



67

IMPACTS OF MARINE DEBRIS ON BIODIVERSITY

*Current Status and
Potential Solutions*



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Impacts of Marine Debris on Biodiversity: Current Status and Potential Solutions

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About STAP

The Scientific and Technical Advisory Panel comprises seven expert advisers supported by a Secretariat, which are together responsible for connecting the Global Environment Facility to the most up to date, authoritative, and globally representative science.

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FOREWORD

Extending over three quarters of the surface of the Earth, oceans are the origin of all life on this planet and play a critical role in planetary life support systems. Global biogeochemical cycles and weather patterns are dependent on oceans and affect every person and living organism on this planet. Economically, there is considerable reliance on the world's oceans – from fisheries which support over 15% of the global protein supply, to off-shore petroleum production and the risks this entails, along with the millions of jobs supported by tourism and fishing.

Our oceans are increasingly bearing the brunt of direct and indirect impacts from human activities. A wide range of threats such as increasing acidification, coral bleaching, toxins and chemical pollution, nutrient overloading, and fisheries depletion including many others are undermining the ocean's ability to sustain ecological functions. Marine debris is a part of this phenomenon—made up of persistent, manufactured solid materials that are discarded or otherwise abandoned in the marine and coastal environment. Large quantities of debris can now be found in the most remote places of the ocean, and persist almost indefinitely in the environment. This represents a significant cause for concern, although much of this growing threat to biodiversity and human health is easily preventable with solutions readily available.

The global impacts of marine debris on biodiversity and the urgency of action to prevent and mitigate adverse impacts were recognized by the latest meeting of the Subsidiary Body on Scientific, Technical and Technological Advice to the Convention on Biological Diversity. This led to the adoption of several recommendations addressing the impacts of marine debris on marine and coastal biodiversity (CBD SBSTTA 16 Recommendation XVI/5), in line with the current efforts of Parties in achieving Aichi Biodiversity Targets on marine and coastal biodiversity, in particular Targets 6, 8 and 11.

This publication is a result of fruitful collaboration between the Secretariat of the Convention on Biological Diversity and the Scientific and Technical Advisory Panel of the Global Environment Facility. We believe it is a timely response to the main Outcome Document of the 2012 United Nations Conference on Sustainable Development, that reaffirmed its concern for the health of the oceans and marine biodiversity – and committed nations to take action by 2025 to achieve significant reductions in marine debris to prevent harm to the coastal and marine environment (A/66/L.56, paragraph 163). With the endorsement by the UN General Assembly of the Rio+20 Outcome Document, prevention and mitigation of marine debris is now recognized among global priorities for sustainable development and the post-2015 UN development agenda. We thus hope this report will support Parties, other Governments, along with civil society and the scientific community in further enhancing their awareness of the urgency of this issue and facilitating immediate actions to address the sources and causes of marine debris in the ocean.



A stylized, handwritten signature in black ink.

Braulio Ferreira de Souza Dias
Executive Secretary
Convention on Biological Diversity



A handwritten signature in black ink that reads "Thomas E. Lovejoy".

Thomas E. Lovejoy
Chair, Scientific and Technical Advisory Panel
Biodiversity Chair
The Heinz Center

LIST OF ACRONYMS

ABNJ	Areas beyond National Jurisdiction
ACC	American Chemical Council
ALDFG	Abandoned, Lost or Otherwise Discarded Fishing Gear
BPA	Biosphenol-A
CBD	Convention on Biological Diversity
CEP	Caribbean Environment Programme (UNEP)
CMS	The Convention on the Conservation of Migratory Species of Wild Animals
COFI	FAO Committee on Fisheries
COP	Conference of the Parties
EPA	Environmental Protection Agency (USA)
EPR	Extended producer responsibility
FAO	Food and Agriculture Organization of the United Nations
GEN	Eco-Labeling Network
GHG	Greenhouse Gases
GPA	Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities (UNEP)
IMO	International Maritime Organization
ISO	International Organization for Standardization
IUCN	International Union for Conservation of Nature
MARPOL	International Convention for the Prevention of Marine Pollution from Ships
MDP	Marine Debris Program (NOAA)
NGO	Non-governmental organization
NOAA	National Oceanic and Atmospheric Administration (USA)
NOWPAP	North-West Pacific Action Plan
OECD	Organization for Economic Cooperation and Development
OSPAR	Oslo and Paris Conventions for the Protection of the Marine Environment of the North- East Atlantic
PBT	Persistent, bio-accumulative and toxic substances
PET	Polyethylene terephthalate
POP	Persistent organic pollutants
Rio+20	United Nations Conference on Sustainable Development
RNLI	Royal National Lifeboat Institution (UK)
SBSTTA	Subsidiary Body on Scientific, Technical, and Technological Advice (CBD)
SMM	Sustainable materials management
SPPI	International Sustainable Public Procurement Initiative
SPREP	Secretariat of the Pacific Regional Environment Programme
STAP	Scientific and Technical Advisory Panel (GEF)
UNCLOS	United Nations Convention on the Law of the Sea
UNEP	United Nations Environment Programme
WWF	World Wildlife Fund

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KEY MESSAGES

RATIONALE

Marine habitats throughout the world are contaminated with man-made items of debris and solid waste. This report reviews the current state of knowledge of the effects of marine debris, and provides a preliminary assessment of the impact on ecosystems and biodiversity. It seeks to inform the Parties and other participants in the CBD on the nature of this emerging issue and potential strategies to address it, following discussion the discussion at the 16th Meeting of the Subsidiary Body on Scientific, Technical, and Technological Affairs (SBSTTA) of the Secretariat of the Convention on Biological Diversity (CBD)¹. Section 1 of the report provides a systematic assessment of research to date in the fields of marine biology and ecology and examines the evidence of its effects on marine species and ecosystems. Section two addresses potential solutions, drawing on waste management experience and practices, and providing examples of approaches that can be used to reduce land-based sources of marine debris.

DEFINING MARINE DEBRIS

Marine debris is any persistent, manufactured or processed solid material discarded, disposed of, or abandoned in the marine and coastal environment. While this definition encompasses a wide range of materials, most items fall into a relatively small number of material types such as glass, metal, paper and plastic. Plastic items are the most abundant type of marine debris on a global scale and plastic is also the most frequently reported material in encounters between debris and marine organisms. Marine debris commonly stems from shoreline and recreational activities, ocean/waterway activities, smoking related activities, and dumping at sea (Ocean Conservancy, 2010). Man-made items of debris are now found in marine habitats throughout the world, from the poles to the equator, from shorelines and estuaries to remote areas of the high seas, and from the sea surface to the ocean floor.

WHY IS THIS ISSUE IMPORTANT?

The incidence of debris in the marine environment is cause for concern. It is known to be harmful to organisms and to human health (Coe & Rogers 1997; Derraik 2002; Gregory 2009), it presents a hazard to shipping, it is aesthetically detrimental (Mouat et al., 2010), and it may also have the potential to transport contaminants over long distances (Holmes et al., 2012; Mato et al., 2001; Teuten et al., 2009). Marine debris, and in particular the accumulation of plastic debris, has been identified as a global problem alongside other key issues of our time including climate change, ocean acidification and loss of biodiversity (Sutherland et al., 2010).

At present, the major perceived threats to marine biodiversity include the effects of climate change, ocean acidification, invasive species, overfishing and other extractive activities, pollution and marine debris, habitat degradation, fragmentation and loss, human population expansion, tourism, and the impact of a wide range of human activities in the coastal zone (Gray, 1997; Harley et al., 2006; Occhipinti-Ambrogi, 2007; Molnar et al., 2008). The presence of marine debris in this list highlights its importance as a factor considered to contribute toward biodiversity loss, underscoring the need for greater understanding of the impacts of such debris and the potential measures to facilitate mitigation and management.

Marine debris can impact biodiversity in a number of ways, namely through entanglement in, or ingestion of, debris items by individuals, through facilitation of the transport of organisms via rafting on marine debris, through the provision of new habitat for colonization, and through effects at an ecosystem level. Impacts vary depending on the type and size of the marine debris items and the organisms that encounter it.

1 UNEP/CBD/SBSTTA/16/6

Incidence of small plastic particles (microplastics, fragments less than 5 mm in diameter) in the environment is of particular concern as a wide range of organisms may ingest them. Microplastics found in the marine environment are likely to be derived either directly or through the fragmentation of larger items. Knowledge about the effects of microplastics is limited, but there are concerns that these particles could have adverse physical and toxicological effects on biota. A horizon scan of global conservation issues recently identified microplastics to be one of the main global emerging environmental issues.

Aside from its impacts on biodiversity, marine debris can also have substantial negative socio-economic impacts. It can cause or contribute to economic losses to industries such as commercial fishing and shipping, as well as recreation and tourism. Marine debris can be transported by wind and ocean currents and hence should be regarded as a transboundary problem.

IMPACTS ON MARINE BIODIVERSITY

This report reviewed and synthesized literature in order to describe the impact of marine debris on biodiversity. The review focused on the following impact categories: entanglement and ingestion (including microplastics), dispersal via rafting (potential to facilitate transport of invasive species), provision of new habitat (potential to provide new habitats), and ecosystem level effects.

Impacts of marine debris were reported for 663 species. Over half of these reports documented entanglement *in* and ingestion *of* marine debris, representing a 40 % increase since the last review in 1997, which reported 247 species (Laist, 1997). Entanglement *in* and ingestion *of* marine debris can be fatal but can also have a range of sublethal consequences, compromising the ability to capture and digest food, sense hunger, escape from predators, and reproduce as well as decreasing body condition and compromising locomotion, including migration. Ingestion, particularly of microplastics, is also of concern as it could provide a pathway for transport of harmful chemicals.

Reports revealed that all known species of sea turtles, about half of all species of marine mammals, and one-fifth of all species of sea birds were affected by entanglement or ingestion of marine debris. The frequency of impacts varied according to the type of debris; over 80 % of the impacts were associated with plastic debris while paper, glass and metal accounted for less than 2 %:

- Plastic—Rope and netting (24 %)
- Plastic—Fragments (20 %)
- Plastic—Packaging (17 %)
- Plastic—Other fishing debris (16 %)
- Plastic—Microplastics (11 %)
- Paper (0.64 %)
- Glass (0.39 %)
- Metal (0.39 %)

The species for which incidence of entanglement *in* or ingestion *of* marine debris was greatest were:

- *Callorhinus ursinus* (Northern fur seal)
- *Zalophus californianus* (California sea lion)
- *Fulmarus glacialis* (Northern fulmar)
- *Chelonia mydas* (Green Turtle),
- *Eubalaena glacialis* (North Atlantic Right Whale)
- *Caretta caretta* (Loggerhead Turtle)

About 15 % of the species affected through entanglement and ingestion are on the IUCN Red List. Of particular concern are the critically endangered Hawaiian monk seal *Monachus schauinslandi*, endangered loggerhead turtle *Caretta caretta*, and vulnerable northern fur seal *Callorhinus ursinus* and white chinned petrel *Procellaria aequinoctialis*. Population level effects are evident in some species such as the northern fulmar *Fulmarus glacialis* (van Franeker et al., 2011), and the commercially important lobster *Nephrops norvegicus* (Murray & Cowie, 2011).

STRATEGIES TO ADDRESS THE CHALLENGE OF MARINE DEBRIS

The potential for plastic debris to travel considerable distances, its persistence and its potential to accumulate in habitats far from its point of origin, present a distinct challenge. Traditional area-based management tools such as marine protected areas are largely ineffective. There are no readily available tools that would be effective to collect and clean-up marine debris from large areas once it is adrift. Prevention at source is therefore the key to reducing marine debris and its associated impacts. The lack of overarching jurisdictional responsibility in any single agreement or commitment dealing with marine debris management for the entire life-cycle chain of the items that become marine debris, from production to disposal to clean-up, is compounded by a lack of appropriate infrastructure, a lack of enforcement of existing regulations, and a lack of clear standards describing more sustainable patterns of production and consumption.

A combination of measures in a regionally coherent context is required, with a focus on reducing the rate at which waste is produced as well as ensuring that appropriate management measures are in place for the safe disposal of material that cannot be reused or recycled. Where feasible and practical, the debris already contaminating ocean waters and sediments should be removed. At present, even the best waste management practices may be insufficient to address the marine debris challenge on a global scale and there is a need for wider scale adoption of “green chemistry”, environmentally friendly design and other complementary up-stream innovations to reduce the potential for items to become marine debris.

This assessment provides examples of proactive policies and programs that have been successfully used in waste management and recycling and which could be applied to reduce land-based sources of marine debris including:

- Packaging and plastics reduction;
- Eco-labeling;
- Green procurement;
- Extended producer responsibility (EPR);
- Deposit return programs;
- Other instruments such as fees charged on single use plastic bags and user fees;
- Viewing wastes as resources;
- Engaging with corporations and industry associations on sustainability;
- Encouraging reuse and reduction through “green chemistry”;
- Encouraging better product and packaging design; and,
- Supporting marine debris awareness.

CONCLUSIONS

Biodiversity loss is known to be strongly driven by habitat change, over exploitation, pollution, invasive species and climate change (Secretariat of the Convention on Biological Diversity, 2010). Given the number of species and the substantial proportion of some populations that are affected by marine debris, coupled with the frequency of entanglement, ingestion and debris related dispersal of organisms, it is likely that marine debris is an important contributor among the anthropogenic stresses acting on habitats and biodiversity. It is increasingly evident that marine debris is having a substantial impact on individuals, populations and ecosystems, and ultimately on the important services we depend on from the world's oceans and coastal regions. For species that are already at risk such as the Hawaiian Monk Seal *Monachus schauinslandi*, Loggerhead turtle *Caretta caretta* and White Chinned Petrel *Procellaria aequinoctialis*, marine debris also has the potential to be an important contributor to species level decline and extinction.

SECTION 1: Impacts of marine debris on biodiversity

1.1 INTRODUCTION

The global impacts of marine debris on biodiversity and the urgency of action to prevent and mitigate these adverse impacts were recognized during the meeting of the Subsidiary Body on Scientific, Technical and Technological Advice to the Convention on Biological Diversity (CBD) in May 2012. This discussion built on the decision concerning Marine and Coastal Biodiversity during the 10th Conference of the Parties to the CBD². It also contributed to the recent Rio +20 Conference, in which concern for the health of the oceans and marine biodiversity was reaffirmed, committing nations to take action by 2025 to achieve significant reductions in marine debris to prevent harm to the coastal and marine environment³.

Man-made items of debris are now found in marine habitats throughout the world, from the poles to the equator, from shorelines and estuaries to remote areas of the high seas beyond national jurisdictions, and from the surface to the ocean floor (Thompson et al., 2009). This debris is harmful to organisms and to human health (Coe & Rogers 1997; Derraik 2002; Gregory 2009), can assist increased transport of organic and inorganic contaminants (Holmes et al., 2012; Mato et al., 2001; Teuten et al., 2009), presents a hazard to shipping, and is aesthetically detrimental (Mouat et al., 2010). Marine debris, and in particular the accumulation of plastic debris, has been identified as a global problem alongside other key issues of our time including climate change, ocean acidification and loss of biodiversity⁴ (Sutherland et al., 2010).

At present, the major perceived threats to marine biodiversity include the effects of climate change, ocean acidification, invasive species⁵, overfishing and other extractive activities, pollution and marine debris, habitat degradation, fragmentation and loss, human population expansion, tourism, and the impact of a wide range of human activities in the coastal zone (Gray, 1997; Harley et al., 2006; Occhipinti-Ambrogi, 2007; Molnar et al., 2008). The presence of marine debris in this list highlights its importance as a factor considered to contribute toward biodiversity loss. It therefore underscores the importance of this report in order to provide greater understanding of the impacts of such debris and to inform potential measures to facilitate mitigation and management.

This report reviews the current state of knowledge about the effect of marine debris on ecosystems and biodiversity, in Section 1. A variety of effects are assessed along with the types and potential origins of debris. Existing international and national efforts to address this challenge are summarised. Section 2 of this report explores potential solutions to tackle this problem, and considers successful examples of waste reduction practices with direct benefits to addressing the challenge of marine debris.

2 Decision X/29 on Marine and Coastal Biodiversity.

3 A/66/L.56, paragraph 163.

4 Biodiversity (biological diversity) 'means the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems' (Article 2, Convention on Biological Diversity, 1992). It encompasses the variability among life forms on Earth, at all levels of organization including genes, species and ecosystems (article 2, Convention on Biological Diversity 1992), and it is widely accepted that biodiversity is under stress at each of these levels (Millennium Ecosystem Assessment, 2005).

5 An alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health, (National Invasive Species Council, Executive Order 13112)

1.2 DEFINING THE PROBLEM

Marine debris is typically described as any persistent, manufactured or processed solid material discarded, disposed of, or abandoned in the marine and coastal environment. It consists of items that have been made or used by people, and deliberately discarded or unintentionally lost into the marine environment. This definition does not include semi-solid remains of, for example, mineral and vegetable oils, paraffin and chemicals (Galgani et al., 2010). Whilst marine debris encompasses a very wide range of products, most items fall into a relatively small number of material types such as glass, metal, paper and plastic (Figure 1).

Some of the most common items are plastic/polystyrene pieces, rope/cord/nets, cotton swabs, and food packets (OSPAR, 2007). Plastic items consistently rank among the most abundant type of marine debris at a global scale (EA 2001; OSPAR 2007; Sutherland et al., 2010; Thompson et al., 2009; UNEP-CAR/RCU, 2008; UNEP, 2005; UNEP, 2009). For example, on European beaches, plastics represent around 75 % of all debris, followed by metal and glass (Figure 1). The relatively high proportion of plastic in comparison to other materials is consistent at other locations (e.g., Table 1, UNEP, 2009, Gregory and Ryan, 1997; Derraik, 2002; Morishige et al., 2007). This trend holds true for seabeds where items of plastic debris recovered by fishermen have been found to be more abundant (> 58 %) than those of metal (21 %) (KIMO 2008).

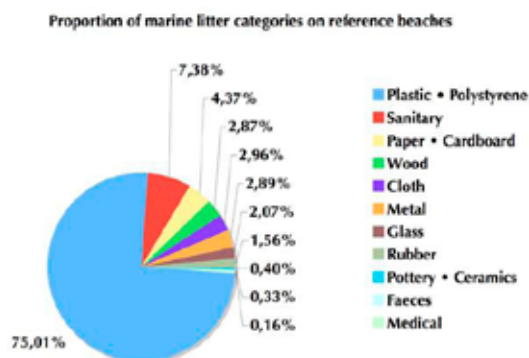


FIGURE 1: Proportion of different categories of marine debris found on reference beaches between 2001 and 2006. Note the prevalence of plastic items as the major components of the debris recorded. These trends are broadly consistent across regions and at a global scale. The analysis was based on data from 609 surveys made in eight countries—Belgium, Denmark, Germany, The Netherlands, Portugal, Spain, Sweden and the United Kingdom (51 regular reference beaches altogether) (OSPAR 2007).

TABLE 1: Ten most common items of marine debris collected in South America during the 2005 International Coastal Clean-Up. Each item is shown as a percentage of related sources of debris with the combined percentages for the top ten items shown by country at the base of the table (Source: UNEP, 2009). Note these data are not intended for comparison among countries as recording approaches vary; they are illustrative of the main categories of debris recorded.

	Panama	Columbia*	Ecuador	Perú	Chile
Percentage of related sources of litter					
Beverage plastic bottles	11.8	Beverage plastic bottles 20.6	Cigarettes/ filters 55.5	Beverage plastic bottles 41.4	Bottle caps and other containers 38.7
Bags	10.6	Beverage glass bottles 16.6	Bottle caps and other containers 8.4	Bags 10.3	Beverage plastic bottles 30.9
Clothes	10.2	Bottle caps and other containers 12.8	Bottle caps and other containers 6.4	Bottle caps and other containers 7.1	Cigarette/filters 8.4
Cups, plates and utensils	8.6	Bags 12.2	Bags 4.8	Cups, plates and utensils 4.1	Food wrappings 4.4
Beverage glass bottles	7.4	Plastic joints 8.4	Food wrappings 3.9	Clothes 3.0	Bags 4.1
Beverage cans	6.5	Clothes 4.7	Rope 2.9	Toys 2.6	Plastic joints 2.8
Bottle caps and other containers	6.4	Cups, plates and utensils 4.2	Cups, plates and utensils 2.9	Cigarettes/ filters 2.5	Beverage glass bottles 1.4
Food wrappings	6.2	Food wrappings 3.7	Beverage glass bottles 2.3	Plastic straws and swizzle sticks for drinks 2.5	Chlorine bottles and other cleaning articles 1.1
Plastic joints	4.1	Beverage cans 3.1	Plastic joints 1.7	Diapers 2.3	Cigarette packs and wrappings 0.9
Oil bottles	2.9	Plastic straws and swizzle sticks for drinks 2.7	Plastic straws and swizzle sticks for drinks 1.6	Beverage cans 2.2	Building materials 0.9
Total	74.7	Total 89.0	Total 89.2	Total 78.0	Total 93.6

* Data reference for San Andrés, Colombia (Caribbean island)
Source: Ocean Conservancy

An area of growing concern is the accumulation of buoyant debris such as plastic items and microplastic fragments in the open oceans. Goldstein et al., (2012) determined that the concentration of microplastics within the North Pacific Central Gyre had increased by two orders of magnitude in the past four decades, similarly, Law et al., (2010) showed that the greatest abundance of debris in subtropical locations was far from land, and in a study of the north western Mediterranean, Collingnon et al., (2012) estimated the mean abundance of microplastics to be the same order of magnitude as that found by Moore et al., (2001) within the North Pacific Gyre (1.334 particles m⁻²).

Oceanic gyres result from the complex network of currents that circulate water around the oceans, coupled with the effects of wind and the rotation of the globe. They form slowly rotating current systems in which marine debris can accumulate. Due to the durability and persistence of some items of marine debris, once it enters a gyre system it can remain for long periods of time, meaning that the concentration of debris within these systems can be considerably greater than in other areas of the ocean. Moore et al., (2001), for example, found densities of plastic of 334,271 pieces km⁻², or 5114 g km⁻², within the North Pacific Subtropical Gyre—the largest recording of debris in the Pacific Ocean.

1.3 METHODOLOGY

Section 1 of this report reviews the current state of knowledge about the effect of marine debris on ecosystems and biodiversity. Evidence of the effects of marine debris on species is examined, the number of reported encounters between individuals and debris and their effects considered and compared with the species' conservation status as defined by IUCN, and effects on ecosystems were assessed. Indirect effects such as the facilitation of transport of invasive species and the potential provision of novel habitats provided by marine debris are also considered.

Impacts are considered under four broad headings:

- | | |
|--|--|
| 1) Ingestion and entanglement | 3) Dispersal via rafting, including transport of |
| 2) Provision of new habitat—potential for debris to provide new habitats | invasive species |
| | 4) Ecosystem level effects |

Data in peer reviewed publications and reports in grey literature. Literature was identified using electronic keyword searches using Web of Science, Google Scholar and Google. Keywords for debris included: marine debris, floating marine debris, marine litter, debris, plastic, metal, glass, and paper, together with key words for effects including: impact, entanglement, ingestion, ecosystem, habitat, biodiversity, rafting, invasive and alien. Limitations in the data collection process are outlined in Annex 2.

The reference list from an extensive review by Laist (1997) was also revisited and all traceable sources used. Where papers referenced other studies that had not already been captured, they were examined and included where relevant. A species list was then compiled, and additional species-specific searches conducted for each of the aforementioned effect terms to ensure that coverage was as extensive as possible. Contact by e-mail was made with key researchers and the coordinators of UNEPs Regional Seas Programmes to identify additional data, and in particular, grey literature.

Each report and publication was examined and information extracted in relation to documented encounters between marine debris and an organism. This information is outlined in Annex 1. Data on species affected by marine debris was then cross referenced with the IUCN Red List in order to establish the extent to which endangered or vulnerable species were implicated.

For reports of species rafting on marine debris, and the use of marine debris as habitat, data were extracted as described above. Numbers of individuals, however, was not commonly reported, and consequently was not included in the analysis. Type of harm was also not relevant here.

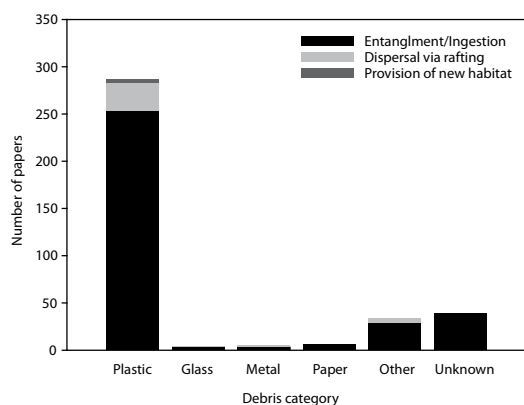


FIGURE 2: Number of papers or reports documenting encounters between marine organisms for entanglement/ingestion, dispersal via rafting (potential to facilitate the transport of invasive species), and provision of new habitat (potential to provide new habitats) expressed as numbers of reports according to material type. Figure excludes papers reporting damage to ecosystems as it was not possible to extract quantitative information from these studies.

1.4 RESULTS

In all, 319 original publications addressing the impacts of marine debris on biodiversity were examined. When considering the types of material reported in relation to the categories of encounter being examined, plastic items were the most frequently documented, representing 76.5 % of all publications (Figure 2).

The literature search identified additional taxonomic groupings not originally included in the search criteria (see Annex 1). For 'physical harm to individuals as a consequence of ingestion and entanglement', the final groupings used were therefore: Marine Mammals, Birds, Fish, Sea Turtles, Sea Snakes, Crustaceans, Cephalopods, Bivalves, Gastropods, Echinoderms, Cnidaria; and, for 'the potential for floating debris to facilitate the transport of invasive species', they were: Sponges, Cnidaria, Worms, Sea Spiders, Crustaceans, Bryozoans, Echinoderms, Ascidians, Seagrass and Algae, Plankton, Non-marine, and Other.

Considering reports of encounters between marine debris and organisms across all four categories, 663 species were identified, of which the taxonomic groupings with the greatest number of species impacted were birds ($n = 161$) and fish ($n = 114$).

1.4.1 Global distribution

Regions with the largest number of reported effects included: the east and west coasts of North America ($n = 117$), Europe ($n = 52$), and Australasia ($n = 56$). Few reports exist from Asia ($n = 6$), Africa ($n = 12$), the Arctic ($n = 5$) and Antarctic ($n = 7$). Data for this distribution is outlined in greater detail in Figure 11 below. This pattern is most likely to represent differences in the frequency of reporting with some regions producing far fewer reports per unit area of coastline than others, rather than being a true representation of the quantities of debris present.

1.4.2 Ingestion and entanglement

The first documented encounters between organisms and debris were in the early 1960s with a clear trend of increasing frequency of reports for both the numbers of individuals and the numbers of species affected thereafter. This increasing pattern was, however, not reflected in the average number of documents reporting ingestion and entanglement which has remained relatively constant since 1980. There were documented encounters between organisms and debris for 47,963 individuals and 373 species. As noted above, the majority of reports considered (76 %) described encounters with plastic debris as opposed to other types of material (Figure 2). Across all debris types there was a 40 % increase over the 267 species reported by Laist (1997).

Species with the greatest number of individuals impacted by entanglement or ingestion were *Callorhinus ursinus* (Northern fur seal, $n = 3835$), *Zalophus californianus* (California sea lion, $n = 3650$), and *Fulmarus glacialis* (Northern fulmar, $n = 3310$), with the most frequently reported species all being either birds or marine mammals (Table 2). Species for which the greatest number of papers exist reporting incidence of entanglement or ingestion were *Chelonia mydas* (Green Turtle, $n = 39$), *Eubalaena glacialis* (North Atlantic Right Whale, $n = 38$) and *Caretta caretta* (Loggerhead Turtle, $n = 23$). The most frequently reported species include four of the seven species of turtle, two marine mammals, and four species of seabird (Table 2).

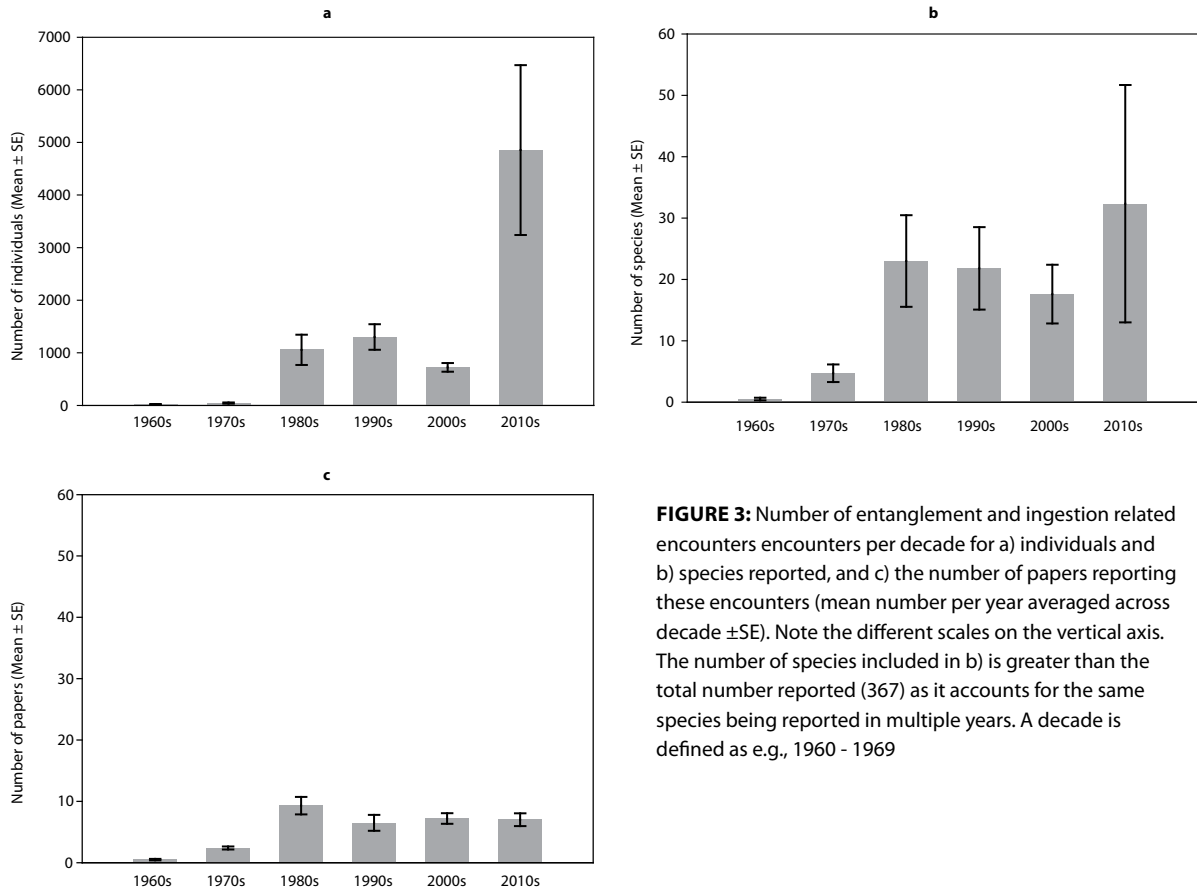


FIGURE 3: Number of entanglement and ingestion related encounters encounters per decade for a) individuals and b) species reported, and c) the number of papers reporting these encounters (mean number per year averaged across decade ±SE). Note the different scales on the vertical axis. The number of species included in b) is greater than the total number reported (367) as it accounts for the same species being reported in multiple years. A decade is defined as e.g., 1960 - 1969

TABLE 2: a) Species with the greatest number of individuals reported entangled and ingesting debris and b) species for which the greatest number of documents / papers report entanglement or ingestion

a) Number of individuals

Species name	Common name	Number recorded
<i>Callorhinus ursinus</i>	Northern fur seal	3835
<i>Zalophus californianus</i>	Californian sea lion	3650
<i>Fulmarus glacialis</i>	Northern fulmar	3310
<i>Fratercula arctica</i>	Horned puffin	1678
<i>Phoca vitulina</i>	Harbour seal	1339
<i>Puffinus gravis</i>	Greater shearwater	1331
<i>Arctocephalus gazella</i>	Antarctic fur seal	1148
<i>Puffinus griseus</i>	Sooty shearwater	1122
<i>Uria aalge</i>	Common guillemot	983
<i>Diomedea immutabilis</i>	Laysan Albatross	972

b) Number of papers

Species name	Common name	Number recorded
<i>Chelonia mydas</i>	Green sea turtle	39
<i>Eubalaena glacialis</i>	North Atlantic Right Whale	38
<i>Caretta caretta</i>	Loggerhead Turtle	26
<i>Eretmochelys imbricata</i>	Hawksbill Turtle	23
<i>Fulmarus glacialis</i>	Northern Fulmar	22
<i>Puffinus griseus</i>	Sooty Shearwater	19
<i>Dermochelys coriacea</i>	Leatherback Turtle	18
<i>Puffinus gravis</i>	Greater Shearwater	18
<i>Diomedea immutabilis</i>	Laysan Albatross	15
<i>Callorhinus ursinus</i>	Northern Fur Seal	11
<i>Lepidochelys olivacea</i>	Olive Ridley Sea Turtle	11

There was a clear increase in the number of species affected since the last similar review by Laist in 1997. All known species of sea turtles, 45 % of all species of marine mammals, and 21 % of all species of sea birds are affected by ingestion or entanglement. The number of species of fish affected has roughly doubled since Laist (1997) (Table 3).

TABLE 3: Number of species with records of entanglement and ingestion documented in Laist (1997), the number reported here and the total number of species identified worldwide. The percentage of the total number of known species that are affected by entanglement and ingestion is given in brackets. Sources for total number of identified species: Laist (1997); First Census of Marine Life (2010).

Species group	Total number of known species	Number of species with entanglement records		Number of species with ingestion records	
		Laist (1997)	This report	Laist (1997)	This report
Marine Mammals	115	32 (28 %)	52 (45 %)	26 (23 %)	30 (26 %)
Fish	16,754	34 (0.20 %)	66 (0.39 %)	33 (0.20 %)	41 (0.24 %)
Seabirds	312	51 (16 %)	67 (21 %)	111 (36 %)	119 (38 %)
Sea Turtles	7	6 (86 %)	7 (100 %)	6 (86 %)	6 (86 %)

There were two instances where numerous small invertebrates were reportedly associated with derelict gill nets (Gilardi et al., 2010; Good et al., 2010). These papers were more closely examined to determine whether some species (e.g. the butter clam, *Saxidomus giganteus*) were entangled or whether they were using the nets as a substratum. All species reported by Gilardi et al., (2010) and the majority reported by Good et al., (2010) were included here when the authors referred to them as ‘entangled’. This paper, however, specified some species they had included which may not have been entangled, and were rather ‘animals living/dying on nets that may become entangled only during removal process’ or ‘animals that may live or move across nets but also are entangled and killed by net’. These species (n = 8) were therefore not included, and were instead reported in the category: ‘The potential to provide new habitats’.

Since the majority of reported encounters were with plastic debris, this category was further evaluated in terms of debris type or use; rope and netting accounted for 57 % of encounters with individuals, followed by fragments (11 %), packaging (10 %), other fishing related debris (8 %), microplastics (6 %), paper (0.03 %), glass (0.01 %), and metal (0.01 %). Patterns for encounters by species were also most strongly associated with rope and netting (24 %) followed by fragments (20 %), packaging (17 %), other fishing debris (16 %), microplastics (11 %), paper (0.64 %), glass (0.39 %) and metal (0.39 %) (Figure 4).

Considering the data according to type of effect, the frequency of reports of entanglement (n = 170) was 34 % greater than that of ingestion (n = 127). Direct harm or death was also considerably more frequently documented in reports of entanglement (80 %) than of not for ingestion (5 %) (Figure 5). The data, however, should be interpreted with caution as they are likely to be biased by differences in the frequency of reporting. For example, cuts, lacerations and deformity resulting from entanglement can readily be observed and reported following external examination of individuals whereas effects associated with ingestion can only be determined by necropsy. In addition, in some cases it may be more difficult to confirm harmful effects of ingestion as consequences such as reduced feeding capacity will have various indirect effects on individuals.

Reports which described some form of deleterious effect or harm on species were cross referenced with data on the conservation status of these species using the IUCN Red List. This indicated that around 15 % of the species affected by marine debris were vulnerable, endangered or critically endangered. Of particular concern are reports indicating a total of 215 *Monachus schauinslandi* (Hawaiian Monk Seal) being affected, a species which is critically endangered; 753 *Caretta caretta* (Loggerhead Turtle) an endangered species; and 3835 *Callorhinus ursinus* (Northern Fur Seal), and 678 *Procellaria aequinoctialis* (White chinned petrel) which are both considered vulnerable.

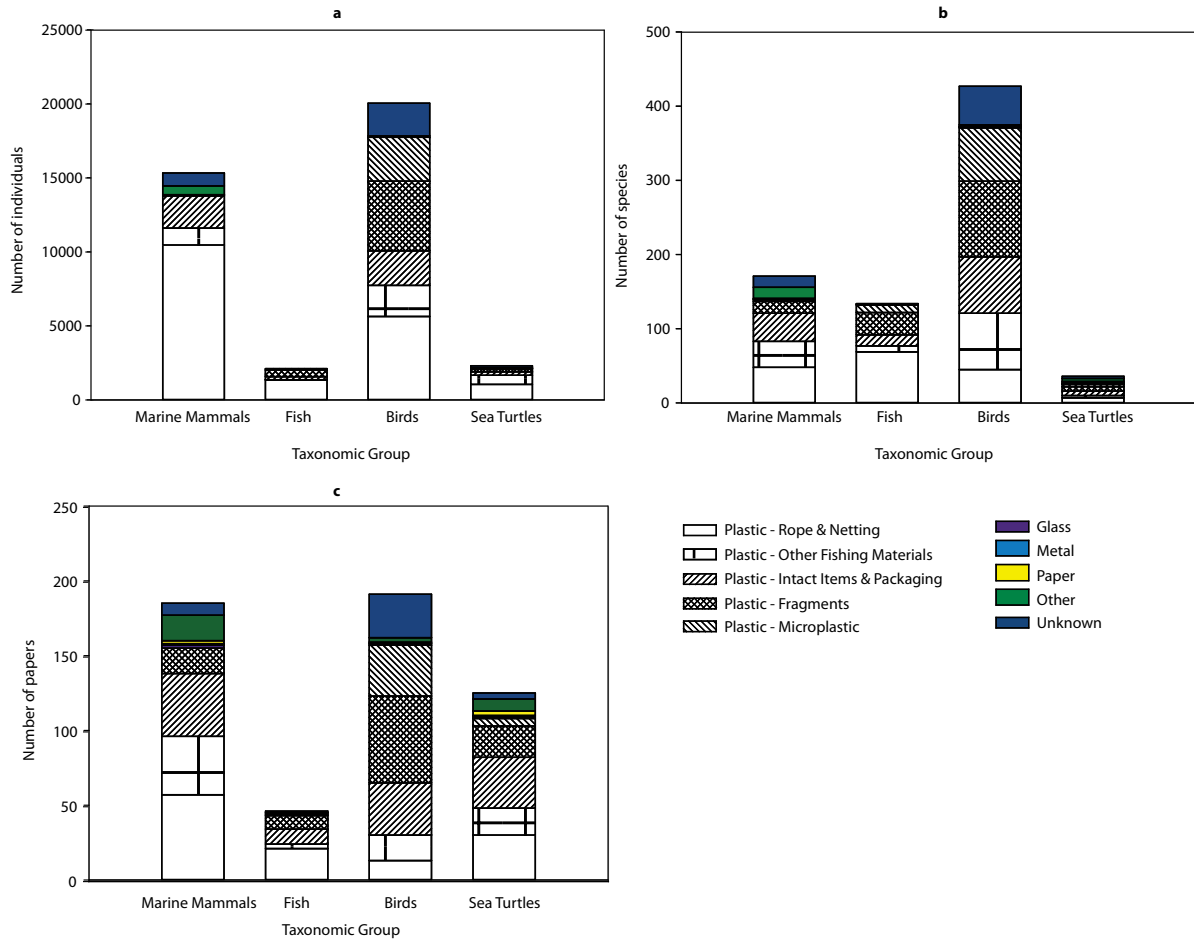


FIGURE 4: Reports of entanglement/ingestion caused by marine debris according to number of a) individuals, b) species, and c) documents / papers per taxonomic grouping—Marine Mammals, Birds, Fish, Sea Turtles. Bars are divided by impact according to debris type - Plastic material (Rope and netting, Other fishing materials (mainly lines, pots), Plastic—Intact items and packaging, Plastic—Fragments > 5 mm, Plastic—Microplastic < 4.99 mm), Glass, Metal, Paper, Other and Unknown. The number of species is greater than that reported in Figure 3 as it accounts for species encountering more than one debris type, and total number of papers is greater than 280 as it accounts for papers reporting impacts on more than one species.

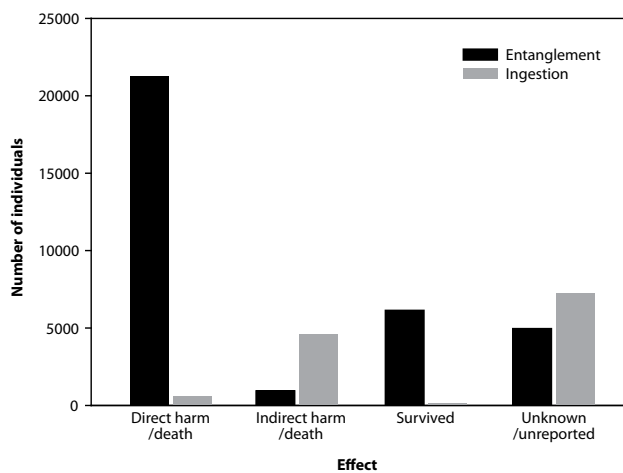


FIGURE 5: Incidence of ingestion of or entanglement in marine debris, indicating the consequence of the encounter where described.

It is evident that a wide range of species are affected by ingestion of and entanglement in marine debris (Figure 6), and that for some species this accounts for a substantial proportion of the population. For example, data collected by van Franeker in the Netherlands over the last 30 years indicated that around 95 % of Northern fulmars *Fulmarus glacialis* washed ashore dead in the North Sea contain plastic debris, and of these, many birds contain substantial quantities of debris (Figure 7), (van Franeker et al., 2011). Such is the extent of contamination that it has been proposed that these birds be used as a monitoring tool to assess changes in surface debris on a regional basis within the north-east Atlantic. Further south in Europe, where fulmars are not found, it is currently under consideration to use other species (possibly turtles) to provide an index of marine debris. Other populations that appear heavily affected by ingestion include the edible crustacean *Nephrops norvegicus* where 83% of the population in the Clyde Sea, UK contained microplastic debris (Murray & Cowie, 2011), while a study on the Brazilian coast found that 34 of 34 green turtles and 14 of 35 seabirds had ingested debris—with plastic being the main material (Tourinho et al., 2010).



FIGURE 6: A) Turtle entangled in plastic rope in Caribbean (photo: UNEP-CAR/RCU, 2008); B) Entangled seal (Courtesy of Salko de Wolff, ECOMARE at Texel); C) plastic packaging from the carcass of a Laysan albatross at Kure Atoll, (Courtesy of Cynthia Vanderlip and Algalita Marine Research Institute); D) Plastic bags and film from stomach of young Minke whale that had been washed ashore dead in France (Courtesy of G. Mauger and F. Kerleau, Group d'Etudes de Cétacés du Cotentin (GECC)).

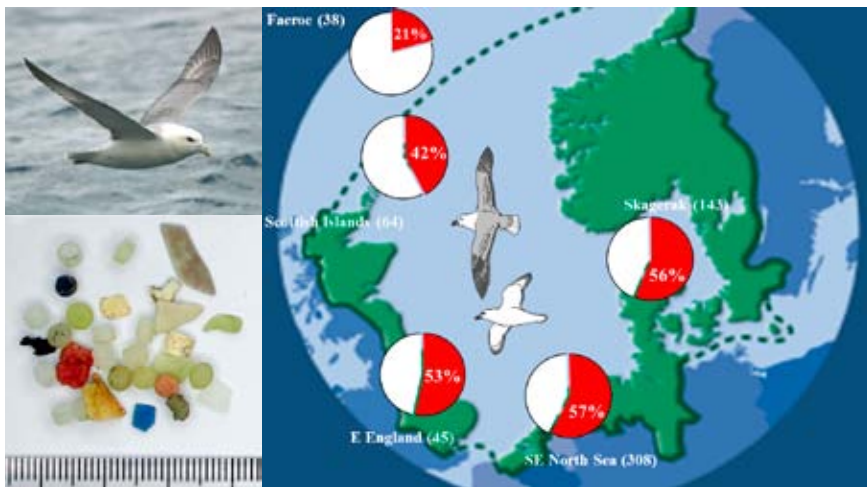


FIGURE 7: (A) Fulmars are known to ingest plastic debris. (B) Example of plastic debris from the stomach of a dead fulmar, 95% of which have some plastic in their stomachs. (C) A target Environmental Quality Objective (EcoQO) that <2% of dead birds should have < 0.1g of plastics in their stomachs has been proposed (top right). However, this target is far from being realised. Map shows regional trends, 2002 -2004, for the percentage of birds that had more than 0.1 g of plastic in their stomachs. Courtesy of J. A. van Franeker, IMARES, Texel, the Netherlands.

It is clear from these reports that numerous individuals and species have died or become harmed as a consequence of entanglement and ingestion encounters with marine debris. It is, however, likely that a much larger number of individuals are compromised by sub-lethal effects that have not been fully reported. For example, debris on beaches has been shown to affect behaviour of intertidal organisms such as the gastropod *Nassarius pullus* (Aloy et al., 2011) and adversely affect the ability of turtle hatchlings to reach the sea (Ozdilek et al., 2006).

It seems inevitable that entanglement and ingestion of marine debris will alter the biological and ecological performance of individuals. A number of possibilities have been suggested, including compromising an individual's ability to capture food, digest food, sense hunger, escape from predators, and reproduce—as well as decreasing body condition and compromising locomotion, including migration (e.g. Ryan, 1988; Spear et al., 1995; Laist, 1987; Laist, 1997; Derraik, 2002; Gregory, 2009; Aloy et al., 2011). It has also been widely suggested that ingestion of debris, and in particular microplastic debris, might provide a pathway facilitating the transport of harmful chemicals to organisms (Oehlmann et al., 2009; Teuten et al., 2009). (see also Section 1.4.3 below).

The consequences of ingestion are not fully understood. There are concerns that microplastics may cause physical disruption for example, by interfering with feeding and digestion. Little is known about such physical effects, although there is evidence that particles can be retained for several weeks after ingestion (Browne et al., 2008).

1.4.3 Microplastics

Marine debris, and in particular plastic debris, is fragmenting in the environment. Much of the debris collected during survey trawls (Law et al., 2010; Thompson et al., 2004) and on shorelines (Browne et al., 2010) consists of tiny particles of microplastic (Figure 8). This material has been defined as pieces or fragments less than 5 mm in diameter (Arthur et al., 2009; Barnes et al., 2009). The abundance of microplastics is increasing in the oceans (Thompson et al., 2009; Goldstein et al., 2012), and data presented here indicate that around 10 % of all reported encounters are with microplastics.



FIGURE 8: A) Marine debris on a strandline where it fragments into smaller pieces. B) A fragment of microplastics next to a grain of sand found on a beach in Cornwall, UK. C) Scanning electron microscope image of microplastic fragments. Source: R.C. Thompson.

Microplastics accumulate in the water column, on the shoreline and in subtidal sediments (Barnes et al., 2009; Thompson et al., 2004; Zarfl et al., 2011). Due to their small size, they have a relatively large surface area to volume ratio and therefore have greater capacity to facilitate the transport of contaminants, and also have the potential to be ingested by a diverse range of marine organisms (STAP, 2011). Fragments as small as 2 µm have been identified from marine habitats (Ng and Obbard 2006), but due to limitations in analytical methods, the abundance of smaller fragments is unknown. As a consequence of the fragmentation of larger items and the direct release of small particles, the quantity of fragments is expected to increase in the seas and oceans (Andrady 2011; Thompson et al., 2009). It is therefore recognized that there are important questions that should be investigated regarding the emissions, transport and fate, physical effects, and chemical effects of microplastics (Zarfl et al., 2011).

1.4.4 Impacts of persistent, bio-accumulative and toxic substances (PBTs) associated with marine debris

Plastics contain a variety of potentially toxic chemicals incorporated during manufacture (monomers and oligomers, bisphenol-A (BPA), phthalate plasticisers, flame retardants and antimicrobials) (Lithner et al., 2011), which could be released into the environment. These chemicals can be transferred to humans through, for example, plastic containers used for food and drink, plastic used in medical applications, and plastic toys (Koch & Calafat 2009; Lang et al., 2008; Meeker et al., 2009; Talsness et al., 2009). Hence, a hazard could exist if plastic fragments containing these chemicals are ingested by marine organisms. Research has identified that chemicals used in plastics such as phthalates and flame retardants can have toxicological effects on fish, mammals and molluscs (Oehlmann et al., 2009; Teuten et al., 2009).

There is no evidence to confirm a direct link between the chemical characteristics of marine debris and adverse effects on marine life, but experimental studies have shown that phthalates and BPA affect reproduction in all study species, impairing development in crustaceans and amphibians, and generally inducing genetic aberrations (Oehlmann et al., 2009). If these impacts were identified in the field it would pose a substantial problem, as no option exists for remediation due to the nature of the accumulation of debris within the marine environment (GESAMP 2010; Thompson et al., 2009). It is therefore concerning that concentrations of these substances in the marine environment have been found to match those identified as harmful in laboratory studies, inferring that they could be impacting natural populations (Oehlmann et al., 2009).

In addition to the potential for release of additive chemicals, plastic debris can adsorb⁶ persistent, bio-accumulative and toxic substances, including persistent organic pollutants (POPs) that are present in the oceans from other sources. Within a few weeks these substances can become orders of magnitude more concentrated on the surface of plastic debris than in the surrounding water column (Mato et al., 2001; Teuten et al., 2009; Hirai et al., 2011; Rios et al., 2010). This presents a second mechanism that may facilitate the transport of chemicals to biota upon ingestion. Our understanding of the extent to which plastic particles facilitate the transport of contaminants is, however, uncertain, and more work is required to establish the relative importance compared to other pathways.

1.4.5 Potential for debris to provide new habitat

By definition, marine debris represents the introduction of additional hard surfaces into the sea; and such materials will readily become colonised firstly by microorganisms, followed by macrobiota (Whal, 1989; Ye & Andrady, 1991; Harrison et al., 2011). If buoyant, this debris may facilitate the transport of organisms by rafting; however, even if relatively static on the seabed, or buoyant but (for example) retained in oceanic gyres, debris will still become colonised. Hence marine debris provides additional habitat, and has the potential to influence, the relative abundance of organisms within local assemblages. This will be particularly pronounced where debris provides isolated hard habitat, either within the water column or in areas of otherwise extensive sediment plains. In such locations, the species using debris as habitat may differ from those otherwise present, thus increasing overall diversity (Pace et al., 2007), but also having potential effects on the balance of species within the native assemblage.

⁶ (of a solid) hold (molecules of a gas, liquid, or solute) as a thin film on surfaces outside or within the material (Concise Oxford English Dictionary, 2008)

A total of 85 taxa were identified in this report, taken from 6 papers which described the use of marine debris as habitat (Table 4). Four of the papers (Carr et al., 1985; Donohue et al., 2001; Ayaz et al., 2006; Good et al., 2010) reported species colonizing derelict fishing nets as habitat. These included both mobile and sessile species. Pace et al., (2007), reported the use of marine debris as habitat in the Maltese Islands, including plastics, glass, pottery, metals and sacks and identified 47 associated species (listed under unknown in Table 4 as no species list was included).

TABLE 4: Number of taxa and number of papers by taxonomic group that report the use of marine debris as a habitat. Unknown represents those species identified by Pace et al., 2007 as no species list was presented.

Taxonomic group	Number of taxa	Number of papers
Bivalves	1	1
Bryozoans	1	1
Cephalopods	1	1
Cnidaria	3	2
Crustaceans	14	3
Echinoderms	6	3
Fish	10	1
Gastropods	1	1
Pelagic Insects	1	1
Polycheates	2	1
Porifera	1	1
Seagrass & Algae	2	1
Unknown	47	1

In deep water sedimentary habitats, Pace et al., (2007) found a greater abundance of taxa on debris than the surrounding sediment, but greater species richness on the sediment. The assemblage structure differed, however, with the debris increasing overall diversity of species present within the area sampled. There are also references to floating debris such as microplastic providing a habitat for microorganisms. It has been suggested that some microorganisms might use plastic as a food source leading to biodegradation of debris (PlasticsEurope.org, 2010). While there are reports of biodegradation of compostable plastics (Song et al., 2009; O’Brine & Thompson, 2010), there are no peer reviewed articles documenting biodegradation for conventional plastics. Some species of *Vibrio* bacteria have been shown to grow preferentially on plastic debris in the ocean, but it is unknown whether those found are pathogenic. Harrison et al., (2011) suggest that microbes may raft on marine debris, causing concern as they are the causative agents of disease for corals.

An area of growing interest is the potential for accumulated buoyant debris, such as plastic items and microplastic fragments, to provide new habitats in the open ocean. Goldstein et al., (2012) determined that the concentration of microplastics within the North Pacific Central Gyre had increased by two orders of magnitude in the past four decades. Similarly, Law et al., (2010) showed that the greatest abundance of debris in subtropical locations was far from land, and in a study of the north western Mediterranean, Collingnon et al., (2012) estimated the mean abundance of microplastics to be the same order of magnitude as that found by Moore et al., (2001) within the North Pacific Gyre (1.334 particles m⁻²). The surfaces of debris items within these systems are available for colonization, thus increasing the potential for transport of organisms on marine debris. At the same time, this debris can provide a novel habitat for mobile organisms.

1.4.6 Dispersal via rafting, including transport of invasive species

In terms of organisms rafting on debris, there were 32 reports representing 270 species; of these only 3 reports specifically distinguished the presence of invasive species, listing 5 such species in total. It is, however, likely that this is an underrepresentation due to the limited number of reports, and because not all papers identified organisms to species level.

Data on numbers of individuals were seldom reported and have not been included here. The number of species reported rafting on debris has increased markedly since the 1970s. As with the data on the effects on individuals and species, the increase in the numbers of species being reported rafting on debris far exceeds the change in the number of papers and documents themselves, and so there is a strong indication that this represents a true increase in the frequency of rafting rather than merely an increase in reporting (Figure 9).

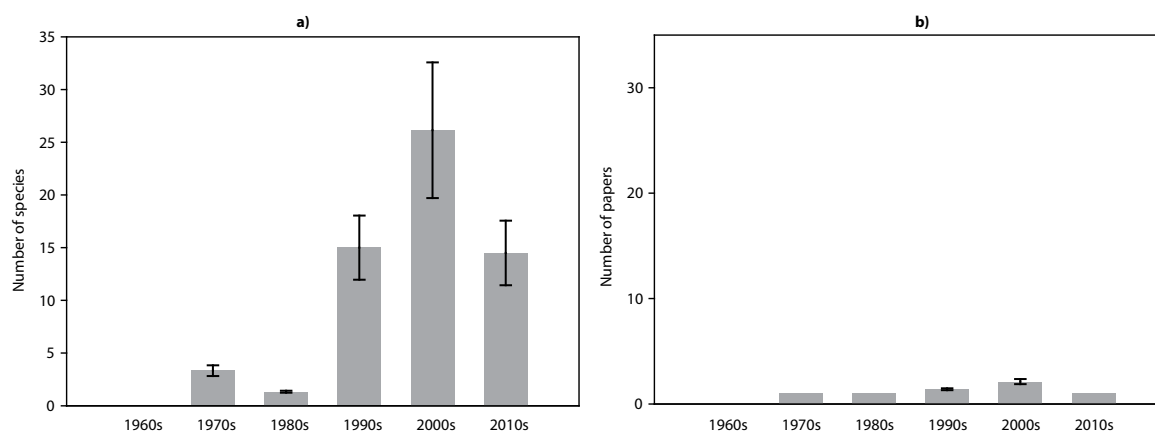


FIGURE 9: Cumulative number of reports of a) species rafting on marine debris and b) the number of papers reporting these encounters (mean number per year averaged across decade \pm SE). The total number of species in a) is greater than the total number reported (180) as it accounts for the same species being reported in multiple years. A decade is defined as e.g. 1960–1969

Intact items and packaging accounted for 40 % of all reported encounters with species, followed by fragments (36 %), rope and netting (17 %), other fishing materials (1.50 %) and microplastics (1.50 %) (Figure 10). The number of species per taxonomic group (Figure 10a) is mirrored by the number of reports (Figure 10b), which seems to indicate that reporting has still to capture all of the species that are actually rafting on debris.

1.4.7 Ecosystem level effects

Eight references which report the effects of marine debris on habitats or ecosystems were identified. Of these, five documented impacts on coral reef ecosystems (Al-Jufaili et al., 1999; Donohue et al., 2001; Chiappone et al., 2002; Chiappone et al., 2005; Richards, 2011), one on soft sediment habitats (Uneputty and Evans, 1997), and two on the impact of microplastics and fragments on sandy sediments in the intertidal zone (Aloy et al., 2011; Carson et al., 2011). Effects on ecosystems vary in severity with debris type with, for example, derelict fishing nets known to be particularly destructive. A study in the north-western Hawaiian Islands reported that 20 % of the weight of derelict fishing gear could be attributed to broken coral that had become entangled (Boland, *unpubl.*, cited in Donohue et al., 2001).

Richards (2011) identified a significant negative relationship between the level of marine debris cover and coral cover, with coral cover and species diversity decreasing with increasing debris abundance on Majuro Atoll. A study in Oman identified similar effects, with 69 % of sites showing impacts from lost and discarded fishing gear, and 87 % showing impacts from debris. Abandoned gill nets caused the most severe damage, affecting over 20 coral genera at almost half the study sites, and accounting for 70 % of all the severe human impacts measured (Al-Jufaili et al., 1999).

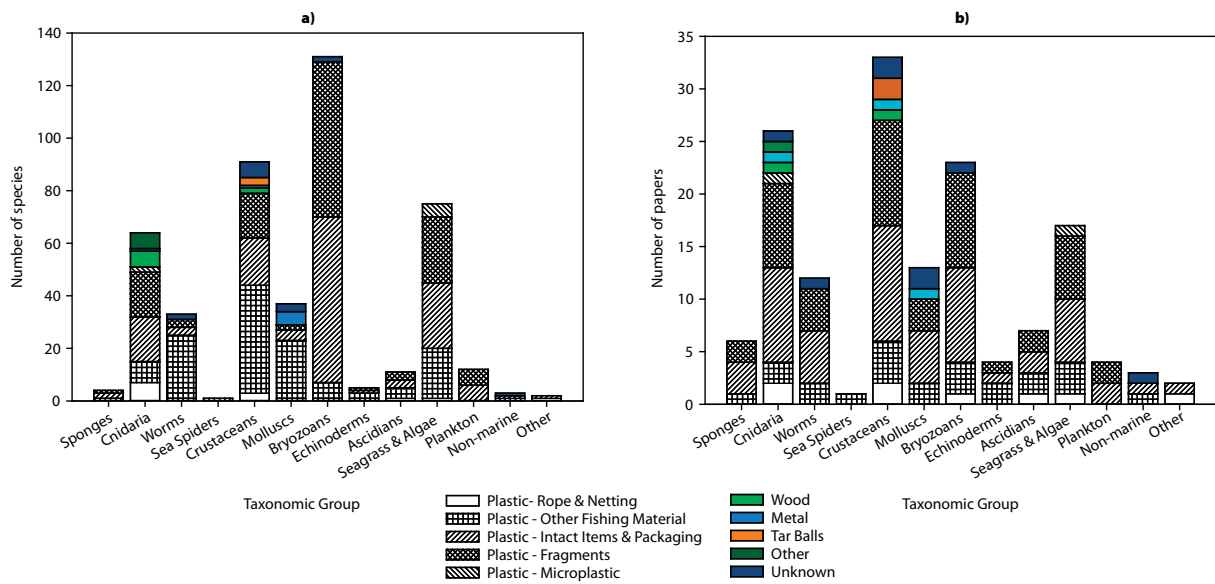


FIGURE 10: Incidence of rafting on marine debris reported by number of a) taxa and b) papers per taxonomic grouping—Mammals, Birds, Fish, Sea Turtles, Crustaceans, Cephalopods, Bivalves, Gastropods and Echinoderms. Bars are divided by impact per debris type (Rope and netting, Other fishing materials (mainly lines, pots), Plastic—Intact items and packaging, Plastic—Fragments > 5 mm, Plastic—Microplastic < 4.99 mm, Wood, Metal, Tar Balls and Type not reported). Number of individuals was not commonly reported in the literature and so has not been included. Total number of taxa is greater than 370 as it accounts for taxa being impacted by more than one debris type, and total number of papers is greater than 19 as it accounts for reports of more than one taxon per paper.

Damage is evident from fishing activities in other regions; for example on the Florida Keys 49 % of marine debris (predominantly hook and line (monofilament) gear and debris from lobster traps) was found to cause tissue abrasion, damage, and/or mortality of sessile invertebrates (Chiappone et al., 2002), and approximately one sessile organism per 100 m² was impacted by lost hook and line gear (Chiappone et al., 2005).

Unepputy & Evans (1997) studied the effects of marine debris on the ecosystem within Ambon Bay, Indonesia, finding significant differences in the abundance of meiofauna (small benthic invertebrates) and diatoms in sediment samples taken from beneath marine debris compared to areas free from debris. Samples from under debris contained higher densities of meiofauna, but lower densities of diatoms than those from areas free from debris. The consequences of this were not quantified, but it was suggested that they might be significant in altering the ecosystem of the Bay, especially if debris aggregating sub-littorally had a similar impact.

Ecosystem impacts can also occur in the intertidal. For example, microplastics and debris fragments on beaches have been reported to alter the porosity of the sediment and its heat transfer capacity (Carson et al., 2011). Carson et al., (2011) also suggest that increased debris loads could lead to reduced subsurface temperatures, potentially affecting organisms such as sea turtles whose sex-determination relies on temperature. Debris can also affect the foraging habits of intertidal organisms such as the gastropod *Nassarius pullus*, whose foraging efficiency was found to be negatively correlated with the quantity of plastic debris (Aloy et al., 2011).

1.5 DISCUSSION

1.5.1 Socio-economic impacts of marine debris

The socio-economic impacts of marine debris are extensive and overwhelmingly negative, causing (or contributing to) economic losses to industries such as commercial fishing and shipping, as well as recreation and tourism. Furthermore this is a trans-boundary problem, resulting in costs to countries that may be far from the point of origin of the debris.

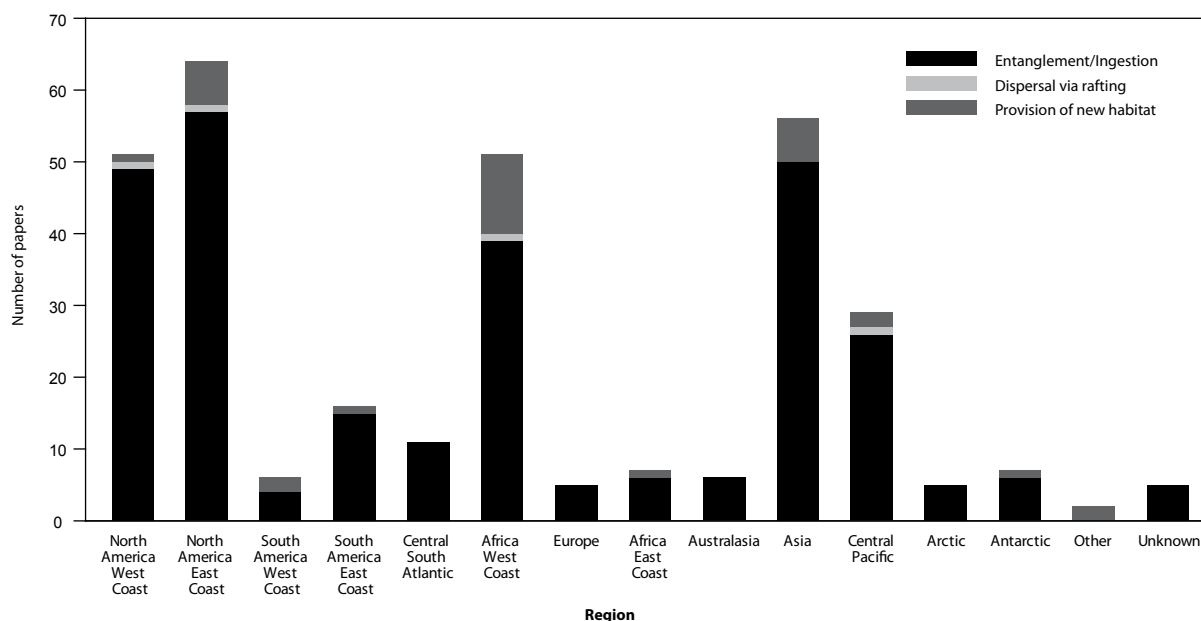


FIGURE 11: Encounters between marine debris and organisms in terms of numbers of papers according to region—North America West Coast, North America East Coast, South America West Coast, South America East Coast, Central South Atlantic, Europe, Africa West Coast, Africa East Coast, Asia, Australasia, Central Pacific, Arctic, Antarctic, Other (where studies included multiple regions and no break-down was provided), and Unknown (where studies did not report location).

The loss of economic revenue can be substantial. For example, It has been reported to cost the Scottish fishing industry between US \$15 million and US \$17 million per year (KIMO, 2008) through the loss of fishing time and potentially costly repairs due to the need to remove debris from fishing gear, propellers and water intake pipes (ten Brink et al., 2009). In the Shetland Isles, UK, 92 % of fishermen reported that they experienced recurring problems associated with accumulated debris in their nets, 69 % had experienced contamination of their catch by debris, and 92 % had experienced problems due to snagging their gear on debris on the seabed (Hall, 2000). The estimated cost for each boat per year due to these impacts was estimated to range from US \$9,500 - \$47,000. Similar impacts are reported by fishermen in Indonesia, with fouling of propellers and alterations in fishing location and gear type used, all being given as effects of marine debris on the artisanal fishing industry surveyed by Nash (1992).

One of the most substantial costs of marine debris to the fishing industry is the loss of revenue due to ghost fishing⁷ which removes commercial species from the fishery. A study in Oman estimated that the cost of ghost trapped fish was approximately US \$145 per trap after 3 months, and US \$168 per trap after 6 months (Al-Masroori et al., 2004). Gilardi et al., (2010) assessed the ability of derelict gill nets to ghost fish in Puget Sound, USA, and performed a cost-benefit analysis which concluded that entanglement of Dungeness crab by a single study net could cost the commercial fishery US \$19,656, compared to US \$1358, the cost of removing the net and so preventing it from ghost fishing.

Harbour authorities also encounter costs in removal of marine debris, which is vital to ensure that their facilities remain clean, safe and attractive for users. For example it has been reported that the cost to UK port authorities for debris removal amounts to approximately US \$3 million per year (Mouat et al., 2010).

In some locations, the impact of marine debris on the tourism industry is largely aesthetic, relating to the attractiveness of the coastline and beaches with clean ups needed in order to continue to attract tourists to the area. In other locations, however, such as tropical Small Islands Developing States, it is also detrimental to

⁷ Capture of commercially targeted fish or crustacean species in the water by lost, abandoned or discarded fishing gear

eco-tourism and sporting activities that rely on the presence of healthy ecosystems. In addition, the presence of marine debris can have negative implications for human health.

Activities associated with beach clean ups and the removal of debris from coastal zones can be very costly. For example, beach clean ups on one beach in Orange County, USA cost US \$350,000 per year, and the cost of removing plastic bags alone from UK beaches is approximately US \$454,000 a year (Marine Conservation Society, 2005). The effect of such impacts on countries dependent upon the resources provided by reefs are poorly documented, but are likely to be substantial where there is considerable reliance on these resources for tourist income. Activities such as sport fishing, submarine tours, turtle and whale watching trips, snorkelling, scuba diving and spear fishing depend upon the presence of healthy reefs, and these are also crucial for the provision of seafood and numerous other resources. The reliance of such economies on healthy reefs therefore suggests that they may face an additional level of vulnerability to marine debris impacts.

Social costs are also substantial. Marine debris indirectly increases risk and loss of life within the fishing and commercial shipping industries, as evidenced by reports such as those from the Royal National Lifeboat Institution (RNLI) in the UK: that 1 % of all deaths occurring on fishing vessels and approximately 300 calls made to the RNLI from 1992-2001 were caused by the fouling of propellers by marine debris (RNLI, 2005). Data from Korea further supports this, showing that from 1996-1998, 9 % of all maritime accidents occurred due to marine debris (Dong Oh Cho, 2005).

Marine debris could also potentially pose a threat to scuba divers via entanglement in ghost nets, rope, etc. Records from the British Sub-Aqua Club, however, indicate that this is negligible at present. Between 1997 and 2012, a total of 4401 incidents and 179 deaths occurred in British seas; however, none were directly attributed to marine debris.

1.5.2 Sources of marine debris

There are two major sources of marine debris: land based sources and ship based sources. Ship based sources formed the major focus of early concerns about marine debris and include waste dumped at sea from commercial vessels such as cruise ships, as well as disposal from fishing vessels (Ryan et al., 2009). Land based sources are more varied, and have several pathways by which this debris can enter the sea. The main pathways are rivers and storm drains, and a smaller amount is transported by wind (Ryan et al., 2009). The most common sources have been identified as shoreline and recreational activities, ocean/waterway activities, smoking related activities, dumping activities and medical/personal hygiene (Ocean Conservancy, 2010).

A further source of debris comes from natural disasters, such as hurricanes and tsunamis (Thompson et al., 2005). Following the tsunami in Japan in 2010 the Japanese government estimated 5 million tonnes of debris had entered the marine environment.

1.5.3 Plastics as a major component of marine debris

It is evident that plastics represent a major component of marine debris (Figure 1, Table 1). It is also apparent from the data summarized and reviewed here that plastic debris is the most widely reported type of debris in terms of ingestion, entanglement, dispersal of species and generation of new habitat (Figures 4 & 9).

Production of plastics has increased considerably over the last few decades, with global production increasing from 5 million tonnes in the 1960s to 280 million tonnes today (PlasticsEurope, 2011). Data from the USA has shown a steady increase since the 1960s, with generation reaching approx. 30 million tonnes per year by 2010 (US EPA, 2010), (Figure 12). Recovery has also increased during this time, although levels remain below four million tonnes per year in 2010, representing only around 13 % of the amount generated (Figure 12).

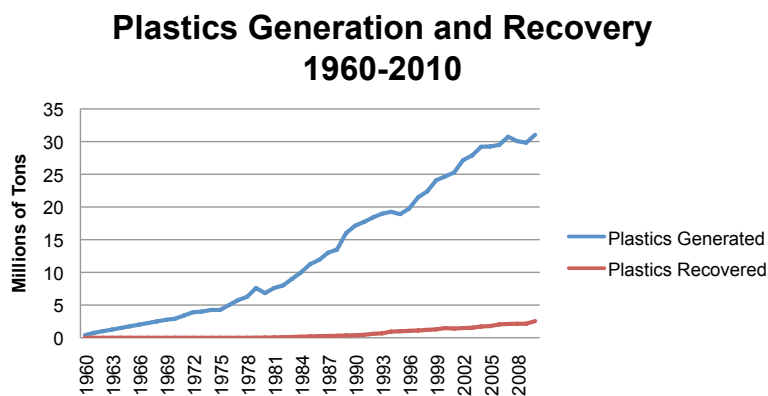


FIGURE 12: Generation and recovery of plastics in the USA from 1960-2010 presented as millions of tonnes per year. Source: US Environmental Protection Agency, 2011

Plastics are incredibly durable and represent a ubiquitous category of marine debris. For example, in 2006, plastic from a plane shot down in 1944 was discovered in the gut of an albatross some 9600 km away from the plane's location (Barnes et al., 2009). Data on temporal trends vary between regions and are typically restricted to sampling at or near the sea surface in coastal waters or on the shoreline (Barnes et al., 2009; Derraik 2002; Gregory 2009). From these habitats, there is evidence that despite efforts to remove debris from the marine environment and legislation to restrict dumping at sea, quantities of plastic debris are stable in some locations, but have increased significantly in others (Barnes et al., 2009; Thompson et al., 2004; Goldstein et al., 2012). For example, data on the quantities of plastic bottle caps and lids show a 10 fold increase on shorelines in South Africa when comparing data over a 20 year period to 2005 (Ryan, 2009).

The amount of debris (not specifically plastic) present on the UK coastline doubled between 1994 and 1998 (Barnes, 2002), and during the early 1990s it increased 14-15 fold in some parts of the Southern Ocean (Walker et al., 1997). Yet in contrast, extensive data from the sea surface in the North Atlantic Ocean and Caribbean Sea show no clear temporal trend over 22 years (Law et al., 2010). Since most plastic items will not biodegrade in the environment, it seems inevitable that quantities of debris will increase over time (Andrady, 2011). Furthermore, any lack of consistent trends in temporal data probably represents movement of debris into compartments that have not traditionally been monitored, such as the deep sea and offshore regions. It could also represent the fragmentation of plastic debris into pieces so small that they are not routinely recorded by sampling protocols. This is supported by recent findings from the Pacific Gyre which show a two-fold increase in the abundance of microplastics since 1972 (Goldstein et al., 2012).

In terms of larger items of debris, it is evident that of particular concern is the accumulation of Abandoned, Lost or Otherwise Discarded Fishing Gear (ALDFG), including fishing nets, which continue to ghost fish long after they have become marine debris. Plastics-based ALDFG can threaten marine habitats and fish stocks and is also a concern for human health (Macfadyen et al., 2009). The replacement by the majority of the world's fishing gear from natural materials to those made from synthetics has led to increasing problems from marine debris accumulation in the environment (Good et al., 2010). Whereas fishing gear made from natural materials deteriorated relatively quickly, those made from modern materials last much longer, and as a consequence, the extent and impacts of ALDFG has increased substantially over the last 50 years (Macfayden et al., 2009).

Because of their buoyancy and durability, plastic items can travel substantial distances; plastic cargo lost from ships have, for example, been reported over 4,000 km from the point of loss (Ebbesmeyer and Ingraham, 1994). Hence, in addition to shoreline or near-shore impacts, marine debris can have long-term impacts in the open ocean (Barnes et al., 2009). Ocean modeling indicates that floating marine debris originating from the western coast of South America, French Polynesia, New Caledonia, Fiji, Australia, and New Zealand not only fouls the coastlines of nations and archipelagos in the region where released, but much of it is also pushed by wind and currents to the South Pacific subtropical gyre where it accumulates (Martinez et al., 2009).

A recent publication in the journal *Science* presented over 20 years of data clearly demonstrating that some of the most substantial accumulations of debris are now in oceanic gyres far from land (Law et al., 2010). Plastic debris, therefore, represents a growing transboundary problem from coasts to the open ocean and areas beyond national jurisdiction.

SECTION 2: Strategies to Address the Challenge of Marine Debris

2.1 INSTITUTIONAL RESPONSES

2.1.1 *Global/Regional*

The global importance of the marine debris problem is reflected in recent resolutions by the UN General Assembly on oceans and the Law of the Sea. At its 65th session, the UN General Assembly urged states to support measures aimed at prevention, reduction, and pollution control of any source of marine debris. A resolution called on states to cooperate regionally and sub-regionally to implement joint prevention and recovery programs for marine debris (A/65/L.20). The most recent development was the endorsement by the UN General Assembly of “The future we want”, the Outcome Document of the United Nations Conference on Sustainable Development (also known as the Rio+20 Conference). This endorsement marked the most significant step in bringing ocean pollution in general, and plastic debris pollution in particular, to the forefront of global priorities for sustainable development (A/66/L.56).

The Rio+20 Outcome Document reaffirmed the concern for the health of the oceans and marine biodiversity, which is being negatively impacted by marine debris. It also committed nations to take action based on collected scientific data, by 2025 in order to achieve significant reductions in marine debris to prevent harm to the coastal and marine environment (para 163). Furthermore, the document recognized the importance of adopting a life cycle approach, and of further development and implementation of policies for resource efficiency and environmentally sound waste management. It called on nations to develop and enforce comprehensive national and local waste management policies, strategies, laws and regulations, including those pertaining to plastic waste (para 218). With the endorsement by the UN General Assembly of the Rio+20 Outcome Document, measures to address marine debris were included among global priority actions to assure sustainable development.

There are multiple global legal instruments and voluntary agreements aimed at the prevention and management of marine debris, both on land and sea. Currently, the most applicable overarching legal framework addressing marine debris is provided by the United Nations Convention on the Law of the Sea (UNCLOS). It entered into force in 1994 calling for the protection of the entire marine environment from all sources and types of marine pollution, including marine debris. UNCLOS does not directly address the issue of terrestrial waste reduction, except for Article 207 calling on states to pass national legislation combating pollution from rivers, estuaries, and pipelines. Among the more specific agreements regulating different sources of marine debris are:

- The Conference of the Parties to the Convention on Biological Diversity (COP 10), in its tenth meeting, provided an overarching framework for addressing impacts of human activities to marine biodiversity in its decision X/29. In this decision, the COP noted an urgent need to further assess and monitor the impacts and risks of human activities on marine and coastal biodiversity, building upon the existing knowledge (paragraph 68); requested the Executive Secretary to work with competent organizations which conduct marine assessments, including the United Nations General Assembly Regular Process for Global Reporting and Assessment of the State of Marine Environment including Socioeconomic Aspects, the Food and Agriculture Organization of the United Nations, the United Nations Environment Programme, the United Nations Educational, Scientific and Cultural Organization (UNESCO), Intergovernmental Oceanographic Commission (IOC), the International Maritime Organization (IMO) and International Seabed Authority (ISA), and other relevant organizations and scientific groups, to ensure their assessments adequately address biodiversity concerns in marine and coastal commercial activities and management, and, as necessary, where gaps are found, work with these agencies to improve the consideration of biodiversity in assessments (paragraph 69).

- The decision further requested Parties, other Governments, and other relevant organizations, to mitigate the negative impacts and risk of human activities to the marine and coastal biodiversity (paragraph 70); and urged Parties, other Governments and relevant organizations to adopt, in accordance with international law, including the United Nations Convention on the Law of the Sea, complementary measures to prevent significant adverse effects by unsustainable human activities to marine and coastal areas, especially those identified as ecologically or biologically significant (paragraph 73).
- The Convention on the Conservation of Migratory Species of Wild Animals (CMS) has adopted UNEP/CMS Resolution 10.4 on marine debris. This resolution includes the recommendation that 'Parties develop and implement their own national plans of action which should address the negative impacts of marine debris in waters within their jurisdiction'. It also instructs the Scientific Council to 'identify knowledge gaps in the management of marine debris and its impacts on migratory species', 'identify best practice strategies for waste management used on board commercial marine vessels,' and 'facilitate an analysis of the effectiveness of current public awareness and education campaigns to identify gaps and areas for improvement'.
- The International Convention for the Prevention of Marine Pollution from Ships (MARPOL) and its Annex V prohibiting at-sea pollution by various materials, including all plastics, and restrictions on at-sea discharge of garbage from ships. Current IMO efforts are underway to implement the revised MARPOL Annex V provisions aimed at prohibiting almost any garbage discharges from ships at sea, on tackling the inadequacy and upgrade of port reception facilities, and development of a port reception facilities database as a module of the Global Integrated Shipping Information System. Revisions are due to take effect in January 2014.
- The London Convention for the Prevention of Marine Pollution by Dumping of Wastes and other Matter, and its 1996 Protocol.
- Certain provisions (Annex IX Wastes containing Annex I materials) of the Basel Convention on the trans-boundary movements of hazardous wastes and their disposal are applied to marine debris wastes.
- The FAO Code of Conduct for Responsible Fisheries encourages states to tackle issues addressing requirements of the MARPOL. The FAO Committee on Fisheries (COFI), the only intergovernmental forum on fisheries, regularly considers marine debris issues associated with fisheries activities, specifically ALDFG.
- The ALDFG issue is also considered by the UN Fish Stocks Agreement which has been in force since 2001, and by a number of soft law agreements such as the 1991 Voluntary Guidelines for the marking of fishing gear, and the 2011 International Guidelines for by catch management and reduction of discards.

Among prominent multilateral implementation mechanisms with specific provisions for marine debris are:

- The Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities (GPA) created by the Washington Declaration in 1995 and putting, *inter alia*, priority on addressing land-based sources of marine debris emphasising implementation at the regional level. Marine litter is one of nine source categories under the GPA. The Manila Declaration of the Third Intergovernmental Review of the GPA (IGR-3, 25-26 January) declared marine litter one of three priority areas for 2012-2016.
- Launched during the Rio+20 Conference, the UNEP-led Global Partnership on Marine Litter could become an important coordinating platform for the management of this problem⁸. This new partnership builds on the Honolulu Strategy - a global framework for tackling marine litter backed by governments, members of the plastics industry, scientists, NGOs and other groups - which was presented at the Fifth International Marine Debris Conference in 2011⁹. The Honolulu Strategy could serve as a common framework of reference for collaboration and sharing best practices and lessons learned in preventing and reducing marine litter. It does not supplant or supersede activities of marine litter stakeholders; rather, it provides a framework document for improved collaboration and coordination among stakeholders across the globe concerned with marine litter issues. As an initial step, UNEP aims to facilitate an on-line forum to enable the global marine litter community to monitor progress on implementing the Honolulu Strategy and share information, lessons learned, and tools.

8 UNEP Press Release: UN and Partners Launch Global Partnership on Marine Litter at Rio+20 (<http://www.unep.org/newscentre/default.aspx?DocumentID=2688&ArticleID=9184&l=en>)

9 Honolulu Strategy (<http://5imdc.wordpress.com/about/honolulustrategy/>)

- The Regional Seas Conventions and Action Plans are main partners in implementing measures addressing marine debris at the regional level. Through a range of activities aimed at the assessment on distribution and sources of marine debris, and preparation of Regional Action Plans and management initiatives, twelve Regional Seas programmes (Conventions and Action Plans) took part in the Global Initiative including Baltic Sea, Black Sea, Caspian Sea, East Asian Seas, Eastern Africa/West Indian Ocean, Mediterranean, Northeast Atlantic/OSPAR, Northwest Pacific/NOWPAP, Red Sea and Gulf of Aden, South Asian Seas, Southeast Pacific/SPREP, and the Wider Caribbean/CEP.
- Marine debris is also considered a focal area of the Global Partnership on Waste Management launched by UNEP in 2010¹⁰.
- The Global Partnership for Oceans led by the World Bank is a growing alliance of more than 100 governments, international organizations, civil society groups, and private sector interests committed to addressing the threats to the health, productivity and resilience of the world's oceans. Among its strategic objectives and 2022 goals, the partnership lists support for the GPA to reduce marine litter.

Hence there are a range of applicable instruments and frameworks at the global level.

A wide range of non-governmental organizations (NGOs) are focusing efforts on marine debris prevention, reduction, and clean up in the seas and shores, including Algalita Marine Research Foundation, 5 Gyres Initiative, International Coastal Cleanup by Ocean Conservancy, Project Kaisei, Plastic Pollution Coalition, Surfriders, Dyer Island Conservation Trust, Marine Conservation Society, World Wildlife Fund, Project Aware, and many others. The International Coastal Cleanup by Ocean Conservancy is the largest global volunteer effort to clean up beaches, but also to address the sources and distribution of marine debris globally. Recognition that the problems and solutions to issues relating to marine litter are broad and have their roots on land is also emphasized by the recent STAP report, *Marine Debris as a Global Environmental Problem* (STAP, 2011).

2.1.2 National Level Responses

There are hundreds of legal, regulatory and management initiatives at regional, national, sub-national and community levels going on in different parts of the world. It would be challenging if not impossible to cover the entire spectrum of activities aimed at solving the problem of marine debris at these levels. For illustrative purposes, some of the ongoing initiatives in a few countries are listed below, but these represent only a small portion of the global total:

- The development of marine debris indicators for the European Commission Marine Strategy Framework Directive. The EU is currently discussing a pilot project in the Mediterranean that would provide alternative income to local fishermen through buy-back of collected marine debris;
- For more than 10 years the Practical Integrated System for Marine Debris in South Korea has been a successful national example of an integrated and highly sophisticated infrastructure project addressing marine debris using a life-cycle approach from identification, waste prevention, deep survey, removal, and marine debris treatment and recycling;
- Other notable examples include marine debris work done by the National Oceanic and Atmospheric Administration (NOAA) and its partners in the United States; the Waste and Resources Action Programme of the UK and others;
- Dozens of initiatives on marine debris, including plastics, are implemented by industries such as Operation Clean Sweep, reducing losses of resin pellets by American and British Plastics Industries, Waste Fishing Gear Buy-Back Project in Korea;
- Expand-Away-from-Home Access initiative promoting recycling in the State of California and Keep America Beautiful Initiative in the USA;
- Collection of discarded fishing gear on some South African coasts and in Hawaii via NOAA/MDP.

¹⁰ <http://www.unep.org/gpwm/Home/tabid/79392/Default.aspx>

2.2 EXAMPLES OF SUCCESSFUL STRATEGIES TO REDUCE MARINE DEBRIS: LESSONS FROM WASTE MANAGEMENT AND RECYCLING

While there are a broad range of instruments addressing the marine debris issue from sectoral, land-based or sea-based perspectives, it is evident from trends in this and other reports (Thompson et al., 2009; UNEP Year Book, 2011; Goldstein et al., 2012) that their effectiveness so far is limited. One suggestion has been to consider a more holistic range of measures rather than concentrating on end-of-pipe solutions focused on management of waste and legislation to control dumping. The issue is complex, however, and extends beyond the jurisdictional authority or ability of any one institution or global entity (e.g., STAP, 2011).

In addition to irresponsible behavior resulting in littering, the causes of many common items becoming debris in the marine environment may be attributed to inadequate design, for example mass production of single use packaging or products, that are unnecessarily difficult to recycle. In addition, increasing consumption is exacerbated by inadequate waste management practices that fall under sub-national jurisdiction. For example, the global regulatory frameworks described above and relevant national obligations are almost entirely applied to maritime issues when discarded items have already become debris or waste.

The lack of overarching jurisdictional responsibility in any single agreement for the entire life-cycle chain from production to disposal to clean up is compounded by the lack of appropriate infrastructure, enforcement in existing regulations, and lack of standards for more sustainable production and consumption activities. In contrast, more efficient production processes can actually lead to economic savings for companies, and economic incentives for recycling waste can also be instituted by governments.

Even the best waste management practices may also be insufficient to address the challenge. This is largely because waste management focused approaches do not take into account upstream solutions such as the design of more environmentally friendly packaging. Key aspects of design should include getting goods safely to markets as well as material reduction and design for end of life recyclability. In relation to quantities of end-of-life plastics, there is substantial additional synergy in terms of reducing use of non-renewable resources and reducing carbon emissions.

At present we produce around 280 million tonnes of plastic per annum globally (PlasticsEurope, 2011; see also Figure 12 above re: US plastic production). This requires around 8 % of world oil production, yet around 30 % of the items produced are packaging which is typically discarded within one year. Reducing material consumption will therefore reduce use of non-renewable resources as well as reducing end-of-life material that could become marine debris. In addition, recent calculations show that recycling end-of-life plastics into new products results in lower carbon emissions than production from new polymers (WRAP, 2006). Hence there are considerable and broad synergistic benefits gained by material reduction and recycling in terms of both reduction in the quantity of end-of-life material/marine debris and more sustainable patterns of production and consumption.

It is increasingly evident that a combination of measures are required to reduce the problems associated with marine debris, and that the relative importance of these measures will vary regionally. An increased focus on reducing the rate at which waste is produced is required, as well as ensuring that appropriate management measures are in place for the safe disposal of material which cannot be reused or recycled. In combination with these measures is the need to remove debris that is already contaminating the oceans, where feasible and practical. For many locations, however, the removal of debris is difficult due to the practicalities of extracting and transporting debris.

A further important consideration is that it will not be practical to address the impacts of some marine debris with the same approaches that are used to reduce other human impacts such as fisheries over-exploitation and habitat disturbance. The latter can be regulated to some extent through the application of integrated coastal zone management and the use of area-based management tools including marine protected areas and marine spatial planning. Given the potential for plastic debris to persist in the marine environment for long periods, to

travel considerable distances, and to accumulate in habitats far from its point of origin, this presents a distinct challenge that is difficult if not impossible to resolve once the debris is adrift. Conservation measures based on spatial tools alone will therefore be ineffective to deal with plastic debris in most settings.

As recognized in the Honolulu Commitment adopted by the 5th International Marine Debris Conference (20-25 March 2011) and elsewhere, to support a focus on prevention from land based sources there is a need for a coordinated international framework, through which proven multifaceted and multi-sectoral pollution prevention and waste reduction approaches can be employed. While these approaches should have broad applicability in both the developed and developing worlds, it is recognized that the effectiveness of any particular measure is subject to local context and to such issues as waste management infrastructure, regulatory capacity, economic resources and social culture.

A waste management system based on the principles of polluter pays, on best management practices, on public awareness and participation, and driven by effectiveness and efficiency objectives can have, over time, a positive impact, increasing the amount of waste diverted toward secondary use and recycling. The following policies and programs are examples of approaches and opportunities that have shown success and that could be used to promote initiatives to develop concrete and practical answers to the challenges of preventing land based marine debris.

2.3 REUSE AND REDUCTION

2.3.1 Packaging and Plastics Reduction

Packaging and plastics reduction have been documented in the Extended Producer Responsibility (EPR) programs for packaging and printed paper in Europe. Under these programs brand owners who package and sell products have been made responsible for the environmentally sound management of that packaging at the end of its life (also see section 2.3 below).

PRO Europe, the organization representing producer organizations formed in response to EPR legislation and using the Green Dot logo, has documented changes in packaging design, reduced material use and resulting easier recycling (PRO Europe, 2012). Reducing the number of materials in a package, using less material, and redesigning the product itself have all been cited as some of the changes that have taken place since the first EPR program for packaging waste started in 1991. PRO Europe states that “acceptance of producer responsibility and the establishment of Green Dot organizations have brought about significant changes in Europe’s packaging and waste markets as well as in consumer behavior.”(PRO Europe, 2012)

Waste reuse and reduction changes in North America, where fewer EPR programs exist, and other areas without EPR are likely more exclusively a result of the cost of materials and transportation and of market driven innovation than of considerations regarding end-of-life recycling. As an example, the average weight of a standard sized plastic water bottle in the US has fallen 32 % , from a weight of 18.9 grams in 2000 to 12.7 grams to 2008 (International Bottled Water Association, 2010). Light weighting has undoubtedly increased the efficiency of the container; however, it should be noted that over the same time, the number of bottles marketed has continued to grow to a degree that might offset the gains from using less material. Bottled water consumption in the US is predicted to increase 6.7 % in 2012 (Worldwatch Institute, 2012) and in Canada bottled water consumption increased by 107 % over the 10 years from 1999 to 2009 (Agriculture and Agri-food Canada).

2.3.2 Eco-labels

Eco-labels represent an established approach which is used to identify environmental performance in products, packaging and services. These can be effective to differentiate products and packaging in the marketplace and to provide information to consumers who are then equipped to make better, more proactive environmental decisions in purchasing. Awarding eco-labels to products which are sold with reduced or minimal packaging can have some influence in the market place.

The Global Eco-Labeling Network (GEN) represents 27 national and regional eco-labelling programs from countries as diverse as Thailand, India, the Nordic countries, Canada and Japan. GEN eco-labelling programs address multiple environmental criteria across the life cycle and are independently audited, which distinguishes them from the multiplicity of self-declared and unaudited labels in the marketplace which have given rise to concerns about unsubstantiated “green-washing” environmental claims. One of the primary areas of activity has been eco-labelling for packaging and containers where GEN recognises 43 different sets of packaging labelling certifications used in 10 different countries (GEN). As an example, Environmental Choice New Zealand has an eco-label certification standard for recycled plastic products. Dependent on the type of product to be awarded the logo, the producer has to use 30-90 % recycled post-consumer plastic resin, identify its involvement in take back programs, and not use any hazardous substances (Environmental Choice New Zealand).

2.3.3 Voluntary action

Leading groups of plastics and packaging producers and users have played significant roles in supporting reduction and reuse of plastics and packaging, both through individual corporate actions and through collective activity in such areas as research and development and standard setting. In Canada, for example, the Packaging Association has initiated PacNext, a program to promote packaging sustainability with a vision of “a world without packaging waste”. As one of its initiatives, PacNext has recently launched a program to develop a packaging design guide to promote best practices and innovative packaging design end-of-life solutions (Packaging Association of Canada, 2012).

Similarly, the Association of Plastics Recyclers in the US has developed a set of Design for Recyclability Guidelines, and the Sustainable Packaging Coalition has developed programs on the essentials of sustainable packaging, a design for recycling guide and a comparative packaging assessment software tool.

2.3.4 Green procurement

Green procurement has also been used to advance better, more sustainable product and packaging design. Procurement strategies commonly rely on eco-labels and environmental assessments to facilitate proactive environmental purchasing. Recycled content and minimal packaging are common requirements which assist in reducing packaging and sustaining secondary materials markets. In addition, some purchasers have instituted mandatory take back programs for the packaging in which they receive new products. Government agencies have historically taken a lead in this area (US EPA), underscored by the recent announcement of the International Sustainable Public Procurement Initiative (SPPI) at the recent Rio+20 Summit, but major companies are also playing a role. Walmart, for example, has used a sustainability index tool to measure all of their suppliers and to assess such things as material efficiency and responsibly sourced raw materials in the products they purchase and sell (Walmart Sustainability Index).

2.3.5 Biodegradable products

Redesign of plastics for biodegradability and “compostability” is underway and does show reduction potential for selected application (European Commission, 2011). The market penetration of such plastics is, however, still very small—0.1–0.2 % of plastics in the European Union, according to the European Commission—and ‘there is debate as to whether they actually degrade in natural habitats’ and ‘also doubt as to whether they will degrade in the marine environment where heat and pressure conditions are significantly different’ (European Commission; Song et al., 2009; O’Brine and Thompson, 2010). Recyclers are also very wary about degradable plastics, as they are effectively a contaminant in conventional mixed plastics recyclable streams. Research is needed to assess the impact on both marine environments and on waste and recycling infrastructure before such plastics can be viewed as contributing to the reduction of marine debris.

2.4 PRODUCER RESPONSIBILITY

Transferring funding and operational responsibilities for waste packaging and plastics to the producers of products and packaging has its origins in the German Packaging Ordinance of 1991, and the creation of the

Duales System Deutschland (DSD) packaging collection and recycling program. Known as Extended Producer Responsibility (EPR), the approach has been identified by the Organisation of Economic Cooperation and Development (OECD) as: “an environmental policy...in which a producer’s responsibility, physical and/or financial, for a product is extended to the post-consumer stage of the product’s life cycle” (OECD, 2001).

Traditionally, and still very commonly in most parts of the world, waste management responsibilities have defaulted to, and rested largely with municipalities, financed through public funding. Under an EPR program the producers, manufacturers, brand owners and first importers of products and packaging are given the legal responsibility for collection, recycling and for end-of-life management. EPR programs exist across Europe, Canada and Japan for a wide range of products, including packaging and plastic containers, and are being considered in countries as diverse as the United States, Brazil and Costa Rica. To date, EPR has generally not been used in developing countries but it could be applied with a focus not only on brand owners but on the importers of targeted products as the responsible party.

The EPR approach has successfully been used to develop sustainable producer funding for municipal recycling programs and has supported the development of new markets for recovered packaging materials. EPR is also built on the idea that producers make decisions on types of packaging materials and have the most ability to redesign packaging to facilitate reduction, reuse and recycling. As noted in section 2.2, EPR programs have demonstrated some impact on packaging waste. Packaging EPR programs can cover costs through fees applied per packaging unit and fees are commonly differentiated based on the costs to recycle particular packaging materials (Stewardship Ontario, 2012). Plastics conventionally pay higher fees because they are more expensive and technically harder to segregate and recycle than materials like aluminum, steel, glass or paper.

Most EPR programs for packaging are primarily focused on providing a service to residences. However, a new EPR initiative for packaging in the Canadian province of British Columbia (British Columbia Recycling Regulation amendment, 2011) not only gives producers a mandate for packaging waste typically found in the residential waste stream, but also for packaging found in public areas such as municipal parks, on sidewalks and pedestrian areas and in city plazas and town squares. These are the kind of areas which can generate plastic and packaging litter which can end up in bodies of water if not properly managed through easily accessible and available litter bins and recycling collection containers. As discussed previously, producer responsibility programs for packaging have also shown positive impacts on packaging design and on packaging and plastics reduction.

2.5 INCENTIVES FOR COLLECTION AND RECYCLING

Increased diversion of plastics and packaging and preventing littering or disposal can be enhanced by providing incentives for collection and recycling.

Beverage container deposit return systems are one example of such an approach with a long and proven track record of success. Under such programs, consumers pay a deposit on the container which can be redeemed when the empty container is returned. Deposit return has a long history and was originally employed to ensure the return of glass bottles for reuse. In recent times, with the increasing use of lightweight plastic containers, such returned containers are more commonly recycled than refilled.

According to the U.S. Container Recycling Institute, across the US approximately 2 out of 3 beverage containers, of all types, end up as litter or being disposed of in landfill. Contrasted with these national statistics is data from US states which have container deposit refund programs where the recovery rate of containers for recycling ranges between 66 and 96% of containers sold (Container Recycling Institute, 2001). In the Canadian province of Ontario, 94% of all glass and aluminum beer containers were returned in 2008, and wine and spirit containers which also have deposits, were returned at a rate of 67% (CM Consulting, 2009). In both cases, relatively small returnable deposits of 5-20 cents per container, or approximately 10-15 % of the product value, had a large impact on overall recovery.

Incentives to encourage and enhance recycling have been applied in a number of EPR programs to offset the costs of recovery of materials from more remote communities or from communities further away from larger scale regional recyclable materials processing infrastructure. These types of incentives, which might take the form of a transportation subsidy or a higher material price paid at the point of collection, have been used for the collection of used tires and end-of-life electronics (Alberta Recycling Management Authority). They could also be applied based on this model in an EPR packaging program to encourage and support the collection of recyclable materials from public spaces, with the costs covered from the fees paid by producers across the whole program and market place.

In all of these cases the incentives and the enhanced recovery rates that they entail are closely linked to the development of markets for the recovered materials.

2.6 OTHER ECONOMIC INSTRUMENTS

A variety of economic instruments can also be used to discourage disposal, encourage collection and recycling and the development of more sustainable life-cycle environmental strategies. Many of these instruments, however, require robust legal, regulatory, compliance and enforcement regimes which may not be available in all countries or situations. In all cases, such instruments are generally only adopted as supportive measures for more proactive strategies for collection and recycling of plastics and packaging, and in situations where there are clear and widely available alternatives to littering and disposal.

2.6.1 *Municipal ordinances and user fees*

Plastic bags, which form a common element of marine debris, have been the target of policies designed to reduce use and to switch consumers to reusable alternatives. Starting in March 2012, Kenya banned the manufacture and import of lightweight plastic bags (less than 0.06mm thickness) to address widespread windblown bag litter (The Independent, 2011). In 2009, the cities of Seattle and Toronto adopted ordinances and by-laws requiring all retailers to charge a fee on all bags used for carry out. Both programs have been very successful. In Toronto's case the first year of the program saw the estimated number of bags used in the city drop by 53% (Recycling Council of Ontario, 2012). Consumers have adopted new shopping habits and many retailers have actively promoted and distributed reusable bags. Both cities have since adopted outright bans on such bags with Seattle's new policy being implemented on July 1, 2012 and Toronto's ban set to take effect in January 2013.

User fees for waste management services and managing waste through a public utility, with rates charged based on use rather than as a public service paid out of general taxation, have had some impact on waste in some communities. In such programs, recycling services are provided at no visible cost, and waste collection services are charged on a per bag/bin basis or by weight. Such schemes are, however, reliant on rigorous enforcement and compliance to ensure that user fees do not promote indiscriminate dumping. Such an approach is not applicable to wastes generated in common public spaces where no one waste generator can be identified. In addition, such programs have proven difficult to adopt in urban settings where there are large numbers of multi-unit dwellings, and individual waste generators are impossible to identify.

2.6.2 *Waste diversion and secondary markets*

Subsidies and grants to support the development of secondary markets for recyclable materials can be used, but ultimately such markets will succeed or fail on the economics of the market place, and on competition between secondary and virgin materials prices. One of the benefits of EPR programs is that producers are legally responsible for the recycling of their products and packaging, and as a result they have often invested in secondary materials research and development, and occasionally actively financed the start-up of processing and end market infrastructure for recyclables. In the Canadian province of Ontario, for example, the Continuous Improvement Fund, which is funded by a percentage of stewardship fees paid by producers for their portion of the packaging and printed paper recycling program, has been established to support innovation and experimentation

in municipal recycling programs. One of its current objectives is to implement the collection and recycling of more plastic packaging (Continuous Improvement Fund, Waste Diversion Ontario).

Taxes have been put on disposal at landfill sites to increase the cost to users, to better reflect the true life-cycle cost of disposal, and to drive waste materials into recycling systems. The United Kingdom established such a tax in 1996, and it is currently (2012) charged at a rate of GBP 64 for each tonne disposed. Such disposal surcharges have been used to generate revenues for public authorities, which can then be used to support a variety of waste diversion initiatives. Revenues could be used to promote reduction in the generation of material frequently found in marine debris and for marine debris remediation.

2.6.3 Bans and penalties

Bans on disposal at landfill sites have been used to support some EPR programs such as those for electronics and other programs targeting types of construction materials. They have not generally been used in the area of packaging because the practicalities of enforcement can be challenging, even in situations where regulatory and enforcement capacities are well established.

Penalties for lack of performance of a producer responsibility program or failures to meet regulatory requirements of any kind are common in most legislation governing waste management and waste diversion. Application of such penalties is rare except in the most notable of cases, but the fact that such a penalty could be applied can serve to help drive program performance. In order to institute any kind of penalty, regulated programs must have clear performance requirements and be subjected to independent auditing. Compliance promotion is also necessary in advance of any legal action.

2.7 RESOURCES, NOT WASTES

End-of-life management of products and packaging has traditionally focused on the ease and convenience of disposal, and only secondarily on materials recovery and recycling. Comprehensive municipal recycling programs in OECD countries are heavily dependent on sustainable markets for collected materials. With increasing demands for commodities in the global market place many end-of-life products, including plastics and packaging, are increasingly being seen as sources of valuable secondary materials which are lost forever if disposed of. At the same time, the recycling of secondary materials has been documented to have positive GHG impacts in contrast to landfill disposal (US EPA, 2012).

The OECD had focused considerable attention on the issue of secondary materials through its sustainable materials management (SMM) initiative. SMM is seen as the framework within which more targeted waste and recycling policies and programs could be implemented. According to the OECD, “sustainable materials management proposes a shift from policies focused on isolated aspects of the material chain, causing leakages and unintended side effects, to an integrated policy approach that embraces the full life cycle of products and materials.” It is also suggested that “there is a large potential for diverting waste from landfills, for stepping up recycling and for more environmentally sound management” (OECD, 2010).

The OECD recognizes that enhancing recovery of materials is important, but also notes that the efficient and sustainable use of materials has to improve as well. Both of these objectives speak to the opportunities available to reduce the amount of plastics and packaging waste that escapes recovery, may be improperly disposed of, and potentially ends up as marine debris.

Similarly, the UNEP Marrakesh 10 Year Framework for Sustainable Consumption and Production has focused on life cycle approaches to support its goals for greener economies and greener business models, with attention on integrated waste management and product and production sustainability in support of sustainable consumption (UNEP Marrakech Process, 2011).

One country that was an early adopter of the sustainable materials management concept is Japan. Its Basic Law for Establishing a Sound Material Recycling Society was adopted in 1997 and was reviewed in 2010 (Japan Ministry of Environment, 2010). This law has been the broad enabling legislation for a variety of initiatives designed to increase the diversion of materials and the enhanced use of secondary materials for various industrial sectors. The strategy has been supported by a scarcity of disposal capacity in the country and by the relatively high cost of the capacity that is available, either as landfill or as incineration. It is under this law that Japan has enacted its regulations for the collection and recycling of containers and packaging. Data shows that the recovery rate of PET plastic containers increased significantly after passage of the law, and has slowly grown since (Japan Ministry of Environment, 2010). The development of markets for collected materials and closing the supply chain and manufacturing loop as much as possible have been key elements of Japanese policies.

2.8 ENGAGEMENT WITH BUSINESS LEADERS

Leading private sector companies and their business associations in the plastics and packaging industry have started to recognize proactive roles that they can play to address waste management and marine debris. Such companies and producer organizations often have global reach, and can play a major role in the production, consumption, and end-of-life management of plastics and packaging across national boundaries.

Significant players in the international plastics and packaging industry have recognized that their public profile may be impacted by an increasing awareness of the marine debris issue. Many companies now see packaging and plastics sustainability as part of broader corporate social responsibility, and negative brand image is becoming a major driving force which is being harnessed in the interests of improving packaging materials and technologies.

In response to concerns by industry leaders, international plastics industry associations have come together to sign a Declaration for Solutions on Marine Litter. The Declaration, which was initiated at the 5th International Marine Debris Conference in Hawaii in March 2011, has now been signed by 54 industry organizations in 29 countries including India, Korea, South Africa, Canada, Germany and Brazil (Marine Litter Solutions, 2011). Commitments focus on cooperation and education and also explicitly on enhancing “opportunities to recover plastic for recycling and energy recovery”.

In the United States, as part of this initiative, the American Chemistry Council has sponsored a program in California to encourage recycling awareness and reusable water bottles (American Chemistry Council) in schools and around the State of California. The ACC has also provided recycling bins, particularly for plastic bottles at public beaches and parks, areas where there are high risks of littering leading to marine debris (American Chemistry Council).

Another major industry association, Plastics Europe, has initiated a number of projects to help address marine litter problems. They are undertaking a program to promote better and more secure treatment of plastic pellets at manufacturing and processing plants to ensure that such pellets are not mismanaged or otherwise end up indiscriminately discarded with risks to nearby water courses. They have also expressed concerns about the continuing high volumes of plastics that end up in landfills across Europe, and have embarked on a “Zero Plastics to Landfill” campaign (Plastics Europe).

2.9 SUPPORT AWARENESS BUILDING IN COASTAL COMMUNITIES

There are a large number of prevention and remedial initiatives around the world which are tackling land-based marine debris generated from beaches and coastal communities and impacting coastal environments. Engaging with such communities and initiatives and helping such programs grow and prosper serves to enhance public awareness about marine debris, and helps to develop new attitudes towards littering.

UNEP has documented the wide range of such initiatives in a number of the major coastal and ocean regions. “Regional seas programs ---- reported that numerous organizations and government groups routinely conduct public education campaigns to support their missions and program objectives that include marine conservation issues and marine litter prevention” (UNEP, 2009)

The Blue Flag program is one successful international example of a proactive campaign focused on coastal conservation using criteria for environmental management, education and information, water quality and safety, and services with key program elements aimed at preventing the creation of marine debris. Blue Flag has recognized 3849 beaches and marinas in 46 countries across Europe, South Africa, Morocco, Tunisia, New Zealand, Brazil, Canada and the Caribbean. Among its beach criteria, it mandates the availability of waste disposal bins and containers, and facilities for the separation of recyclable materials.

It is essential, however, to recognize that marine debris can be generated in locations far from the sea, and can be transported to the sea via rivers and wind dispersal. The practices outlined in this document should be regarded as good practice to reduce the accumulation of debris on a global scale, including regions far from the ocean. For example, in the United Kingdom, the Blue Flag program is linked to a larger national litter prevention and clean-up program, Keep Britain Tidy. This is a charitable environmental organization with a mandate to support access to clean, safe and green community spaces. Similar organizations exist at a national level in many other countries, and at regional and local levels, often linked to jurisdictional areas such as sub-national states and municipalities.

Success in any of the above programs is dependent largely on increasing public awareness through public education and communication campaigns linked to waste reduction and recycling promotion programs. Availability of reliable information accurately disseminated via local media support, print advertising and signage in key public areas can be bolstered with campaigns built around creative use of social media, including a focus on children and schools.

CONCLUSIONS

Given the numbers of species, numbers of individuals, and for some species the substantial proportion of the population affected—coupled with an increasing incidence of ingestion, entanglement and dispersal in recent years—marine debris represents a significant additional and escalating anthropogenic factor affecting marine habitats and biodiversity.

Where population level effects of marine debris combine with other anthropogenic stressors, it seems likely that marine debris could also contribute to extinction at species level, particularly where IUCN Red List species are concerned. The consequences of marine debris on species and individuals may also have indirect effects on trophic interactions and on assemblages, something which will be particularly important where a keystone species is affected.

While it is difficult to isolate the impacts of marine debris from other anthropogenic factors affecting marine biodiversity, it is increasingly evident that marine debris should be acknowledged as a major additional driver contributing to the degradation of marine environments. Strategies for prevention at source, producer responsibility, and greater awareness raising have been identified as being key to minimizing further increases in marine debris and its associated impacts.

There is wide recognition that the debris described in this report does not belong in, nor does it need to be, in our oceans and along coastlines. In parallel, it is evident that there are a wide range of measures available to tackle the issue of marine debris. Control of sources of marine debris is an issue which can benefit from a broadly based framework approach focused on prevention. There are numerous policies, programs and instruments which have been successfully used in waste management and recycling programs. These measures can be effectively used in reducing debris at points of origin and in improved life cycle management.

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ANNEX 1:

Information extracted from reports and publications in relation to documented encounters between marine debris and an organism

An extensive literature review of data published prior to April 2012 in peer reviewed publications and reports in grey literature was conducted for this review, and the following information was extracted:

- Species name (scientific and common)
- Taxonomic grouping e.g. Mammals, Birds, Fish, Sea Turtles, Crustaceans, Cephalopods, Bivalves, Gastropods, Echinoderms, Cnidaria. As numbers of organisms from other taxonomic groups were low, subsequent reporting is focussed on Mammals, Birds, Fish, and Sea Turtles
- Number of individuals (for reports where this was not given, it has been recorded as a nominal value of 1)
- Debris type e.g.: Metal, Plastic, Paper, Glass, Wood (other than driftwood), Other, Unknown (where the study did not report the debris type)
- For plastic debris which was the main material type reported, an additional category 'Debris usage / type' was recorded, e.g. Rope & Netting, Other Fishing Material, Intact Items and Packaging, Fragments (> 5 mm), Microplastics (< 4.99 mm).
- Type of encounter e.g. ingestion, entanglement, rafting
- Number of individuals documented per species according to debris type (consequently some individuals were recorded more than once if, for example, they had ingested two types of debris).
- Consequence(s) of encounter: Direct Harm/Death, Indirect Harm/Death, Survived, Unknown (where the study stated that they did not know the fate of the individuals), or Not Reported
- Location: grouped according to region—North America West Coast, North America East Coast, South America West Coast, South America East Coast, Central South Atlantic, Europe, Africa West Coast, Africa East Coast, Asia, Australasia, Central Pacific, Arctic, Antarctic, Other, Unknown.
- Reference to the source of the report

ANNEX 2:

Limitations of the data available

The data presented in this report are an accurate representation of the current literature on marine debris. There are, however, a number of limitations which should be considered when interpreting the findings presented. The report summarizes impacts, types of debris and its geographic distribution from data based on reports in scientific papers and grey literature. Hence the summary will be influenced by the frequency of impacts themselves and by the frequency of reporting. In general it should be considered that where species, ecosystems and types of debris are reported frequently, at numerous locations they represent the most reliable evidence. It is reasonable to apply greater caution, however, when considering impacts that are seldom described, as these could be a reflection of a lack of reporting. Some examples are outlined below:

Trophic level considerations

- Few reports exist that consider low level trophic organisms. This report has focused on organisms from higher trophic levels for which there are more reports, in particular mammals, birds, fish and sea turtles. It is important to note that this does not indicate that organisms from lower trophic levels are not impacted by marine debris, only that any such impacts are, as yet, not fully described. Some evidence does exist relating to the ingestion of microplastics by low trophic level organisms, such as sea cucumbers, marine worms and detritivours (Thompson et al., 2004; Graham & Thompson, 2009; Murray & Cowie, 2011), but further research is required before the impacts can be fully understood.

Ingestion impacts

- It is likely that there is an underreporting of ingestion impacts. Entanglement effects are more widely reported, but this does not necessarily mean that entanglement has a larger impact on biodiversity than ingestion; rather, it reflects the fact that entanglement is more readily observable and therefore easier to report, whereas ingestion can only be established by necropsy and studies are either opportunistic i.e. the discovery of a dead organism which is then dissected to ascertain cause of death, or experimental, where organisms are tested specifically to assess the extent to which they ingest debris.
- Consequences of ingestion can be indirect and are difficult to determine (for the reasons described above), whereas it is comparatively easy to determine whether entanglement has directly led to injury or death.

Invasive species

- It is likely that the number of invasive species rafting on marine debris is underreported. The studies that this

report has identified have not always specified whether the species they report are considered invasive.

Study locations

- The majority of studies to date have been from on Europe, North America, and Australasia. This is unlikely to reflect the true distribution of marine debris and its associated impacts, and it should be recognised that a lack of studies does not necessarily indicate a lesser impact on biodiversity. Further studies are therefore required in data deficient areas.

Socio-economic Impact data

- There is limited data on the socio-economic impacts of marine debris in the most vulnerable of economies, and for locations where dependence on the sea is particularly high and fundamental to local economy (e.g. tropical sea-based tourism, (semi-)subsistence situations in the developing country context etc.). The literature tends to have monetary impacts of marine debris for developed countries, for example based on fishing industries, but there is limited work on the socio-economic effects of marine debris on coral reef ecosystems, or the consequences of degradation to the economies of developing countries.

Types of debris

- This report indicates rope, netting, intact items, packaging and plastic fragments as being the main categories of waste implicated in ingestion, entanglement and rafting. Plastic items are also the main types of material reported as debris. In terms of specific types of debris it will, however, be easier to observe and report on the impacts from items that are large and conspicuous, such as rope and netting. Hence the data presented here may under represent impacts from less conspicuous types of debris, such as fragments and microplastics.

