PLASTIC IN THE MARINE ENVIRONMENT

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ABSTRACT

Plastic is cheap, ubiquitous and persistent. In 2010 the world produced 265M tonnes. Annual output is increasing with new uses and varieties augmenting demand. Plastic persists for centuries, much of it finding its way into coasts and waterways. Approximately 80% of marine debris is plastic (mostly bags and bottles), accumulating through spillage, runoff, dumping and discharge; with varied environmental, economic, cultural and aesthetic implications. This paper examines the nature of plastic in the marine environment, its environmental impacts and the roles assumed by Member Councils of Sydney Coastal Council Group Incorporated in addressing the situation.

INTRODUCTION and DISCUSSION

Plastic

Plastics are synthetic organic polymers (Derraik 2002). Mass production commenced in the 1950s (Barnes *et al.* 2009) and has increased from 1.5 million t/y to 265 million t/y with a projected future growth of 4% p.a. (PE 2011). Plastics are playing an increased role in day-to-day life as traditional materials are replaced and new compounds and uses are devised (Quayle 1992; Thompson *et al.* 2009).

Plastic debris comes in a range of shapes and sizes from microscopic fragments up to boat hulls and fishing nets (Thompson *et al.* 2004) and can be broadly be divided into micro (<5 mm), meso (5-20 mm), macro (>20 mm) and mega (>100mm) size classes (Andrady 2011; Barnes *et al.* 2009). Most plastics are buoyant until they become waterlogged or fouled with marine life and sediment causing them to sink (Barnes *et al.* 2009).

Persistence

Plastic is recalcitrant. Whilst plastic degrades by photolytic, biological and mechanical processes its longevity is still estimated at 100-1000s of years depending on the physical and chemical properties of the polymer and surrounding environment (Barnes *et al.* 2009). Exposure to UV light and physical abrasion causes plastic to embrittle, crack and fragment into powdery fragments invisible to the naked eye. This process is particularly evident in areas with high levels of solar radiation, wave-action and abrasion such as shorelines (Browne *et al.* 2010; Thompson *et al.* 2004). However, in the marine environment plastics take longer to degrade due to lower temperatures, reduced UV exposure (at depth or due to surface fouling organisms) and lower O_2 concentrations (Andrady 2011; Barnes *et al.* 2009). In one study, polyethylene bags showed no signs of degradation after 40 weeks of exposure (O'Brine & Thompson 2010).

Accordingly to Thompson *et al.* (2005) all conventional plastic that has entered the marine environment persists today, either whole or fragmented. Even if production ceased today, existing debris would remain for centuries.

Source

Plastic debris originates from either intentional or accidental mishandling (Sheavly & Register 2007): littering, illegal dumping, runoff, spillage and discharge from rivers, stormwater and sewage outfalls. (Barnes *et al.* 2009; Browne *et al.* 2010; Derraik 2002). Land-based sources represent ~80% of marine plastic pollution (Andrady 2011) with most debris entering along populated coasts, important fishing grounds and shipping corridors (Laist 1987).

Distribution

Plastic is ubiquitous. Its scale of production, durability and poor rates of recycling has resulted in the accumulation of debris in the most remote of locations - from the poles to the equator and from mountaintops to the ocean depths (Barnes *et al.* 2009; Gregory 2009; Quayle 1992).

Typically 50 – 80% of the waste that accumulates on beaches, the ocean surface and the seabed is plastic (Barnes *et al.* 2009; Derraik 2002; Islam & Tanaka 2004), increasing in proportion with distance from source (Ryan *et al.* 2009). There are reports of >100000 items m^{-2} on shorelines, up to 3,520,000 items km^{-2} at the ocean surface (e.g. Thompson *et al.* 2009) and up to 70,000 items km^2 on continental shelves and slopes (Galgani *et al.* 2000). In recent decades plastic pollution in the marine environment has increased dramatically and substantially (Barnes *et al.* 2009).

There is large spatial and temporal heterogeneity in the distribution of plastic debris due to geomorphology, human activity and physical factors such as wind (and thus currents and wave-action) and the size, shape and density of plastic (Barnes *et al.* 2009; Browne *et al.* 2010; Ryan *et al.* 2009; Thompson *et al.* 2009). Whilst patchy, abundance is correlated with human population density (Andrady 2011; Barnes 2002; Barnes *et al.* 2009). Its buoyant nature due to low density relative to seawater facilitates dispersal over long distances (Derraik 2002) and it can be concentrated by natural processes such as current gyres, along lines of convergence between water masses and in areas of upwelling which are often prominent feeding areas with high densities of marine species (Joyner & Frew 1991; Laist 1987; Ryan *et al.* 2009).

Plastic accumulates along strandlines (the shore area between high and low water, Weihaupt 1979) and in the ocean's pelagic and benthic zones (Browne *et al.* 2010; Galgani *et al.* 2000; Thompson *et al.* 2004). Vertical distribution within the water column is mediated by density and the amount of fouling by organisms and sediment (Browne *et al.* 2010). Under the weight of fouling organisms and adsorbed sand, shells and other debris, plastics sink to the seabed (Andrady 2011; Barnes *et al.* 2009; Islam & Tanaka 2004) and can 'yo-yo' as fouling organisms and their predators alter density (Andrady 2011; Gregory 2009).

Microplastics

Microplastics (particles <5 mm) present particular environmental problems. They are manufactured (e.g. feedstock in plastic manufacture; spherules used in cleaning, cosmetics and airblasting media) or are the breakdown products of meso-and macroplastics (Andrady 2011; Barnes *et al.* 2009; Browne et al. 2007; Derraik 2002). A major contributor is washing machine wastewater which enters the sewerage network and is subsequently discharged into marine environment via treatment plants (Browne *et al.* 2011). A single garment can produce >1900 fibres per wash with polyester (67%) and acrylic (17%) the dominant fibres (Browne *et al.* 2011).

Microplastics absorb and concentrate persistent organic pollutants (POPs) from seawater by partition, providing a pathway for entry into the food web (Andrady 2011; Hirai *et al.* 2011; Rios *et al.* 2010) and onto the dinner table. POPs are hydrophobic, facilitating concentration at levels several orders of magnitude higher than in the surrounding seawater. POPs ingested by animals can be taken up and stored by tissues and cells, and biomagnified across trophic levels (Andrady 2011; Browne *et al.* 2011). Humans consume species from all trophic levels, from filter feeders to fin fish at the apex of the cascade.

In 2010 Hornsby Council commissioned a report to characterise the sources and sinks of microplastics in the Hawkesbury Estuary (Browne 2010). Sampling revealed the presence of microplastics in estuarine, freshwater and terrestrial habitats (0.3 – 1.6 fibres/L) with the likely source being the breakdown products of mesoplastics and drain and laundry effluent.

Risks and implications

Plastics are popular because they are versatile, inexpensive, durable and lightweight (Andrady & Neal 2009) and for these reasons they are one of the world's most pervasive problems (Joyner & Frew 1991; Sheavly & Register 2007). The UN Environment Programme listed plastic debris in oceans as one of three global emerging issues (UNEP 2011). Threats to benthic and pelagic marine life (>250 species, Laist 1997) such as birds, fish, marine mammals and invertebrates are primarily mechanical (suffocation, wounding, entanglement and ingestion causing internal injuries or blockage) and toxicological (absorption of toxic chemicals through the gut, Derraik 2002; Laist 1987). However, plastic debris is responsible for a host of deleterious environmental effects extending beyond those to marine life (Table 1).

Table 1. The risks and implications of plastic in the marine environment.

NATURE OF RISK	IMPLICATIONS
Marine organisms	
Entanglement	Impaired movement, feeding and respiration Strangling / choking Wounding
Ingestion	Impaired feeding and food assimilation and thus reduced reproductive output Clogging of the feeding apparatus and the digestive system Physical internal injuries
Poisoning	Ingested debris can accumulate in the gut and translocate into the circulatory system Transfer of contaminants sorbed by plastic into body tissues Concentration of toxins along the food chain
Visual	
	Aesthetically displeasing Attract some marine species which mistake plastic as prey or represent a play object or an item of curiosity (e.g. seals to packing loops)
Physical damage	
	Debris can physically damage habitats through abrasion, scouring, ensnaring and smothering Debris can damage recreational and commercial vessels
Vector	
Organisms	Drift plastics are colonised by motile, encrusting and fouling organisms (e.g. bacteria, diatoms, algae, barnacles, hydroids and tunicates) and act as vectors for 'hitchhiking' non-indigenous and/or pest species
Chemicals	Vector for the transport of sorbed chemicals
Benthos	
Biochemistry	Debris on the sea floor can inhibit gas exchange between sediment and overlying waters causing hypoxia or anoxia
Community structure	The accumulation of plastic can alter benthic community structure e.g. via smothering, habitat changes
Geochemistry	Microplastics reduce the temperature and increase the permeability of sediments which can impact upon biota
Economic	
	Impacts upon marine life can have fisheries implications Clean-up costs Negative impacts to tourism Public safety Loss of ecosystem services Cost of repair to damage to vessels

(From Barnes 2002; Barnes *et al.* 2009; Browne *et al.* 2010; Carson *et al.* 2011; Derraik 2002; Gregory 2009; Joyner & Frew 1991; Laist 1987; Quayle 1992; Sheavly & Register 2007; Thompson *et al.* 2009)

SCCG Member Councils

A survey of Member councils revealed that, independent of waste management and recycling strategies, each has developed a Sustainable Events Management Policy (under the Local Council Waste and Sustainability Improvement Payments program) aiming to minimise waste and increase resource recovery. Policies and the events to which they apply vary. For example, some ban plastic bottles and/or bags for all internal and external events including private events on council assets (Fig 1.). Some policies are available online.

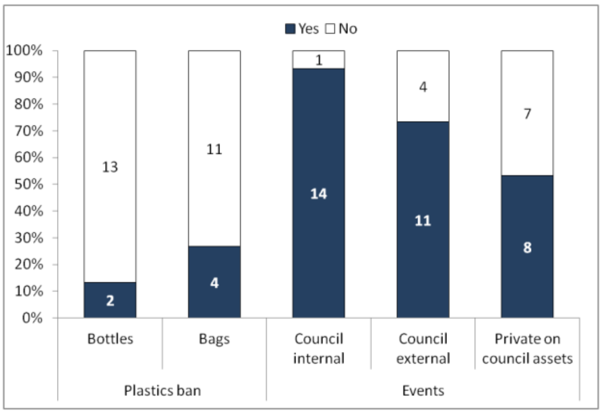

Fig. 1. Plastics bans by Member Councils: internal and external events.

Table 2 lists each Member Council and the application of their respective sustainable events management policy to plastic bottles and bags.

Table 2. The application of Member Councils' sustainable events management policies to plastic bottles and bags.

Council	Plastics ban		Events		
	Bottles	Bags	Council internal	Council external	Private on council assets
Botany Bay	No	No	Yes	No	No
Sydney City	No	No	Yes	Yes	Yes
Hornsby	No	No	Yes	No	No
Leichhardt	No	No	Yes	No	No
Manly	Yes	Yes	Yes	Yes	No
Mosman	Yes	Yes	Yes	Yes	Yes
North Sydney	No	No	Yes	Yes	Yes
Pittwater	No	No	Yes	Yes	No
Randwick	No	No	Yes	Yes	No
Rockdale	No	No	Yes	Yes	Yes
Sutherland	No	No	Yes	Yes	No
Warringah	No	No	No	No	Yes
Waverley	No	Yes	Yes	Yes	Yes
Willoughby	No	No	Yes	Yes	Yes
Woollahra	No	Yes	Yes	Yes	Yes

Solutions

Substituting plastics that are (bio)degradable and/or made from renewable resources for petroleum based (conventional) plastics is only part of the solution. Degradable plastics can reduce the amount of large debris, but hazardous breakdown products may remain (Barnes *et al.* 2009). In addition, the production of 'friendly' plastics may be more environmentally damaging than conventional plastics (e.g. using more pesticides, land and water), and degradation rates may be too slow to prevent risks to biota (Quayle 1992; Gironi & Piemonte 2011). A full 'cradle-to-grave' life cycle assessment is required to weigh up relative environmental impacts (Gironi & Piemonte 2010).

Plastic recycling rates are low (Barnes *et al.* 2009). Legislation can increase recycling and require the use of environmentally friendly biodegradable and photodegradable plastics (Derraik 2002; Quayle 1992). Beach clean ups and *in situ* collection of marine debris whilst of value must be vigilant to ensure they do not destroy ecologically significant habitats (Gregory 2009).

As the environmental consequences of plastic are many and varied, solutions must be equally diverse. The combined efforts of all is required - government, scientists, communities and the private sector. Education has been posited as a powerful tool and building block to reduce plastic pollution, especially utilising children as catalysts for change (Derraik 2002; Ryan *et al.* 2009). Promoting descriptive norms to influence behaviour has also been found to be extremely valuable in mediating community action and change (UK Cabinet 2011). Outreach programs, strong laws, policies and enforcement (Sheavly & Register 2007), especially addressing the source are also of benefit (Gregory 2009).

Scientific knowledge is patchy in relation to the emission, transport, fate and effects of plastics in the marine environment (Zarfl *et al.* 2011), inhibiting understanding and effective management strategies (Islam & Tanaka 2004). Furthermore, the large spatial and temporal variability in the distribution and abundance of plastic pollution can mask its true effects (Laist 1987). Research is required to understand the magnitude of societal and environmental impacts, measure long term trends and assess the relative costs and benefits of reduction measures.

Conclusion

Plastic is an integral part of life. It is likely to play an increasing future role, intensifying the input and impacts of litter in the marine environment. Its utility, durability and low cost have resulted in its accumulation worldwide. The problems of plastic pollution are multifaceted such that there is no simple single solution. Creative, effective and sustainable management is required coupled to research and monitoring programs. Enlisting community-wide support to reduce use at-source together with economic incentives, legislation and education can significantly assist address impacts.

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