and the location of sites used for quantification of debris in the intertidal region.

Mangroves dominate the intertidal shore of Motupore Island from the south-eastern tip around to the north-western sector (Fig. 1). Benthic habitats in the areas with densest mangal growth are predominantly sedimentary while those associated with the more exposed shore on the westerly to south-westerly aspects comprise rock.

South to south-easterly trade winds dominate the weather patterns during much of the year with a shift to north to north-westerly winds during the wet season (Jan – March). As the bay is relatively shallow, these winds primarily determine current patterns and surface flow.

Sampling methods

Marine debris (macro-debris, > 5mm) was sampled at 20 sites around the island over a 1-week period in Sept 2009 (Fig. 1). While most studies of intertidal debris have used transects with a minimum length of 50 m (e.g. Ryan et al., 2009), the sheer density of debris at some sites precluded this approach. Instead, sampling was done with relatively small sampling units (1 x 2 m quadrats) which were replicated within each site (n = 5 at each site; note that greater replication (n = 8) occurred at the sites with the densest debris loads - sites 1, 2 and 20 – Fig. 1). Sites extended across 20 m of shore and were placed ~50 m apart in areas with high debris loads and 100 m apart elsewhere. Sampling was conducted randomly within each site between the upper tidal limit (the highest extent of debris) and the accessible lower shore (the lowest extent of marine debris).. The approximate width (down the shore) of the deposit was also measured (to the nearest 0.5 m). All debris was removed from the quadrats and each item was identified and counted. The composition of each item was also noted. If items comprised multiple materials, they were allocated into the category for the dominant material type. Additional scrutiny was given to a 50-m section of mangal area which supported the densest aggregations of debris on the island (adjacent to sites 1 and 2). Here, in addition to sorting items into categories, the mass of debris was determined for each quadrat.

Results

A total of 3,349 items was counted during the study and mean debris load per site ranged from 1.2 – 78.3 items m^{-2} (with an average across the entire island of 15.3 items m^{-2}) (Table 1). The most prevalent items were pieces of styrofoam (1,125), food and toiletry wrappers (501), plastic bags (326), plastic pieces (263), plastic bottles (261), and plastic bottle tops (211). The overwhelming majority (89.7%) of items were made of plastic (Table 2).

The highest loads occurred in the mangrove-dominated habitats on the north-eastern section of the island (sites 1, 2 and 20 - Table 1), where debris occurred over a band 6-10 m wide with a vertical depth >0.5 m, and a mean weight of 1.9 kg m^{-2} (SE = 0.225). Extrapolation for the 50-m stretch of shore adjacent to sites 1 and 2 indicated a debris load of >37,000 items with a combined weight of 889 kg. Away from the sites characterised by dense mangroves, debris loads declined considerably and were at their lowest on the south-western section of the island. This area is characterised by steeply plunging rocky slopes and a narrow shore that is fully inundated at high tide. The area is also directly exposed to the predominant south-easterly trade winds. As a result, there are few sites where debris can accumulate. Correlation between debris load and width of the mangrove stands (determined using Google Earth – image from 2009) using mean debris load at each site, indicated a highly significant positive relationship (*r* = 0.81, *p* <0.001). Extrapolating to the whole of Motupore Island, this study estimated there to be ~53,000 items of debris on the intertidal shore (90% CI ~38,700 – 67,500).

Table 1. Mean debris loads (SE), predominant habitat type, and width of the debris band at each of the sampling sites.

Site	Habitat	Width (m)	Mean (SE)
1	Mangroves	10	78.3 (15.1)
2	Mangroves	6	40.8 (5.5)
3	Mangroves	1	7.6 (2.4)
4	Beach	1.5	13.1 (3.8)
5	Mangroves	2	14.9 (2.7)
6	Mangroves	1	5.6 (2.0)
7	Open shore	0.5	2.6 (1.4)
8	Open shore	0.5	6.0 (2.6)
9	Open shore	0.5	11.8 (10.5)
10	Open shore	0.5	7.4 (2.2)
11	Open shore	0.5	5.7 (4.0)
12	Open shore	0.5	1.8 (0.8)
13	Open shore	0.5	2.5 (0.8)
14	Open shore	0.5	1.2 (0.4)
15	Gap in mangroves	0.5	3.8 (1.1)
16	Mangroves	0.5	9.2 (5.8)
17	Mangroves	5.0	12.9 (3.5)
18	Mangroves	0.5	1.2 (0.3)
19	Mangroves	0.5	2.4 (0.4)
20	Mangroves	3.5	39.4 (13.3)

Table 2. Percentage contribution of different materials to the debris surveyed at Motupore Island (3,349 items)

Composition	%
Glass	2.3
Metal	1.1
Paper	1.6
Plastic	89.7
Rubber	2.9
Textile	0.6
Wood	1.7

Discussion

Debris loads on Motupore Island are exceptionally high in comparison to similar studies conducted elsewhere. For example, the densest aggregation of debris (site 1) supported more than the highest densities documented from the Pulau Seribu Archipelago (The Thousand Islands), Indonesia (max. of 54 items m^{-2} of beach) (Uneputty and Evans, 1997b; Willoughby et al., 1997), an area in Jakarta Bay which is renowned for exceptionally high debris loads. Indeed, the average load for the Motupore Island, while only one-fifth of the highest site-specific value, was within the range recorded on islands adjacent to Jakarta (Uneputty and Evans, 1997b), a city with a population exceeding 8.5 million. The distribution around the island was strongly correlated with the presence of mangroves – this is unsurprising given their presence in depositional areas and their ability to trap any debris that is transported onto the shore. However, this pattern of distribution suggests that impacts may also be greatest in mangal habitats and this may have broader consequences for Bootless Bay (see below).

The majority of items were clearly of domestic origin. The island itself houses few people (~5 residents apart from during field classes from UPNG) who either burn their refuse or return it to the mainland (the latter is now standard practice). Given the predominance of south-easterly trade winds for much of the year, and the location of the largest population centre (Tubusereia) to the south east, there is little doubt that this is the primary source of debris. Motupore Island is likely to receive only some of the debris disposed of by residents of Tubusereia and other communities to the south-east. Indeed, the shores of Tubusereia also support vast loads of debris (although this was not quantified). Given the ability of mangroves to trap debris once it floats onto intertidal habitats, it is not possible to determine the period over which the debris assessed during this study had accumulated and, thus, get an estimate of depositional rates (for which accumulation-focused studies are necessary - Ryan et al., 2009).

Although this study did not attempt to measure direct effects on the ecology of the intertidal habitats, anoxic conditions evident below the debris at sites 1 and 2 (pers. obs.) suggest these may be high for benthic infauna (Aloy et al., 2011; Uneputty and Evans, 1997a). In addition to direct impacts, the high debris loads potentially affects local human populations through reduced fishing efficiency (Nash, 1992) as well as through other social and economic costs (e.g. McIlgorm et al., 2008).

While these results are for one small island in Bootless Bay, they are part of a worrying picture about the broader health and sustainability of the ecosystem. Bootless Bay is lined by mangroves which are a valuable resource for local people, both as building materials (e.g. for the stilts supporting the houses at Tubusereia) and firewood. Progressive harvesting over past decades, and which continues today, has resulted in loss of much of the mangal cover - this may have considerable flow-on effects through loss of a range of ecosystem services (e.g. Barbier et al., 2011; Warren-Rhodes et al., 2011). Mangrove removal has consequences for adjacent reefs through loss of nursery habitat for fish (e.g. Mumby et al., 2004), increased sedimentation rates (Victor et al., 2004) and loss of organic input into food webs (Duke et al., 2007). This may lead to further stock reductions in a fishery that is already considered to be overexploited (Cinner and McClanahan, 2006). At the same time, land adjacent to the bay is being cleared for cultivation by the increasing human population (Cinner, 2009), mostly by hillside burning. The increased rates of terrestrial runoff likely to result from this practice can only exacerbate the problem of sedimentation within the bay.

Mangrove rehabilitation has been identified as a critical step in fostering ecosystem sustainability at the local scale (e.g. Duke et al., 2007), and internationally funded programs to establish nurseries, and involve local communities in large-scale planting, have been in operation for the past decade. However, these programs often fail as seedlings become blanketed and smothered by marine debris (Thomas Maniwavie, pers. comm.).

There is now a strong body of evidence suggesting that the Bootless Bay ecosystem is in a state of rapidly increasing stress. Local fisheries resources are overexploited (Cinner and McClanahan, 2006), and there have been recent reports of outbreaks of crown-of-thorns starfish (Pratchett et al., 2009), as well as prolonged episodes of coral bleaching (pers. obs. 2009). Research and adaptation imperatives in a climate-change focused world are increasingly directed towards fostering ecosystem resilience (e.g. Hughes et al., 2010). In this case, a clear first step down this path is through concerted efforts to deal with marine debris.

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References

Aloy, A.B., Vallejo Jr, B.M., Juinio-Meñez, M.A., 2011. Increased plastic litter cover affects the foraging activity of the sandy intertidal gastropod *Nassarius pullus*. Marine Pollution Bulletin 62, 1772-1779.

Baine, M., Harasti, D., 2007. The marine life of Bootless Bay Papua New Guinea. Motupore Island Research Centre, Port Moresby.

Barbier, E.B., Hacker, S.D., Kennedy, C., Koch, E.W., Stier, A.C., Silliman, B.R., 2011. The value of estuarine and coastal ecosystem services. Ecological Monographs 81, 169-193.

Cinner, J.E., 2009. Migration and coastal resource use in Papua New Guinea. Ocean and Coastal Management 52, 411-416.

Cinner, J.E., McClanahan, T.R., 2006. Socioeconomic factors that lead to overfishing in small-scale coral reef fisheries of Papua New Guinea. Environmental Conservation 33, 73-80.

Derraik, J.G.B., 2002. The pollution of the marine environment by plastic debris: a review. Marine Pollution Bulletin 44, 842-852.

Duke, N.C., Meynecke, J.O., Dittmann, S., Ellison, A.M., Anger, K., Berger, U., Cannicci, S., Diele, K., Ewel, K.C., Field, C.D., Koedam, N., Lee, S.Y., Marchand, C., Nordhaus, I., Dahdouh-Guebas, F., 2007. A World Without Mangroves? Science 317, 41-42.

Gregory, M.R., 2009. Environmental implcations of plastic debris in marine settings - entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. Philosophical Transactions of the Royal Society of London Series B 364, 2013-2025.

Hughes, T.P., Graham, N.A.J., Jackson, J.B.C., Mumby, P.J., Steneck, R.S., 2010. Rising to the challenge of sustaining coral reef resilience. Trends in Ecology & Evolution 25, 633-642.

Katsanevakis, S., 2008. Marine debris, a growing problem: Sources, distribution, composition, and impacts, in: Hofer, T.N. (Ed.), Marine Pollution: New Research. Nova Science Publishers, New York, pp. 53-100.

McIlgorm, A., Campbell, H.F., Rule, M.J., 2008. Understanding the Economic Benefits and Costs of Controlling Marine Debris in the APEC region (MRC 02/2007). A report to the Asia-Pacific Economic Cooperation Marine Resource Conservation Working Group. National Marine Science Centre, Coffs Harbour, Australia.

Moore, C.J., Moore, S.L., Leecaster, M.K., Weisberg, S.B., 2001. A comparison of plastic and plankton in the North Pacific Central Gyre. Marine Pollution Bulletin 42, 1297-1300.

Mumby, P.J., Edwards, A.J., Arias-Gonzalez, J.E., Lindeman, K.C., Blackwell, P.G., Gall, A., Gorczynska, M.I., Harborne, A.R., Pescod, C.L., Renken, H., Wabnitz, C.C.C., Llewellyn, G., 2004. Mangroves enhance the biomass of coral reef fish communities in the Caribbean. Nature 427, 533-536.

Nash, A.D., 1992. Impacts of marine debris on subsistence fishermen - an exploratory-study. Marine Pollution Bulletin 24, 150-156.

Pratchett, M.S., Schenk, T.J., Baine, M., Syms, C., Baird, A.H., 2009. Selective coral mortality associated with outbreaks of Acanthaster planci L. in Bootless Bay, Papua New Guinea. Marine Environmental Research 67, 230-236.

Roberts, C.M., McClean, C.J., Veron, J.E.N., Hawkins, J.P., Allen, G.R., McAllister, D.E., Mittermeier, C.G., Schueler, F.W., Spalding, M., Wells, F., Vynne, C., Werner, T.B., 2002. Marine biodiversity hotspots and conservation priorities for tropical reefs. Science 295, 1280-1284.

Ryan, P.G., Moore, C.J., van Franeker, J.A., Moloney, C.L., 2009. Monitoring the abundance of plastic debris in the marine environment. Philosophical Transactions of the Royal Society B: Biological Sciences 364, 1999-2012.

Todd, P.A., Ong, X., Chou, L.M., 2010. Impacts of pollution on marine life in Southeast Asia. Biodiversity and Conservation 19, 1063-1082.

Uneputty, P., Evans, S.M., 1997a. The impact of plastic debris on the biota of tidal flats in Ambon Bay (eastern Indonesia). Marine Environmental Research 44, 233-242.

Uneputty, P.A., Evans, S.M., 1997b. Accumulation of beach litter on islands of the Pulau Seribu Archipelago, Indonesia. Marine Pollution Bulletin 34, 652-655.

Victor, S., Golbuu, Y., Wolanski, E., Richmond, R.H., 2004. Fine sediment trapping in two mangrove-fringed estuaries exposed to contrasting land-use intensity, Palau, Micronesia. Wetlands Ecology and Management 12, 277-283.

Warren-Rhodes, K., Schwarz, A.M., Boyle, L.N., Albert, J., Agalo, S.S., Warren, R., Bana, A., Paul, C., Kodosiku, R., Bosma, W., Yee, D., Ronnback, P., Crona, B., Duke, N., 2011. Mangrove ecosystem services and the potential for carbon revenue programmes in Solomon Islands. Environmental Conservation 38, 485-496.

Willoughby, N.G., Sangkoyo, H., Lakaseru, B.O., 1997. Beach litter: an increasing and changing problem for Indonesia. Marine Pollution Bulletin 34, 469-478.