The Origin and Fate of Artefacts Stranded on Islands in the African Sector of the Southern Ocean

by

PETER G. RYAN, M.Sc.(Cape Town)
Scientific Officer, FitzPatrick Institute of African Ornithology, University of Cape Town, Rondebosch 7700, South Africa.

INTRODUCTION

Plastic objects and other artefacts are widespread sea-surface pollutants which recently have attracted considerable scientific attention (e.g. Shomura & Yoshida, 1985) following such early observations as those of Heyerdahl (1970, 1971) and Carpenter & Smith (1972). Little is known, however, about the impacts and fates of such debris at sea, though mortality of a wide range of organisms from entanglement in, or ingestion of, plastic objects and other artefacts, has been documented (Balazs, 1985; Day *et al.*, 1985; Wallace, 1985).

The long life-spans of many artefacts at sea allow them to disperse over large distances to areas far from sources of pollution (e.g. Carpenter & Smith, 1972; Morris, 1980). Thus plastic objects have been reported from beaches in the Antarctic (Gregory *et al.*, 1984; Torres & Gajardo, 1985), and seals at South Georgia have been found entangled in a variety of artefacts (Bonner & McCann, 1982).

Concern was expressed recently when parties to the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) failed to accept proposals to restrict the dumping of plastic and other non-biodegradable materials from vessels in the Southern Ocean (Morris, 1985). However, some steps to monitor the incidence of artefacts in the Southern Ocean were agreed upon, including periodic beach-surveys for stranded artefacts, paying particular attention to their sources (*idem*). The present study documents such surveys on five islands in the African sector of the Southern Ocean, the quantities, types, origins, and probable fates, of the stranded artefacts being discussed.

STUDY AREA AND METHODS

All of the islands which were surveyed lie on mid-oceanic ridges, far from continental land-masses and major shipping routes. The Tristan da Cunha Island group (37°15′ S, 12°30′ W) has three main islands, named Tristan da Cunha, Inaccessible, and Nightingale, and lies almost midway between South America and South Africa, being some 3,000 km from each. Gough Island (41°21′ S, 9°53′ W) lies 400 km south-east of the Tristan de Cunha Island group. The Prince Edward Island group (46°45′ S, 37°50′ E) has two main islands, Prince Edward and Marion, and lies some 2,000 km south-east of South Africa.

Tristan da Cunha is the only one of these islands with a normally resident human population, having approximately 300 people living in the settlement, Edinburgh, on the northern point of the island. Their major activities are agriculture and fishing. Gough and Marion Islands each support a meteorological station which is manned all-year-round by a complement of between 6 and 32 contract personnel. Prince Edward and Inaccessible Islands are uninhabited and are seldom visited. However, there was a four-months' expedition to Inaccessible Island in 1981 (Fraser, 1983). There is a commercial fishery, primarily for Rock-lobster (*Jasus tristani*), close inshore at Gough and the Tristan de Cunha Island group, but there is no fishery at the Prince Edward Island group.

Surveys for stranded artefacts were made on all beaches on Marion Island (totalling 3,855 m in length) and Prince Edward Island (where they totalled 1,050 m in length) during August–September 1984 (cf. Fig. 1). Surveys of beaches on Gough Island and on the Tristan de Cunha Island group were made during October–November 1984. On Gough Island 7,630 m of coast were surveyed, but no beaches on

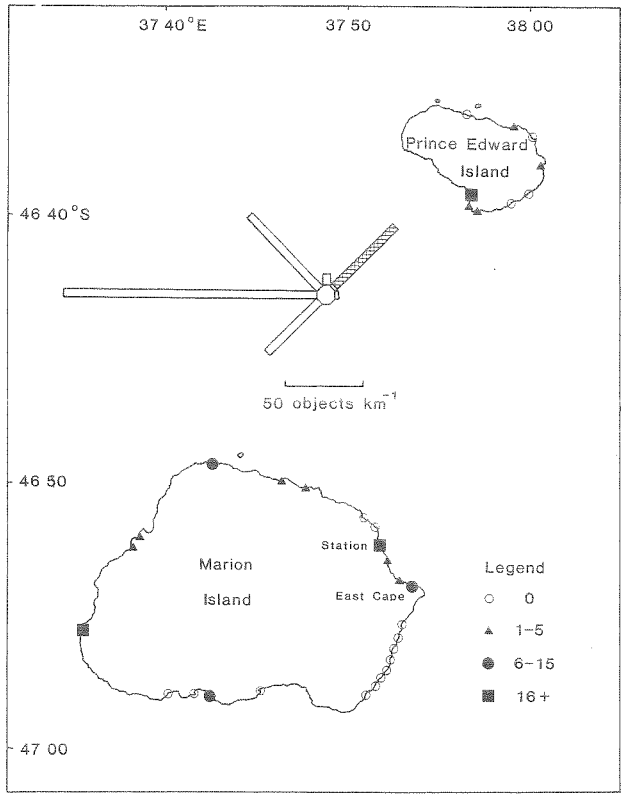

FIG. 1. *The distribution of non-wooden artefacts on beaches on the Prince Edward Islands, southern Indian Ocean. Values are the number of artefacts per 100 m of beach surveyed. The rose diagram shows the density of artefacts on beaches with different orientations. The shaded area represents items from the meteorological station.*

Environmental Conservation, Vol. 14, No. 4, Winter 1987—© 1987 The Foundation for Environmental Conservation—Printed in Switzerland.

the west or north coasts were surveyed, because of problems of accessibility. Tristan da Cunha Island and Inaccessible Island were visited briefly, but only three short stretches of coast were surveyed. Two of these stretches were on Tristan itself—a short stretch (150 m long) below the settlement, just west of the harbour at Herald Point (north-facing), and a longer stretch (900 m long) beyond the Potato Patches, between The Hardies and Gane's Beach (west-facing). The third stretch was on Inaccessible Island, where some 900 m of west- and north-facing beach were surveyed between Skua Bog and a point 500 m east of the Denstone Expedition hut.

All sizeable artefacts found on beaches were identified as far as possible to determine their origin, though only large items (> 10 mm in diameter) were counted. The rocky nature of most of the beaches precluded sampling for smaller items. However, searches for small items (principally industrial plastic pellets) were made on sandy beaches at Marion Island (Ship's Cove) and Tristan da Cunha Island (Hottentot Gulch). The count for Inaccessible Island is a minimum figure, because artefacts were found above the beach, hidden amongst dense tussock-grass, and more are likely to have been overlooked there than elsewhere.

Artefacts were categorized according to type of material: plastic, metal, glass, cork, wooden, or other. Not all metal items were stranded (e.g. fencing wire, tins, and corrugated iron, at Tristan and Inaccessible), but were included for completeness. The numbers of wooden objects noted on the Prince Edward Islands were not counted. The following were identified as fishing gear: floats, netting, traps, polypropylene ropes, monofilament line, fish trays, and fish packaging material. Manufacturers' marks were used to identify the country of origin.

Subjective estimates were made of the state of decay of individual artefacts. Plastics objects were considered worn if they had 'crazed' (bearing numerous small cracks) surfaces that were typical of degradation by ultraviolet radiation (Gregory, 1978). The presence of corrosion on metal objects was recorded, as was the incidence of breakages of glass and cork objects.

The lengths of the beaches that were surveyed were measured from maps or were estimated by pacing. For comparative purposes, densities of stranded artefacts were expressed per kilometre of beach. Chi-squared tests were used to test significant differences in the proportional composition and origin of artefacts between localities.

RESULTS

A total of 1,080 non-wooden artefacts was counted on 14,485 m of beaches on the five islands—a mean density of 75 items per km of beach. However, the density varied greatly between localities (*see* below). Plastic articles were the most abundant, making up 73% of the total number. Metal (18%), cork (5%), and glass (4%), items were less numerous. Four lumps of wax and a cloth bandage made up the balance of the non-wooden artefacts.

Prince Edward Islands

A total of 4,905 m of beach was surveyed and 155 non-wooden artefacts were counted on those islands, yielding a mean density of 32 items per km* (Table I). Most artefacts were plastic (88%), and the rest were metal (Table I). No glass objects were found other than those presumed to have been left by sealers, and no cork floats were found. The only fishery-related items were plastic and metal floats (21% of total).

TABLE I

Numbers of Artefacts Found on Beaches at the Prince Edward Islands, Southern Indian Ocean, During August–September 1984.

Type of Artefact	*Prince Edward Island*	*Marion Island*		*Total*
		Far from station	*Near station*	
(distance surveyed)	*(1,050 m)*	*(2,975 m)*	*(880 m)*	*(4,905 m)*
Plastic articles (total)	(35)	(38)	(64)	(137)
Fishery floats	17	3		20
Expanded polystyrene	9	24	46	79
Other foamed plastics	3	4		7
Bags		2	10	12
Packing strips			1	1
Bottles and containers	5	3	6	14
Miscellaneous items	1	2	1	4
Metal articles (total)	(11)	(6)	(1)	(18)
Fishery floats	11	2		13
Drums, aerosols (floating)		1	1	2
Other items (non-floating)		3		3
Total	46	44	65	155

Artefacts were most abundant on west-facing beaches and on beaches between the meteorological station and East Cape at Marion Island (Fig. 1). The composition of stranded artefacts varied between islands, and between beaches adjacent to and distant from the meteorological station. Floats were more abundant on Prince Edward Island (61% of all artefacts, 27 per km) than on Marion Island (5%, 1 per km, $\chi^2 = 61.1$, df = 1, $p < 0.001$). Expanded polystyrene and other packaging was more abundant on beaches near the station (87%, 65 per km) than on beaches that were distant from it (39%, 9 per km, $\chi^2 = 34.8$, df = 1, $p < 0.001$).

Manufacturers' marks indicating the country or region of manufacture were found on the following: a 20-litres' cannister made in Argentina, three floats and a detergent bottle made in the orient, and a shampoo bottle, a food wrapper, and two plastic sacks, made in South Africa. The origin of two hard yellow floats bearing the trade name 'Moscuzza' is unknown.

No industrial pellets or other small items were found on the sandy beach at Ship's Cove.

Gough Island

A total of 7,630 m of coast was surveyed and 105 non-wooden artefacts were counted on Gough Island—a mean density of 14 items per km* (Table II). Most artefacts were plastic (84%), the remainder being of metal (13%) or glass,

* A referee asked 'what is the variance in such circumstances?': to which the Author replied (*in litt.*) 'no measure of variance was deemed necessary; it can be inferred from [Fig. 2], and the purpose of presenting the numbers per km is merely to aid comparison between localities.'—Ed.

TABLE II

Numbers of Artefacts Found on Beaches at Gough Island, Inaccessible Island, and at Two Localities at Tristan da Cunha, Central South Atlantic Ocean, During October–November 1984.

Type of Artefact	*Gough*	*Inaccessible*	*Tristan da Cunha*		*Total*
			Remote	*Settlement*	
(distance surveyed)	*(7,630 m)*	*(900 m)*	*(900 m)*	*(150 m)*	*(9,580 m)*
Plastic articles (total)	(88)	(312)	(152)	(98)	(650)
Fishery floats	17	80	6		103
Fish boxes	3	41	14	6	64
Polypropylene ropes	10	18	24	9	61
Netting	9	34	6		49
Rock-lobster traps	11	29	3	3	46
Other fishery gear	2			2	4
Expanded polystyrene	4	21	28	26	79
Other foamed plastics	3	3	4	3	13
Bags		1		11	12
Packing strips	4		1		5
Bottles and containers	18	55	47	30	150
Miscellaneous items	7	30	19	8	64
Metal articles (total)	(14)	(89)	(57)	(17)	(177)
Fishery floats	1	12	1		14
Rock-lobster traps	9	15	1		25
Drums, aerosols (floating)	2	9	4	3	18
Other items (non-floating)	2	53	51	14	120
Glass articles (total)	(1)	(13)	(27)	(1)	(42)
Floats		8	5		13
Bottles	1	3	22	1	27
Light-bulbs		2			2
Cork floats	1	22	23	5	51
Wax, bandages	1		4		5
Total (non-wooden)	105	436	263	121	925
Wood	42	67	24	1	134

cork, or bandage (*c.* 1% each). Fishery-related items accounted for 60% of the total. There was no difference in density between beaches situated near to the meteorological station and those that were distant from it (both had 14 items per km).

Tristan da Cunha and Inaccessible Islands

A total of 1,950 m of beach was surveyed and 820 non-wooden artefacts were counted on these Islands—a mean density of 421 items per km (Table II). Most artefacts were plastic (68%), with smaller numbers of metal (20%), cork (6%), glass (5%), and wax (1%), objects. Fishery-related items accounted for 45% of the total.

The density and composition of stranded artefacts varied with the distance from the settlement on Tristan. Artefacts were most abundant on the beach below the settlement (807 per km), with lower densities at Tristan away from the settlement (292 per km), and intermediate densities at Inaccessible Island (484 km). The proportion of fishery-related artefacts tended to increase with distance from the settlement (Fig. 2), largely as a result of higher densities of floats farther from the settlement (33, 39, and 136, floats per km at Tristan settlement, Potato Patches, and Inaccessible, respectively). Most floats that were found on Tristan da Cunha Island were made of cork and were broken. The proportion of locally-derived artefacts (excluding the local fishery) decreased with distance from the settlement (cf. Fig. 2). However, the density of wooden artefacts increased with distance from the settlement (7, 27, and 74 per km at Tristan settlement, Potato Patches, and Inaccessible, respectively).

After those from the local fishery, the most artefacts of which the origins could be determined came from South America (Table III). However, the more precise origin differed between Gough and the Tristan Island group; only products from Argentina and Uruguay were found on Gough Island, whereas products from Brazil predominated on the Tristan Islands. Six hard yellow floats labelled 'Moscuzza' were found (one on Gough Island and five on Inaccessible Island).

A 20-m stretch of recent drift-line at Hottentot Gulch on Tristan da Cunha Island had 13 industrial plastic pellets, two small plastic fragments, and five expanded polystyrene spherules.

State of Decay

Most plastic articles found stranded on the Prince Edward Islands appeared fresh, with little sign of ultraviolet degradation. Exceptions were a milk-container, found near the station, which had almost disintegrated, and several hard floats which were 'crazed' and pitted. By contrast, many plastic articles on Gough Island and the Tristan Island group showed signs of degradation. The incidence of worn plastic articles was highest on Inaccessible Island and

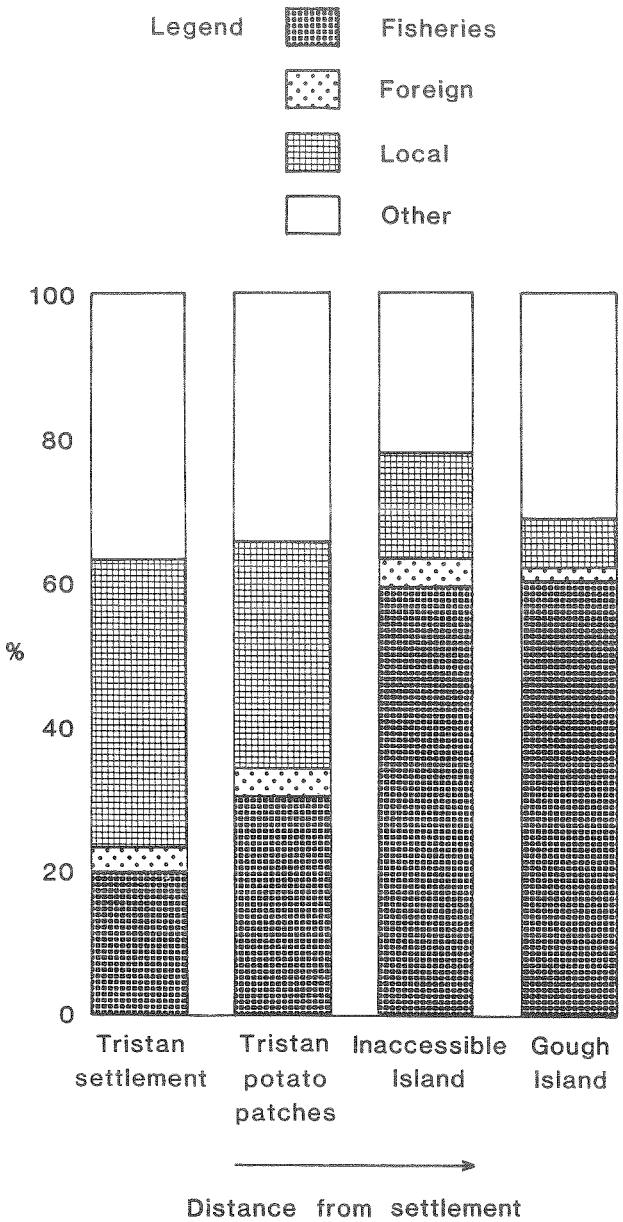

FIG. 2. *The proportions of artefacts by origin on beaches at Gough Island and the Tristan Island group, South Atlantic Ocean.*

TABLE III

Countries or Regions of Origin of Artefacts Found on Beaches on Gough Island and the Tristan Island Group.

Country/region	*Gough*	*Inaccessible*	*Tristan*	*Total*
Tristan fishery	20	32	4	56
Argentina	6	10	3	19
Uruguay	1			1
Brazil		8	10	18
Orient		14		14
South Africa			11	11
Europe (& USSR)		6	1	7
Australasia		1		1
Total	27	71	29	127

lowest on the beach near the settlement on Tristan. The soft, inflatable plastic floats that are used in the Tristan Rock-lobster fishery, appear to perish and disintegrate much faster than do hard plastic floats.

Apart from the metal floats and two sections of aluminium tubing, all metal artefacts were corroded. Most glass articles were whole, except for glass floats which usually were broken. Many of the cork floats were split or broken.

DISCUSSION

The artefacts that were found on the oceanic island beaches which were surveyed had been derived from two main sources, being (1) those which had drifted to the islands from distant source-regions and might be termed 'oceanic', and (2) those which had been dumped on the island or in the surrounding water and so are termed 'local'. It is not always possible to place individual items in one or other category, but it is useful to consider these two sources separately.

Oceanic Origin

All of the islands that were sampled in this study lie within the westerly wind-belt which circles the Southern Ocean between 35° S and 60° S. Objects floating at the sea's surface in this region drift from west to east, driven by the prevailing winds and surface currents (Shannon *et al.*, 1973). In the absence of local sources, the density of stranded debris is determined largely by beach orientation relative to prevailing winds and currents*; thus on islands in the Southern Ocean, most artefacts were found on west-facing beaches. The preponderance of fishery-related items among oceanic debris in the Southern Ocean agrees with findings from Heard Island, where floats predominate (Burton & Williams, 1985; Keage, 1987), and is similar to the situation on remote beaches in Alaska (Merrell, 1984).

The mean density of artefacts on beaches on the Tristan de Cunha Island group was greater than that on either Gough Island or the Prince Edward Islands. These differences can be ascribed partially to biases resulting from sampling beaches with different orientations at Gough Island and at islands in the Tristan group—which sampling differences preclude comparisons between densities at Gough Island and the Tristan group. However, the density of artefacts on west- and north-facing beaches on the Prince Edward Islands (54 per km) was lower than that at a comparable site on Inaccessible Island (484 per km). This difference is partly due to the absence of a local fishery at the Prince Edward Islands, having regard to the fact that fisheries contribute at least 40% of all artefacts found on Inaccessible Island beaches (Table II). However, after removing the effect of fisheries and other local sources, the residual density of artefacts on Inaccessible Island (282 per km) is

* A referee asked, 'Could [not] beach gradient and texture, and local tidal [and other] differences, explain a 'significant' part of the variance found?': to which the Author replied (*in litt.* 9 September 1987) 'Clearly these factors play a role, but they are probably minor in this case due to limited tidal ranges (< 0.5 m) and similar beach structure throughout (almost all boulder beaches).'—Ed.

still greater than that on the Prince Edward Islands. This suggests that the density of artefacts at sea off the Tristan Island group is greater than that off the Prince Edward Islands.

The countries of origin of oceanic debris do not necessarily reflect the drift-tracks of objects at sea. Artefacts bearing an oriental script (chiefly fishing floats, but also detergent bottles, bags, and light-bulbs) probably derive primarily from oriental fishing fleets operating in the Southern Ocean or adjacent seas. Similarly, a recovered medicine bottle emanating from Australasia could have come from a ship from that region merely passing through the South Atlantic.

Many South African and European artefacts on the Tristan Island group probably derive from local sources. However, most items from South American countries probably drifted to the islands from continental waters—a distance greater than 3,000 km—because there is virtually no trade between Tristan and South America. The difference in origin of South American artefacts between Gough Island (chiefly articles from Argentina) and the Tristan Island group (chiefly articles from Brazil) presumably results from oceanographic differences; Gough Island lies to the south of the Subtropical Front, whereas Tristan lies to the north of the Front (Miller & Tromp, 1982).

Local Origin

Fisheries were the most important source of the artefacts found at Gough and Inaccessible Islands, with most articles probably coming from the local Rock-lobster fishery. However, pollution from coastal settlements also was important, exceeding the input of fisheries at Tristan da Cunha (cf. Fig. 2). The effect of a settlement can generally be expected to be inversely proportional to the distance from it (Willoughby, 1986).

At the Prince Edward Islands, the meteorological station was responsible for most artefacts that were found on beaches downwind from the station (Huntley, 1971), involving more than 40% of all articles found on both islands. Plastic wastes from the station are incinerated, but some escape and are either dumped into the sea with biodegradable wastes or are blown to sea. Much of the polystyrene that was found adjacent to the station was packaging that had been lost while ferrying supplies ashore. The meteorological station at Gough Island had no noticeable effect on the density of the plastic items found on near-by beaches—probably because access to those beaches is difficult and so supplies are customarily landed by helicopter operating from ships.

Fate of Artefacts

Most artefacts that get stranded on isolated island beaches probably remain ashore until they decay. The lower proportion of worn plastic articles found on the Prince Edward Islands as opposed to the Tristan Island group presumably is due to lower irradiation levels farther south, and hence slower degradation (Baum, 1974). Plastic articles are subject to very little ultraviolet degradation at sea compared with the wear-rates of stranded articles (Shannon *et al.*, 1973). Most metal artefacts probably corrode rapidly, given the high levels of humidity and salt spray to which they are subjected on those beaches.

Not all of the articles remain on the beaches until they decay. Some light-weight items (e.g. expanded polystyrene and polyethylene bags) are removed by the wind, and either become lodged in vegetation or carried out to sea. However, other artefacts, such as fishing floats and wood, are removed by local inhabitants for further use. This alters the composition of debris on beaches that are accessible to local inhabitants.

The composition of beach debris is a function of the differential frequencies of stranding and removal of the various items involved. Plastic items of various kinds are probably the most abundant artefacts on all beaches—*inter alia* because they are long-lived, which allows long-range dispersal and a long life when once they are stranded.

Environmental Impacts

Such artefacts as those found stranded on beaches on the five islands surveyed, have little apparent impact on the local fauna or flora. Fur-seals (*Arctocephalus* spp.) are occasionally found entangled in netting or packing strips at Marion, Prince Edward, and Gough, Islands (J. Cooper, C.R. Brown & C.A. Gilbert, pers. comm.), but it is likely that they had become entangled at sea (Bonner & McCann, 1982).

Many seabirds breeding on the islands have plastic particles in their stomachs, but these also are collected primarily at sea (Ryan, in press). There are only three reports of birds being entangled in artefacts on the islands (S. Hunter *in litt.*): a Gentoo Penguin (*Pygoscelis papua*) was found with plastic line wrapped around its head between the mouth-gape and the back of the head, and a male Southern Giant Petrel (*Macronectes giganteus*) was found with string around its ankle; both birds were disentangled and released, but a dead White-chinned Petrel (*Procellaria aequinoctialis*) was found entangled in the string marking a research area.

All the above three incidents occurred at Marion Island and it seems probable that both the Penguin and the Giant Petrel had become entangled at sea. Entanglement in stranded artefacts is probably infrequent, but could be a problem for King Penguins (*Aptenodytes patagonicus*) which, if tripped by debris, are vulnerable to attack from giant petrels (*Macronectes* spp., pers. obs.).

Logs of species of *Nothofagus* (southern beeches) and other trees are occasionally stranded on Southern Ocean islands and may act as dispersal vectors for a number of organisms (Barber *et al.*, 1959; Bakker *et al.*, 1971; Smith, 1985). Although there is no evidence as yet, artefacts of oceanic origin may also act as dispersal vectors, increasing the rate of immigration to isolated islands.* An additional impact is the resultant reduced aesthetic appeal.

These observations further illustrate the widespread distribution of artefacts at sea. The only solution to this ever-increasing problem is the adoption and enforcement of policies to prevent littering at sea and on land. An example should be set in the Southern Ocean, where national bases

* Here may be suggested such widely-floating marine products as kelp stipes and mats of *Sargassum* or other Algae.—Ed.

and supply vessels are responsible for a considerable proportion of any local pollution.

Acknowledgements

J. Cooper, C.A. Gilbert, and B.P. Watkins, provided assistance in the field. Permission to work at the Tristan Island group was granted by the Foreign and Commonwealth Office, of London, England, UK, and the Administrator and Island Council of Tristan da Cunha. Financial and logistic support was received from the South African Departments of Transport and Environment Affairs, and from the South African Scientific Committee for Antarctic Research.

Summary

The ever-increasing amount of marine debris in the Southern Ocean gives cause for concern, but the subject is little studied. I surveyed beaches on Tristan da Cunha, Inaccessible, Gough, and the Prince Edward Islands, in the African sector of the Southern Ocean, for stranded artefacts during 1984. The types of debris, their origin, and probable fate, were recorded and are reported in this paper.

More than 70% of the artefacts found were plastic. The density of artefacts was greater on the Tristan Island group than on the Prince Edward Islands—apparently owing to different frequencies of artefacts at sea, and the presence of a local fishery based on the Tristan group. Debris was most abundant on beaches exposed to prevailing westerly winds, and near human settlements. This pattern reflects the two chief sources of pollution: oceanic and local. Some plastic objects had apparently drifted at least 3,000 km from adjacent continental waters. Decay-rate appeared to vary greatly between different types of debris, while some items were removed from beaches near settlements by local inhabitants for their own use.

At present levels, stranded debris apparently has little impact on island faunas and floras and is less hazardous than debris at sea. However, active steps to curtail dumping by national bases and their supply vessels in the Southern Ocean are warranted, to maintain the aesthetic appeal of these remote islands.

References

Bakker, E.M. van Zinderen, sen. (1971). Introduction. Pp. 1–15 in *Marion and Prince Edward Islands: Report on the South African Biological & Geological Expedition of 1965–1966* (Eds E.M. van Zinderen Bakker, sen., J.M. Winterbottom & R.A. Dyer). Balkema, Cape Town, South Africa: xi + 427 pp., illustr.

Balazs, G.H. (1985). Impact of ocean debris on marine turtles: entanglement and ingestion. Pp. 387–429 in *Proceedings of the Workshop on the Fate and Impact of Marine Debris, 27–29 November 1984, Honolulu, Hawaii* (Eds R.S. Shomura & H.O. Yoshida). NOAA-TM-NMFS-SWFC-54, Washington, DC, USA: 580 pp., illustr.

Barber, H.N., Dadswell, H.E. & Ingle, H.D. (1959). Transport of driftwood from South America to Tasmania and Macquarie Island. *Nature* (London), **184**, pp. 203–4.

Baum, B. (1974). The weathering degradation of polyolefins. *Polymer Eng. Sci.*, **14**, pp. 206–11.

Bonner, W.N. & McCann, T.S. (1982). Neck collars on fur seals, *Arctocephalus gazella*, at South Georgia. *Br. Antarct. Surv. Bull.*, **57**, pp. 73–7.

Burton, H.R. & Williams, D.L. (1985). *Heard Island ANARE 1985 Report*. Antarctic Division, Kingston, Australia: 149 pp., illustr.

Carpenter, E.J. & Smith, K.L. (1972). Plastics on the Sargasso Sea surface. *Science*, **175**, pp. 1240–1.

Day, R.H., Wehle, D.H.S. & Coleman, F.C. (1985). Ingestion of plastic pollutants by marine birds. Pp. 344–86 in *Proceedings of the Workshop on the Fate and Impact of Marine Debris, 27–29 November 1984, Honolulu, Hawaii* (Eds R.S. Shomura & H.O. Yoshida). NOAA-TM-NMFS-SWFC-54, US Department of Commerce, Washington, DC, USA: 580 pp., illustr.

Fraser, M.W. (1983). The Denstone Expedition to Inaccessible Island. *Cormorant*, **11**, pp. 69–73.

Gregory, M.R. (1978). Accumulation and distribution of virgin plastic granules on New Zealand beaches. *N. Zeal. J. Mar. Freshwater Res.*, **12**, pp. 399–414.

Gregory, M.R., Kirk, R.M. & Mabin, M.C.G. (1984). Pelagic tar, oil, plastics and other litter in surface waters of the New Zealand sector of the Southern Ocean, and on Ross Dependency shores. *N. Zeal. Antarct. Rec.*, **6**, pp. 12–28.

Heyerdahl, Thor (1970). Atlantic Ocean pollution observed by Expedition Ra. *Biological Conservation*, **2**(3), pp. 221–2, fig.

Heyerdahl, Thor (1971). Atlantic Ocean pollution and biota observed by the 'Ra' Expeditions. *Biological Conservation*, **3**(3), pp. 164–7, map.

Huntley, B.J. (1971). Vegetation. Pp. 98–160 in *Marion and Prince Edward Islands: Report on the South African Biological & Ecological Expedition of 1965–1966* (Eds E.M. van Zinderen Bakker, sen., J.M. Winterbottom & R.A. Dyer), Balkema, Cape Town, South Africa: xi + 427 pp., illustr.

Keage, P.L. (1987). Management plan. Pp. 87–97 in *Heard Island Expedition, ANARE 1986–87* (Ed. R. Ledingham). Australian Antarctic Division, Kingston, Australia: 180 pp., illustr.

Merrell, T.R., jun. (1984). A decade of change in nets and plastic litter from fisheries off Alaska. *Mar. Pollut. Bull.*, **15**, pp. 378–84.

Miller, D.G.M. & Tromp, B.B.S. (1982). The hydrology of waters close to Gough Island. *S. Afr. J. Antarct. Res.*, **12**, pp. 23–33.

Morris, R.J. (1980). Plastic debris in the surface waters of the South Atlantic. *Marine Pollution* Bull., **11**, pp. 164–6.

Morris, R.J. (1985). Antarctica's living resources: are they in safe hands? *Oryx*, **19**, p. 65.

Ryan, P.G. (in press). The incidence and characteristics of plastic particles ingested by seabirds. *Mar. Environ. Res.*

Shannon, L.V., Stander, G.H. & Campbell, J.A. (1973). Oceanic circulations deduced from plastic drift cards. *S. Afr. Sea Fish. Investig.* Report, **108**, pp. 1–31.

Shomura, R.S. & Yoshida, H.O. (Eds) (1985). *Proceedings of the Workshop on the Fate and Impact of Marine Debris, 27–29 November 1984, Honolulu, Hawaii*. NOAA-TM-NMFS-SWFC-54, U.S. Department of Commerce, Washington, DC, USA: 580 pp., illustr.

Smith, R.I.L. (1985). *Nothofagus* and other trees stranded on islands in the Atlantic sector of the Southern Ocean. *Br. Antarct. Surv. Bull.*, **66**, pp. 47–55.

Torres, D. & Gajardo, M. (1985). Informacion preliminar sobre desechos plasticos hallados en Cabo Shirreff, Isla Livingston, Shetland del Sur. *Bol. Antarct. Chileno*, **5**(2), pp. 12–3.

Wallace, N. (1985). Debris entanglement in the marine environment: a review. Pp. 259–77 in *Proceedings of the Workshop on the Fate and Impact of Marine Debris, 27–29 November 1984, Honolulu, Hawaii* (Eds R.S. Shomura & H.O. Yoshida). NOAA-TM-NMFS-SWFC-54, U.S. Department of Commerce, Washington, DC, USA: 580 pp., illustr.

Willoughby, N.G. (1986). Man-made litter on the shores of the Thousands Islands archipelago, Java. *Mar. Pollut. Bull.*, **17**, pp. 224–8.