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Marine plastics threaten giant Atlantic Marine Protected Areas

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There has been a recent shift in global perception of plastics in the environment, resulting in a call for greater action. Science and the popular media have highlighted plastic as an increasing stressor [1,2]. Efforts have been made to confer protected status to some remote locations, forming some of the world's largest Marine Protected Areas, including several UK overseas territories. We assessed plastic at these remote Atlantic Marine Protected Areas, surveying the shore, sea surface, water column and seabed, and found drastic changes from 2013–2018. Working from the RRS James Clark Ross at Ascension, St. Helena, Tristan da Cunha, Gough and the Falkland Islands (Figure 1A), we showed that marine debris on beaches has increased more than 10 fold in the past decade. Sea surface plastics have also increased, with in-water plastics occurring at densities of 0.1 items m^{-3}; plastics on seabeds were observed at ≤0.01 items m^{-2}. For the first time, beach densities of plastics at remote South Atlantic sites approached those at industrialised North Atlantic sites. This increase even occurs hundreds of meters down on seamounts. We also investigated plastic incidence in 2,243 animals (comprising 26 species) across remote South Atlantic oceanic food webs, ranging from plankton to seabirds. We found that plastics had been ingested by primary consumers (zooplankton) to top predators (seabirds) at high rates. These findings suggest that MPA status will not mitigate the threat of plastic proliferation to this rich, unique and threatened biodiversity.

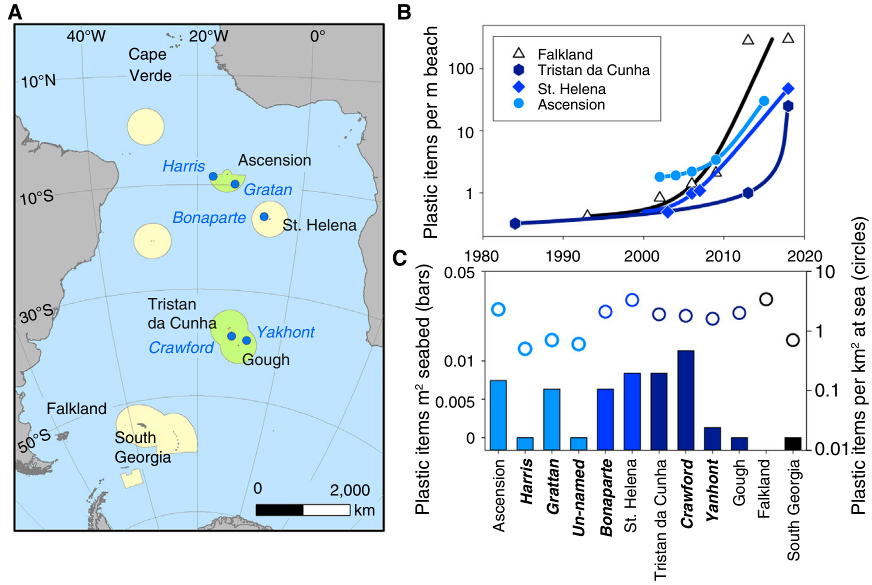

Figure 1. Plastic in remote Atlantic oceanic environments.
(A) Study area, islands and seamounts (blue italic). (B) Increase in shore-stranding plastic with time. (C) Plastic density levels found on seabed (bars) and sea surface (circles) by South Atlantic location (seamounts in bold/italic). Marine Protected Areas are shown in cream (established) and green (proposed).

Our across-ecosystem approach surveyed plastic densities in shoreline strandings (per m, per year), on the sea surface (per km^2), in the water column (per net haul), with seabed observations in images (per m^2) or in miniTrawls (per tow), and in the foodweb, from primary consumers (gelatinous zooplankton), through mid-trophic fish and seabird top predators. Between 20 and 301 debris items m^{-1} of beach were recorded at Ascension and East Falkland, respectively, higher than previously found [3] by one to two orders of magnitude (Figure 1B); more than 90% of the items recorded were plastic, similar to studies of less remote, South Atlantic sites [4]. Plastic fragments <5 mm (microplastics) were most abundant, comprising 35% of items, followed by plastic bottles, fishing-related items and films. Plastic fragments rarely had source-identifying marks but the level of UV damage (opaqueness, paling of coloured branding and micro-roughness) suggests >70% were of non-local origin. Plastic densities on remote Atlantic beaches are now comparable with the more populated and industrialised shores of the North Atlantic [5].

On the sea surface, plastic densities varied from 0–33 items km^{-2} (mean 1.7 items km^{-2}; values per location are shown in Figure 1C), with increases of 76% since 2013 and 92% since 1993. Thus, observed (macro) plastic at sea has increased considerably, but not as much as on beaches. Marine plastic levels have been explored around other South Atlantic Islands closer to continental margins (Brazil) using a surface tow net, yielding 0.6 and 2.4 items per tow [4]. South Atlantic plastic densities are highest at the 'garbage patch', concentrated within the gyre at >6 items km^{-2} [6].

In the water column, none of the large nets captured macroplastics around Gough, Tristan da Cunha, St. Helena or the surrounding seamounts. However, in 2018, 5 Bongo nets caught 5.9 items per net, per haul in the top 200 m around St. Helena and Bonaparte seamount — a mean density of ~0.1 plastic item m^{-3}. These were mainly microplastics (95% of items). Inshore, we used two plankton nets with 100 μm and 250 μm meshes and found 6.5–90.5 fragments m^{-3} (mean 38.6 m^{-3}).

We found many native, faunal colonists of floating plastics — the so-called 'plastisphere' habitat. In a millennium of habitat loss, residents of this habitat are amongst the very few 'winners' as their habitat availability, area and distribution are increasing. Plastic rafts are mobile and can persist for years to decades, providing near infinite opportunities for spread of species to new locations. Remote areas with little marine traffic and intact populations of endemic species, such as our South Atlantic study islands, are thus highly vulnerable to invasion. Macro-biological colonisation of stranded beach debris varied from 30% at Ascension to <10% on Falkland shores, within the range of previous findings [5]. A fishing buoy we recovered was home to seven morphotypes (barnacles, hydroids, bryozoans, corals and crabs).

To assess the food web we sampled 1,572 gelatinous zooplankton primary consumers, including appendicularians and seven salp genera (*Iasis, Ihlea, Pegea, Salpa, Thalia, Thetys* and *Weelia*). None of the 106 salps examined from offshore Bongo nets contained microplastics, but a salp in the larger RMT8 net had ingested a microplastic. Inshore zooplankton entanglement in microplastics varied from 1.8–48.7 zooplankton m^{-3}. Recent literature has highlighted this bioaccumulation threat for giant plankton feeders such as rays and whalesharks [2,7]. Around St. Helena they are prominent ecosystem components — iconic and key targets for regional conservation. At a higher trophic level, we investigated the stomach contents of 387 fish from 7 species. These included three mid-trophic-level species (*Helicolenus mouchezi, Brama brama* and *Sebastes capensis*) and three higher trophic-level species (*Hyperoglyphe antarctica, Schedophilus velaini, Scomber japonicus* and *Thyrsites atun*). One specimen of *Scomber japonicus* had swallowed polystyrene, obscuring 50% of the stomach volume. The object was of a texture, shape and size that would be unlikely to be dislodged within the lifetime of the individual. Plastic entanglement and ingestion are considered the biggest global threats to marine turtles, impacting thousands each year [8]. At top trophic levels, we examined 284 seabird cadavers. These included five species from prions to Albatrosses (*Ardenna gravis, Pachyptila vittata, Phoebetina fusca, Pterodoma mollis* and *Thalassarche chlororhynchos*) and 16 pellets of *Stercorarius skua*. These seabirds were the most impacted part of the food web with 71% incidence of plastics ingested and all study species affected. Plastic pieces 2 cm x 2 cm were the most commonly ingested.

Plastics have been widely reported from continental shelf seabeds [9], but rarely from remote locations. We captured and analysed 2,498 seabed images using a bespoke high-resolution Shelf Underwater Camera System for anthropogenic debris, including plastic. These were supplemented by collection from short tows of a bespoke mini-Agassiz trawl. We found seabed plastic around island shelves and seamounts at Ascension (Grattan), St. Helena (Bonaparte) and near Tristan da Cunha (Crawford) (Figure 1C). A plastic bag at Ascension and boot at Crawford seamount were uncolonized by macro-organisms (~3 mm or more in size) and might be recent. An intact bottom-fishing net at Crawford was colonized by algae and hydroids, and a fishing net from Yakhont seamount was covered by slow-growing corals (*Caryophyllia*). The nearly 2,500 seabed images that we collected of remote island shelves and seamounts is the most significant imaging of South Atlantic seabeds to date; only at Crawford seamount was marine plastic found at >0.01 item m^{-2}. SCUBA surveys undertaken at Ascension (in 2016) and St. Helena (in 2018) yielded >200 kg of marine debris.

Our study provides a snapshot in time of marine plastics in South Atlantic Marine Protected Areas and their associated food webs. These sentinels of global ocean pollution show drastic increases in marine plastic levels, with shore stranding higher than ever recorded in the last decade and pelagic plastic around St. Helena higher than around less remote islands off Brazil [4]. Observations of bait-fish gut contents at St. Helena showed that they have also ingested plastic. Our work shows a worrying state of the environment in these proposed and new MPAs, where plastics are now entering the food chain, as already seen elsewhere [2,7,8]. Policy needs to catch up with high and escalating risks from plastic pollution. Global mass attention on an issue tends to be brief, yet our work highlights the need to increase progress on solutions to the plastic crisis.

SUPPLEMENTAL INFORMATION

Supplemental Information includes two figures, experimental procedures and supplemental references, and can be found with this article online at https://doi.org/10.1016/j.cub.2018.08.064.

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