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Journal of the Royal Society of New Zealand

ISSN: 0303-6758 (Print) 1175-8899 (Online) Journal homepage: https://www.tandfonline.com/loi/tnzr20

The hazards of persistent marine pollution: drift plastics and conservation islands

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© *Journal of the Royal Society of New Zealand,*
Volume 21, Number 2, June 1991, pp 83-100

The hazards of persistent marine pollution: drift plastics and conservation islands

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Plastic litter and debris of all kinds is conspicuous on many contemporary shorelines, most frequently near populated and industrial centres, but also on remote and seldom-visited or uninhabited islands, including Raoul, Campbell and Auckland Islands. Pollution by plastics is aesthetically distasteful and unnecessary, and also creates a number of environmental problems: *e.g.* death and/or debilitation of wildlife through entanglement; blockages to the intestinal tract through ingestion leading to starvation and death, or ulceration of delicate tissues by jagged fragments; reduction in quality of life and reproductive performance. Larger items may also hazard shipping. An encrusting pseudoplanktic biota, similar to that found on floating *Sargassum* and other seaweeds has been recognised on drift plastics. Alien species, rafted on drifting plastic, could endanger the flora and fauna of protected and conservation island ecosystems.

The sources of plastic pollution can be both distant (the truly 'oceanic' debris which has drifted from afar) and regional and local (*e.g.* shipping, fishing and recreational boating activities). Data compiled during a recent clean-up campaign on beaches of the inner Hauraki Gulf islands suggest that nearby land-based sources are also important.

There is need to educate the public about the environmental problems arising from the indiscriminate disposal of plastics and other persistent synthetic compounds. It is unlikely that these problems can ever be solved by regulation, although, along with technological advances, that could alleviate them.

Keywords: plastics, pollution, environmental hazards, Hauraki Gulf, conservation islands, endangered taxa, ecosystems at risk, management.

INTRODUCTION

Those very attributes which are found desirable in plastics - lightness, strength, cost effectiveness, safety, versatility, adaptability and flexibility in manufacturing, durability together with relative inertness and resistence to microbial and other degradational processes, not to mention transparency and prolonged shelf life and benefits in packaging - are also the very reasons that they have become a globally significant contaminant of marine waters (*e.g.* Gregory, 1978, 1987, 1990, in press; Pruter, 1987; Andrady, 1988; Johnson, 1988). Because they float, discarded plastic items are a highly visible, and comprise both a volumetrically and numerically over-represented constituent of beach litter (Pruter, 1987). The sources of these materials can be deliberate, accidental or incidental, and are either land-based or off-shore. Surveys of beaches facing the North Sea have emphasised that most marine litter found there is packaging originating from the routine disposal of garbage from ships at sea (Dixon and Dixon, 1983). Elsewhere, commercial fishing activities have been identified as an important source of persistent synthetic materials in marine debris (Pruter, 1987). Seaborne litter on New Zealand's remote outlying islands (*e.g.* Campbell, Auckland and Raoul Islands) has been attributed to distant deep-water fisheries (Gregory, 1990, in press). However, it must also be recognised that land-based sources are important closer to densely populated

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and industrialised areas, and where recreational use by picknickers and beachgoers is heavy (Pruter, 1987; Golik and Gertner, in press).

Plastic debris of all kinds is widely spread on the shores of New Zealand and its off-shore islands (Gregory, in press). However, the quantities are probably not great by world standards except near metropolitan centres (Gregory, 1978; Ridgway and Glasby, 1984). The distribution of small virgin plastic resin granules has been mapped in detail (Gregory, 1978). Larger plastic items, particularly those stranding on outlying islands, have also received attention (Cawthorn, 1985; Mattlin and Cawthorn, 1986; Gregory, 1987, 1990, in press). Hayward (1984) reported the results of four beach litter surveys conducted at Kawerua (a remote Northland west coast beach) between 1974 and 1982. He noted compositional changes over that period, including a volumetric increase in plastic items, which he attributed to changes in packaging.

For many observers the issue of plastic debris in the marine environment (and elsewhere for that matter) has been portrayed largely as one of cosmetic and aesthetic values. However, it is today universally acknowledged that seaborne plastic debris poses an ever increasing threat to marine wildlife, both large and small, including seabirds, mammals, fish, turtles and invertebrates (see Laist, 1987). The environmental problems are simple yet varied. They include death, injury or debilitation through entanglement; starvation and death resulting from ingestion and consequent blockage of the intestinal tract; ulcerating body wounds and damage to delicate internal tissues; deterioration in 'quality of life' and reduction in reproductive performance. Furthermore, large plastic items can hazard recreational boating as well as commercial shipping. There has been some speculation on the chemical toxicity of plastics and/or their degradational products, as well as their propensity to adsorb and concentrate quantities of trace toxic compounds from sea water (*e.g.* PCB's: Colton *et al.*, 1974; Gregory, 1978); in this the finer particles are the more efficient (Andrady, 1987).

TYPES OF PLASTIC

In addition to classifying the components of marine plastic litter by chemical identity, *e.g.* polystyrene (PS), low and high density polyethylene (LDPE and HDPE), polyvinylchloride (PVC), polypropylene (PP) and polyethylene terephthate (PET), it is convenient to recognise three broad categories of size.

1. Mesolitter is mostly material less than 5-10mm across. It is dominated by the small transluscent/transparent ovoidal to rounded and rod-shaped granules of virgin plastic resins that are the imported feedstock of New Zealand's plastic industry, plus small amounts of jagged chips of similar size, produced through granulation and destined for recycling. The smaller, angular degradation and disintegration fragments that derive from embrittlement and oxidative ageing also fall in this category.
2. Macrolitter includes small items and fragments coming from the breakdown of larger items, and are up to 10 cm or so across. Material of this kind is easily visible to the naked eye during shoreline surveys. Many confectionary wrappings and convenience food packagings also fall in this category.
3. Megalitter includes all larger fragments and fabricated items that are large enough to be visually identified by a shipboard observer, i.e. measuring decimetres or more across. Fishing floats, fish boxes, milk crates, a diversity of plastic containers and bottles, netting, ropes, hawsers and strapping loops are typical examples.

It is further possible to generalise on the source(s) of plastics accumulating on shorelines.

1. Material of local and land-based origin (Fig. 1). Much of this is industrial waste and domestic refuse, and in which items such as primary and secondary packaging, detergent and cosmetic containers, and a diversity of plastic bottles are commonly conspicuous. Some pollution of this kind reflects poor to ineffective methods of refuse disposal by local authorities and/or casual recreational visitors. Failure to provide and/or empty rubbish bins may also be a factor.
2. Material from sources close offshore, *e.g.* fishing and commerical shipping and

Fig. 1 – Beach litter in which confectionary and convenience food wrappings, beverage containers, 'fast-food' and take away packaging and paper is conspicuous, as well as obvious domestic refuse, is considered to indicate local "onshore" sources - picnickers, day trippers and casual recreational use; plus accidental/incidental/deliberate disposal of domestic garbage. Material assembled on Takapuna Beach Auckland, November 1989.

recreational boating. It will include significant amounts of domestic refuse impossible to distinguish from many items of land-based origin. Irresponsible dumping of garbage from vessels of all sizes and in the traditional mariners' way is a continuing fact of life. Some items, such as fish crates and boxes, trawl web and netting, rope, hawsers, and floats are readily attributed to the fishing industry.

3. Items which have been afloat for some considerable time, and which have possibly drifted from distant waters, driven by surface currents and winds (Fig. 2). Artifacts of this kind, which can be considered truly 'oceanic', are identified by an encrusting biota (below, Fig. 3) and are often embrittled or show other signs of degradation. Where the country of origin can be identified, long distance drift may be implied: *e.g.* an Argentinian fishing float reached the Snares Islands; a French chemical container, possibly originating from Kerguelan or Reunion Islands, was stranded on Campbell Island (Gregory, 1987); items from Brazil reached Inaccessible Island in the central South Atlantic Ocean (Ryan and Watkins, 1988); materials from the Caribbean have been washed ashore on the Florida coast (Winston, 1982); Asian floats and cordage from the Tasman Sea drift-netting operations have been stranded on the Auckland Islands (Cawthorn, pers. comm., 1990) and also on South Auckland-North Taranaki shores (author, unpublished).

ENCRUSTING BIOTA

Plastic items adrift on the high seas for any length of time commonly attract encrusting marine organisms (Fig. 3). This biota resembles that living on *Sargassum* (*e.g.* Butler *et al.*, 1983). Taxa identified on plastics from around New Zealand and the SW Pacific region

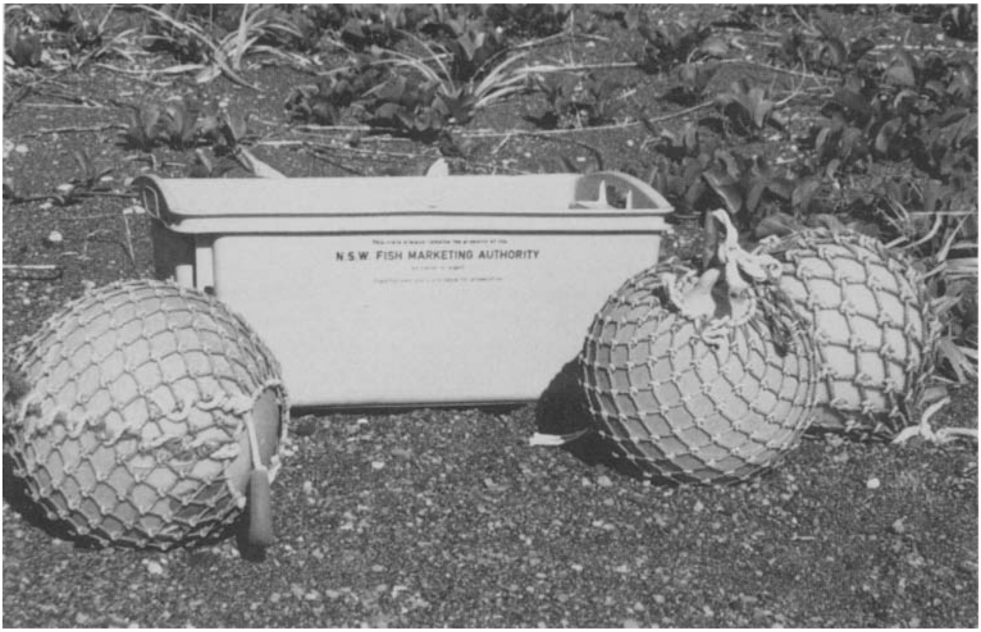


Fig. 2 – "Oceanic" plastics are often heavily encrusted (see Fig. 3) and may include floats, boxes, crates, netting and other evidence of fishing related activities. Note the fish crate from N.S.W., Australia. Denham Bay, Raoul Island, February, 1990.

include several bryozoan species, coralline algae, calcareous annelids, barnacle species, a hermatypic coral (Raoul Island), the pink foraminiferid *Homotrema rubra* (Tuvalu), and filimentous algae (Gregory, 1978, in press).

The bryozoan *Membranipora tuberculata* sometimes encrusts virgin plastic granules from northernmost New Zealand (Gregory, 1978). The same bryozoan is also known from drift plastics collected on the shores of eastern Australia, Fiji, Norfolk, and Raoul Islands, and Gregory (1978, in press) inferred eastwards dispersal from Australian waters, by way of eddies, across the north Tasman Sea. Similarly, Winston (1982) noted that plastics washing up on the Florida coast were commonly encrusted by several taxa, including the bryozoa, *M. tuberculata* and *Electra tenella*, and suggested distant Caribbean sources. This evidence, together with that cited for distant 'oceanic' origins, suggests that pelagic plastic litter may be an important vector in the transoceanic and regional dispersal of a limited but varied biota. It may increase the chances of dispersal and migration to distant shores by circum-Antarctic biotas (Ryan 1987; Smith *et al.*, 1989) or actively expand the abundance and range of certain marine organisms (Winston, 1982).

DISTRIBUTION

The distribution of seaborne plastic litter on shores around the SW Pacific has been reviewed by Gregory (1990, in press). Plastic mesolitter spreads from metropolitan and industrial centres, but there is also strong evidence of a global 'oceanic' population, in the significant quantities recorded on quite remote shores (*e.g.* the islands of, Norfolk, Raoul, Vanua Mbalavu, Tongatapu and Rarotonga).

Plastic macro- and megalitter is common on shores near metropolitan centres, but it is also found at remote localities, both on mainland New Zealand and on its inshore and offshore islands. On the Subantarctic Islands most of the plastic litter originates from fishing activities,

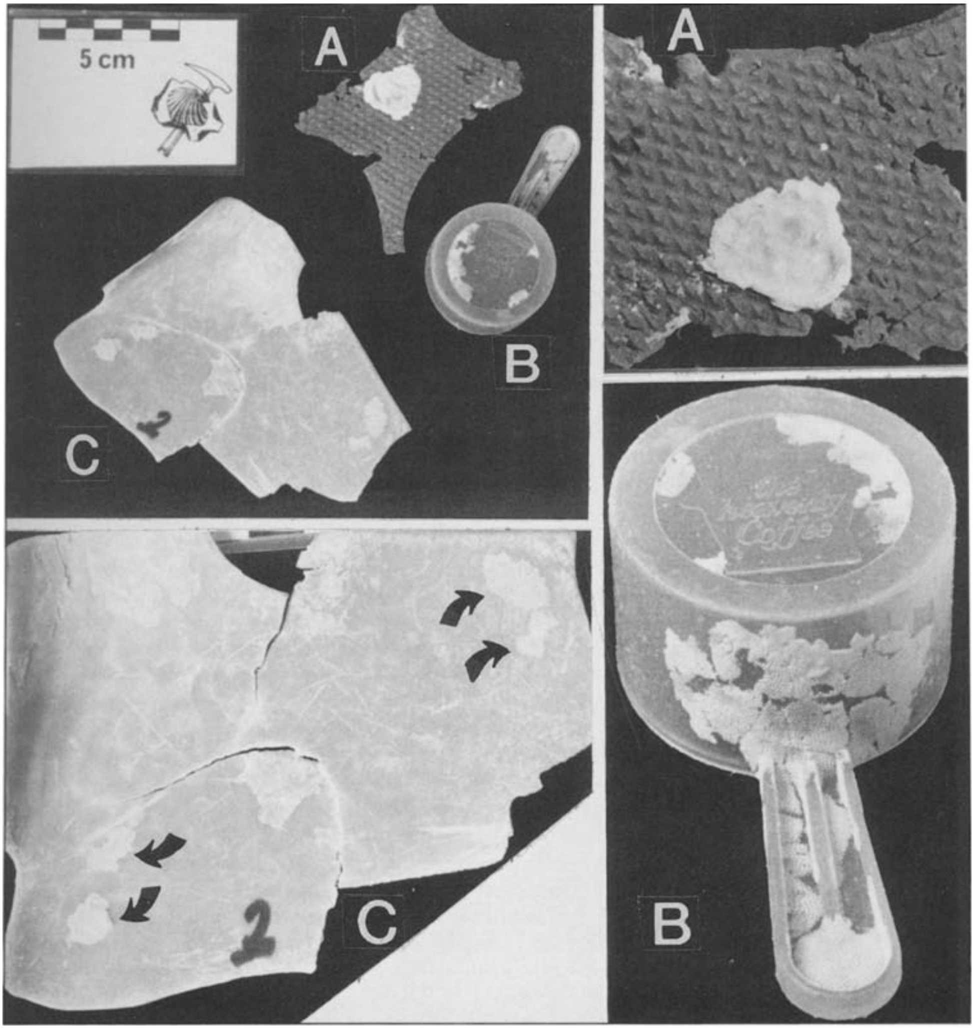


Fig. 3 – 'Oceanic' plastic megalitter items collected in February 1990 from North Beach, Raoul Island, with encrustations suggesting they have been afloat for some time and could have drifted from afar: (A) flexible spongey sheeting with attached mollusc valve; (B) small HDP measure with extensive bryozoan colonies; (C) surface chalkiness, crazing and embrittlement, evidence of progressive degradation and ultimate disintegration of a fragment of a HDP container - note the bryozoa (arrowed).

and concentrates on west-facing (windward) shores; little reaches east-facing (leeward) shores (Gregory, 1987).

On SW Pacific islands plastic meso-, macro- and megalitter is herded onto beaches facing the SE trade winds. Much of this material can be identified as 'oceanic', although some is of local origin, and it is often associated with the drift pumice common on these shores (Sachet, 1955). The principle sources are likely to be shipboard disposal. On many islands (*e.g.* Fiji, Tonga, Rarotonga, Samoa), little of it can be attributed, with any certainty, to fishing activities either in distant or local waters. Larger settlements here tend to be situated on leeward (north-facing) coasts, and domestic macro- and megalitter is dispersed down wind from these local sources (Gregory, in press). However on Raoul Island, the evidence for fishing-related and 'oceanic' sources is incontestable (Table 1). Debris is present on north,

BEACH CLEAN UP & SURVEY RECORD CARD

Date: 9/8/89 General Location: *(eg Bethells Beach, Auckland)* Motuihe Island

Exact Site on beach North facing side – eastern end

Approx. size of area:___metres long by ___metres wide

Character of survey area *(circle one)*: rock, (sand), mud, gravel, other *(specify)* sand

Name of surveyor or organisation: M.R. Gregory

Contact address and tel. no: 737-999 – ext 7680

An easy way to record the material you pick up is by counting in groups of five like this:
Bottles ~~||||~~ || Total 7

HARD PLASTICS	Total	GLASS	Total
Bottles, containers ~~||||~~ ~~||||~~ I 7, 6, 6, 3, 8, 6	47	Bottles ~~||||~~ ~~||||~~ ||||	14
Tops 10, 20, 15, 12, 12, 12, 2, 24, 36, 30, 16, 12, 25, 24, 13, 6	377	Light bulbs and tubes |||	3
6-pack yokes ~~||||~~ II	7	Broken fragments 7, 36, 150, 30, 20, 14, 5, 50, 6	291
Buckets ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ I	—	ALUMINIUM	
Toys/combs ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ I	31	Cans, cartons ~~||||~~ ~~||||~~ |||| ~~||||~~ ~~||||~~	24
Fragments 10, 12, 15, 35, 12, 25, 13	122	Foil/trays/wrapping ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ||||	39
Other 12, 6, 5, ~~||||~~ ~~||||~~ II	35	Other	–
FOAM PLASTICS		TIN/STEEL	
Trays/cups/packaging ~~||||~~ ~~||||~~ ~~||||~~	15	Tins/cans ~~||||~~ ||||	9
Fishing floats II	2	Drums	—
Foam fragments 12, 10, 12, 4, 20, 4, 20, 7, 4, 15, 24, 36, 50	206	Wire ||||	4
Other ~~||||~~ ~~||||~~	10	Bottle tops ~~||||~~ I	6
PLASTIC SHEET AND FIBRES		Other	
Plastic sheets ~~||||~~ |||	8	PAPER ~~||||~~ ||| ~~||||~~	13
Plastic & cellophane bags ~~||||~~ ||||	9	CARDBOARD	—
Fishing nets I	1	TIMBER (leave driftwood on beach) 9, 8	17
Fishing lines ~~||||~~ (approx. length in metres) >1m	5	CLOTH ITEMS II	2
		RUBBER ITEMS |||| (tyres)	4
Other rope/cord ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ II (approx length in metres)) >4 m	22	FOREIGN DEBRIS (describe overleaf)	
Packing tape/strapping - cut I	1	ENTANGLED/STRANDED ANIMALS (describe overleaf)	
Packing tape/strapping - uncut —	—		

ESTIMATE OF TOTAL VOLUME OF RUBBISH COLLECTED FROM YOUR AREA 8 Sacks

THANK YOU FOR COMPLETING THIS SURVEY CARD. PLEASE RETURN IT TO YOUR BEACH CO-ORDINATOR, OR YOUR LOCAL DEPARTMENT OF CONSERVATION OFFICE, OR POST TO ANNIE WHEELER, MARINE DEBRIS NETWORK, C/O DEPARTMENT OF CONSERVATION, P O BOX 8 NEWTON, AUCKLAND.

Fig. 4 – A completed marine debris network clean-up and survey record card for a 1000m stretch of North Beach, Motuihe Island, September, 1989.

south and west facing shores in similar amounts (see Fig. 7), presumably because this island is intermittently affected by both SE trade and westerly winds.

HAURAKI GULF

During conservation week 1989, the Department of Conservation co-ordinated, an ambitious

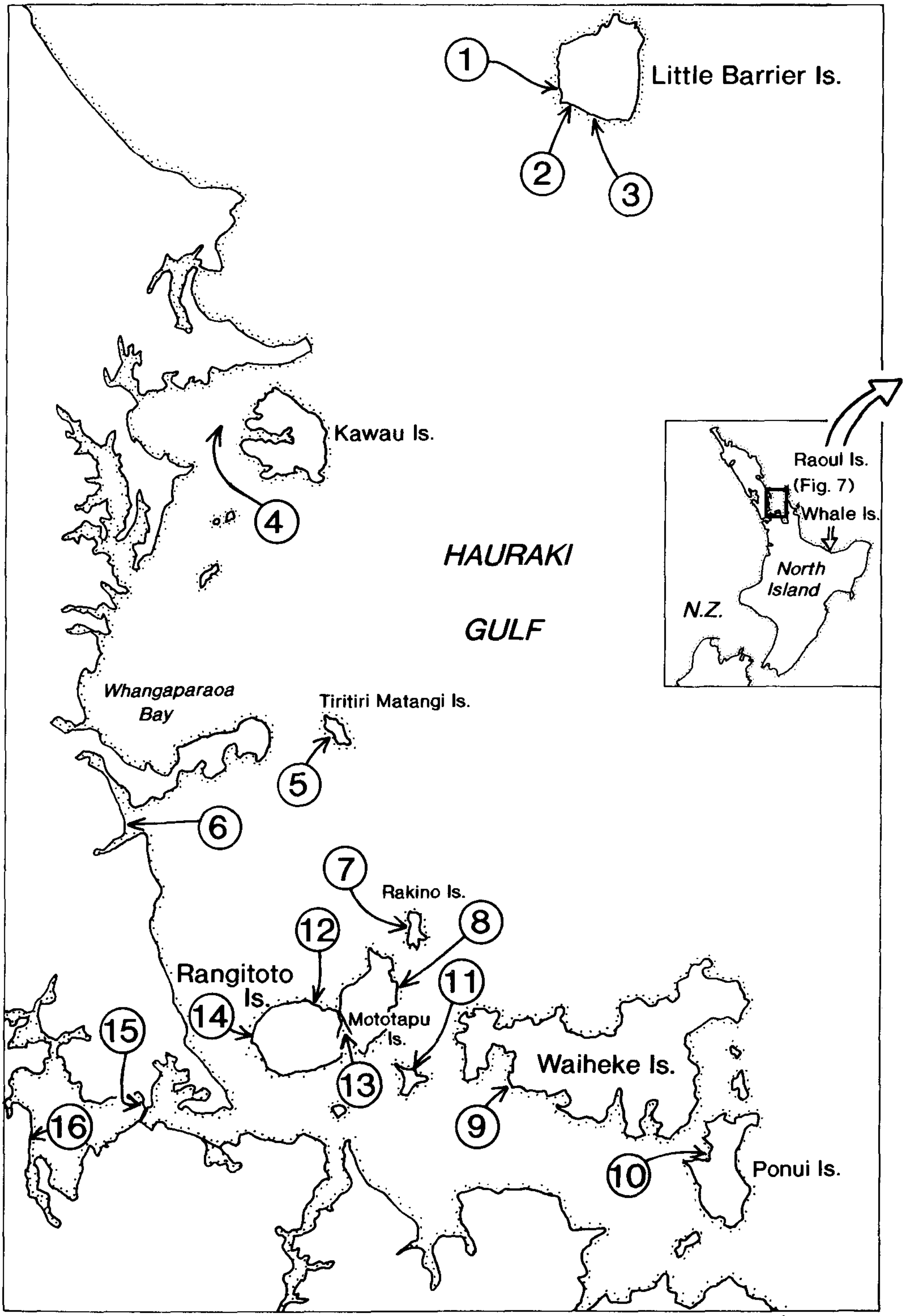


Fig. 5 – Hauraki Gulf with localities mentioned in text and in Fig. 6.

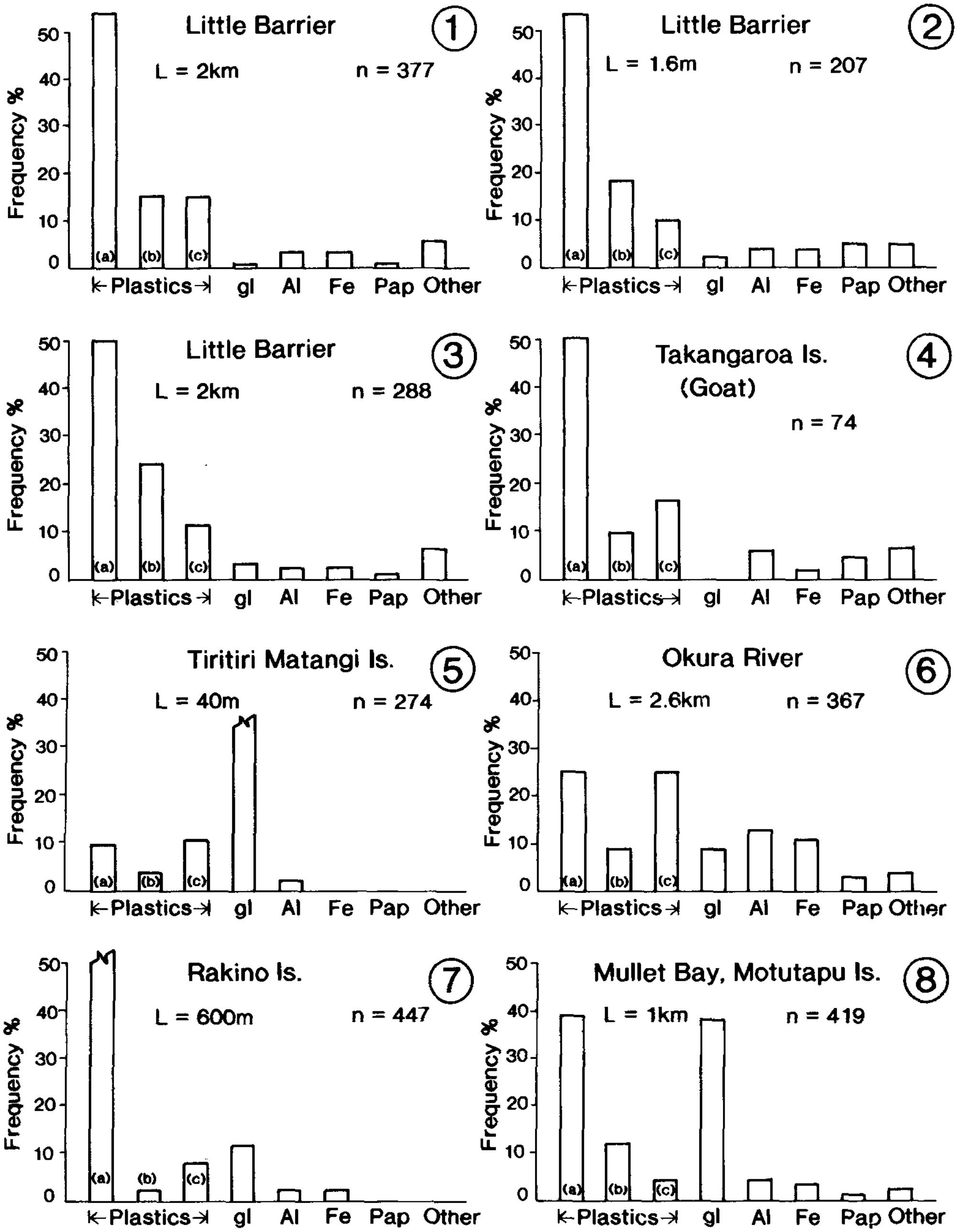
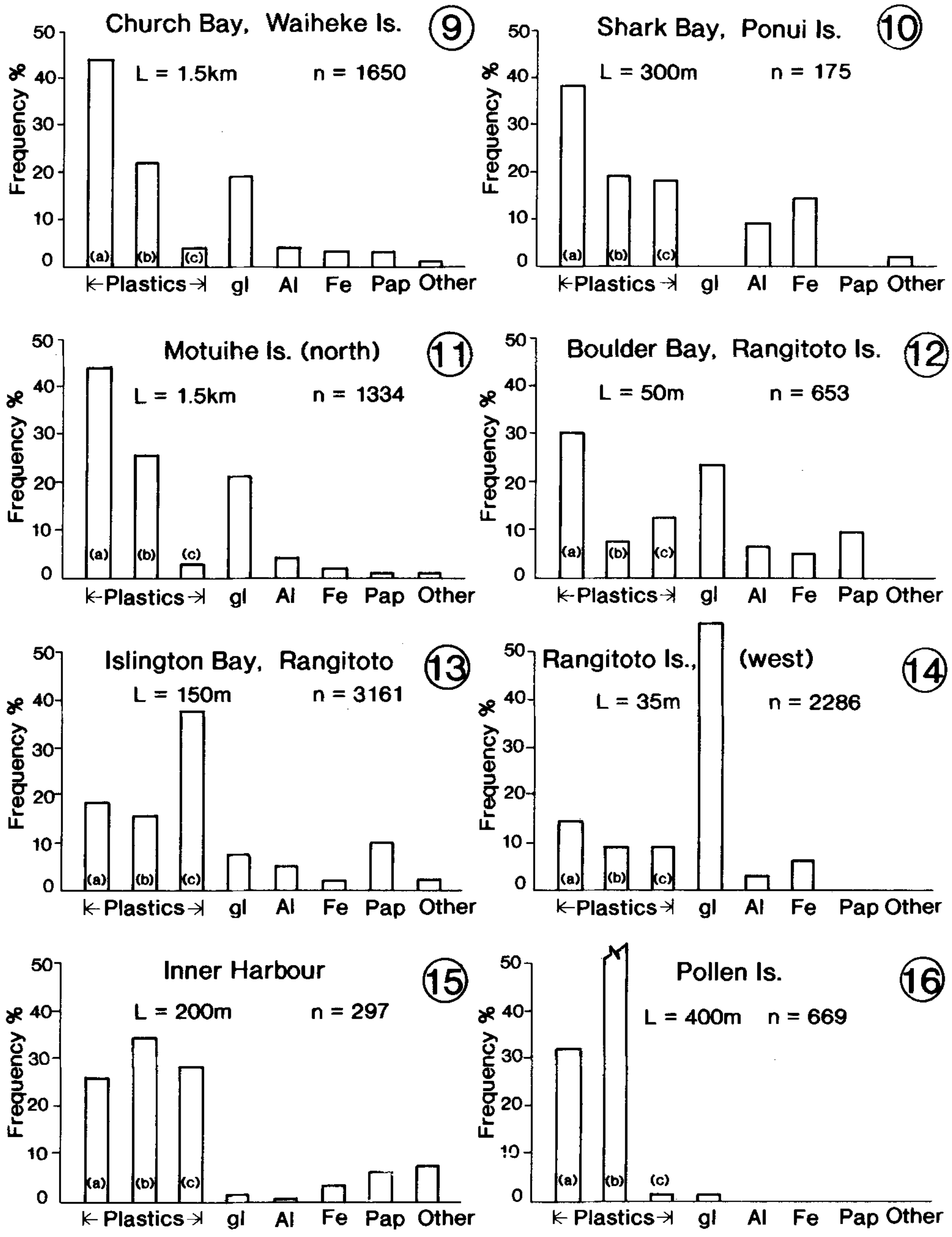


Fig. 6 – Proportions of littering items for selected beaches of islands of the Hauraki Gulf, for comparison with Raoul Island and Whale Island (Fig. 7). Based on number counts, not weight or volume. a = hard plastics, b = foam plastics, c = plastic sheet and fibres, gl = glass, Al = aluminium, Fe = iron, Pap = paper and other. For locations see Fig. 5. L = length of shoreline examined, in metres; n = number of items counted.



nationwide shoreline clean-up and survey (Fig. 4). In the Auckland area this was concentrated around the Waitemata Harbour and islands of the inner Hauraki Gulf (Fig. 5). The programme involved many hundreds of volunteers drawn from various interest and service groups (*e.g.* school pupils, Scouts, Guides and Sea Cadets, Royal Forest and Bird Society and Greenpeace members, the University community and boating clubs).

Considerable quantities of rubbish were removed from over 30km of shore, *e.g.* *c*28m^3 of rubbish from Rangitoto and Motutapu Islands (J. Cotterall, pers. comm., 1989). Beach clean-

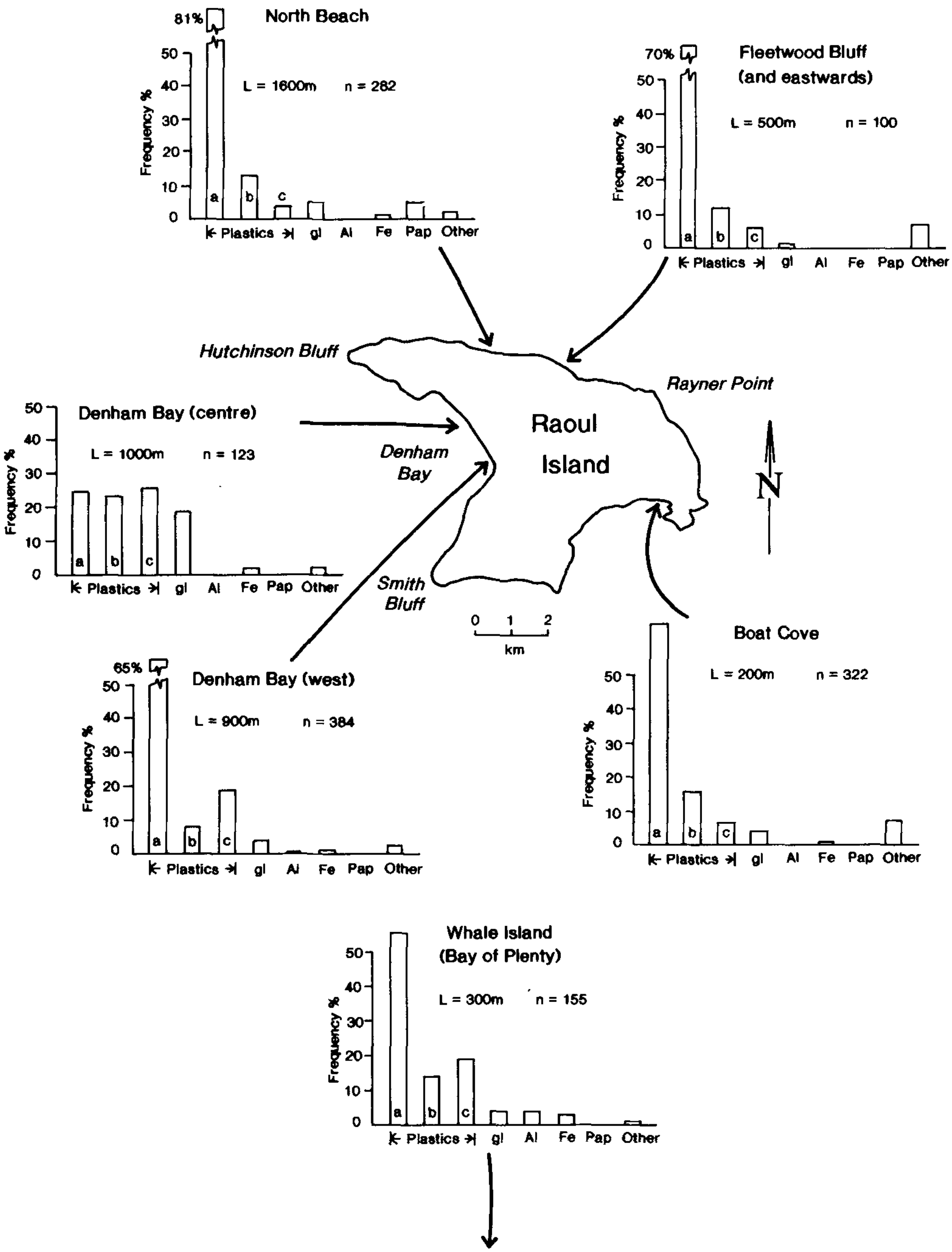


Fig. 7 – Proportions of drift items reaching shores of Whale and Raoul Islands. Symbols as in Fig. 6.

Table 1 – Variation in the local onshore, nearby offshore and 'oceanic' components of beach litter for selected localities. **a** = confectionary items plus beverage containers; **b** = domestic purpose containers (detergent, cosmetic, etc.); **c** = items related to fishing activities (floats, nets, lubricant canisters); **d** = encrusted items. Expressed as a percentage of the total number of items counted.

Locality	**a**	**b**	**c**	**d**
Auckland Harbour Beaches				
Pt Chevalier	25	>20	<1	-
Herne Bay	>35	<5	-	-
Shoal Bay	>20	>25	-	-
St Heliers	>55	<5	-	-
Inner Hauraki Gulf Beaches				
Motuihe	>10	18	<1	-
Motutapu	35	>10	<1	-
Orewa	32	<10	>2	>1
Outer Hauraki Gulf Beaches				
Omaha	20	10	19(?)	2
Marine Reserve, Leigh	15	<15	<10	4
Little Barrier Island	10	5	9	2
Remote (Conservation) Islands				
Whale*	20	9	11	2
Raoul (North Beach)	5	13	14-17	20-30
(Denham Bay)	<1	7	36-48	15

* Frequently visited by recreational craft

up and marine debris survey cards (Fig. 4) were returned from over 100 localities with shoreline lengths ranging from <100m to >2000m.

The data gathered (*e.g.* Fig. 6) give a valuable insight into the composition and identity of persistent plastics and other litter accumulating along these shores. Of the individual items counted, plastics constituted approximately 70%. The proportions and patterns of distribution were similar to those reported from elsewhere around New Zealand (see Smith and Tooker, 1990) and from several overseas studies (*e.g.* Caulton and Mocogni, 1987; Podolsky, 1989; Golik and Gertner, in press). The non-plastic components were most commonly glass, fewer aluminium and tin (steel) cans, and least of all paper, which degrades rapidly. Many plastic items appeared to be 'domestic' and of local land-based or close offshore origin (*e.g.* Fig. 1). At more frequently visited places, beverage containers, confectionary wrappings and convenience or fast food packaging were relatively conspicuous amongst the litter. Very few items sported an encrusting biota indicating distant sources, or a lengthy period afloat (Table 1). On the shores of the Waitemata Harbour and inner Hauraki Gulf islands, trawl webbing, netting, packaging loops, floats and other items attributable to the fishing industry are rarely encountered. At more distant, infrequently visited localities, items of obvious local land-based origin were rare, and evidence for nearby recreational boating and commerical fishing activities may be stronger (Figs. 2 and 7). On Little Barrier Island, for instance (Figs. 5 and 6), this evidence includes company-labelled crates and boxes, fishing floats, netting and line, as well as lubricant cannisters. The extent and character of these variations is demonstrated in Table 1. Glass is locally and irregularly abundant (Fig. 6), and much of it is made 'old' in appearance by abrasion or 'sand blasting'.

Some glass fragments may be well rounded and frosted (*e.g.*, on Tiritiri Matangi and Little Barrier Islands). These observations indicate a decreasing input of fresh material, reflecting recent replacement of glass by plastics for reasons of safety, convenience and cost effectiveness.

On the survey cards used for the inner Hauraki Gulf islands' clean-up campaign, participants were asked to nominate the source of the (plastics) pollution they encountered. Of >100 returns, responses were as follows: land-based sources <5%; picknickers 12%; recreational boating and/or inshore fisheries 18%; no indication 65%. However, data for beaches near to and down-drift from major metropolitan centres, including Auckland, indicate a dominance of primary and secondary packaging that could as well have come from local land-based sources as from routine garbage disposal at sea. It is appropriate to comment that in Smith and Tooker's (1990) census of marine debris on New Zealand beaches, fishing-related materials are over-represented in the comparative analysis: in their calculation, unidentified smaller fragments (of plastic) have been excluded, whilst the fishing-related categories includes all pieces recovered, no matter how small, together with some items that could have come from other sources.

DISCUSSION

Plastics are a significant component of the garbage and litter stream in New Zealand (Denne *et al.*, 1989). It is estimated that disposal of discarded plastics involves 140,000 tonnes entering the waste stream each year, of which as little as 3% ends up as litter (Ministry for the Environment, 1987). However, the quantities entering the marine waters of the region have not been established, and I consider that Denne *et al.* (1989: 14) have underplayed the environmental significance of plastics pollution in the sea.

Drift plastics support a pseudoplanktic, encrusting biota (Gregory, in press). Is it not conceivable that aggressive and unwanted alien taxa could be introduced into shallow coastal waters by way of a plastic substrate vector? The impact could be to the detriment of shallow littoral, intertidal and shoreline ecosystems. There are already several well known examples of adventive seaweeds in New Zealand harbours (*e.g.* Adams, 1983; Hay and Luckens, 1987; Hay, 1988). At least 10 taxa, including bivalve molluscs, brown and green algae, a sea anenome, a bryozoan, a calcareous worm and an ascidian, have been introduced to waters of the Waitemata Harbour and inner Hauraki Gulf (Dromgoole and Foster, 1983). Most of these arrivals are attributed to ship fouling and ballast waters (Adams, 1983; Dromgoole and Foster, 1983; Hay and Luckens, 1987), as are similar invasions elsewhere around the Pacific (see Carlton, 1987). An example is the recent successful colonisation of local shallow littoral substrates by the small mussel *Musculista senhousia*, for the arrival of this aggressive species may have quite serious ecological implications (Willan, 1987). Jokiel (1989) described logs and pumice flotsam carrying a cargo of corals, calcareous algae, fleshy algae, oysters, barnacles, polychaetes, foraminifera, bryozoa, tunicates, anemones and teredos over the vast expanses of the tropical Pacific. He calculated distances of 4000 km, to 32000 km if several circuits were involved, and suggested that herein lay a largely ignored factor in the dispersal and biogeography of Pacific corals. Most of the above taxa have been recognised on drift plastic substrates.

In addition to passive dispersal of marine biota by ship fouling and ballast waters (Carlton, 1987), the potential of fortuitous transoceanic transport within flotsam, for seeds as well as many terrestrial invertebrates, is widely acknowledged (*e.g.* Heatwole and Levins, 1972; Smith *et al.*, 1989); several Pacific examples have been documented (*e.g.* seeds - Darwin, 1859; mosquitoes - Belkin, 1962). Larger terrestrial vertebrates are also known to be rafted on mats of vegetation. It has been suggested that the iguanas of Fiji and Samoa arrived from the Americas in this manner by means of the west-flowing, South Equatorial Current (Cogger, 1974; Gibbons, 1981, 1985). The Atlantic mangrove, *Rhizophora mangle*, may have reached the region in the same manner before the Panama isthmus seaway closed (Gibbons, 1981). Other elements of Fiji's land fauna may have arrived in a similar manner (Gibbons, 1984; Ryan, 1984) as may have some reptiles and amphibians in New Zealand (Sharell, 1966; Robb, 1980).

If such long distance transport has been possible in the past by natural mechanisms, is it not plausible that matted rafts of plastic and other man-made flotsam could provide a comparable platform for survival? Local candidates for such transport include:- rats, mice, rabbits, possums, and perhaps cats, mustelids and even dogs. The possibility, remote as it may be, that small goats and pigs too could reach island shores in this way must also be contemplated. All of these aliens have had disastrous impacts on island ecosystems (see Moors *et al.*, 1989). They could embark their plastic ark during periods of strong offshore winds, and finding refuge and sustenance, arrive on nearby downdrift islands where they disembark. Harris (in, Atkinson, 1986) has suggested that kiore (*Rattus exulans*) could reach some local islands on floating mats of vegetation during flood periods. The potential for infestation of islands from which any or all of these animals are absent, or reinfestation of those from which they have been eradicated (*e.g.* Hawea and Breaksea Islands, Fiordland - Thomas and Taylor, 1988; Taylor and Thomas, 1989) are self-evident. The prospect of a catastrophe similar to the avifaunal extinction on Lord Howe Island following a rat invasion (Hindwood, 1940) is real and deserves serious contemplation by those responsible for the management of conservation islands. Administrators and managers must not become complacent once an island is cleared of noxious animals or plants - the need for continued vigilance is evident.

The impact of rats on the avifauna of oceanic islands has been reviewed by Atkinson (1985). Moors *et al.* (1989) suggest that in contingency planning for the protection of nature reserve islands from rodents, or other islands considered to be at risk, flotsam from vessels foundering within 2 km of shore should be checked for rats. They advise that trap and poison stations should be established around the adjacent coast. I think that this distance is an underestimate. Furthermore, while flotsam carrying rats may endanger 'oceanic' islands, inshore islands lying downwind of larger land-masses and metropolitan centres are at greater risk of invasion from land-based sources harbouring greater variety of noxious species as potential introductions.

Around the Hauraki Gulf there are many islands, large and small. Most are nature or scientific reserves and wildlife sanctuaries, and their conservation value has long been appreciated (*e.g.* Atkinson, 1973; Towns *et al.*, 1990). The irregular or strange distribution of some lizard species on islands around the Hauraki Gulf (Towns and Robb, 1986) has in the past been considered to be possible evidence of rafting, or accidental introductions (Sharell, 1966). However, recent genetic divergence studies (Towns *et al.*, 1985) imply that some New Zealand lizards have an older and perhaps Gondwana ancestry. Their distribution is influenced primarily by population isolation accompanying post-glacial rise in sea-level, and secondarily by introduced predators. Evidence gathered during the beach clean-up and survey campaign of September 1989 and its continuation (Figs 5,6 and Table 1) indicate that much plastic and other domestic refuse arrives on these islands, often after periods of strong westerly winds. The logical source is metropolitan Auckland. Efforts to translocate and/or re-establish endangered avifauna on conservation islands (*e.g.* kakapo to Little Barrier; saddleback and whitehead to Tiritiri Matangi) could be wasted by a single alien introduction through rafting. The arrival of rats on the Noises Islands, perhaps by rafting in ships' garbage and refuse dumped several kilometres offshore, and the difficulties encountered in subsequent attempts to eradicate them (Moors, 1985), illustrate the dangers. This is a salutory lesson. A further relevent and local example is West's (1981) record of 8 seed species on a toy plastic boat that stranded in Hobbs Bay, Tiritiri Matangi. This bay faces west and is 3.5 km from Whangaparaoa Peninsula. Of the eight species of seeds, five were native and three exotic; one was from a plant not previously known from the island, and at least three were considered viable. West (1981: 175) concluded that " ... species which are incapable of sea dispersal through their own lack of buoyancy or inability to withstand the effects of seawater could be safely transported in ..." the shelter of plastic artifacts to colonise new areas of land.

The rates at which plastics degrade and disintegrate, whether afloat or stranded on the shore, and are ultimately absorbed into the environment, are not well established (Gregory, 1978, 1983, 1990, in press), and the population dynamics of drift debris are also poorly known (Gerrodette, 1985). Limited experimental studies show that the most common plastics in marine debris are far more durable (as measured by reduction in tensile strength) if left

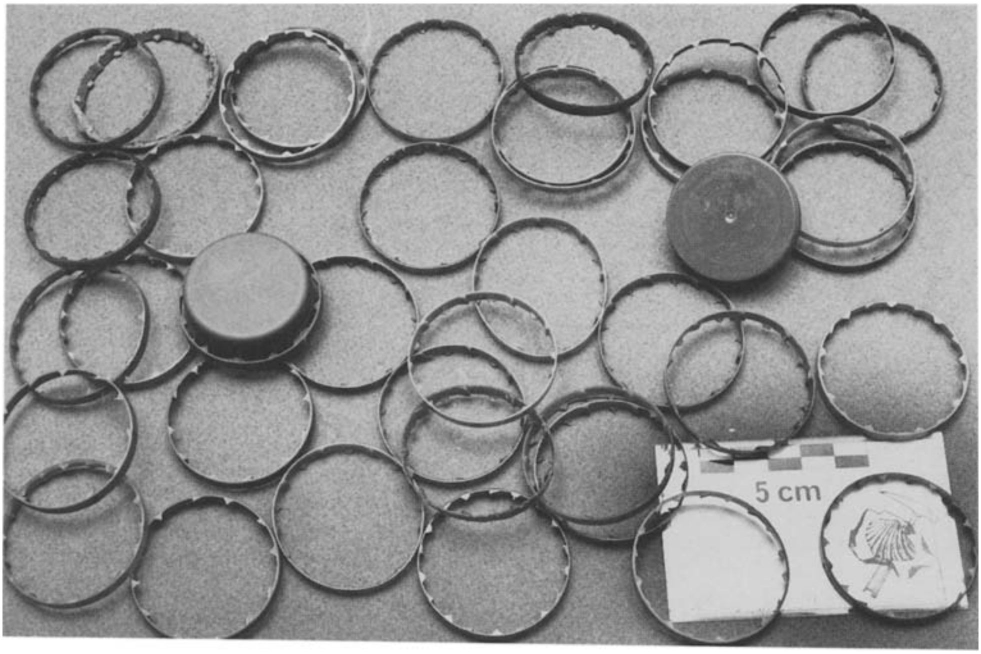


Fig. 8 – Locking rings for the caps on 21 plastic milk containers, as well as the containers, are becoming an increasingly common hazard in debris littering beaches close to Auckland. They have also been recently recorded on remote Raoul Island (author, unpublished; Feb. 1990).

floating in seawater than if exposed on land at the same location (Andrady, 1987). Plastics beaching at low (tropical) latitudes, tend to embrittle through photodegradation. Eventually they collapse to powder and dust, and disappear from view more rapidly than they do at middle and high latitudes (Gregory, 1983, in press). On inadequate evidence, it is often speculated that the survival time for beached, common domestic-purpose plastics (detergent, cosmetic containers etc.) is up to 5 years. Observations in progress imply that this estimate may be too high for sunny low and middle latitude beaches - some items have been seen to collapse in less than 18 months (author, unpublished).

The widespread use of plastics in packaging, and elsewhere, and their replacement of traditional materials, seems likely to increase (Kolbe, 1988). Typical examples are the 21 plastic milk bottles, their tops and locking rings (Fig. 8). The rings could snare shore birds and fish. Despite rapidly evolving prospects of biodegradation (Johnson, 1987) and inovative recycling technology (Thayer, 1989), the quantities of plastic on beaches seem ever likely to increase in the future. In general there is insufficient appreciation of the environmental problems caused by plastics, and an overly simplistic faith that such problems can be solved by public education initiatives (*e.g.* Mitchell, 1988; PINZ, 1988; Denne *et al.*, 1989). Plastic artifacts are readily buried under blowing sand (Podolsky, 1989) and could remain hidden for some time until exposed during a subsequent erosional episode to refoul the shore. Burial may therefore only serve to delay the problem, as it does with tarry residues.

It is also pertinent to note that in USA pleasure craft dispose 0.7kg of solid litter, much of it plastic, each day spent afloat. Fortunately, personal experience indicates that the New Zealand boating fraternity has a reasonably responsible attitude to waste litter, and much that they generate is returned to shore disposal facilities.

Another disturbing possibility with regional SW Pacific, if not global environmental implications, has arisen recently. There have been serious suggestions that the lagoons of some remote atolls could be infilled with garbage from industrialised (and more wealthy) countries (see Fosberg, 1989). It follows that the long term prospects for uncontrolled release of toxic and hazardous wastes, as well as plastics and other persistent synthetic materials, must be great. An increase in the population or loading of 'oceanic' plastics is predictable. The risk to conservation-worthy, delicately balanced and sensitive atoll ecosystems must not be underestimated.

CONCLUSIONS

1. Drift plastics pose environmental threats to conservation and protected habitat islands, whether distant or near.
2. As the environmental sinks of drift plastics in coastal environments are unknown, and as their use in packaging and elsewhere is likely to increase into the foreseeable future, the problems are unlikely to lessen.
3. The widely identified threats are those arising from entanglement and ingestion by wildlife, both of which could further endanger marine and avian taxa already considered at risk.
4. It is quite conceivable (if not highly likely) that drift plastics could introduce alien flora and fauna to conservation and protected islands, endangering ecosystems. Perceived threats are to both shallow littoral and terrestrial ecosystems. Surveillance will need to be particularly conscientious on islands declared rat free (*e.g.* Whale Island, Bay of Plenty) and which have been subsequently repopulated with an endangered avifauna.
5. It is questionable that drift plastics, excepting biocide containers, could prove harmful to terrestrial invertebrates.
6. The risks appear greatest for islands lying close to or down-drift from the mainland and/or larger metropolitan centres (*e.g.* Mana, Tiritiri Matangi and Little Barrier Islands). Remote and uninhabited or seldom-visited islands (*e.g.* Raoul, Breaksea, Campbell and Auckland Islands) are not devoid of risk, particularly where there is nearby an intensive distant-water fishery.
7. Whilst the normal perception is that drift plastics are largely an aesthetic and cosmetic problem, those responsible for the stewardship of New Zealand's many conservation islands need to be aware of them and make planning and management descisions accordingly.
8. It is doubtful if the problems caused by plastics in the environment and their indiscriminate disposal will ever be solved by regulation and technological innovation. These approaches, together with public education may help, but there will be continued need for vigilance and carefully considered management.

ACKNOWLEDGEMENTS

My long term studies of drift plastics have been funded by the University of Auckland Research Committee. Recent support has come from the Research Agenda of the Ministry for the Environment. The assistance of the Marine Debris Network and the many hundreds of individuals who participated in the Islands of the Hauraki Gulf is appreciated. My 1990 visit to Raoul Island was by permit of DOC and facilited by RV Vulkanolog and I. Menyailov of the Institute of Volcanolgy, Petrapavlovsk, Kamchatsky. Particular thanks go to J. Cotterall, M. Donoghue, G. Johnson, P. Smith, and A. Wheeler. The MS was typed by R. Bunker and figures drafted by L. Cotterall. I also appreciated the encouragment and thoughtful comments of M.W. Cawthorn and D.R. Towns.

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Received 24 April 1990; accepted 14 December 1990