Exceptional and rapid accumulation of anthropogenic debris on one of the world's most remote and pristine islands

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In just over half a century plastic products have revolutionized human society and have infiltrated terrestrial and marine environments in every corner of the globe. The hazard plastic debris poses to biodiversity is well established, but mitigation and planning are often hampered by a lack of quantitative data on accumulation patterns. Here we document the amount of debris and rate of accumulation on Henderson Island, a remote, uninhabited island in the South Pacific. The density of debris was the highest reported anywhere in the world, up to 671.6 items/m^2 (mean ± SD: 239.4 ± 347.3 items/m^2) on the surface of the beaches. Approximately 68% of debris (up to 4,496.9 pieces/m^2) on the beach was buried <10 cm in the sediment. An estimated 37.7 million debris items weighing a total of 17.6 tons are currently present on Henderson, with up to 26.8 new items/m accumulating daily. Rarely visited by humans, Henderson Island and other remote islands may be sinks for some of the world's increasing volume of waste.

Henderson Island | Pitcairn Island Group | South Pacific Gyre | marine debris | plastic pollution

Since the beginning of its mass manufacture in the 1950s, the annual production of plastic has increased from 1.7 million tons in 1954 to 311 million tons in 2014 (1). Because plastic is very durable and most is not recycled (2), accidentally or intentionally littered items eventually enter our waterways. Here, plastic's buoyancy facilitates its transport by currents and wind throughout the world's oceans, persisting for decades and breaking into increasingly smaller pieces as a result of physical abrasion from wave action or photodegradation (3). This relatively new but permanent aspect of the marine environment is now ubiquitous in the world's oceans, even in the most remote locations, far from metropolitan and populated areas (4, 5). The surface layer of the world's oceans now contains more than five trillion items, mostly microplastics (<5 mm) (6). This proliferation of debris in our oceans has led to the recognition of plastic pollution as a major global environmental issue (7).

The significant quantities of plastic in the ocean, although widespread, concentrate in defined areas, such as oceanic convergence zones (8) and ocean gyres (9), reaching densities as high as 890,000 pieces/km^2 (6). The plastic from these gyres likely poses a significant threat to the wildlife inhabiting these waters and the islands on their periphery (e.g., through dispersal of colonizing species) (10). However, few data are available because of the remote nature of the gyres and islands and the species within them, and the fate of plastic pollution in the marine environment generally is poorly known.

An improved understanding of the abundance, diversity, and sources of plastic is required to mitigate the plastic pollution, and there are a number of recognized ways to quantify these factors (11). They include quantifying plastic directly through at-sea trawl data (12) or indirectly by studying interactions with wildlife, e.g., frequency of ingestion or entanglement (13). For example, more than 200 species are now known to be at risk from the ingestion of plastic (14, 15), with evidence that some species exhibit preferences for certain colors or types of plastic while foraging at sea (16, 17). Importantly, beach surveys provide similar and often complementary data on sources, patterns, and trends in the abundance and sources of marine plastic (18, 19). Examining the accumulation of plastic pollution on islands, particularly remote, uninhabited islands, can provide unique insights (11, 20).

Here, we present the results of a comprehensive survey of beach plastic in a UNESCO World Heritage site, Henderson Island, in the Pitcairn Group, South Pacific Ocean. Henderson Island is uninhabited and is very remote, with no major terrestrially based industrial facilities or human habitations within 5,000 km. Because there are no significant local sources of pollution, all anthropogenic debris on the island is derived from the global disposal and dispersal of waste. Here we summarize the limited data available for remote, uninhabited islands and provide quantitative data on the accumulation of debris on Henderson Island to highlight the utility of comprehensive beach surveys as reliable proxies for the state of the world's oceans.

Results

The density of surface debris ranged from 0.35–1.05 items/m^2 in the beach embayment forest (hereafter "beach-back") and 20.5–671.6 items/m^2 on beaches (Table 1; also see *SI Results*). The density of debris buried to a depth of 10 cm within quadrats ranged from 53.1–4,496.9 pieces/m^2 on North and East Beaches (Table 1). The total number of visible and buried debris items estimated to be present on Henderson Island was 37,661,395 items weighing a total of 17,601 kg; the estimated mass of buried

Significance

The isolation of remote islands has, until recently, afforded protection from most human activities. However, society's increasing desire for plastic products has resulted in plastic becoming ubiquitous in the marine environment, where it persists for decades. We provide a comprehensive analysis of the quantity and source of beach-washed plastic debris on one of the world's remotest islands. The density of debris was the highest recorded anywhere in the world, suggesting that remote islands close to oceanic plastic accumulation zones act as important sinks for some of the waste accumulated in these areas. As global plastic production continues to increase exponentially, it will further impact the exceptional natural beauty and biodiversity for which remote islands have been recognized.

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Table 1. Mean density (items/m^2 ± SD) of plastic debris items recorded in transects and quadrats on Henderson Island

	Mean recorded density (items/m^2)			Estimated debris items						Estimated island total	
				Beach		Beach-back		Buried			
Site	Beach	Beach-back	Buried	Number	Mass, kg	Number	Mass, kg	Number	Mass, kg	Number	Mass, kg
North Beach	30.3 ± 13.8	0.50 ± 0.19	104.7 ± 58.0	812,116	2,985	21,000	3,176	6,800,936	97	7,634,052	4,744
East Beach	239.4 ± 374.3	0.94 ± 0.12	1,286.7 ± 1,559.8	3,053,901	12,611	35,530	2,961	26,937,912	1,079	30,027,343	12,857
Total				3,866,017	15,597	56,530	6,137	33,738,848	1,176	37,661,395	17,601

Items include surface items on the beach and beach-back and items buried on the beach to a depth of 10 cm. Estimated total debris is based on mean mass, density, and dimensions for each beach.

debris items (1,176 kg) (Table 1) accounted for only a small proportion (0.07%) of the total, because the majority of buried items (65.5%) were <5 mm. Each day, 17–268 new items washed up on a 10-m section of North Beach, representing a daily accumulation rate of 1.7–26.8 items/m.

Materials and Methods

Study Site. Henderson Island (4,308 ha, 9 × 5 km; 24°20′S, 128°19′W), one of four islands belonging to the Pitcairn Group, is a remote, uninhabited island in the South Pacific Ocean. The nearest settlement is Pitcairn Island, 115 km to the west and home to ~40 residents (Fig. 1). Henderson Island is surrounded by a fringing limestone reef up to 75 m wide (21), with beaches composed of fine to coarse white sand, pebbles, shells, and coral rubble. The predominant wind and current direction is from the northeast (Fig. 1) (21). Henderson Island is located on the western boundary of the South Pacific Gyre, a known plastic-accumulation zone (Fig. 1) (22).

Sample Collection and Calculation of Accumulated Debris. Micro- (2–5 mm) and macrodebris (≥5 mm) items, including plastic, glass, wood, and metal items, were sampled along the North (2.1 km long) and East (1.9 km long) Beaches of Henderson Island from 2015 May 29–August 15. Because of the dynamic nature of the marine environment and a number of challenging island features, we used three different transect and quadrat designs aimed at providing specific types of data (Fig. 2 and *SI Materials and Methods*). We sampled surface beach debris along five 30-m transects and 10 20-m transects in the beach-back. Buried debris (0–10 cm) was sieved from all sediment excavated in 10 0.4 × 0.4 m quadrats. Plastic accumulation was sampled along a 10 × 0.2 m transect centered on the high tide line on North Beach for six consecutive days. To extrapolate the total amount of debris on Henderson Island, we multiplied the mean surface densities and mean buried volumetric densities by total beach area and added the debris from a highly polluted area separately (*SI Materials and Methods*). All debris items (≥2 mm on beaches and ≥5 mm in the beach-back) encountered on sample transects or quadrats were counted, weighed, and sorted by type and color (see *SI Materials and Methods* for categories). All values are presented as mean ± SD.

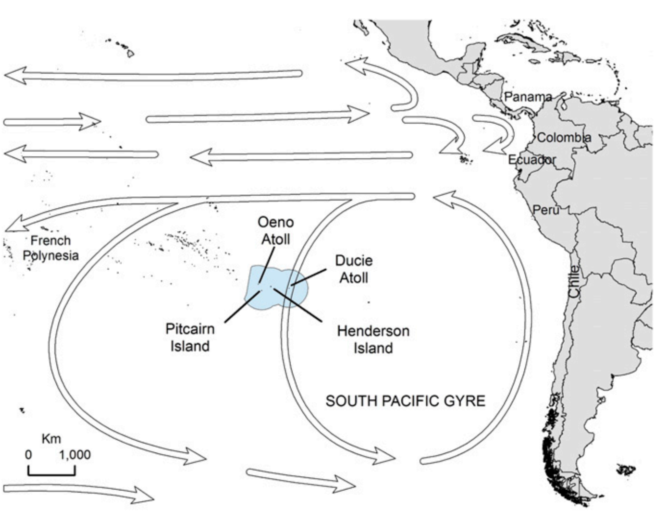

Fig. 1. The location of Henderson Island. The boundary of the Pitcairn Islands Exclusive Economic Area is shown in light blue. Arrows indicate the direction of major oceanic currents and the South Pacific Gyre.

Discussion

We enumerated >53,100 anthropogenic debris items within transects, resulting in a minimum estimate of 37.7 million pieces of plastic debris weighing 17.6 tons on the sandy beaches of Henderson Island in 2015 (Table 1). Although alarming, these values underestimate the true amount of debris, because items buried >10 cm below the surface and particles <2 mm (<5 mm in the beach-back area) and debris along cliff areas and rocky coastlines could not be sampled. Small items are numerically dominant among all debris, with microplastics accounting for 55% of items floating in surface waters of the South Pacific Ocean (22) and 61.6% of items recorded in beach transects on Henderson Island (Table S1). In April and November 1991, "frighteningly large" amounts of beach debris were recorded on uninhabited Ducie and Oeno Atolls, at densities of 0.12 and 0.35 pieces/m^2, respectively (see Table S2) (23). Twenty-five years later, the density of debris on neighboring Henderson Island is 200–2,000× higher (Fig. 3*A* and Table 1). Given that these islands are in the same group and experience similar oceanic conditions, their plastic densities are likely to be similar. If so, debris on Henderson Island has increased by 6.6–79.9%/y. The remote and isolated nature of Henderson Island means the standing stock of debris has not been affected by previous clean-up efforts or local land-based sources. The increase in debris on this isolated island therefore mirrors the long-term accumulation and the increased abundance of debris in our oceans (6, 11). Information on trends in the abundance of debris at sea are lacking (but see refs. 8 and 24), largely because of the currently prohibitive cost of offshore sampling, so beach-based surveys are a valuable source of information.

A range of factors influence the abundance of beach debris, including local currents, beach topography, and weather conditions, which can result in burial (11, 20). Few studies of debris on beaches have included buried material, even though it has been shown to comprise the majority of debris (~65%) (Table S3) (25, 26). We found that 68% of all debris on Henderson was buried (Table 1). Data on beach debris accumulation rates are similarly rare (Table S2). We estimated a minimum of 3,570 debris items were deposited on North Beach daily (13,316 ± 10,094 items·km^{-1}·d^{-1}), five orders of magnitude greater than the accumulation rates reported elsewhere (Table S2). The daily accumulation accounts for around a quarter of the total debris present on the beach (Table 1) and highlights the dynamic process of the deposition of new debris, movement of debris already present on the beach, burial of existing debris, and removal of debris by outgoing waves and tides (26).

Land-based sources (e.g., storm drains) represent ~80% of plastic inputs to the ocean (27). However, on oceanic islands (23, 28) and undeveloped continental beaches (29), marine-based

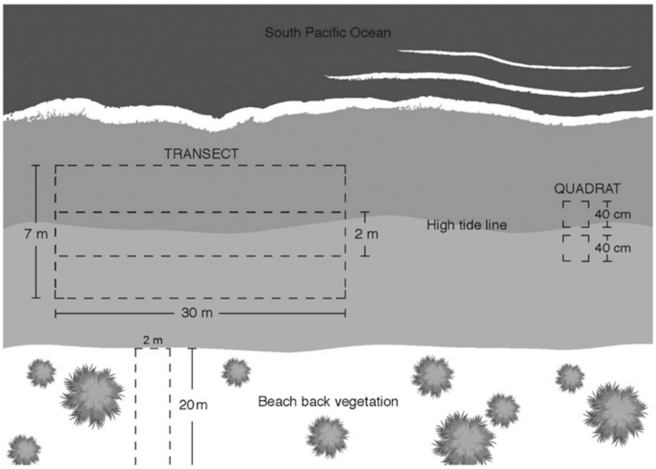

Fig. 2. Schematic drawing (not to scale) of the sampling design used to quantify debris on Henderson Island's beaches.

sources of debris (e.g., fishing boats) can be more important sources. Asian and South American sources of plastic on Henderson may reflect fishing activity in the surrounding waters (Table S4) (30, 31); fishing-related items (e.g., buoys) accounted for 7.7% of items recorded (Table S4). The high frequency of items from South America (27.3% of identifiable items) (Table S5) also may result from Henderson's position in the South Pacific gyre (9). This current flows in an anticlockwise direction, after traveling north along the coast of South America, transporting coastal waste to the island (Fig. 1) (32). Remote islands off Chile and their adjacent waters contain high densities of beach plastic (Table S2), primarily fishing gear (33), suggesting that this pattern is widespread throughout the region.

Plastic debris on beaches creates a physical barrier, contributing to a reduction in the number of sea turtle laying attempts (Henderson Island is the only known nesting site in the Pitcairn Group) (Fig. 3*A*) (34, 35), lowered diversity of shoreline invertebrate communities (36), and increased hazard of entanglement for coastal-nesting seabirds (37, 38). The presence of debris on beaches therefore negatively impacts marine biodiversity, particularly on remote islands where significant volumes of debris accumulate and where prevention or mitigation is extremely challenging and costly and requires considerable time.

Conclusions

Changes in the frequency of wildlife ingestion of or entanglement in debris are often used as an indicator of pollution in the

Fig. 3. (*A*) Plastic debris on East Beach of Henderson Island. Much of this debris originated from fishing-related activities or land-based sources in China, Japan, and Chile (Table S5). (*B*) Plastic items recorded in a daily accumulation transect along the high tide line of North Beach. (*C*) Adult female green turtle (*Chelonia mydas*) entangled in fishing line on North Beach. (*D*) One of many hundreds of purple hermit crabs (*Coenobita spinosa*) that make their homes in plastic containers washed up on North Beach.

marine environment (39–41). Globally, the number of species known to interact negatively with marine debris has increased 49% in <20 y (14), with >55% of the world's seabird species [including two species from Henderson Island (42)] currently at risk (14). Combined with beach surveys, these data suggest that the quantity of anthropogenic debris in our oceans is increasing (3, 24).

Although detrimental impacts are observed and suspected across all levels of the marine ecosystem (43, 44), the true magnitude and fate of this pollution are often unclear because data are insufficient or incomplete (e.g., the lack of repeated sampling at sea). The quantity of floating debris in some areas of the oceans may be declining, potentially "lost" to other as-yet undetermined sinks in the marine environment (6, 39, 45). The end point, or removal mechanism, for some of this plastic likely includes remote islands such as Henderson, which have become reservoirs for the world's waste. The 17.6 tons of anthropogenic debris estimated to be present on Henderson Island account for only 1.98 seconds' worth of the annual global production of plastic (46). As global plastic production continues to increase exponentially (47), it will further impact the exceptional natural beauty and biodiversity for which this island and many other UNESCO World Heritage Sites have been recognized.

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Supporting Information

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SI Materials and Methods

To calculate the area of North and East Beaches, we walked the perimeter of each zone (beaches were surveyed at low tide) with a handheld GPS device (accuracy: 3–5 m). Beach transects (sampled area 130 × 7 m) and transects in the coastal scrub forest adjacent to the beach, i.e., the beach-back (sampled area 200 × 2 m), represented 3.7% and 0.5% of the total substrate on Henderson Island, respectively.

Surface Debris. The standing stock of accumulated plastic debris (47) on Henderson Island was quantified by measuring the density of items on four 7 × 30 m transects centered on the high tide line (Fig. 1), with two transects on North Beach and two on East Beach. A fifth, shorter (10 m) transect on East Beach was preselected to encompass an area of high pollution (total area: 4,481 m^2 or ∼12.6% of the total area of East Beach). The density of debris was estimated separately for this transect with values applied only to this area of the beach. Each transect covered most of the distance from the water's edge to the start of the vegetation. Within this area, debris from the central 2-m-wide strip along the high tide mark was enumerated separately to provide information on whether plastic accumulated at greater densities along the high tide line (Fig. 2). All debris was counted and sorted as detailed below.

Beach-Back Debris. We collected data on the density of debris located within the beach-back, a low-lying vegetated area comprised mainly of *Argusia argentea* (48). Only macrodebris (≥5 mm) was recorded because of the difficulty of detecting items in areas of dense vegetation. Ten 2-m-wide transects (five on North Beach and five on East Beach) ran perpendicular to the water's edge, extending 20 m in from the vegetation line toward the base of the limestone cliffs (Fig. 2). All macrodebris was counted and sorted as detailed below.

Buried Debris. The amount of debris buried in the beach sediment was examined following the quadrat design developed by Kusui and Noda (25). Five pairs of quadrats were established along the length of each beach, with each pair comprising one quadrat above the high tide line and one 2 m below the vegetation line (Fig. 2). At each quadrat, a 40 × 40 cm wooden frame was inserted into the sand, and the contents of the frame were exhumed down to depths of 5 and 10 cm. All anthropogenic debris items (excluding items located above a depth of 0.5 cm, i.e., surface debris) were counted and sorted as detailed below.

Debris Accumulation. To estimate the daily rate of debris accumulation, a 10-m section (with a 5-m buffer on either side to minimize the redistribution of debris already present on the beach) of North Beach was cleared on 2015 July 27 to remove the standing stock of debris (i.e., all anthropogenic items were removed from the surface between the water's edge and the vegetation line). Debris was removed using a custom-made rake that removed all natural and anthropogenic surface debris. Removal was done around the full moon (2015 July 28–August 3, with peak tide on 2015 July 31), because the high tide mark was either obscure or absent on most other days when the waves failed to extend sufficiently beyond the rocky platform (up to 4 m wide in some areas) where the water meets the beach. Shortly after the morning high tide on each day, all debris items (≥2 mm) visible on the surface were collected within 10 cm on either side of the high tide line.

Sample Processing. All visible debris items from all transects and quadrats were collected, counted, and weighed to the nearest 0.1 g using an electronic balance (for microplastic items 2–5 mm) or 1 g using a spring balance (for macroplastic items ≥5 mm). For comparisons with the only other beach debris study in the region (Ducie and Oeno Atolls, ref. 23), we used many of the same plastic categories (Table S4). Additional categories commonly reported in the recent literature [e.g., industrial resin pellet ("nurdle"), melted plastic] were used also. Items were further categorized according to their color (red, green, blue, white, black, purple, and yellow). When possible, the provenance of items was identified based on the country of distribution printed on the label. All values are presented as mean ± SD unless specified otherwise.

SI Results

Surface Debris. The five transects (total sampled area 130 × 7 m) represented 3.7% of the total beach substrate on Henderson Island. The standing stock of visible micro- and macrodebris recorded within transects on North Beach and East Beach was 10,971 and 49,870 pieces, respectively. Extrapolated to the total area of the beach, the total number of visible debris items on North Beach was estimated as 812,116 pieces (Table 1), the majority of which (56.1%, n = 455,838 items) were located away from the high tide line. The total number of visible debris items estimated for East Beach was 3,053,901 (Table 1), the majority of which (36.8%, n = 1,123,255 items) were located 2 m on either side of the high tide line. The mass of visible micro- and macrodebris recorded in surface transects on North Beach and East Beach was 16.8 and 160.8 kg, respectively. The estimated mass of visible debris along the total length of North Beach and East Beach was 1,471 and 8,817 kg, respectively (Table 1). Debris items within the high-pollution area of East Beach (Fig. 3*A*) accounted for an estimated 40.2% (n = 4,137,305) of items present on the beach by number and 69.9% of items by mass (102.2 kg), with up to 671.6 items and 1.25 kg of debris/m^2.

Beach-Back Debris. The 10 transects (total sampled area 200 × 2 m) represented ∼0.50% of the total beach-back area on Henderson Island. The mean density of visible macrodebris recorded for North Beach and East Beach was 0.50 ± 0.19 pieces/m^{-2} (n = 100 items) and 0.94 ± 0.12 pieces/m^2 (n = 187 items), respectively (Table 1). Extrapolated to the total area of the beach-back, the number of visible debris items present within the North and East beach-backs was estimated to be 21,000 and 35,530 items, respectively. The estimated mass of debris along the total length of the beach-back on North Beach and East Beach was 118,423 and 127,050 kg, respectively, based on a recorded density of 0.08 ± 0.03 and 0.08 ± 0.04 kg/m^2, respectively (Table 1).

Buried Debris. The density of buried micro- and macrodebris items within quadrats on Henderson Island ranged from 53.1 pieces/m^2 (North Beach, 10-cm depth) to 4,496.9 pieces/m^2 (East Beach high-pollution area, 5-cm depth) (Tables S1 and S3). The mean mass of debris ranged from 0.6 kg/m^2 (North Beach, 10-cm depth) to 187.2 kg/m^2 (East Beach high-pollution area, 5-cm depth). When extrapolated to include the total area of North and East Beach, the estimated number of debris items present in the top 5 cm and 10 cm of sediment was 6,800,936 and 26,937,912, respectively (Table 1).

Debris Accumulation. The number of visible micro- and macrodebris items recorded within 10 × 0.2 m accumulation transects on North Beach over 6 d was 107.2 ± 69.4 and 42.2 ± 38.6 items, respectively (average for all debris: 133.2 ± 100.9) (Fig. 3*B* and Table S2). Extrapolated to the total length of North Beach, the total number of debris items estimated to wash up along the high tide line of North Beach daily is 27,965 ± 21,199.

Debris Composition and Provenance. Plastic accounted for the great majority (99.8%) of items counted on the surface of North Beach and East Beach, with glass, polystyrene foam, wood, and aluminum accounting for only 0.14%, 0.02%, 0.002%, and <0.001% of items, respectively (Table S4). Of the plastic items collected, the majority were unidentifiable fragments (79.0%) and resin pellets (11.2%), followed by thread-like plastics (e.g., fishing line and rope; 6.2%) and bottle caps and lids (0.8%) (Table S4). Microplastics (<5 mm) accounted for the majority (61.8%) of items. Overall, white plastic was the most commonly recorded color (58.6%), with smaller proportions of blue (13.3%), black (12.6%), green (8.6%), yellow (3.9%), red (2.9%), and purple (0.2%) plastic. The most common countries of origin of identifiable items were China (18.2%), Japan (18.1%), and Chile (12.5%) (Table S5).

Table S1. Mean density and mass of microdebris (<5 mm) and macrodebris (≥5 mm) items (±SD) recorded in transects and quadrats on Henderson Island

	Density recorded, items/m^2				Mass recorded, kg/m^2			
	Surface		Buried		Surface		Buried	
Site	Micro	Macro	Micro	Macro	Micro	Macro	Micro	Macro
North Beach	28.4 ± 2.4	22.8 ± 1.1	156.3 ± 78.4	53.1 ± 25.8	0.001 ± 0.001	0.138 ± 0.050	0.001 ± 0.001	0.002 ± 0.001
East Beach	198.8 ± 309.8	237.0 ± 358.7	1675.0 ± 1725.0	898.4 ± 893.7	0.003 ± 0.004	0.891 ± 0.668	0.022 ± 0.025	0.080 ± 0.087

Data include surface items on the beach and items buried to a depth of 10 cm.

Table S2. Review of anthropogenic beach debris density and accumulation rates (items·km^{-1}· d^{-1}) on remote, uninhabited islands

Location	Ocean basin	Year	Density	Items·km^{-1}·d^{-1}	Source
North Beach, Henderson Island	South Pacific	2015	30.3 ± 13.8/m^2	13,316 ± 10,094	This study
East Beach, Henderson Island	South Pacific	2015	239.4 ± 374.3/m^2		This study
Ducie Atoll, Pitcairn Group	South Pacific	1991	0.12/m^2		(23)
Oeno Atoll, Pitcairn Group	South Pacific	1991	0.35/m^2		(23)
Midway Atoll, Hawaii	North Pacific	2008–2010	256.65/m^2		(49)
Amchitka Island, Alaska	North Pacific	1972–1974	0.62/m^2	1.36	(50)
Macquarie Island, Tasmania	Southern Ocean	2001	0.03/m^2	0.10	(51)
St. Brandon's Rock, Mauritius	Indian Ocean	2010	7.19/m		(52)
Gough Island	South Atlantic	1984	0.01/m^2	0.05	(53)
Prince Edward Island	South Indian	1984	0.03/m^2	0.19	(53)
South Georgia	South Atlantic	1993	0.30/m		(54)
Saunders Island, South Sandwich Islands	South Atlantic	1997	0.28/m		(54)
Signy Island, South Orkney Islands	South Atlantic	1993	0.02/m		(54)
Livingston Island, South Shetland Islands	South Atlantic	1996	0.12/m		(54)

Table S3. Mean density (items/m^2 ± SD) and mass of beach debris items recorded in 40 × 40 cm quadrats to a depth of 5 and 10 cm on Henderson Island and on other beaches around the Pacific Ocean

	Mean recorded density, items/m^2		Mean recorded mass, kg/m^2		
Site	1–5 cm	6–10 cm	1–5 cm	6–10 cm	Source
North Beach	153.1 ± 26.5	56.3 ± 4.4	2.2 ± 0.2	0.8 ± 0.2	This study
East Beach	1,620.3 ± 2,002.3	953.1 ± 1,170.8	72.5 ± 80.2	29.4 ± 44.2	This study
Japan, west coast	2,610.0		0.014		(25)
Russia, east coast	31.3		0.009		(25)

Table S4. Number (n) and frequency of occurrence (FO) of major categories of anthropogenic debris in the Pitcairn Islands

	Ducie Atoll*		Oeno Atoll*		Henderson Island	
Item	n	FO	n	FO	n	FO
Disposable items						
Caps and lids	74	0.078	76	0.086	486	0.008
Plastic bottle	71	0.075	62	0.071	115	0.002
Plastic bag (and pieces)					60	0.001
Glass fragment					67	0.001
Lollipop stick					24	<0.001
Polystyrene					16	<0.001
Pen lid	2	0.002	3	0.003	10	<0.001
Drinking straw					10	<0.001
Glass bottle	171	0.179	148	0.168	8	<0.001
Fluorescent light tube	6	0.006	22	0.025	8	<0.001
Plastic razor					4	<0.001
Cigarette lighter	3	0.003	5	0.006	3	<0.001
Light bulb	6	0.006	31	0.035	2	<0.001
Toothbrush					2	<0.001
Plastic cutlery					2	<0.001
Fishing related						
Cord/rope	44	0.046	51	0.058	3,336	0.054
Plastic strapping	0	0.000	16	0.018	642	0.010
Crates (and pieces)	14	0.014	0	0.000	245	0.004
Fishing line					220	0.004
Plastic netting					207	0.003
Buoy – plastic	179	0.188	67	0.08	50	0.001
Buoy – aluminum					16	<0.001
Buoy – foam					4	<0.001
Bucket (and pieces)	0	0.000	5	0.006	25	<0.001
Glow stick (squid fishery)					16	<0.001
Other						
Plastic fragment	268	0.282	305	0.350	48,121	0.791
Resin pellet (nurdle)					6,774	0.111
Plastic fencing					121	0.002
Melted plastic					43	<0.001
Plastic pipe	29	0.030	26	0.03	27	<0.001
Wood					7	<0.001
Metal			6	0.007	5	<0.001
Shoes	25	0.026	7	0.008	4	<0.001
Tiling spacer					3	<0.001

Data for Henderson Island include only visible items recorded during five standing-stock transects. Single items have been excluded.
*Data from Ducie Atoll and Oeno Atoll adapted from ref. 23.

Table S5. Number (*n*) and frequency of occurrence (FO) by country of origin of items washed up on Ducie Atoll in 1991 and Henderson Island in 2015

	Ducie Atoll*		Henderson Island	
Country	*n*	FO	*n*	FO
Japan	41	0.315	16	0.181
China	0		16	0.182
Scotland	11	0.085	2	0.022
United Kingdom	9	0.069	1	0.011
United States of America	8	0.061	3	0.034
Chile	0		11	0.125
Peru	0		8	0.091
Ecuador	0		5	0.057
Spain	1	0.008	4	0.045
New Zealand	3	0.023	3	0.034
Germany	3	0.023	1	0.011
France	2	0.015	2	0.022
Russia	2	0.015	2	0.022
Panama	0		3	0.034
The Netherlands	2	0.015	0	
Singapore	0		2	0.022
Total items recorded	130		88	
Total countries represented	15		24	

Only countries from which two or more items were collected are shown.
*Data from Ducie Atoll are all glass bottles (adapted from ref. 55).