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Litter survey detects the South Atlantic 'garbage patch'

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ABSTRACT

A distance-based technique was used to assess the distribution and abundance of floating marine debris (>1 cm) in the southeast Atlantic Ocean between Cape Town and Tristan da Cunha, crossing the southern edge of the South Atlantic 'garbage patch' predicted by surface drift models. Most litter was made of plastic (97%). Detection distances were influenced by the size and buoyancy of litter items. Litter density decreased from coastal waters off Cape Town (>100 items km^{-2}) to oceanic waters (<10 items km^{-2}), and was consistently higher (6.2 ± 1.3 items km^{-2}) from 3 to 8°E than in adjacent oceanic waters (2.7 ± 0.3 items km^{-2}) or in the central South Atlantic around Tristan (1.0 ± 0.4 items km^{-2}). The area with high litter density had few seaweeds, suggesting that most litter had been drifting for a long time. The results indicate that floating debris is accumulating in the South Atlantic gyre as far south as 34–35°S.

1. Introduction

Given increasing concern about the accumulation of persistent litter items in the sea (e.g. Thompson et al., 2009), several studies have used surface drifter data to predict the fate of litter floating at the sea surface (e.g. Lebreton et al., 2012; Maximenko et al., 2012; van Sebille et al., 2012). All these models predict that persistent floating debris will accumulate in mid-ocean sub-tropical gyres, forming so-called 'garbage patches' (Kaiser, 2010). The North Pacific garbage patch is best known (Moore et al., 2001; Titmus and Hyrenbach, 2011), and similar litter aggregations have been detected in the North Atlantic gyre (Law et al., 2010), but there is little empirical evidence to confirm the presence of garbage patches forming in Southern Hemisphere gyres. A recent net-sampling survey demonstrated that litter is accumulating in the South Pacific gyre (Eriksen et al., 2013), and the small sample of net tows reported by Morris (1980) suggest that even in the 1970s industrial pellets were more abundant in the southeast Atlantic Ocean west of 12°E (1500–3600 km^{-2}) than closer to the Cape coast (0–2000 km^{-2}). Here I report evidence that large litter items are accumulating at 34–35°S in the southeast Atlantic Ocean.

Marine litter comes from two main sources: at sea (fisheries and shipping flotsam and jetsam) and land-based inputs (Ryan et al., 2009). Few ships cross the South Atlantic between South America and Africa (Lebreton et al., 2012), and there is little high-seas fishing effort in the study area (e.g. Lewison et al., 2004), so most litter in oceanic waters presumably has dispersed there from coastal waters (deriving from land-based sources or coastal shipping and fisheries). Depending on model assumptions, Lebreton et al. (2012) predicted that South America contributes 60–80% of land-based litter to the South Atlantic garbage patch, with most of the remainder coming from Africa. Surveys of stranded litter at Tristan da Cunha and Gough Island in the central South Atlantic confirm that most litter derives from South America (Ryan, 1987; Ryan and Watkins, 1988).

The boundaries of the litter accumulation zone predicted to form in the South Atlantic sub-tropical gyre differ slightly among studies and are influenced to some extent by the assumptions made about litter input sources (Lebreton et al., 2012; Maximenko et al., 2012; van Sebille et al., 2012). However, all three studies show the greatest concentration of litter around 25–35°S and 0–20°W, with an area of low litter density in the Benguela region off the west coast of South Africa. In this study I use a simple size and distance-based sampling protocol (Ryan, 2013) to assess whether the density of marine debris in the southeast Atlantic Ocean between Cape Town and Tristan da Cunha accords with the predictions of surface drifter models.

2. Materials and methods

Floating marine debris was counted during a research cruise aboard the R.V. *S.A. Agulhas II* from 5 September to 9 October 2013. The ship travelled from Cape Town (34°S, 18°E) to Tristan da Cunha (37°S, 12°W) and then south-southeast to Gough Island (40°S, 10°W) before returning to Cape Town via Tristan (Fig. 1). The track from Cape Town to Tristan ran due west at 34°30′S until the Greenwich Meridian, whereas the return route followed a direct course from Tristan to Cape Town. Frequent stops for oceanographic work on the outbound leg reduced coverage relative to the return leg.

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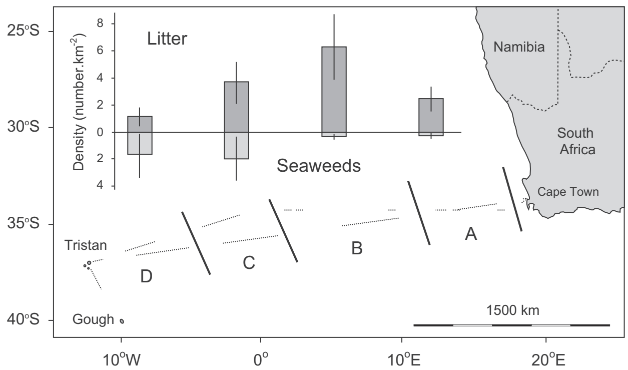

Fig. 1. The location of litter transects in the southeast Atlantic Ocean (fine dashed lines) divided into four regions (A–D) in oceanic waters. Histograms show the mean density (±95% confidence limits) of litter and large seaweeds in the four regions.

Observations were conducted throughout daylight hours while the ship was underway. Only debris on one side of the bow was counted. Most observations were made from the bridge wing or from the deck above the bridge, 12–15 m above sea level and 50 m from the ship's bow, but some observations were made from the ship's bow (elevation 6 m) during calm conditions. Litter was mostly detected with the naked eye, but regular scans of waters away from the ship were made with 8 × 32 binoculars to detect more distant debris. Binoculars or images taken with a digital SLR camera with a 500 mm telephoto lens were used to identify litter items, but some submerged items could not be identified. Natural debris (mainly large seaweeds) and drifting biota (epipelagic jellyfish *Physalia physalis* and *Velella velella*, bubble raft shells *Janthina* spp. and buoy barnacles *Dosima fascicularis*) were also counted. Two seaweeds were encountered: *Macrocystis pyrifera* from Tristan da Cunha and Gough Islands and *Ecklonia maxima* from the South African coast. Numbers of by-the-wind sailors *V. velella* were too great to count individually in some areas, and so their abundance was estimated to the nearest order of magnitude (1s, 10s, 100s, 1000s, etc.).

Observations were recorded continuously for up to 11.5 h per day (mainly by one observer, but with assistants standing in for occasional short breaks), with location and environmental parameters (wind speed, direction, sea surface temperature, salinity) recorded from the ship's data logger at the start and end of each hour. Track length was calculated from the ship's positional record to measure the distance covered during observations. To compensate for the patchy nature of floating debris at sea, data were pooled into transects of roughly 50 km (2–3 h of transects), which sample 2.5 km^2 of sea surface given an effective transect width of 50 m. This sample scale was deemed suitable to average out small-scale aggregations of floating debris associated with fronts and local convergence zones (Lebreton et al., 2012; Ryan, 2013). Density estimates per 50-km transect as well as environmental conditions were compared among regions using one-way ANOVA with post-hoc Newman–Keuls range tests to assess which regions differed significantly.

The size of items and their distance from the side of the ship were estimated following Ryan (2013). Distance from the ship was placed into one of seven categories: 0 = 0–10 m from the side of ship, 1 = 11–20 m, 2 = 21–30 m, 3 = 31–40 m, 4 = 41–50 m, 5 = 51–100 m, and 6 = >100 m. The size of each debris item was allocated to one of five size classes based on its longest dimension: a < 5 cm, b = 5–15 cm, c = 15–30 cm, d = 30–60 cm, and e > 60 cm. Minimum item size was approximately 1–2 cm. Litter items were placed into one of the following categories based on the type of material and likely use of the item. Plastic items were divided into packaging (bottles, tubs/cups, lids and lid-rings, bags, food wrapping, polystyrene, and other packaging such as packing strips, etc.), fishery-related plastic articles (ropes and nets, floats, and other fishing gear such as fish trays), other plastic user items (designed for repeated use, unlike packaging, divided into three categories: buckets, shoes/gloves/hats, and other user items), and finally, other plastic pieces (mostly fragments of items that could not be identified, but some items too deep to see clearly also were placed into this category). Non-plastic items were divided into glass jars/bottles, light bulbs, tins/aerosols, cardboard/paper, and wood (worked timber). The incidence of encrusting biota on litter items was recorded.

The effect of item size on detection distance was determined from the frequency of encounters in relation to distance from the ship (Ryan, 2013). χ^2 goodness-of-fit tests were used to compare the effect of distance on detection rate within each size category between this study and Ryan (2013), as well as the effect of buoyancy on detection distance. A simple correction factor for items within 50 m of the ship was calculated by assuming that all litter items were detected within the 10-m wide distance band with the largest number of encounters. Other zones within 50 m of the ship were scaled to compensate for 'missed' items by standardizing relative to the maximum count (Ryan, 2013). Correction factors were then applied weighted by the size composition of litter items. This size-based counting technique allows estimates of the densities of different litter size classes at sea. Densities of all litter items as well as items >5 cm were estimated to facilitate comparison with estimates from studies with different minimum item sizes.

3. Results

Just under 79 h of litter counts were conducted covering 1963 km of transects (38 50-km transects), counting 281 litter items (Table 1) and 90 seaweed clumps. Almost a third of litter items (30%) and 8% of seaweeds were found in coastal waters over the African continental shelf, despite comprising only 2.6% of transect distance (51 km). Average wind speed during transects was 8.8 ± 2.4 knots (SD, range 5–15 knots), with slightly greater wind speeds in Region C (10.7 ± 2.0 knots) than in the other three regions (8.3 ± 2.1 knots; $F_{3,73}$ = 6.2, P < 0.001; see Fig. 1 for region

Table 1
The abundance and composition of litter in coastal (51 km) and oceanic waters (1911 km) in the southeast Atlantic Ocean during September–October 2013.

Type of litter	Coastal waters		Oceanic waters		Total	
	n	%	*n*	%	*n*	%
All plastic items	82	98	191	97	273	97
Packaging	63	75	80	41	143	51
Bottles	2	2	25	13	27	10
Polystyrene	0	0	5	3	5	2
Bags	34	40	30	15	64	23
Food wraps	27	32	3	2	30	11
Tubs/cups	0	0	4	2	4	1
Lids and lid-rings	0	0	9	5	9	3
Other packaging	0	0	4	2	4	1
Fishing/boating	6	7	44	22	50	18
Ropes/nets	6	7	10	5	16	6
Floats	0	0	6	3	6	2
Other fishing gear	0	0	28	14	28	10
User items	0	0	14	7	14	5
Buckets	0	0	10	5	10	4
Shoes/gloves/hats	0	0	2	1	2	1
Other user items	0	0	2	1	2	1
Pieces	13	15	53	27	66	23
All non-plastic items	2	2	6	3	8	3
Glass bottles	0	0	3	2	3	1
Light bulbs	0	0	2	1	2	1
Tins/aerosols	0	0	1	1	1	0
Cardboard/paper	2	2	0	0	2	1
Total (all artefacts)	84		197		281	