Agenda Item 3.4.3

Review of New Information on Threats to Small Cetaceans

Pollution and its Effects

CMS Reviews: Marine Debris and Migratory Species

Information Document 3.4.3.b

CMS Report I: Migratory Species, Marine Debris and its Management

Action Requested

- Take note

Submitted by

Secretariat

UNEP ASCOBANS

NOTE:
IN THE INTERESTS OF ECONOMY, DELEGATES ARE KINDLY REMINDED TO BRING THEIR OWN COPIES OF DOCUMENTS TO THE MEETING

Secretariat's Note

UNEP/CMS/Resolution 10.4 on Marine Debris instructed the Scientific Council to:

(a) Identify knowledge gaps in the management of marine debris and its impacts on migratory species;

(b) Identify best practice strategies for waste management used on board commercial marine vessels, taking into account the extensive work being undertaken by the International Maritime Organization, FAO and the International Standards Organization to avoid duplication, identify existing codes of conduct and determine the need for the improvement and/or development of new codes of conduct;

(c) Facilitate an analysis of the effectiveness of current public awareness and education campaigns to identify gaps and areas for improvement; and

(d) Report progress and developments to the Conference of Parties as appropriate.

Thanks to a voluntary contribution by the Government of Australia, the CMS Secretariat was able to support the Scientific Council with this task by hiring a consultant.

Three comprehensive reviews were produced in close consultation with the Secretariat and presented to the 18th Meeting of the CMS Scientific Council as

(a) UNEP/CMS/ScC18/Inf.10.4.1: Migratory Species, Marine Debris and its Management

(b) UNEP/CMS/ScC18/Inf.10.4.2: Marine Debris and Commercial Marine Vessel Best Practice

(c) UNEP/CMS/ScC18/Inf.10.4.3: Marine Debris Public Awareness and Education Campaigns

This document contains the first of these reports.

Report I: Migratory Species, Marine Debris and its Management

Review Required under CMS Resolution 10.4 on Marine Debris

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Report for:

The Secretariat of the Convention on Migratory Species

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Disclaimer

EXECUTIVE SUMMARY

Eunomia Research & Consulting (Eunomia) has worked in partnership with the International Union for the Conservation of Nature (IUCN) and the Marine Conservation Society (MCS) to prepare three reports for the Convention on the Conservation of Migratory Species of Wild Animals (CMS) for 'Reviews required under Resolution 10.4 on Marine Debris'. The three reports are as follows:

- Report I: Migratory Species, Marine Debris and its Management;
- Report II: Marine Debris and Commercial Marine Vessel Best Practice; and
- Report III: Marine Debris Public Awareness and Education Campaigns.

E1.0 Approach

Report I was undertaken principally, in accordance with UNEP/CMS/Resolution 10.4, to

> *"Identify knowledge gaps in marine debris management and impacts on migratory species"*

The report first outlines knowledge gaps regarding types, sources and pathways for marine debris, and its impacts on migratory species. Where possible, regional distinctions were made, and impacts were considered for the different high level species groups relevant to migratory species (i.e. mammals, reptiles, birds and fish).

Initially a brainstorming approach was used as a tool to explore the different potential item types, materials, sources, pathways and impacts of marine debris. The result was an inventory of possible characteristics of marine debris and its impacts. This allowed the extension of the subsequent literature review to explore currently un-documented or under-documented types and impacts of debris.

The literature review used academic and 'grey' literature to outline the present state of knowledge as regards these different aspects of marine debris and its impacts. The brainstorm and subsequent review were used to draw conclusions regarding which areas of the topic currently exhibit knowledge gaps.

A review was then undertaken on the management of marine debris, which included monitoring, removal and prevention strategies. Knowledge gaps with regard to these strategies were evaluated by reviewing both academic and grey literature, as well as other web-based sources of information.

Finally, challenges in the management of marine debris' impacts on migratory species were outlined and recommendations were made for opportunities for CMS to engage and assist in filling the identified knowledge gaps and overcoming the indicated challenges.

E2.0 Key Findings

In "Origins and Pathways" (Section 2.0) the knowledge gaps regarding types of marine debris and their origins are assessed. Although there are many sources of data on marine debris, when considered globally, the key findings are:

- There is very limited information available regarding debris prevalence by source and pathway;

- Information regarding prevalence of marine debris by material type is not collected systematically in most regions, even where there is monitoring effort;
- There is slightly better information available regarding the prevalence of marine debris by item type. However, some key types, particularly microplastics, are not yet included in systematic monitoring attempts;
- Monitoring of prevalence of debris types in different marine compartments such as the sea bed, the water column and the surface is poor relative to the monitoring of beach debris;
- There are no robust data regarding the amount of debris in the ocean or how much enters the ocean each year;
- There are not yet robust data regarding the geographical distribution of debris or its distribution between marine compartments;
- The fate of debris in terms of fragmentation, decomposition, distribution and accumulation is not well characterized;
- Knowledge of these characteristics of marine debris is constrained both by methodological limitations and uneven geographical distribution of monitoring and research effort; and
- Studies in different geographical regions and sea compartments currently tend to produce incomparable data because standardized methods either do not exist or are not applied.

In "Impacts on Migratory Species" (Section 3.0) the current state of knowledge regarding the impacts of marine debris on migratory species are surveyed and knowledge gaps assessed. The key findings, in terms of knowledge gaps, are as follows:

- There is not enough quantitative information on the prevalence of impacts within populations to understand which species are the most affected by marine debris;
- The mechanisms and extent of harm associated with sublethal impacts of marine debris are poorly characterized;
- Interaction between sublethal impacts of marine debris and other stressors are unknown;
- The reporting of impacts does not take into consideration measures of animal welfare;
- There are almost no data on the population level effects of marine debris;
- The specific effects of marine debris on migratory as opposed to resident species are poorly understood;
- Further research would be needed to establish if associations between vulnerability to marine debris and life history stage or habits warrant targeted approaches;
- Absence of evidence regarding debris impacts generally reflects uneven allocation of monitoring resources rather than regional distinctions; and
- Impact studies currently tend to produce incomparable data because standardized methods do not exist.

Additionally, the contribution of different types of debris to the different impacts is evaluated. It is found that:

- The scoring of impacts according to marine debris type is not undertaken on a sufficiently comparable basis to allow robust ranking of debris types for risk of harm across different species groups and impacts, even though some trends within specific impact types are evident;
- Scoring is likely to be biased towards conspicuously identifiable items;
- The effect of microplastics on the species ingesting them is not yet fully characterized; and
- Apart from a few specific examples (such as items designed specifically for catching wildlife, or soft plastics) the effects of colour, shape or plastic type on the likelihood of causing harm are not well enough understood to warrant focussing of management strategies at present.

In “Management of Debris in Marine Ecosystems” (Section 4.0) knowledge gaps specific to monitoring, removal and prevention of debris are considered.

Concerning monitoring and with particular regard to migratory species, the following areas were found to have significant gaps:

- Prevalence of all the types of debris that may, or are known to, have impacts on migratory species;
- Sources and pathways of these types of debris;
- Geographic distribution of these types of debris;
- Impacts on migratory species, within and between regions; and
- Population level effects on migratory species.

The kind of information gaps most relevant to the impacts on migratory species as regards debris removal management initiatives are:

- Efficacy in terms of impact on stock and flow of marine debris;
- Efficacy in terms of mitigating impacts on marine species, specific to migratory species if possible;
- Efficacy in terms of public awareness and behaviour change – whether regarding the public, fishermen, industry, and other stakeholders; and
- Cost-effectiveness.

Regarding preventing waste reaching the marine environment, there are a number of aspects of the different strategies that are as yet poorly characterized. The key areas are:

- Effectiveness in terms of flow of marine debris;
- Effectiveness in terms of impacts on marine species, specific to migratory species if possible; and
- Cost-effectiveness.

However, preventative measures focused on land-based sources will inevitably reduce the amount of debris reaching the marine environment in the first place, and these should be pursued even in the absence of more robust information.

Economic instruments and other measures preventing litter (such as deposit-refunds on beverage containers, and levies on single-use carrier bags) have the added benefit of tackling the disamenity impacts of litter on land, which given the identification of emerging evidence on *indirect* costs of litter in respect of crime and mental health, are considerable. Therefore the benefits are not just of relevance to the marine environment. In the context of uncertainty regarding sources of marine debris, they are 'no regrets' measures with a range of additional benefits. Focus should also be directed on management strategies that deal with debris known to be of high impact on marine species – such as fishing gear, soft plastic and (micro)plastic fragments. The numbers we do have on debris abundance also suggest that prevention must be addressed before removal can be effective.

This report also reviewed the jurisdictional, legislative and financial challenges in the management of marine debris. The jurisdictional challenges relate to the transboundary nature of both marine debris and migratory species. There are a number of relevant multilateral agreements that could provide an adequate framework for tackling marine debris such as

- The Convention on Migratory Species itself,its Family Agreements and MoUs relevant to marine species
- The UNEP Regional Seas Conventions and Action Plans (RSCAPs);
- MARPOL Annex V;
- The London Convention; and
- UNEP's Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities (GPA-Marine).

However each of these has significant gaps in coverage, for example:

- Only around 60% of countries with a coastline are Parties to the Convention on Migratory Species, Family Agreements or MOUs with relevance to a marine species. This leaves many range states for marine migratory species outside the influence of the Convention with regard to marine debris;
- RSCAPs do not cover every marine region, with the South West Atlantic, North West Atlantic and the northerly parts of the Pacific not included. Some of the Regional Seas do not yet have legally binding Conventions detailing how Regional Action Plans will be implemented. Not all countries within RSCAPs have ratified the existing Protocols relevant to marine debris. RSCAPs also do not cover landlocked countries which may be contributing to marine debris via estuarine litter;
- Many countries are not parties to MARPOL Annex V or the London Convention (for more detail, see Report II). These Conventions only address at-sea sources of debris;
- Many countries do not yet have action plans for the implementation of GPA-Marine, which covers land based sources of debris; and
- Addressing marine debris already present in the high seas is outside the scope of any of these agreements, and there are limitations to how effective they are at controlling the activities of flag vessels on the high seas.

With the exception of the high seas, the different agreements are otherwise able to complement each other to provide full coverage of the issue geographically and in terms of sources of debris, but in order to do so they must be ratified by every relevant country.

In terms of the legislature itself, the main problems are that agreements or action plans:

- Are generally not legally binding;

- Often lack specific mention of marine debris; and
- Usually lack a mechanism for enforcement.

Because there are few legally binding instruments regarding marine debris at the national level, enforcement issues are exacerbated.

Financially, the mandatory and voluntary contributions available to conservation-related Conventions are of a scale suitable for supporting strategic actions, such as those covered in the Recommendations below. However, filling knowledge gaps requires sustained concerted effort and funding, and obtaining this kind of funding is in itself one of the greatest conservation challenges. Some suggestions regarding funding sources have been made in Section 6.4.2.

E3.0 Recommendations

The challenges for the management of marine debris are many. The following opportunities for the Convention on Migratory Species to assist in overcoming these have been identified. The recommendations have been prioritized according to the rationale that global frameworks are an important foundation for action, but concrete management actions are needed to reduce impacts of marine debris; Parties to the Convention are the principal actors in this regard and finally, that land based activities are the predominant source of debris.

Parties and Signatories could

- Address their commitments under the Convention relevant to marine debris and/*or* implement relevant provisions of Conservation Plans by:
    - Implementing specific actions directly such as
        - Deposit-refund schemes;
        - Levies on single-use carrier bags;
        - Obligations for the use of reusable items at events; and
        - Marine debris awareness and action campaigns.
    - Engaging with other global marine initiatives such as:
        - GPA-Marine – including completion of GPA-Marine National Plans of Action, and to ensure these have specific mention of marine debris;
        - Regional Seas Programmes – including conclusion of specific Protocols on protection of the marine environment from land-based activities, and completion of Regional Action Plans either containing specific mention of marine debris, or completion of a specific Action Plan exclusively on marine debris;
        - The Global Partnership on Marine Litter (GPML);
        - The Global Partnership on Waste Management (GPWM); and
        - The Honolulu Commitment and the Honolulu Strategy on marine debris.
    - Ratifying other relevant Conventions such as MARPOL Annex V and the London Convention;

- Amend, if necessary, existing Action Plans to make more specific reference to marine debris.
- Appoint a dedicated Councillor for Marine Debris to the Scientific Council.

The Scientific Council, with support from the Secretariat of CMS and where applicable the assistance of the Secretariats and Coordinating Units of relevant Family Agreements and MOUs could:

- Propose that Parties appoint a dedicated Councillor to the Scientific Council and establish a specific marine debris working group to develop the Convention's marine debris work;
- Co-operate with other biodiversity-related agreements such as the UNEP Regional Seas Conventions, the Convention on Biological Diversity or the International Whaling Commission to establish an approach to encourage Parties to tackle marine debris, via an inter-convention working group;

The Secretariat could:

- Expand the network of organisations it works with to include as great a variety of stakeholders with relevance to marine debris as possible. UNEP RSCAPs are a high level example; on a smaller scale field projects could be used to engage with stakeholders of particular relevance to or having particular contact with migratory species;
- Co-ordinate, encourage the creation of, or give endorsement to, marine debris campaigns of specific relevance to migratory species;
- Remind Parties of their commitments under the Convention with relevance to marine debris; i.e. the commitment to conserve habitats and reduce the impacts of activities that endanger species or impede migration;
- Remind MOU Signatories of the elements of agreements they have made relevant to marine debris such as the protection of species and conservation of habitats;
- When future Agreements and Action Plans are developed, encourage that these contain specific reference to marine debris in;
- Endeavour to increase the number of Parties to the Convention, especially coastal nations;
- Strive to ensure that all the countries relevant to Family Agreements and Memoranda of Understanding with relevance to marine species respectively become Parties of or Signatories to these agreements;
- Use all of the fora it participates in to make policy-makers aware that marine debris is an important issue, and therefore:
    - Marine debris should be included in relevant legislation;
    - Funding should be provided for measures; and
    - Enforcement mechanisms should be put in place.

Based on the extensive research conducted outlining what is, and what is not known about marine debris and its impacts on migratory species, the following recommendations were made for opportunities the Convention could assist in regarding filling the identified knowledge gaps.

Parties to the Convention or Family agreements should;

- Participate in marine debris monitoring programmes in the Regional Seas areas; Parties in Regional Seas areas that have not yet assessed current status should be encouraged to implement marine monitoring strategies;
- Plan for and carry out evaluation of any marine debris management strategy undertaken and make the data available to the Secretariat, especially if carried out under the auspices of the Convention or Family Agreements.

Parties to Family agreements could:

- Use National Reporting mechanisms for Family Agreements to return data related to the impacts of marine debris on migratory species relevant to the Agreements;

The Secretariat of CMS could:

- Develop the CMS Initiative on Marine Debris further so it can provide a framework for helping to co-ordinate scientific research programmes on debris and migratory species by;
  - Facilitating the sharing of information relevant to marine debrisand research programmes between Family Agreements;
  - Supporting impact monitoring and its standardization by encouraging cooperation between organizations that carry out this kind of monitoring;
- Support the standardization of monitoring in partnership with the Regional Seas Programmes. IOC/UNEP and Regional Seas guidelines are a good foundation for this standardization. It is important for the management of marine debris and its impacts on marine species that:
  - Both weight and count be recorded;
  - Microplastics monitoring is implemented; and
  - Monitoring of impacts on marine species should be implemented where possible.
- Use the return of information about marine debris under the request to Parties made in CMS resolution 10.4, item 6, as an opportunity to focus attention on, and request data which are deemed necessary in the future;
- Support where possible the development of a relational database to translate information on marine debris into risk presented to wildlife; and
- Support the setting of marine debris targets, which encourages the implementation of monitoring programs. These targets should include targets relating directly to impacts on wildlife.

Secretariats and Coordinating Units of relevant Family Agreements and MOUs could

- Request partner organizations such as NGOs or research groups to give access to much needed data;

As a final and overarching recommendation regarding the issue of marine debris, it is considered very important that CMS Parties or any other stakeholder do not delay actions to prevent debris reaching the marine environment in the first place, while information gaps are filled. Care must be taken to discriminate against strategies and tactics that are ineffectual or counterproductive. However sufficient information is available to be sure that the recommended actions on marine debris will have a positive effect on marine debris and its impacts.

Contents

1.0 Knowledge Gaps in Management of Marine Debris

Marine debris is a global problem with many negative environmental, social and economic consequences. The nature, scale and extent of these impacts are an area of active research and the knowledge serves the purpose of building a solid case for action in addressing marine debris. It also helps to define the action that needs to be taken. The Scientific Council of the Convention on Migratory Species was instructed, in Resolution 10.4 on Marine Debris, to identify knowledge gaps in marine debris management and impacts on migratory species.

The Convention on Migratory Species considers marine debris to include:[1]

> *Any anthropogenic, manufactured or processed solid material, irrespective of its size, discarded, disposed of or abandoned in the environment, including all materials discarded into the sea, on the shore, or brought indirectly to the sea by rivers, sewage, storm water or winds*

This report serves to outline what we know about marine debris and its impacts on migratory species, and what, conversely, represents knowledge gaps in this regard. It also describes challenges in the management of marine debris, and provides recommendations, relevant to the role of the Convention on Migratory Species, for addressing these challenges and filling information gaps.

1.1 Approach

Initially, a brainstorm was carried out for the four properties of marine debris under consideration here – i.e. material, type, source and pathway. This generated lists of the different potential kinds of marine debris. The lists were used as a framework for considering whether there are gaps in our knowledge in respect of any of these properties of marine debris. We also assessed the state of knowledge regarding marine debris in different regions, as defined by the 18 Regional Seas Programme areas.

Regarding the impacts of marine debris on migratory species, a brainstorm was also undertaken, to produce a framework for assessing knowledge gaps. It covered both impacts that could be applicable to marine mammals generally, as well as those that were hypothesised to be more specific to migratory species.

With these frameworks in mind, a literature review was undertaken to outline the current state of knowledge regarding these areas. Internet searches were conducted (using Google) to reveal grey literature such as reports and information on websites. Web of Science and Google Scholar were used to make more specific searches in the academic literature regarding particular topics, especially regarding impacts on migratory species. Information on migratory species was provided by CMS and also

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[1] UNEP, and CMS (2011) Resolution 10.4 Marine Debris. UNEP/CMS/Resolution 10.4

obtained from the IUCN Redlist. Literature recommendations were collated from the client and the collaborator's prior knowledge and references pursued from the bibliographies of already identified references ("snowballing"). No limitations were placed on literature in terms of date or amount of quantitative information.

Information on management approaches was gathered in the same way.

2.0 Origins and Pathways

There are little to no empirical data on the quantity of marine debris in or entering the marine environment. Early estimates from the National Academy of Sciences (NAS) put the influx at approximately 6.4 million tons annually.[2] This estimate was derived from the amount of waste generated from ocean vessels (i.e. maritime sources alone), prior to MARPOL Annex V which prohibits and restricts the dumping of garbage at sea, coming into force in 1988.[3] Therefore this may now be an overestimate of maritime sources of waste, although an increase in maritime traffic in the intervening period may counterbalance any overestimation. Also, between 80-90% of marine debris is thought to originate from land-based sources,[4,5] and post-consumer waste has increased markedly since 1975 when the estimate was made by the NAS. Even single events can cause dramatic point-source increases of a comparable magnitude, such as the 2011 Japanese tsunami which created an estimated 1.5 million tons of floating debris.[6] Therefore there are potentially very large quantities of debris still entering the ocean every year from both at sea sources such as marine vessels, and land-based pathways with vectors such as rivers, tides and the wind carrying away waste that is not adequately controlled.

Debris accumulates in five main oceanic gyres, and gathers in drift lines and convergence zones, which are also important feeding areas for many oceanic species, such as sea birds, pelagic fish and sea turtles.[7]

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[2] National Academy of Sciences (1975) *Assessing Potential Ocean Pollutants: A Report of the Study Panel on Assessing Potential Ocean Pollutants to the Ocean Affairs Board, Commission on Natural Resources, National Research Council.*, 1975

[3] http://www.imo.org/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-%28MARPOL%29.aspx

[4] Faris, J., and Hart, K. (1994) Seas of Debris: A Summary of the Third International Conference on Marine Debris: A Summary of the Third International Conference on Marine Debris

[5] Equating the classes "Shoreline & recreational activities", "Smoking related litter", "Dumping" and "Medical/Hygiene" summed together to land based sources. Ocean Conservancy 2012 Data Release, CSV files http://www.oceanconservancy.org/our-work/international-coastal-cleanup/2012-ocean-trash-index.html

[6] NOAA (2013) *Japan Tsunami Debris FAQs*, accessed 5 November 2013, http://marinedebris.noaa.gov/tsunamidebris/faqs.html

[7] Lebreton, L.C.-M., Greer, S.D., and Borrero, J.C. (2012) Numerical modelling of floating debris in the world's oceans, *Marine Pollution Bulletin*, Vol.64, No.3, pp.653–661

2.1 Marine Debris – Sources and Pathways

2.1.1 Sources

Many different classifications of sources exist within marine debris monitoring programs, and these classifications define what information is available about prevalence. The only global monitoring program that has a standardized data recording method is the International Coastal Clean-up (ICC), which has been coordinated internationally by the Ocean Conservancy (a US environmental advocacy group) since 1989. The ICC categorizes debris items into five sources:[8]

- Shoreline & Recreational Activities – e.g. food-related litter, plastic and paper bags, clothing, shoes, toys, shotgun shells;
- Ocean/Waterway Activities – e.g. bait containers, strapping bands, tarps and plastic sheeting, pallets, nets, line, rope, and traps, light bulbs, oil bottles, cleaner bottles, fishing lures;
- Smoking-Related Activities – e.g. filters, lighters, tobacco packaging
- Dumping Activities – e.g. appliances, batteries, building materials, car parts, drums, tyres; and
- Medical/Personal Hygiene – e.g. condoms, diapers, syringes, tampons/applicators.

Worldwide prevalence from the different sources is presented in Table 1. On the whole, shoreline and recreational activities are the source of most debris (65%), with smoking- related activities making the next largest contribution (22%).

Table 1: Prevalence of Litter Items by Source (based on item counts)

Sector	Prevalence of items by source
Shoreline & Recreational Activities	65%
Ocean/Waterway Activities	9%
Smoking-Related Activities	22%
Dumping Activities	2%
Medical/Personal Hygiene	2%

Source: The Ocean Conservancy 2012 The Ocean Trash Index

Ocean/waterway activities on average appear to be contributing only 9% to the total debris count. This is of note given that fishing equipment is so prevalent, apparently disproportionately so, when it comes to impacts on marine species (see Section 3.0). It is important to bear in mind however that these data are mostly derived from beach clean-ups, with surveys under the waterline/by watercraft making up only 6% of the

[8] Ocean Conservancy (2012) *The Ocean Trash Index - Results of the International Coastal Cleanup (ICC)*, 2012, http://www.oceanconservancy.org/our-work/marine-debris/2012-icc-data-pdf.pdf

distance covered by the surveys.[9] This will affect the debris composition recorded and hence the prevalence of different sources of litter.

Regionally, further distinctions can be made (Table 2) although the overall pattern of waste source is similar across most regions. Items categorized under 'shoreline and recreational activities' are most common in the Western Africa Region at 82% and least common in the Black Sea Area (16%). By contrast the Black Sea Area is the most afflicted by smoking-related litter (80%), while the least affected is the Western Africa Region. The North West Pacific and the North East Atlantic have the highest proportions of ocean and waterway activity derived debris. For dumping activities, the South East Pacific is the worst afflicted (9%), while the Black Sea is the least (<1%). And for medical/personal hygiene items, the East Asian Seas, the Red Sea Area and Gulf of Aden Region and the South East Pacific are the worst affected.

Table 2: Sources of Marine Debris by Region

RSCAP	Shoreline & Recreational Activities	Ocean/ Waterway Activities	Smoking-Related Activities	Dumping Activities	Medical/ Personal Hygiene
Baltic Sea	57%	3%	38%	3%	0%
Black Sea	16%	2%	80%	0%	1%
Caspian Sea	52%	3%	44%	2%	0%
East Asian Seas	63%	18%	12%	1%	6%
Eastern African Region	77%	12%	8%	2%	1%
Mediterranean	31%	5%	62%	2%	1%
North-East Atlantic	55%	20%	23%	2%	1%
North-East Pacific	74%	5%	19%	1%	1%
North-West Pacific	55%	22%	20%	3%	0%
Pacific	59%	6%	32%	2%	1%
Red Sea & Gulf of Aden Region	71%	12%	13%	1%	3%
ROPME Sea Region	63%	11%	21%	4%	2%
South Asian Seas	70%	13%	14%	2%	2%
South East Pacific	67%	11%	11%	9%	3%
Western Africa Region	82%	11%	5%	1%	1%
Wider Caribbean	67%	5%	25%	2%	1%
Grand Total	64%	7%	26%	2%	1%

Source: The Ocean Conservancy 2012 The Ocean Trash Index.

[9] 1,119 miles out of a total of 17,719 miles. Ocean Conservancy (2012) *The Ocean Trash Index - Results of the International Coastal Cleanup (ICC)*, 2012, http://www.oceanconservancy.org/our-work/marine-debris/2012-icc-data-pdf.pdf

Another informative way of categorizing debris by source is by defining it simply as derived from land-based versus sea-based sources. As discussed in the introductory Section (2.0), approximate global proportions, of which there are few estimates, are given as 80-90% coming from land-based sources. In terms of regional distinctions, from this dataset, if we consider shoreline, smoking, dumping and medical waste as land-based, the area with the lowest proportion of land-based debris is the North West Pacific at 78%, and the highest is the Black Sea, with 98%. This range shows how predominant land activity derived debris is likely to be. However there are many items which could in theory be scored against more than one source category, so this should be taken into consideration when interpreting these data; the proportion of land derived debris is likely to be overestimated to a moderate extent because of this. Some of the item types within this category could conceivably be sourced from passenger shipping, other commercial shipping or recreational boating, for example. In the US, the National Marine Debris Monitoring Program (NMDMP) recognized this by assigning their 31 indicator items into three categories – sea-based, land-based and general, the general category including mostly packaging. The resultant split from 2007's data was 49% land-based, 33% general and 18% sea-based, which gives an indication as to the extent to which the ICC figures for land-based debris are maxima.[10] For example, if the assumption was made that half of the items in the general category are actually land-based and half sea-based, the proportion of land-based to sea-based debris would be 64% and 38% respectively.

The ICC scoring method, because it is based on the attribution of item types to sources, has limitations regarding the information it can provide about the sources of marine debris. The choice of item type and its attribution will cause some sources to be underestimated or neglected, and others to be overestimated. Because it does not (and cannot) include all item types (e.g. plastic pellets), it cannot estimate the contribution of the corresponding source to marine debris (the manufacturing industry). There are also many items that it does not consider because it is difficult to assign them exclusively to one particular source. An example is plastic sheeting, which might derive from the agricultural sector as covering for polytunnel greenhouses, from use as tarpaulins from commercial shipping or fishing activities, or as covering for building materials in the construction industry. Many items types it does consider could derive from multiple sources. There will always be limitations to the extent to which it is possible to assign items to a source.

An interesting methodology to overcome the limitations of marine litter monitoring methods as regards determination of source was used in a pilot study for the European Commission. The aim was to determine points at which plastic waste was escaping legitimate management systems in the EU through a mixture of workshops and interviews with stakeholders in Member States and data modelling.[11] Fifteen

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[10] Ocean Conservancy, and Sheavley (2007) *National Marine Debris Monitoring Program - Final Program Report, Data Analysis and Summary*, 2007

[11] Arcadis (2012) *Case studies on the plastic cycle and its loopholes in the four European regional seas areas*, Report for DG Environment, 2012

different sectors were identified, contributing to marine debris via 27 different pathways and five different vectors. The 15 sectors were:

- Agriculture;
- Aquaculture;
- Construction and demolition (C&D);
- Coastal/Beach Tourism;
- Dump sites/landfills;
- Fishing;
- General Household;
- Other industrial activities;
- Other maritime industries;
- Ports;
- Recreational Boating;
- Recreational Fishing;
- Sewage;
- Shipping; and
- Waste collection/treatment.

A set of assumptions was made about the probability that a particular item type is associated with each sector. This was used to relate item types as recorded by local marine litter monitoring schemes to the 15 sources. The probabilities were informed by OSPAR 'indicator-item' types (which are considered to be attributed to certain sources) as well as interview/workshop information to help validate the assumptions made about the probabilities. The result was a semi-quantitative framework allowing attribution of litter types to sources and hence the determination of the contribution of different sources to marine litter, as presented in Table 3. Only the four categories that together accounted for most of the debris (>90%) are shown).

Table 3: Marine Debris by Source, presented as ranges across four EU locations. Regional Sea Area represented by each location in brackets.

Sector	Oostende (North Sea)	Barcelona (Medite-rranean)	Riga (Baltic Sea)	Costanta (Black Sea)
Recreation and tourism	39%	41%	34%	59%
Sewage	1%	26%	29%	0.3%
Waste Collection/Treatment/Landfill/Household	10%	17%	19%	28%
Shipping, fisheries	41%	10%	12%	8%

Source: Arcadis (2012) *Case studies on the plastic cycle and its loopholes in the four European regional seas areas*, Report for DG Environment, 2012

This method suggests that in the North Sea, ocean/waterways activities are responsible for more debris (41%) than perhaps suggested by the ICC results (20% for the North East Atlantic). It ascribes much higher proportions of debris to the Sewage Sector for the Mediterranean and Baltic (26 and 29% respectively) than the ICC results (1 and 0% respectively). Also it allows attribution to the Waste Management Sector, which is a quite significant proportion, at 10-28%. The comparison between the two methods demonstrates what a difference different methodologies – i.e. item types and attributions – make to estimates of source and hence what we assume about the relative importance of different sources.

An overview of Regional Seas reports catalogued major sources of marine litter.[12] The list is reproduced below and features an even more detailed breakdown than the above. Aside from the approaches used above to attribute item types to the categories, much of the information that exists about these sources is simply related to reports that support the fact that they exist, or anecdotes, with scarce quantitative information, or simply 'common sense' about what is possible and likely. This list does not distinguish source (as in sector of society/industry) and pathway (means by which debris reaches the ocean).

- Land based sources:
    - Wastes from legal and illegal dumpsites located on the coast or river banks;
    - Rivers and floodwaters;
    - Industrial outfalls;

[12] UNEP (2009) *Marine Litter - A Global Challenge*, April 2009, http://www.unep.org/pdf/unep_marine_litter-a_global_challenge.pdf

    - Discharge from storm water drains;
    - Untreated municipal sewerage;
    - Littering of beaches and coastal picnic and recreation areas;
    - Tourism and recreational use of the coasts;
    - Fishing industry activities;
    - Ship breaking yards; and
    - Others
- Sea based sources:
    - Shipping;
        - Merchant;
        - Public transport;
        - Pleasure;
        - Naval;
        - Research;
    - Fishing;
        - Vessels;
        - Angling;
        - Aquaculture;
    - Offshore mining and extraction;
        - Vessels;
        - Offshore platforms;
    - Authorized and unauthorized dumping at sea;
    - Fishing gear (ALDFG);
    - Illegal, unreported and unregulated fishing activities; and
    - Tsunamis, hurricanes and other natural disasters.[13]

Disparate information was found regarding a number of sources of marine debris, and this is provided below. At the very least, this provides evidence that these sectors contribute to marine debris (which the above methods are mostly not taking into account, or considering as separate categories), and therefore provides useful information. Global estimates of absolute amounts are few and far between, and are often outdated. Generally the information found does not allow either the absolute or

[13] Thompson, R., Moore, C., Andrady, A., Gregory, M., Takada, H., and Weisberg, S. (2005) New Directions in Plastic Debris, *Science*, Vol.310, No.5751, pp.1117–1117

relative contribution of a sector to be determined, whether global estimates or regional distinctions.

- Agricultural activity – Around 75% of material by weight found in the stomach of a stranded Sperm Whale in the Mediterranean was estimated to come from coastal greenhouse agriculture (prevalent in the region), with plastic sheeting, rope, plastic burlap sacking, plastic mulch, hosepipe and plant pots all prominent items.[14]
- Aquaculture – In some areas of the South East Pacific, debris mainly comes from aquaculture activities, so the Chilean government added regulations to laws governing fishing and aquaculture assigning responsibility to centres of aquaculture for keeping adjacent waters litter-free, and requiring aquaculture centres to use flotation systems that avoid the release of styrofoam fragments[15]
- Coastal landfill sites – in the UK, there are 184 current and 1561 historic landfills in the coastal flood zone.[16] It is likely that worldwide, there are many landfills that risk creating debris either through coastal erosion, or via poor containment and wind-blown debris. However the size of this problem is not quantified. Perhaps Arcadis' estimation of the contribution of debris derived from Waste Collection/Treatment/Landfill/Household for the four EU regions as 10-28% represents a maxima for the size of this problem in this region.
- Construction –The ICC debris counts scores building materials (such as siding, shingles, lumber, bricks, roofing material, rebar) as 1.4% of the number of items of debris collected, suggesting a figure for the contribution of this sector to the marine debris problem. It is unknown whether plastic items such as fencing or piping are included, so this may be an underestimate. However this method does not allow correct attribution to erosion and wave damage to property versus poorly contained materials or waste on building sites or dumping by the industry; this may mean that it is an overestimate.
- Fishing - There is some quantitative evidence regarding the number of fishing nets, line or traps lost for at least nine Regional Sea Areas.[17] The data available are however very fragmented. One estimate was found of 135,400 tons of plastic fishing gear and 23,600 tons of packaging material from the

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[14] de Stephanis, R., Giménez, J., Carpinelli, E., Gutierrez-Exposito, C., and Cañadas, A. (2013) As main meal for sperm whales: Plastics debris, *Marine Pollution Bulletin*, Vol.69, No.1–2, pp.206–214

[15] Núñez, P., Pacheco, A.S., and Vásquez, N. (2011) Anthropogenic litter in the SE Pacific: an overview of the problem and possible solutions, *Revista Da Gestão Costeira Integrada*, Vol.11, No.1, pp.115–134

[16] CIRIA (2013) *Guidance on the management of landfill sites and land contamination on eroding or low-lying coastlines*, Report for Defra and the Environment Agency, 2013

[17] Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for WSPA, 2012, http://www.wspa-international.org/Images/Untangled%20Report_tcm25-32499.pdf

fishing industry dumped into the sea in 1975. [18,19] No robust global estimate exists of total amounts.

- Industrial processing – It is evident that pre-processing plastic pellets do escape the manufacturing cycle. Some surveys have put the prevalence of pellets as high as 10% of small plastics sampled.[20] However this is subject to wide variation depending on the location. For example, on the Belgian coast, the prevalence of pellets was low except in harbour areas, suggesting also that shipping of raw materials is a source here too.[21]
- Medical sector– we can infer from items recorded in (e.g., the ICC clean-ups) that medical waste does find its way into the oceans, and the proportion of debris that comes from this source (0.1%). However it may be a step too far to attribute medical debris to the hospital sector in particular. In one example, the "Syringe Tide" that affected New Jersey and New York in the late '80s, was traced to improper waste management at the Fresh Kills Landfill on Staten Island.[22] This illustrates the difficulty with making assumptions regarding source from item type alone.
- Military activity – There are many marine sites historically used for dumping military waste such as munitions, constituting hundreds of thousands if not millions of tonnes of debris. The fate and movement of this kind of debris is unknown but natural disasters such as tsunamis may increase the distribution of debris of this nature.[23]
- Nuclear sector – prior to international treaties banning ocean dumping, thirteen countries used ocean disposal as a method for dealing with radioactive waste, both spent fuel, contained and uncontained, and parts of reactors. This is likely to have been at least hundreds of thousands of tons of material.[24]

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[18] Goldberg, E.D. (1997) Plasticizing the Seafloor: An Overview, *Environmental Technology*, Vol.18, No.2, pp.195–201

[19] Derraik, J.G. (2002) The pollution of the marine environment by plastic debris: a review, *Marine Pollution Bulletin*, Vol.44, No.9, pp.842–852

[20] McDermid, K.J., and McMullen, T.L. (2004) Quantitative analysis of small-plastic debris on beaches in the Hawaiian archipelago, *Marine Pollution Bulletin*, Vol.48, No.7–8, pp.790–794

[21] Claessens, M., Meester, S.D., Landuyt, L.V., Clerck, K.D., and Janssen, C.R. (2011) Occurrence and distribution of microplastics in marine sediments along the Belgian coast, *Marine Pollution Bulletin*, Vol.62, No.10, pp.2199–2204

[22] http://en.wikipedia.org/wiki/Syringe_Tide

[23] Stauber, R. (2011) Research effort to document military munitions disposal sites worldwide, *Technical Proceeding of the 5th International Marine Debris Conference* (2011) and http://www.globalissues.org/news/2011/04/14/9280

[24] IAEA (1999) *Inventory of Radioactive Waste Disposals at Sea*, 1999, http://www-pub.iaea.org/MTCD/Publications/PDF/te_1105_prn.pdf

- Recreational vessels vs naval vessels - Recreational vessels were considered to be the source of 52% of all rubbish and U. S. Naval vessels responsible for around 20%, according to an estimate made around 1994.[25,26]
- Shipping – although detailed statistics are not kept, the World Shipping Council made an estimate, based on industry interviews, of 675 containers being lost per year on average, out of 100m containers transported per year.[27] Other figures of 2,000-10,000 containers are popularly cited but it has not been possible to substantiate these. In 1982 it was estimated that 639,000 plastic containers were dumped by merchant ships each day. [28,29] The ICC's 9% for debris relating to 'ocean/waterway activities' is potentially an overestimate because it includes all marine activity such as fishing, yet may by contrast be an underestimate because it is unlikely to include cargo.
- Water treatment sector – Untreated sewage may get into waterways via combined sewage overflows or incorrectly connected plumbing.[30] There are also many places in the world where there is no sewage treatment. However it is not clear what percentage of wastewater this applies to. It is not just untreated sewage that is potentially a source of marine debris. Treated sewage may also be contributing to debris entering the marine environment, simply because treatment is unable to capture all the relevant material. One example is clothing fibres derived from washing clothes, which were determined by one study as a dominant source for the microplastic particles sampled.[31] Microplastic particles in exfoliants or cleaning agents can also get into the water system via legitimately treated sewage, though there is no systematic monitoring in this regard.[32] Another source of marine debris identified from sewage treatment is the accidental release of sewage discs (used to increase the surface area for treatment bacteria to grow on) from plant discharge outlets. In Hooksett, New Hampshire, up to 8 million plastic

[25] Goldberg, E.D. (1997) Plasticizing the Seafloor: An Overview, *Environmental Technology*, Vol.18, No.2, pp.195–201

[26] Derraik, J.G. (2002) The pollution of the marine environment by plastic debris: a review, *Marine Pollution Bulletin*, Vol.44, No.9, pp.842–852

[27] World Shipping Council (2011) Containers Lost at Sea

[28] Goldberg, E.D. (1997) Plasticizing the Seafloor: An Overview, *Environmental Technology*, Vol.18, No.2, pp.195–201

[29] Derraik, J.G. (2002) The pollution of the marine environment by plastic debris: a review, *Marine Pollution Bulletin*, Vol.44, No.9, pp.842–852

[30] http://www.theguardian.com/environment/2013/jul/07/england-polluted-beaches-tide-of-filth

[31] Browne, M.A., Crump, P., Niven, S.J., Teuten, E., Tonkin, A., Galloway, T., and Thompson, R. (2011) Accumulation of microplastic on shorelines worldwide: sources and sinks, *Environmental Science & Technology*, Vol.45, No.21, pp.9175–9179

[32] Fendall, L.S., and Sewell, M.A. (2009) Contributing to marine pollution by washing your face: Microplastics in facial cleansers, *Marine Pollution Bulletin*, Vol.58, No.8, pp.1225–1228

discs were released.[33] Two other incidents were also identified, in Groton, Connecticut (a million discs released)[34] and Mamaroneck (New York).[35] Another example is cotton bud sticks – treatment plant filter mesh size is inadequate to stop all of them.[36] Cotton bud sticks are an item type not scored by the ICC, yet have been shown to be a significant item in surveys in the North-East Atlantic and the Mediterranean where they are a counted item type (in OSPAR and MAP litter surveys).[37] Microplastics are also not scored by the ICC. This shows the types of knowledge gaps that can arise simply as a result of scoring methodology. The relevant ICC category (medical/personal hygiene) may therefore be underestimating the extent of the contribution of this sector to marine debris.

The remainder, which the project team hypothesised were significant sources, but for which no specific information was found, are as follows:

- Beach establishments and coastal hotels – items that would be generated by this sector are likely to be included within 'Recreational and shoreline activities' in the ICC monitoring scheme – yet it is not clear whether they are responsible for a significant proportion of these.
- Informal Waste Sector – in many countries, informal waste operatives contribute significantly to waste management. Whether there are practices in this sector that make the creation of marine debris more likely, such as lack of containment, is unknown, and their general contribution to marine debris, likewise. This however is unsurprising given that even the relative size of this sector globally represents an unknown.[38]
- Industrial outfall – the identification of 'Taprogge balls', small abrasive sponges used for cleaning pipes in power stations and other industrial systems, in marine debris is evidence that this sector is a source of marine debris; though there is no measure of how significant this source is globally.[39]
- Off-shore platforms – no information was found in this regard.
- Passenger vessels – Cruise ships generate a large amount of waste (see Report II) which is likely to be similar in type to household waste. It therefore

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[33] http://www.gloucestertimes.com/local/x814643010/City-advances-sewage-disc-cleanup/print

[34] http://www.nashuatelegraph.com/news/913108-196/disks-in-the-river-wasted-material.html

[35] http://theloopny.com/blog/news/larchmont-beach-mystery-once-hit-block-island/

[36] Berkley, C., and ENCAMS (2007) *Sewage related litter: flushing toilets onto beaches : research report*, 2007

[37] InterSus, University of Trier, Milieu, UBA, and COM (2013) Issue Paper to the 'International Conference on Prevention and Management of Marine Litter in European Seas'

[38] Lange, U., and Linzner, R. (2013) Role and size of informal sector in waste management – a review, *Proceedings of the ICE - Waste and Resource Management*, Vol.166, No.2, pp.69–83

[39] http://www.sas.org.uk/campaign/ufos/

will not feature in the attributions made by the ICC and so the amount of debris generated by passenger ships remains an unknown quantity.

- Ports and harbours – Although it is logical that ports and harbours can be a source of debris, most work so far has been in evaluating the costs of debris to them.[40] Also, it is difficult to see how waste sourced from ports and harbours could be differentiated from ocean/waterway activity type waste, so litter counts are not going to be able to provide information about this.
- Recreational Angling – a US based initiative for collecting and recycling monofilament line from marinas, camps and boating access points has processed 9 million miles of line since 1990, indicating how much might otherwise be ending up in the environment. There are several examples of campaigns targeting anglers, which is evidence that this is considered a significant source of debris.[41] However there is no way of quantifying this via the monitoring currently undertaken.
- Shipbreaking yards – South East Asia has a growing ship-breaking industry and there is concern at the marine debris this generates.[42] One study examined microplastics found adjacent to a shipbreaking yard, but it is not clear what sort of contribution ship-breaking yards are making to marine debris in quantitative terms.[43] Whether other types of scrapyard that happen to be located coastally make significant contributions to debris is unknown.

2.1.2 Pathways

Various different pathways exist by which debris is released into the marine environment. Evidence for them tends to be anecdotal or qualitative, so it is difficult to determine how prevalent the different mechanisms are. Below we summarize the main pathways and information available about them, or rather lack thereof. We also give a selection of miscellaneous pathways for which there is evidence. We then consider what constitutes the knowledge gaps for this topic.

An overview of Regional Seas reports characterized the major pathways by which marine litter was considered to find its way into the sea. The resulting list was as follows:[44]

- Negligent – Loss;

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[40] KIMO (2000) *Impacts of Marine Debris and Oil: Economic and Social Costs to Coastal Communities*, 2000

[41] NOAA (2007) Reeling In Marine Debris - A Reference Guide to Recycling Monofilamnet Fishing Line

[42] UNEP (2009) *Marine Litter - A Global Challenge*, April 2009, http://www.unep.org/pdf/unep_marine_litter-a_global_challenge.pdf

[43] Reddy, M.S., Basha, S., Adimurthy, S., and Ramachandraiah, G. (2006) Description of the small plastics fragments in marine sediments along the Alang-Sosiya ship-breaking yard, India, *Estuarine, Coastal and Shelf Science*, pp.656–660

[44] UNEP (2009) *Marine Litter - A Global Challenge*, April 2009, http://www.unep.org/pdf/unep_marine_litter-a_global_challenge.pdf

- Negligent - System failures;
- Negligent - Outdated and inadequate waste management practices; and
- Intentional - Public behaviours leading to illegal waste disposal/indiscriminate littering and dumping.

Vectors can also be considered

- Human - By direct dumping;
- Water - Transported by storm water, via drains and rivers towards the sea; and
- Wind - Blown into the sea.

No quantitative information is provided in the report. Clearly part of the difficulty is that establishing pathway is not easy and each category given above, for example, cuts across many sectors and will have a huge range of point sources and possible pathways that fall within those broad categories. There can only be very disparate information available for each one and many different types of research projects would be needed to provide the necessary data. We are not aware of any major monitoring program or standardized methodology for determining the amounts of material travelling via these pathways or vectors.

The modelling approach taken within the EU by Arcadis (2012) concluded that for areas representing the Baltic, the Mediterranean and the North Sea, only around 40% of litter could possibly represent accidental loss, while for the Black Sea region, this went down to 17%. According to these numbers, this means that most debris in all areas derives from intentional littering or dumping, with the Black Sea being the poorest in that regard. This modelling approach perhaps represents the only effort to establish relative contributions of pathway that we are aware of.

In addition, we found some evidence for the following potential pathways for debris to make its way into the ocean.

- Negligent - Loss/Intentional - Illegal: Commercial Fishing activity

The UNEP/FAO report into abandoned, lost or discarded fishing gear noted that there were many factors contributing to gear loss, including the intentional, such as lack of convenient shoreside disposal leading to at sea dumping, and aggravating factors in unintentional loss such as poor weather, illegal fishing, and operational incidents such as snagging on the sea bed or on debris, tangling of lines, gear conflict, gear failure and discards from repair. The pathways were different for each fishery.[45] Therefore aside from indications from the litter counts (overall 9% debris from ocean related activities), there are no estimates of the relative contributions of the different pathways in the fishing industry. Specific examples of particular relevance to marine species are as follows.

Sections of fishing net that are damaged are sometimes temporarily repaired with contrasting coloured twine (to allow easy relocation of damaged area when the net is

[45] UNEP, and FAO (2009) *Abandoned, Lost or Otherwise Discarded Fishing Gear*, 2009

retrieved). During subsequent permanent repair, the damaged areas are cut out in a square; Zavadil et al's 2007 study of entangled Northern Fur Seals (*Callorhinus ursinus*) in Alaska, draws attention to the fact that over the years, these two-colour net fragments have been retrieved repeatedly. Anecdotal evidence suggests that net fragments left on deck after mending are easily swept overboard, or may be discarded at sea, in contravention of MARPOL Annex V. Net with large ragged holes or hand stitched repairs was also noted in the stomach contents of Sperm Whales.[46]

A recognized pathway via which seabirds ingest fishhooks is via the eating of offal from fishing boats (particularly that from longline fishing) containing discarded hooks.[47]

- Negligent – Loss: Wreckage and cargo

UNESCO estimated that there are 3m shipwrecked vessels lying on the seabed.[48] A number of this magnitude suggests they could be a considerable source of debris. When the Concordia, a cruise ship, grounded off the coast of Tuscany in 2012, the debris that was produced from the ship's contents gradually floating away was considerable enough that it was requested that a plan be drawn up to manage it.[49] The evidence related to lost cargo is provided in Section 2.1.1

- Negligent - System failures: Sewage treatment and industrial outfalls

Examples of these types of losses might include the ones mentioned above relating to the inability of the water treatment system to deal with microplastics and other items; and incidents such as the loss of sewage treatment discs or pipe cleaning balls. There is no centralised source of information about these kinds of outfalls globally.

- Negligent - Outdated and inadequate waste management practices: lack of formal waste management

A UN report states that half the refuse generated in urban areas is uncollected in developing countries.[50] Where urban centres are close to the coast, this represents a risk for the production of marine debris. It was not possible to find any further analysis of the amount of solid waste generated on coastlines and the percentage covered by formal waste management.

- Negligent - Outdated and inadequate waste management practices: Disposing of solid waste down toilets

A survey in the UK revealed that 57% of the population had disposed of solid items down the toilet in the past year, which, given the significant contribution of sewage

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[46] Jacobsen, J.K., Massey, L., and Gulland, F. (2010) Fatal ingestion of floating net debris by two sperm whales (Physeter macrocephalus), *Marine Pollution Bulletin*, Vol.60, No.5, pp.765–767

[47] UNEP, and FAO (2009) *Abandoned, Lost or Otherwise Discarded Fishing Gear*, 2009

[48] http://www.unesco.org/new/en/culture/themes/underwater-cultural-heritage/the-underwater-heritage/wrecks/

[49] http://blog.marine-conservation.org/2012/01/debris-from-costa-concordia-wreckage.html

[50] UN Habitat (2010) *Collection of Municipal Solid Waste in Developing Countries*, 2010

and medical related items to marine debris, gives an indication of part of the pathway via which they tend to reach the sea.

- Intentional - Public behaviours leading to indiscriminate littering

No quantitative statistics exist on littering in terms of the amount of material generated by this behaviour. Inferences can be made based on the frequencies of typically littered items, and that is the basis of the estimation of marine debris generated from shoreline and recreational activities by the ICC; the item types also would likely cover estuarine litter from inland sources too. The proportion was estimated as 65%. One might assume that most of the items counted constitute litter rather than accidentally lost items; the figure could be viewed as a maxima of the contribution of public littering to marine debris.

- Intentional: Release of items into the sky

Weather balloons have recently received recognition as a potentially significant source of marine debris. In Australia, an estimated 68 weather balloons are released every day in coastal regions; if half ended up in the ocean, it would equal 12,410 per year.[51] In the UK, the RSPCA and MCS have released statements regarding the danger of balloons to wildlife.[52,53] They point out the scale of the problem – in the US, the largest balloon release was 1.5 million balloons; in the UK, the number of balloons found on beaches has increased three-fold in 10 years.

The following information was found regarding vectors:

- Water - Transported by storm water, via drains and rivers towards the sea

There is scattered estuarine monitoring data. For example, after one storm, 81g/m^3 of plastic debris was recorded in storm water running from the land to the sea, and this was considered a major vector for marine debris as a result.[54] In California, Total Maximum Daily Loads (TMDL) are being established for river pollutants including rubbish; one study measured litter loadings in run off after storms as between 3 and 17 kgs per hectare of catchment area, in order to provide information for the setting of these TMDLs for litter.[55] Another instance of water as a vector was the Japanese

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[51] O'Shea, O.R., Hamann, M., Smith, W., and Taylor, H. (2014) Predictable pollution: An assessment of weather balloons and associated impacts on the marine environment – An example for the Great Barrier Reef, Australia, *Marine Pollution Bulletin*

[52] RSPCA (2005) Wildlife factsheet: Balloon Releases

[53] Marine Conservation Society (2006) What happens to balloons after they are released?

[54] Ryan, P.G., Moore, C.J., Franeker, J.A. van, and Moloney, C.L. (2009) Monitoring the abundance of plastic debris in the marine environment, *Philosophical Transactions of the Royal Society B: Biological Sciences*, Vol.364, No.1526, pp.1999–2012

[55] Kim, L.-H., Kayhanian, M., and Stenstrom, M.K. (2004) Event mean concentration and loading of litter from highways during storms, *Science of The Total Environment*, Vol.330, No.1–3, pp.101–113

tsunami of 2011, which was estimated to have deposited 1.5m tonnes of marine debris in the ocean.[56]

- Water – Coastal Erosion

There are no data available on this, save for the indirectly informative information about coastal landfill sites in the UK discussed above. To what extent coastal erosion leads to debris via its action on coastal property or developments is not known. Coastal erosion is expected to increase as a result of climate change and resultant sea level rise and increased extreme weather events.[57]

- Human – by direct dumping

One significant example found was disposal of vessels and platforms at sea. Disposal of vessels and platforms at sea is permitted by the Protocol to the London Convention, given the satisfaction of various criteria and the granting of a permit. In the US, a general permit from the EPA allows ex-naval vessels to be sunk to provide target practice for the military as well as a method of disposal for the ships – this is the SINKEX navy program.[58] In the past 10 years 70% of all naval vessel disposals were carried out in this way. Thousands of other items such as cars, buses, train carriages, tyres, tanks and oil rigs have also been disposed of under permit from the EPA, even though it is acknowledged that these items can contain asbestos, PCBs and lead. This neglects obligations under international law. The sheer scale of this type of dumping suggests it may be a significant source of marine debris.

According to the US Coast Guard Office of Compliance, the Marine Pollution Act (MARPOL) does not regulate the disposal of fiberglass wrecks at sea. Although MARPOL (1) considers fiberglass as plastic because of the resin in it and (2) makes it illegal to dump plastic anywhere in the ocean, the disposal of fiberglass hulls at sea is not prohibited by this act because MARPOL applies only to "shipboard-generated garbage."[59]

It was not possible to find global figures of how many vessels are dumped using these exceptions and omissions.

The ICC makes its estimate of the contribution of dumping to marine debris (2%) via the monitoring of indicator item types such as car parts, tyres, building materials, drums and appliances. Illegal dumping however encapsulates a broader range of items including general household waste that would not really be accounted for by the indicator item types, as well as the type of vessel, vehicle and platform dumping

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[56] NOAA (2013) *Japan Tsunami Debris FAQs*, accessed 5 November 2013, http://marinedebris.noaa.gov/tsunamidebris/faqs.html

[57] Zhang, K., Douglas, B.C., and Leatherman, S.P. (2004) Global Warming and Coastal Erosion, *Climatic Change*, Vol.64, No.1-2, pp.41–58

[58] BAN (2011) *Dishonorable Disposal - The Case Against Dumping U.S. Naval Vessels at Sea*, 2011, http://ban.org/library/Dishonorable%20Disposal_BAN%20Report.pdf

[59] http://www.epa.gov/region2/water/oceans/wrecks.htm#Fiberglass

described above. Therefore the estimate of 2% may well be an underestimate of the contribution of illegal dumping to marine debris. Data regarding illegal dumping generally are not easy to obtain and it is likely that only a fraction of countries keep records of it. In the UK, local authorities reported 744,000 incidents of illegal dumping in 2011/2012, two-thirds of which involved household waste.[60] 1,885 (0.25%) were recorded in watercourses and 25,255 (3.5%) in the 'other' category, which includes sea-fronts and harbour mouths.[61] However although this shows that this is very likely a pathway for marine debris, making estimates of the relative contribution of illegal dumping to marine debris is very difficult.

- Wind

It is not difficult to imagine why there is little information on wind as a vector for marine debris, given the sheer number and geographical spread of point sources it could be affecting. Wind features in a number of reports about possible vectors for marine debris but there has been no monitoring found.

We conclude that there is some disparate data available about pathways, but it is not enough to integrate into a very coherent picture of the most significant ways that debris is reaching the sea either globally or in different regions.

2.2 Marine Debris – Types and Prevalence

2.2.1 Material

The availability of robust, comparable data on the prevalence of material types in marine debris is limited by the fact that not every survey methodology completely categorizes items by material. Furthermore, some items are of mixed materials and therefore defy straightforward categorization. As plastic is very much the predominant material type, sometimes scoring even only takes the form of 'plastic versus other material types'.

A review of many studies suggested that 60-80% of marine debris is comprised of plastic.[62] This trend, from coastline data, is also seen on the seabed, where in one study, in the North Sea, plastic debris was the most prevalent by material type (58%) with metal, wood and textiles making up the remainder.[63] On European coasts, sea floor data revealed that plastics (mainly bags and bottles) came to more than 70% of the total item count.[64] Similar predominance of plastic is observed even in the deep

[60] Environment Agency (2012) *Official Statistics - Fly-tipping Statistics for England, 2011/12*, Report for DEFRA, 2012

[61] Environment Agency (2009) Flycapture Guidance

[62] Derraik, J.G. (2002) The pollution of the marine environment by plastic debris: a review, *Marine Pollution Bulletin*, Vol.44, No.9, pp.842–852

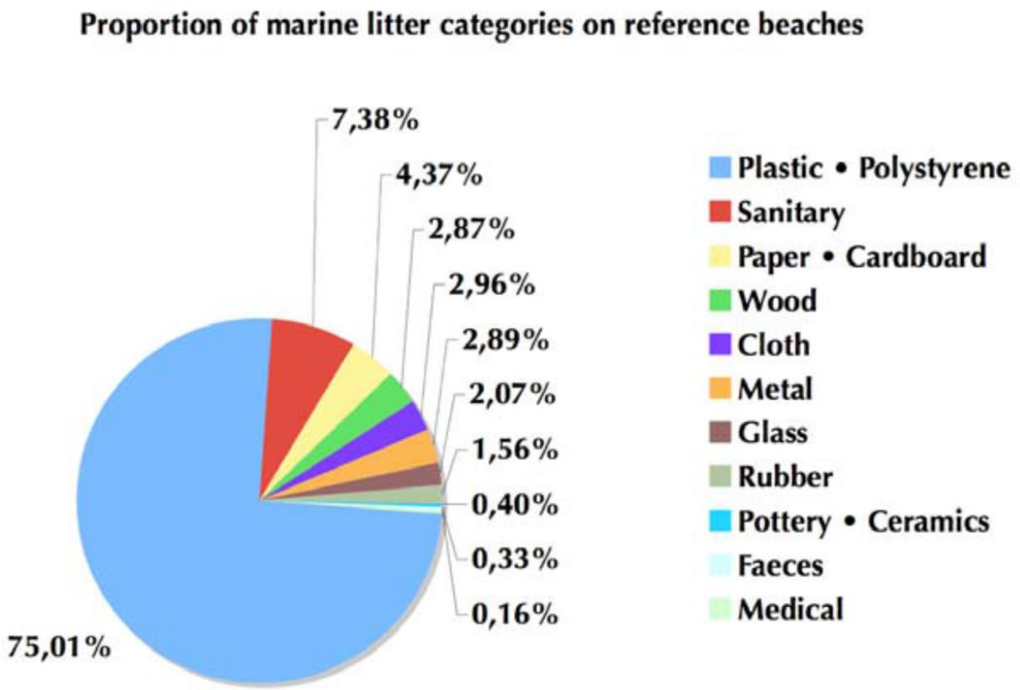
[63] KIMO (2008) *Fishing for Litter Scotland Final Report 2005-2008*, 2008

[64] Galgani, F., Leaute, J.P., Moguedet, P., et al. (2000) Litter on the sea floor along European coasts, *Marine Pollution Bulletin*, Vol.40, No.6, pp.516–527

sea, for example off the west coast of Japan and also off the Californian coast, however this is less marked, with the lowest percentage of plastic observed of 33%.[65]

Figure 1 presents one of the few litter monitoring initiatives that categorizes by material type, for beaches in the North East Atlantic. Plastic is again predominant at 75% and the breakdown into other materials is visible.

Figure 1 Proportion of marine debris by material, 2001-2006, data for OSPAR (North East Atlantic) reference beaches.



Source: [1] OSPAR, UNEP, and KIMO (2007) *OSPAR Pilot Project on Monitoring Marine Beach Litter: Preventing a Sea of Plastic*, 2007, http://qsr2010.ospar.org/media/assessments/p00306_Litter_Report.pdf

This scheme leaves few materials unmonitored, but perhaps leaves a few questions unanswered about the prevalence of significant sub-types of material such as different types of plastic (e.g., bioplastics and biodegradeable plastics – though this is very difficult to evaluate during beach counts), composite materials such as fibreglass (made of glass and plastic – probably scored as a type of plastic) or composite woods such as chipboard (made of wood and glue) or treated wood, that may contain additives that are toxic, such as creosote or preservatives.

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[65] Miyake, H., Shibata, H., and Furushima, Y. (2011) Deep-sea litter study using deep-sea observation tools, *Interdisciplinary Studies on Environmental Chemistry-Marine Environmental Modeling and Analysis*, pp.261–269,Schlining, K., von Thun, S., Kuhnz, L., et al. (2013) Debris in the deep: Using a 22-year video annotation database to survey marine litter in Monterey Canyon, central California, USA, *Deep Sea Research Part I: Oceanographic Research Papers*, Vol.79, pp.96–105

Significantly, this kind of monitoring is not carried out in different regions either in a comparable format, or at all. It is not possible therefore to readily make regional distinctions save perhaps to say that plastic is consistently the predominant material. Also there are specific materials for which it might be informative to have information about their global distribution, such as polystyrene, for example, yet this information is not available.

2.2.2 Object Type

The ICC clean-up scorecard focuses on 43 different item types. The global prevalence of each according to 2012 data is shown in Table 4. The most common items by count are cigarette butts (19%), food wrappers/containers (10.2%), beverage bottles (10%), plastic bags (9%) and caps/lids (9%).

This is not necessarily proportional to the impacts they have on marine species. This point has already been made regarding fishing debris, which is not always a large percentage, but is particularly prevalent in terms of impacts (see Section 3.2.2). We also note that glass bottles, at around 5% are a significant item type, yet glass tends not to be recorded in relation to impacts on animals, perhaps because it tends to sink and is also an inert material.

Table 4: Prevalence of Item by Type; within and across Sectors.

Sector/Item type	Prevalence within Sector	Overall Prevalence
Shoreline & Recreational Activities		
Bags(Paper)	4%	2.7%
Bags(Plastic)	14%	9.1%
Balloons	1%	0.6%
Beverage Bottles (plastic) 2 liters or less	15%	9.5%
Glass Beverage Bottles	7%	4.7%
Beverage Cans	5%	3.0%
Caps, Lids	13%	8.6%
Clothing, Shoes	4%	2.6%
Cups, Plates, Forks, Knives, Spoons	10%	6.2%
Food Wrappers/Containers	16%	10.2%
Pull Tabs	1%	0.7%
6-Pack Holders	0%	0.2%
Shotgun Shells/Wadding	0%	0.3%
Straws, Stirrers	8%	5.5%
Toys	1%	0.9%
Ocean/Waterway Activities		
Bait Containers/Packaging	5%	0.4%
Bleach/Cleaner Bottles	5%	0.5%
Buoys/Floats	7%	0.7%

Sector/Item type	Prevalence within Sector	Overall Prevalence
Crab/Lobster/Fish Traps	2%	0.2%
Crates	1%	0.1%
Fishing Line	13%	1.2%
Fishing Lures/Light Sticks	3%	0.3%
Fishing Nets	7%	0.6%
Light Bulbs/Tubes	2%	0.2%
Oil/Lube Bottles	5%	0.4%
Pallets	1%	0.1%
Plastic Sheeting/Tarps	19%	1.7%
Rope	24%	2.2%
Strapping Bands	6%	0.5%
Smoking-Related Activities		
Cigarettes/Cigarette Filters	86%	18.9%
Cigarette Lighters	3%	0.6%
Cigar Tips	7%	1.5%
Tobacco Packaging/Wrappers	5%	1.1%
Dumping Activities		
Appliances (refrigerators, washers, etc.)	4%	0.1%
Batteries	10%	0.2%
Building Materials	65%	1.4%
Cars/Car Parts	8%	0.2%
55-Gallon Drums	2%	0.0%
Tires	12%	0.3%
Medical/Personal Hygiene		
Condoms	12%	0.2%
Diapers	65%	1.3%
Syringes	6%	0.1%
Tampons/Tampon Applicators	17%	0.4%

Source: The Ocean Conservancy 2012 The Ocean Trash Index.

To illustrate regional distinctions between item prevalence, the top 10 items found for 6 different regions (the ones with most weight of trash collected per person per mile) are presented in Table 5. As can be seen, there is no great variation in the most common types of item found, these being smoking or food related debris. The regions where ocean activity related debris makes the top ten are therefore perhaps notable. These regions are the North-East Atlantic, the Eastern Africa Region, the Caspian Sea, the North-West Pacific, the Red Sea & Gulf of Aden Region, the South Asian Seas and the Western Africa Region.

Table 5: Regional Top Ten Items Found During Beach Clean-ups.

Item type	Wider Caribbean
Cigarettes/Cigarette Filters	22%
Beverage Bottles (plastic) 2 liters or less	14%
Caps, Lids	11%
Bags(Plastic)	9%
Food Wrappers/Containers	9%
Cups, Plates, Forks, Knives, Spoons	5%
Glass Beverage Bottles	5%
Beverage Cans	4%
Straws, Stirrers	3%
Bags(Paper)	2%

Item type	North-East Atlantic
Cigarettes/Cigarette Filters	22%
Food Wrappers/Containers	12%
Caps, Lids	10%
Rope	9%
Clothing, Shoes	7%
Beverage Bottles (plastic) 2 liters or less	6%
Bags(Plastic)	6%
Fishing Nets	5%
Beverage Cans	4%
Fishing Line	3%

Item type	North-East Pacific
Bags(Plastic)	17%
Caps, Lids	15%
Beverage Bottles (plastic) 2 liters or less	14%
Cigarettes/Cigarette Filters	14%
Cups, Plates, Forks, Knives, Spoons	6%
Straws, Stirrers	5%
Cigar Tips	4%
Glass Beverage Bottles	4%
Food Wrappers/Containers	3%
Clothing, Shoes	3%

Item type	Mediterr-anean
Cigarettes/Cigarette Filters	60%
Caps, Lids	6%
Straws, Stirrers	4%
Beverage Bottles (plastic) 2 liters or less	4%
Bags(Plastic)	3%
Beverage Cans	3%
Food Wrappers/Containers	3%
Bags(Paper)	2%
Cups, Plates, Forks, Knives, Spoons	2%
Glass Beverage Bottles	1%

Item type	Baltic Sea
Cigarettes/Cigarette Filters	30%
Bags(Plastic)	10%
Caps, Lids	9%
Food Wrappers/Containers	8%
Beverage Cans	7%
Tobacco Packaging/Wrappers	6%
Glass Beverage Bottles	6%
Beverage Bottles (plastic) 2 liters or less	6%
Bags(Paper)	4%
Clothing, Shoes	3%

Item type	ROPME Sea Region
Cigarettes/Cigarette Filters	19%
Pull Tabs	10%
Beverage Bottles (plastic) 2 liters or less	10%
Cups, Plates, Forks, Knives, Spoons	6%
Bags(Plastic)	6%
Food Wrappers/Containers	6%
Straws, Stirrers	6%
Glass Beverage Bottles	5%
Caps, Lids	5%
Beverage Cans	4%

Source: The Ocean Conservancy 2012 The Ocean Trash Index

Monitoring defined item-types such as the 43 chosen by the ICC is essential for standardization. However it makes it impossible to detect changes in non-target items. For example, the important category of unidentifiable items such as large items >50cm, fragments and microplastics, is unaddressed by the ICC survey.

Microplastics have been defined as particles of less than 5mm in size, an arbitrary threshold based on the propensity for ingestion.[66] They derive either from the breakdown of larger items (from hard plastics, to fibres in clothes and fishing gear)[67] or are manufactured as such (e.g. nurdles, cosmetic exfoliants or sandblasting particles). Particles down to 2μm have been isolated from the marine environment but limitations in the ability to detect such fragments limit knowledge regarding their abundance.[68] Microplastics have been found in all types of marine environment, from deep sea areas of the North and South Atlantic and the Mediterranean,[69] the shoreline on six continents,[70] floating in open waters with a prevalence of 88% in the North Atlantic for particles <10mm,[71] and 89% prevalence in the South Pacific for particles 1-5mm;[72] and in the water column in the North Sea and the East Pacific.[73,74] Additionally, they have been found in freshwater environments.[75,76] Their known

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[66] Arthur, C., Baker, J., and Bamford, H. (2009) Proceedings of the International Research Workshop on the Occurrence, Effects and Fate of Micro-plastic Marine Debris, Sept 9-11, 2008 (2009)

[67] Browne, M.A., Crump, P., Niven, S.J., Teuten, E., Tonkin, A., Galloway, T., and Thompson, R. (2011) Accumulation of microplastic on shorelines worldwide: sources and sinks, *Environmental Science & Technology*, Vol.45, No.21, pp.9175–9179,Murray, F., and Cowie, P.R. (2011) Plastic contamination in the decapod crustacean Nephrops norvegicus (Linnaeus, 1758), *Marine Pollution Bulletin*, Vol.62, No.6, pp.1207–1217

[68] Ng, K.L., and Obbard, J.P. (2006) Prevalence of microplastics in Singapore's coastal marine environment, *Marine Pollution Bulletin*, Vol.52, No.7, pp.761–767

[69] Van Cauwenberghe, L., Vanreusel, A., Mees, J., and Janssen, C.R. (2013) Microplastic pollution in deep-sea sediments, *Environmental Pollution*, Vol.182, pp.495–499

[70] Browne, M.A., Crump, P., Niven, S.J., Teuten, E., Tonkin, A., Galloway, T., and Thompson, R. (2011) Accumulation of microplastic on shorelines worldwide: sources and sinks, *Environmental Science & Technology*, Vol.45, No.21, pp.9175–9179

[71] Law, K.L., Morét-Ferguson, S., Maximenko, N.A., Proskurowski, G., Peacock, E.E., Hafner, J., and Reddy, C.M. (2010) Plastic Accumulation in the North Atlantic Subtropical Gyre, *Science*, Vol.329, No.5996, pp.1185–1188

[72] Eriksen, M., Maximenko, N., Thiel, M., et al. (2013) Plastic pollution in the South Pacific subtropical gyre, *Marine Pollution Bulletin*, Vol.68, No.1-2, pp.71–76

[73] Dubaish, F., and Liebezeit, G. (2013) Suspended Microplastics and Black Carbon Particles in the Jade System, Southern North Sea, *Water, Air, & Soil Pollution*, Vol.224, No.2, pp.1–8

[74] Lattin, G.L., Moore, C.J., Zellers, A.F., Moore, S.L., and Weisberg, S.B. (2004) A comparison of neustonic plastic and zooplankton at different depths near the southern California shore, *Marine Pollution Bulletin*, Vol.49, No.4, pp.291–294

[75] Eriksen, M., Mason, S., Wilson, S., et al. (2013) Microplastic pollution in the surface waters of the Laurentian Great Lakes, *Marine Pollution Bulletin*

[76] Imhof, H.K., Ivleva, N.P., Schmid, J., Niessner, R., and Laforsch, C. (2013) Contamination of beach sediments of a subalpine lake with microplastic particles, *Current Biology*, Vol.23, No.19, pp.R867–R868

distribution roughly reflects the distribution of marine debris generally (higher concentrations in northern hemisphere than southern, for example),[77] and appears to be limited only by the locations until now assayed; it is to be expected that wherever they are searched for, they will be found. As microplastics are in part derived from fragmentation of larger items, their abundance is liable to continue to increase.[78]

Pre-manufactured plastic pellets are a debris type that has received some attention owing to their recognisability as such, and their abundance. Some surveys have put the prevalence of pellets as high as 10% of small plastics sampled.[79] However this is subject to wide variation depending on the location. For example, on the Belgian coast, the prevalence of pellets was low except in harbour areas (incidentally suggesting a source for them).[80]

For most debris that we could think of, at least some indication of its existence was found, even though the high-level significance of them was not always known. Some of the items feature in regional marine debris monitoring initiatives. These include: cotton buds,[81] rubber gloves,[82] skylanterns,[83] hooks,[84] packing peanuts,[85] bubblewrap,[86] PPE (personal protective equipment),[87] pallets,[88] flares,[89] fireworks,[90] large fragments such as pieces of boats,[91] disposable barbecues,[92] toothbrushes, floss,[93] bagged dog faeces,[94] printer cartridges[95] and golf balls,[96]

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77 Ivar do Sul, J.A., and Costa, M.F. (2014) The present and future of microplastic pollution in the marine environment, *Environmental Pollution*

78 Barnes, D.K.A., Galgani, F., Thompson, R.C., and Barlaz, M. (2009) Accumulation and fragmentation of plastic debris in global environments, *Philosophical Transactions of the Royal Society B: Biological Sciences*, Vol.364, No.1526, pp.1985–1998

79 McDermid, K.J., and McMullen, T.L. (2004) Quantitative analysis of small-plastic debris on beaches in the Hawaiian archipelago, *Marine Pollution Bulletin*, Vol.48, No.7–8, pp.790–794

80 Claessens, M., Meester, S.D., Landuyt, L.V., Clerck, K.D., and Janssen, C.R. (2011) Occurrence and distribution of microplastics in marine sediments along the Belgian coast, *Marine Pollution Bulletin*, Vol.62, No.10, pp.2199–2204

81 OSPAR, UNEP, and KIMO (2007) *OSPAR Pilot Project on Monitoring Marine Beach Litter: Preventing a Sea of Plastic*, 2007, http://qsr2010.ospar.org/media/assessments/p00306_Litter_Report.pdf

82 http://marinedebris.noaa.gov/sites/default/files/photo_guide.pdf

83 http://balloonsblow.org/flaming-litter

84 UNEP, and FAO (2009) *Abandoned, Lost or Otherwise Discarded Fishing Gear*, 2009

85 http://www.scdhec.gov/environment/ocrm/marine_debris.htm

86 Tangaroa Blue Foundation (2012) Marine Debris Identification Manual

87 http://www.bsee.gov/Regulations-and-Guidance/Notices-to-Lessees/2012/2012-BSEE-G01-pdf/

88 http://sero.nmfs.noaa.gov/pr/pdf/Marine%20Debris%20in%20GOM.pdf

89 http://sanctuaries.noaa.gov/science/condition/pmnm/pressures.html

90 http://thegardenisland.com/news/local/article_6b47c3e2-a60f-11e0-8e55-001cc4c03286.html

91 http://www.kpfaalaska.org/wp-content/uploads/2013/05/2013-04-30-Kullluk-Debris-Removal-from-Sitkalidak-Island.pdf

There were few for which no real information was available at all. These included: industrial platforms, off-shore wind turbines, small Waste Electrical and Electronic Equipment (WEEE) such as phones, fishing spears or harpoons, sails, EPIRBs (distress radio beacons), geotextiles for mitigation of coastal erosion, lagging foam and insulation. Obviously any type of item can become marine debris, but it was felt worthwhile exploring whether any of these had been signalled as significant for any reason. It is difficult to distinguish whether lack of information signifies low frequency and low impact, or just no information.

2.3 Knowledge Gaps

2.3.1 Absence of Data - Flow and Stock

There is a very significant general knowledge gap regarding the amounts of marine debris in and entering the sea. There is no reliable estimate of the total amount of debris already in the ocean (the 'stock' of debris) nor of the amount of debris entering the ocean each year (the 'flow' of debris). There are rare examples of estimates of inputs to the ocean by item type, item source or pathway that may be either regional or global. However often they are based on scarcely more than assumptions or guesses educated by little in the way of hard information.

Strategies to address this type of knowledge gap will be of limited success because global spatial distribution and movements of debris in both vertical and horizontal dimensions occur on such a large geographical and temporal scale, that they dwarf the extent of sampling coverage that is practicable or affordable by researchers. The information that exists reveals wide variation in some of the debris monitoring measures used, such as floating litter. One study that reviewed data from over 6,000 trawls of the North Atlantic gyre over a period of 22 years found that the values fluctuated massively, to a degree that appeared random.[97] There was no trend visible at this time scale because of the variability of the data. Another study of 22 years' worth of deep sea data also saw no trend, and large fluctuations year on year.[98] The authors, with the expectation that the data would instead have reflected debris accumulating indefinitely in the ocean, suggested that there were fluxes out of the

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[92] http://www.doeni.gov.uk/marine_litter_watch-edition_1.pdf

[93] http://www.amazon.com/Hawaiian-Islands-Marine-debris-toothbrushes/dp/B00AEEHY7O, http://www.uvnsw.net.au/galleries/marine-debris?page=1

[94] http://nhmarinedebris.blogspot.co.uk/

[95] Tangaroa Blue Foundation (2012) Marine Debris Identification Manual

[96] http://www.cleanwater.org/feature/problem-of-marine-plastic-pollution

[97] Law, K.L., Morét-Ferguson, S., Maximenko, N.A., Proskurowski, G., Peacock, E.E., Hafner, J., and Reddy, C.M. (2010) Plastic Accumulation in the North Atlantic Subtropical Gyre, *Science*, Vol.329, No.5996, pp.1185–1188

[98] Schlining, K., von Thun, S., Kuhnz, L., et al. (2013) Debris in the deep: Using a 22-year video annotation database to survey marine litter in Monterey Canyon, central California, USA, *Deep Sea Research Part I: Oceanographic Research Papers*, Vol.79, pp.96–105

system in directions or on a spatial scale that were not being considered, such as vertically, or they were becoming fragmented and too small to be detected by those sampling methods.[99] Indeed, the fact is that we do not actually know what is happening to the debris in the ocean system – what is its fate, including where and on what geographical scale it can be said to be accumulating.[100,101] Just the information that the North Pacific Subtropical Convergence Zone (STCZ), which is the location of the North Pacific 'garbage patch' where there is a higher concentration of debris, can move around 900km across latitudes seasonally, depending on weather patterns,[102] gives an idea of the scale of factors that are influencing marine debris amounts and even prevalence of different item types, which may be affected differently by vertical and horizontal currents and wind.

A research group modelled how many surface samples would be needed to detect changes in floating plastic of between 10% and 100% to within reasonable certainty. They calculated that it would take 250 samples to detect a 50% increase in microplastic with 80% probability.[103] To give an indication of the expense of this kind of undertaking, the sampling they undertook of the North Pacific Subtropical Gyre to gather the data to support this model covered 6,000 miles of ocean, with 119 samples, and the analysis of the samples took one year for the lab and a team of volunteers,. In Figure 2 a graph is shown of the number of samples needed to assess changes in the concentration of plastic in the ocean to a particular degree of certainty.

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[99] Law, K.L., Morét-Ferguson, S., Maximenko, N.A., Proskurowski, G., Peacock, E.E., Hafner, J., and Reddy, C.M. (2010) Plastic Accumulation in the North Atlantic Subtropical Gyre, *Science*, Vol.329, No.5996, pp.1185–1188

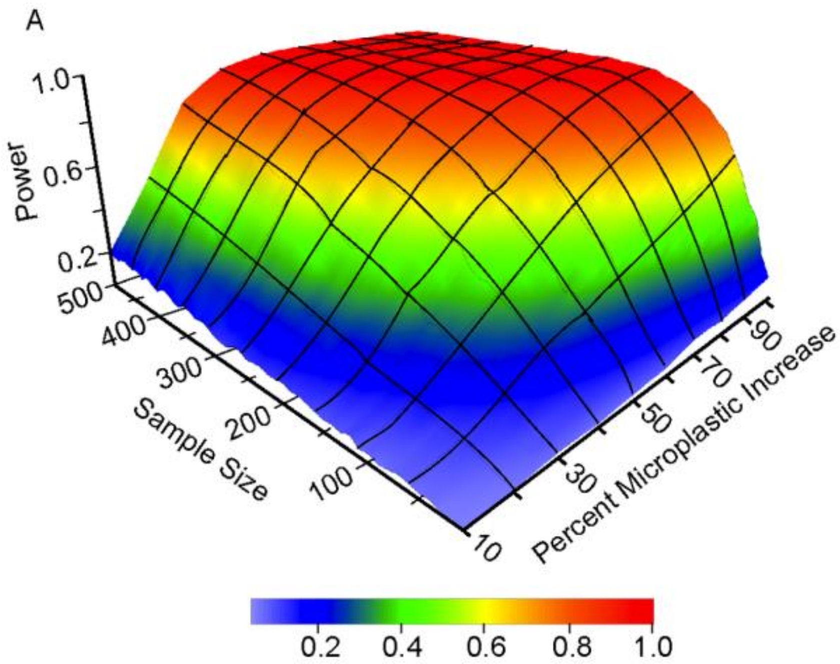
[100] Ryan, P.G., Moore, C.J., Franeker, J.A. van, and Moloney, C.L. (2009) Monitoring the abundance of plastic debris in the marine environment, *Philosophical Transactions of the Royal Society B: Biological Sciences*, Vol.364, No.1526, pp.1999–2012

[101] Thompson, R.C., Olsen, Y., Mitchell, R.P., et al. (2004) Lost at Sea: Where Is All the Plastic?, *Science*, Vol.304, No.5672, pp.838–838

[102] Donohue, M., and Foley, D.G. (2007) Remote Sensing Reveals Links Among the Endangered Hawaiian Monk Seal, Marine Debris, and El Niño, *Marine Mammal Science*, Vol.23, No.2, pp.468–473

[103] Goldstein, M.C., Titmus, A.J., and Ford, M. (2013) Scales of Spatial Heterogeneity of Plastic Marine Debris in the Northeast Pacific Ocean, *PLoS ONE*, Vol.8, No.11, p.e80020

Figure 2: Number of samples needed to assess changes in concentration of plastic in ocean to a given degree of certainty



Source: Goldstein, M.C., Titmus, A.J., and Ford, M. (2013) Scales of Spatial Heterogeneity of Plastic Marine Debris in the Northeast Pacific Ocean

The conclusion is that we do not have robust answers to the following questions:

- How much debris enters the marine environment each year? (Whether the total or by country or by type)
- What is the geographic distribution of marine debris?
- What is the distribution of marine debris in different marine compartments?
- What is the fate of different types of marine debris (i.e. decomposition/ fragmentation and accumulation/ distribution pattern)?

These kinds of knowledge gaps lead to problems when trying to determine the relative importance of different sources and pathways globally and regionally, which are important for devising management strategies and tactics. The old dictum states that what can't be measured can't be managed. Subsequently they lead to difficulties in setting quantitative policy targets on marine debris at any level, whether global, regional or by sector.

It may be possible to circumvent some of these issues by using 'operational' measures i.e. that take measurements closer to point sources, such as estuarine litter monitoring. Research could help to evaluate hypotheses about these unanswered questions, for example by improving knowledge about how long each type of marine debris persists (the rates of deterioration of fragmentable and biodegradable plastics in the natural environment is not very well characterized). Modelling approaches have also been used to elucidate the geographic distribution of marine debris. Surveys should also be targeted to answer specific questions; for example, those concerned with biotic interactions should concentrate on monitoring at a smaller scale in areas where there are high levels of biological activity and debris, such as fronts or eddies. Working with existing oceanographic monitoring programs may also help overcome resource limitations.

2.3.2 Absence of Data - Prevalence

Another way of assessing marine debris is by measuring prevalence according to different parameters. This would be useful because understanding what are the most significant sources or kinds of debris can be the basis for managerial decisions on actions to prevent, reduce and control problems caused by marine litter.[104]

The International Coastal Cleanup is a volunteer program carried out by citizens. Although it has the benefit of being standardized in some parameters and having a global reach, it is not considered fully scientific and statistically valid.[105] The Regional Seas areas themselves do not carry out systematic or comprehensive regional measurements and this makes it more difficult to assess the status of marine debris in the regional areas.[106] A summary of the data returned by the twelve Regional Seas areas that participated in the UN's Global Initiative on Marine Litter is provided by the UNEP 2009 report.[107] It is of note that several Regional Seas areas did not participate in the initiative, and of those that did, only six out of twelve returned data. Data was not provided, for example, by North East Pacific, Pacific, ROPME Sea Area, Western Africa and the Antarctic and Arctic, however, as covered above, there is some ICC data from countries in these areas.

Most of the data regarding sources is derived from assumptions regarding the source of particular objects. The reliability of the data depends on how robust the assumptions are about the sources of particular items of debris. There is very little data based on the monitoring of point sources themselves. Therefore there is a lack of data or a lack of specific data on a number of sources that we know exist. Examples are the informal waste sector, industrial outfall, coastal commercial enterprises, off-shore platforms, passenger vessels, ports and harbours, recreational angling, and ship-breaking yards. In broad terms we are fairly certain that the majority originates from land based activities, giving an indication of what some of the more important pathways are likely to be. The points at which waste is escaping management are likely identified correctly, but the absolute or relative quantities of waste entering the ocean via any single one, and hence their relative importance, is an unknown. Regional distinctions are also not possible on a quantitative basis. Even less is understood about the relevant importance of different pathways and vectors

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[104] UNEP (2009) *Marine Litter - A Global Challenge*, April 2009, http://www.unep.org/pdf/unep_marine_litter-a_global_challenge.pdf

[105] p19-20, Ocean Conservancy, and Sheavley (2007) *National Marine Debris Monitoring Program - Final Program Report, Data Analysis and Summary*, 2007

[106] UNEP (2009) *Marine Litter - A Global Challenge*, April 2009, http://www.unep.org/pdf/unep_marine_litter-a_global_challenge.pdf

[107] p204 - UNEP (2009) *Marine Litter - A Global Challenge*, April 2009, http://www.unep.org/pdf/unep_marine_litter-a_global_challenge.pdf

for marine debris such as rivers, coastal erosion, or intentional dumping. These are fundamental gaps in our knowledge as regards sources, pathways and vectors of marine debris.

What *is* known about the prevalence of debris by material or item type is limited by the fact that prevalence will vary depending on the type of measure used. Different types of measure include counts of beach litter, floating (neustonic) debris, water column (pelagic) debris or seabed (benthic) debris. For the Regional Seas areas, most data are from beaches; some from open waters and very little from the sea floor. Models suggest that material from sea-based sources is slightly less likely to become beached than material from land-based sources (at 28% versus ~38%).[108] Accordingly it would be expected that the prevalence of item types especially will vary slightly in relation to the different profiles of the sources of debris. Although some trends are observable irrespective of the measure used (e.g. predominance of plastic litter), there may be important nuances that are being lost. One example is the disproportionate effects of fishing nets. Making up only 0.6% of beach debris globally, they appear among the most prevalent items in both entanglement and also ingestion tallies. This may reflect both the fact that their design and presentation gives them the greatest impact (see Section 3.2.3), yet also that perhaps beached debris is not actually well correlated with the amounts of this item type out at sea, which may be greater.

Regarding knowledge gaps for particular materials, the difficulty is that most regional reporting, if there is any, does not monitor by material. However there appears to be at least the consistent message from monitoring that is carried out in this regard, that plastic is the dominant material type. The picture is less clear for other material types and whether their importance is significantly different between regions. There is also not much information regarding different kinds of plastic such as polystyrene or biodegradable plastic, or composite materials such as fibreglass.

Regarding knowledge gaps for particular items, the most significant is undoubtedly microplastics. As plastic in the marine environment breaks down, much of it is destined to become microplastics – so it is, *a priori*, a major item type. There is therefore great concern that there is not enough information on its prevalence or source. One reason there is little information is that microplastics are not always scored in debris data collection efforts. There is also no official, standardized definition of a microplastic particle. Additionally there is no current method for tracing where a piece of microplastic has come from, if it is possible at all. There are suggestions that pre-processing pellets may be traceable based on some properties but these are lost during manufacturing. This leaves the rest of microplastics as unattributable by source. The relative contributions of different pathways for the emission of microplastics into the oceans, whether direct emission as plastic waste, direct emission resulting from their use in cleaning products, or from the weathering of macroplastics, are also not known.

[108] Lebreton, L.C.-M., Greer, S.D., and Borrero, J.C. (2012) Numerical modelling of floating debris in the world's oceans, *Marine Pollution Bulletin*, Vol.64, No.3, pp.653–661

Other examples were found of marine debris types for which little information could be found. There is a difficulty with assessing whether lack of information signifies low frequency and low impact, or just no information. What is known can be limited simply by the fact that a particular object is not listed on a coastal monitoring checklist. Some coastal monitoring methodologies do however have ‘other’ categories that would allow other significant items to come to light.

In conclusion, the following questions do not yet have comprehensive answers. Though there is a lot of indicative information and some detailed information for a few regions, it is far from comprehensive.

- What are the major sources of marine debris?
- What are the most important pathways and vectors for marine debris?
- What is the geographic distribution of marine debris? Of different kinds?
- What are the relative proportions of macro, micro and nanoplastic entering the marine environment (and which pose the greatest threat)?
- What are the key sources of microplastics?
- Are there any other items that may be of significance that are unmonitored?

2.3.3 Relationships between Item Parameters

A difficulty is that for a large proportion of items, there is a one-to-many relationship between an item type and item material, its source, and also the means by which it found its way into the ocean. There are also many other parameters by which a piece of debris can be scored (e.g. source: land based vs. sea based) that also do not map easily onto other types of categorization such as pathway. As an illustration, examples of items for which these relationships are more straightforward are cotton wool bud sticks and fishing nets. Cotton wool bud sticks found in the marine environment are plastic, they come from sewage (the majority of which is land-based), are purposely discarded of in toilets, and make their way into the ocean either via water treatment works, faultily connected civic water works, or combined sewage overflows. Fishing nets are with rare exception made of plastic, the vast majority (depending on the location, which will provide further clues) will come from commercial fisheries. Even so, there are multiple pathways and behaviours via which nets are lost.

These difficulties make it impossible, with current data collection efforts, to determine source and pathway, which are important for choosing management strategies, identifying stakeholders and target audiences, and devising tactics. However, a modelling approach as exemplified by Arcadis (2012) is a novel approach for circumventing this problem, and could be applied in other regions.

2.3.4 Comparability of Data

Different scoring methods influence the comparability of data between studies. Scoring methods understandably tend to use categories that are the most practicable to assign items to, and these mix item material, item type, and item source quite freely (e.g. plastic items, fishing nets, fishing gear might all be used within the same classification). This can also arise in reports as authors or researchers strive to highlight trends in prevalence. However this means that different studies use different categories. It makes it difficult to assess regional distinctions and to look at global trends.

The Regional Seas areas use differing methodologies to carry out measurements even within the same marine compartment. Therefore it is not possible to use their data to make comparisons between the regions or to analyse trends.[109]

It has been stated that

> *"Without the systematic collection of reliable data on amounts of marine litter using an internationally approved methodology, no serious assessment of the extent of the problem can be made, and consequently no proper response to the problem can be planned or implemented"*[110]

However it is not necessarily the all-or-nothing situation that this quote might suggest. An adequate response may indeed be possible without the information being in as good a shape as it would be in an ideal world. A balance is probably achievable between precision and inaction, to avoid stalling progress completely. A parallel might be seen with the 'precautionary approach', here described in the Rio +20 declaration:

> *"In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall be not used as a reason for postponing cost-effective measures to prevent environmental degradation."*[111]

The difference here is that irreversible damage is clear, it can be thought of as serious by various different measures, and there are many management approaches that are highly likely to be effective, irrespective of how precisely the extent of the problem is mapped out.

3.0 Impacts on Migratory Species

Any species spending all or part of its life history in a marine area is potentially affected by marine debris. There are approximately 200,000 known marine animal species of which the majority are invertebrates.[112] There are around 22,000 vertebrate marine species (including seabirds), within which grouping, all the marine migratory species are found.[113] This includes those fish which spend part of their

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[109] UNEP (2009) *Marine Litter - A Global Challenge*, April 2009, http://www.unep.org/pdf/unep_marine_litter-a_global_challenge.pdf

[110] UNEP (2009) *Marine Litter - A Global Challenge*, April 2009, http://www.unep.org/pdf/unep_marine_litter-a_global_challenge.pdf

[111] United Nations (1992) The Rio Declaration on Environment and Development

[112] Appeltans, W., Ahyong, S.T., Anderson, G., et al. (2012) The Magnitude of Global Marine Species Diversity, *Current Biology*, Vol.22, No.23, pp.2189–2202

[113] WoRMS Editorial Board (2013) *World Register of Marine Species.*, http://www.marinespecies.org at VLIZ

lives in saltwater and part in freshwater. Further bird species, not generally classed as seabirds, but which spend time in marine environments, are also in the scope of this review, because they are also potentially affected by marine debris, and include many migratory species.

As the Convention on Migratory Species covers a defined list of migratory species considered under threat or vulnerable, it was felt useful to have a definitive list of which of the species featured are marine and so potentially affected by marine debris, and what their ranges are in the ocean basins. This was to allow the rapid evaluation of what species fall within knowledge gaps regarding impacts of marine debris within particular regions. A database was created and annotated by the Convention for this purpose. Of the approximately 370 species explicitly featuring in the appendices of the Convention,[114] 209 are marine (as defined for the purposes of this report, i.e. spending all or part of its life history in a marine area) and so potentially affected by marine debris, highlighting the relevance of the issue for Parties to the Convention.

In order to assess knowledge gaps regarding the impacts of marine debris on migratory species, including regional distinctions, ideally it would be known in a broader sense, of the species which are marine, which are migratory, as well as their ranges in the marine environment. The largest database assembled of migratory species has information on around 4,000 species considered migratory, with around 1,000 annotated with species ranges.[115] The alternative to using such a database is to look up each species individually as it appears during literature review and determine whether it is migratory and what its range is.[116] Both approaches are equally limited by the fact that there is frequently not enough information available to annotate an organism as migratory or not.

Because of a lack of centralized information at the time of this review,[117] or simply lack of the required information, knowledge gaps are instead assessed at the class level – i.e. in terms of mammals, birds, reptiles and fish.[118] At this resolution it is not necessary to have knowledge of the entire 'set' of migratory marine species. Despite there not being an exhaustive database of migratory species there are certain classes or groups which have a large proportion of migratory species within them. This makes it easier to assess what information on impacts of marine debris is or is not available for migratory species belonging to different classes.

[114] CMS (2012) Appendices I and II of the Convention on the Conservation of Migratory Species of Wild Animals (CMS)

[115] This is the Global Register of Migratory Species (GROMS) http://www.groms.de/

[116] IUCN Redlists (http://www.iucnredlist.org/) are another of the most comprehensive sources of information in this regard.

[117] The GROMS database was not available for the duration of this study as it was undergoing the process of being migrated to a new online home courtesy of the University of Bonn and the Museum Koenig.

[118] This approach was agreed in conjunction with the Secretariat

For example, of the marine mammals, there are four main groups containing migratory species – baleen whales, toothed whales (which includes dolphins and similar), seals (which are carnivores) and Sirenia species (such as manatees and dugongs, which are herbivorous). All of the approximately 14 species of baleen whales are migratory, and 12 feature in the Convention appendices. A majority of the marine dolphins are migratory, with 33 out of around 43 species appearing in the appendices. The likelihood is that only a minority of the other kinds of toothed whales are migratory, but there appears to be a general lack of information for many toothed whales in this regard. 5 out of 29 species appear in the Convention appendices. For seals, there are about 32 species, of which around 10 are commonly recognized as migratory, and 5 appear in the Convention appendices. All the four Sirenia species are considered migratory, and all of them appear in the Convention.

For reptiles, only the turtles are migratory, and all seven of the marine turtle species appear in the Convention.

There are over a thousand known species of marine sharks and rays.[119] It was not possible to determine an overall estimate of how many are migratory, although the UN Convention on the Law of the Sea (UNCLOS) lists about 73 shark species as being 'highly migratory',[120] and there are 7 sharks and one ray in the Convention on Migratory Species appendices. Of the other types of fish, of which there are over 16,000 marine species, we similarly were unable to determine how many are migratory, but around 47 feature in UNCLOS and a further 14 appear in the CMS lists.

Around 850 bird species are categorized as spending part of their life history in the marine environment in the IUCN Redlists, which has completed its evaluation of all known bird species. It has been estimated that of the 10,000 or so known bird species in total 19% are migratory. If this were true for the marine birds, we would expect around 160 to be migratory. 123 birds in the Convention appendices are classed as marine in the broadest sense (in that they spend some of their time in the marine environment though they do not rely exclusively on it).

Taking these facts into consideration, the following can be concluded: any research on baleen whales, dolphins, Sirenia, and turtles as regards the impacts of marine litter is highly relevant to migratory species. Research on other toothed whales, seals, sharks/rays, fish and birds, where concerning the many non-migratory species, will be of relevance to migratory species in that within these groups, species will share many physical traits and behaviours, and therefore, susceptibilities to marine debris impacts. These groups could in principle be used to assess to what extent migratory species are impacted to a greater or lesser extent by marine debris, compared to resident species.

These considerations also make it clear that with over half of marine mammals known to be migratory, all marine turtles, and a significant proportion of birds and

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[119] WoRMS Editorial Board (2013) *World Register of Marine Species.*, http://www.marinespecies.org at VLIZ

[120] United Nations (1982) Annex I, United Nations Convention on the Law of the Sea

sharks (in total, at least double the number already present on the Convention appendices), the issue of marine debris is highly significant to those concerned with the conservation of migratory species.

The literature on marine debris and its impacts on different species is substantial. A detailed review was carried out in 2012 by the Scientific and Technical Advisory Panel of the Global Environment Facility on behalf of the Convention on Biological Diversity.[121] They found evidence of impacts for 663 species. This provides a good idea of the number of species for which information on marine debris impacts is available. Significantly, this is a large increase from the last time such a review was carried out – more than doubling the number of species known to be impacted, which at the time was found to be 247.[122] An evaluation of the high level numbers for different classes of organisms gives us a feel of what information there might be as regards migratory species.

The six species for which the impacts of entanglement or ingestion of marine debris were found to be greatest in the report are all migratory, and three, *Chelonia mydas* (Green Turtle)*, Eubalaena glacialis* (North Atlantic Right Whale) and *Caretta caretta* (Loggerhead Turtle) appear in the CMS Appendix I and/or II. *Procellaria aequinoctialis* (White-chinned Petrel) is another Convention-listed migratory species the report singles out for concern. However the migratory *Callorhinus ursinus* (Northern Fur Seal), which is not in a CMS appendix, is considered vulnerable according to the IUCN Redlists. The report further highlights research on the migratory *Fulmarus glacialis* (Northern Fulmar), which though not endangered, has an informative time series for prevalence of ingestion of debris of different types within the population.[123]

All known species of sea turtles, all of which are migratory, were found to be affected by entanglement or ingestion of marine debris. Half of the known marine mammal species were found to be similarly affected; and one-fifth of sea birds as defined by the report. If these proportions are assumed to be applicable to the migratory species within each class, it demonstrates how widespread the impacts of marine debris are. However the true percentages of migratory species affected may be more or less, depending on their relative susceptibility to marine debris than resident species.

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[121] STAP/GEF (2012) *Impacts of marine debris on biodiversity: Current status and potential solutions*, Report for CBD, 2012

[122] Laist, D.W. (1997) Impacts of Marine Debris: Entanglement of Marine Life in Marine Debris Including a Comprehensive List of Species with Entanglement and Ingestion Records, *Marine Debris: Sources, Impacts and Solutions* (1997) pp.99–139

[123] van Franeker, J.A., Blaize, C., Danielsen, J., et al. (2011) Monitoring plastic ingestion by the northern fulmar Fulmarus glacialis in the North Sea, *Environmental Pollution (Barking, Essex: 1987)*, Vol.159, No.10, pp.2609–2615

3.1 Impacts of Marine Debris on Migratory Species – Types of Impact

3.1.1 Physical - Entanglement

The way in which a species is entangled depends on the animal's body shape and behaviours. For example, seals usually become entangled around the neck or body towards the front flipper after putting their head through loops in items, a behaviour that is common in seals[124] and is perhaps exploratory and/or playful. Cetaceans and turtles may become snagged on ghost-fishing line or net around the mouth, flippers or tail (cetaceans) which then can become entangled around the whole body. Birds are more likely to become entangled by ingesting baited hooks and lines, the remainder of which becomes entangled around the body.[125] Entanglement is more likely to kill or injure than ingestion, with direct harm or death reported in 80% of reports of entanglement and in only 5% of ingestion reports. [126,127] However there are a range of sublethal and lethal impacts for entanglement via a variety of mechanisms.

It would be a considerable omission not to address the experience of pain and suffering that an animal goes through when evaluating the severity of an impact. There have been attempts to classify injuries according to severity for whales and for marine mammals more generally on a hierarchical descriptive scale.[128] This sort of index does not exist for all species classes, and reports are not presented in such a way that allows the systematic ranking of incidents according to severity on such a scale. A broad consideration of the severity of marine debris impacts in terms of animal suffering was made which resulted in the acute impacts of drowning and starvation in the event of complete inability to feed as being characterized as the most severe, and these are impacts generally associated with entanglement. A series of chronic impacts (nominally less severe) were also associated with entanglement, which were injury, infection, amputation, exhaustion and long term starvation due to reduced ability to feed.[129]

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[124] Fowler, C.W. (1987) Marine debris and northern fur seals: A case study, *Marine Pollution Bulletin*, Vol.18, pp.326–335

[125] Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for WSPA, 2012, http://www.wspa-international.org/Images/Untangled%20Report_tcm25-32499.pdf

[126] Laist, D.W. (1996) Marine Debris Entanglement and Ghost Fishing: A Cryptic and Significant Type of Bycatch?, *Solving Bycatch: Proceedings of the Solving Bycatch Workshop: Considerations for Today and Tomorrow* (1996)

[127] STAP/GEF (2012) *Impacts of marine debris on biodiversity: Current status and potential solutions*, Report for CBD, 2012

[128] Andersen, M.S., Forney, K.A., Cole, T.V., et al. (2008) Differentiating Serious and Non-Serious Injury of Marine Mammals: Report of the Serious Injury Technical Workshop, *NOAA Technical Memorandum NMFS-OPR*, Vol.39

[129] Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for WSPA, 2012, http://www.wspa-international.org/Images/Untangled%20Report_tcm25-32499.pdf

3.1.1.1 Sublethal Impacts

Tissue damage is a widespread result of entanglement. Skin lesions with ulceration can result. Necrotising myositis (death of muscle tissue) is also observed.[130] Ligatures can cause amputation of limbs, cutting into bone and muscle as the animal grows. In turtles and manatees, for example, entanglement is known to result in the loss of flippers. [131,132] In turtles, the loss of one flipper apparently does not necessarily affect the geographical range of the affected individual, but the loss of two flippers cannot be compensated for, making it very difficult for the individual to dive and feed. Flipper stumps are vulnerable to further attack by sharks, birds and crabs. This might have consequences for the probability of secondary infection or predation.[133] Fins and tails of whales, sharks and dolphins can also be severed or deformed by entanglement; the implication of fin loss *per se* is uncertain but damage to the tail, especially if it affects the midline (i.e. the bilateral axis of symmetry along the spine), is considered a very serious injury.[134] In whales, massive proliferation of new bone in an attempt to wall off constricting, encircling lines has been observed.[135] Deformation of bills and missing lower bills have been observed in entangled gannets, which again may impair feeding.[136]

Entanglement in trawl netting debris increases the drag on an animal as it swims through the water; it has been shown that a 400g piece of net increases the energy requirement for a California Sea Lion by about four times.[137] It is also known that in

[130] Orós, J., Torrent, A., Calabuig, P., and Dniz, S. (2005) Diseases and causes of mortality among sea turtles stranded in the Canary Islands, Spain (1998–2001), *Diseases of Aquatic Organisms*, Vol.63, No.1, pp.13–24

[131] Carrington, D. (2013) 'CSI turtle' launches investigation into ghost fishing nets found in the Maldives, *Guardian* and the Maldivian Sea Turtle Conservation Program (MSTCP) http://www.seaturtle.org/tracking/?project_id=750

[132] Beck, C.A., and Barros, N.B. (1991) The impact of debris on the Florida manatee, *Marine Pollution Bulletin*, Vol.22, No.10, pp.508–510

[133] Carrington, D. (2013) 'CSI turtle' launches investigation into ghost fishing nets found in the Maldives, *Guardian* and the Maldivian Sea Turtle Conservation Program (MSTCP) http://www.seaturtle.org/tracking/?project_id=750

[134] Andersen, M.S., Forney, K.A., Cole, T.V., et al. (2008) Differentiating Serious and Non-Serious Injury of Marine Mammals: Report of the Serious Injury Technical Workshop, *NOAA Technical Memorandum NMFS-OPR*, Vol.39

[135] Cassoff, R., Moore, K., McLellan, W., Barco, S., Rotstein, D., and Moore, M. (2011) Lethal entanglement in baleen whales, *Diseases of Aquatic Organisms*, Vol.96, No.3, pp.175–185

[136] Rodríguez, B., Bécares, J., Rodríguez, A., and Arcos, J.M. (2013) Incidence of entanglements with marine debris by northern gannets (Morus bassanus) in the non-breeding grounds, *Marine Pollution Bulletin*, Vol.75, No.1–2, pp.259–263

[137] Feldkamp, S.D. (1985) The effects of net entanglement on the drag and power output of a California sea lion, Zalophus californianus, *Fishery Bulletin*, Vol.83, No.4

the Northern Fur Seal, entangled lactating females spend more time at sea feeding than non-entangled females.[138]

Debris may also restrict feeding, if inhibiting mouthparts or limbs necessary for foraging or other feeding behaviour, to the point of malnutrition. For example, neck entanglement in seals, where the line cuts the skin and muscles, can limit movement of the neck and the rest of the body, and can in this way impair diving ability.[139] Sharks with collars of lid parts of plastic bottles and severe tissue damage during growth were found to be emaciated.[140]

3.1.1.2 Lethal Impacts

If a mammal, bird or reptile is prevented from resurfacing because it is entangled and trapped under the surface of the water, it will asphyxiate and drown. This can take minutes or hours. This has been observed in all these classes of organisms. [141,142,143,144]. Asphyxiation can also be caused by pulled and tightened or ingrown ligatures around the neck (several species), or occlusion of the nares (blowhole) in whales.[145]

Chronic entanglement can cause severance of the carotid artery by ingrown ligatures (seals especially).[146] It can also cause haemorrhaging and debilitation due to severe damage to tissues including laceration of large blood vessels (whales).[147]

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[138] Delong, R.L., Gearin, P.J., Bengtson, J.L., and Dawson, P. (1990) Studies of the Effects of Entanglement on Individual Northern Fur Seals, *Proceedings of the Second International Conference on Marine Debris* (1990) Honolulu, Hawaii

[139] Campagna, C., Falabella, V., and Lewis, M. (2007) Entanglement of Southern Elephant Seals in Squid Fishing Gear, *Marine Mammal Science*, Vol.23, No.2, pp.414–418

[140] Sazima, I., Gadig, O.B.., Namora, R.C., and Motta, F.S. (2002) Plastic debris collars on juvenile carcharhinid sharks (Rhizoprionodon lalandii) in southwest Atlantic, *Marine Pollution Bulletin*, Vol.44, No.10, pp.1149–1151

[141] Scordino, J., Kajimura, H., Baba, N., and Furuta, A. (1988) Fur Seal Entanglement Studies in 1984, St Paul Island, Alaska., *Fur Seal Investigations, 1985* (1988) NOAA Tech. Memo NMFS-F/NWC-146,Wilcox, C., Hardesty, B.D., Sharples, R., Griffin, D.A., Lawson, T.J., and Gunn, R. (2013) Ghostnet impacts on globally threatened turtles, a spatial risk analysis for northern Australia, *Conservation Letters*, Vol.6, No.4, pp.247–254

[142] Cassoff, R., Moore, K., McLellan, W., Barco, S., Rotstein, D., and Moore, M. (2011) Lethal entanglement in baleen whales, *Diseases of Aquatic Organisms*, Vol.96, No.3, pp.175–185

[143] Tasker, M.L., Camphuysen, C.J., Cooper, J., Garthe, S., Montevecchi, W.A., and Blaber, S.J. (2000) The impacts of fishing on marine birds, *ICES Journal of Marine Science: Journal Du Conseil*, Vol.57, No.3, pp.531–547

[144] Wilcox, C., Hardesty, B.D., Sharples, R., Griffin, D.A., Lawson, T.J., and Gunn, R. (2013) Ghostnet impacts on globally threatened turtles, a spatial risk analysis for northern Australia, *Conservation Letters*, Vol.6, No.4, pp.247–254

[145] Cassoff, R., Moore, K., McLellan, W., Barco, S., Rotstein, D., and Moore, M. (2011) Lethal entanglement in baleen whales, *Diseases of Aquatic Organisms*, Vol.96, No.3, pp.175–185

[146] Delong, R.L., Gearin, P.J., Bengtson, J.L., and Dawson, P. (1990) Studies of the Effects of Entanglement on Individual Northern Fur Seals, *Proceedings of the Second International Conference on Marine Debris* (1990) Honolulu, Hawaii

Entangled individuals can die from systemic infection as a consequence of open wounds.

They can also die from starvation via prevention of feeding behaviours. For example in fish, entanglement which entraps an animal will lead to starvation rather than asphyxiation. However this is generally classed as bycatch, which provides an example of the grey area between the classification of marine debris impacts and those caused by ALDFG (abandoned, lost or discarded fishing gear). Death by starvation after entanglement has also been reported in pinnipeds.[148]

It has been conjectured that entanglement in the mouth area (common in baleen whales – one study in right whales found 77.4% of gear attachment sites were here)[149] may interfere with their 'hydrostatic oral seal' – a mechanism by which the animal can keep its mouth closed with little effort even when it is swimming. If this ability is impaired, it could compromise the animal's ability to dive, feed and even breed – enough to cause its death.[150]

In the case of the Northern Fur Seal, entangled lactating females spend more time at sea feeding than non-entangled females and some entangled females die at sea, pups with entangled mothers have lower survival rates than other pups.[151]

Seals under chronic stress may eventually stop producing aldosterone, a stress hormone, which results in sodium being flushed out of the body; the individual can become hyponatremic and die as a result. This has been cited as a concern for entangled pinnipeds. It is also thought that in cetaceans, a stress response, which is characterized by a number of metabolic changes and signs, can be fatal if it is severe enough.[152] Given the acute and chronic stress that can be caused by entanglement, it is of concern that it might lead to fatal outcomes via this mechanism. [153]

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[147] Cassoff, R., Moore, K., McLellan, W., Barco, S., Rotstein, D., and Moore, M. (2011) Lethal entanglement in baleen whales, *Diseases of Aquatic Organisms*, Vol.96, No.3, pp.175–185

[148] Dau, B.K., Gilardi, K.V.K., Gulland, F.M., Higgins, A., Holcomb, J.B., Leger, J.S., and Ziccardi, M.H. (2009) Fishing Gear Related Injury In California Marine Wildlife, *Journal of Wildlife Diseases*, Vol.45, No.2, pp.355–362

[149] Johnson, A., Salvador, G., Kenney, J., Robbins, J., Kraus, S., Landry, S., and Clapham, P. (2005) Fishing Gear Involved in Entanglements of Right and Humpback Whales, *Marine Mammal Science*, Vol.21, No.4, pp.635–645

[150] Lambertsen, R.H., Rasmussen, K.J., Lancaster, W.C., and Hintz, R.J. (2005) Functional Morphology of the Mouth of the Boewhead Whale and it Implications for Conservation, *Journal of Mammalogy*, Vol.86, No.2, pp.342–352

[151] Delong, R.L., Gearin, P.J., Bengtson, J.L., and Dawson, P. (1990) Studies of the Effects of Entanglement on Individual Northern Fur Seals, *Proceedings of the Second International Conference on Marine Debris* (1990) Honolulu, Hawaii

[152] Angliss, R., and DeMaster, D.P. (1998) Differentiating Serious and Non-Serious Injury of Marine Mammals Taken Incidential to Commercial Fishing Operations: Report of the Serious Injury Workshop, *NOAA Technical Memorandum NMFS-OPR*

[153] Feldkamp, S.D. (1985) The effects of net entanglement on the drag and power output of a California sea lion, Zalophus californianus, *Fishery Bulletin*, Vol.83, No.4

Death can also be brought about because of a reduced ability to evade predators, or ship strike (a prominent cause of death for whales). [154,155] Death after chronic entanglement may take months or years.[156]

3.1.1.3 Prevalence and Regional Distinctions

Entanglement incidents have been reported in all the major classes of animals that are relevant to marine migratory species – i.e., pinnipeds, cetaceans, turtles, sharks, Sirenia, fish and birds, comprising 192 species. This corresponds to about 45% of all marine mammals (including 58% of all seals), 0.39% of all fish, 21% of all seabirds (67/312) and all sea turtles (100%). [157,158] It has been reported that the animals most frequently affected by entanglement are pinnipeds, humpback and right whales, birds and turtles, though this is as likely to reflect reporting bias as prevalence of this type of impact within different classes.[159]

Examples of the prevalence of entanglement in the populations of different high level species classes are shown below. It is worth noting that there are no estimates of the total numbers of individuals affected by entanglement each year, but it is thought likely that it is in the millions.[160] For species groups that are the best characterized in terms of entanglement (pinnipeds and baleen whales alone, for which there are fewer individuals so monitoring effort is greater in both absolute and proportional terms), figures of 57,000 - 135,000 have been estimated.[161] The range of reported

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[154] Beck, C.A., and Barros, N.B. (1991) The impact of debris on the Florida manatee, *Marine Pollution Bulletin*, Vol.22, No.10, pp.508–510,Delong, R.L., Gearin, P.J., Bengtson, J.L., and Dawson, P. (1990) Studies of the Effects of Entanglement on Individual Northern Fur Seals, *Proceedings of the Second International Conference on Marine Debris* (1990) Honolulu, Hawaii

[155] Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for WSPA, 2012, http://www.wspa-international.org/Images/Untangled%20Report_tcm25-32499.pdf

[156] Moore, M.J., Knowlton, A., Kraus, S.D., McLellan, W.A., and Bonde, R.K. (2005) Morphometry, gross morphology and available histopathology in North Atlantic right whale (Eubalaena glacialis) mortalities, *Journal of Cetacean Research and Management*, Vol.6, No.3, pp.199–214

[157] STAP/GEF (2012) *Impacts of marine debris on biodiversity: Current status and potential solutions*, Report for CBD, 2012

[158] Boland, R.C., and Donohue, M.J. (2003) Marine debris accumulation in the nearshore marine habitat of the endangered Hawaiian monk seal, Monachus schauinslandi 1999–2001, *Marine Pollution Bulletin*, Vol.46, No.11, pp.1385–1394

[159] Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for WSPA, 2012, http://www.wspa-international.org/Images/Untangled%20Report_tcm25-32499.pdf

[160] Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for WSPA, 2012, http://www.wspa-international.org/Images/Untangled%20Report_tcm25-32499.pdf

[161] Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for WSPA, 2012, http://www.wspa-international.org/Images/Untangled%20Report_tcm25-32499.pdf

entanglement rates is very wide within and between species, and like most estimates, based on a wide range of methodologies and recorded over varying time periods, which influences the metric considerably.[162]

Baleen whales

A review of studies of entanglement in Baleen whales reported a range of population entanglement rates of from 5% to 65%; with an average of 35%. These estimates have been made for at least 7 different species, all of which are migratory (as all baleen whales are). Five of the species appear in the appendices of the Convention; they are:

- the Humpback Whale, *Megaptera novaeangliae*;
- the North Atlantic Right Whale, *Eubalaena glacialis;*
- the Fin Whale, *Balaenoptera physalus*;
- the Blue Whale, *Balaenoptera musculus;* and
- the Bryde's Whale, *Balaenoptera edeni*.

The average mortality estimate (i.e. the proportion of animals estimated to be killed by their entanglement) is 23%, with a range of 1% to 44% for different species.[163]

The most commonly recorded species facing entanglement is the North Atlantic Right Whale but this is thought to be the result of the fact that monitoring effort is concentrated on the population (which numbers only about 500 individuals) which is most threatened by extinction.[164] Therefore it is difficult to attribute variation in impact prevalence to, for example, regional debris densities. Likewise, there is some variation in the most common items causing entanglement but it is not clear exactly what this reflects – be it surrounding debris composition or differential species vulnerability to different item types.

Toothed whales (non-baleen whales, and dolphins)

[162] Schuyler, Q., Hardesty, B.D., Wilcox, C., and Townsend, K. (2013) Global Analysis of Anthropogenic Debris Ingestion by Sea Turtles, *Conservation Biology*, p.n/a–n/a

[163] Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for WSPA, 2012, http://www.wspa-international.org/Images/Untangled%20Report_tcm25-32499.pdf

[164] Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for WSPA, 2012, http://www.wspa-international.org/Images/Untangled%20Report_tcm25-32499.pdf

In Hawaii 3,75% of False Killer Whales (*Pseudorca crassidens*) had major dorsal fin disfigurements thought to be caused by entanglement.[165] However although there are reports of entanglement for at least five species of toothed whale, there is a lack of any estimates of occurance within species populations.[166] Regionally, one review stated that coastal species appear particularly at risk from the impacts of marine debris and human activities such as fisheries.[167] However, the lack of quantitative data does not allow regional distinctions to be made easily.

Seals

Estimates of entanglement rate for seals are around 1% of the population on average, with a range of 0.001% all the way to 7.9% for a particular population of California Sea Lions in Mexico.[168] These estimates have been made for at least 13 different species of seal of which about six are considered migratory, including the Harbour Seal (*Phoca vitulina*) and the Grey Seal (*Halichoerus grypus*), which feature in the Convention appendices. The entanglement rates for the migratory species span the range above, so a rough comparison does not suggest that their entanglement rates are pronouncedly different. However, estimates are so variable and the number of observations so few that the data are not sufficient to enable a proper analysis to be performed. The average mortality rates in terms of the percentage of entangled animals estimated to be killed by their entanglement is 48% and ranges from 16% to 80% depending on the study.[169]

Sirenia

A study of manatees in Florida showed that 1.7% of the sample had signs of entanglement such as scarred, missing or entangled flippers, and 1.2% died as a direct result. [170] A quarter of dugongs in Australia that were recorded as being

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[165] Neilson, J.L., Straley, J.M., Gabriele, C.M., and Hills, S. (2009) Non-lethal entanglement of humpback whales (Megaptera novaeangliae) in fishing gear in northern Southeast Alaska, *Journal of Biogeography*, Vol.36, No.3, pp.452–464

[166] Simmonds, M.P. (2012) Cetaceans and Marine Debris: The Great Unknown, *Journal of Marine Biology*, Vol.2012

[167] Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for WSPA, 2012, http://www.wspa-international.org/Images/Untangled%20Report_tcm25-32499.pdf

[168] Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for WSPA, 2012, http://www.wspa-international.org/Images/Untangled%20Report_tcm25-32499.pdf

[169] Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for WSPA, 2012, http://www.wspa-international.org/Images/Untangled%20Report_tcm25-32499.pdf

[170] Beck, C.A., and Barros, N.B. (1991) The impact of debris on the Florida manatee, *Marine Pollution Bulletin*, Vol.22, No.10, pp.508–510

involved in entanglement incidents died as a result.[171] Entanglements of the African manatee and the South American manatee have been reported but no prevalence was estimated. [172,173]

Turtles

In one study in the Canary Islands, 25% of turtles necropsied were thought to have been killed via entanglement, of which 11% had suffered necrotising myositis (muscle tissue death) and 26% the amputation of one or two flippers.

Entanglement is the primary cause of mortality for turtles reported in the Gulf of Carpentaria region of Australia.[174]

Birds

Some birds use marine debris for nesting material, which makes them vulnerable to entanglement in their breeding grounds in the North East Atlantic region.[175] In another study of the same species, this time in their wintering areas in the Mediterranean, 0.93% of all encountered individuals were found to be entangled.[176] 94% of beached birds found dead were entangled, also in the North East Atlantic region.[177]

Fish

One study found 0.18% of sharks captured had plastic strapping bands around the body.[178]

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[171] Ceccarelli, D.M., and C. R. Consulting (2009) Impacts of plastic debris on Australian marine wildlife, *Report by C&R Consulting to the Australian Government Department of the Environment, Water, Heritage and the Arts*

[172] Silva, M.A., and Araújo, A. (2001) Distribution and current status of the West African manatee (Trichechus senegalensis) in Guinea-Bissau, *Marine Mammal Science*, Vol.17, No.2, pp.418–424

[173] http://www.iucnredlist.org/details/22102/0

[174] Wilcox, C., Hardesty, B.D., Sharples, R., Griffin, D.A., Lawson, T.J., and Gunn, R. (2013) Ghostnet impacts on globally threatened turtles, a spatial risk analysis for northern Australia, *Conservation Letters*, Vol.6, No.4, pp.247–254

[175] Votier, S.C., Archibald, K., Morgan, G., and Morgan, L. (2011) The use of plastic debris as nesting material by a colonial seabird and associated entanglement mortality, *Marine Pollution Bulletin*, Vol.62, No.1, pp.168–172

[176] Rodríguez, B., Bécares, J., Rodríguez, A., and Arcos, J.M. (2013) Incidence of entanglements with marine debris by northern gannets (Morus bassanus) in the non-breeding grounds, *Marine Pollution Bulletin*, Vol.75, No.1–2, pp.259–263

[177] OSPAR (2009) *Marine litter in the Northeast Atlantic Region: assessment and priorities for response*, Report for London, U.K., 2009

[178] Cliff, G., Dudley, S.F.J., Ryan, P.G., and Singleton, N. (2002) Large sharks and plastic debris in KwaZulu-Natal, South Africa, *Marine and Freshwater Research*, Vol.53, No.2, pp.575–581

3.1.1.4 Relationship between Debris Density and Entanglement

In order to estimate organisms' encounter rates with debris, one study profiled risk associated with "ghost-fishing" debris, based on predicted debris density and spatial overlap with the vulnerable species. The resulting model was considered to have good predictive capabilities regarding impacts when compared with real data. [179] Hence, for example, areas with the highest concentration of nets in Oceania and Southeast Asia such as the Gulf of Carpentaria (up to 3 tons/km) have seen an enormous range of species suffering entanglement.[180] It suggests entanglement is driven by the frequency with which turtles encounter debris rather than turtle foraging behaviour in general. In birds, the amount of fishing gear in nests, known to cause entanglement, was related to the fishing effort in the foraging ranges around their nests.[181] Models of debris distribution, combined with species distribution data even at a coarse scale, would provide estimates of relative encounter rates of debris for species. This could identify global hotspots for impact, which would not necessarily be where the highest concentrations of debris are. It could also identify which species might be the most heavily impacted. This could allow the prioritization of mitigation actions.

This is contrasted however against the poor correlation between the ingestion of debris and regional debris densities (see 3.1.2.4).

3.1.2 Trophic - Ingestion

Trophic impacts can be classified as direct – i.e. impacting on the ability of migratory species to obtain adequate nutrition post-ingestion, and indirect – i.e. impacting on other members of the food chain important for the migratory species, via ecosystem effects such as on habitat and biodiversity more generally. In this section, the trophic impacts of marine debris are reviewed, restricted to those relating to direct, physical mechanisms upon ingestion, together with behavioural effects on nutrient intake where they are consequences of those physical impacts. Trophic impacts related to habitat and ecosystem level effects and toxicological mechanisms are dealt with in separate sections (3.1.4 and 3.1.3.1 respectively).

In the interest of not omitting the animal suffering component of the impacts of marine debris, it is noted that the following consequences of ingestion were considered 'acute' by one evaluation on an animal welfare scale: drowning (e.g. in the case of obstruction of the larynx by an ingested item) and internal bleeding caused by

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[179] Wilcox, C., Hardesty, B.D., Sharples, R., Griffin, D.A., Lawson, T.J., and Gunn, R. (2013) Ghostnet impacts on globally threatened turtles, a spatial risk analysis for northern Australia, *Conservation Letters*, Vol.6, No.4, pp.247–254

[180] Gunn, R., Hardesty, B.D., and Butler, J. (2010) Tackling 'ghost nets': Local solutions to a global issue in northern Australia, *Ecological Management & Restoration*, Vol.11, No.2, pp.88–98

[181] Bond, A.L., Montevecchi, W.A., Guse, N., Regular, P.M., Garthe, S., and Rail, J.-F. (2012) Prevalence and composition of fishing gear debris in the nests of northern gannets (Morus bassanus) are related to fishing effort, *Marine Pollution Bulletin*, Vol.64, No.5, pp.907–911

ingestion of sharp debris. The impact of ingestion considered to be 'chronic' on the same scale was starvation over long time periods due to impaction of nutrient dilution.[182]

3.1.2.1 Sublethal Impacts

There have been some indications, from turtles, that ingestion of plastic and latex are correlated with lower blood glucose levels, suggesting that they may be affecting nutrient absorption or metabolism,[183] This might be a toxicological effect or it may be to do with inflammation, ulceration of the gut (this last, observed in dolphins which ingested plastic bags)[184] or physical obstruction, reducing absorption of nutrients by the gut via reduced surface area or cellular processes. [185]

Ingestion of plastic and latex has also been linked to increased gas in the intestine in turtles, leading to impaired buoyancy control.[186]

Other forms of tissue damage that are caused by ingestion of debris are oesophagitis (inflammation of the oesophagus) and oesophageal perforation, observed for example in turtles,[187] or ulceration of the proventriculus (birds).[188]

One of the mechanisms by which ingestion of marine debris can harm an organism sublethally is via the displacement of equivalent volumes of food and consequent 'nutrient dilution'. The effects of the nutrient dilution effect on food intake in turtle hatchlings was evaluated and it was shown that young turtles do not compensate for the reduced volume of food taken in as a result of ingestion of debris. [189] Therefore the potential for impaired nutrition and sublethal consequences of this is very real, and it is possible that the consequences of this would be greater for migratory species than resident animals. For example, in migratory birds, there have been several studies showing that body condition (which includes amount of fat deposition)

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[182] Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for WSPA, 2012, http://www.wspa-international.org/Images/Untangled%20Report_tcm25-32499.pdf

[183] Lutz, P.L. (1990) Studies on the ingestion of plastic and latex by sea turtles, *Proc. Int. Conf. Marine Debris.(Eds. RS Shomura & ML Godfrey) NOAA-TM-154* (1990) pp.719–735

[184] Meirelles, A.C.O. de, and Barros, H.M.D. do R. (2011) Plastic debris ingested by a rough-toothed dolphin, Steno bredanensis, stranded alive in northeastern Brazil., *Biotemas*, Vol.20, No.1, pp.127–131

[185] Bjorndal, K.A. (1997) Foraging Ecology and Nutrition of Sea Turtles (1997)

[186] Bjorndal, K.A. (1997) Foraging Ecology and Nutrition of Sea Turtles (1997)

[187] Orós, J., Torrent, A., Calabuig, P., and Dniz, S. (2005) Diseases and causes of mortality among sea turtles stranded in the Canary Islands, Spain (1998–2001), *Diseases of Aquatic Organisms*, Vol.63, No.1, pp.13–24

[188] Fry, D.M., Fefer, S.I., and Sileo, L. (1987) Ingestion of plastic debris by Laysan Albatrosses and Wedge-tailed Shearwaters in the Hawaiian Islands, *Marine Pollution Bulletin*, Vol.18, pp.339–343

[189] McCauley, S.J., and Bjorndal, K.A. (1999) Conservation Implications of Dietary Dilution from Debris Ingestion: Sublethal Effects in Post-Hatchling Loggerhead Sea Turtles, *Conservation Biology*, Vol.13, No.4, pp.925–929

is correlated with return rates, i.e. survival, including in the migrant seabird (*Calidris canutus*), the Red Knot.[190, 191, 192, 193, 194] Where fledgling body mass is low, this has also been shown to be correlated with reduced migration survival.[195] Threats to survival are magnified for birds at staging sites where birds must accumulate the extra-large reserves necessary to cross an 'ecological barrier' such as a stretch of water (therefore, highly relevant to shorebirds and waterfowl).[196]

The plastic load ingested by Fulmars (*Fulmarus glacialis*) in the North Sea was 0.3 g on average; if this were scaled up to size it would equate to an average portion of lunch for a human adult.

It is known that some birds such as Petrels retain plastic in their stomach for months, therefore any sublethal effects of ingestion are likely to be chronic, and could escalate into an acute condition where tissue damage or occlusion of some vital internal conduit occurs at any time. [197] There are some indications that plastic particles are gradually eroded in the stomach, but the rate of wear is unknown and probably differs between types of plastic. [198] Large plastic particles tend not to be found in the faeces of seabirds, suggesting the plastic accumulates in the gut in those species that do not regurgitate indigestible stomach contents.

However there is little, and conflicting, hard evidence about what the severity of the impacts are for avian species. There is some evidence that plastic slows growth in chickens, through reduced food intake (rather than impeded assimilation).[199]

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[190] Morrison, R.G. (2006) Body transformations, condition, and survival in Red Knots Calidris canutus travelling to breed at Alert, Ellesmere Island, Canada, *ARDEA-WAGENINGEN-*, Vol.94, No.3, p.607

[191] Benson, T.J., and Bednarz, J.C. (2010) Relationships Among Survival, Body Condition, and Habitat of Breeding Swainson's Warblers, *The Condor*, Vol.112, No.1, pp.138–148

[192] Studds, C.E., and Marra, P.P. (2005) Non-breeding Habitat Occupancy and Population Processes: An Upgrade Experiment with a Migratory Bird, *Ecology*, Vol.86, No.9, pp.2380–2385

[193] Merila, J., and Svensson, E. (1997) Are Fat Reserves in Migratory Birds Affected by Condition in Early Life?, *Journal of Avian Biology*, Vol.28, No.4, p.279

[194] Newton, I. (2006) Can conditions experienced during migration limit the population levels of birds?, *Journal of Ornithology*, Vol.147, No.2, pp.146–166

[195] Menu, S., Gauthier, G., Reed, A., and Holberton, R.L. (2005) Survival of Young Greater Snow Geese (Chen caerulescens atlantica) During Fall Migration, *The Auk*, Vol.122, No.2, pp.479–496

[196] Newton, I. (2006) Can conditions experienced during migration limit the population levels of birds?, *Journal of Ornithology*, Vol.147, No.2, pp.146–166

[197] Spear, L.B., Ainley, D.G., and Ribic, C.A. (1995) Incidence of plastic in seabirds from the tropical pacific, 1984–1991: Relation with distribution of species, sex, age, season, year and body weight, *Marine Environmental Research*, Vol.40, No.2, pp.123–146,Ryan, P.., and Jackson, S. (1987) The lifespan of ingested plastic particles in seabirds and their effect on digestive efficiency, *Marine Pollution Bulletin*, Vol.18, No.5, pp.217–219

[198] Ryan, P.., and Jackson, S. (1987) The lifespan of ingested plastic particles in seabirds and their effect on digestive efficiency, *Marine Pollution Bulletin*, Vol.18, No.5, pp.217–219

[199] Ryan, P.G. (1988) Effects of ingested plastic on seabird feeding: Evidence from chickens, *Marine Pollution Bulletin*, Vol.19, No.3, pp.125–128

However White-chinned Petrels (*Procellaria aequinoctialis*) showed no change in assimilation efficiency but also no mass loss when fed large quantities of plastic particles.[200]

Evidence from the field is mixed: one paper concluded, from a small sample of the migratory Red Phalarope (*Phalaropus fulicarius*), that there was a negative correlation between amount of plastic and fat deposition, though this wasn't actually statistically significant.[201] A study of albatross chicks on Midway Atoll showed that Laysan Albatross (*Diomedea immutabilis*) chicks had significantly lower fledgling weights if they had high volumes of proventricular plastic.[202] In another approach, one study found that chicks found dead had significantly higher weights of plastic than chicks that had been struck by cars and necropsied, suggesting that the plastic was associated with poorer survival.[203] No effect was observed for Black-footed Albatross (*Diomedea nigripes*) chicks. Another concluded that no influence of ingested plastic on weight was detectable in White-faced Storm Petrels.[204] Another stated the same for the Short-tailed Shearwater (*Puffinus tenuirostris*).[205] Even in species that ingested the greatest amount of plastic in another study (Northern Fulmars (*Fulmarus glacialis*), Red Phalaropes (*Falaropus fulicaria*) and Greater Shearwaters (*Puffinus gravis*)), no evidence that seabird health was affected was found.[206]

It has been proposed that that whether plastic ingestion has effects on feeding and growth via food displacement is a function of digestive tract morphology and regurgitation habit, which varies between species. In some species, the gizzard and the proventriculus are quite separate chambers joined by a small conduit. Plastic is mostly retained in the gizzard which is not however used for food storage (the role of the proventriculus) – this may be why procellariformes (petrels, shearwaters and albatrosses), who have this morphology, do not seem to lose weight as the amount of plastic ingested increases (and these species accumulate plastic to a great extent because they cannot regurgitate it like other species). Other species (sphenisciforms, pelecaniforms and charadriiforms) have a single sac-like stomach, where plastic

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[200] Ryan, P.., and Jackson, S. (1987) The lifespan of ingested plastic particles in seabirds and their effect on digestive efficiency, *Marine Pollution Bulletin*, Vol.18, No.5, pp.217–219

[201] Connors, P.G., and Smith, K.G. (1982) Oceanic plastic particle pollution: suspected effect on fat deposition in red phalaropes, *Marine Pollution Bulletin*, Vol.13, No.1, pp.18–20

[202] Sievert, P.R., and Sileo, L. (1993) The effects of ingested plastic on growth and survival of albatross chicks, *The Status, Ecology and Conservation of Marine Birds of the North Pacific* (1993)

[203] Auman, H.J., Ludwig, J.P., Giesy, J.P., and Colborn, T. (1997) Plastic ingestion by Laysan albatross chicks on Sand Island, Midway Atoll, in 1994 and 1995, *Albatross Biology and Conservation*, pp.239–244

[204] Furness, R.W. (1985) Ingestion of plastic particles by seabirds at Gough Island, South Atlantic Ocean, *Environmental Pollution Series A, Ecological and Biological*, Vol.38, No.3, pp.261–272

[205] Vlietstra, L.S., and Parga, J.A. (2002) Long-term changes in the type, but not amount, of ingested plastic particles in short-tailed shearwaters in the southeastern Bering Sea, *Marine Pollution Bulletin*, Vol.44, No.9, pp.945–955

[206] Moser, M.L., and Lee, D.S. (1992) A Fourteen-Year Survey of Plastic Ingestion by Western North Atlantic Seabirds, *Colonial Waterbirds*, Vol.15, No.1, p.83

would be displacing food. However most of these species regurgitate indigestible items regularly, with the exception of some auks and phalaropes, and this might also mitigate any body mass effects of the plastic. Albatrosses and Giant Petrels have intermediate stomach morphology, and atypically for the procellariiformes, do exhibit regurgitation; nevertheless they do accumulate large amounts of plastic in their digestive system showing the complex relationship between plastic accumulation, bird morphology and behaviour.[207]

Fish are known to ingest pieces of plastic. In the laboratory, some fish have been observed to ingest but reject or pass the pellets; other observations reveal that plastic can be retained in fish guts for prolonged periods of time and may become encysted or ingrown into the gut lining. Ingestion in fish has been hypothesised, as for other species, to result in displacement of food, and large pieces that cannot be expelled from the fish has been suggested to cause ulceration but there is not experimental evidence to support this. [208] It has also been suggested that ingested plastic may influence the buoyancy of fish, and be especially detrimental to those that migrate vertically.[209]

3.1.2.2 Lethal Impacts

Ingestion of marine debris by turtles has been demonstrated to result in death in one of two ways. One is by impaction, where a blockage of the digestive tract causes paralysis of the gut, in which case, death will result from starvation.[210] In the other scenario, debris can puncture the gut lining, causing peritonitis or septicaemia.[211] In one study, of turtles found stranded and the fatality attributed to ingestion, impaction was found to have led to more fatalities (83%) than perforation (17%).[212] Ingestion of debris was suspected to be the cause of death in two stranded Sperm Whales, one of which was emaciated, while the other had a ruptured stomach, both suspected to be caused by intestinal impaction.[213] Intestinal impaction and starvation has also been observed in birds including the migratory and endangered Laysan Albatross, though

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[207] Ryan, P.G. (1988) Effects of ingested plastic on seabird feeding: Evidence from chickens, *Marine Pollution Bulletin*, Vol.19, No.3, pp.125–128

[208] Hoss, D.E., and Settle, L.R. (1990) Ingestion of plastics by teleost fishes, *Proceedings of the Second International Conference on Marine Debris. NOAA Technical Memorandum. NOAA-TM-NMFS-SWFSC-154. Miami, FL* (1990) pp.693–709

[209] Carson, H.S. (2013) The incidence of plastic ingestion by fishes: From the prey's perspective, *Marine Pollution Bulletin*

[210] Lutz, P.L. (1990) Studies on the ingestion of plastic and latex by sea turtles, *Proc. Int. Conf. Marine Debris.(Eds. RS Shomura & ML Godfrey) NOAA-TM-154* (1990) pp.719–735

[211] Beck, C.A., and Barros, N.B. (1991) The impact of debris on the Florida manatee, *Marine Pollution Bulletin*, Vol.22, No.10, pp.508–510

[212] Townsend, K.A. (2011) Impact of ingested marine debris on sea turtles of eastern Australia: Life history stage susceptibility, pathological implications and plastic bag preference., *Technical Proceedings of the 5th International Marine Debris Conference* (2011) pp.180–183

[213] Jacobsen, J.K., Massey, L., and Gulland, F. (2010) Fatal ingestion of floating net debris by two sperm whales (Physeter macrocephalus), *Marine Pollution Bulletin*, Vol.60, No.5, pp.765–767

such observations are as yet rare.[214,215] Intussusception of the intestine (a potentially fatal condition where the one portion of the intestine slides into another) was also identified as caused by ingestion of monofilament line in a manatee.[216]

Ingestion has also been shown to result in larynx strangulation in dolphins, where ingestion of netting is followed by the netting becoming wrapped around the larynx (which in dolphins connects the breathing tube to the breathing hole) of the animal inside its throat. This progressively cuts into the larynx, causing oedema, tissue damage and thickening of the tissue, which in itself can present as a chronic condition, although at some point, asphyxiation can occur if the stricture becomes too tight or the tissue gives way and occludes the wind pipe. At present this is linked to dolphins learning to depredate small commercial fisheries for fish and biting off small pieces of netting. However in principle, it could apply to free-floating debris.[217]

3.1.2.3 Prevalence and Regional Distinctions

Ingestion is thought to be more widespread than entanglement.[218] At present however there are only marginally more marine species for which ingestion incidents have been recorded than entanglement, at 196 versus 192. This includes mammals (26% of all marine mammal species), turtles (86%), birds (38% [199/312]) and fish (0.24%).[219] It has been reported that the animals most frequently affected by ingestion are birds and turtles.[220]

Examples of the prevalence of ingestion in the populations of different species follow. There are no estimates of the total numbers of individuals affected by ingestion each year, but it is thought likely that it is in the millions.[221]

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[214] Fry, D.M., Fefer, S.I., and Sileo, L. (1987) Ingestion of plastic debris by Laysan Albatrosses and Wedge-tailed Shearwaters in the Hawaiian Islands, *Marine Pollution Bulletin*, Vol.18, pp.339–343

[215] Pierce, K.E., Harris, R.J., Larned, L.S., and Pokras, M.A. (2004) Obstruction and starvation associated with plastic ingestion in a northern gannet Morus bassanus and a greater shearwater Puffinus gravis, *Marine Ornithology*, Vol.32, pp.187–189

[216] Beck, C.A., and Barros, N.B. (1991) The impact of debris on the Florida manatee, *Marine Pollution Bulletin*, Vol.22, No.10, pp.508–510

[217] Gomerčić, M., Galov, A., Gomerčić, T., et al. (2009) Bottlenose dolphin (Tursiops truncatus) depredation resulting in larynx strangulation with gill-net parts, *Marine Mammal Science*, Vol.25, No.2, pp.392–401

[218] Secchi, E.R., and Zarzur, S. (1999) Plastic debris ingested by a Blainville's beaked whale, Mesoplodon densirostris, washed ashore in Brazil

[219] STAP/GEF (2012) *Impacts of marine debris on biodiversity: Current status and potential solutions*, Report for CBD, 2012

[220] Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for WSPA, 2012, http://www.wspa-international.org/Images/Untangled%20Report_tcm25-32499.pdf

[221] Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for WSPA, 2012, http://www.wspa-international.org/Images/Untangled%20Report_tcm25-32499.pdf

Baleen whales

Filter-feeding Baleen whales are known to ingest debris during feeding, though there are no statistics on prevalence, as it is not systematically documented; and reports are few. Examples are the Bowhead Whale, *Balaena mysticetus,* the Minke Whale, *Balaenoptera acutorostrata* and Bryde's Whale, *Balaenoptera edeni*. It is therefore impossible to make any regional distinctions for the impacts of the ingestion of marine debris within the range of these species.

Toothed whales (non-baleen whales, and dolphins)

Toothed whales are liable to ingest debris during play, exploration or feeding. One study found 31% of beached La Plata Dolphins (*Pontoporia blainvillei*) had ingested plastic debris.[222] In Bottlenose Dolphins (*Tursiops truncatus)* in the Adriatic, 10% of stranded individuals died from constriction of the larynx post net ingestion,[223] Fatalities have also been reported in sperm whales (*Physeter macrocephalus*) and the Tucuxi (*Sotalia fluviatilis*);[224,225] each of these species are migratory and endangered. In Baird's Beaked Whale (*Berardius bairdii*), debris ingestion was found in 15-27% of individuals, at different locations in the Pacific coastal waters of Japan.[226] There are many other reports of ingestion, for at least 26 different species of toothed whale in total.[227] However, because as a rule only isolated incidents are reported, it is not possible to make well supported regional distinctions about prevalence of this impact for these animals.

Seals

There are few quantitative studies of debris ingestion in seals; the first study on earless seals, in the North Sea, found plastic in the stomach of 11% of the individuals

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[222] Bastida *et al.,* 2000 in Marsh, H., Arnold, P., Freeman, M., et al. (2003) Strategies for Conserving Marine Mammals, *Marine Mammals: Fisheries, Tourism and Management Issues: Fisheries, Tourism and Management Issues* (2003)

[223] Gomerčić, M., Galov, A., Gomerčić, T., et al. (2009) Bottlenose dolphin (Tursiops truncatus) depredation resulting in larynx strangulation with gill-net parts, *Marine Mammal Science*, Vol.25, No.2, pp.392–401

[224] Jacobsen, J.K., Massey, L., and Gulland, F. (2010) Fatal ingestion of floating net debris by two sperm whales (Physeter macrocephalus), *Marine Pollution Bulletin*, Vol.60, No.5, pp.765–767

[225] Geise, L., and Gomes, N. (1992) Ocorrência de Plástico no estômago de um golfinho, Sotalia guianensis (Cetacea, Delphinidae)., *Proceedings of the Third. Reunión de Trabajo de Especialistas de Mamíferos. Acuáticos de América Del Surr*

[226] Simmonds, M.P. (2012) Cetaceans and Marine Debris: The Great Unknown, *Journal of Marine Biology*, Vol.2012

[227] Baird, R., and Hooker, S. (2000) Ingestion of Plastic and Unusual Prey by a Juvenile Harbour Porpoise, *Marine Pollution Bulletin*, Vol.40, No.8, pp.719–720

sampled, albeit in very small quantities.[228] This was <10% of the prevalence as measured by faecal samples, demonstrating how prevalence varies according to methodology. Plastic has also been found in the faeces of fur seals.[229]

Sirenia

A study of West Indian manatees in Florida showed that 14% of the sample of stranded manatees had ingested debris and 0.9% died as direct result.[230] There are no reports of ingestion in the other three species of Sirenia.

Turtles

It has been suggested that sea turtle anatomy predisposes them to ingesting larger quantities of marine debris and that this is why all sea turtle species, all of which are migratory, have be found to experience this impact.[231] Sea turtles have downward facing, keratinized papillae in their oesophagus, the presumed function of which is to trap food while excess water is expelled prior to swallowing. This mechanism may prevent regurgitation of plastics and increases the probability that they remain within the digestive tract.

A global review on turtles and ingestion found that the probability of ingesting debris had increased for some species (green and leatherback turtles) over time. Turtles in nearly all regions studied ingest debris, with the exception of the Persian Gulf. Across all the studies, an average 30% of deceased turtles sampled had ingested debris. Depending on the study reviewed, death was attributed to marine debris for 9% of those individuals on average, and overall mortality owing to marine debris calculated at between 2% and 17%.[232] There were regions where the proportion of individuals ingesting debris was higher than others, but there was a high degree of variability over time and within regions. There is not a clear correlation between ingestion rates and local debris densities (see Section 3.1.2.4).

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228 Bravo Rebolledo, E.L., Van Franeker, J.A., Jansen, O.E., and Brasseur, S.M.J.M. (2013) Plastic ingestion by harbour seals (Phoca vitulina) in The Netherlands, *Marine Pollution Bulletin*, Vol.67, No.1–2, pp.200–202

229 Eriksson, C., and Burton, H. (2003) Origins and Biological Accumulation of Small Plastic Particles in Fur Seals from Macquarie Island, *AMBIO: A Journal of the Human Environment*, Vol.32, No.6, pp.380–384

230 Beck, C.A., and Barros, N.B. (1991) The impact of debris on the Florida manatee, *Marine Pollution Bulletin*, Vol.22, No.10, pp.508–510

231 Müller, C., Townsend, K., and Matschullat, J. (2012) Experimental degradation of polymer shopping bags (standard and degradable plastic, and biodegradable) in the gastrointestinal fluids of sea turtles, *Science of The Total Environment*, Vol.416, pp.464–467

232 Schuyler, Q., Hardesty, B.D., Wilcox, C., and Townsend, K. (2013) Global Analysis of Anthropogenic Debris Ingestion by Sea Turtles, *Conservation Biology*, p.n/a–n/a

Birds

95% of Northern Fulmars (*Fulmarus glacialis*) whose bodies were washed ashore were found to have plastic debris in their digestive system.[233] OSPAR set an 'Ecological Quality Objective' of plastic ingested not exceeding 0.1g in 90% of the population; 55% of all examined birds exceeded this limit.[234] The endangered, migratory Balearic Shearwater (*Puffinus mauretanicus*) had an ingestion occurrence of 70% of individuals, in the western Mediterranean.[235] In a study of Laysan Albatrosses (*Phoebastria immutabilis*), also endangered and migratory, 97% of chicks had ingested plastic,[236] while in another study, 7% of chicks that had ingested plastic had ulcerative lesions or impactions in the proventriculus.[237]

Fish

Many species of fish have been found to have ingested plastic. This includes migratory species, such as the Atlantic Cod (*Gadus morhau*), Blackfin Tuna (*Thunnus albacares*), Yellowfin Tuna (*Thunnus atlanticus*), many species of shark, many of which are migratory, and the anadromous Striped Bass (*Morone saxatilis*).[238,239]

One study found 0.38% of sharks captured had ingested plastic debris.[240] In the English Channel, 21% of flounder (*Platychthyes flesus*) individuals and 25% of the fish *Liparis liparis* had ingested polystyrene spherules, though those levels subsequently

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[233] van Franeker, J.A., Blaize, C., Danielsen, J., et al. (2011) Monitoring plastic ingestion by the northern fulmar Fulmarus glacialis in the North Sea, *Environmental Pollution (Barking, Essex: 1987)*, Vol.159, No.10, pp.2609–2615

[234] OSPAR (2010) *Quality Status Report 2010*, 2010, http://qsr2010.ospar.org/en/media/chapter_pdf/QSR_complete_EN.pdf

[235] Codina-García, M., Militão, T., Moreno, J., and González-Solís, J. (2013) Plastic debris in Mediterranean seabirds, *Marine Pollution Bulletin*

[236] Auman, H.J., Ludwig, J.P., Giesy, J.P., and Colborn, T. (1997) Plastic ingestion by Laysan albatross chicks on Sand Island, Midway Atoll, in 1994 and 1995, *Albatross Biology and Conservation*, pp.239–244

[237] Fry, D.M., Fefer, S.I., and Sileo, L. (1987) Ingestion of plastic debris by Laysan Albatrosses and Wedge-tailed Shearwaters in the Hawaiian Islands, *Marine Pollution Bulletin*, Vol.18, pp.339–343

[238] U. S. Fish and Wildlife Service Southern New England-New York Bight Coastal Ecosystems Program(1996) *Regionally Significant Habitats and Habitat Complexes of the New York Bight Watershed*, http://library.fws.gov/pubs5/web_link/text/int_fish.htm

[239] Laist, D.W. (1997) Impacts of Marine Debris: Entanglement of Marine Life in Marine Debris Including a Comprehensive List of Species with Entanglement and Ingestion Records, *Marine Debris: Sources, Impacts and Solutions* (1997) pp.99–139

[240] Cliff, G., Dudley, S.F.J., Ryan, P.G., and Singleton, N. (2002) Large sharks and plastic debris in KwaZulu-Natal, South Africa, *Marine and Freshwater Research*, Vol.53, No.2, pp.575–581

declined.[241] Another, off the west coast of the USA, found that 8 out of 14 fish species examined had ingested such material, and up to 33% of the individuals within a species.[242] In the North Sea, five out of seven species had ingested debris, and overall 2.6% of individuals, though in one species (cod from the English Channel) it was 33%.[243] In the central North Pacific, one study found that 19% of individuals had ingested plastic on average, with a range of <1% to 58% of individuals.[244] In one Mediterranean study, plastic was found in 5 out of 26 species of deep sea fish. The highest prevalence within species was 3.2%.[245]

3.1.2.4 Relationship between Debris Density, Quantity of Debris Ingested and Cause of Death

In turtles, the probability of ingestion was not closely related to modelled debris densities where the turtles were sampled.[246] This was thought to reflect the fact that most turtles migrate long distances during their post hatching pelagic phase and during breeding migrations, so they are highly likely to encounter ocean-borne debris at some life stage. Furthermore, it is important to highlight, especially in the context of marine debris ingestion potentially being used as an environmental quality indicator (for the North-East Atlantic region (OSPAR) - the EcoQO or 'Ecological Quality Objective'),[247] that the amount of debris ingested is not necessarily linearly correlated with the potential to cause fatality. For example, in one turtle study in Florida, of 24 stranded turtles that had ingested marine debris, just two of the deaths could be clearly attributed to marine debris. However, the weight and volume of debris in these specimens was small and was within the range of that ingested by other individuals.[248] Therefore these parameters do not predict the mortality caused by debris ingestion well and instead it is proposed that the chance orientation of a piece

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241 Kartar, S., Abou-Seedo, F., and Sainsbury, M. (1976) Polystyrene spherules in the Severn Estuary—a progress report, *Marine Pollution Bulletin*, Vol.7, No.3, p.52

242 Carpenter, E.J., Anderson, S.J., Harvey, G.R., Miklas, H.P., and Peck, B.B. (1972) Polystyrene spherules in coastal waters, *Science (New York, N.Y.)*, Vol.178, No.4062, pp.749–750

243 Foekema, E.M., De Gruijter, C., Mergia, M.T., van Franeker, J.A., Murk, A.J., and Koelmans, A.A. (2013) Plastic in North Sea Fish, *Environmental Science & Technology*, p.130711150255009

244 Choy, C.A., and Drazen, J.C. (2013) Plastic for dinner? Observations of frequent debris ingestion by pelagic predatory fishes from the central North Pacific, *Marine Ecology Progress Series*, Vol.485, pp.155–163

245 Anastasopoulou, A., Mytilineou, C., Smith, C.J., and Papadopoulou, K.N. (2013) Plastic debris ingested by deep-water fish of the Ionian Sea (Eastern Mediterranean), *Deep Sea Research Part I: Oceanographic Research Papers*, Vol.74, pp.11–13

246 Schuyler, Q., Hardesty, B.D., Wilcox, C., and Townsend, K. (2013) Global Analysis of Anthropogenic Debris Ingestion by Sea Turtles, *Conservation Biology*, p.n/a–n/a

247 van Franeker, J.A., Heubeck, M., Fairclough, K., et al. (2005) *'Save the North Sea' Fulmar Study 2002–2004: A Regional Pilot Project for the Fulmar-Litter-EcoQO in the OSPAR Area*, 2005, http://www.vliz.be/imisdocs/publications/72498.pdf

248 Bjorndal, K.A., Bolten, A.B., and Lagueux, C.J. (1994) Ingestion of marine debris by juvenile sea turtles in coastal Florida habitats, *Marine Pollution Bulletin*, Vol.28, No.3, pp.154–158

of debris as it transits the digestive tract will determine whether it becomes lodged in the tract and causes an obstruction and death. The majority of debris appears to be excreted through defecation.[249]

Therefore as a consequence of these non-linear relationships between debris density, probability of ingestion and probability of acute, severe impacts, it has been stated that anthropogenic debris must be managed at a global level; and that targeted approaches according to 'hotspots' are not going to be as effective as a global approach, for ingestion, at least.[250]

On the other hand for some species and areas, there does seem to be a correlation between local spatial distributions of debris and the prevalence of ingestion. Some studies suggest that the amounts of plastic in the intestines of birds reflects regional differences in the abundance of marine debris.[251] For example, Northern Fulmars in the North Sea, which is highly contaminated, have very high rates of plastic ingestion (95% of individuals), whereas in birds of the same species in Arctic Canada, the figure is only 36%.[252] Therefore using species-level impacts as a way of monitoring environmental quality may be robust, but only for certain species and certain areas.

3.1.3 Physiological

3.1.3.1 Toxicological Impacts via Ingestion

Plastics contain a wide range of additives such as plasticizers (to make them pliable), flame retardants and colorants. They also accumulate chemicals from sea water.[253] The chemicals of concern are persistent, bio-accumulative and toxic substances (PBTs), which tend to be hydrophobic, fat-soluble, organic molecules that accordingly have a tendency to associate with plastic surfaces as opposed to remaining dissolved in the water of the ocean. Microplastics, because of their very large surface area to volume ratio, are especially significant in this regard, as the greater the surface area the greater the surface for molecule exchange, whether via off-gassing or adsorption and desorption.[254] There is evidence that desorption is enhanced under physiological

[249] Tourinho, P.S., Ivar do Sul, J.A., and Fillmann, G. (2010) Is marine debris ingestion still a problem for the coastal marine biota of southern Brazil?, *Marine Pollution Bulletin*, Vol.60, No.3, pp.396–401

[250] Schuyler, Q., Hardesty, B.D., Wilcox, C., and Townsend, K. (2013) Global Analysis of Anthropogenic Debris Ingestion by Sea Turtles, *Conservation Biology*, p.n/a–n/a

[251] van Franeker, J.A., Blaize, C., Danielsen, J., et al. (2011) Monitoring plastic ingestion by the northern fulmar Fulmarus glacialis in the North Sea, *Environmental Pollution (Barking, Essex: 1987)*, Vol.159, No.10, pp.2609–2615

[252] Mallory, M.L., Robertson, G.J., and Moenting, A. (2006) Marine plastic debris in northern fulmars from Davis Strait, Nunavut, Canada, *Marine Pollution Bulletin*, Vol.52, No.7, pp.813–815

[253] Lee, H., Shim, W.J., and Kwon, J.-H. (2013) Sorption capacity of plastic debris for hydrophobic organic chemicals, *Science of The Total Environment*

[254] Mato, Y., Isobe, T., Takada, H., Kanehiro, H., Ohtake, C., and Kaminuma, T. (2001) Plastic Resin Pellets as a Transport Medium for Toxic Chemicals in the Marine Environment, *Environmental Science & Technology*, Vol.35, No.2, pp.318–324

conditions, i.e. post-ingestion.[255] Therefore even small amounts of ingested material may be having an impact beyond its physical mass, which may not be large, sharp or obstructive enough to pose any welfare problems for the animal by physical means.

Plasticizers such as phthalates (e.g. DEHP - bis(2-ethylhexyl) phthalate), BPA (bisphenol A) and PCBs (polychlorinated biphenyls), incorporated into plastics at production can leach into the environment or into tissue.[256] Because these molecules are similar in structure to hormones, they can interfere with hormonal signalling pathways.[257] They have effects at very low levels, distinguishing them from classic dose-response curves used in toxicology. [258] Other toxins adsorbed onto microplastics can also be transferred into the tissues of animals upon ingestion.[259] There is growing evidence as to whether and how these chemicals can affect wildlife, an overview of which is given below, yet more research is needed to discover whether these translate into population level effects.

The plasticizer polychlorinated biphenyl (PCB) has been shown to accumulate in (migratory) seabirds such as the Great Shearwater (*Puffinus gravis*), and this was positively correlated with the birds' ingestion of plastic particles.[260] The concentration of certain PCBs in fatty tissue was also found to be correlated with the amount of ingested plastic in the Short-tailed Shearwater (*Puffinus tenuirostris*).[261]

PCBs have been shown to lead to reduced reproductive success in birds via increased embryo mortality and reduced hatching rates, altered reproductive behaviour such as nest attentiveness[262] and song,[263] egg shell thinning, lowered steroid hormone levels

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[255] Bakir, A., Rowland, S.J., and Thompson, R.C. (2014) Enhanced desorption of persistent organic pollutants from microplastics under simulated physiological conditions, *Environmental Pollution*, Vol.185, pp.16–23

[256] Oehlmann, J., Schulte-Oehlmann, U., Kloas, W., et al. (2009) A critical analysis of the biological impacts of plasticizers on wildlife, *Philosophical Transactions of the Royal Society B: Biological Sciences*, Vol.364, No.1526, pp.2047–2062

[257] Talsness, C.E., Andrade, A.J.M., Kuriyama, S.N., Taylor, J.A., and Saal, F.S. vom (2009) Components of plastic: experimental studies in animals and relevance for human health, *Philosophical Transactions of the Royal Society B: Biological Sciences*, Vol.364, No.1526, pp.2079–2096

[258] Vandenberg, L.N., Maffini, M.V., Sonnenschein, C., Rubin, B.S., and Soto, A.M. (2009) Bisphenol-A and the Great Divide: A Review of Controversies in the Field of Endocrine Disruption, *Endocrine Reviews*, Vol.30, No.1, pp.75–95

[259] Teuten, E.L., Saquing, J.M., Knappe, D.R.U., et al. (2009) Transport and release of chemicals from plastics to the environment and to wildlife, *Philosophical Transactions of the Royal Society B: Biological Sciences*, Vol.364, No.1526, pp.2027–2045

[260] Ryan, P.G., Connell, A.D., and Gardner, B.D. (1988) Plastic ingestion and PCBs in seabirds: Is there a relationship?, *Marine Pollution Bulletin*, Vol.19, No.4, pp.174–176

[261] Yamashita, R., Takada, H., Fukuwaka, M., and Watanuki, Y. (2011) Physical and chemical effects of ingested plastic debris on short-tailed shearwaters, Puffinus tenuirostris, in the North Pacific Ocean, *Marine Pollution Bulletin*, Vol.62, No.12, pp.2845–2849

[262] Peakall, D.B., and Peakall, M.L. (1973) Effect of a Polychlorinated Biphenyl on the Reproduction of Artificially and Naturally Incubated Dove Eggs, *The Journal of Applied Ecology*, Vol.10, No.3, p.863

causing delayed ovulation,[264] plus increased risk of cardiomyopathy with presumed increase in mortality,[265] and impaired immune function.[266] Impaired hatching has been shown to be correlated with PCB concentration in wild populations of the migratory Double-crested Cormorant (*Phalacrocorax auritis*) from the Great Lakes in North America; although the bird is estuarine rather than marine, it eats fish and is at risk of ingestion of plastic debris directly or indirectly.[267]

In Baltic Grey and Ringed Seals (*Halichoerus grypus* and *Phoca hispida)*, high body burdens of PCBs are linked to reproductive effects resulting in population declines.

Seabirds have also been shown to accumulate PBDEs (a family of flame-retardant chemicals) in proportion to the quantity of plastic ingested.[268]

The toxicological implications of absorption of chemicals by fish through plastic pellet ingestion has been only recently directly demonstrated, with fish ingesting pellets that had been immersed in the water in San Diego Bay, California, for three months, inducing hepatic stress in fish, compared with the ingestion of clean plastic pellets. In the two month duration of the feeding experiment, the fish accumulated some of the chemicals to which they had been exposed (one each of several PAHs and PCBs and all but one PBDE measured). The effects observed included glycogen depletion, attributed to the direct effect of the chemicals on carbohydrate metabolism and the energy cost of detoxification, and cellular changes that can lead to fatty liver degeneration and have already been observed in rats exposed to PCBs. [269]

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[263] Ottinger, M.A., Lavoie, E., Abdelnabi, M., Quinn, M.J., Marcell, A., and Dean, K. (2009) An Overview of Dioxin-Like Compounds, PCB, and Pesticide Exposures Associated with Sexual Differentiation of Neuroendocrine Systems, Fluctuating Asymmetry, and Behavioral Effects in Birds, *Journal of Environmental Science and Health, Part C*, Vol.27, No.4, pp.286–300

[264] Hoffman, D.J., Rice, C.P., and Kubiak, T.J. (1996) *PCBs and dioxins in birds*, 1996, http://pubs.er.usgs.gov/publication/5210754

[265] Carro, T., Dean, K., and Ottinger, M.A. (2013) Effects of an environmentally relevant polychlorinated biphenyl (PCB) mixture on embryonic survival and cardiac development in the domestic chicken, *Environmental Toxicology and Chemistry*, Vol.32, No.6, pp.1325–1331

[266] Grasman, K.A., and Fox, G.A. (2001) Associations between altered immune function and organochlorine contamination in young Caspian terns (Sterna caspia) from Lake Huron, 1997-1999, *Ecotoxicology (London, England)*, Vol.10, No.2, pp.101–114

[267] Tillitt, D.E., Ankley, G.T., Giesy, J.P., et al. (1992) Polychlorinated biphenyl residues and egg mortality in double-crested cormorants from the great lakes, *Environmental Toxicology and Chemistry*, Vol.11, No.9, pp.1281–1288

[268] Tanaka, K., Takada, H., Yamashita, R., Mizukawa, K., Fukuwaka, M., and Watanuki, Y. (2013) Accumulation of plastic-derived chemicals in tissues of seabirds ingesting marine plastics, *Marine Pollution Bulletin*, Vol.69, No.1–2, pp.219–222

[269] Rochman, C.M., Hoh, E., Kurobe, T., and Teh, S.J. (2013) Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress, *Scientific Reports*, Vol.3

Phthalate plasticizers such as DEHP have been associated with intersex conditions in fish.[270] The breakdown product of DEHP, MEHP was detected in the blubber of stranded Fin Whales (the migratory *Balaenoptera physalus)* in the Mediterranean; microplastic and phthalates were also detected in ocean water samples in the surrounding coastal areas. The upregulation of the oestrogen receptor alpha gene in Mediterranean fin whales compared with individuals from the Sea of Cortez was attributed to corresponding differences in the concentrations of organic pollutants in the whale blubber and ultimately to differences in environmental pollution in the surrounding areas.[271] In birds, in vitro exposure to environmentally relevant concentrations of MEHP can negatively affect spermatogenesis.[272]

In turtles, the ingestion of plastic and latex is correlated with lower blood glucose levels, suggesting that they may be affecting nutrient absorption or metabolism.[273] It is not known whether this is a toxicological effect or to do with other trophic effects, however this is consistent with results from fish where effects of chemicals on carbohydrate metabolism were attributed to the energy cost of detoxification.

Bisphenol A is an oestrogen agonist and an androgen antagonist. It affects reproduction in the fish and different invertebrates assayed, in concentration and species dependent ways. In fish it has been shown to affect spermatogenesis, ovulation and sex steroid levels at environmentally relevant concentrations. These changes can affect growth, bone and brain development, cellular division, and cause masculinization or feminization. One study demonstrated delayed sexual development in male chickens at environmentally relevant doses. Many detrimental effects on reproduction and development have been demonstrated in experimental rodents at high levels of BPA. There has been little research into the effects of long term, low level, chronic exposure on marine species, whether fish, turtles, birds or mammals.[274, 275]

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270 Oehlmann, J., Schulte-Oehlmann, U., Kloas, W., et al. (2009) A critical analysis of the biological impacts of plasticizers on wildlife, *Philosophical Transactions of the Royal Society B: Biological Sciences*, Vol.364, No.1526, pp.2047–2062

271 Fossi, M.C., Panti, C., Guerranti, C., Coppola, D., Giannetti, M., Marsili, L., and Minutoli, R. (2012) Are baleen whales exposed to the threat of microplastics? A case study of the Mediterranean fin whale (Balaenoptera physalus), *Marine Pollution Bulletin*, Vol.64, No.11, pp.2374–2379

272 Guibert, E., Prieur, B., Cariou, R., et al. (2013) Effects of mono-(2-ethylhexyl) phthalate (MEHP) on chicken germ cells cultured in vitro, *Environmental Science and Pollution Research*, Vol.20, No.5, pp.2771–2783

273 Lutz, P.L. (1990) Studies on the ingestion of plastic and latex by sea turtles, *Proc. Int. Conf. Marine Debris.(Eds. RS Shomura & ML Godfrey) NOAA-TM-154* (1990) pp.719–735

274 Oehlmann, J., Schulte-Oehlmann, U., Kloas, W., et al. (2009) A critical analysis of the biological impacts of plasticizers on wildlife, *Philosophical Transactions of the Royal Society B: Biological Sciences*, Vol.364, No.1526, pp.2047–2062

275 Flint, S., Markle, T., Thompson, S., and Wallace, E. (2012) Bisphenol A exposure, effects, and policy: A wildlife perspective, *Journal of Environmental Management*, Vol.104, pp.19–34

There is at least one monitoring program that is mapping the traces of organic pollutants on plastic pellets from worldwide samples so as to produce maps of microplastic associated pollutants.[276]

3.1.3.2 Immunity and Disease

One possible pathway via which organisms may be impacted by marine litter is via effects on the immune system. There are indications that chemicals associated with plastics can compromise immune function in birds.[277] In Baltic grey and ringed seals (*Halichoerus grypus* and *Phoca hispida)*, high body burdens of PCBs are linked to impairment of immune function and mass mortalities due to morbillivirus infection.[278]

Marine debris puts animals at risk of long term, open wounds. These can be external like those caused by some kind of constricting ligature, which are often infected.[279] Stumps left by fins lost through entanglement of turtles were noticed to be scarred, and it was thought that they had been further attacked by sharks, crabs or birds attracted by blood, necrotizing tissue, and possibly the prospect of food to be scavenged or an easy prey. [280] Open wounds can also be internal, like ulceration caused by ingestion, or a fish hook embedded in the jaw. These open wounds are potential initiation points for secondary infection. It has been suggested that uncontrolled infection can lead to microbes entering the blood stream and causing secondary infections in the lungs, heart, brain or other internal organs.[281] Infection in the jaw and resulting abscess can result in loss of teeth.[282] Peritonitis following intestinal perforation or rupture is an example of an acute infection that would follow immediately on from the occurrence of the internal injury, and is usually fatal. [283,284]

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[276] http://www.pelletwatch.org/

[277] Grasman, K.A., and Fox, G.A. (2001) Associations between altered immune function and organochlorine contamination in young Caspian terns (Sterna caspia) from Lake Huron, 1997-1999, *Ecotoxicology (London, England)*, Vol.10, No.2, pp.101–114

[278] Vos, J.G., Dybing, E., Greim, H.A., et al. (2008) *Health Effects of Endocrine-Disrupting Chemicals on Wildlife, with Special Reference to the European Situation*, accessed 13 December 2013, http://informahealthcare.com/doi/abs/10.1080/10408440091159176%20

[279] Raum-Suryan, K.L., Jemison, L.A., and Pitcher, K.W. (2009) Entanglement of Steller sea lions (Eumetopias jubatus) in marine debris: Identifying causes and finding solutions, *Marine Pollution Bulletin*, Vol.58, No.10, pp.1487–1495

[280] Carrington, D. (2013) 'CSI turtle' launches investigation into ghost fishing nets found in the Maldives, *Guardian*

[281] Raum-Suryan, K.L., Jemison, L.A., and Pitcher, K.W. (2009) Entanglement of Steller sea lions (Eumetopias jubatus) in marine debris: Identifying causes and finding solutions, *Marine Pollution Bulletin*, Vol.58, No.10, pp.1487–1495

[282] Raum-Suryan, K.L., Jemison, L.A., and Pitcher, K.W. (2009) Entanglement of Steller sea lions (Eumetopias jubatus) in marine debris: Identifying causes and finding solutions, *Marine Pollution Bulletin*, Vol.58, No.10, pp.1487–1495

[283] Beck, C.A., and Barros, N.B. (1991) The impact of debris on the Florida manatee, *Marine Pollution Bulletin*, Vol.22, No.10, pp.508–510

Stress hormones such as glucocorticoids are known to be released as a response to tissue damage – the example cited refers to cetaceans but it perhaps this mechanism applies to other animals. This suppresses lymphocyte production (part of the immune response) and may compromise the animal's ability to fight secondary infections or other disease.[285]

An example from turtles suggests that stranded turtles have high rates of parasite related death and makes the point that death from parasitism is an indicator of general poor health levels, as natural selection dictates that a successful parasite tends not to kill its host.[286] This is one example of how different factors in combination can affect mortality in the population. Small cetaceans that have been entangled in fishing gear were also thought to have above average parasite loads.[287] It has also been noted that large cetaceans who had suffered entanglement appeared more likely to display cutaneous white fungal infection (around 50%) compared to only a small fraction of the population at large.[288]

3.1.3.3 Temperature Dependent Sex Determination in Reptiles

An empirical approach that reconstructed sediment cores with different concentrations of microplastics in them found that the fragments altered the permeability of the sediment and this caused it to warm more slowly. As 95% of plastic fragments found on a heavily polluted Hawaiian beach occur in the top 15cm of sediment, it was deemed possible that this could affect species with temperature-dependent sex determination such as turtles, and alter the balance of males and females in the population.[289]

3.1.3.4 Migration Speed and Timing

There are strong indications that alterations to the timing of migration, such as delays which lead to late arrival at stopover or breeding sites, can have considerable effects

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[284] Jacobsen, J.K., Massey, L., and Gulland, F. (2010) Fatal ingestion of floating net debris by two sperm whales (Physeter macrocephalus), *Marine Pollution Bulletin*, Vol.60, No.5, pp.765–767

[285] Angliss, R., and DeMaster, D.P. (1998) Differentiating Serious and Non-Serious Injury of Marine Mammals Taken Incidential to Commercial Fishing Operations: Report of the Serious Injury Workshop, *NOAA Technical Memorandum NMFS-OPR*

[286] Townsend, K.A. (2011) Impact of ingested marine debris on sea turtles of eastern Australia: Life history stage susceptibility, pathological implications and plastic bag preference., *Technical Proceedings of the 5th International Marine Debris Conference* (2011) pp.180–183

[287] Angliss, R., and DeMaster, D.P. (1998) Differentiating Serious and Non-Serious Injury of Marine Mammals Taken Incidential to Commercial Fishing Operations: Report of the Serious Injury Workshop, *NOAA Technical Memorandum NMFS-OPR*

[288] Angliss, R., and DeMaster, D.P. (1998) Differentiating Serious and Non-Serious Injury of Marine Mammals Taken Incidential to Commercial Fishing Operations: Report of the Serious Injury Workshop, *NOAA Technical Memorandum NMFS-OPR*

[289] Carson, H.S., Colbert, S.L., Kaylor, M.J., and McDermid, K.J. (2011) Small plastic debris changes water movement and heat transfer through beach sediments, *Marine Pollution Bulletin*, Vol.62, No.8, pp.1708–1713

on reproductive fitness.[290] There are examples of migratory birds stopping over longer where food resources are poor in the stopping-over area, so that they attain sufficient weight, leading to subsequent delays resuming migration. There may also be severe competition for food resources at stop-over sites. At breeding sites, late arrivals may find resources already depleted by earlier arrivals, which can range from food and mates to territory. Birds with the best body condition arrive earlier and so have their pick of nesting and feeding sites; they start breeding sooner and have larger clutch sizes. [291,292] It is possible that individuals whose nutrition is negatively affected by marine debris, may be induced to spend longer at stopover sites, and/or compete less successfully for food at those sites (in the case of suppressed appetite). This could result in a generally poorer body condition, or later arrival at breeding sites, or both, and the affected individuals might suffer smaller clutch sizes as a result; however there is no direct evidence of this occurring as yet.

A further risk that could be incurred by individuals staying longer at stop-over sites is predation; for example, the Western Sandpiper (*Calidris mauri*), a shorebird, has been found to be making its stays at stopover sites shorter, apparently in response to the recovery of peregrine falcon populations after the reduction in the use of DDT, as a means of limiting their exposure to the predator. A factor leading them to extend their stay could conversely put them more at risk.[293]

There are even examples of birds apparently unable to accumulate sufficient body reserves in time to migrate at an appropriate date, in which case, they may remain in wintering areas or stop-over sites, where one assumes their ability to reproduce is severely compromised, or in breeding areas, where they may die as winter approaches.[294] The risk of this may be greater in birds that have consumed marine debris.

Another behavioural trait relevant to the marine debris issue is that lean pre-migratory birds take greater risks than fatter ones, spending less time scanning for predators, feeding for longer each day, more actively and in more dangerous places, and that this is how they speed their rate of feeding and weight gain.[295] This type of behaviour might be evident in a bird undernourished because of debris ingestion

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[290] Faaborg, J., Holmes, R.T., Anders, A.D., et al. (2010) Recent advances in understanding migration systems of New World land birds, *Ecological Monographs*, Vol.80, No.1, pp.3–48

[291] Newton, I. (2006) Can conditions experienced during migration limit the population levels of birds?, *Journal of Ornithology*, Vol.147, No.2, pp.146–166

[292] Smith, R.J., and Moore, F.R. (2005) Arrival timing and seasonal reproductive performance in a long-distance migratory landbird, *Behavioral Ecology and Sociobiology*, Vol.57, No.3, pp.231–239

[293] Ydenberg, R.C., Butler, R.W., Lank, D.B., Smith, B.D., and Ireland, J. (2004) Western sandpipers have altered migration tactics as peregrine falcon populations have recovered, *Proceedings of the Royal Society of London. Series B: Biological Sciences*, Vol.271, No.1545, pp.1263–1269

[294] Newton, I. (2006) Can conditions experienced during migration limit the population levels of birds?, *Journal of Ornithology*, Vol.147, No.2, pp.146–166

[295] Newton, I. (2006) Can conditions experienced during migration limit the population levels of birds?, *Journal of Ornithology*, Vol.147, No.2, pp.146–166

Although the timing of migration to coincide with types of vegetation or food resources and/or avoidance of certain predators [296] is felt to be of concern for the conservation of some migratory species in the context of climate change,[297] there is little direct evidence to demonstrate where this has occurred at present. Arguably such scenarios could be extended to any factor that could prevent a migratory species tracking some resource peaks such as delays that might be caused by marine debris impacts. However a marine debris impact affecting this type of migratory delay has not yet been demonstrated.

3.1.3.5 Feeding Behaviour

There is evidence from sharks, seals, turtles and whales, that entanglement can physically inhibit feeding behaviours and lead to starvation. See section 3.1.1.1 for details.

3.1.3.6 Obstacles to Migration

Litter on beaches has been shown to adversely affect the ability of turtle hatchlings to reach the Mediterranean Sea with two of three turtles having contact with litter on their way to reach the water[298]

3.1.4 Other Ecosystem or Habitat-related Impacts

One of the least well characterized impacts of marine debris is via ecosystem level effects.

For example, coral reefs, seagrass beds and the bottom-dwelling species associated with them are vulnerable to the impacts of marine debris in the following ways.[299] Netting snags itself on coral and can tear it apart. Debris can smother benthic habitats. It has been suggested that the accumulation of debris on the sea floor might inhibit gas exchange between water within the sediment and the overlying water, resulting in decreased oxygen in the benthos that could alter the composition of life on the sea floor.[300] Benthic debris coverage can be considerable. In a highly polluted bay in the Antarctic 15% of the surface area was covered by debris in parts.[301] An

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[296] Skov, C., Chapman, B.B., Baktoft, H., et al. (2013) Migration confers survival benefits against avian predators for partially migratory freshwater fish, *Biology Letters*, Vol.9, No.2, p.20121178

[297] Faaborg, J., Holmes, R.T., Anders, A.D., et al. (2010) Recent advances in understanding migration systems of New World land birds, *Ecological Monographs*, Vol.80, No.1, pp.3–48

[298] Triessnig, P., Roetzer, A., and Stachowitsch, M. (2012) Beach Condition and Marine Debris: New Hurdles for Sea Turtle Hatchling Survival, *Chelonian Conservation and Biology*, Vol.11, No.1, pp.68–77

[299] Ocean Conservancy, and Sheavley (2007) *National Marine Debris Monitoring Program - Final Program Report, Data Analysis and Summary*, 2007

[300] Goldberg, E.D. (1997) Plasticizing the Seafloor: An Overview, *Environmental Technology*, Vol.18, No.2, pp.195–201

[301] Lenihan, H.S., Oliver, J.S., Oakden, J.M., and Stephenson, M.D. (1990) Intense and localized benthic marine pollution around McMurdo Station, Antarctica, *Marine Pollution Bulletin*, Vol.21, No.9, pp.422–430

Indonesian study showed that there were fewer diatoms in the sediments underneath marine debris but more small invertebrates.[302] Additional hard substrate on the sea-floor attracts colonies of sessile marine organisms, and will affect the biodiversity.[303] Any alteration to these habitats will have knock on effects on species that rely on them, or species in higher trophic levels which feed on those species. For example, herbivorous turtles graze on sea-grass 'pastures'. Smothering or abrasion of these benthic habitats might degrade an important habitat for them, and additionally leave the turtles more vulnerable to ingestion of debris. [304,305]

In another example, the level of marine debris cover and coral cover was found to be negatively correlated, with debris abundance associated with decreasing species diversity, in the South Pacific.[306]

An emerging issue is the effect of ingestion of microplastics on invertebrates such as annelids, echinoderms, molluscs and crustaceans that are part of the food chain for marine vertebrates.[307] One concern is that plastics and their impacts will accumulate up the food chain exponentially. Much remains to be elucidated about this type of effect. For example, birds were shown to accumulate flame-retardants that are not present in their food diet, in direct proportion to the amount of plastic ingested, but not other chemicals that were expected to be found in the fish in their diet.[308]

Another concern is that microplastics might affect the productivity of these important prey items, and this would have implications for the species that feed on them. For example, blue mussels reduce their filter feeding activity upon ingestion of

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[302] Uneputty, P., and Evans, S.M. (1997) The impact of plastic debris on the biota of tidal flats in Ambon Bay (eastern Indonesia), *Marine Environmental Research*, Vol.44, No.3, pp.233–242

[303] Harms, J. (1990) Marine plastic litter as an artificial hard bottom fouling ground, *Helgoländer Meeresuntersuchungen*, Vol.44, No.3-4, pp.503–506

[304] Kiessling, I. (2003) *Finding Solutions: Derelict Fishing Geat and Other Marine Debris In*, Report for the National Oceans Office and the Department of the Environment and Heritage, 2003, http://www.environment.gov.au/system/files/resources/e4f285b6-6181-4c73-a510-8bc0ac0e2c0b/files/marine-debris-report.pdf

[305] Gunn, R., Hardesty, B.D., and Butler, J. (2010) Tackling 'ghost nets': Local solutions to a global issue in northern Australia, *Ecological Management & Restoration*, Vol.11, No.2, pp.88–98

[306] Richards, Z.T., and Beger, M. (2011) A quantification of the standing stock of macro-debris in Majuro lagoon and its effect on hard coral communities, *Marine Pollution Bulletin*, Vol.62, No.8, pp.1693–1701

[307] Ivar do Sul, J.A., and Costa, M.F. (2014) The present and future of microplastic pollution in the marine environment, *Environmental Pollution*

[308] Tanaka, K., Takada, H., Yamashita, R., Mizukawa, K., Fukuwaka, M., and Watanuki, Y. (2013) Accumulation of plastic-derived chemicals in tissues of seabirds ingesting marine plastics, *Marine Pollution Bulletin*, Vol.69, No.1–2, pp.219–222

microplastics.[309] Microplastic concentration in sediment, reduced lugworm feeding and weight loss was shown to be positively correlated in a laboratory experiment.[310]

Another scenario is the introduction of alien species which are known to significantly impact marine ecosystems.[311] One study predicted that global marine species diversity might decrease by as much as 58% if worldwide biotic mixing occurs.[312] Floating debris provides a platform upon which invasive species can raft, increasing the probability of 'biotic mixing'. 270 species have been reported rafting so far. This is considered an underestimate by the authors of the report. The size of this impact is not fully apparent, as whether a species is considered invasive or what particular impact it might have is not evaluated or stated.[313]

Floating plastic may also change population structure in a subtly different way. For example, it was recently demonstrated that for the Sea Skater (*Halobates sericeus)*, an insect that lives on the surface of the sea, increased density of microplastic in the ocean positively correlated with the density of Sea Skater eggs. Normally, because the species needs hard surfaces upon which to lay its eggs, the availablility of such surfaces limits the number of eggs that are laid.[314] This shows how increasing microplastic levels might lead to changes in population density, the extension of the range of certain species or the introduction of new ones,85 different species have been found using marine debris as a habitat so far. [315] Invertebrates are an important link in the marine food chain, and anything that significantly affects their population and distribution may represent a very significant change in the population structure of an ecosystem.

[309] Wegner, A., Besseling, E., Foekema, E.M., Kamermans, P., and Koelmans, A.A. (2012) Effects of nanopolystyrene on the feeding behavior of the blue mussel (Mytilus edulis L.), *Environmental Toxicology and Chemistry / SETAC*, Vol.31, No.11, pp.2490–2497

[310] Besseling, E., Wegner, A., Foekema, E.M., van den Heuvel-Greve, M.J., and Koelmans, A.A. (2013) Effects of microplastic on fitness and PCB bioaccumulation by the lugworm Arenicola marina (L.), *Environmental Science & Technology*, Vol.47, No.1, pp.593–600

[311] Hansen, G.J.A., Vander Zanden, M.J., Blum, M.J., et al. (2013) Commonly Rare and Rarely Common: Comparing Population Abundance of Invasive and Native Aquatic Species, *PLoS ONE*, Vol.8, No.10,Sala, O.E., Chapin, F.S., 3rd, Armesto, J.J., et al. (2000) Global biodiversity scenarios for the year 2100, *Science (New York, N.Y.)*, Vol.287, No.5459, pp.1770–1774

[312] Mckinney, M.L. (1998) On predicting biotic homogenization: species-area patterns in marine biota, *Global Ecology & Biogeography Letters*, Vol.7, No.3, pp.297–301

[313] STAP/GEF (2012) *Impacts of marine debris on biodiversity: Current status and potential solutions*, Report for CBD, 2012

[314] Goldstein, M.C., Rosenberg, M., and Cheng, L. (2012) Increased oceanic microplastic debris enhances oviposition in an endemic pelagic insect, *Biology Letters*, p.rsbl20120298

[315] STAP/GEF (2012) *Impacts of marine debris on biodiversity: Current status and potential solutions*, Report for CBD, 2012

3.1.5 Knowledge Gaps

Filling in knowledge gaps is necessary to help focus management priorities. In some circumstances, focussing initiatives on particular species, stakeholders or regions may be a highly effective use of limited resources. However there will be limitations, whether because of economic, technological, or practical feasibility, to what it is possible to know, consequent limitations for the comprehensiveness of any dataset, and difficulties in making analyses of trends through the integration of multiple datasets. The argument can be made that a great deal of time and momentum would be needlessly lost awaiting information that answers *all* the unanswered questions that remain about marine debris and its impacts, a goal which is only ever going to be attainable in part. Many initiatives have been proposed on the basis of qualitative information or hypotheses with a narrow evidence base. It is unlikely that all of the actions deemed highly likely to be effective at present would change radically with more knowledge, save better focussing and some exceptions. Some researchers have stated that studies of debris need to move on from documenting occurrence and invest more effort in estimating the lethal and sublethal impacts at the population level, as they could represent a significant proportion of affected individuals not yet accounted for.[316] Others remind that a balance must be achieved between avoiding delay and guiding action with a reasonable amount of evidence:

> *"Sometimes it is justified to act before all information we would like is available – but needs to be proportionate and adaptive, as some proposed 'solutions' may make the marine litter situation worse"* [317]

3.1.5.1 Quantitative Information on Prevalence

It is not known, with any accuracy, which species are the most affected by marine debris. The quantitative information available is unequally distributed across species groups and impacts. Most quantitative data comes from studies of seals and entanglement.[318,319] There is a moderate amount, relatively speaking, of information regarding baleen whales and entanglement also. There are a number of quantitative studies regarding birdsand entanglement but poor global coverage. This is also true for turtles and entanglement. Toothed whales are lacking almost any quantitative data on entanglement. There is a single large scale quantitative study on manatees,

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[316] Bjorndal, K.A. (1997) Foraging Ecology and Nutrition of Sea Turtles (1997)

[317] Kershaw, P.J. (2013) *Marine Litter - where are we?*, Global Conference on Land - Ocean Connections, Jamaica

[318] Marsh, H., Arnold, P., Freeman, M., et al. (2003) Strategies for Conserving Marine Mammals, *Marine Mammals: Fisheries, Tourism and Management Issues: Fisheries, Tourism and Management Issues* (2003)

[319] Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for WSPA, 2012, http://www.wspa-international.org/Images/Untangled%20Report_tcm25-32499.pdf

entanglement and ingestion. As bycatch and entanglement in debris is not distinguished for fish, no quantitative data has been considered.

There is a considerable amount of quantitative information on birds and ingestion, and also on turtles and ingestion, albeit with incomplete regional coverage. There is a moderate amount of information on fish and ingestion but with little global coverage. There is very little information however on seals and ingestion. Data regarding baleen whales and ingestion are almost entirely represented by occasional incidents.

It is difficult to assess to what extent the number and geographical distribution of reported animal-debris interactions represents occurrence of impacts as opposed to focus of monitoring effort, however several reviews conclude it is a result of the latter.

Of the quantitative information available, there are few population level estimates of impact. There are several reasons why it is difficult to determine the significance of marine debris impacts at population levels. At the most basic level, it is often made impossible by the fact that impact monitoring is often not accompanied by estimates of total population as it would be too resource intensive to produce them.

Another reason that it is not known, with any accuracy, which species are the most affected by marine debris is that observed incidences of any impact underestimate actual figures. (For example, entangled species may die at sea prior to detection.)[320] For seals, studies have shown that the probability of sighting entangled animals on land is reduced because entangled seals spend more time at sea and have lower survival rates.[321] One study on whales estimated that only 3 to 10% of entanglements were witnessed and reported.[322] Of all the killer whale mortality documented in British Columbia, only 6% of cases result in the finding of carcasses.[323] Total debris-related mortality will therefore be underestimated.[324]

Furthermore, accurate data related to ingestion is unavailable because there is currently no reliable method for assessing debris ingestion in live populations. [325] For ingestion, most data is based only on examination of carcasses and attempts to

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[320] Marsh, H., Arnold, P., Freeman, M., et al. (2003) Strategies for Conserving Marine Mammals, *Marine Mammals: Fisheries, Tourism and Management Issues: Fisheries, Tourism and Management Issues* (2003)

[321] Fowler, C.W. (1987) Marine debris and northern fur seals: A case study, *Marine Pollution Bulletin*, Vol.18, pp.326–335,Delong, R.L., Gearin, P.J., Bengtson, J.L., and Dawson, P. (1990) Studies of the Effects of Entanglement on Individual Northern Fur Seals, *Proceedings of the Second International Conference on Marine Debris* (1990) Honolulu, Hawaii

[322] Cole, T.V., Hartley, D., and Garron, M. (2006) Mortality and Serious Injury Determinations for Baleen Whale Stocks along the Eastern Seaboard of the United States, 2000-2004

[323] Williams, R., Ashe, E., and O'Hara, P.D. (2011) Marine mammals and debris in coastal waters of British Columbia, Canada, *Marine Pollution Bulletin*, Vol.62, No.6, pp.1303–1316

[324] Marsh, H., Arnold, P., Freeman, M., et al. (2003) Strategies for Conserving Marine Mammals, *Marine Mammals: Fisheries, Tourism and Management Issues: Fisheries, Tourism and Management Issues* (2003)

[325] Schuyler, Q., Hardesty, B.D., Wilcox, C., and Townsend, K. (2013) Global Analysis of Anthropogenic Debris Ingestion by Sea Turtles, *Conservation Biology*, p.n/a–n/a

establish prevalence at the population level are rarely made. The sample population, which in that case consists solely of stranded, deceased individuals, is likely to be unrepresentative of the total population, and in addition will miss out the majority of affected individuals, whether affected fatally or sublethally (for example birds that die from ingestion though obstruction of the intestinal tract and starvation will mostly sink in the water or be scavenged,[326] and this is also thought to be the case for baleen and toothed whales, especially the deep-sea diving ones).[327] This makes the extrapolation of prevalence to the population as a whole untenable. Some studies have tried to make the sample population more representative by collecting birds that have died via other means (e.g. accidentally caught in longline fishing,[328] or those hit by vehicles).[329] In both cases, accidentally killed birds had lower quantities of ingested plastic than those found dead, further suggesting that plastic ingestion is contributing to mortality, however occurrence was not necessarily lower. Nevertheless, this form of sampling may still be biased against an unknown number of deceased individuals lost or scavenged at sea, and so still not as reliable for making population wide estimates as desired.

It has been suggested that relative to entanglement, ingestion is generally likely to be underreported, simply because of the fact that entanglement and its consequences are more easily observed.[330]

On the other hand, techniques to obtain representative live sample populations and assess them for ingestion are also known to lead to underestimates, for some species at least, but is likely to be true of other animals too. [331] For example, when lavage (gastric irrigation) and faecal analysis were compared in the same population of turtles, faecal analysis revealed 10 times more individuals having ingested debris than lavage at 19% vs. 1.9%. Necropsy revealed a proportion of 29%.[332] It is also very difficult to establish exact cause of death, with only a clinical history plus a necropsy

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[326] Pierce, K.E., Harris, R.J., Larned, L.S., and Pokras, M.A. (2004) Obstruction and starvation associated with plastic ingestion in a northern gannet Morus bassanus and a greater shearwater Puffinus gravis, *Marine Ornithology*, Vol.32, pp.187–189

[327] Simmonds, M.P. (2012) Cetaceans and Marine Debris: The Great Unknown, *Journal of Marine Biology*, Vol.2012

[328] Codina-García, M., Militão, T., Moreno, J., and González-Solís, J. (2013) Plastic debris in Mediterranean seabirds, *Marine Pollution Bulletin*

[329] Auman, H.J., Ludwig, J.P., Giesy, J.P., and Colborn, T. (1997) Plastic ingestion by Laysan albatross chicks on Sand Island, Midway Atoll, in 1994 and 1995, *Albatross Biology and Conservation*, pp.239–244

[330] STAP/GEF (2012) *Impacts of marine debris on biodiversity: Current status and potential solutions*, Report for CBD, 2012

[331] Schuyler, Q., Hardesty, B.D., Wilcox, C., and Townsend, K. (2013) Global Analysis of Anthropogenic Debris Ingestion by Sea Turtles, *Conservation Biology*, p.n/a–n/a

[332] Schuyler, Q., Hardesty, B.D., Wilcox, C., and Townsend, K. (2013) Global Analysis of Anthropogenic Debris Ingestion by Sea Turtles, *Conservation Biology*, p.n/a–n/a

able to do so with a reasonable success rate, which is not feasible for most observational studies on wild populations.[333]

It is clear that the data available is likely to underestimate the population wide prevalence of the impacts of marine debris.

3.1.5.2 Difficulty Establishing Extent of Sublethal Impacts

One turtle study pointed out that sublethal impacts of ingestion are relatively rarely reported upon, even though sublethal effects such as partial obstruction of the digestive tract and reduction of feeding stimulus are more likely to be the major threats in the long term.[334] There have been some studies making progress around the state of knowledge about the exact nature and severity of such impacts. Some are experimental [335,336] and some are field studies – yet a great deal more specific research is needed to unequivocally establish mechanisms and extent of harm, and this has been stated by a variety of researchers.[337,338] It is challenging to establish causation versus correlation in the few studies where plastic ingestion has been correlated with poorer body condition and year on year survival, and empirical approaches are needed. [339]

3.1.5.3 Interaction between Factors

There is not currently a great deal of research on interactions between impacts of marine debris and other threats, as large and comprehensive datasets would be needed to tease out the likely subtle influence of multiple factors on a population. If marine debris impairs the health of an organism, it may make them more vulnerable to other threats. One example is effects of debris on the immune system via toxicological effects of chemicals associated with plastic, or stress from entanglement, and parasite load (Section 3.1.3.2).

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[333] Pierce, K.E., Harris, R.J., Larned, L.S., and Pokras, M.A. (2004) Obstruction and starvation associated with plastic ingestion in a northern gannet Morus bassanus and a greater shearwater Puffinus gravis, *Marine Ornithology*, Vol.32, pp.187–189

[334] Tourinho, P.S., Ivar do Sul, J.A., and Fillmann, G. (2010) Is marine debris ingestion still a problem for the coastal marine biota of southern Brazil?, *Marine Pollution Bulletin*, Vol.60, No.3, pp.396–401

[335] McCauley, S.J., and Bjorndal, K.A. (1999) Conservation Implications of Dietary Dilution from Debris Ingestion: Sublethal Effects in Post-Hatchling Loggerhead Sea Turtles, *Conservation Biology*, Vol.13, No.4, pp.925–929

[336] Ryan, P.G. (1988) Effects of ingested plastic on seabird feeding: Evidence from chickens, *Marine Pollution Bulletin*, Vol.19, No.3, pp.125–128

[337] Vlietstra, L.S., and Parga, J.A. (2002) Long-term changes in the type, but not amount, of ingested plastic particles in short-tailed shearwaters in the southeastern Bering Sea, *Marine Pollution Bulletin*, Vol.44, No.9, pp.945–955

[338] Bjorndal, K.A. (1997) Foraging Ecology and Nutrition of Sea Turtles (1997)

[339] Ryan, P.G. (1987) The effects of ingested plastic on seabirds: Correlations between plastic load and body condition, *Environmental Pollution*, Vol.46, No.2, pp.119–125

3.1.5.4 Migratory vs. Resident Species

As is often stated, migratory species are particularly vulnerable because of the fact that they rely on a whole series of habitats throughout their ranges, and if any one of these is impacted, it will constitute a threat to the population as a whole. Because multiple locations are involved, there is a greater likelihood that one or more *will* be affected.[340,341] And these threats come from multiple sources – not just marine debris but many other human activities such as hunting, egg removal, feral animals, fishing practices and physical barriers as well as larger scale environmental changes which are also predominantly anthropogenic.[342,343] For a migratory species in any one range state, their survival depends on their continued viability in a whole series of locations in their global distribution.

However, there are no studies systematically examining whether and how migratory species are more vulnerable to marine debris than resident species.

Within research on species which happen to be migratory, several points have, however, been noted.

One is that more research is needed to properly establish the causal chain between plastic ingestion, trophic effects and/or behavioural effects, and impacts on fitness or survival, for migrant individuals. It is thought that en route conditions can limit migrant populations; but it is recognized that linking migration habitat quality indicators to fitness or population consequences presents a major challenge, and there are very few studies that have attempted to do this.[344,345] This can equally apply to marine debris.

Many observations relate to the geospatial distribution of animals, debris, and the en route habits of particular migrants.

Some migratory species feed constantly, as they migrate across areas that are generally ecologically hospitable to them (most marine migratory species). Some species pick their way forward in stages upon modest fat resources (some bird species). While others still make their way nonstop across ecological barriers (particular bird species especially).

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340 GRID-Arendal (2011) *Living planet: connected planet: preventing the end of the world's wildlife migrations through ecological networks*, Report for UNEP, 2011

341 Newton, I. (2006) Can conditions experienced during migration limit the population levels of birds?, *Journal of Ornithology*, Vol.147, No.2, pp.146–166

342 GRID-Arendal (2011) *Living planet: connected planet: preventing the end of the world's wildlife migrations through ecological networks*, Report for UNEP, 2011

343 National Research Council of the United Stated of America(1990) *Decline of the Sea Turtles: Causes and Prevention*,

344 Faaborg, J., Holmes, R.T., Anders, A.D., et al. (2010) Recent advances in understanding migration systems of New World land birds, *Ecological Monographs*, Vol.80, No.1, pp.3–48

345 Newton, I. (2006) Can conditions experienced during migration limit the population levels of birds?, *Journal of Ornithology*, Vol.147, No.2, pp.146–166

Species that feed constantly are expected to ingest litter all through their range. Items that they ingest will reflect the debris composition across the range that they are able to travel across in the time it takes for debris to transit their digestive systems. For example, petrels retain debris in their stomachs for months, and so this is held to reflect the composition of debris found all over the Pacific Ocean, where they range.[346] Similarly, the debris found in the stomachs of turtles, which migrate over distances of thousands of miles, is not well correlated with the location in which the turtle is found.[347] This highlights one way in which migratory species are more vulnerable than sedentary populations: as they travel, they are less likely to be able to avoid areas where debris accumulates than resident populations, which may have proportions residing in less polluted areas. This is true for entanglement as well as ingestion; however there are some indications that entanglement risk can be more localized.

However there are also migratory species that travel large distances in very few days such as the Bar-tailed Godwit (*Limosa lapponica*),[348] or the endangered Pink-footed Shearwater (*Puffinus creatopus*).[349] They will therefore cover considerable distances without being at risk of encountering marine debris; this will affect the relationship between impact risk and distribution of marine debris for these species. Breeding and non-breeding distributions may be very large for these birds and so, as a population, they will perhaps benefit in the way that resident species might from parts of their population being able to avoid areas most impacted by marine debris.

However it has been suggested that habitat degradation would have the most severe effect on migrants in the places where the habitat is the last possible feeding place before an ecological barrier, or the first feeding place after such a barrier.[350] For shorebirds, like the Golden Plover (*Pluvialis dominica*), or the Turnstone, (*Arenarius interpres*), many of these 'staging sites' will be coastal areas,[351] and so a prime location for these birds to encounter marine debris.

Birdlife International has assessed these and other important locations (which they term 'Important Bird Areas' (IBAs)) for 300 waterbird species.[352] It would be informative to compare the IBAs with distributions of debris for entanglement and

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[346] Ryan, P.G. (2008) Seabirds indicate changes in the composition of plastic litter in the Atlantic and south-western Indian Oceans, *Marine Pollution Bulletin*, Vol.56, No.8, pp.1406–1409

[347] Schuyler, Q., Hardesty, B.D., Wilcox, C., and Townsend, K. (2013) Global Analysis of Anthropogenic Debris Ingestion by Sea Turtles, *Conservation Biology*, p.n/a–n/a

[348] http://www.birdlife.org/datazone/speciesfactsheet.php?id=3005

[349] Hodum, P., and Hyrenbach, D. (2006) Conservation Implications of Migration Routes of Pink-footed Shearwaters

[350] Newton, I. (2006) Can conditions experienced during migration limit the population levels of birds?, *Journal of Ornithology*, Vol.147, No.2, pp.146–166

[351] Alerstam, T.(1993) *Bird Migration*, Cambridge University Press

[352] Birdlife International (2008) *A network of critical sites for migratory waterbirds is being identified across Africa and Eurasia. Presented as part of the BirdLife State of the world's birds website.*, accessed 26 November 2013, http://www.birdlife.org/datazone/sowb/casestudy/101

ingestion risk.[353] The few studies that have attempted to do this for any migratory species tend to use proxies to estimate marine debris in some way, such as shipping routes for example, [354] and even fewer have used detailed species distributions and records of impacts.[355] None have been found that utilize migratory path data. This comes as no surprise as it would require considerable research effort; with plenty of the necessary data about migration routes, feeding locations and marine debris distribution perhaps never collected on an adequate spatial resolution or even at all. To integrate this spatial information, probably in very different formats and resolutions, would also represent a challenge.

The anadromous Striped Bass (*Morone saxatilis*) is known to ingest debris. Anadromous species spawn in fresh water but live most of their lives in marine environments; there is concern that this life-history trait, which brings the fish into close contact with areas of concentrated human activity, can increase their risk of exposure to anthropogenic threats.[356]

3.1.5.5 Differential Vulnerability to Marine Debris at Different Life History Stages and other Trends

Several studies have shown that in seals, juveniles are the age class most susceptible to entanglement[357,358] and it has been suggested that this is because of their playful behaviour, inexperience and the comparatively small size of their heads, which enable them to fit through a wide range of mesh sizes [359] Additionally, some studies have shown that juvenile males are very significantly more likely to become entangled than juvenile females; so much so that this was thought to mitigate any population level effects of entanglement as the number of males is not the limiting factor on breeding in this polygynous species.[360] In turtles, it is also the younger life stages that appear to be more affected; in Australian waters and amongst stranded

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353 http://maps.birdlife.org/marineIBAs/default.html

354 Pompa, S., Ehrlich, P.R., and Ceballos, G. (2011) Global distribution and conservation of marine mammals, *Proceedings of the National Academy of Sciences*, p.201101525

355 Schuyler, Q., Hardesty, B.D., Wilcox, C., and Townsend, K. (2013) Global Analysis of Anthropogenic Debris Ingestion by Sea Turtles, *Conservation Biology*, p.n/a–n/a

356 U. S. Fish and Wildlife Service Southern New England-New York Bight Coastal Ecosystems Program(1996) *Regionally Significant Habitats and Habitat Complexes of the New York Bight Watershed*, http://library.fws.gov/pubs5/web_link/text/int_fish.htm

357 Pemberton, D., Brothers, N., and Kirkwood, R. (1992) Entanglement of Australian fur seals in man-made debris in Tasmanian waters, *Wildlife Research*, Vol.19, No.2, pp.151–159

358 Arnould, J.P.Y., and Croxall, J.P. (1995) Trends in entanglement of Antarctic fur seals (Arctocephalus gazella) in man-made debris at South Georgia, *Marine Pollution Bulletin*, Vol.30, No.11, pp.707–712

359 Marsh, H., Arnold, P., Freeman, M., et al. (2003) Strategies for Conserving Marine Mammals, *Marine Mammals: Fisheries, Tourism and Management Issues: Fisheries, Tourism and Management Issues* (2003)

360 Arnould, J.P.Y., and Croxall, J.P. (1995) Trends in entanglement of Antarctic fur seals (Arctocephalus gazella) in man-made debris at South Georgia, *Marine Pollution Bulletin*, Vol.30, No.11, pp.707–712

individuals, young, pelagic feeders had ingested debris at a disproportionate rate (55%) relative to 25% for older, benthic feeding turtles.[361] It was suggested that a range of factors may play a role in the probability of the turtles dying due to ingested marine debris, such as size of animal, feeding strategy, location during life stage (such as open versus coastal areas), and length of time spent in the open ocean. For example, the young pelagic individuals may be spending time in convergence zones where marine debris tends to accumulate.[362]

Maximal debris ingestion was found in recently weaned dolphins by one study, suggesting juveniles might also be more vulnerable in this group of animals too, correlated with changes in feeding behaviour during development.[363] Younger whales are more vulnerable to entanglement as they can become entangled in ropes of lower breaking strength than adults.[364] It is also noted that calves have the lowest annual scarring rate of all ages – it is thought that this reflects higher mortality owing to softer and growing tissues being more susceptible to debris becoming embedded and resulting in constriction, wounding and infection.[365]

Young birds often have a higher load of plastic in their digestive tracts compared with adults, which is thought to either be because of transfer from parents to offspring during feeding or because of lack of discrimination during feeding by naïve juveniles.[366] The Northern Gannet (*Morus bassanus*), which is migratory, has been found to use nets as nesting material, either found *in situ* or actively gathered by the birds, with ensuing grave entanglement and mortality risk predominantly for nestlings

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[361] Townsend, K.A. (2011) Impact of ingested marine debris on sea turtles of eastern Australia: Life history stage susceptibility, pathological implications and plastic bag preference., *Technical Proceedings of the 5th International Marine Debris Conference* (2011) pp.180–183

[362] Carr, A. (1987) Impact of nondegradable marine debris on the ecology and survival outlook of sea turtles, *Marine Pollution Bulletin*, No.18, p.352

[363] Denuncio, P., Bastida, R., Dassis, M., Giardino, G., Gerpe, M., and Rodríguez, D. (2011) Plastic ingestion in Franciscana dolphins, Pontoporia blainvillei (Gervais and d'Orbigny, 1844), from Argentina, *Marine Pollution Bulletin*, Vol.62, No.8, pp.1836–1841

[364] Werner, T. (2011) Preliminary Report of the Dynamics of Large Whale Entanglements in Fishing Gear Workshop (2011)

[365] Neilson, J.L., Straley, J.M., Gabriele, C.M., and Hills, S. (2009) Non-lethal entanglement of humpback whales (Megaptera novaeangliae) in fishing gear in northern Southeast Alaska, *Journal of Biogeography*, Vol.36, No.3, pp.452–464

[366] Ryan, P.G. (1988) Effects of ingested plastic on seabird feeding: Evidence from chickens, *Marine Pollution Bulletin*, Vol.19, No.3, pp.125–128,Mallory, M.L., Robertson, G.J., and Moenting, A. (2006) Marine plastic debris in northern fulmars from Davis Strait, Nunavut, Canada, *Marine Pollution Bulletin*, Vol.52, No.7, pp.813–815

but also adults.[367] Young gannets at sea were also found to be overwhelmingly the ones affected by entanglement.[368]

The implication of this is that prioritizing breeding areas where there are high concentrations of juveniles may be one way of concentrating effort against marine debris to its greatest effect; at least for clean-up initiatives. However removal strategies are not always demonstrably successful; there have been regular efforts to disentangle Hawaiian monk seals and remove derelict fishing gear from their pupping beaches, but there has been no apparent decline in the number of entanglements or the amounts of material removed.[369] But perhaps more data is needed to make a firm conclusion, as for example, background levels of debris were not simultaneously monitored. Despite the acknowledged paucity of data, it is still suggested that removal of debris from breeding areas and adjacent waters may be particularly beneficial.[370] Mapping breeding areas of importance to migratory species, akin to Birdlife's 'Important Bird Area' mapping would be a good start if such an approach was desired.

In a survey of plastic ingestion among 36 seabird species in the southern hemisphere, incidence of ingested plastic was directly related to foraging technique. Foraging techniques were categorized as dipping/pattering. A greater number of species that feed by dipping /pattering ingested plastic compared to species classified as surface-seizing, pursuit diving, plunge diving and piracy; and the incidence within these species was also greater. This is thought to be linked to the fact that most plastic debris is found floating on the surface of the water. Incidence was inversely related to the frequency of regurgitation of indigestible stomach contents. Birds that periodically regurgitate include albatrosses, giant petrels, cormorants, skuas and gulls. They tended to have lower incidence of plastic ingestion than birds that do not regurgitate habitually, such as penguins and other types of petrels. [371,372] Additionally, omnivores were more likely to have ingested plastic than those eating crustaceans, cephalopods or fish alone, perhaps because

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[367] Votier, S.C., Archibald, K., Morgan, G., and Morgan, L. (2011) The use of plastic debris as nesting material by a colonial seabird and associated entanglement mortality, *Marine Pollution Bulletin*, Vol.62, No.1, pp.168–172

[368] Rodríguez, B., Bécares, J., Rodríguez, A., and Arcos, J.M. (2013) Incidence of entanglements with marine debris by northern gannets (Morus bassanus) in the non-breeding grounds, *Marine Pollution Bulletin*, Vol.75, No.1–2, pp.259–263

[369] Henderson, J.R. (2001) A Pre- and Post-MARPOL Annex V Summary of Hawaiian Monk Seal Entanglements and Marine Debris Accumulation in the Northwestern Hawaiian Islands, 1982–1998, *Marine Pollution Bulletin*, Vol.42, No.7, pp.584–589

[370] Marsh, H., Arnold, P., Freeman, M., et al. (2003) Strategies for Conserving Marine Mammals, *Marine Mammals: Fisheries, Tourism and Management Issues: Fisheries, Tourism and Management Issues* (2003)

[371] Tourinho, P.S., Ivar do Sul, J.A., and Fillmann, G. (2010) Is marine debris ingestion still a problem for the coastal marine biota of southern Brazil?, *Marine Pollution Bulletin*, Vol.60, No.3, pp.396–401

[372] Ryan, P.G. (1987) The incidence and characteristics of plastic particles ingested by seabirds, *Marine Environmental Research*, Vol.23, No.3, pp.175–206

they are less discriminating feeders. A greater proportion of smaller bird species ingested plastic, with a lower degree of colour selectivity. It was suggested that this might be due to more specific prey-identification in large birds that feed on squid or larger fish, whereas it might be more difficult for small species which eat smaller planktonic organisms to distinguish them from small pieces of debris.

Procellariiformes (petrels, shearwaters and albatrosses), of which a large proportion are migratory and many are endangered, exhibit the largest plastic loads because they frequently forage at, or near the surface of the sea, taking a wide range of prey types, and seldom regurgitate indigestible stomach contents.[373] Charadriiformes (gulls, terns, curlews and others), of which there are also many migratory and endangered species, generally have lower incidence of plastic ingestion because of their different behaviours.[374] However there are exceptions to all these observed trends, with some albatross and the giant petrel, which despite the fact that they, atypically for the procellariiformes, do exhibit regurgitation, still accumulate large quantities of plastic. Some studies have found a low incidence of ingestion in penguins, despite the fact that they seldom regurgitate indigestible items.[375] It has been suggested that the entanglement risk for gannets is related to their plunge-diving fishing behaviour.[376]

For turtles, different species have been shown to have different susceptibility to different marine debris impacts. Carnivorous species (such as the Loggerhead or Kemp's Ridley turtles) are less likely to ingest debris than herbivorous, omnivorous or gelatinovorous species (such as Green or Leatherback turtles). This could be for a variety of reasons, such as soft plastic having a closer resemblance to gelatinous organisms as compared to any kind of debris and carnivore prey; or because herbivores are less selective or feed in areas that accumulate debris. It was suggested that other species-specific differences in prevalence might be due to different species having different size diameter digestive tracts within similar age classes; those with smaller diameter tracts may find it more difficult to pass ingested materials.[377] In an entanglement study more Hawksbill and Olive Ridley turtles were affected than Green or Flatback turtles. However whether this was disproportionate

[373] Ryan, P.G. (1987) The incidence and characteristics of plastic particles ingested by seabirds, *Marine Environmental Research*, Vol.23, No.3, pp.175–206

[374] Tourinho, P.S., Ivar do Sul, J.A., and Fillmann, G. (2010) Is marine debris ingestion still a problem for the coastal marine biota of southern Brazil?, *Marine Pollution Bulletin*, Vol.60, No.3, pp.396–401

[375] Tourinho, P.S., Ivar do Sul, J.A., and Fillmann, G. (2010) Is marine debris ingestion still a problem for the coastal marine biota of southern Brazil?, *Marine Pollution Bulletin*, Vol.60, No.3, pp.396–401

[376] Rodríguez, B., Bécares, J., Rodríguez, A., and Arcos, J.M. (2013) Incidence of entanglements with marine debris by northern gannets (Morus bassanus) in the non-breeding grounds, *Marine Pollution Bulletin*, Vol.75, No.1–2, pp.259–263

[377] Schuyler, Q., Hardesty, B.D., Wilcox, C., and Townsend, K. (2013) Global Analysis of Anthropogenic Debris Ingestion by Sea Turtles, *Conservation Biology*, p.n/a–n/a

compared to the local population composition was not tested because the sample sizes were considered to be too small to do so.[378]

It has been proposed that animals whose feeding behaviour includes bottom feeding, such as the sperm whale, accounts for the tendency of this species to ingest a variety of non-food items, such as sand, rocks, coconuts or other debris, so this and species with similar behaviour, may be at greater risk from marine debris, at least that on the sea-floor.[379] Beluga and Grey whales are also benthic feeders, and may also run similarly elevated risk. Sperm whales and other toothed whales have also been singled out as at greater risk because of their 'suction feeding' behaviour, while the northern right whale (*Eubalaena glacialis*) has been singled out as being at particular risk from entanglement because it is a 'ram feeder' and so likely to encounter various forms of marine debris with their mouths open.[380]

In a study of pelagic predatory fish, the species with the highest rates of ingestion were thought to live and feed primarily in the subsurface part of the water column. This was deemed surprising as most of the plastic found was buoyant in samples of seawater mimicking all depths.[381]

3.1.5.6 Regional Distinctions

Regarding whether there can be considered 'hotspots' for particular impacts the report commissioned for the Convention on Biological Diversity states that it is likely that there is an underreporting in some regions. More reports are from North America, Europe and Australasia, while few reports of impacts exist from Asia, Africa, the Arctic and Antarctic. It was felt that this reflected frequency of reporting rather than a reflection of quantities of debris and therefore decreased frequency of impacts.[382] Survey efforts were also felt to determine the distribution of records of impacts within regions, such as Australian waters. For example, it was noted that seabird records tend to be concentrated around large urban centres, especially where zoos or wildlife rescue organizations receive dead and injured birds and maintain records, and on

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[378] Wilcox, C., Hardesty, B.D., Sharples, R., Griffin, D.A., Lawson, T.J., and Gunn, R. (2013) Ghostnet impacts on globally threatened turtles, a spatial risk analysis for northern Australia, *Conservation Letters*, Vol.6, No.4, pp.247–254

[379] de Stephanis, R., Giménez, J., Carpinelli, E., Gutierrez-Exposito, C., and Cañadas, A. (2013) As main meal for sperm whales: Plastics debris, *Marine Pollution Bulletin*, Vol.69, No.1–2, pp.206–214

[380] Simmonds, M.P. (2012) Cetaceans and Marine Debris: The Great Unknown, *Journal of Marine Biology*, Vol.2012

[381] Choy, C.A., and Drazen, J.C. (2013) Plastic for dinner? Observations of frequent debris ingestion by pelagic predatory fishes from the central North Pacific, *Marine Ecology Progress Series*, Vol.485, pp.155–163

[382] STAP/GEF (2012) *Impacts of marine debris on biodiversity: Current status and potential solutions*, Report for CBD, 2012

offshore islands where plastic ingestion by particular seabird species has been studied.[383]

There are areas where turtles occur in large numbers such as Southeast Asia, Western and Northern Australia, South America, Africa, and in the high seas at subtropical latitudes, where the effects of debris are considered under-researched.[384] There is reasonably good coverage of reports of ingestion across these regions, but this is not the case for reports of entanglement. However there are enough reports of impacts all in all to understand that debris is a significant issue for sea turtles.

However, another review states that even though research and reporting effort is not uniformly distributed, with no reporting at all in some regions, it is felt that in some regions, the elevated number of reports does reflect areas where there is a higher risk of impacts, and that it may be helpful to target resources in those areas. For entanglement, the review concluded that the Eastern coast of the USA, the Northern Pacific and Sea of Japan were risk areas for whales, the Western coast of the USA was a risk area for fur seals, sea lions and humpback whales, the Eastern Coast of Australia and the Southern African a hotspot for fur seals, the North Sea a risk area for grey seals, Minke Whales and gannets, and the Northern Coast of Australia a hotspot for turtle entanglement.[385] Each of these areas includes range states of migratory species and will arguably pose a risk for whatever species passes through or spends time there.

The same review concluded that for ingestion, the distribution of reports for birds reflected that the risk of ingestion is global for them. Studies on turtle species were considered to be rather more sporadic geographically, yet it was held to be a reasonable assumption that a species will ingest plastic waste wherever both it and the waste are present.

One example was found where a hotspot approach could be an effective way of targeting resources. In the Gulf of Carpentaria, spatial distribution of nets and turtle impacts were found to correlate. Furthermore, monitoring revealed that most nets enter the Gulf from a prevalent direction, the northwest, cross to the northernmost part of the eastern shore and continue to travel along it in a clockwise direction. Hence monitoring or even interception of nets was hypothesised to be possible by covering a relatively small area north of the Gulf, before it enters the bay, and encounters high-density turtle areas.[386]

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[383] Ceccarelli, D.M., and C. R. Consulting (2009) Impacts of plastic debris on Australian marine wildlife, *Report by C&R Consulting to the Australian Government Department of the Environment, Water, Heritage and the Arts*

[384] Schuyler, Q., Hardesty, B.D., Wilcox, C., and Townsend, K. (2013) Global Analysis of Anthropogenic Debris Ingestion by Sea Turtles, *Conservation Biology*, p.n/a–n/a

[385] Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for WSPA, 2012, http://www.wspa-international.org/Images/Untangled%20Report_tcm25-32499.pdf

[386] Wilcox, C., Hardesty, B.D., Sharples, R., Griffin, D.A., Lawson, T.J., and Gunn, R. (2013) Ghostnet impacts on globally threatened turtles, a spatial risk analysis for northern Australia, *Conservation Letters*, Vol.6, No.4, pp.247–254

3.1.5.7 Incomparability of Data

Although there are examples of many different types of impact on different high level classes of animal, in different regions, this does not really constitute a comprehensive body of data regarding where debris occurs, where it is from, what species it interacts with and what the direct impacts are of those interactions.[387] In addition, of the data that does exist, several reports state that globally, there is a lack of standardized reporting methods on debris effects on wildlife, including debris type and size, species and life history stage of animals affected.[388]

For example, different types of prevalence statistics tend to be reported for different animals. The type of statistic likely to be reported is influenced by the population size and therefore ease of monitoring/estimation of that population size, and the nature of the impact, as assessed above. Therefore we see a range of different statistics, such as:

- percentage of deceased individuals suffering a particular impact;
- percentage of deceased individuals which died as a result of that impact;
- % of the population suffering an impact in a year;
- % of the population at any one time point that are suffering from an impact;
- mortality over one year as a proportion of either the affected individuals or the population; and
- cohort mortality (i.e. % of individuals in the population or of a particular age that die over a lifetime from that impact).

Prevalence is also estimated inter-species with statistics such as the proportion of all animals found entangled belonging to a particular species or higher taxon.

This means that there is not a globally consistent and comparable dataset that comprehensively covers even the most well studied impacts such as entanglement or ingestion, for any high level class of species. This makes it difficult to compare the prevalence of different types of impact.

3.2 Scale of Impacts of Marine Debris on Migratory Species – Ranking by Debris Type

There are many different ways that impacts can be ranked, which are all worth consideration. Impacts can be categorized according to:

- whether they are lethal or sublethal;
- whether they are acute or chronic;

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[387] Derraik, J.G. (2002) The pollution of the marine environment by plastic debris: a review, *Marine Pollution Bulletin*, Vol.44, No.9, pp.842–852,Wilcox, C., Hardesty, B.D., Sharples, R., Griffin, D.A., Lawson, T.J., and Gunn, R. (2013) Ghostnet impacts on globally threatened turtles, a spatial risk analysis for northern Australia, *Conservation Letters*, Vol.6, No.4, pp.247–254

[388] Schuyler, Q., Hardesty, B.D., Wilcox, C., and Townsend, K. (2013) Global Analysis of Anthropogenic Debris Ingestion by Sea Turtles, *Conservation Biology*, p.n/a–n/a

- the degree of suffering caused to the animal;
- how widespread they are in the population; and
- how many species they affect and their geographical distribution.

However, recording efforts are not at sufficient scale, detail or comparability between species and impact type to produce rankings that take into account all these aspects.

Considering the ranking of impacts by debris item material or type for different species, the simplest method is by prevalence of item causing impact on a group of individuals. Even this can be expressed in a variety of ways, such as the number of animals found to have ingested that item expressed as a proportion of animals that have ingested debris or as a proportion of the population as a whole; or by the proportion of total items ingested by an individual or across a population. There is not enough data to produce a comprehensive ranking of impact by marine debris type according to the main species classes relevant to migratory species, however there are some clear trends.

3.2.1 By Material Type

The report commissioned by the Convention on Biological Diversity found that around 80% of the species impacts were associated with plastic debris, while paper, glass and metal together accounted for less than 2%. For ingestion, many items are unidentifiable fragments so the main feature of note is that plastic is always the prevalent material, across all taxa and all regions, and that generally the items have the characteristic of being of swallowable size (of course increasing in size for whales). 90% of the items ingested by turtles from the Australian coast were plastic.[389] Two South American studies found that 60-71% of stranded turtles had ingested plastic. [390, 391] 94% by weight of foreign material ingested by a sperm whale was plastic (around 18 kg of material).[392] A further illustration is given as 95% of Northern Fulmars (*Fulmarus glacialis*) whose bodies were washed ashore were found to have plastic debris in their digestive system.[393] It has been noted in several studies

[389] Schuyler, Q., Hardesty, B.D., Wilcox, C., and Townsend, K. (2012) To eat or not to eat? Debris selectivity by marine turtles, *PloS One*, Vol.7, No.7, p.e40884

[390] Tourinho, P.S., Ivar do Sul, J.A., and Fillmann, G. (2010) Is marine debris ingestion still a problem for the coastal marine biota of southern Brazil?, *Marine Pollution Bulletin*, Vol.60, No.3, pp.396–401

[391] Ivar do Sul, J.A., and Costa, M.F. (2007) Marine debris review for Latin America and the Wider Caribbean Region: From the 1970s until now, and where do we go from here?, *Marine Pollution Bulletin*, Vol.54, No.8, pp.1087–1104

[392] de Stephanis, R., Giménez, J., Carpinelli, E., Gutierrez-Exposito, C., and Cañadas, A. (2013) As main meal for sperm whales: Plastics debris, *Marine Pollution Bulletin*, Vol.69, No.1–2, pp.206–214,van Franeker, J.A., Blaize, C., Danielsen, J., et al. (2011) Monitoring plastic ingestion by the northern fulmar Fulmarus glacialis in the North Sea, *Environmental Pollution (Barking, Essex: 1987)*, Vol.159, No.10, pp.2609–2615

[393] van Franeker, J.A., Blaize, C., Danielsen, J., et al. (2011) Monitoring plastic ingestion by the northern fulmar Fulmarus glacialis in the North Sea, *Environmental Pollution (Barking, Essex: 1987)*, Vol.159, No.10, pp.2609–2615

that higher proportions of seabirds appear to ingest plastic than other taxa, regularly in the range of 90-100% of individuals. Although it has been suggested that this reflects the fact that plastic is the most prevalent in the oceans, it does not explain inter-species differences.

3.2.2 By Item Type

The report commissioned by the Convention on Biological Diversity found that the most prevalent item types within the plastics category were rope and netting (24%), fragments (20%), packaging (17%), other fishing debris (16%) and microplastics (11%).[394]

In another recent review, across all species, net fragments, rope and line, monofilament line, packing bands, plastic rings and can yokes were the debris most frequently associated with entanglement.[395]

In the US, beach clean-up data estimated that 32% of beach litter had the potential to entangle animals. Of the nine items which contributed to this total, the five most numerous were: plastic bags with seams of less than one metre (9%); balloons (8%); rope (6%); fishing line (3%); and fishing nets (1.4%).[396] By comparing these percentages with the prevalence of these items in entanglement incidents, an indication is given of whether items causing entanglement are disproportionately affecting individuals and species; with prevalence of net and fishing gear in entanglement reports over 90% in some cases (see below), the conclusion is that they are massively overrepresented.

Regarding ingestion, the most common items recorded are small plastic fragments of swallowable size, with plastic bags of particular concern for turtles and whales, and larger items of plastic waste including netting also of concern for baleen whales.[397]

Regarding the relative importance of different impacts, although entanglement appears to result in more acute consequences than ingestion,[398,399] its prevalence is

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394 STAP/GEF (2012) *Impacts of marine debris on biodiversity: Current status and potential solutions*, Report for CBD, 2012

395 Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for WSPA, 2012, http://www.wspa-international.org/Images/Untangled%20Report_tcm25-32499.pdf

396 Ocean Conservancy, and Sheavley (2007) *National Marine Debris Monitoring Program - Final Program Report, Data Analysis and Summary*, 2007

397 Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for WSPA, 2012, http://www.wspa-international.org/Images/Untangled%20Report_tcm25-32499.pdf

398 STAP/GEF (2012) *Impacts of marine debris on biodiversity: Current status and potential solutions*, Report for CBD, 2012

399 Laist, D.W. (1996) Marine Debris Entanglement and Ghost Fishing: A Cryptic and Significant Type of Bycatch?, *Solving Bycatch: Proceedings of the Solving Bycatch Workshop: Considerations for Today and Tomorrow* (1996)

considered to be less than, for example, ingestion.[400] Therefore items more likely to result in entanglement, such as fishing equipment or packing bands would top the list in terms of impact for the individual but not necessarily at the population level. However too little population level data exists for this to be stated conclusively.

3.2.3 Plastic: Rope, Line and Netting

Rope and netting are the most prevalent item type causing impacts when all species and impacts are considered together. The prevalence however varies between taxonomic grouping. For example, fish were the most disproportionately affected by rope and netting in terms of number of species, with around half of the species recorded impacted by this item type. For marine mammals the comparable figure was a third, while for birds and turtles this proportion was markedly less. [401]

It is a fair assumption that rope and netting are more likely to be associated with entanglement than other types of debris, as they are specifically designed for capturing wildlife, and it is known that the prevalence of fishing items an animal encounters can be well correlated with entanglement rates.[402] For turtles, the numbers of species suffering entanglement versus ingestion were more or less equal while for mammals and fish more species had been recorded as being involved with entanglement rather than having ingested material. For birds, many fewer species had been recorded as having suffered entanglement (67 species) versus ingestion (199 species). This may reflect the fact that birds spend less time in the water and may be less likely to come into contact with the kind of debris that causes entanglement, or that other behaviours make them more circumspect about the possibility of entanglement. On the other hand there is little information available, for example, on the incidence of seabird entanglements caused by adrift plastic debris both because of difficulty detecting it before animals die and carcasses are lost, and because of biases in sampling and reporting.[403] Bird research is more resource intensive at sea where bird population densities will be so much lower than on the coast, while concurrently this is exactly where a considerable proportion of bird entanglement incidents might occur.

Fishing line was however noted as one of the most common items ingested by seabirds around the Australian coast, according to a recent review, and also by fish in the North Pacific, so these items are not exclusively associated with

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[400] Secchi, E.R., and Zarzur, S. (1999) Plastic debris ingested by a Blainville's beaked whale, Mesoplodon densirostris, washed ashore in Brazil

[401] Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for WSPA, 2012, http://www.wspa-international.org/Images/Untangled%20Report_tcm25-32499.pdf

[402] Wilcox, C., Hardesty, B.D., Sharples, R., Griffin, D.A., Lawson, T.J., and Gunn, R. (2013) Ghostnet impacts on globally threatened turtles, a spatial risk analysis for northern Australia, *Conservation Letters*, Vol.6, No.4, pp.247–254

[403] Rodríguez, B., Bécares, J., Rodríguez, A., and Arcos, J.M. (2013) Incidence of entanglements with marine debris by northern gannets (Morus bassanus) in the non-breeding grounds, *Marine Pollution Bulletin*, Vol.75, No.1–2, pp.259–263

entanglement.[404,405] One study on fish ingestion stated that 19% of the items were fishing gear.[406] For Steller Sea Lions, (*Eumetopias jubatus*) in the North Pacific, many had ingested fishing equipment such as salmon fishery flashers/lures, longline gear, hooks and lines, spinners/spoons and bait hooks.[407]

For seals, on average 38% of entanglement cases were attributed to net and 28% to fishing line. It appears that studies vary a great deal as to what the predominant impact causing debris item type is.[408] This may reflect local composition of debris but this has never been tested.

For baleen whales, net was also the most prevalent item in which individuals were entangled at 50% on average, closely followed by 'fishing pot gear', at 42%.[409] In a study on Right Whales and Humpback Whales, 81% of entanglements involved vertical or horizontal lines such as buoy lines or groundlines from pots.[410]

Of the few recorded incidents of debris ingestion in toothed whales, two Sperm Whales had 134 different types of net pieces in their stomachs ranging from 10cm^2 to 16m^2 in size, although fishing line also featured heavily.[411] 18% by weight of the indigestible stomach contents of another was rope (thought to be derived from the greenhouse industry).[412]

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[404] Ceccarelli, D.M., and C. R. Consulting (2009) Impacts of plastic debris on Australian marine wildlife, *Report by C&R Consulting to the Australian Government Department of the Environment, Water, Heritage and the Arts*

[405] Choy, C.A., and Drazen, J.C. (2013) Plastic for dinner? Observations of frequent debris ingestion by pelagic predatory fishes from the central North Pacific, *Marine Ecology Progress Series*, Vol.485, pp.155–163

[406] Anastasopoulou, A., Mytilineou, C., Smith, C.J., and Papadopoulou, K.N. (2013) Plastic debris ingested by deep-water fish of the Ionian Sea (Eastern Mediterranean), *Deep Sea Research Part I: Oceanographic Research Papers*, Vol.74, pp.11–13

[407] Raum-Suryan, K.L., Jemison, L.A., and Pitcher, K.W. (2009) Entanglement of Steller sea lions (Eumetopias jubatus) in marine debris: Identifying causes and finding solutions, *Marine Pollution Bulletin*, Vol.58, No.10, pp.1487–1495

[408] Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for WSPA, 2012, http://www.wspa-international.org/Images/Untangled%20Report_tcm25-32499.pdf

[409] Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for WSPA, 2012, http://www.wspa-international.org/Images/Untangled%20Report_tcm25-32499.pdf

[410] Johnson, A., Salvador, G., Kenney, J., Robbins, J., Kraus, S., Landry, S., and Clapham, P. (2005) Fishing Gear Involved in Entanglements of Right and Humpback Whales, *Marine Mammal Science*, Vol.21, No.4, pp.635–645

[411] Jacobsen, J.K., Massey, L., and Gulland, F. (2010) Fatal ingestion of floating net debris by two sperm whales (Physeter macrocephalus), *Marine Pollution Bulletin*, Vol.60, No.5, pp.765–767

[412] de Stephanis, R., Giménez, J., Carpinelli, E., Gutierrez-Exposito, C., and Cañadas, A. (2013) As main meal for sperm whales: Plastics debris, *Marine Pollution Bulletin*, Vol.69, No.1–2, pp.206–214

Of stranded bottlenose dolphins from the Adriatic Sea, 10% had been affected by larynx strangulation post ingestion of fragments of gill net. In another dolphin study, 45% of the items recovered from stomachs were classified as fishing related debris, including net, rope and line. [413]

For Sirenia species, manatees and dugongs predominantly become entangled in net, line and rope.[414]

For turtles, one study attributed 25% of deaths in stranded turtles to entanglement in netting, of which 26% were contributed to by amputation of one or two flippers.

Turtles also ingest rope – in the Adriatic Sea, 42% of ingested items were rope.[415]

In birds, it was reported that 48% of beached birds were entangled in line or rope, 39% in nets and 7% with line and hooks. In another study in California, 11.3-16.1% of entanglement cases, including birds, were owing to fishing related debris.[416] A study into entanglement in debris that was collected by one species for nesting material showed that about 83% of the inorganic nesting material was synthetic fibre rope, and 15% was netting.[417]

3.2.4 Plastic: Bags and Film

In turtles, there is some evidence that the species target particular types of plastic for ingestion. In one Australian study, 55% of inorganic items recovered from stranded turtle digestive tracts were flexible plastics such as bags and film, which is far higher than the fraction of such items making up marine debris in the area at around 15%.[418] Similarly, in the Adriatic, 68% of debris ingested by turtles was soft plastic.[419] Balloons were also singled out as an item disproportionately ingested by turtles off

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[413] Bastida *et al.,* 2000 in Marsh, H., Arnold, P., Freeman, M., et al. (2003) Strategies for Conserving Marine Mammals, *Marine Mammals: Fisheries, Tourism and Management Issues: Fisheries, Tourism and Management Issues* (2003)

[414] Beck, C.A., and Barros, N.B. (1991) The impact of debris on the Florida manatee, *Marine Pollution Bulletin*, Vol.22, No.10, pp.508–510,Ceccarelli, D.M., and C. R. Consulting (2009) Impacts of plastic debris on Australian marine wildlife, *Report by C&R Consulting to the Australian Government Department of the Environment, Water, Heritage and the Arts*

[415] Lazar, B., and Gračan, R. (2011) Ingestion of marine debris by loggerhead sea turtles, Caretta caretta, in the Adriatic Sea, *Marine Pollution Bulletin*, Vol.62, No.1, pp.43–47

[416] OSPAR (2009) *Marine litter in the Northeast Atlantic Region: assessment and priorities for response*, Report for London, U.K., 2009

[417] Votier, S.C., Archibald, K., Morgan, G., and Morgan, L. (2011) The use of plastic debris as nesting material by a colonial seabird and associated entanglement mortality, *Marine Pollution Bulletin*, Vol.62, No.1, pp.168–172

[418] Townsend, K.A. (2011) Impact of ingested marine debris on sea turtles of eastern Australia: Life history stage susceptibility, pathological implications and plastic bag preference., *Technical Proceedings of the 5th International Marine Debris Conference* (2011) pp.180–183

[419] Lazar, B., and Gračan, R. (2011) Ingestion of marine debris by loggerhead sea turtles, Caretta caretta, in the Adriatic Sea, *Marine Pollution Bulletin*, Vol.62, No.1, pp.43–47

the Australian coast, found in 30% of turtles which ingested debris.[420] Several studies found that black, white and clear bags are prevalent in turtle guts (hypothesized to be similar to jellyfish prey). However, the authors did not compare this prevalence statistically with the colour distribution of plastic film in the environment, so it could not be proved that turtles, who are able to discriminate colour, were selectively feeding on different colours of plastic.[421] However one study did successfully show that pelagic, younger turtles, were less selective in terms of items and colours ingested, while older, benthic feeders, were statistically more likely to ingest flexible, clear plastic, when compared with surrounding debris composition.[422]

The few reports of death in the toothed Pygmy Sperm Whale (*Kogia breviceps*) by ingestion of debris involved plastic bags, and plastic bags made up 2% of the items recovered from a Sperm Whale (*Physeter macrocephalus*), also suffering the fatal consequences of ingestion.[423] In another Sperm Whale incident, plastic sheeting from the greenhouse industry was implicated, and made up 43% of the stomach remains by weight.[424] A review of ingestion reports from toothed whales pre-1990 states that plastic bags and sheeting were the predominant items ingested (62.5%).[425] One study on fish ingestion stated that 22% of the items were small pieces of plastic bag.[426]

Small fragments of plastic film were also the predominant item ingested by the migratory Glaucous-Winged Gull *Larus glaucescens,* found in 67% of the individuals who had ingested plastic.[427]

3.2.5 Plastic: Miscellaneous Items

There are many other item types that have been indicated as being involved in a significant proportion of debris related impacts. For example, packing bands feature very frequently in entanglement reports. In one study, they caused more than 50% of

[420] Schuyler, Q., Hardesty, B.D., Wilcox, C., and Townsend, K. (2012) To eat or not to eat? Debris selectivity by marine turtles, *PloS One*, Vol.7, No.7, p.e40884

[421] Bugoni, L., Krause, L., and Virgínia Petry, M. (2001) Marine debris and human impacts on sea turtles in southern Brazil, *Marine Pollution Bulletin*, Vol.42, No.12, pp.1330–1334

[422] Schuyler, Q., Hardesty, B.D., Wilcox, C., and Townsend, K. (2012) To eat or not to eat? Debris selectivity by marine turtles, *PloS One*, Vol.7, No.7, p.e40884

[423] Jacobsen, J.K., Massey, L., and Gulland, F. (2010) Fatal ingestion of floating net debris by two sperm whales (Physeter macrocephalus), *Marine Pollution Bulletin*, Vol.60, No.5, pp.765–767

[424] de Stephanis, R., Giménez, J., Carpinelli, E., Gutierrez-Exposito, C., and Cañadas, A. (2013) As main meal for sperm whales: Plastics debris, *Marine Pollution Bulletin*, Vol.69, No.1–2, pp.206–214

[425] Simmonds, M.P. (2012) Cetaceans and Marine Debris: The Great Unknown, *Journal of Marine Biology*, Vol.2012

[426] Anastasopoulou, A., Mytilineou, C., Smith, C.J., and Papadopoulou, K.N. (2013) Plastic debris ingested by deep-water fish of the Ionian Sea (Eastern Mediterranean), *Deep Sea Research Part I: Oceanographic Research Papers*, Vol.74, pp.11–13

[427] Lindborg, V.A., Ledbetter, J.F., Walat, J.M., and Moffett, C. (2012) Plastic consumption and diet of Glaucous-winged Gulls (Larus glaucescens), *Marine Pollution Bulletin*, Vol.64, No.11, pp.2351–2356

neck entanglements for Steller Sea Lions in Alaska, and other studies reported similar rates for this item type.[428] Rubber packing bands have also been identified in one case as being a significant cause of entanglement (30% of cases) in a similar population.[429] This draws attention to the rather obvious fact that it is the shape of some materials (i.e. that they are looped) that is of particular relevance to the impact that they have. Hence education campaigns promoting simple procedures such as cutting entangling loops of material should help prevent entanglement.[430]

Styrofoam (15%) was a major group within items ingested by turtles in the Adriatic Sea[431] and also off the Australian coast (12% of turtles ingesting debris having ingested that item).[432]

13% by weight of the items ingested by a sperm whale were classified as 'small plastics' (less than 4 cm), and several miscellaneous household items were also found too.[433] In one dolphin study, 45% of items ingested were classed as general 'plastic packaging' and a further 16% as small pieces of plastic. [434] One study on fish ingestion stated 56% of the items were small pieces of plastic.[435]

Seabirds have been shown to exhibit a preference for darker, more conspicuously-coloured debris, and a comparison between ingested plastic and surrounding debris suggests they are mistaking the plastic for prey. Ingested consumer plastic tends to be larger than the average mass of particles found at sea and they also display some colour selectivity – for example, it has been suggested that Albatrosses prefer red particles because they resemble the colouration of some crustaceans.[436] Gannets

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428 NOAA (2013) *Pinniped Entanglement in Marine Debris*, accessed 14 November 2013, http://alaskafisheries.noaa.gov/protectedresources/entanglement/pinnipeds.htm

429 Raum-Suryan, K.L., Jemison, L.A., and Pitcher, K.W. (2009) Entanglement of Steller sea lions (Eumetopias jubatus) in marine debris: Identifying causes and finding solutions, *Marine Pollution Bulletin*, Vol.58, No.10, pp.1487–1495

430 Waluda, C.M., and Staniland, I.J. (2013) Entanglement of Antarctic fur seals at Bird Island, South Georgia, *Marine Pollution Bulletin*

431 Lazar, B., and Gračan, R. (2011) Ingestion of marine debris by loggerhead sea turtles, Caretta caretta, in the Adriatic Sea, *Marine Pollution Bulletin*, Vol.62, No.1, pp.43–47

432 Schuyler, Q., Hardesty, B.D., Wilcox, C., and Townsend, K. (2012) To eat or not to eat? Debris selectivity by marine turtles, *PloS One*, Vol.7, No.7, p.e40884

433 de Stephanis, R., Giménez, J., Carpinelli, E., Gutierrez-Exposito, C., and Cañadas, A. (2013) As main meal for sperm whales: Plastics debris, *Marine Pollution Bulletin*, Vol.69, No.1–2, pp.206–214

434 Bastida *et al.,* 2000 in Marsh, H., Arnold, P., Freeman, M., et al. (2003) Strategies for Conserving Marine Mammals, *Marine Mammals: Fisheries, Tourism and Management Issues: Fisheries, Tourism and Management Issues* (2003)

435 Anastasopoulou, A., Mytilineou, C., Smith, C.J., and Papadopoulou, K.N. (2013) Plastic debris ingested by deep-water fish of the Ionian Sea (Eastern Mediterranean), *Deep Sea Research Part I: Oceanographic Research Papers*, Vol.74, pp.11–13

436 Derraik, J.G. (2002) The pollution of the marine environment by plastic debris: a review, *Marine Pollution Bulletin*, Vol.44, No.9, pp.842–852,Gregory, M.R. (2009) Environmental implications of plastic debris in marine settings—entanglement, ingestion, smothering, hangers-on, hitch-hiking and

also were entangled most frequently in red items (however this was not compared against baseline ambient colour composition of debris). [437] However the fact that they ingested plastic at all was taken to mean that the birds are relatively non-selective, opportunistic foragers.[438]

There are even reports that fish feed selectively for debris that is white, plastic and spherical.[439] Others suggest that blue and yellow items are attacked more frequently as evidenced by bite marks. Fish also attack bottle shaped items disproportionately relative to their abundance in the environment.[440]

Although plastic beads were the prevalent item ingested by birds decades ago, 'user plastics' are now the prevalent item.[441]

3.2.6 Plastic: Microplastics

The impacts of microplastics are currently hypothesised to be via one of two main mechanisms: firstly, via their physical mass which could have impacts post ingestion, and secondly, via toxicological means, either through chemicals that derive from the plastic directly, or which the small plastic particles accumulate (see Section 3.1.3.1). These chemicals are associated with all marine debris made of plastic, however the large surface area of microplastics plus their potential ease of ingestion by the widest range of organisms aggravates the impact. One review calculates that 10% of all marine debris encounters are with microplastics.[442] Many items that would fall within the definition of microplastic tend to be counted together with other miscellaneous plastic fragments, therefore it is not possible to obtain prevalence information by this item type for different species groups or regions. There is increasing evidence that microplastics are also ingested by marine invertebrates such as amphipods, lugworms, barnacles, mussels, lobster and squid.[443] This is of concern because they are eaten by species higher up the food chain, and may provide a further vector for

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alien invasions, *Philosophical Transactions of the Royal Society B: Biological Sciences*, Vol.364, No.1526, pp.2013–2025

[437] Rodríguez, B., Bécares, J., Rodríguez, A., and Arcos, J.M. (2013) Incidence of entanglements with marine debris by northern gannets (Morus bassanus) in the non-breeding grounds, *Marine Pollution Bulletin*, Vol.75, No.1–2, pp.259–263

[438] Ryan, P.G. (1987) The incidence and characteristics of plastic particles ingested by seabirds, *Marine Environmental Research*, Vol.23, No.3, pp.175–206

[439] Carpenter, E.J., Anderson, S.J., Harvey, G.R., Miklas, H.P., and Peck, B.B. (1972) Polystyrene spherules in coastal waters, *Science (New York, N.Y.)*, Vol.178, No.4062, pp.749–750

[440] Carson, H.S. (2013) The incidence of plastic ingestion by fishes: From the prey's perspective, *Marine Pollution Bulletin*

[441] Ryan, P.G. (2008) Seabirds indicate changes in the composition of plastic litter in the Atlantic and south-western Indian Oceans, *Marine Pollution Bulletin*, Vol.56, No.8, pp.1406–1409

[442] STAP/GEF (2012) *Impacts of marine debris on biodiversity: Current status and potential solutions*, Report for CBD, 2012

[443] Ivar do Sul, J.A., and Costa, M.F. (2014) The present and future of microplastic pollution in the marine environment, *Environmental Pollution*

microplastics and their impacts, or alternatively a mechanism for ecosystem level effects, for instance if the growth and productivity of these invertebrates were significantly affected.

3.2.7 Other Materials: Fishing Hooks

26% of stranded turtles in one Canary Island study had suffered inflammation or perforation of the oesophagus through the ingestion of fishing hooks.[444] Seals are also known to ingest debris such as fish hooks.[445] Albatrosses are regularly found with hooks embedded in their mouthparts or intestines with the accompanying risk of oesophageal damage.[446] Fishing hooks have also been ingested by Sperm Whales.[447] With this item type there is again the issue of what counts as bycatch and what counts as ingestion of marine debris, as these incidents might well result from scavenging behaviour.

3.2.8 Knowledge Gaps

3.2.8.1 Ranking of Item Type by Impact – Data Integration

Scoring of debris items by material or type is not consistent enough between studies in terms of categories (which may include a mixture of categories defined by material, type or source), to compare prevalence for a given category across impacts and species groups. Environmental debris levels are usually not measured so as rule it is not possible to determine if risk is owing to nature of item (demonstrated by its over-representation in debris encounters) or its prevalence in the environment. A few items are very obviously overrepresented for particular types of species and impacts. For an overview of impact risk globally for different species, a comprehensive database of geographical regions, background debris composition, linked to data on item type prevalence in debris encounters would be needed. Yet there is a distinct lack of global coverage for both variables; it is not known, with any accuracy, which species are the most affected by marine debris. In addition, lack of consistency in data scoring, would make it difficult to integrate even the available data.

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[444] Orós, J., Torrent, A., Calabuig, P., and Dniz, S. (2005) Diseases and causes of mortality among sea turtles stranded in the Canary Islands, Spain (1998–2001), *Diseases of Aquatic Organisms*, Vol.63, No.1, pp.13–24

[445] Osinga, N., and 't Hart, P. (2006) Fish-Hook Ingestion in Seals (<I>Phoca vitulina</I> and <I>Halichoerus grypus</I>): The Scale of the Problem and a Non-Invasive Method for Removing Fish-Hooks, *Aquatic Mammals*, Vol.32, No.3, pp.261–264

[446] Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for WSPA, 2012, http://www.wspa-international.org/Images/Untangled%20Report_tcm25-32499.pdf

[447] de Stephanis, R., Giménez, J., Carpinelli, E., Gutierrez-Exposito, C., and Cañadas, A. (2013) As main meal for sperm whales: Plastics debris, *Marine Pollution Bulletin*, Vol.69, No.1–2, pp.206–214

3.2.8.2 Difficulty Including Animal Welfare Considerations

The factoring in of animal suffering to the weighting of impacts in a ranking is also not currently possible. Reporting of debris encounters does not include a consideration of measures of animal welfare. As addressed in Section 3.1, very few measures of the kind exist and have only been developed for whales.

3.2.8.3 Scoring Bias

It is likely that large, conspicuous and easily identified items are more likely to be identified and reported, like rope and netting. Therefore fragments of plastic and microplastics are likely to be underreported. [448]

3.2.8.4 Microplastics

The impacts of microplastics are not yet fully understood. It is known that they are ingested by many types of organism, but a full picture is not yet known. What happens to microplastics after they have been ingested by marine invertebrates has also barely been demonstrated. The bioavailability of associated contaminants is undetermined. Geographical variation in adsorbed pollutants and the role of microplastics as a vector is only just beginning to be addressed. The mechanisms by which damage may occur are in the process of being established but are incomplete for many species and potential impacts. Whether and how microplastics or their impacts accumulate in successive levels of the food chain has not been demonstrated. Harm has not been established at population levels and ultimately ecosystem levels, and it will be difficult because much of it will be sublethal, subtle and extremely complex to unravel the influence of different factors (see above).

3.2.8.5 Effects of Colour, Shape, Plastic Type on Impacts Prevalence

A moderate number of studies have been carried out demonstrating statistically significant effects of colour, shape and plastic type on the likelihood of ingestion or composition of adsorbed chemicals. It would be useful to have a more comprehensive understanding of this aspect of marine debris impacts in case the information could be utilized in focussing management strategies.

4.0 Management of Debris in Marine Ecosystems

4.1 Current Management Strategies

In this section, current management measures and strategies for waste already present in marine systems (e.g. removal strategies and monitoring) are reviewed and current knowledge gaps identified. As regards monitoring, knowledge gaps have however been thoroughly addressed in Section 2.3.

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[448] STAP/GEF (2012) *Impacts of marine debris on biodiversity: Current status and potential solutions*, Report for CBD, 2012

4.1.1 Monitoring

Monitoring is an important part of any management strategy. Without monitoring no strategy can be evaluated; and the relative success of different tactics cannot be determined. Monitoring is also necessary for the setting of targets.

The following main questions have been defined regarding the monitoring of marine debris:[449]

- What is the abundance, distribution and composition of debris, and are these attributes changing over time?
- What are the main sources of debris, and are they changing over time?
- What are the impacts of debris (environmental and economic) and are they changing over time?

Distribution refers to the different marine compartments of the coast, the surface of the sea, the water column, the sea floor and even the sediment under the sea floor.

Methods of marine debris monitoring can be divided into three approaches; beach surveys, at-sea surveys and estimates of the amounts entering the sea.[450]

4.1.1.1 Beach Surveys

Beach surveys are widely viewed as the simplest to implement and the most cost effective. However, because they are influenced by many factors (i.e. inputs and outputs such as beach dynamics and contamination by beach users) that are not related to overall marine debris abundance, they do not necessarily provide a good indicator of changes in overall marine debris abundance.

There are many different ways to approach beach litter sampling. Different parameters can be recorded such as litter count, or weight and items categorized by material, function or assumed source. Different studies have different lower limits for debris size and beach width also tends to vary between studies, with some standardizing the breadth of the area sampled and others not. Buried litter is usually not sampled, though it may be a considerable proportion of beach litter (40% of total in one study).[451]

Some beaches will better indicate specific sources of debris than others, for example, remote beaches track litter from ships and long-distance drift litter better than urban beaches, which track urban input. Finally, some studies report standing stock of litter, while others observe the rate of accumulation following removal of existing debris.

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[449] Ryan, P.G., Moore, C.J., Franeker, J.A. van, and Moloney, C.L. (2009) Monitoring the abundance of plastic debris in the marine environment, *Philosophical Transactions of the Royal Society B: Biological Sciences*, Vol.364, No.1526, pp.1999–2012

[450] Rees, G., and Pond, K. (1995) Marine litter monitoring programmes—A review of methods with special reference to national surveys, *Marine Pollution Bulletin*, Vol.30, No.2, pp.103–108

[451] Kusui, T., and Noda, M. (2003) International survey on the distribution of stranded and buried litter on beaches along the Sea of Japan, *Marine Pollution Bulletin*, Vol.47, No.1–6, pp.175–179

The latter is considered a better indicator of at-sea debris than the former. Because of these many different parameters, global guidelines on marine debris monitoring have been developed by the Intergovernmental Oceanographic Commission in conjunction with UNEP. These are yet to be implemented by the Regional Seas areas, although there has been, and continues to be, considerable work towards standardizing monitoring approaches within the EU, the USA and Australia.

Beach surveys generally neglect micro-debris as floatation systems needed to separate out low-density debris are costly compared to visual counts. For the same reason, accumulation studies are not really possible as they would require clean-up prior to subsequent monitoring. Additionally, some of the fragments will derive from the disintegration of debris *in situ*; and hence are unlikely to provide a stable indication of micro-debris abundance at sea, as so many new particles will be derived from closer sources. The sampling of micro-debris is in its early stages. Identification of polymer type is possible via infrared spectroscopy (a technology also used to sort plastics for recycling).

4.1.1.2 At-sea Surveys

At-sea surveys probably reflect overall debris abundance better than beach surveys. However, sampling has to be much more intensive in order to detect change because of the geospatial scale involved and the complexity introduced by ocean circulation. It is therefore more expensive and logistically challenging. At-sea surveys can also only assess stock and not accumulation, therefore changes detected are likely to be reflecting a shift in the balance between many different inputs and losses, rather than differences owing to mitigation measures. From-deck observation sampling suffers from the fact that litter detectability goes down the farther from the transect it is, though this can be modelled and taken into account. Trawl surveys can be used to sample floating litter or litter in the water column, depending on nets used. Aerial surveys are most suitable for recording spatial distribution of larger items.

Seabed surveys are conducted with divers, submersibles and remote-operated vehicles. It is possible to obtain both accumulation and stock data in this marine compartment.

Another approach to monitoring is to look at impacts directly. Entanglement data or ingestion data can be used for this purpose and trends are visible in this type of data. Entanglement data does suffer from not always being expressed as a proportion of the population, because of a lack of population estimates, and can wrongly be conflated with within-species prevalence. Ingestion data similarly suffers as the sample population is often restricted to deceased, stranded individuals as opposed a sample from the population at large. An alternative way of sampling which might broaden the sample population base is to examine the pellets regurgitated by predators of seabirds who expel the bones, feathers and other indigestible remains of birds they eat.[452]

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[452] Ryan, P.G. (2008) Seabirds indicate changes in the composition of plastic litter in the Atlantic and south-western Indian Oceans, *Marine Pollution Bulletin*, Vol.56, No.8, pp.1406–1409

It has been noted that there are correlations between certain interventions and downward trends in impact data.[453] In one example, the halving of entanglement observations in Antarctic Fur Seals (*Arctocephalus gazella*) post MARPOL Annex V implementation was accompanied by a doubling in population size; therefore this 'correlation' could actually have been showing that the abundance of the litter in the sea did not change.[454] A further longer term study of the same population did however calculate a change in entanglement incidence from 0.4% in 1988/1989 to 0.016% between 1994 and 2013, on average.[455] This shows the importance of attempting to estimate prevalence at the population level. There are other studies that have failed to show a correlation between interventions and impact rates.[456]

It has been argued that entanglement is in fact quite rare within the population as a whole and so the number of observations obtained might not be enough for adequate statistical power unless constant surveillance is being undertaken. In contrast, ingestion is much more widespread, given that up to 100% of sampled individuals of certain species may be found to have ingested debris. It is felt to reflect spatial heterogeneity of debris, incidence being greatest for, for example, the Northern Fulmar (*Fulmarus glacialis*) in more highly contaminated areas of the North Sea, as compared to Arctic populations. Although some Fulmar subpopulations do migrate, most of the population is considered relatively sedentary in the North Atlantic. This can be contrasted with birds such as petrels, which range widely over, for example, the Pacific Ocean. They retain plastic in their stomachs for months, and so their ingested plastic reflects changes in the composition of plastic over much of the Pacific Ocean.[457] Whether this statement is always true for migratory and non-migratory species still needs to be comprehensively answered, and only data collection will resolve it. The conclusion is that it is important to choose the indicator species carefully.

It is considered that the composition of ingested plastic in birds accurately reflected the decrease of plastic manufacturing pellets over the last 20 years and its displacement in most populations, by fragments from consumer generated plastic debris, i.e. it is held to reflect ambient debris composition. However, the relationship between overall plastic loads and environmental plastic abundance is also not yet totally clear, as the total amount of plastic over the same period did not change

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[453] Ryan, P.G., Moore, C.J., Franeker, J.A. van, and Moloney, C.L. (2009) Monitoring the abundance of plastic debris in the marine environment, *Philosophical Transactions of the Royal Society B: Biological Sciences*, Vol.364, No.1526, pp.1999–2012

[454] Arnould, J.P.Y., and Croxall, J.P. (1995) Trends in entanglement of Antarctic fur seals (Arctocephalus gazella) in man-made debris at South Georgia, *Marine Pollution Bulletin*, Vol.30, No.11, pp.707–712

[455] Waluda, C.M., and Staniland, I.J. (2013) Entanglement of Antarctic fur seals at Bird Island, South Georgia, *Marine Pollution Bulletin*

[456] Ryan, P.G., Moore, C.J., Franeker, J.A. van, and Moloney, C.L. (2009) Monitoring the abundance of plastic debris in the marine environment, *Philosophical Transactions of the Royal Society B: Biological Sciences*, Vol.364, No.1526, pp.1999–2012

[457] Ryan, P.G. (2008) Seabirds indicate changes in the composition of plastic litter in the Atlantic and south-western Indian Oceans, *Marine Pollution Bulletin*, Vol.56, No.8, pp.1406–1409

significantly, in some studies at least.[458] There is some suggestion that at some density of environmental debris, plastic loads stabilise at a maxima and no longer track the levels in the environment.[459]

Nevertheless, the need to take action means that targets are being proposed for this measure of marine debris, despite these uncertainties, for areas where the spatial distribution of debris and plastic ingestions appears to be better related. For the North-East Atlantic region (OSPAR) - the EcoQO or 'Ecological Quality Objective' is proposed at <10% of fulmars having more than 0.1g of plastic in their stomachs).[460] Three other European Member States have proposed turtles, lobsters and cetaceans as potential indicator species.[461] Other indicator species suggested, to cover the Mediterranean part of Europe, as the Northern Fulmar does not range so far south, include various species of migratory Shearwater (Cory's Shearwater (*Calonectris diomedea*), Yelkouan Shearwater (*Puffinus yelkouan*), and the Balearic Shearwater (*Puffinus mauretanicus*), which is also a Convention listed species).[462]

4.1.1.3 At-source Input Modelling

The last approach for monitoring marine debris is at-source input monitoring. This is considered to be the most indicative of changes related to management initiatives. In theory it is possible to monitor ship-based sources by obtaining records from port waste reception facilities and from independent fishery observers' examination of garbage log books. However no attempt has been made to estimate the amount of waste disposed of by vessels at sea since the implementation of MARPOL Annex V. Sampling of land based sources can occur in rivers or storm drains, though there is much temporal heterogeneity owing to weather events and the washing away of accumulated debris that must be taken into account when deciding on sampling frequency. A variety of techniques can be used such as manta trawling, use of hand nets, weighted nets, stream bed nets or scooping of sediments, and both active or passive sampling methods can be used.

As has been covered in Section 2.0, global monitoring efforts are currently focused on beach litter. There is very little coverage of any other marine compartment and there is not standardization. This means that it is difficult to compare the nature of the

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[458] Ryan, P.G. (2008) Seabirds indicate changes in the composition of plastic litter in the Atlantic and south-western Indian Oceans, *Marine Pollution Bulletin*, Vol.56, No.8, pp.1406–1409

[459] Vlietstra, L.S., and Parga, J.A. (2002) Long-term changes in the type, but not amount, of ingested plastic particles in short-tailed shearwaters in the southeastern Bering Sea, *Marine Pollution Bulletin*, Vol.44, No.9, pp.945–955

[460] van Franeker, J.A., Heubeck, M., Fairclough, K., et al. (2005) *'Save the North Sea' Fulmar Study 2002–2004: A Regional Pilot Project for the Fulmar-Litter-EcoQO in the OSPAR Area*, 2005, http://www.vliz.be/imisdocs/publications/72498.pdf

[461] InterSus, University of Trier, Milieu, UBA, and COM (2013) Issue Paper to the 'International Conference on Prevention and Management of Marine Litter in European Seas'

[462] Codina-García, M., Militão, T., Moreno, J., and González-Solís, J. (2013) Plastic debris in Mediterranean seabirds, *Marine Pollution Bulletin*

problem from region to region. There is also the possibility that important item types may be neglected. Attribution of litter to source is not very robust and hence does not allow very detailed appraisal of the importance of different sources.

4.1.2 Removal

There are a range of different strategies employed throughout the world in an attempt to remove litter from marine ecosystems. Each management initiative may vary depending on the type of operation, who is responsible or involved in the scheme, and the type of litter that is targeted. A number of different types of strategies (as outlined in Table 6) are set out in the following sections, with examples of practical operation.

Table 6: Debris Removal Strategies

Type of Management Strategy	Description	Example Strategies
Removal of litter at sea during regular fishing activity	Trawlers retain on board the marine litter caught in their nets and deposit in ports	➢ KIMO Fishing for Litter ➢ S Korea Marine Debris Buyback Program
Targeted removal of marine litter at sea during special purpose trips	Payments are made for conducting special trips to collect litter (this is restricted to floating litter)	➢ Waste Free Oceans (WFO) ➢ S Korea Clean Up Deposited Marine Litter Program
Targeted retrieval of derelict fishing gear (DFG) at sea during special purpose trips	Payments are made for conducting special trips to collect DFG	➢ Norway DFG retrieval program ➢ WWF Poland, Lithuanian Fund for Nature removal campaign
Coastal Beach Clean Ups	Voluntary or paid for efforts to collect debris from coastline	➢ International Coastal Clean-up ➢ S Korea Coastal Cleanup Program

We review a selection of these types of initiatives, focussing on how the model works, its efficacy in terms of litter removal, its efficacy in terms of their ability to raise awareness and promote behaviour change in industry, its efficacy in terms of reducing the impacts of marine debris, and cost effectiveness.

4.1.2.1 Removal of Litter During Regular Fishing Activity

KIMO (Local Authorities International Environmental Organisation) is an association of coastal local authorities whose goal is to eliminate pollution from Northern Seas. KIMO's Fishing for Litter initiatives now operate in 6 countries around the North and

Baltic seas, involving more than 40 ports and 400 vessels. The programs have removed more than 3500 tonnes of litter from the sea since the first project began in the Netherlands in 2000. However KIMO's own estimate of 20,000 tonnes of litter dumped into the North Sea alone *every year* shows that the primary achievement of the project is likely to be awareness raising and hopefully change in waste management practices in the fishing industry.[463]

As far as costs are concerned, it is conducted on a voluntary basis, with funding covering the costs of co-ordinators, reporting, bags for collecting the debris, and the cost of the waste disposal. The Fishing for Litter Scheme (Scotland) funding for 2005-2008 was £199,218.75, and 117 tonnes of litter was removed. The cost was borne jointly by the Scottish Executive, Scottish Natural Heritage, the Crown Estate, Shetland Enterprise and Western Islands and Aberdeenshire Councils.[464] In 2009-2011, 242 tonnes was collected at a similar cost.[465] Regarding the type of debris collected, the Scotland Fishing for Litter scheme reports that the prevalence of heavy metal objects is greater than in coastal clear-ups, reflecting the propensity of these items to sink. There is anecdotal evidence that in areas that are regularly trawled, this type of debris is starting to be encountered less often.

South Korea has been running a marine debris buy-back program as part of their national marine debris strategy, where fishermen were paid a small fee for collecting and depositing the debris and used fishing gear they encountered while fishing. A report stated this was collecting 6,000 tonnes per annum at a cost of around $4,000 annually,[466] and the tonnage does however include some fishermen's daily waste and used fishing gear too. (This turns it partly into a waste prevention program though). A study estimated the tonnage of discarded fishing traps and gill-nets in the coastal waters of South Korea as 11,436 t of traps and 38,535 t of gill-nets per year.[467]

In the US Fishing for Energy program, fishermen bring back fishing gear debris they encounter on their trips and it is sent to an energy recovering facility. Participation is voluntary. One thousand tonnes of gear has been collected since 2008, and $2,000,000 has been invested in the program.[468] Early on in the project's

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[463] KIMO website, accessed June 2013. http://www.kimointernational.org/FishingforLitter.aspx

[464] Ibid.

[465] KIMO (2011) *Final Report. Fishing for Litter Scotland 2008-2011*, 2011, http://www.kimointernational.org/WebData/Files/FFL%20Scotland/FFL%20Scotland%20Report%20FINAL.pdf

[466] Morishige, C. (2010) *Marine Debris Prevention Projects and Activities in the Republic of Korea and United States: A compilation of project summary reports. NOAA Technical Memorandum NOS-OR&R-36*, Report for National Oceanic and Atmospheric Administration, 2010, http://permanent.access.gpo.gov/gpo2954/koreawkshop.pdf

[467] Kim, S.-G., Lee, W.-I., and Yuseok, M. (2014) The estimation of derelict fishing gear in the coastal waters of South Korea: Trap and gill-net fisheries, *Marine Policy*, Vol.46, pp.119–122

[468] Fishing for Energy (2013) Fishing for Energy Factsheet 2013

implementation, eight media events and 30 news stories in print, radio, TV news and the web generated 2 million media impressions.[469]

4.1.2.2 Targeted Removal of Marine Debris During Special Purpose Trips

Waste Free Oceans (WFO)/Ecover's 'Message in Our Bottle Campaign' involves Waste Free Oceans working with fishermen to fish for plastic. It addresses floating marine debris and doesn't deal with debris in the water column or on the seabed. Ecover will recycle the plastic into bottles. Ecover has stated that the aim of the 'Message in Our Bottle' project is to create a closed loop packaging material,[470] however the likely expense of obtaining plastic recyclate via this means as opposed to using separately collected plastic bottles via conventional waste collection routes suggests that this is largely a public awareness exercise. However, if material is to be recovered from the ocean, it may as well be recycled. As Ecover will incur costs of the project, it may represent a novel funding model, but the overall cost is unclear at present.

South Korea also runs a clean-up project for that involves special trips to collect marine debris. This proved more expensive than fishing for litter type schemes, as capital is needed for vessels and other equipment. The scheme collected around 4,000 tonnes of marine debris per year and cost around $8,000 annually. [471]

4.1.2.3 Targeted Retrieval of Derelict Fishing Gear (DFG) During Special Purpose Trips

There are a number of examples of such projects:

- Fishermen participating in a joint project led by WWF Poland collected 22 tonnes of DFG in 2012.[472] An estimated 5,500-10,000 gillnets are lost each year in the Baltic. If the average weight of a gill-net is 480kg, [473] this is 2,640 – 4,800t.

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[469] Morishige, C. (2010) *Marine Debris Prevention Projects and Activities in the Republic of Korea and United States: A compilation of project summary reports. NOAA Technical Memorandum NOS-OR&R-36*, Report for National Oceanic and Atmospheric Administration, 2010, http://permanent.access.gpo.gov/gpo2954/koreawkshop.pdf

[470] Guardian website, accessed June 2013 http://www.guardian.co.uk/environment/2013/mar/07/ecover-sea-plastic-bottles-recycling

[471] Morishige, C. (2010) *Marine Debris Prevention Projects and Activities in the Republic of Korea and United States: A compilation of project summary reports. NOAA Technical Memorandum NOS-OR&R-36*, Report for National Oceanic and Atmospheric Administration, 2010, http://permanent.access.gpo.gov/gpo2954/koreawkshop.pdf

[472] http://www.balticsea2020.org/english/press-room/261-135-kilometres-of-dangerous-fishing-nets-collected-in-the-baltic-sea

[473] Kim, S.-G., Lee, W.-I., and Yuseok, M. (2014) The estimation of derelict fishing gear in the coastal waters of South Korea: Trap and gill-net fisheries, *Marine Policy*, Vol.46, pp.119–122

- Norway carries out annual efforts to remove derelict fishing gear, with one vessel spending 5 weeks covering 1000 nautical miles of ocean, removing an average of 450 nets per year.[474]

- Interface's Aquafil/Net-Works™ Program. In the pilot phase in the Philippines, one tonne of fishing nets was collected by a community based supply chain who sold the recovered nylon based material to Interface to be reprocessed into carpet tiles.[475] The economics of this project are affected by the relatively low income of the local communities involved and that many nets can be collected on the coast rather than at-sea. However detailed information regarding costs is not available.

- The Northwest Straits Initiative has removed 4,605 gillnets from Puget Sound (a marine estuarine system in Washington State).[476] They have been awarded $3.5m to finish removing the remaining shallow nets (estimated to be around 900 in number). Unknown numbers of derelict deepwater nets are in the area.

4.1.2.4 Coastal Beach Clean-ups

Two such examples are given below:

- International Coastal Clean-up. The ICC cleared about 4,200 tonnes of beach litter worldwide in 2012 with the help of around 600,000 volunteers.[477] It has a budget of about $2,200,000 annually.[478]

- The South Korean Coastal Clean-up program removed 27,401 tonnes of marine debris in 2007. One citizen based effort with 46,150 volunteers removed 2,218 t of debris with a budget of $1,600,000. [479]

4.1.2.5 Efficacy of Removal Strategies in Terms of Amount of Debris Removed

Evaluating removal strategies in this way is made difficult by the lack of information on the amount of debris entering the oceans and thus what proportion is being addressed by current initiatives. Better data would help. Also the relevant information

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[474] Volckaert, A., and Van Breusegem, W. (2013) *MARELITT - Overview of project objectives and activities*

[475] Interface (2013) *Press Release 7th January 2013. Interface, Inc.and the Zoological Society of London pilot in the Philippines hailed a success*

[476] http://www.derelictgear.org/

[477] Ocean Conservancy (2012) *The Ocean Trash Index - Results of the International Coastal Cleanup (ICC)*, 2012, http://www.oceanconservancy.org/our-work/marine-debris/2012-icc-data-pdf.pdf

[478] The Ocean Conservancy (2012) *The Ocean Conservancy Annual Report 2012*, 2012, http://www.oceanconservancy.org/assets/financial-pdfs/2012-annual-report-1.pdf

[479] Morishige, C. (2010) *Marine Debris Prevention Projects and Activities in the Republic of Korea and United States: A compilation of project summary reports. NOAA Technical Memorandum NOS-OR&R-36*, Report for National Oceanic and Atmospheric Administration, 2010, http://permanent.access.gpo.gov/gpo2954/koreawkshop.pdf

is often in different units, and a more thorough assessment of the available data would help in this regard. This constitutes a knowledge gap.

Where there is a little indicative data, no matter how rough the estimates are, it is clear that removal efforts so far are only tackling a small percentage of debris entering the sea. For example, the Fishing for Litter scheme in the North Sea is only tackling about 2% of the quantity of marine debris entering the North Sea every year. The WWF Poland led initiative retrieved perhaps 0.2-0.8% of the quantity of nets entering the Baltic every year. This means that removal initiatives are not reducing the stock of marine debris in the ocean. This is true of all the types of removal strategy assessed. If removal strategies of all types were implemented by every nation, they might be enough to bring the rate of increase of the stock of marine debris down significantly, but whether they would succeed in counterbalancing it entirely is less likely, and whether they would decrease overall levels of marine debris is less likely still. Unless the flow of debris into the oceans can be staunched, the impact that removal strategies have on marine debris levels globally is likely to remain small.

It has been asserted that given the difficulties of retrieving debris from the sea (systematic at-sea collection being considered unfeasible because of the scale of the endeavour and the impossibility of separating meso- and microplastic from plankton at scale and speed) beach clean-up *is* an effective method of ocean clean up.[480] This invokes the theory that the gyres, which are often talked of as indefinite accumulators of plastic, actually releases a considerable proportion (50%) of their debris every cycle, and that this eventually ends up on the coasts, where it can be more cost-effectively removed. Another, simple 'model' of debris movement (which has been said to be based on little more than anecdotes) holds that 70% of marine debris sinks, 15% ends up on the coast and 15% floats in the sea (so, half of floating debris ends up beached and half remains floating).[481] A more sophisticated mathematical model produced the result that material from sea-based sources is slightly less likely to become beached than material from land-based sources (at 28% versus ~38%).[482] This collection of information roughly corroborates the other. However it highlights that the movement and fate of debris in the ocean is not well characterized, yet it is important for judging what removal strategies are actually achieving, and for making informed policy decisions. This is an information gap.

In conclusion, the removal of litter from ocean at present scales is not having a big impact globally. Beach clean-up may be a way of addressing floating marine debris globally, but research is needed to assess this more effectively.

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[480] http://inhabitat.com/the-fallacy-of-cleaning-the-gyres-of-plastic-with-a-floating-ocean-cleanup-array/

[481] OSPAR, UNEP, and KIMO (2007) *OSPAR Pilot Project on Monitoring Marine Beach Litter: Preventing a Sea of Plastic*, 2007, http://qsr2010.ospar.org/media/assessments/p00306_Litter_Report.pdf

[482] Lebreton, L.C.-M., Greer, S.D., and Borrero, J.C. (2012) Numerical modelling of floating debris in the world's oceans, *Marine Pollution Bulletin*, Vol.64, No.3, pp.653–661

4.1.2.6 Efficacy in Terms of Reducing the Impacts of Marine Debris

There has been little consideration, in the implementation of these programs, to measuring whether there are at least local changes in the impacts of marine debris.

The Fishing for Litter scheme in Scotland reports anecdotally that in areas that are regularly trawled, heavy, metal debris is starting to be encountered less often. This might reduce snagging, which in turn, might reduce the rate of net loss.

In Puget Sound, benthic habitat was considered to be substantially restored within a year of the removal of derelict fishing gear.[483] The relative abundance of algae, invertebrates and fish between newly cleared areas and the control areas which had not been abraded by nets changed from 41% less to 6% less after a year.

Even though there have not been attempts to estimate or measure the impacts of the removal of derelict fishing gear in terms of ghost fishing where this is carried out, efforts have been made to quantify the fishing capacity of ghost nets over time. Many studies show that capacity does decrease as nets become weighed down and/or become more visible because of the accumulation of detritus and marine organisms growing on the nets, but the extent varies widely from study to study.[484] Generally in Europe, ghost fishing is estimated to account for <1% of the weight of landed catch, with some exceptions for different types of fishing (such as deep water nets for shark and monkfish, where net loss and ghost fishing is thought to be high), though no estimates exist for this.[485] Their contribution as stressors on some populations of over exploited species could be significant, and it is not really clear what the population level effects on endangered migratory species might be, for example (see Section 3.1.1.3). Perhaps work could be undertaken to relate available information to specific removal programs and span this knowledge gap in this way. Improving knowledge regarding the wider environmental implications of derelict fishing gear would also be useful.

Routine efforts to disentangle Hawaiian Monk Seal pups and to remove derelict fishing gear and other potentially entangling debris has not led to a reduction in the amount of debris removed or the number of entanglements.[486] The amount of debris accumulating year on year did not change. Removal on this scale was not reducing impacts relative to preceding years.

In conclusion, it is possible that marine debris removal has significant local benefits, but there is very little data in this regard. It would be useful to have better monitoring

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[483] June, J., and Antonelis, K. (2009) *Marine Habitat Recovery after Derelict Fishing Net Removal*, Report for Northwest Straits Initiative, 2009, http://depts.washington.edu/uwconf/psgb/proceedings/papers/7d_june.pdf

[484] UNEP, and FAO (2009) *Abandoned, Lost or Otherwise Discarded Fishing Gear*, 2009

[485] Brown, J., and Macfadyen, G. (2007) Ghost fishing in European waters: Impacts and management responses, *Marine Policy*, Vol.31, No.4, pp.488–504

[486] Henderson, J.R. (2001) A Pre- and Post-MARPOL Annex V Summary of Hawaiian Monk Seal Entanglements and Marine Debris Accumulation in the Northwestern Hawaiian Islands, 1982–1998, *Marine Pollution Bulletin*, Vol.42, No.7, pp.584–589

in conjunction with the removal programs so that the benefits in different regions and of particular programs can clearly be assessed.

4.1.2.7 Efficacy in Terms of Awareness Raising and Promotion of Behaviour Change

This aspect of removal programs is rarely monitored, but data would be extremely informative as this may be the biggest contribution that removal programs are currently making. The Fishing for Energy programs have good media penetration (2 million media impressions for the campaign) and are the only example where such an output has been measured. For other such removal programs the awareness raising and behaviour change impacts are a key knowledge gap.

The general impression is that fishing for litter schemes are received with enthusiasm by fishermen, even where, as is mostly the case, they are voluntary. It would be useful to assess to what extent the presumed increase in awareness of fisherman of the amount and nature of marine debris they are recovering would lead to behaviour change in terms of waste management and prevention of marine debris from at-sea sources. Sometimes the schemes, in providing a cost-effective means of disposal of derelict gear (such as the Fishing for Energy program), and even an incentive for their collection (such as the Aquafil project) may also prevent abandonment of gear.

4.1.2.8 Cost Effectiveness

There are widely varying costs estimated for removal schemes, possibly in large part because the estimates are not made on a comparable basis and will not include the same components of cost.[487] Judging the cost-effectiveness also requires reliable quantification of debris removed, and the local stock and flow of debris, which as addressed above, is generally lacking.

Relatively speaking, the impression is that debris collection that is carried out in the regular course of fishing or by volunteer programs is probably cheapest, as it will require least equipment and resources to carry out. Collection of floating debris is likely to be next cheapest, but will vary (on a per tonne basis at least) a great deal depending on the density of the debris and other factors. Removing DFG can require geolocation and specialist equipment as well as the financing of special trips, meaning this is likely to be the most expensive approach (on a per tonne basis, but not necessarily on a 'per impact on migratory species' basis). Some retrieval schemes are carried out with the involvement of divers, which can also contribute to the expense.

One cost-benefit analysis of ghost fishing in the EU estimated that the cost of net retrieval per fleet (€46,500) would outweigh the benefits (€22,664) for the fishery of reducing ghost fishing by more than a factor of two. Benefits per vessel of the retrieval programme would be limited to just over €500 per vessel.[488] However this

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[487] UNEP, and FAO (2009) *Abandoned, Lost or Otherwise Discarded Fishing Gear*, 2009

[488] Brown, J., and Macfadyen, G. (2007) Ghost fishing in European waters: Impacts and management responses, *Marine Policy*, Vol.31, No.4, pp.488–504

study only takes into account economic value of the catch of commercially exploited fish and not wider environmental benefits, which, the study conceded, are difficult to quantify. To do so, considerable financial resources would have to be deployed on additional studies. The study suggested that although such quantification may itself not be cost-effective, these other types of costs and benefits should also be considered as part of the decision-making process about whether to engage in retrieval programmes or other management measures.

Other studies have found a more favourable cost:benefit ratio. In Puget Sound, for one gillnet, a loss of $19,656 of Dungeness crab to the commercial fishery was estimated, compared to $1358 in costs to remove a given gillnet, yielding a cost:benefit ratio of 1:14.5.[489]

Various removal strategies attempt to create an economic incentive for marine litter to be collected (e.g. collected plastics can be sold to a plastics reprocessor or sent for energy recovery), or even converted to transport fuel. The Fishing to Energy project found however that distance transported to processors could be cost prohibitive, limiting participation to where reprocessing can be undertaken close to collection points.[490] For other schemes, recycling has proved difficult. Scotland's Fishing for Litter project set recycling targets of 10% for their recovered waste. However, this was not met because often the material was too fouled by marine organisms to be considered for recycling, and also the quantities recovered were too small for waste companies to consider taking unless pre-sorted, for which there was no budget and such a requirement viewed as a potential discouragement for participation in the program.[491] More work is needed to establish whether any of these schemes are economically self-sustaining or if they could become so.

In conclusion, removal schemes appear relatively expensive given the benefits obtained, but there is difficulty obtaining enough comparable data to make a full assessment.

4.1.2.9 Other Benefits

Removal programs can also be useful for debris monitoring, such as the ICC campaign. However if they are to do so, systematic and standardized recording should be used to make the data as useful as possible.

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[489] Gilardi, K.V.K., Carlson-Bremer, D., June, J.A., Antonelis, K., Broadhurst, G., and Cowan, T. (2010) Marine species mortality in derelict fishing nets in Puget Sound, WA and the cost/benefits of derelict net removal, *Marine Pollution Bulletin*, Vol.60, No.3, pp.376–382

[490] Morishige, C. (2010) *Marine Debris Prevention Projects and Activities in the Republic of Korea and United States: A compilation of project summary reports. NOAA Technical Memorandum NOS-OR&R-36*, Report for National Oceanic and Atmospheric Administration, 2010, http://permanent.access.gpo.gov/gpo2954/koreawkshop.pdf

[491] KIMO (2011) *Final Report. Fishing for Litter Scotland 2008-2011*, 2011, http://www.kimointernational.org/WebData/Files/FFL%20Scotland/FFL%20Scotland%20Report%20FINAL.pdf

The social benefits of removal schemes are generally seen as important; for example, Ghost Nets Australia has brought together indigenous communities in working together to care for the marine environment.[492]

4.2 Addressing Knowledge Gaps

Stakeholders relevant to addressing and filling knowledge gaps in the management of marine debris already in the environment are considered in this section. Ideally, stakeholders specific to reducing impacts on migratory species are required. This does not necessarily limit the group of stakeholders a great deal, given the wide-reaching impacts of all types of marine debris. Steps to filling the information gaps are addressed in Section 6.5.

Regarding monitoring, the specific information gaps most relevant to the impacts on migratory species are:

- Prevalence of types of debris that have high impacts on migratory species;
- Sources and pathways of these types of debris;
- Geographic distribution of these types of debris;
- Debris monitoring measures that consist of impacts on organisms, specific to migratory species if possible; and
- Population level effects on migratory species.

On this basis, relevant stakeholders for filling these gaps might be:

- Regional Seas area committees

  In so far as they are a point of contact for national debris monitoring, and where it is done, collate the data into regional statistics, they are an important stakeholder. It has to be borne in mind that globally, debris monitoring by the Regional Seas is still not at a mature stage of co-ordination. This however might mean that it is a good juncture at which to work with the designers or implementers to make sure that the most relevant data to migratory species is collected. This might be particular types of marine debris, such as fish hooks, or micro- and meso-plastic fragments, which don't appear in every monitoring checklist, or anything else known to have particular impacts on marine species.

- Intergovernmental Organizations

  The European Commission (EC) is currently considering setting marine debris targets, and many years of work has already gone into considering and developing indicators for this. These include indicators that are of the nature of impacts on migratory species, and there is still development going on in this area. There may be opportunities to influence this debate and in the process

[492] Gunn, R., Hardesty, B.D., and Butler, J. (2010) Tackling 'ghost nets': Local solutions to a global issue in northern Australia, *Ecological Management & Restoration*, Vol.11, No.2, pp.88–98

garner useful data relevant to migratory species. This might be for example, impact data on both non-migratory and migratory species; as mentioned above, the choice of species has implications as to what the indicator means, and so needs careful consideration.

- National governments

  Governmental decision makers have a general role to play in pushing forward appropriate national legislation regarding marine debris that as a consequence will require monitoring to be stepped up, and providing the motivation and funding for the research needed to address current knowledge gaps.

- NGOs, university groups or governmental departments that carry out environmental monitoring

  These stakeholders tend to be national in terms of scope but not always; examples of both have been found.

  - There are examples of groups that take a special interest in particular item types or sources of debris, such as the International Pellet Watch, (Tokyo University of Agriculture and Technology)[493] Tangaroa Blue (NGO) and weather balloons, GhostNets Australia, or Global Green USA (NGO) and military waste.[494] Ideally the key here would be to identify groups who have interests in debris which is particularly impactful for migratory species. As regards microplastics, for which there is a working group, GESAMP Working Group 40, who will report on "Sources, fate & effects of microplastics in the marine environment – a global assessment" in November 2014.[495] This is a general assessment to complement the UN GA Regular Process on the State of the Marine Environment. This working group is supported by UNESCO - IOC, UNEP, IMO, UNIDO, UNDP, NOAA, ACC and Plastics Europe, to give an idea of the number and variety of stakeholders involved.
  - Research groups of any kind could carry out research to help elucidate pathways, such as via estuarine litter monitoring, for improving information we have about source and type of debris, specific to different countries and regions.
  - If it is decided that a key part missing from the case for action is the demonstration of population level effects on species, this can be pursued by research groups of any kind, given a political mandate and appropriate funding if necessary. NGOs with focuses on particular groups of species, such as BirdLife International, who already

493 http://www.pelletwatch.org

494 http://www.globalgreen.org/events/174

495 Kershaw, P.J. (2013) *Marine Litter - where are we?*, Global Conference on Land - Ocean Connections, Jamaica

coordinate lots of bird monitoring initiatives, could be a partner, for example, in undertaking threat-specific monitoring such as impacts of marine debris on migratory birds. WSPA is working toward the establishment of the “Untangled Alliance”,[496] a multi-stakeholder alliance to catalyse action for a ghost-gear free sea; monitoring and feedback will be a part of this and so they could be a source of data relevant to these issues. The International Whaling Commission has established a Marine Debris Working Group and is conducting a two-year investigation into the interaction of marine debris with cetaceans, including whales and dolphins. Microplastics have been recognized as having a potential impact on baleen whales, including through digestion of associated chemical pollutants and microbes. The overall objective is to assess, by 2014, the extent of the problem and to propose potential mitigation and management solutions. They make an ideal partner for CMS to work on this given how many cetaceans are migratory and that they already work with CMS. There are various independent research groups who have undertaken high level reviews on marine debris impacts such as those by STAP/GEF[497], WSPA[498] or reviews according to high level taxa and impact type, such as ones on turtles and ingestion,[499] or whales and ingestion.[500] More of these types of reviews would be useful for leveraging the research that has already been done to its greatest potential.

  - Other agencies or NGOs concerned with wildlife such as UNEP –WCMC (Wildlife Conservation Monitoring Centre), (which already support CITES and CBD Conventions), WWF (Worldwide Fund for Nature), IFAW (International Fund for Animal Welfare) or WSPA (World Society for the Protection of Animals) could help to establish standardized reporting methods for threats to species such as marine debris impacts.

- NGOs, university groups involved in data curation
  - In order to store and integrate information with the greatest relevance to migratory marine species, the IUCN Red List, the Global Biodiversity Information Facility (GBIF) and the Global Register of Migratory Species

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[496] Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for WSPA, 2012, http://www.wspa-international.org/Images/Untangled%20Report_tcm25-32499.pdf

[497] STAP/GEF (2012) *Impacts of marine debris on biodiversity: Current status and potential solutions*, Report for CBD, 2012

[498] Butterworth, A., Clegg, I., and Bass, C. (2012) *Untangled - Marine Debris: a global picture of the impact on animal welfare and of animal-focused solutions*, Report for WSPA, 2012, http://www.wspa-international.org/Images/Untangled%20Report_tcm25-32499.pdf

[499] Schuyler, Q., Hardesty, B.D., Wilcox, C., and Townsend, K. (2013) Global Analysis of Anthropogenic Debris Ingestion by Sea Turtles, *Conservation Biology*, p.n/a–n/a

[500] Simmonds, M.P. (2012) Cetaceans and Marine Debris: The Great Unknown, *Journal of Marine Biology*, Vol.2012

(GROMs – which has found a new home with Bonn University and the Museum Koenig Natural History Museum) could be partnered with to ensure accurate and consistent recording and mapping of the threats posed by marine debris to migratory species. This could perhaps integrate information from independent research groups who have undertaken high level reviews on marine debris impacts.

- Citizen science

  Many research efforts rely heavily on volunteer effort (for example, the ICC's beach monitoring, the Sea Education Association's at-sea monitoring and International Pellet Watch's monitoring of POPs on plastic pellets).[501] In order to be systematic and comparable, they should be organised via official monitoring programmes. There are also particular groups of citizens such as divers and surfers who are notable for their involvement with the issue of marine debris. Perhaps other groups such as anglers and recreational boaters might also provide a fruitful resource for researchers.

- Commercial sector
  - The potential contribution of sectors of industry may be best directed to filling gaps about sources; specifically, by monitoring their own production of marine debris. Perhaps to guarantee the independence of the estimates, it could be done in conjunction with NGOs or public research institutes. For example, port owners (e.g. PSA International) could be engaged with (a number of harbours already engage with Fishing for Litter schemes for example and monitor the amount and composition of waste landed). Shipping companies (e.g. A.P. Moller – Maersk Group), fishing and aquaculture companies (e.g. Pescanova), passenger line companies (e.g. Carnival Cruise Lines) and waste contractors similarly, could be approached to participate. A coordinating role could be played by industry or regulatory bodies such as the World Shipping Council or regional fisheries boards or bodies.
  - Currently, land-based industries are not obliged to report emissions and incidents for debris release into waterways as they are for other pollutants. A voluntary disclosure initiative could be set up in conjunction with industry, which would provide useful information in an area where there is so little.
  - The plastics industry is an important stakeholder that might become engaged in monitoring endeavours in some way, such as funding, or development of research techniques regarding the identification of different types of plastic, or isolation of plastic from the marine environment, for example.

[501] Law, K.L., Morét-Ferguson, S., Maximenko, N.A., Proskurowski, G., Peacock, E.E., Hafner, J., and Reddy, C.M. (2010) Plastic Accumulation in the North Atlantic Subtropical Gyre, *Science*, Vol.329, No.5996, pp.1185–1188

- Consultants. There are examples of private sector commercial enterprises conducting research relevant to marine debris, such as the EW Wells group and their research into marine military disposal sites in collaboration with Global Green USA.[502]

The kind of information gaps most relevant to the impacts on migratory species as regards debris removal management initiatives are:

- Efficacy in terms of impact on stock and flow of marine debris;
- Efficacy in terms of mitigating impacts on marine species, specific to migratory species if possible;
- Efficacy in terms of public awareness and behaviour change – public, fishermen, industry, and other stakeholders; and
- Cost-effectiveness.

It is this information that would provide the basis for deciding whether and where these sorts of management strategies would be appropriate in areas relevant to migratory species particularly.

Relevant stakeholders for filling these gaps will include any of the organisations that partner in removal schemes. There are a very large number of these because they are usually multi-stakeholder partnerships between national or local government and industry, whether the plastics industry or the fishing industry. However, they may have staff allocated to coordination for the schemes who would be the most appropriate contact for obtaining more information. Via the removal schemes themselves, information could be provided on all the above points apart from on the stock and flow of marine debris. Also, not every removal scheme will be appropriate for monitoring the mitigation of impacts on species, whether migratory or not.

We are aware of one research project that aims to evaluate removal programs in the EU, a pilot project for the MARELITT research endeavour. This again is a multi-stakeholder effort, involving research from Milieu Ltd and its partners ARCADIS, MEGAPESCA Lda, IMARES, LEI, RSS Marine, Plymouth University, the Coastal & Marine Union (EUCC), EUCC Mediterranean Centre, the Baltic Environmental Forum and Mare Nostrum. This is a mix of private and public sector research organizations, consultancies and NGOs. It is likely that it would take research projects of this kind, in partnering with removal schemes, to be able to fill information gaps regarding them.

Regarding estimates of stock and flow and further work on the effect of removal schemes on species impacts, we refer the reader to the section on filling knowledge gaps in monitoring.

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[502] Stauber, R. (2011) Research effort to document military munitions disposal sites worldwide, *Technical Proceeding of the 5th International Marine Debris Conference* (2011)

5.0 Preventing Waste Reaching the Marine Environment

While there is considerable spatial variation, overall, the majority of marine debris is understood to be land based in origin.[503] Awareness of the importance of reducing (land-based) littering is increasing, and is, albeit slowly, leading to legislative action. This is encouraging, as the adage of 'prevention being better than cure' would seem particularly apt in the case of marine debris.

While there is clearly merit in removing debris, especially plastic debris and fishing gear, from the marine environment, it is more cost-effective to implement measures that prevent (land-based) littering in the first place. As well as ultimately reducing the flow of debris to the marine environment, preventing land-based littering delivers a number of benefits, such as improved local environmental quality. Research suggests that a less littered local environment can lead to lower levels of crime, improved mental health and wellbeing, as well as reducing the likelihood that further littering will occur.[504] Moreover, depending upon the instrument chosen to reduce littering, the costs of waste treatment can be considerably reduced, and notable carbon savings achieved.

The choice of instrument is very important. In the example below, two scenarios are presented, both of which achieve zero littering, and hence no flows of land-based material to the marine environment:

- Scenario 1 involves extensive provision of litter bins, with a 'zero tolerance' approach to littering supported by punitive fines, backed up by considerable public expenditure on enforcement.
- Scenario 2 involves economic instruments such as deposit-refunds on beverage containers and a levy on single-use carrier bags, alongside obligations requiring the use of reusable beverage containers, cutlery and crockery at public events. Provision of litter bins is moderate, and while fines for littering exist, they are rarely used.

While the littering outcomes may be identical, Scenario 2 delivers a segregated stream of high quality, and valuable, materials for recycling, through the container deposit scheme. Recycling these materials, avoiding the requirement for primary manufacture, can lead to considerable carbon savings. The levy on single-use carrier bags, and the event obligation both incentivise the use of re-usables, preventing waste and the associated management cost. By contrast, Scenario 1, already involving expensive enforcement and infrastructure provision, will incur further expense in that the collected materials are mixed together, and hence any recyclables

[503] GESAMP(1991) *The State of the Marine Environment*, Oxford: Blackwell Scientific Publications

[504] Eunomia Research & Consulting (2013) *Indirect Costs of Litter*, Report for Zero Waste Scotland, 2013

will be of a lower quality (due to contamination) and hence less valuable if subsequently segregated for recycling. If destined for residual treatment, this is typically more expensive for public authorities than recycling (depending upon the legislative context and the location) and will lead to much greater carbon impacts.

In the section below, we outline a number of instruments that have been shown to be effective in reducing littering. Key among these are economic instruments, that use price signals to incentivise appropriate behaviour.

5.1 Key Knowledge Gaps

In respect of the routes by which land-based litter reaches the marine environment, there is considerably uncertainty as to the proportions attributable to each specific pathway. For example it is known that items that end up as marine debris:

- Could be dropped by members of the public, or arise from commercial / industrial sites, or during transport of materials; or
- Could escape from formal waste management systems; and
    - From litterbins, including from waste left at the side of bins that are full;
    - At the doorstep of the household;
    - At 'bring' sites;
    - During transportation;
    - At poorly managed landfill sites;
- Could then be washed, during periods of heavy rainfall and surface water flooding into rivers and hence travel to the sea;
- Could be windblown and hence travel to the sea; or
- Could be deposited directly on the beach and then enter the sea directly; or alternatively
- Could enter the sea via the sewage system, including combined sewer overflows.

While it would undeniably be of interest to develop a better understanding of the pathways by which litter reaches the sea, we would suggest that this should not be the immediate priority, or at least it should not be the sole priority. Furthering our knowledge of pathways should not take precedence over implementing measures that are known to be effective in reducing debris at source. Such measures, which include deposit-refunds for beverage containers, and levies on single-use carrier bags, are described in subsequent sections (Section 5.5.1 and Section 5.5.2 respectively).

Prioritising the implementation of measures also makes sense from the perspective of making the best use of limited budgets for research. If the contribution to marine debris of priority items such as plastic bottles and carrier bags can be significantly reduced, this allows researchers to focus more closely on what remains. As an example, might there be a way of incentivizing the return of crisp packets in a similar manner to that possible for beverage containers?

5.2 Links with Waste Prevention

Measures that seek to prevent waste from occurring in the first place also tend to bring about positive impacts in respect of reducing the flow of land-based debris into the marine environment. The approach to waste prevention and management, and the associated legislation, is relatively well developed within the EU. Accordingly it is appropriate to look towards the European example and draw lessons from this. In European law, the key piece of legislation relating to land-based waste prevention and management is the revised Waste Framework Directive (2008/98/EC) (WFD). The Directive does not, however, refer to litter explicitly. Article 36, however, on Enforcement and Penalties, obliges Member States to:

> *Take the necessary measures to prohibit the abandonment, dumping or uncontrolled management of waste*.

In principle, this should imply that littering, by virtue of being 'uncontrolled management of waste', is prohibited in Member States. The fact that litter remains a problem, albeit varying in extent across the EU, implies that this 'prohibition' is not enforced with great vigour in many locations.

The revised WFD places great emphasis on the role of waste prevention.[505] Preventing materials from becoming waste in the first instance holds considerable potential for reducing the amount of litter entering the marine environment. The WFD:[506]

- Makes waste prevention one of its primary objectives (Article 1);
- Specifically defines waste prevention (Article 2 (2));
- Places it at the top of the waste hierarchy (Article 4), to which Member States are now required to give force in policy and law (with some latitude for deviations where clearly justified on environmental grounds);
- Encourages Member States to make use of extended producer responsibility with a view, in particular, to increasing that responsibility (Article 8);
- Requires the Commission to produce various reports, accompanied where necessary by proposals for any measures necessary to support preventive activities and the implementation of prevention programmes (Article 9);
- Obliges Member States to promote re-use (Article 11); and
- Makes the implementation of prevention programmes an essential requirement (Article 29).

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[505] European Parliament, and Council of the European Union (2008) Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives, *Official Journal of the European Union*

[506] Bruxelles Environnement (2011) New European Legal Requirements Relating to Waste Prevention. Background paper to the International Pre-waste Workshop, Brussels, 28 March 2011.

This represents a significant development from the previous Directive (2006/12/EC), in which prevention was addressed in only one provision, which outlined a waste hierarchy (Article 3).

The requirement to implement waste prevention programmes (Article 29) includes an obligation on Member States to:

- Set out waste prevention objectives;
- Describe the existing prevention measures; and
- Evaluate the usefulness of the examples of measures indicated in Annex IV or other appropriate measures.

Examples of waste prevention measures that have associated benefits in terms of reduced littering include:

- Taxes/levies/charges on single use carrier bags;
- Obligations on event organisers to use reusable containers (as in, for example, Munich, Vienna etc.);
- Use of refillable beverage containers (as is the case for wine in the Styria region of Austria). These are often accompanied by a deposit, which is then refunded upon return to the retailer. [507]

One potential weakness, relating to litter impacts, in the application by Member States of the waste hierarchy, is the formulation of Paragraph 2 of Article 4, which states that:

> *When applying the waste hierarchy referred to in paragraph 1, Member States shall take measures to encourage the options that deliver the best overall environmental outcome. This may require specific waste streams departing from the hierarchy where this is justified by life-cycle thinking on the overall impacts of the generation and management of such waste.*

The obvious example here is of single-use plastic carrier bags, where life-cycle assessments have been used to justify *not* implementing measures to reduce their use.[508] However, such studies typically focus on the carbon impacts of different types of bags, and explicitly exclude from consideration the effects of littering. While LCA as a methodology is unable to account for a number of the downstream consequences of litter, Cost-Benefit Analysis, although better placed to incorporate such effects, only

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[507] Such a 'two-way' refillable deposit system is less common than 'one-way' deposits, where beverage containers are returned for recycling rather than for reuse. However, from discussion with drinks industry representatives we understand that they believe that one-way deposits, in increasing the upfront cost may bring about a waste prevention effect, albeit through reduced sales as consumers switch to alternatives such as tap water. Whether a waste prevention measure or simply a way to boost recycling, the evidence on the reductions in litter that are associated with one-way deposit refunds is compelling.

[508] Intertek Expert Services (2011) *Life Cycle Assessment of Supermarket Carrier Bags: A Review of the Bags Available in 2006*, Report for Environment Agency, February 2011

rarely does so. The primary reason in the case of CBA has until recently been a lack of studies relating to all the different impacts, although progress is now being made in areas such as local neighbourhood litter disamenity, and indeed beach litter disamenity values.[509]

5.2.1 European Marine Debris Targets

In addition to giving legislative priority to waste prevention through placing it at the top of the waste hierarchy, the European Commission is considering implementing marine debris targets. The Technical Subgroup (TSG) on Marine Litter has reviewed EU monitoring efforts and made recommendations on the setting of targets for reductions in marine debris. In addition they have drafted guidance for the harmonization of marine debris monitoring methods. A further two initiatives have involved the consideration of targets by Member States.

Subsequent to the TSG's review of EU marine litter monitoring efforts, it became clear that there is more data on beach debris than for debris in the water column, even though TSG ML states that there is: [510]

> *Not so much information available in EU marine waters to set quantitative thresholds related to the reduction of marine litter washed ashore and/or deposited on coastlines.*

TSG ML does, however, go on to say that quantitative reduction targets for beach litter should nevertheless be considered. For litter on beaches, it was proposed that the goal of a general measurable and significant reduction of marine litter by 2020 be adopted in the first instance, albeit it was felt that reductions in abundance of marine litter in the order of 50% per decade are a feasible target when adequate measures are taken. Research which showed that changing methods in production and transport processes were associated with a halving of the abundance of industrial plastic pellets in seabird stomachs was cited in support of this statement.[511]

An interesting point to note in this respect is that if higher targets are set, and appropriate measures are instituted to meet the targets, it will be easier to determine, through monitoring, that a change has indeed occurred, then if weak targets had been set. [512] For example, if a 5% reduction target were set, it would be very difficult

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[509] Eunomia Research & Consulting (2013) *Indirect Costs of Litter*, Report for Zero Waste Scotland, 2013

[510] TSG ML (2011) *Marine Litter - Technical Recommendations for the Implementation of MSFD Requirements*, Report for JRC-IES, 2011, http://books.google.be/books/about/Assessing_potential_ocean_pollutants.html?id=kIYRAAAAYAAJ&redir_esc=y

[511] TSG ML (2011) *Marine Litter - Technical Recommendations for the Implementation of MSFD Requirements*, Report for JRC-IES, 2011, http://books.google.be/books/about/Assessing_potential_ocean_pollutants.html?id=kIYRAAAAYAAJ&redir_esc=y

[512] p18 - TSG ML (2013) *DRAFT MSFD Monitoring Guidance for Marine Litter in European Seas*, 2013, https://circabc.europa.eu/d/a/workspace/SpacesStore/b627cfb6-cece-45bc-abc1-e4b3297adb91/DRAFT%20MSFD%20Monitoring%20Guidance%20TSG-ML%2011072013.pdf

to identify whether or not this had actually been achieved, or whether what was being measured was simply 'background noise', i.e. the variation one might reasonably expect to be exhibited in measurements. The extent of the monitoring that would be required to have sufficient confidence that such a modest target had been met would make it more expensive to determine than would be the case for a more ambitious target.

Moreover, politically, one could foresee a situation where an apparent failure to achieve a modest target (due to the uncertainty involved in the monitoring) may be cited by some as evidence that more ambitious targets are not feasible, and should not be pursued.

European Member States' initial assessments of marine environmental status and target proposal as mandated by Marine Strategy Framework Directive Articles 8 and 10 respectively have been completed and targets proposed.[513] Examples of the types of targets proposed so far are as follows:[514]

- To reduce litter from beaches based on a five year moving average;
- Negative annual trend in beach litter;
- Reduction in litter on sea surface, water column and seabed;
- Litter proved to be harmful to marine organisms (especially microplastic) reduced towards zero over the long term;
- Entanglement and strangulation reduced towards a minimum;
- Less than 10% of Fulmars having more than 0.1g of plastic in their stomachs;
- Various operational targets regarding better waste collection in coastal regions;
- Reduced inflow from rivers and sewers; and
- Targets related to changes in behaviour, such as littering on beaches.

5.2.2 Existing Commission Studies Supporting MSFD Implementation

In support of the implementation of the Marine Strategy Framework Directive (which is driving consideration of targets for marine debris), the European Commission has funded background research. In 2011 the Commission launched three pilot projects to improve understanding of the sources and routes by which debris, and plastic debris in particular arrives in the marine environment. The projects dealt with:

- Loopholes in the plastics cycle in the EU's four marine regions (See Section 5.2.2.1);

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[513] European Commission website. http://ec.europa.eu/environment/marine/good-environmental-status/index_en.htm Accessed August 2013.

[514] InterSus, University of Trier, Milieu, UBA, and COM (2013) Issue Paper to the 'International Conference on Prevention and Management of Marine Litter in European Seas'

- Loopholes in the recycling of plastic packaging material in the EU (and a selection of countries outside the EU but sharing European seas) (See Section 5.2.2.2); and
- The feasibility of introducing instruments to prevent littering (See Section 5.2.2.3).

The key findings from these reports are summarised below.

5.2.2.1 Pilot Project on Loopholes in Plastic Recycling Cycle in Regional Seas Areas

The European Commission launched this pilot project to support the implementation of the Marine Strategy Framework Directive.[515] The aim was to identify the main possible sources of marine litter in the four regional seas areas relevant to the EU. Further to this, a set of feasible measures was designed to address the identified sources of litter. These sources were identified as:

- Tourism and recreational activities in coastal areas (all regional seas areas);
- Land-based household waste entering the marine environment via the sewage system, poorly managed landfill sites in coastal areas, and in some cases, via rivers (especially the Mediterranean, Baltic and Black Sea areas); and
- Shipping and fisheries (North Sea area especially).

Many measures were proposed to tackle these different sources, including

- Enforcement of littering laws;
- Adequate provision of bin infrastructure;
- Educational and awareness campaigns for members of the public;
- Clean-up activities;
- Improved collection, treatment and disposal of municipal solid waste, including improved street cleaning;
- Waste prevention (e.g. by encouraging re-use, or via levies);
- Incentivising of collection of specific materials (e.g. deposit refund systems, extended producer responsibility); and
- Enforcement of compliance with Landfill Directive.

In addition, a number of potential measures aimed specifically at commercial and industrial waste producers were recommended.

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[515] Arcadis (2012) *Case studies on the plastic cycle and its loopholes in the four European regional seas areas*, Report for DG Environment, 2012

5.2.2.2 Pilot Project on Loopholes in Plastic Packaging Waste Management in Member States

This study was also launched in support of the implementation of the MSFD, by the European Commission. Its objective was the identification of the largest loopholes in the plastic packaging life cycle through which plastic packaging waste could escape and enter the marine environment, hence contributing to marine litter.[516] Plastic packaging was chosen as the focus because of the prevalence of this waste item and material type in compositional analysis of marine litter (reported here as 50%). The study also emphasised that of this type of litter, plastic bags and bottles make up the largest proportion.

The largest loopholes identified were related to:

- The production of plastic packaging;
- Consumption and disposal behaviour of consumers;
- Suboptimal collection infrastructure;
- Illegal dumping; and
- Poor landfilling practices.

These loopholes match those identified in the previous study on the plastics recycling cycle quite closely, and this study also makes recommendations on how to address these production, consumption and disposal loopholes. These are:

- Reducing the high consumption of plastic packaging products (particularly bags and bottles);
- Improving the disposal behaviour of consumers;
- Optimise the design of plastic packaging production (e.g. design for re-use, recycling, low material demand);
- Better enforcement of extended producer responsibility; and
- Improved performance of the waste management system (e.g. increase waste collection frequency and recovery/recycling or close non-compliant landfills particularly close to the coast).

5.2.2.3 Feasibility Study of Introducing Instruments to Prevent Littering

A third study undertaken in support of the implementation of the MSFD considered the feasibility of introducing specific instruments to prevent littering.[517] The report highlights a wide range of possible instruments, and considers relevant issues associated with their implementation. However, there appears to be something of a 'disconnect' between this report and the first two studies relating to loopholes.

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[516] BIPRO (2013) *Study of the largest loopholes within the flow of packaging material*, Report for DG Environment, 2013, about:newtab

[517] ABP MER, Arcadis, and RPA (2013) *Feasibility Study of Introducing Instruments to Prevent Littering*, Report for DG Environment, 2013

While the first two studies emphasise the pre-eminence of plastic packaging waste in marine litter, notably single-use plastic bags and plastic bottles, the report by RPA, Arcadis and ABPmer fails to recommend that Member States might implement measures that demonstrably lead to reduced littering of these items namely levies on single-use carrier bags, and deposit-refunds on beverage containers.[518]

5.3 Provision for Waste Management

Globally, there is considerable variation in the provision of waste collection and management services. Clearly where provision is poor, or non-existent, the potential for items to be littered, and ultimately end up as marine debris, is greater. However, the absence of a formal waste management service should not be a reason for holding back on the implementation of measures that can effectively tackle littering – notably of priority items such as plastic bottles and single-use carrier bags.

Significant reductions in the use of single-use carrier bags, an effective form of waste prevention, can be achieved through imposing a ban, or introducing a levy, requiring no investment in the provision of waste management services. Similarly, a deposit-refund system for beverage containers does not depend upon the existence of a waste management service for households.

Waste management projects funded by international donors tend to focus on large scale infrastructure provision, typically of facilities such as incinerators. Rather than prioritise prevention, to reduce the overall amount of the waste to be managed, these focus on the bottom of the 'waste hierarchy' on disposal or 'recovery' activities – the latter actually requiring a steady throughput of waste, and therefore arguably inimical to large scale reductions in waste. Prioritising investment in such a way is not the most effective way of tackling littering.

5.3.1 Poorly Managed Landfill

Landfills that are badly managed can contribute to the problem of marine debris, especially if they are adjacent to rivers, or near the coast. However, the extent of the contribution is poorly understood. The problem is not just with landfills that are currently operational, but also those that have been closed, but are now being eroded.

A particular knowledge gap is that of the relative scale of the contribution of landfills to the problem of marine debris, and moreover, of identifying which particular landfill sites are the priorities for action, on the basis of their contribution and the associated impact.

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[518] See for example Eunomia Research & Consulting (2011) *A Comparative Study on Economic Instruments Promoting Waste Prevention*, Report for Bruxelles Environnement, December 2011, www.ibgebim.be/uploadedFiles/Contenu_du_site/Professionnels/Formations_et_s%C3%A9minaires/Waste_Prevention_Conference/Formulaire_WPC/Waste%20Prevention%20Final%20Report%2008.11.2011%202.pdf?langtype=2060

An interesting example of where this issue is being addressed is in Alaska. The Alaska Department of Environmental Conservation recognises that:[519]

> *Coastal and river erosion has the potential to cause hazardous substances and garbage from Alaska's eroding landfills, closed dump sites, and contaminated sites to be released into the ocean and the state's rivers, jeopardizing Alaska's waters, fish and wildlife.*

The Department is now engaged in a four-year $1.4 million project to create an inventory of such sites, identify priority locations, and generate action plans to mitigate the impacts of erosion. The inventory, ranking and action plans will help state and federal agencies, as well as rural communities seeking funding, to control eroding areas or relocate landfills that are in danger of eroding.

This is an approach that could usefully be replicated elsewhere. Another high profile example relates to the coastal landfill on the southern coast of the city of Saïda in Lebanon. Since 1982 this has been the main waste disposal site for the city and its surrounding municipalities. The dumpsite has a surface area of 3 ha and a height of 55 m, and is understood to receive 300 tons of waste per day. The dumpsite is said to be ineffectively managed and is reported not to meet basic environmental requirements.[520] The dumpsite thus represents an environmental and human health risk, in particular given its location near a water body. Waste from the dumpsite regularly slides into the Mediterranean, littering coastlines and degrading the marine environment. The impact of the dumpsite is not restricted to the coastal area of Saïda. Reportedly, waste from the landfill is washing ashore in northern Lebanon, Syria, Cyprus and Turkey.

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519 http://dec.alaska.gov/eh/sw/wear.html

520 http://www.wastefreeoceans.eu/sites/default/files/projects/Press%20Release%20WFO%20Saida.pdf

5.4 Prevalence of Land-Based Items in Marine Debris

As indicated in Section 2.2.2, of the 43 different item types in the ICC Clean-Up Scorecard (relating to identifiable debris on beaches), the most prevalent items, by count, are as shown in Table 7

Table 7: Prevalence of Item Types in International Coastal Clean-up

Sector	Item Type	Overall Prevalence
Smoking–Related Litter	Cigarettes/Cigarette Filters	18.9%
Shoreline & Recreational Activities	Food Wrappers/Containers	10.2%
Shoreline & Recreational Activities	Plastic Beverage Bottles	9.5%
Shoreline & Recreational Activities	Plastic Bags	9.1%
Shoreline & Recreational Activities	Caps/Lids	8.6%
Shoreline & Recreational Activities	Plastic Cups, Plates, Forks, Knives, Spoons	6.2%
Shoreline & Recreational Activities	Plastic Straws/Stirrers	5.5%
Shoreline & Recreational Activities	Glass Beverage Bottles	4.6%
Shoreline & Recreational Activities	Beverage Cans	3.0%
Ocean/Waterway Activities	Rope	2.2%
Ocean/Waterway Activities	Plastic Sheeting/Tarps	1.7%
Ocean/Waterway Activities	Fishing Line	1.2%

Source: The Ocean Conservancy 2012 - The Ocean Trash Index.

The majority of these items are categorized by the ICC as belonging to the 'Shoreline & Recreational Activities' sector. The exceptions are Rope, Plastic Sheeting/Tarps, and Fishing Line ('Ocean/Waterway Activities'), and Cigarettes/Cigarette Filters ('Smoking-Related Activities'). What is clear from this list is that debris originally derived from land-based activities appears to makes the greatest contribution to the debris on surveyed beaches.

This prevalence by type does not necessarily reflect the relative extent of impacts on migratory species from such items of debris. In part, this may be due to the focus in the ICC on beach debris. Debris discarded offshore, having impacts offshore, and remaining offshore, would clearly not be counted.

The report commissioned by the Convention on Biological Diversity found that around 80% of the impacts on marine species were associated with plastic debris, while paper glass and metal together accounted for less than 2%.[521] Within the plastics category were:

- Rope and netting (24%);
- Fragments (20%);
- Packaging (17%)
- Other fishing debris (16%); and
- Microplastics (11%).

Rope and netting, and fishing debris, are likely to be predominantly from marine-based sources (albeit some marine debris from recreational fishing may be from inland waterways or (land-based) fishing on the coastline).

'Fragments', which by their nature cannot be allocated to a particular source or item type may be land-based in origin to a large degree, and the same could be said for microplastics. Primary microplastics will almost certainly be land-based in origin, given their application as cleaning agents and their use in personal care products.[522] Secondary microplastics (which have fragmented from larger plastic fragments) may be from either land or marine derived sources of debris. Packaging materials will predominantly be land based in origin.

The available data suggests that the majority of the flow of debris into the marine environment is land-based in origin (possibly up to 80%). There are numerous difficulties associated with monitoring and enforcement in respect of reducing the flow of debris from marine-sources (e.g. fishing, shipping). However, for land-based sources, with clearer lines of legal responsibility, reducing the flow of debris should, in theory, be more straightforward. This point was highlighted by Achim Steiner, UN Under-Secretary-General and UNEP Executive Director at the launch of UNEP's 2009 report: Marine Litter: A Global Challenge:[523]

> *Marine litter is symptomatic of a wider malaise: namely the wasteful use and persistent poor management of natural resources. The plastic bags, bottles and other debris piling up in the oceans and seas could be dramatically reduced by improved waste reduction, waste management and recycling initiatives. Some of the litter, like thin film single use plastic bags which choke marine life, should be banned or phased out rapidly everywhere there is simply zero justification for manufacturing them anymore, anywhere. Other*

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[521] Secretariat of the Convention on Biological Diversity, and Scientific and Technical Advisory Panel - GE (2012) *Impacts of Marine Debris on Biodiversity: Current Status and Potential Solutions, Technical Series No. 67*, 2012

[522] http://www.stowa.nl/upload/publicaties/Inventarisatie%20risico%20microplastics%20engels.pdf

[523] http://www.rona.unep.org/documents/pressreleases/2009PR-LaunchOfMarineLitterReport.pdf

> *waste can be cut by boosting public awareness, and proposing an array of economic incentives and smart market mechanisms that tip the balance in favor of recycling, reducing or reuse rather than dumping into the sea.*

For a number of the item types referred to above, and listed in Table 7, there are indeed specific measures that can be implemented in order to prevent them reaching the marine environment. These are detailed in Section 5.5.

5.5 Item–Specific Measures

A range of item-specific interventions are available to prevent waste reaching the marine environment. Such measures also prevent terrestrial debris, leading to a number of, arguably, more immediately tangible benefits for the residents and authorities in the country/region/city where the measures are implemented.

5.5.1 Deposit-Refunds for Beverage Containers

In 2011 Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO), in partnership with Earthwatch, commenced a three year marine debris research survey. The aim of the survey is to identify and understand the threat marine debris poses to wildlife and ecosystems by mapping out where – and how – it is accumulating along Australian coastlines.[524]

To date, CSIRO researchers have visited more than 170 sites around Australia, completing over 575 transects, stopping at 100 kilometre intervals along the Australian coast, investigating:

- Sources, distribution, and ultimate fate of marine debris;
- Exposure of marine wildlife to debris; and
- The effects of ingestion and entanglement on marine wildlife populations.

The research team is being led by Dr Britta Denise Hardesty. On being interviewed by the Australian Broadcasting Corporation in 2012, she noted that:[525]

> *Observationally we do not find full plastic bottles or cans or glass bottles in [...] South Australia and I would likely attribute that [...] to the container deposit scheme that they have there.*

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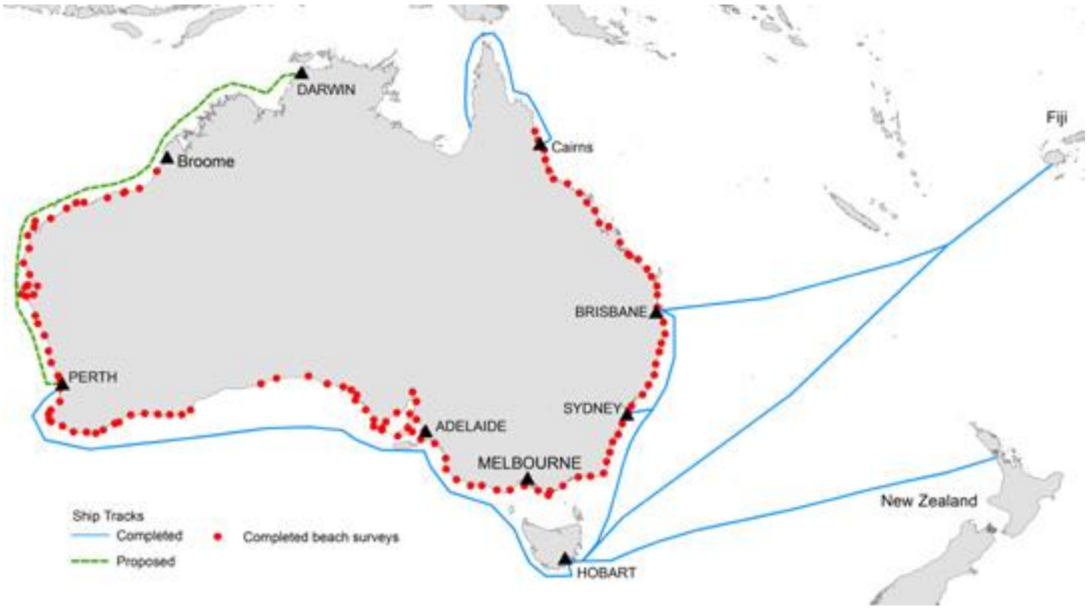
[524] http://www.csiro.au/Organisation-Structure/Flagships/Wealth-from-Oceans-Flagship/marine-debris.aspx

[525] http://www.abc.net.au/catalyst/stories/3583576.htm

Figure 3: CSIRO Marine Debris Survey Locations



Source: CSIRO

There is considerable evidence to suggest that deposit refund policies can reduce litter and even reduce associated direct impacts on members of the public, such as the number of lacerations caused by glass in the environment.[526] Several one-way deposit systems were implemented with the clear objective of reducing littering (e.g. Sweden, British Columbia, California, Michigan and others). Hawaii is a more recent example of this trend.

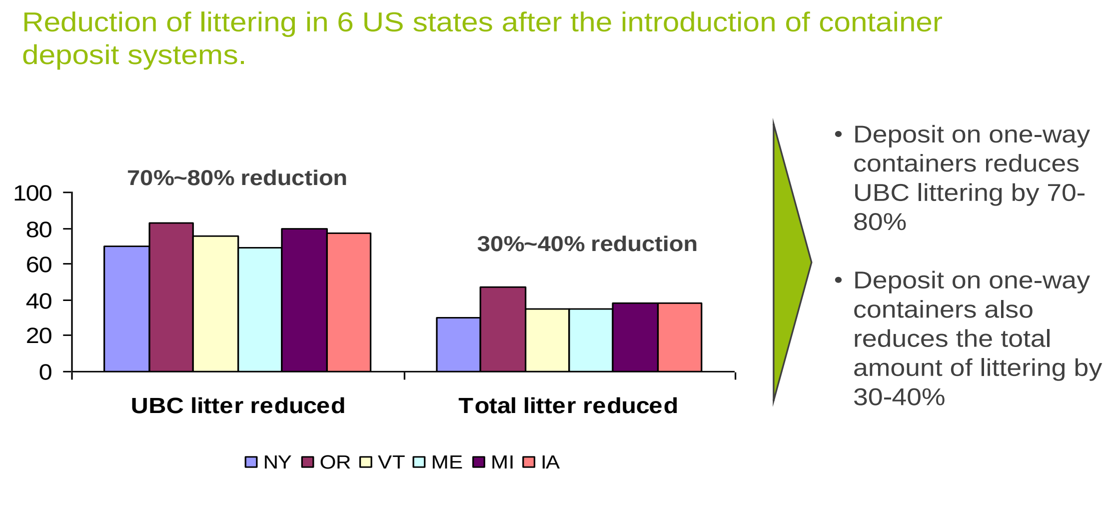
The potential for deposit systems to be effective in reducing littering has an intuitively plausible rationale - if the deposit is significant, then if the consumer does decide to litter, the possibility exists that someone else will pick up the container to redeem the deposit.

The Container Recycling Institute suggested significant reductions in littering following introduction of deposits in some US states (see Figure 4). The effects on used beverage containers (UBCs) and on total litter are shown as being between 70-80% and 30-40%, respectively. It must be said, however, that all studies of this nature suffer in terms of the lack of clarity about the metric used to measure the contribution of beverage containers to total litter. It is not clear what the most relevant indicator should be (counts, volume, hazardousness, etc.) partly because no systematic studies have been carried out, to our knowledge, to understand the contribution of different attributes of litter to the disamenity felt by those who experience litter. There is also

[526] M. Douglas Baker, MD, Sally E. Moore, and Paul H. Wise, MD, PhD, MPH, "The Impact of 'Bottle Bill' Legislation on the Incidence of Lacerations in Childhood", *American Journal of Public Health*, October 1986.

the matter of cost to be considered since cleaning up litter costs money. The effect of litter reduction on costs is considered below.

Figure 4: Reduction in Littering in US States Linked to Deposit Schemes



Source: Container Recycling Institute, USA

Where supposed counter-arguments to the 'litter reduction' effect are put forward, these very rarely challenge the likely reality of this effect. Indeed, the counter-arguments tend to adopt the view that this effect is not significant because beverage containers constitute only a small proportion of litter. Even if one accepts the argument that this might be true, implicit in the counter-argument appears to be an assumption that if litter 'is there', then the amount of it is not a matter of any importance, or more specifically, that the reduction in the quantity of beverage packaging in litter is of no significance. Yet none of the literature actually offers any evidence to support this implied claim. The validity of the implied claim is also affected by the nature of the assumption (as highlighted above) concerning the metric used to measure 'litter'. What the right metric might be has not, as discussed above, been given adequate consideration by either advocates, or detractors, of the effects of deposit schemes.

In Ireland, Perchards argue that:[527]

> *The National Litter Survey for 2006 indicates that drinks containers (excluding cartons) represent 5.36% of total litter, with all packaging representing 13% of litter. This indicates that* ***a deposit could reduce the incidence of drinks containers in packaging, but it would have little impact on total litter.*** *Other litter surveys undertaken around the world have reached the same conclusion. Through Repak, Irish industry is already helping to combat litter, and it is unlikely that a deposit*

[527] G. Bevington (2008) *A Deposit and Refund Scheme in Ireland*, Report commissioned by Repak Ltd., September 2008.

would result in significant cost savings for Irish local authorities on litter abatement activities.

A problem with this analysis is that it assumes that the relevant indicator regarding litter is the measure used in the Litter Survey. This actually measures 'counts' of litter.

It could be argued that the disamenity effect of litter, and indeed its impact on migratory species, is a function more of its volume, and possibly, its potential to persist, than the number of items (i.e. the counts). In this respect, it is worth reporting that the 2007 National Litter Survey reports that the two most prominent items in litter in terms of counts are cigarette related litter, accounting for 46.7% of counts, and food related litter, accounting for 28% of counts. The majority of the two combined– though certainly requiring clean-up – are less visible cigarette ends and chewing gum. Chewing gum clearly has the potential to cause nuisance in its own particular way. After these categories, the component with the highest number of counts is packaging items, at 11.75%, of which around 5.64% - roughly half – were beverage containers.[528]

Given the relative insignificance – in volume terms – of chewing gum and cigarette ends, it might reasonably be considered that beverage containers could actually constitute a significant proportion of litter when considered in volume terms. As a result, one might argue that they are not as insignificant – in terms of their contribution to the disamenity associated with litter – as the count number would suggest if, as seems not entirely implausible, some of the litter-related disamenity experienced by communities relates to litter's visibility.

Furthermore, in terms of value of materials in the litter stream, their contribution may also be significant. It is notable that the contribution of beverage containers to the litter count associated with packaging is around 50%, even though in weight terms, such containers account for only 10% or so of packaging in the waste stream. In other words, where packaging is concerned, beverage containers appear to figure in a disproportionately significant manner within litter. Hence, whilst many argue that deposits only address a fraction of all packaging, their effect on litter may address a form of packaging which contributes disproportionately to the problem of litter.

In jurisdictions such as Hawaii, the prevalence of beverage containers in terrestrial and marine debris has been a motivation for the scheme. One report from the State of Hawaii shows how beverage containers have changed in terms of their prevalence in debris over time.[529] The data are shown in Table 8 and Table 9.

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[528] TOBIN (2008) *Litter Monitoring Body: System Results 2007*, The National Litter Pollution Monitoring System Survey, Report for DoEHLG, June 2008, http://www.environ.ie/en/Environment/Waste/LitterPollution/NationalLitterMonitoringSystem/PublicationsDocuments/FileDownLoad,18616,en.pdf

[529] State Of Hawaii Department Of Health (2008) *Pursuant To Sections 342g-102.5(H), 342g-114.5(B), And 342g-123, Hawaii Revised Statutes, Requiring The Department Of Health To Give A Report On The Activities Of The Deposit Beverage Container Program*, Report To The Twenty-Fifth Legislature State Of Hawaii 2009, November 2008.

Table 8: Number of Debris Found During Cleanup

Beverage Container Type	2003	2004	2005	2006	2007
Glass Bottles	7,687	11,362	7,194	5,759	5,008
Plastic Bottles	5,246	5,215	3,824	4,799	2,965
Metal Cans	4,946	6,894	3,518	3,959	2,932
Total	**17,879**	**23,471**	**14,430**	**14,517**	**10,905**

Source: State Of Hawaii Department Of Health (2008) Pursuant To Sections 342g-102.5(H), 342g-114.5(B), And 342g-123, Hawaii Revised Statutes, Requiring The Department Of Health To Give A Report On The Activities Of The Deposit Beverage Container Program, Report To The Twenty-Fifth Legislature State Of Hawaii 2009, November 2008

Table 9: Percentage of Total Debris Collected During Cleanup

Beverage Bottles & Cans	2003	2004	2005	2006	2007
Glass, Metal, & Plastic	15.9%	14.5%	12.3%	8.7%	6.7%

Source: State Of Hawaii Department Of Health (2008) Pursuant To Sections 342g-102.5(H), 342g-114.5(B), And 342g-123, Hawaii Revised Statutes, Requiring The Department Of Health To Give A Report On The Activities Of The Deposit Beverage Container Program, Report To The Twenty-Fifth Legislature State Of Hawaii 2009, November 2008

The report notes:

> *While there appears to be a downward trend in the number of bottles and cans found at beaches, beverage containers, along with associated caps and lids, continue to be a large portion of beach litter. This is why it is important to continue to place a deposit on beverage containers to decrease the temptation to litter and increase the incentive to recycle.*

A somewhat interesting feature of the Hawaii data is that they show that beverage containers appear to be (relatively) more problematic in underwater cleanups (see Table 10).

Regarding plastics in particular, UNEP's 2009 report notes the prevalence of plastic bottles, caps (and bags) among the key forms of debris giving rise to increasingly serious problems in the marine environment due to the longevity and potential harm caused by the material.[530]

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[530] Ljubomir Jeftic, Seba Sheavly, and Ellik Adler (2009) *Marine Litter: A Global Challenge*, Report for UNEP, April 2009, http://www.unep.org/regionalseas/marinelitter/publications/docs/Marine_Litter_A_Global_Challenge.pdf

Table 10: Top 5 Debris Items Collected During the 2007 Cleanup

Land Cleanups Only	**Number of Debris Items**	**Percent of Total Collected**
1. Cigarettes & Filters	72,053	44.7%
2. Caps & Lids	21,210	13.1%
3. Food Wrappers and Containers	16,554	10.3%
4. Beverage Containers *(glass, metal, plastic)*	10,505	6.5%
5. Cups, Plates, and Utensils	7,331	4.5%
Underwater Cleanups Only	**Number of Debris Items**	**Percent of Total Collected**
1. Fishing Line	1,081	54%
2. Beverage Containers *(glass, metal)*	393	19.6%
3. Cigarettes, Filters, & Cigar Tips	248	12.3%
4. Food Wrappers and Containers	55	2.7%
5. Caps & Lids	39	1.9%

Source: State Of Hawaii Department Of Health (2008) Pursuant To Sections 342g-102.5(H), 342g-114.5(B), And 342g-123, Hawaii Revised Statutes, Requiring The Department Of Health To Give A Report On The Activities Of The Deposit Beverage Container Program, Report To The Twenty-Fifth Legislature State Of Hawaii 2009, November 2008

Interesting evidence of the effects of deposits on littering comes from Denmark. In Denmark, there is a prominent cross-border trade in alcohol from Germany owing to the differences in excise duties between the countries. The Danish Society for Nature Conservation is the largest nature conservation and environmental organization in Denmark. With the support of 140,000 members, they work to protect nature and the environment, and each year conduct debris clean-up campaigns. What is most intriguing about these campaigns is the proportion of littered cans which do not carry a deposit, because they are imported from Germany from areas specifically exempted from the German deposit system. A short summary of the main results concerning beverage cans since 2008 from the "Clean Up Denmark" campaigns is given below:

- 2008: 154,400 cans, of this only 7,800 with a paid Danish deposit;
- 2009: 153,000 cans, of this only 10,000 with a paid Danish deposit; and
- 2010: 197,000 cans, of this only 7,800 with a paid Danish deposit.

The data indicates that the vast majority of cans which are found in litter are those which bear no deposit. The suggestion appears to be that the deposit system has a significant bearing upon whether cans are littered or not. The Danish EPA notes that the majority of the machines receiving containers bearing the Danish deposit are also equipped to receive those which do not. Hence, the only differences between the German and Danish containers is that the Danish ones bear a deposit, which seems to act as a significant incentive to motivate return to the appropriate system. The absence of incentive in the case of German containers leads to greater littering,

A 2009 study undertaken in Australia suggested that deposit schemes were likely to be the most effective policy option for reducing litter amongst those considered for improving recycling:[531]

> *A national CDS [container deposit scheme] is expected to provide the greatest reduction in overall litter levels, with the potential to provide a 6% reduction in the total national litter count and a 19% reduction in the total national litter volume.*

Finally, there is another way in which removal of used beverage containers from litter could contribute to cleaner streets. To the extent that beverage containers are relatively voluminous items, then their removal from litter bins would leave more room for other waste. The CPRE's Litterbugs report reports that 91% of the public believe that increasing the number of bins is the most effective way of reducing litter.[532] An equivalent approach might be to free up space in existing bins. The report cites the New York bottle bill as reducing container litter by 70-80%. Clean-up costs, as well as landfill costs, were reduced. The scheme enjoys solid public support (84% of voters in 2004) and so has been extended in 2009 to cover non-carbonated drinks, which make up 27% of beverage sales.

5.5.1.1 Effects on Disamenity

Discussion of impacts of litter is often framed in terms of costs. The most obvious type is the 'direct cost', which is the cost to local authorities and other duty bodies of clearing away litter. Beyond these direct costs is what one might term 'indirect costs' – i.e. the costs to other stakeholders. While these are less well understood, initial estimates suggest that they are considerable - far outweighing the direct costs.

Research commissioned in early 2013 by Zero Waste Scotland (ZWS) has begun to explore a number of these indirect cost categories, looking both at costs that are 'internalised' within market transactions, and 'externalities', for which no market exists. An example of an internalised cost is that arising from having to deal with a bicycle puncture caused by broken glass from a littered bottle. An externalised cost, by contrast, could be the sense of 'welfare loss' associated with the visual disamenity of a beach being strewn with litter.

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[531] BDA Group (2009) *Beverage Container Investigation*, Report for the EPHC beverage Container Working Group, March 2009.

[532] A. Lewis, P. Turton and T. Sweetman (2009) *Litterbugs How to Deal with the Problem of Littering*, Report for CPRE, March 2009.

The ZWS research identified evidence that a littered environment can contribute to poor mental health, increase the likelihood of crime, and reduce property values.[533] Other types of indirect costs identified were associated with road traffic accidents, fires, and vermin. The study also built upon research into local environmental quality undertaken for Defra in 2011.[534] Looking at externalised costs, this report identified the public's mean willingness to pay (WTP), via an increase in council tax, for a number of improvements in a range of local environmental factors.

Litter was identified in the research as the factor with the most significant effect on local environmental quality, with the highest mean WTP to reduce it, at over £100 per person per year. Applying the values from this research to Scotland, an aggregate WTP of between £500 million and £770 million was identified. This can be taken as a broad measure of the disamenity impact, i.e. just how upset people feel about the level of litter in their local neighbourhood.

A 2010 study for CPRE on the introduction of a UK-wide deposit-refund system for beverage containers found that the benefits of such a system outweighed the costs once account was taken of the disamenity impact of litter.[535] At the time, prior to the publication of the Defra study cited above, there was an absence of reliable estimates on disamenity, and the values selected were much lower than those more recently identified. On the basis of the revised disamenity figures, the case for deposits looks even stronger. What is important to note about these findings is that such interventions appear to be able to be justified even *without* considering the benefits associated with reduced impacts on the marine environment. Once these positive impacts are taken into account, the argument in support of actions such as deposit refunds becomes even more compelling.

While ultimately it seems intuitive that reducing the amount of debris entering the marine environment is in everyone's self-interest, evidence such as that relating to local disamenity strengthens the case for countries to take action on litter, even on the narrowest definition of self-interest.

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[533] Eunomia Research & Consulting (2013) *Exploring the Indirect Costs of Litter in Scotland*, May 2013

[534] Mark Wardman, Abigail Bristow, Jeremy Shires, Phani Chintakayala, and John Nellthorp (2011) *Estimating the Value of a Range of Local Environmental Impacts*, Report for Dept. for Environment, Food and Rural Affairs, April 2011

[535] Eunomia Research & Consulting (2010) *Have We Got the Bottle? Implementing a Deposit Refund System in the UK*, Report for Campaign to Protect Rural England (CPRE), September 2010, www.cpre.org.uk

5.5.2 Levies on Single-use Carrier Bags

In early 2013 the European Commission published three studies looking into the composition, and sources, of marine litter in European seas. In a chapter integrating results from all three studies it noted that:[536]

> *Plastics are the most abundant debris found in the marine environment and comprise more than half of marine litter in European Regional Seas. More than half of the plastic fraction is composed of plastic packaging waste with plastic bottles and bags being predominant types of plastic packaging.*

This summary chapter then goes on to say that:

> *Therefore, measures within a strategy to close the largest loopholes in the plastic packaging cycle should target plastic bottles and plastic bags.*

Plastics dominate marine litter and represent a significant threat to the marine environment due to their abundance, longevity in the marine environment and their ability to travel vast distances.[537] Despite representing only 10% of all waste produced, plastics account for between 50-80% of marine litter and this is not expected to decline for the foreseeable future (particularly as plastics do not degrade quickly).[538] Of all plastics it is single use plastic bags that are arguably the most iconic symbol of the impact of marine debris on migratory species in the mind of the public, notably in respect of their ingestion by turtles.

Data taken from the International Bottom Trawl Survey and the Clean Seas Environmental Monitoring Programme indicate that plastic bags make up 40% of all marine litter in the waters of the North East Atlantic. The French research institute IFREMER has also found that in the Bay of Biscay most of the waste items found on the seabed were plastic (92%) and of those 94% were plastic bags. [539]

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[536] See http://ec.europa.eu/environment/marine/pdf/Integration%20of%20results%20from%20three%20Marine%20Litter%20Studies.pdf

[537] KIMO (2010) Economic Impacts of Marine Litter, Kommunernes Internationale Miljøorganisation Local Authorities International Environmental Organisation, September 2010, available at http://www.kimointernational.org/Portals/0/Files/Marine%20Litter/Economic%20Impacts%20of%20Marine%20Litter%20Low%20Res.pdf

[538] Thompson, R.C., Swan, S.H., Moore, C.J. and vom Saal, F.S. (2009a) Our Plastic Age. Philosophical Transactions of the Royal Society B: Biological Sciences 364(1526): 1969-2166; Barnes, D.K.A., Galgani, F., Thompson, R.C. and Barlaz, M. (2009) Accumulation and fragmentation of plastic debris in global environments. Philosophical Transactions of the Royal Society B: Biological Sciences 364(1526): 1985-1998; Thompson, R.C., Moore, C.J., vom Saal, F.S., and Swan, S.H. (2009b) Plastics, the environment and human health: current consensus and future trends. Philosophical Transactions of the Royal Society B: Biological Sciences 364(1526): 2153-2166.

[539] Seas at Risk (2011) Commission Consults on Binning Plastic Bags, available at http://www.seas-at-risk.org/news_n2.php?page=408

Fortunately, evidence suggests that measures to reduce the use of single-use plastic carrier bags are effective. The Irish plastic bag levy was introduced in March 2002 under the Waste Management (Environmental Levy) (Plastic Bag) Regulations 2001. Initially, the tax was set at €0.15 per plastic bag, with exemptions for smaller plastic bags that met specific conditions and were used to store non-packaged goods such as dairy products, fruit and vegetables, nuts, confectionary, hot or cold cooked food and ice –these are known as levy-free bags (reusable plastic bags are also exempt as long as the charge for the bag exceeds €0.70).[540] The tax is passed directly to consumers at the point of sale, and has thus been reported to provide a clearer, more consistent message than systems where retailers are responsible for the levy (such as in Denmark and South Africa).[541,542]

It has been reported that this policy has been very effective and has *'proved so popular with the Irish public that it would be politically damaging to remove it'*.[543] The tax was implemented to *'change consumers' behaviour to reduce the presence of plastic bags in the rural landscape, and to increase public awareness of littering'.* Revenues from the tax are paid into an Environmental Fund which is administered by the Department of Environment, Heritage and Local Government. The fund is used to cover administrative costs (3% of total revenues) and support a wide range of environmental programmes. The costs of implementation are reported to be very low because bookkeeping and reporting has been integrated with VAT returns. [544]

The levy is not a Pigouvian tax, in that the rate of the tax was not devised with the intention of internalising the marginal external costs. Instead, the Irish Government's intention was to set a rate of tax which would act to change consumer behaviour. As such, the initial rate of tax was set at six times consumers' average maximum willingness to pay for the purchase of plastic bags.[545] This ensured that there was a

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[540] According to the Department of the Environment, Community and Local Government 'Bags not exceeding 225mm in width (exclusive of any gussets), by 345mm in depth (inclusive of any gussets), by 450mm in length, (inclusive of any handles) have been marketed as "Levy Free Bags". The regulations, however, do not provide for "Levy Free Bags". The Plastic Bag Levy applies on all plastic bags, even if marketed as "Levy Free Bags", when used in circumstances not exempted by the regulations'. See: Department of the Environment, Community and Local Government (2007) Plastic Bags, Date Accessed: 19 September 2011, www.environ.ie/en/Environment/Waste/PlasticBags/.

[541] Dikgang, J. Leiman, A. and Visser, M. (2010) *Analysis of the Plastic-Bag Levy in South Africa*, Policy Paper No. 18, Environmental Policy Research Unit, School of Economics, University of Cape Town, July 2010, www.econrsa.org/papers/p_papers/pp18.pdf

[542] Plastic Bag: Friend or Foe? (no date given) *Market Based Examples*, Date Accessed: 20 September 2011, www.plasticbageconomics.com/index.php?option=com_content&task=view&id=26&Itemid=40

[543] Convery, F., McDonnell, S. and Ferreira, S. (2007) The Most Popular Tax in Europe? Lessons from the Irish Plastic Bags Levy, *Environmental and Resource Economics*, September 2007, Vol. 38, No. 1, pp. 1-11

[544] Convery, F., McDonnell, S. and Ferreira, S. (2007) The Most Popular Tax in Europe? Lessons from the Irish Plastic Bags Levy, *Environmental and Resource Economics*, September 2007, Vol. 38, No. 1, pp. 1-11

[545] Ibid.

marked decrease in the use of plastic bags in the short term, a trend which has been reversed slightly over the years. The per capita usage of plastic bags decreased from an estimated 328 to 21 plastic bags per capita per annum after the introduction of the tax. However, the results of the 2006 census indicated that plastic bag usage had risen to 32 bags per capita over the course of 2006. Consequently the levy was increased to €0.22 on 1st July 2007 under Plastic Bag (Amendment) (No. 2) Regulations of 2007.[546]

An evaluation of the impact of the levy on householders and retail sector was undertaken by Convery et al.[547] The authors interviewed seven leaders in the retail sector and conducted random telephone interviews with consumers, the results were as follows:

- Retailers found the effects of the tax on their well-being neutral or positive, closely related to the fact that the additional costs of implementation were generally less than the savings resulting from not having to purchase plastic bags. Implementation costs were low because book-keeping was integrated with VAT returns; and
- Overall, consumers were very much in favour of the levy. While the levy had caused them some expense, through either paying the levy or buying long-life bags, virtually all respondents responded that they felt the impact on the environment was positive, producing a noticeable reduction in plastic bags 'in the environment'.

The main objective of Ireland's plastic bag levy has been to reduce quantities of litter. In this regard the tax has had a marked effect and again Convery et al report that:

> *'A combined project by Irish Business Against Litter and An Taisce (National Trust of Ireland) produced a number of litter surveys. These have found that between January 2002 and April 2003 the number of "clear" areas (i.e. areas in which there is no evidence of plastic bag litter) has increased by 21%, while the number of areas without "traces" has increased by 56%.[548] These numbers are remarkably high given the long lasting nature of plastic bags in the environment. A different source, the National Litter Pollution Monitoring System notes that plastic bag litter accounted for 5% of national litter composition before the introduction of*

546 Department of the Environment, Community and Local Government (2007) *Plastic Bags Levy to be Increased to 22c from 1 July 2007*, Press Release: 21/02/2007, Date Accessed: 19 September 2011, www.environ.ie/en/Environment/Waste/PlasticBags/News/MainBody,3199,en.htm

547 Convery, F., McDonnell, S. and Ferreira, S. (2007) The Most Popular Tax in Europe? Lessons from the Irish Plastic Bags Levy, *Environmental and Resource Economics*, September 2007, Vol. 38, No. 1, pp. 1-11

548 "Traces" of litter is defined as up to five items over a linear distance of 1 m.

the levy. In 2002, this number fell to 0.32%, in 2003 to 0.25% and to 0.22% in 2004'.[549]

This rate has remained more or less constant since this time.[550] In addition, the public commonly believes that the amount of plastic bag litter has decreased substantially since the introduction of the tax.[551]

5.5.2.1 Welsh Carrier Bag Charge

The Welsh Government introduced a £0.05 (€0.06)[552] compulsory charge for single-use carrier bags at the point of sale in October 2011. Unlike Ireland this mechanism is not a levy, but a minimum charge that retailers are guided to pass on to local and environmental causes (although this is not mandatory).[553] Additionally it also applies to all single-use bags including those composed of paper and other plant based material, not just plastic.

Nine months after the introduction of the charge, reductions are cited by Welsh Government as between 70% and 96%, depending upon the sector.[554] Retailers in the following sectors reported a range of reductions:

- Food retail – between 96% and 70% reduction;
- Fashion – between 75% and 68% reduction;
- Home improvement – 95% reduction;
- Food service – up to 45% reduction;
- Telecommunications – 85% reduction.

Data released by WRAP in 2011 shows a reduction of 22% in usage across supermarkets in Wales from 2010 to 2011.[555] This would appear to be consistent

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549 Convery, F., McDonnell, S. and Ferreira, S. (2007) The Most Popular Tax in Europe? Lessons from the Irish Plastic Bags Levy, *Environmental and Resource Economics*, September 2007, Vol. 38, No. 1, pp. 1-11

550 Litter Monitoring Body and TOBIN Consulting Engineers (2011) *The National Litter Pollution Monitoring System – Litter Monitoring Body: System Results 2010*, Report for the Department of the Environment, Heritage and Local Government, April 2011, www.litter.ie/system_survey_results/index.shtml

551 Convery, F., McDonnell, S. and Ferreira, S. (2007) The Most Popular Tax in Europe? Lessons from the Irish Plastic Bags Levy, *Environmental and Resource Economics*, September 2007, Vol. 38, No. 1, pp. 1-11

552Based on a £:€ exchange rate of 1:1.27650, ft.com currency converter, 26th July 2012.

553 Welsh Government (2012), Carrier Bag Charge Wales, Accessed 19th July 2012. http://www.carrierbagchargewales.gov.uk/?lang=en

554 *Welsh Government (2012),* Reduction in Single-use Carrier Bags, *Accessed 7th August 2012.* http://wales.gov.uk/topics/environmentcountryside/epq/waste_recycling/substance/carrierbags/reduction/

555 WRAP (2012), UK Supermarket Retailers Voluntary Carrier Bag Agreement: 2011 Carrier Bag Use, Presentation for the WRAP website, WRAP July 2012

with the reductions noted by the Welsh Government, bearing in mind that the charge was only in place for the final three months of 2011.

A study produced for The Welsh Government by Cardiff University conducted surveys both before and after the introduction of the charge regarding attitudes and behaviours towards it in England and Wales.[556] Results show that the charge has helped to increase greatly own bag use in Wales with a 21% increase in consumers taking a reusable bag to the supermarket (increased from 61% to 82% of the sample).

5.5.2.2 Chinese Plastic Bag Ban

In January 2008, The State Council, China's parliament, prohibited shops, supermarkets, and sales outlets from providing free plastic bags less than 0.025 mm thick. The State Administration of Industry and Commerce also threatened to fine shopkeepers and vendors as much as 10,000 yuan (US$1,465) if they were caught distributing free bags.

In its first review of the ban, the National Development and Reform Commission (NDRC) announced in June 2009 that supermarkets had reduced plastic bag usage by 66% since the policy was implemented one year previously.[557] The China Chain Store and Franchise Association undertook an analysis of the ban as well. The association announced that foreign-owned and local supermarkets reduced plastic bag usage by 80% and 60% respectively. However, compliance with the ban appears to be inconsistent across the country. A survey by Global Village, a Beijing-based environmental group, found that more than 80% of retail stores in rural regions continued to provide plastic bags free of charge.

5.5.3 Incentivizing / Obligating the Use of Reusable Items

Plastic Cups, Plates, Forks, Knives, Spoons account for 6.2% of the items in the ICC Clean-Up Scorecard as shown in Table 7. One possible way to reduce the contribution of these items to marine debris is to ban them. Plastic cutlery was banned in Haryana, India in 2011, although this measure does not appear to be fully enforced, with many people ignoring the ban.[558]

Another approach is to subject such ‘single-use’ items to a tax or levy, to discourage their consumption. Such an approach has been implemented in Belgium, where under the “picnic tax” wholesalers are liable to pay a tax on various single-use items.[559] It has been reported that the tax on disposable plastic bags – set at €3.00

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[556] Poortinga et al (2012), Evaluation of the Introduction of the Single-Use Carrier Bag Charge in Wales: Attitude and Behavioural Spillover, Report for the Welsh Government, Cardiff University 2012.

[557] http://www.worldwatch.org/node/6167

[558] http://www.fridaygurgaon.com/news/2717-get-real-say-no-to-plastic.html

[559] These include the following taxes: €3.00 per kg of non-biodegradable disposable plastic carrier bags; €2.70 per kg for plastic food wrapping (product price increase of approximately 70%); €4.50 per kg for aluminium foil (product price increase of approximately 100%); €3.60 per kg of disposable kitchen utensils.

per kg – has had a marked impact in terms of reducing their use over recent years (decrease of 80% between 2003 and 2007, during this time the sale of reusable bags rose from 4.5million units in 2004 to 25.4million in 2007). However, it is also reported that despite the fact that *'the retail prices of disposable kitchen utensils, food wrap and aluminium foil have gone up substantially, the impact on consumption has been less marked'*.[560]

While the tax may have led to less consumption, and presumably thus levels of associated debris, than would have been the case in the absence of the tax, it does not appear to have been particularly successful. Accordingly, the following actions may be necessary, or supportive when implementing taxes on single-use disposable products:

- Apply taxes to items where alternatives are clearly available (this is likely to ensure a reasonable response to the tax);
- Continual review of the tax to ensure that its effectiveness is not being eroded over time (e.g. through inflation);
- Ensure the tax is designed with sufficient inbuilt flexibility to adapt to changing economic conditions; and
- Prior to introducing the tax, develop an effective communication campaign to advertise the rationale behind the tax. In this respect, there should be a clear rationale for the tax.

A third approach is to ban the use of disposable beverage containers, cutlery and crockery at public events.

Since 1991, the City of Munich has banned the use of disposable cutlery and crockery at large-scale public events that take place on land owned by the city and retail spaces owned by the city.[561] The event organisers instead use reusable items which are made available using a deposit-refund system. The deposit is normally only applied to cups, bottles and plates, but not to cutlery, but when people return cups and plates, any cutlery used is usually returned as well. A similar scheme has been in place in Vienna since 2011. A study for the Brussels Capital Region in 2012 identified that an obligation for event organisers to use reusable cups would lead to both environmental benefits and financial savings to organisers, while extending the obligation to include cutlery and crockery would increase costs to organisers, without

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[560]Bruxelles Environment (2010) *Mapping Report on Waste Prevention Practices in Territories within EU27 - Pre-Waste: Improve the Effectiveness of Waste Prevention Policies in EU Territories*, October 2010, http://www.bruxellesenvironnement.be/uploadedFiles/Contenu_du_site/Professionnels/Formations_et_s%C3%A9minaires/Conf%C3%A9rence_Pre-waste_2011_(actes)/p3-%20prewaste-mapping-report.pdf

[561] Pre-waste (2011) Ban on disposal drink containers and tableware in Munich, Germany (Münchner Einwegverbot).

demonstrating clear environmental benefits.[562] However, a key shortcoming of the environmental analysis, in common with many 'life cycle' approaches was the exclusion of the downstream impacts of littered items.

5.5.3.1 Tackling Singe-use Coffee Cups

Reusable cups for take-away coffee are becoming increasingly popular and are gaining support from the coffee shop chains. Market leader Starbucks aims to serve 5% of beverages in personal tumblers by 2015. The company has rewarded customers using personal tumblers with a discount since 1985 and has recently launched a $1 reusable cup to further facilitate their goal.[563] Popular chains of coffee shops often charge more to drink the item on the premises which in many respects encourages the use of a single-use disposable cup. However, if a levy were placed on beverages purchased in disposable cups, this would be expected to lead to a change in consumer behaviour.

In addition to directly reducing the likelihood of coffee cups becoming littered, such a measure would also have the effect of *indirectly* reducing litter. Coffee cups are high-volume items that, along with plastic bottles, for example, quickly fill up litter bins, meaning that they will be more likely to overflow, and that further items will be placed next to, rather than within, the bins.

5.5.4 Tackling Styrofoam

Legislation to ban Styrofoam (expanded polystyrene foam) food and drinks containers in New York City was passed in December 2013, making it the latest in a string of almost 100 towns and cities to do so.[564] A large number of the bans are found in California, with some having been adopted as early as 1989.[565] The bans vary in nature as some are limited to food and drink containers, some include packaging peanuts and some ban all Styrofoam products. Other related legislation requiring food packaging to be biodegradable or compostable also effectively bans Styrofoam use.

Opposition to Styrofoam bans tends to focus on tackling the waste management issues rather than the health implications of harmful chemicals leaching out of the Styrofoam into food and drink and the wider environment. Dart Container Corp. suggested a kerbside recycling solution for Styrofoam in New York City but the

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[562] Eunomia (2012) A Feasibility Study on a Legal Obligation Aimed at the Systematic Use of Reusable Containers for Drinks and Food Served at Events Held in Public Places in the Brussels Capital Region, Final Report to Bruxelles Environnement

[563] Cup and Materials | Starbucks Coffee Company, accessed 13/1/2013, http://www.starbucks.com/responsibility/environment/cups-and-materials

[564] Plastic-Foam Container Ban Approved by New York City Council – Bloomberg, accessed 6/1/2014, http://www.bloomberg.com/news/2013-12-19/new-york-city-council-approves-ban-on-plastic-foam-containers.html

[565] Polystyrene: Local Ordinances | Californians Against Waste, accessed 7/1/2013, http://www.cawrecycles.org/issues/plastic_campaign/polystyrene/local

economics of such a scheme are thought to be prohibitively costly.[566] The American Chemistry Council states that Styrofoam is currently recycled in over 65 communities in California but such schemes do nothing to tackle the litter problem or the pathway of Styrofoam litter to the marine environment.[567] Furthermore, once outside of the city jurisdiction the fate of the recycled product at end of life is unknown and may be lost, become litter or be landfilled.

5.5.5 Drinking Straws, Plastic Stirrers, Lollipop Sticks

Sustainable alternatives to plastic drinking straws, stirrers and lollipop sticks have recently grown in popularity.

Glass and steel reusable drinking straws are available from a range of manufacturers and have been promoted across the mainstream media by sources including The Guardian newspaper and Oprah Winfrey.[568] Metal straws are popular in Latin America and elsewhere to drink hot *mate* and paper straws were used for almost 100 years before plastic straws became commonplace, which demonstrates the viability of reusable and compostable alternatives to plastic.

Wooden stirrers are now common in coffee shops although they are often provided alongside plastic stirrers or plastic single-use spoons. There is no reason why non-biodegradable materials cannot be avoided without any disbenefit to the customer or business. Furthermore, although a large proportion of coffee shop customers buy drinks to take away (over 50% in the UK) many will add milk and sweeteners at the self-service stand *before* leaving the premises.[569] This suggests that reusable products such as stainless steel teaspoons could be provided, limiting the generation of waste and litter and potentially saving businesses money.

A Facebook campaign asks Chupa Chups to stop using plastic sticks in their lollipops. Pressure from the campaign caused the manufacturer to release a statement of their intention to use a more sustainable material in October 2012 although no such change has been realized yet. [570]

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[566] Why DART Corp's Bribe To New York's City Council Won't Stop Polystyrene In The Environment - 5 Gyres, accessed 7/1/2014, http://5gyres.org/posts/2013/11/25/why_dart_corps_bribe_to_new_yorks_city_council_wont_stop_polystyrene_in_the_environment/

[567] MB Public Affairs, Inc., Fiscal & Economic Impacts of a Ban on Plastic Foam Foodservice and Drink Containers in New York City, accessed 7/1/2013, http://www.putalidonitnyc.com/sites/default/files/NYC%20Foodservice%20Impact%20Study%20March%202013.pdf

[568] 10 ways to make your New Year's resolution a life with less plastic | Leila Monroe, Darby Hoover, Haley Bowling | Comment is free | theguardian.com, accessed 7/1/2014, http://www.theguardian.com/commentisfree/2014/jan/04/10-ways-new-years-resolution-life-with-less-plastic

[569] CoffeeTalk | A Coffee Shop Ratio that Boosts Profits by 50%, accessed 13/1/2014, http://magazine.coffeetalk.com/may13-boost-profits/

[570] Sam Judd: Never underestimate the little people - Opinion - NZ Herald News, accessed 13/1/2014, http://www.nzherald.co.nz/opinion/news/article.cfm?c_id=466&objectid=10843416

Drinking straws, plastic stirrers and lollipop sticks are prevalent in beach surveys of marine debris although viable alternatives exist in all cases. Public-awareness raising campaigns can gather popular support for plastics to be replaced by other materials and put pressure on the manufacturers to do so. However stronger measures such as bans or levies may produce a greater and more immediate change.

5.5.6 Cotton Bud Sticks

The shape and size of cotton bud sticks mean that they are able to pass through sewage filtration systems after being flushed down the toilet, leading to large numbers entering the marine environment. Cotton buds with paper or wooden sticks are available although less common than plastic ones. Wooden sticks have been reported as being better quality and better suited to certain applications such as medical use and gun cleaning.[571] An awareness raising campaign was conducted in the UK over seven years to prevent cotton buds and other sanitary items being flushed down the toilet. The campaign received support from leading retailers and key manufacturers and saw a drop in the number of cotton bud sticks found on UK beaches.[572]

5.5.7 Six Pack Rings

In the USA, EPA regulation has required that all six pack ring carriers be made of photodegradable material since 1994 and the leading manufacturer has used photodegradable plastic since 1988.[573] However, while this may ultimately reduce the chances of entanglement, photodegradablity does nothing to prevent pollution of the marine environment and is likely to increase the chances of ingestion by animals as the plastic breaks down into smaller pieces. Six pack rings are still a common item listed in ICC data and therefore warrant attention as marine debris.[574] Promoting the use of cardboard or other compostable materials will prevent both entanglement and long-term pollution from this item as marine debris. Economic or legislative measures could be used to initiate the change of materials used in the manufacturing of six pack rings. In the USA such measures would benefit from an accompanying public awareness campaign to counter claims that the environmental impact of the product is negated by is photodegradability.

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[571] For Those Who Use Q-Tips for Gun Cleaning....Found Some Old Style Wooden Shaft Q-Tips For Sale - AR15.Com Archive, accessed 13/1/2014, http://www.ar15.com/archive/topic.html?b=6&f=2&t=297941

[572] Bag It and Bin It - Don't Flush it. (UK) – MARLISCO, accessed 13/1/2014, http://www.marlisco.eu/bag-it-and-bin-it-dont-flush-it-uk.en.html

[573] Environmental Protection Agency (1994), *40 CFR Part 238 Degradable Plastic Ring Carriers; Rule*

[574] Ocean Conservancy (2011), *Marine Debris Report*, http://act.oceanconservancy.org/pdf/Marine_Debris_2011_Report_OC.pdf

5.5.8 Balloons

Balloon releases are popular for launching new initiatives and as a fund raising spectacle. Large numbers of helium filled balloons are released into the environment with no attempt to recover the balloons. The resulting balloon litter can easily enter the marine environment and is found to be a particular problem for ingestion by turtles (see Section 3.1.2). Various organisations are campaigning to stop balloon releases (for example The Marine Conservation Society's Don't Let Go Campaign, see Report III) and suggest alternative activities. As the debris is created at a high profile event that is usually designed to produce support and goodwill, public awareness-raising is likely to be relatively effective in stopping balloon releases although legislative measures would ensure more widespread change.

5.5.9 Monofilament Line

Boat U.S. Foundation has a campaign to recycle monofilament fishing line called "Reel In and Recycle!" This program created a network of monofilament recycling collectors so that proper disposal of monofilament is more accessible. They have many local sponsors in states of the US such as Texas, Michigan, and New Jersey who distribute recycling bins and educational materials to marinas, camps and boating access sites. The line is collected and sent to the Berkley Conservation Institute, a branch of the monofilament fishing line manufacturer Berkeley, and is incorporated along with other post-consumer materials into items such as artificial fish habitat. They have recycled 9 million miles of line since 1990. [575] Florida has its own "Monofilament Recovery and Recycling Program" that functions in a similar way.[576]

A similar UK based campaign is the "Hold on to your Tackle" campaign from the Marine Conservation Society, which encourages local sponsors to buy, and install angling litter bins.[577]

5.6 Addressing Knowledge Gaps

Stakeholders relevant to filling and addressing knowledge gaps in the prevention of marine debris are as follows. Ideally, the stakeholders would be specific to reducing impacts on migratory species. Finding stakeholders that are specific to the reduction of impacts on migratory species is not easy, as this last criterion does not necessarily limit the group of stakeholders a great deal, given the wide-reaching impacts of all types of marine debris.

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[575] http://www.miseagrant.umich.edu/explore/fisheries/monofilament-recycling-program/, http://mrrp.tamu.edu/, http://wetlandsinstitute.org/conservation/monofilament-recycling-station-program/

[576] http://mrrp.myfwc.com/

[577] http://www.mcsuk.org/what_we_do/Clean+seas+and+beaches/Campaigns+and+policy/Hang+on+to+your+tackle

The key knowledge gaps around some of the interventions for the prevention of marine debris, as relevant to migratory species regard:

- Cost effectiveness;
- Effectiveness in terms of flow of marine debris; and
- Effectiveness in terms of impacts on marine species, specific to migratory species if possible.

This information would determine whether particular strategies were of more relevance to migratory species than others.

Some of these gaps are concerning general monitoring information gaps, (for which refer to section 4.2); namely regarding the flow of marine debris, and impacts on marine or migratory species. This will involve a wide range of stakeholders involved in research, whether private or public, government, NGO or consultancy based.

Indications of how relevant a strategy might be to marine species can be given by looking at the types of debris that cause most impacts on marine (migratory) species, and prioritizing strategies that specifically deal with those, for example, soft plastic film and turtles – i.e. bag bans. However given that miscellaneous plastic fragments/ingestion are some of the most common ingested items for other species, this does not enable segmentation of strategies by relevance for migratory species – they all become relevant, and a holistic approach must be taken.

Stakeholders for filling these information gaps, aside from those already considered in previous sections, will be manufacturers and processors of items, who can provide information about the costs of implementing different measures; and national governments, who will have further information about the implementation of relevant legislation.

6.0 Recommendations for CMS

In this section, the general legislative, jurisdictional and financial challenges involved in managing marine debris impacts on migratory species are considered. The potential role of the Convention in addressing these obstacles is then assessed and actions are proposed. The challenges stem primarily from the transboundary nature of both the pollution and its receptors (i.e. migratory species), as well as their enormous geographical range, which in the case of marine debris, is limitless.

In the previous sections, what is known about the types, sources, pathways and prevalences of marine debris was reviewed and the limitations of the current state of knowledge were outlined. What is known about the impacts of marine debris on migratory species, or marine species more generally where information on the former is lacking, was also presented, and gaps in the current state of knowledge were also highlighted. Management strategies, including monitoring, remediation and prevention, were also reviewed and what is known about the effectiveness of these strategies, or lack of information in this regard, was examined. In the subsequent section, steps that would be needed to fill identified knowledge gaps are described. We also consider what opportunities the Convention on Migratory Species may specifically assist in.

6.1 Jurisdictional Challenges

Both marine debris and the migratory species it affects cross jurisdictional boundaries, whether between states or out of any general jurisdictional reach such as in the 'high seas'.

For migratory species, which rely on habitats in many different range states, weak 'links' along their migratory routes cannot be afforded. As a general principle, populations of migratory species should be managed as single units, irrespective of jurisdictional boundaries.[578] This is precisely the goal of multilateral international Conventions such as that on migratory species, in establishing the cooperation of range states.

Correspondingly, marine debris, regardless of its source can and will produce impacts in other jurisdictions. Marine debris travels and accumulates far from its origin; states will bear the impacts of debris which does not originate from them. There are many substantiated example of this. For example, a turtle entanglement study based in the Maldives, where fishermen do not use nets, found that nets recovered from the region are likely to arrive from India and Sri Lanka, based on distinguishing features of the items such as types of floats, labels on nets or labels on debris trapped in the nets.[579] On the northern Australian coast, it was possible to identify the country of manufacture or flag state of the vessels for ~55% of nets recovered, 96% of which were not of Australian origin and which included gear originating from fisheries in Taiwan, Indonesia, Korea, Japan, and Thailand as well as from Australia.[580] Co-operation on a regional basis would be appropriate to address jurisdictional challenges on this geographical scale, such as within the framework provided by RSCAPs.

However, the distance that debris travels can be far beyond the areas currently defined for regional agreements on marine matters. For example, a recent model of litter accumulation suggests that South America is the largest contributor of items (59-80% depending on the scenario) to the South Atlantic Gyre. However, the debris accumulates closer to the west coast of Africa, (estimated to contribute 17-40% of the debris). Likewise, China is modelled as being responsible for 58-66% of the debris in the North Pacific gyre, while the highest concentrations of debris in this gyre are in fact near the Central and North American coast. A similar story is told in the South Pacific Gyre, where between 53-58% of debris is predicted to come from Australia/New Zealand and South East Asia/Indonesia, while the greatest accumulation of debris is found off the west coast of South America.

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[578] de Klemm, C. (1994) The problem of migratory species in international law, *Green Globe Year Book International Cooperation on Environment and Development. Oxford. Oxford University Press. UK*, pp.67–77

[579] Carrington, D. (2013) 'CSI turtle' launches investigation into ghost fishing nets found in the Maldives, *Guardian*

[580] Gunn, R., Hardesty, B.D., and Butler, J. (2010) Tackling 'ghost nets': Local solutions to a global issue in northern Australia, *Ecological Management & Restoration*, Vol.11, No.2, pp.88–98

These last examples show that marine debris has to be tackled at a global level and a very high level of co-operation is needed to tackle this issue. It is obvious that a large number of countries are responsible for the litter in any of the world's major accumulation zones. Additionally, where marine debris has its impacts on migratory species can be outside the geographical range of any legally binding commitment on marine pollution or biodiversity involving the states that produced the debris. This is one of many reasons why it is best to tackle marine debris at source.

Therefore to solve the jurisdictional issues, agreements need to be global and action concerted, with no major gaps in the geographical coverage of the legislation. A broad overview of the geographic ranges of the most relevant agreements produced the following observations regarding jurisdictional limitations. The limitations in coverage of MARPOL Annex V or the London Convention (agreements regarding the dumping of waste by marine vessels), which have not yet been ratified by a significant number of countries, are covered in Report II.

One limitation of the Regional Seas Program relates to the release of land-based debris into the ocean. In this case, RSCAPs are unable to address marine debris or other pollution that comes from landlocked states in the form of estuarine litter, at least at source, as bar few exceptions, landlocked states are not members of a Regional Sea area. Therefore other agreements must be used to encourage these countries to commit to addressing the marine debris issue.

Most coastal states are signed up to one Regional Seas area or another, with the only major country not signed up to at least one, being Burma (with significant population, >50m, and with significant coastline). There are however other significant gaps. For example, the coastal zone of southern Brazil is an important habitat for resident and migratory animals.[581] It is noted that there is no Regional Sea area for this area and so no RSCAP covering it (see Figure 5).[582] Likewise the North-West Atlantic and the North-East Pacific at the higher latitudes, around North America, are not covered by specific agreements. The US is involved in other neighbouring Regional Seas agreements such as the Wider Caribbean, but it is not clear that its commitments under them are extended to all bodies of water on the US coastline. The same is true of Canada, which though involved in agreements covering areas at the poles, as there is no regional agreement relevant to most of its coastline, has no formal mechanism for co-operation with other countries in the region regarding these bodies of water.

Again, other agreements can be used to some extent to encourage some of the relevant countries to commit to addressing the marine debris issue – for example, Brazil, Uruguay and Argentina, the countries with the largest expanse of coastline on the Southwest Atlantic, have signed up to MARPOL Annex V. However, this does not address land-based sources of debris. Brazil does have a National Program of Action for the implementation of the GPA Marine (UNEP's Global Programme of Action for the

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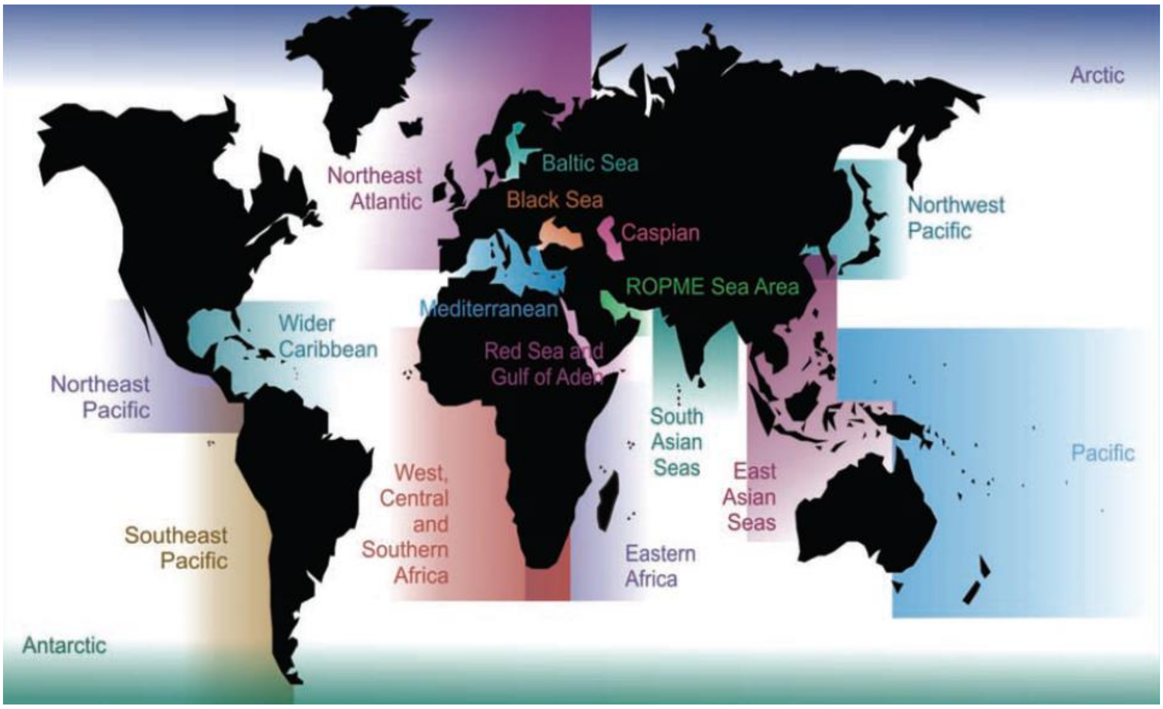
[581] Tourinho, P.S., Ivar do Sul, J.A., and Fillmann, G. (2010) Is marine debris ingestion still a problem for the coastal marine biota of southern Brazil?, *Marine Pollution Bulletin*, Vol.60, No.3, pp.396–401

[582] http://www.unep.org/regionalseas/default.asp

Protection of the Marine Environment from Land-based Activities) which potentially covers that – but this is not legally binding.

Within the Regional Seas programs, only 14 out of the 18 have set up legally binding Conventions detailing how the Regional Action Plans will be implemented. This represents further jurisdictional limitations, with the Arctic, East Asian seas, North-West Pacific and South Asian seas regions having no legally binding mechanism for co-operating on issues regarding the protection of the marine environment.

Figure 5: The Regional Seas Areas. Source: UNEP 2009



The number of Parties to the Convention on Migratory Species has increased significantly since its initial signing in 1979, to the present total of 119 countries.[583] There are major countries which are not Parties to the Convention such as the United States, Canada, and some Latin American countries such as Mexico and Brazil. These countries are of relevance to many migratory American waders, for example. There is an independently negotiated Memorandum of Understanding between Canada, Mexico and the US but it is restricted to ducks, geese and swans. There are many more migratory waterbirds that migrate farther South and so are not covered by any agreement. Similarly, in the Far East, Russia and China are not Parties, together with many other countries in the region. 35 countries which are not Parties to the Convention have still signed Agreements or MOUs under the Convention. However the number of species covered in this way is rather limited, albeit these agreements, for

[583] http://www.cms.int/about/part_lst.htm

nations with coastline, do include species that spend time on the coast or are fully marine, reducing the number of countries that have made no commitment of any kind regarding any migratory marine species and its habitat at all. However it may be unrealistic to expect to be able to leverage the one agreement that a country has signed up to on marine/coastal species (e.g. Russia or China and the Siberian Crane MOU) to encourage it to act on marine litter. Only around 60% of countries with coastline are Parties to the Convention, Family Agreements or MOUs with relevance to a marine species. This means that even if the Convention or Agreements were considered to constitute specific obligations regarding marine debris, alone, they probably would not have adequate coverage to deal effectively with marine debris at present.

The high seas are the areas outside countries' Exclusive Economic Zones (extending not more than 200 nautical miles from the the baselines from which the breadth of the territorial sea is measured)[584] and constitute around two-thirds of the area of the ocean. However, even if all existing relevant maritime agreements were enforced, there would still be no formal recognition of the need to protect biodiversity in the high seas, legal instruments to do so, or way of enforcing them. [585] The taking of catadromous and anadromous species is prohibited on the high seas by UNCLOS (Articles 66 and 67), but these are the only species this applies to and there is little scope for enforcement. Ships on the high seas are generally in the jurisdiction of the ship's flag country, with few exceptions, one being that if a boat is involved in piracy on high seas, any country can claim jurisdiction over it (UNCLOS Art 105).[586] This is not the case for almost any other type of crime, yet if it were, it would increase possibilities for enforcement, for example of the UNCLOS provision described above or waste crime such as that outlawed by MARPOL Annex V or the London Convention. In terms of pollution in the high seas, there is no mechanism for making any state assume responsibility for mitigation efforts. There is no recourse regarding pollution on the high seas when there is no direct impact on the interests of a particular state. The UN General Assembly has an ad-hoc informal working group studying issues relating to the conservation of marine species in the high seas and has committed itself to address this by making a formal decision on developing an international instrument under UNCLOS.[587] However whether this would be capable of addressing the pollution impacting said species, rather than only the taking of individuals, for example, remains to be seen. If it is to provide the required mechanism to make nations responsible for the impacts of their marine debris, it will have to make provision for this.

[584] http://www.un.org/depts/los/convention_agreements/texts/unclos/part5.htm

[585] http://www.globaloceancommission.org/the-global-ocean/the-global-governance-gap/

[586] UN (2013) *United Nations Convention on the Law of the Sea: Chronological lists of ratifications of, accessions and successions to the Convention and the related Agreements as at 29 October 2013*, accessed 23 October 2013, http://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf

[587] Para 162 UNGA (2012) The Future We Want, A/66/L. 56

There is, however, one way in which legislation can drive reductions in marine debris even if legislation is not universally consistent. If enforcement and legislation is strong in one region, it can drive best practice for marine vessels, as ships cross the jurisdictional boundaries and will need to comply with the most stringent legislation they are likely to encounter. However this principle does/would not apply to agreements concerning land-based sources of waste, existing pollution in the ocean, or marine species.

6.2 Legislative Challenges

The discussion on jurisdictional challenges introduced the main legally binding instruments applicable to marine litter and/or migratory species at global and regional levels. There is plenty of scope under these existing multilateral agreements for dealing with marine debris. It is a major gap in the legislation that there is no specific, legally binding global agreement for the tackling of marine debris sourced from land-based activities. Therefore it is significant that the Regional Seas Conventions and Action Plans (RSCAPs) have the potential to address both land and at-sea sources of debris. The London Convention and MARPOL Annex V are the global conventions with most specific relevance to debris produced at sea. There may also be opportunities within the Convention on Migratory Species to encourage more specific action on marine debris, whether from land or at sea activities.

At present, these agreements tend to suffer from one or both of the following limitations regarding marine debris:

- Either they have little specific content regarding marine debris; and/or
- There is no mechanism for enforcing them.

There are also very few specific legal instruments dealing with marine litter at the national level.[588] This exacerbates issues with enforcement.

The Regional Seas programme generally involves the establishment of a National Action Plan, then the ratification of a legally binding Convention. These tend to include general statements regarding the protection of the marine environment from pollution. The Convention acts as a framework through which further legally binding Protocols with more specific provisions for different issues can then be made. Some of the Regional Seas have such Protocols that are relevant to at least some fractions of the marine debris problem. For example, seven Regional Seas areas have established Protocols on Pollution from Land-based Sources and Activities. Some of them are not fully ratified by all countries in the Regional Seas areas and not in force. Two have protocols on dumping, though one is specifically from ships and aircraft (Mediterranean). Two of the Regional Seas areas have (non-legally binding) Action Plans to address pollution from land-based activities.

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[588] UNEP (2009) *Marine Litter - A Global Challenge*, April 2009, http://www.unep.org/pdf/unep_marine_litter-a_global_challenge.pdf

As part of UNEP's GPA Marine (the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities), at least 72 nations have created National Programs of Action (considered the 'backbone' of GPA-Marine implementation),[589] but these are of course, not legally binding. The North-West Pacific Regional Sea area, to our knowledge, is alone in having a specific "Regional Action Plan on Marine Litter", which should in theory cover all sources of debris. The North-East Atlantic region will develop one in 2014. [590] This region has also made a recommendation on the development of fishing for litter initiatives as a way of raising awareness and changing behaviour regarding waste in the fishing industry, and directly removing waste.[591]

So there are a few specific pieces of legislation and agreements on marine debris, but taking these things all together, it is obvious that there is a considerable way to go in fully elaborating the available legislation to give good, legally binding global coverage on the marine debris issue.

There is some scope within the Regional Seas Program for agreements based on the conservation of species. For example, The Mediterranean has a "Strategic Action Programme for the Conservation of Biological Diversity", adopted in 2003. OSPAR has made several (non-legally binding) "Recommendations" for conservation of particular species, however the recommendations have been completed for only 27 out of 57 species that are considered in need of protection. Additionally there is little explicit mention of marine debris in the supporting documentation for the recommendations, with the exception of those for leatherback and loggerhead turtles.[592]

In the Convention on Migratory Species, there is the general statement that all Parties:

> *"shall endeavour to provide immediate protection for migratory species included in Appendix I" (Article II Para 3b)*

This may be considered too general to include all sources of pollution that adversely affect migratory species, especially given how difficult it is to demonstrate population level effects of marine debris. More specific obligations are made in Article III where it states that relevant Parties must endeavour:

> *"a) to conserve and, where feasible and appropriate, restore those habitats of the species which are of importance in removing the species from danger of extinction;*

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[589] UNEP (2012) Progress in Implementing the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities at the National Level, UNEP/GPA/IGR.3/INF/3/Rev.1 (2012)

[590] http://www.ospar.org/content/news_detail.asp?menu=00600725000000_000021_000000

[591] OSPAR (2010) *Quality Status Report 2010*, 2010, http://qsr2010.ospar.org/en/media/chapter_pdf/QSR_complete_EN.pdf

[592] http://www.ospar.org/content/news_detail.asp?menu=00600725000000_000022_000000

b) to prevent, remove, compensate for or minimize, as appropriate, the adverse effects of activities or obstacles that seriously impede or prevent the migration of the species;"

These obligations are limited to range states, but it is likely that, as most Parties to the Convention are coastal states, they are all range states for one marine migratory species or another, and so addressing marine debris may well be within the remit of this provision for most of the Parties. The legally binding Agreements that the Convention recommends be made for species in Appendix II suggest similar obligations and furthermore provision for

"prevention, reduction or control of the release into the habitat of the migratory species of substances harmful to that migratory species"

An analysis of the relevant marine Agreements was carried outto ascertain if they do in fact have this provision.

ACAP contains several general references to the obligation (within a certain frame of reference) to conserve marine habitats. It is only in the annexed Action Plan, which the Parties are bound to 'implement progressively' that makes reference to pollution:

"Annex 2, 2.3.1 The Parties shall endeavour individually and collectively to manage marine habitats so as to:

...b) avoid pollution that may harm albatrosses and petrels."

ACCOBAMS, similarly makes a general commitment to "protect habitats"; and again it is in the Conservation Plan, which Parties undertake to implement in so far as is feasible, that explicit mention is made of pollutants:

"Annex 2, 1d) [Parties shall] "Regulate the discharge at sea of, and adopt within the framework of other appropriate legal instruments stricter standards for, pollutants believed to have adverse effects on cetaceans"

The relevant provision made by the ASCOBANS Agreement is found in the annexed Conservation and Management Plan, which states that Parties should:

"Work towards (a) the prevention of the release of substances which are a potential threat to the health of the animals,"

The Wadden Sea Seals Agreement requires that the Parties

"Art VII,2. The Parties shall preserve habitats and seals present from undue disturbances or changes resulting, directly or indirectly, from human activities";

and makes specific reference to pollution in Article VIII

"The Wadden Sea States are determined to do their utmost to further reduce pollution of the North Sea from whatever source with the aim of conserving and protecting the Agreement Area. To this end they shall a) endeavour to identify the sources of such pollution;"

AEWA's Action Plan contains explicit mention of pollution in section 3.3:

"Parties shall endeavour to rehabilitate or restore, where feasible and approp riate… areas that suffer degradation as a result of the impacts of factors such as climate change, hydrological change, agriculture, spread of aquatic invasive non - native species, natural succession, uncontrolled fires, unsustainable use, eutrophication and pollution .

Unusually, specific mention of solid wastes is made:

"4.3.9 Parties shall establish and effectively enforce adequate statutory pollution controls in accordance with international norms and legal agreements, particularly as related to oil spills, discharge and dumping of solid wastes, for the purpose of minimizing their impacts on the populations listed in Table 1 "

It is important to establish that the above provisions, individually or together, are considered to constitute an obligation to act upon marine debris. This would strengthen the case for action on marine debris and migratory species for many nations.

Significantly for the filling of information gaps, all of these agreements also have some kind of wording to the effect that Parties should undertake research and monitoring on populations, and/or identify threats to the relevant species, sometimes specifically stating as regards current or potential threats of pollution.

MARPOL Annex V and the London Convention, which deal with at-sea sources of debris, are very explicit with regard to their limitations or prohibition of the disposal of waste at sea. However, they do not cover all sizes of vessels, are not ratified by as many countries as would be desired and their enforcement is lacking. Perhaps it is also considered that their focus is more on intentional discarding of waste and not unintentional discarding of waste, which may play a part in the generation of a significant proportion of marine debris. The limitations of these agreements are dealt with in detail in Report II.

6.3 Financial Challenges

Globally, inadequate funding is a problem for even basic waste management infrastructure - hence the particular importance of economic incentives when considering the management of marine debris. However these will not be able to contribute towards funding monitoring and the filling of information gaps. Neither will they help fund the negotiation and administration of international agreements, field projects, or the implementation of legislation and enforcement.

Regarding international agreements, part of the cost is incurred simply by administration such as the creation of a secretariat or regular meetings. The remainder of costs are incurred by field projects. In the case of CMS, mandatory contributions are collected from Parties to the Convention and Signatories of Agreements. This 'core funding' provides for most administrative costs. For some CMS agreements, the CMS Secretariat also functions as the Secretariat of the agreement (e.g. ASCOBANS). Sometimes finance and personnel are donated in part or in full by a Party state. So for example, range states host the secretariat of some agreements (e.g. Wadden Sea Agreement (Germany). NGOs also sometimes donate staff time. In a few cases, voluntary contributions by Parties may also contribute to staffing costs (e.g. AEWA). In 2009, mandatory contributions for the Convention were around $1.9m and for the Agreements, $1.5m. At present, there is a feeling that current funding allows for the maintenance of the status quo, but not for establishing and administering new Agreements. [593] Important information databases have not been able to be maintained by CMS because of lack of funding, such as GROMS, the database on migratory species, and the System of Online National Reporting (SONAR), a system of online reporting for range states on migratory species has incurred many delays owing to funding difficulties. Several Agreements have not achieved everything in their work plan due to a lack of funding. Voluntary funding is by nature uncertain. This may be a constraint on the establishment of dedicated strands within Family Agreements or Action Plans on marine debris, or further development of specific CMS Initiatives concerned with marine debris (for example the appointment of designated personnel and establishment of a working group) .

Voluntary contributions are generally for specific conservation projects that are part of CMS's work programme, for organizing meetings and new agreement development and for publishing. Voluntary contributions come from money or donations in kind pledged by states, institutions (including UNEP and NGOs) or the private sector. In 2009 voluntary contributions were around $0.2m and $0.3m respectively. Voluntary contributors have shown a preference towards supporting specific time limited projects or meetings rather than longer term activities or those of an operational nature, therefore there are difficulties in planning for the future.

A similar story unfolds for a relevant environmental agreement, the Convention on Biological Diversity (CBD). Within the Convention, Articles 20 and 21 make provision for a funding mechanism for the implementation of the Convention by developing country Parties, whereby Parties make predictable, adequate and timely contributions in accordance with the amount of resources needed, to be decided periodically by the Conference of the Parties.[594] These consist of both mandatory and voluntary contributions.[595] Contributions presently amount to tens of millions of dollars per year, as a rule. Globally, national budgetary support to biodiversity and ecosystem services is estimated to be between $15 -$45 billion per year. A sum of $60-$150 billion per year that has been estimated necessary for the implementation of national biodiversity strategies and action plans.[596]

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593 Lee, R., Filgueira, B., Caddell, R., and Frater, L. (2010) *Review of the current organization and activities of CMS and the CMS family. First step of the Inter-Sessional Future Shape Process*, 2010, http://www.cms.int/bodies/future_shape/future_shape_review.pdf

594 United Nations (1992) *Convention on Biological Diversity*

595 http://www.cbd.int/convention/parties/contributions.shtml#tab=0

596 CBD (2012) State of Financing For Biodiversity: Draft Global Monitoring Report 2012 on the Strategy for Resource Mobilization under the Convention. UNEP/CBD/COP/11/INF/16

For taking action on marine debris, which will take sustained concerted effort, the contributions possible via these international agreements are at most likely to be strategic. Accessing sustained funding is one of the greatest conservation challenges, and the same is true where this involves addressing marine debris.

Regarding the funding of addressing marine litter on a wider scale, here we examine briefly the funding of the implementation of UNEP's GPA for the Protection of the Marine Environment from Land-based Activities. At the first intergovernmental review of the GPA-Marine, the Montreal Declaration on the Protection of the Marine Environment from Land-based Activities, was adopted; aside from the general pledge to further the aims of the GPA-Marine, it also promised to "identify new and additional financial resources to accelerate GPA implementation by building capacity for effective partnerships among governments, industry, civil society, international organizations and financial institutions, and by making better use of domestic and international resources." Domestic financing is intended to be the main source of financing for the GPA[597] and a variety of sources of funding have been suggested, from water service pricing and tax and subsidy reform, water funds, water markets, pollution trading and pollution permits; national development program budgets and major financial institution's work programs' budgets; debt relief, ODA, the removal of environmentally destructive subsidies including agricultural subsidies; instruments using the polluter pays principle; tourism tax; and it was pointed out that engagement with stakeholders was essential for mobilizing resources. UNEP has recommended that regional programmes for marine litter should be incorporated into national budgets to support implementation and participation.[598] Some countries in the Americas receive Inter-American Development Bank support for their integrated coastal zone management programmes.[599] Subsequent meetings appear to have resulted in little more than urging for the provision of adequate voluntary financial resources and encouragement to employ market-based instruments to support solid waste minimization and management.

It is recognized that enforcement is an important part of the implementation of legislation regarding marine litter – for example, "building capacity to monitor and enforce compliance regarding litter, dumping, solid waste management, storm water and surface runoff", is a strategy included in GPA Marine's Programme of Work for 2012-2016. Part of the enforcement challenge is practical – monitoring individual vessels on the high seas or much of the EEZs to see whether they are producing marine debris – would require an unreasonable investment of resource. However, there are examples where enforcement is feasible with adequate funding, such as, inspection of ships and waste management plans, logs and facilities, or inspection of port reception facilities. These are not adequately funded. There needs to be enough

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597 http://www.iisd.ca/sd/gpa/sdvol65num5.html

598 UNEP (2009) *Marine Litter - A Global Challenge*, 2009

599 UNEP (2012) Progress in Implementing the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities at the National Level, UNEP/GPA/IGR.3/INF/3/Rev.1 (2012)

personnel, with adequate training. Additionally, political support for their enforcement efforts is necessary, and awareness-raising is important to bring this about (for which funding is also needed).

6.4 Recommendations

6.4.1 Opportunities for CMS Engagement

Opportunities for CMS to engage with these challenges have been identified below. Consideration of funding issues both within and outside CMS is subsequently discussed in Section 6.4.2.

The core role of CMS is to support international collaboration. This is ideal considering the multi-jurisdictional challenges of managing marine debris impacts on migratory species. More simply, marine debris is a shared problem requiring a shared response. The more countries CMS can include under its umbrella, the better its coordinating role can be.

Its main potential for influence is on Parties to the Convention or Signatories of Family Agreements and Memoranda of Understanding, (just under half of which are relevant to marine migratory species). The Convention itself has specific provisions for habitat conservation and reduction of impacts of activities that endanger species or impede migration. These commitments can be seen as highly relevant to the management of marine debris, and CMS can use its coordinating role to remind Parties of their commitments under the Convention.

As outlined above, one of the legislative challenges is that there may not be specific enough reference to marine debris within these agreements. Therefore making more specific reference to marine debris in existing agreements and Action Plans should be considered.

CMS Resolution 9.2 (2008) indicates that future agreements that should be developed with relevance to marine species (in a very broad sense) are Sturgeons, Marine Turtles – Pacific Islands, Cetaceans in the Indian Ocean and South-East Asia, Central Asian Flyway, the East-Asian Australasian Flyway, the Pacific Flyway, and the American Flyways. There is the potential to make specific reference to particular threats, such as marine debris in these agreements.

Some CMS Initiatives already exist that are themed by threat rather than species group (e.g. climate change, bycatch); pursuant to Resolutions passed upon the respective issues, a Councillor was appointed by the Conference of the Parties for each issue. The Appointed Councillor sits on the Scientific Council and there are associated thematic Working Groups for the themes. An similar initiative could be launched that is marine debris themed, with a nominated members and a dedicated workstream. This may have the advantage of not duplicating effort across all the Family Agreements; it is nevertheless desirable that the Family Agreements are aligned on this issue.

The CMS could use appropriate meetings or publications to encourage countries to ratify other relevant conventions such as MARPOL and the London Convention as a way of beginning to address their commitments on marine debris under the Convention on Migratory Species.

It could also encourage its Parties and Signatories to engage with other global marine debris initiatives, such as those being co-ordinated by UNEP, for the same reason – i.e. as a way of addressing their commitments on marine debris under the Convention on Migratory Species. These are many and include:

- GPA-Marine – including completion of GPA-Marine National Plans of Action, and to ensure these have specific mention of marine debris,
- Regional Seas Programme – including conclusion of specific Protocols on protection of the marine environment from land-based activities, and completion of Regional Action Plans either containing specific mention of marine debris, or completion of a specific Action Plan exclusively on marine debris,
- Participation in the Global Partnership on Marine Litter (GPML),
- Participation in the Global Partnership on Waste Management (GPWM)
- Adoption of the Honolulu Commitment and putting Honolulu Strategy into action

There are also specific actions which CMS could encourage its parties to undertake by way of meeting its obligations on marine debris under the Convention, such as:

- Implementing deposit-refund schemes;
- Implementing levies on single-use carrier bags; and
- Creating obligations for the use of reusable items at events.

- If examples of best practice in public awareness campaigns on marine debris can be successfully identified, CMS can encourage Parties to engage in marine debris campaigning. As there are few examples of campaigns specifically with relevance to migratory species CMS might co-ordinate or encourage the creation of some, and/or give its endorsement to appropriate campaigns. CMS might also consider giving endorsement to more general campaigns where it considers it appropriate (e.g. IOSEA could endorse plastic bag specific campaigns, given the evidence suggesting that soft plastic film particularly impacts turtles, for example), which would reinforce the link between marine debris and the vulnerabilities of migratory species in the minds of different stakeholders.

Co-operation with other Biodiversity related agreements. There are few groups of marine organisms that are not impacted negatively by marine debris. So as not to duplicate effort, perhaps an inter-Convention working group can agree an approach to encourage signatories to take action on marine debris. A Secretariat report highlighted how CMS might integrate some of its work with the Convention on Biological Diversity. It suggested that national CMS Focal Points establish contact with CBD Focal Points and work together to ensure migratory species and threats to them are taken into account in National Biodiversity Strategy and Action Plans (NBSAPs), which are the tool for action on biodiversity developed by CBD.[600]

Engagement with as wide a range of stakeholder groups as possible. For action on marine debris, co-operation between specific sectors, such as fishing, shipping, tourism, diving, local authorities etc. is very important. The private sector and civil society must also be involved. CMS is already involved with a number of NGOs and special interest groups. If it can continue to expand this network so that it includes as great a variety of stakeholders as possible, then it will have an ideal audience for its marine debris themed work. Perhaps small field projects could be dedicated to engaging with new stakeholders, with priority given to those that have most relevance or contact with migratory species. This will also have knock-on effect for financing, as it is held that stakeholder engagement is important for the mobilization of resources from those stakeholders.

Finally, the Convention can play a role in the following important tactic in the fight against marine debris. Stakeholders must be informed that marine debris is important and needs to be dealt with. The foundation for this is good information, but it can be argued that there is sufficient information available to make the case for action clear. Policy makers especially have to be made aware of the marine debris issue so that marine debris management is included in relevant legislation, that funding is provided for it and that there is a mandate for enforcement. All of the Convention's actions on marine debris will contribute to this awareness raising and it should take advantage of all the fora it participates in to draw attention to the issue.

6.4.2 Funding

As discussed in Section 6.3, funding for marine debris management can come from a variety of sources, from national budgets, to development banks, to economic instruments used to change behaviour, to any funds generated by the application of the 'polluter pays' principle. Innovative financial mechanisms are advocated in many quarters and this is an area of ongoing work.

It may be worth bearing in mind facts such as that clean-up campaigns are expensive relative to prevention in terms of the direct impact they can have on marine debris. They are excellent awareness raising initiatives and may reduce some of the impacts of coastal marine debris if sustained and frequent. However they may be easier to fund because they can be run as discreet, time-limited projects. Educational awareness campaigns generally have the same advantage.

Funded by voluntary contributions, CMS and some of its Family Agreements (e.g. AEWA) have a small grants program. In 2012, twelve projects were funded via CMS. For the 2013-2014 around €75,000 is available and each project may apply for up to €15,000. These are small amounts of money compared to the scale of the challenges

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[600] CMS (2011) Guidelines on the Integration of Migratory Species into National Biodiversity Strategies and Action Plans (NSBAPs). UNEP/CMS/Conf.10.27, http://www.cms.int/en/education/capacity-building/nbsaps

faced by migratory species due to marine debris, however, they may be helpful for small strategic projects.

It has been suggested that the Convention on Migratory Species and Range States could prepare projects to submit to utilize the funds held for the purposes of the CBD. [601] As outlined in 'financial challenges' this is unlikely to be a source of adequate sustained funding, but may be suitable for smaller field projects. There is currently a great deal of discussion and negotiation ongoing regarding how to mobilize resources for the achievement of the objectives of the CBD. Their 2012 report categorizes the following funding or resource opportunities:

- Official Development Assistance (ODA);
- Domestic budgets at all levels;
- Private sector;
- Non-governmental organizations, foundations, and academia;
- International financial institutions;
- United Nations organizations, funds and programmes;
- Non-ODA public funding;
- South-South cooperation initiatives;
- Technical cooperation

In 2006, CBD published a guide to funding sources.[602] In it there are really only two organizations that seem orientated towards marine issues, The Pew Charitable Trusts[603] and the Institute of Marine Research;[604] however there are plenty of organizations listed that deal with conservation across the globe.

Research projects, even where considered vital for the state of knowledge of a CMS Family Agreement, have been deemed "highly cost-prohibitive".[605] Many monitoring and research programs are carried out with the help of volunteers, whether monitoring of animals (e.g. the international network of partners producing the Global

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601 de Klemm, C. (1994) The problem of migratory species in international law, *Green Globe Year Book International Cooperation on Environment and Development. Oxford. Oxford University Press. UK*, pp.67–77

602 CBD (2006) *Catalogue of Funding Sources*, 2006, http://www.cbd.int/doc/guidelines/fin-sources.pdf

603 http://www.pewtrusts.org/our_work_category.aspx?id=126

604 http://www.imr.no

605 Lee, R., Filgueira, B., Caddell, R., and Frater, L. (2010) *Review of the current organization and activities of CMS and the CMS family. First step of the Inter-Sessional Future Shape Process*, 2010, http://www.cms.int/bodies/future_shape/future_shape_review.pdf

Wild Bird Index relies heavily on volunteers to produce the data),[606] or monitoring of marine debris (e.g. the Ocean Conservancy's International Coastal Cleanup is conducted entirely by volunteers). This has been effective, in the absence of funding from other sources. By associating marine debris monitoring with other oceanographic surveys, savings can be made. These can also be supported by the participation of volunteers (e.g. the Seas Education Association (SEA) used 7,000 volunteers (undergraduate students) in their monitoring program).[607]

There may be other sources of significant funding for research and field projects, such as the Global Environment Facility (GEF), which is the largest public funder of projects to improve the global environment. It funds large scale projects – over 20 years it has channelled $15 billion dollars of funding.[608] It also has a small grants programme that gives directly to civil society and community based organisations.[609] The issue of marine debris spans multiple focal areas of their funding programme such as Biodiversity, International Waters and Persistent Organic Pollutants. The Scientific and Technical Advisory Panel for GEF has recommended that it focus its support on pilot projects testing the life-cycle approach to plastic debris prevention, reduction and management in one of the Regional Seas areas; and by helping to establish private-public partnerships on reducing the environmental impacts of single-use plastics by transforming their use and utilization.[610]

The World Bank's 'Global Partnership for Oceans' hopes to raise $300m of 'catalytic finance' plus $1.2 billion of investment for the protection of the marine environment. When funds are available, they may be appropriate for funding research on or mitigation of marine debris.

There are also regional research funding programs that can be approached, such as the EU's FP7 (Framework Programme for Research 7). The latter, for example, funded the EU CleanSea multidisciplinary research project that is a collaboration of four universities, five research institutes, six small to medium enterprises and a network of coastal local authorities (KIMO). The purpose of the research project is to answer questions regarding the monitoring and management of marine debris. Not every world region has such funding programmes, but there are several examples such as the Australian National Competitive Grants Program, the US National Research Council, and the National Natural Science Fund of China.

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606 http://www.ebcc.info/index.php?ID=516#1.1%20Counting%20birds, http://www.bipindicators.net/WBI

607 Law, K.L., Morét-Ferguson, S., Maximenko, N.A., Proskurowski, G., Peacock, E.E., Hafner, J., and Reddy, C.M. (2010) Plastic Accumulation in the North Atlantic Subtropical Gyre, *Science*, Vol.329, No.5996, pp.1185–1188

608 http://www.thegef.org/gef/trust_funds

609 https://sgp.undp.org/

610 STAP/GEF (2011) Marine Debris as a Global Environmental Problem: Introducing a Solutions Based Framework Focused on Plastic

For species that are commercially exploited, such as migratory waterfowl that are hunted, there are examples of conservation efforts being funded by stakeholders involved in commercial exploitation – for example a large pro-hunting NGO, Ducks Unlimited, collects contributions from its members and acquires and manages wetland habitat in Canada, Mexico and the United States. This can be contrasted however with the management of fishing stock, where stakeholders have been slow to take up any responsibility for safeguarding the habitats of relevant species, such as inshore spawning or nursery areas, and fishing treaties do not provide for protection of habitats; therefore it is not a foregone conclusion that this strategy can be successful. Anglers and amateur fishermen comprise an economic sector that is the same size as the commercial fishing sector in the UK, and this provides an example of a large stakeholder group regarding the issue of marine debris that has not been managed successfully, yet could be in the future.[611] There is traditionally a division between agreements on commercial and non-commercially exploited species; hence there are almost no commercially exploited species within the remit of the Convention on Migratory Species. [612] However, when it comes to marine debris, private sector groups or stakeholders in the marine environment generally can still appreciate that it is in their interest to co-operate on this issues. Stakeholder groups of this kind can be a significant source of funding.

6.5 Filling in Knowledge Gaps

In this section, steps needed to fill in knowledge gaps are considered. However, it is also important to bear in mind that there will be a limit to how much information can be feasibly obtained given the resources that would be required. The case is made that this need not be a barrier to action.

6.5.1 Information on Marine Debris Sources, Pathways and Types

The considerable and very general gaps regarding the abundance, composition and distribution of debris will require a coordinated effort that is rather beyond the scope of the immediate interests of the Convention on Migratory Species. If better information about the amount and distribution of marine debris is required, this will require investment in monitoring programs globally. Methodologies should be standardized, so that better regional distinctions can be made, which may have relevance for the targeting of actions regarding migratory species. An important step forward has been the publishing of guidelines on Survey and Monitoring of Marine Litter published by UNEP/IOC, which can serve as a template for the standardization

[611] Monbiot (2014) Anglers are Our Allies Against Unsustainable Industrial Fishing, *The Guardian24/01/2014* *http://www.theguardian.com/environment/georgemonbiot/2014/jan/24/anglers-sport-fishers-fishing-george-monbiot*

[612] de Klemm, C. (1994) The problem of migratory species in international law, *Green Globe Year Book International Cooperation on Environment and Development. Oxford. Oxford University Press. UK*, pp.67–77

of monitoring worldwide.[613] This covers both sampling method and the categorization of items by object and by material. It also allows for subdivision of recommended litter codes with further finer distinction if required, and also has 'other' categories. This means the methodology has some flexibility, which allows for more specific information to be obtained if deemed relevant, and avoids bias against non-listed types. It is recommended that both counts and weights (where possible) be recorded; which gives most flexibility for trying to assess absolute quantities and making regional comparisons. It also covers different marine compartments, such as beach litter monitoring, benthic monitoring and surface litter monitoring.

In terms of providing information regarding sources, the guidelines suggest that this is a key question for the surveys to answer; and should be done by relating item types to sources where possible ("indicator items"). However, it does not go into very much detail as to how to define these relationships. The guidelines suggest that a relational database could provide lookup tables to re-aggregate litter types to support different analyses, such as the analysis of debris type by source.

Additionally, the guidelines recommend the compilation of a site characterization data sheet which contains information on proximity to likely litter sources, such as the direction and distance of the nearest town, nearest river, whether there is input from pipes or drains, whether the area can be classified as urban or rural etc. This would help to inform the relationship defined for particular item types, by looking at the relationship between proximity to these sources and litter composition.

It is important to note that the methodology in these guidelines does not consider microplastics, as it was considered that its monitoring is technically demanding and requires specialist equipment and training. However it is important that the knowledge gaps in this regard are filled. There is a working group that has been convened for the purpose of studying microplastics (GESAMP Working Group 40). A consensus definition of microplastics should also be reached.

It will be very difficult to fill knowledge gaps related to pathway or vector, although an approach based on a relational database was covered in Section 2.1.2, so it is possible to carry out some analysis of the issue in this way. Other approaches would have to be individually tailored to the local area and carried out on point sources of concern, such as different parts of the waterways with (e.g., estuarine monitoring). Currently this is not a feature of the UNEP/IOC guidelines, but the development of other litter monitoring indicators is possible and should be undertaken. Estuarine systems are important habitats for many migratory species, and better data in this regard could be useful for prioritizing management approaches.

UNEP (2009) suggested that databases be established at the national level and a clearinghouse for information at the regional and global levels.[614] It also pointed out the need for regular publishing of this data on the status and trends of marine debris. It will be helpful for CMS to have access to good data on marine debris if it is to make

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[613] UNEP (2009) *UNEP/IOC Guidelines on Survey and Monitoring of Marine Litter*, 2009

[614] UNEP (2009) *Marine Litter - A Global Challenge*, 2009

decisions about its strategy for mitigating its effects on migratory species and these steps would make this possible. Perhaps the Global Partnership on Marine Litter's online platform could be a home for this sort of database.

6.5.2 Information on Impacts

In the UNEP/IOC guidelines for monitoring marine debris, one of the objectives of monitoring is stated as answering the question "Is there a threat to marine biota and ecosystems?" There are two different ways in which this can be done. Firstly, it recommends that all methodologies should record entanglements and include them in the additional notes section, and additional guidance should outline reporting requirements with respect to animal type, tangle type and status (alive or dead). Secondly, it suggests that indicator items that are considered to present specific risks to wildlife such as looped materials, discarded fishing nets or plastic bags, be defined. The data could then be aggregated, using a relational database, to allow monitoring and analysis based on, for example, risks to wildlife of different kinds such as entanglement or ingestion. It is also significant that the recommendations suggest that both debris counts and weights be recorded, which is important with regard to any subsequent mapping onto potential impacts, because sometimes impact will be more related to count (e.g. plastic bags) than weight and vice versa (e.g. fishing nets).

Not all impact monitoring can be carried out, however, by debris surveys. Co-operation should be encouraged between natural resource agencies, academics conducting field research and conservation groups, to help obtain data and collate existing and future information on wildlife entanglements etc. and habitat impacts from marine debris. Standardization of methods, centralised databases and curation, would all be important steps to undertake to ensure that data is comparable between regions, and provide the right presentation of information to give a chance of filling information gaps such as population level effects. Methods for estimating total mortality based on sampling of stranded individuals or sampling that does allow total mortality to be modelled should be pursued. Standardization of the recording of the material and item type causing the impact is important if it is to be compared with data regarding ambient debris, and targeted approaches attempted. It is important that the whole variety of impacts be considered, whether entanglement, ingestion, toxicological or habitat related.

There are many unanswered questions regarding the specific vulnerability of migratory species, such as, vulnerability according to life history traits and behaviours i.e. migratory vs. non-migratory, migration style, feeding behaviour, physiology, higher taxa belonging to. These are all interesting and valid research questions; however it is perhaps not necessary to understand these fully to understand that the impacts on migratory species are likely to be as great if not greater than those on marine species generally. Therefore it is not necessary to wait for this data before taking action which is known to be effective to combat marine debris.

6.5.3 Information on Management Strategies

One problem when making strategic decisions about which management strategies to invest in is that the strategies are sometimes specific to a particular source, yet the data regarding source of debris is generally poor and/or incomplete. However improved monitoring will help, and we already do have a reasonably good idea that in many places, land based debris is predominant. Therefore action can be taken with reasonable certainty that targeting that type of debris will be having a significant effect.

There are big gaps however in the evaluation of the effectiveness of these programs. Cost-effectiveness and impact on debris amounts and effects on impacts on wildlife all need better monitoring.

Regarding cost-effectiveness, appropriate record keeping and communication would be a start. Regarding the impact on the amount of debris, monitoring debris by weight is a good foundation, as per the UNEP/IOC guidelines. This will help estimates of flow into the sea and the estimation of abundance of debris in the sea. Only then can the relative effectiveness of management strategies be estimated. Regarding impacts on wildlife, it is important that methodologies first be standardized (as mentioned above).

However, based on the information available, it is likely that prevention is more effective in all senses than removal. Unless the removal strategies can clearly be shown to be having an indirect preventative effect through increasing awareness or providing infrastructure for disposal, or to be having a demonstrable effect on improving impacts on wildlife, preventative measures should be prioritized.

6.5.3.1 Targeted Approaches

It is worth considering whether targeted approaches can be helpful when addressing the impacts of marine debris on marine species. The rationale here is to direct limited resources to places where they would have most impact. The relevant evidence is mixed. The benefits of such an approach will probably differ depending on species, specific impact, associated debris type, migratory habit and management strategy. Definitively answering this question would take a considerable amount of research in itself, and if it was decided it could be of benefit, would require the integration of several different datasets, i.e.

- The distribution and migration paths of the species;
- The spatial distribution of the debris; and
- Information on debris related impacts.

The development of such a model for planning debris management strategies would be a further research project in itself. There are databases that contain some of the necessary elements and these could be leveraged (for example, the Red List allows the designation of marine debris as a threat and could be a repository for more specific information on this threat; it also has geographic range information. GROMs has information on migratory pathways. GBIF is a platform for the exchange of biodiversity related information). Information on the distribution of marine debris is probably not at a high enough resolution to make it particularly informative. Also, as most information currently relates to composition alone, this does not enable comparison of relative threat, for which abundance data is needed. In theory, a model such as that made by Lebreton *et al.* (2012) could be used to provide this type of information.[615]

Examples of targeted approaches to conservation issues are:

- The designation of 'Important Bird Areas' (IBAs) by Birdlife International. These are breeding or staging areas deemed particularly important for birds where >1% of the global population congregate, and includes migratory birds. Marine (at-sea) IBAs are also currently being identified worldwide. They do not have any legal status but can be used as priority lists for the designation of protected areas by multi-lateral environmental agreements such as the Ramsar Convention.

- A model of the distribution of marine mammals estimated that 2.5% of marine areas need be protected to protect 84% of the world's marine mammal species.[616]

However, BirdLife's assessment of the use of IBAs in directing management of the competition between birds and fisheries is informative also for the marine debris issue:

> *"Bycatch mitigation needs to occur across ocean basins if conservation gains are to be made, mitigation only in marine IBAs is not likely to achieve this,"*[617]

Like overfishing, marine debris is a threat that extends across boundaries, and generally will have to be addressed on a wide scale if conservation gains are to be made at a local scale.

It is tempting to consider that removal strategies may be effective at local levels – for example, the clearing of debris from haul-out sites where seals breed. However, data on Hawaiian Monk Seals (*Monachus schauinslandii*) in the northwestern Hawaiian Islands over a period of 16 years, showed that despite the implementation of MARPOL Annex V, and yearly clearance of the islands of entangling debris, the amount of debris was not altered and the incidence of entanglement did not go down.[618] Additionally, the seals that suffered most entanglement were not the ones on the island with most debris, suggesting they were encountering debris in a different local area, perhaps at sea. This demonstrates how high the spatial resolution would need to be to successfully identify areas of high risk for wildlife in the first place; and also that yearly clear-ups may make no impact locally.

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[615] Lebreton, L.C.-M., Greer, S.D., and Borrero, J.C. (2012) Numerical modelling of floating debris in the world's oceans, *Marine Pollution Bulletin*, Vol.64, No.3, pp.653–661

[616] Pompa, S., Ehrlich, P.R., and Ceballos, G. (2011) Global distribution and conservation of marine mammals, *Proceedings of the National Academy of Sciences*, p.201101525

[617] http://www.birdlife.org/datazone/info/marfaqs

[618] Henderson, J.R. (2001) A Pre- and Post-MARPOL Annex V Summary of Hawaiian Monk Seal Entanglements and Marine Debris Accumulation in the Northwestern Hawaiian Islands, 1982–1998, *Marine Pollution Bulletin*, Vol.42, No.7, pp.584–589

A study that mapped marine floating debris and 11 species of marine mammal using extensive modelling off the coast of British Columbia, Canada, found that areas of overlap were often far removed from urban centres, suggesting that the extent of interactions would be underestimated by coastal sightings and stranding records and beach litter monitoring.[619] This kind of survey may be possible in small areas, but would be difficult to undertake on a wider scale. It is also not clear what sort of management techniques could be appropriately targeted based on the 'risk' maps produced. The approach may be of most value for estimating impacts and total mortality, once impact data can be fed into the model.

There is one example on turtles and entanglement in the Gulf of Carpentaria, Northern Australia, where spatial mapping of ghost nets was shown to be a good predictor of risk for turtle entanglement. Observations also revealed that the drift pattern of nets might allow for many of them to be headed off at the point they tend to enter the Gulf. This is an example where it makes sense to try a targeted approach for debris removal.[620]

On the other hand, a study on turtles and ingestion that carried out a worldwide literature review found no relationship between the incidence rate of debris ingestion and local abundance of debris, and this was held to be a direct consequence of the large distances travelled by turtles.[621] In this case the only management strategy that is a serious candidate for addressing marine debris over a wide range is prevention. It is unlikely that there will be many instances of prevention initiatives that are of particular value carried out in a targeted manner; as modelling of debris distribution shows, countries' debris does not necessarily end up near their coastline,[622] so detailed knowledge would be needed to match the spatial distribution of threat to the location where prevention initiatives would have to be targeted, and these are very widescale patterns, so there would be quite some inaccuracy in attempting to influence one particular area by this method.

The following example illustrates the kind of level of detail about a species that might be needed to assess whether a hotspot approach might possibly be of value, as it may not only depend on the species but on the subpopulation of a species. Apparently, leatherback turtles use narrow migration corridors in the Pacific Ocean and this led to the suggestion that fishing should be restricted in these areas. However, satellite tracking showed that in the North Atlantic Ocean, there was no

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619 Williams, R., Ashe, E., and O'Hara, P.D. (2011) Marine mammals and debris in coastal waters of British Columbia, Canada, *Marine Pollution Bulletin*, Vol.62, No.6, pp.1303–1316

620 Wilcox, C., Hardesty, B. D., Sharples, R., Griffin, D. A., Lawson, T. j., and Gunn, R. (2013) Ghostnet impacts on globally threatened turtles, a spatial risk analysis for northern Australia, *Conservation Letters*, Vol.6, No.4, pp.247–254

621 Schuyler, Q., Hardesty, B.D., Wilcox, C., and Townsend, K. (2013) Global Analysis of Anthropogenic Debris Ingestion by Sea Turtles, *Conservation Biology*, p.n/a–n/a

622 Lebreton, L.C.-M., Greer, S.D., and Borrero, J.C. (2012) Numerical modelling of floating debris in the world's oceans, *Marine Pollution Bulletin*, Vol.64, No.3, pp.653–661

such equivalent, and they had highly varied and unpredictable migration routes.[623] Combined with the high level of dispersal of marine debris, this limits the potential for hotspot approaches for that population.

6.5.4 Recommendations

CMS has a goal of coordinating scientific research programmes based on identification of common issues/threats shared across the CMS Family, and already there are some thematic initiatives in place, such as that on climate change, or by-catch, which include a specifically appointed Councillor on the Scientific Council and Associated Working Group. If there were similar provision were made for marine debris, it could provide more supportfor the co-ordination of relevant research.

A specific Working Group on marine debris could help co-ordinate programmes and projects relevant to marine debris between Agreements. Regarding information gaps, it could facilitate the sharing of relevant information between Family Agreements on the marine debris issue.

CMS Resolution 10.4, item 6 requests that the Parties provide data on **amounts, sources and impacts of marine debris on Convention-listed migratory species as follows:**

> *"6. Requests that Parties provide available information on the amounts, impacts and sources of marine debris in waters within their jurisdiction on marine species listed on Appendix I and II of the Convention in their National Reports;"*

Although this will cover currently existing data, it could also be used as an opportunity to focus attention on and request data which is deemed necessary in the future, under the guidance of CMS.

For the purpose of filling information gaps, it is also worth keeping in mind that many Family Agreements explicitly require that monitoring and reporting to the Secretariat on the status on threatened species and also on impacts and potential threats to those species, is carried out. National Reporting mechanisms for Family Agreements could therefore be used to return data related to the impacts of marine debris on the migratory species relevant to the Agreements. This includes the on-line reporting system.[624]

Some CMS Family Agreements already have developed partnerships with Regional Seas areas such as ACCOBAMS and the Black Sea (HELCOM). ACCOBAMS has also a programme for conferring 'partner status' upon (e.g. NGOs and university laboratories), one of the benefits of which is that the Agreement may receive scientific information relevant to the implementation of the Agreements on a priority basis. More of this type of collaboration could help CMS to fill relevant knowledge gaps.

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[623] OSPAR (2009) *Background Document for Leatherback turtle Dermochelys coriacea*, 2009, http://www.ospar.org/documents/dbase/publications/p00421/p00421_leatherback_turtle.pdf

[624] http://cms-family-ors.unep-wcmc.org/

The Convention should encourage its Parties to participate in marine debris monitoring programs under the Regional Seas program. There are specific Regional Seas areas that have not yet started to assess their marine debris status and have not yet reported in this regard, namely the Arctic, Northeast Pacific, ROPME region, Pacific, and West and Central Africa. Countries in these regions especially should be encouraged to implement marine monitoring strategies.

The CMS should support the standardization of monitoring and work with Regional Seas and other relevant stakeholders to make sure high impact items are included, that both weight and count be measured, that some sort of microplastics monitoring is implemented, and that monitoring of impacts on marine species be clearly recommended and included to the extent possible. The guidelines for marine litter survey and monitoring programmes for beaches, floating litter and the sea floor, developed by IOC/UNEP and the Regional Seas program provide for most of these considerations and should be distributed and implemented at the national, regional and global levels. In addition, the establishment of a relational database to provide estimates of debris by source, to guide management strategies, should be encouraged, also under the auspices of the Regional Seas program. The Convention should also support the creation of a global clearinghouse for information on marine debris at the regional and global levels.

A relational database could also be created to translate information on marine debris into risk presented to wildlife. This would provide particularly relevant information for the Convention, who could support this by working with Regional Seas programs and University groups.

Impact monitoring should also be carried out in other contexts as the kind of information that can be provided in conjunction with marine debris monitoring programs will be limited. The Convention on Migratory Species should look to encourage co-operation between organizations that have the capacity to carry out this kind of monitoring, including the standardization of methods so that comparable and compelling statistics can be obtained. Suitable stakeholders are suggested in Section 4.2.

In so far as the setting of marine debris targets encourages the implementation of monitoring programs, the Convention could support the setting of marine debris targets. Different types of targets are relevant to different types of information gaps: at-sea targets for improving the state of information about abundance, operational targets such as estuarine monitoring for improving information on pathway, source and regional differences; and targets related to impacts on wildlife improving information in that regard. Targets are an issue currently under discussion for example in the EU. A public consultation was carried out in Autumn 2013 on the establishment of a quantitative reduction headline target for marine litter.[625] Similar opportunities to make the Convention's views heard should be sought.

[625] http://ec.europa.eu/environment/consultations/marine_litter_en.htm

The information gaps regarding management strategies mainly relate to their evaluation in terms of cost, process evaluation and mitigation of impact on wildlife. The Convention can recommend that any strategy undertaken by Parties should plan for and execute evaluation, and may wish to recommend indicators that are consistent between regions and reporting mechanisms It can also insist that any initiative undertaken under its auspices must include evaluation, and require that this data be made available.

The final recommendation is that action should not be delayed while information gaps are filled. Although it would be useful to have information on the stock of debris in the ocean, especially with regards to targets or evaluating the effectiveness of removal strategies, and monitoring prevention strategies, the extent of the sampling required to provide robust information regarding abundance of debris in the ocean may not be generally accepted as feasible in various contexts. It is therefore worth considering whether more information gathering is fruitful, when it does not necessarily alter the selection of many of the initiatives and approaches that have a high likelihood of being successful in combating marine litter. Certainly, if there is information which it is feasible to obtain that would help to clarify what investment it is reasonable to make for a stakeholder or in targeting a particular stakeholder, then this should be done. Furthermore, some measures of debris are more stable and have more power to reliably detect change than others, such as composition rather than abundance, or beach debris vs floating debris, so it is more feasible to implement them. However it must be kept in mind that uncertainty can be taken advantage of by stakeholders as a welcome excuse to delay action, or to favour less expensive actions for combatting debris that are limited in time and scale, even though they might be less effective than even a moderately more expensive option that is, however, holistic and wider in scope in both time and scale. A united front can help discourage stalling on this issue.

Regarding gathering information on impacts on migratory species, it might be decided that gaining more information on the impacts of marine debris on migratory species is required for building a case for action. Ideally, we would require population level effects. However it can be argued that:

a) the extensive animal suffering caused alone constitutes a case for action; and
b) for endangered animals with small populations, such CMS listed species, no amount of extra mortality is acceptable.

In addition, mitigating impacts before populations become threatened will be easier than waiting for population decline to be detected, identifying causal factors, and then trying to reverse it.[626]

Regarding information on regional distinctions, the effort and expense needed to gather this information may not be justified given that because of the distance that debris travels, many of the management strategies need to be applied consistently on

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[626] Taylor, B.L., Martinez, M., Gerrodette, T., Barlow, J., and Hrovat, Y.N. (2007) Lessons from Monitoring Trends in Abundance of Marine Mammals, *Marine Mammal Science*, Vol.23, No.1, pp.157–175

a global scale. It is probably more important to plough resources into a multipronged approach rather than endless segmentation analysis in an attempt to look for 'hotspots' or special 'target issues'.

Even though not all the desired information is available on the efficacy of different management strategies, the information we do have about marine debris and/or its impacts on wildlife is sufficient to indicate that there are some sources and debris types which clearly need addressing .

For example, the predominance of debris from land based sources leads to the particular recommendation of management strategies that address this source of debris. Economic instruments and other measures preventing land based litter have the added benefit of tackling its negative impacts on land, which given the identification of emerging evidence on the indirect costs of litter in respect of crime and mental health, are considerable. Therefore the benefits are not just of relevance to the marine environment. In the context of uncertainty regarding sources of marine debris, they are 'no regrets' measures with a range of additional benefits.

Focus should also be directed on management strategies that deal with debris known to be of high impact on marine species – such as fishing gear, soft plastic and (micro)plastic fragments.

The information we do have on debris abundance in terms of stock (debris already present) and flow (debris entering the sea) also suggests that prevention must be addressed before removal can be effective.

It is important to have enough knowledge to ensure that ineffectual or counterproductive measures or strategies are not pursued. However as soon as the available knowledge allows a judgement to be made, action must not be delayed. The following quote is strongly concurred with:

> *"The authors believe that sufficient empirical knowledge exists to support progress on this issue now. The knowledge gaps outlined … should be considered as means of refining actions, rather than defining or delaying them."*[627]

[627] STAP/GEF (2011) Marine Debris as a Global Environmental Problem: Introducing a Solutions Based Framework Focused on Plastic