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# International policies to reduce plastic marine pollution from single-use plastics (plastic bags and microbeads): A review

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ABSTRACT

Marine plastic pollution has been a growing concern for decades. Single-use plastics (plastic bags and microbeads) are a significant source of this pollution. Although research outlining environmental, social, and economic impacts of marine plastic pollution is growing, few studies have examined policy and legislative tools to reduce plastic pollution, particularly single-use plastics (plastic bags and microbeads). This paper reviews current international market-based strategies and policies to reduce plastic bags and microbeads. While policies to reduce microbeads began in 2014, interventions for plastic bags began much earlier in 1991. However, few studies have documented or measured the effectiveness of these reduction strategies. Recommendations to further reduce single-use plastic marine pollution include: (i) research to evaluate effectiveness of bans and levies to ensure policies are having positive impacts on marine environments; and (ii) education and outreach to reduce consumption of plastic bags and microbeads at source.



**Contents**



## 1. Introduction

Plastics are now ubiquitous in the marine environment, and urgent action is required to mitigate this worsening trend (Rios et al., 2007; Rochman et al., 2015b). In 2010, an estimated 4.8–12.7 Mt of plastics entered the oceans globally (Jambeck et al., 2015). A 2014 study (from six years of research by the 5 Gyres Institute) estimated that 5.25 trillion plastic particles (weighing 269,000 tons) are floating in the sea. Although the contribution of plastics in man-made garbage is roughly 10% by mass (Barnes et al., 2009), it is estimated that plastic debris accounts for 60–80% of marine litter (Derraik, 2002), reaching 90–95% in some areas (Walker et al., 1997, 2006; Surhoff and Scholz-Böttcher, 2016). Due to its durability, the lifespan of plastic is estimated to be hundreds to thousands of years (Wang et al., 2016). In 2014, UNEP announced concern over the threat of widespread plastic waste to marine life.

Plastics have been reported as a problem in the marine environment since the 1970s (Carpenter and Smith, 1972; Colton et al., 1974). However, only recently has the issue of plastic pollution in marine and

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freshwater environments been identified as a global problem (Andrady, 2011; Eriksen et al., 2013; Vegter et al., 2014; Eerkes-Medrano et al., 2015; Perkins, 2015). Consequently, marine plastic pollution has become a significant environmental concern for governments, scientists, non-governmental organizations, and members of the public worldwide (Seltenrich, 2015). Entanglement of species by marine debris can cause starvation, suffocation, laceration, infection, reduced reproductive success and mortality (Katsanevakis, 2008; Baulch and Perry, 2014; UNEP and NOAA, 2015). Previous studies focused on entanglement of marine mammals and other species in net fragment litter or 'ghost fishing gear' (Walker and Taylor, 1996; Laist, 1997; Clapham et al., 1999; Bullimore et al., 2001; Eriksson and Burton, 2003). For example, Antarctic fur seals are commonly entangled in plastic marine debris (Walker et al., 1997; Waluda and Staniland, 2013). Ingestion of plastics by birds (Moser and Lee, 1992; Robards et al., 1997; Cadee, 2002; Mallory, 2008) and turtles (Mascarenhas et al., 2004; Bugoni et al., 2001; Tomas et al., 2002) have also been widely reported. Plastic bags have been identified, among macroplastic litter items, most harmful to marine biota (Besseling et al., 2015; Hardesty et al., 2015), but can also have impacts beyond marine species.

The existence of plastics in the marine environment presents a number of challenges that hinder economic development. Stranded plastic along shorelines creates an aesthetic issue, which has negative impacts for tourism (Jang et al., 2014). Economic losses are associated with reduced tourism revenues, negative impacts on recreational activities, vessel damage, impairment in marine environments, invasive species transport and damage to public health (Hardesty et al., 2015). Stranded shoreline plastic also negatively impacts shipping, energy production, fishing and aquaculture resources (Cole et al., 2011; Sivan, 2011). A conservative estimate of the overall economic impact of plastics to marine ecosystems is ~$13 billion US/year (Raynaud, 2014), although the true environmental costs are difficult to monetarize. However, reported impacts of marine plastic debris on marine life include nearly 700 species, from tiny zooplankton to the largest whales, including fish destined for human consumption. Of the hundreds of marine species impacted, 17% are IUCN red listed species and at least 10% have ingested plastics (Gall and Thompson, 2015).

### 1.1. Microplastics vs macroplastics

Plastics are comprised of microplastics (first coined by Thompson et al. (2004)) and macroplastics. Macroplastics (>5 mm) enter the marine environment via dumping or poor waste management (Pettipas et al., 2016). Over the past decade, growing efforts have been made to monitor impacts of microplastics in the marine environment (Seltenrich, 2015). National Oceanic and Atmospheric Administration (NOAA) define microplastics as fragments <5 mm in diameter (Barboza and Gimenez, 2015), with some researchers using <1 mm diameter as the threshold (Goldstein et al., 2012). Microplastics comprise: primary microplastics (e.g., microbeads), and secondary microplastics, from degraded macroplastics (e.g., plastic bags) (Ivar do Sul and Costa, 2014; UNEP, 2015, 2016; Napper et al., 2015). The annual global production of plastic is ~300 million tonnes (Napper et al., 2015), with roughly 50% disposed of after a single-use (Mathalon and Hill, 2014). Established empirical data suggest that large pieces of plastic (macroplastics) can cause significant harm in the marine environment through entanglement (Rios et al., 2007). Recent studies suggest that risks of microplastics (including degraded macroplastics, microbeads and microplastic fibres) in the marine environment may pose more of a threat than macroplastics (Browne et al., 2011; Desforges et al., 2014; Thompson, 2015), but research and policies to reduce pollution from these sources are lacking.

### 1.2. Evidence of impacts

Microplastics in the marine environment can travel vast distances floating in seawater, or sediment to the seabed (UNEP, 2015). The five plastic gyres established throughout the oceans are well documented, particularly the "Great Pacific Garbage Patch" (Goldstein et al., 2012). Accumulation in these gyres is exacerbated because plastics take centuries to degrade (Cole et al., 2011). In addition to floating and stranded plastic debris, the deep sea is possibly the largest global marine litter depocentre (Pham, 2014; Tubau et al., 2015).

Large plastic items, such as discarded fishing rope and nets, can cause entanglement of invertebrates, birds, mammals, and turtles (Harper and Fowler, 1987; Walker and Taylor, 1996; Laist, 1997; Eerkes-Medrano et al., 2015) but marine environment is also contaminated with much smaller microplastic particles. These have been reported at the sea surface (Law and Thompson, 2014), stranded on shorelines (Claessens et al., 2011), and on the seabed (Van Cauwenberghe et al., 2015; Tubau et al., 2015). Microbeads are commonly white or opaque in colour, and research has found microbeads to be commonly mistaken for plankton by many surface feeding fish species. Ingestion of plastics by aquatic organisms is one of the major deleterious environmental impacts in the marine environment (Baulch and Perry, 2014; UNEP, 2016). Due to their small size and presence in pelagic and benthic ecosystems, contaminants associated with microplastics are potentially bioavailable for many organisms (Barboza and Gimenez, 2015). Persistent organic pollutants sorbed onto microplastics can accumulate at concentrations several orders of magnitude higher than in ambient seawater (Andrady, 2011). A growing concern related to microplastics is that they can also enter the human food chain through ingestion of fish, shellfish and filter feeders (Mathalon and Hill, 2014; Chang, 2015), causing potential human health impacts (UNEP, 2015; GESAMP, 2016). Filter-feeding mussels have been reported to contain microplastics in their tissues (Besseling et al., 2015; Mathalon and Hill, 2014), but the toxicological risks are poorly understood and represents an important challenge for future research (Goldstein et al., 2012; Seltenrich, 2015; Miranda and de Carvalho-Souza, 2016).

### 1.3. Microbeads in cosmetics

Microbeads have increasingly been manufactured (to replace natural exfoliating materials, including pumice, oatmeal, and walnut husks) for single-use cosmetics, such as abrasive exfoliating cleansers and toothpastes (Chang, 2015). Recent studies reported that some cosmetic products contain approximately as much plastic by weight as there are in the plastic container packaging (UNEP, 2015). Microbeads are designed to be disposed of via wastewater treatment infrastructure. However, wastewater treatment facilities are not designed to remove manufactured microplastic particles, which means that these are currently released into aquatic ecosystems. An estimated 8 trillion microbeads are released into aquatic environments daily via wastewater treatment plants (Rochman et al., 2015a).

### 1.4. International strategies to reduce plastic marine debris

Governments have struggled for decades to reduce marine plastic debris (Rochman et al., 2015a). The International Convention for the Prevention of Pollution From Ships (MARPOL 73/78) was signed in 1973, although a complete ban on the disposal of plastics at sea was not enacted until 1988. Even though 134 countries agreed to eliminate plastics disposal at sea, research has shown that the problem of marine debris has worsened since MARPOL 73/78 was signed. This may be because the marine debris problem is related to incorrect disposal of waste on land.

Many non-governmental organizations (NGOs) conduct monitoring research on marine debris to increase awareness (Pettipas et al., 2016). For example, The 5 Gyres Institute and the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection engage in awareness campaigns. The Ocean Conservancy oversees the International Coastal Cleanup (ICC). The ICC encourages other NGOs and volunteer