A sea of plastic: Evaluating the impacts of marine debris on cetaceans

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Abstract

Global in its distribution and pervading all levels of the water column, marine debris poses a serious threat to marine habitats and wildlife. Ingestion of and entanglement in debris can cause chronic and acute injuries, and increase pollutant loads, resulting in morbidity and mortality of cetaceans. This literature review assesses the impacts of marine debris on cetaceans reported to date. The review documented ingestion of debris in 252 individual cetaceans and entanglement in 57 individuals, representing 41 cetacean species. This is an additional 15 cetacean species since Laist's review in 1997 and represents 48% of all cetacean species. Of the 309 debris interactions documented, 20% were identified as the cause of mortality in the individual. Whilst the number of reported mortalities associated with debris interactions is low compared to total population sizes of the affected species, evidence is largely based upon strandings data, which is considered to represent less than 10% of actual mortality levels. Moreover, a large number of entanglement incidences were excluded from the analysis since it was not possible to determine if fishing gear was active or derelict when the entanglement occurred. While no population impacts of debris on cetaceans have been documented, even low observed rates of entanglement have resulted in population-level impacts in other marine mammal species. Moreover, recent evidence indicates that current levels of population surveillance of most species are insufficient to detect even precipitous population declines. Thus, difficulties in evidence gathering and a low ability to detect impacts should not be mistaken as evidence of an insignificant issue. For cetaceans, the rate of increase of ingestion of plastic debris appears to be a growing concern. Recommendations for further research are given to determine how marine debris is affecting cetacean populations and how best to monitor and mitigate for these effects.

KEYWORDS: DEBRIS, INCIDENTAL CATCHES, STRANDINGS

Introduction

The continued accumulation of debris in our marine environment represents a growing global issue. From the benthic environment to the pelagic zone, the whole spectrum of marine habitats is under pressure from its affects. It has the potential to effect all trophic levels and for impacts to travel through the food chain, from planktonic microorganisms through to marine megafauna (Barnes *et al*., 2009; Derraik, 2002; Gregory, 1996). Only recently recognised as a significant environmental problem, ecological, social and economic consequences have already been observed (Stefatos *et al*., 1999; UNEP, 2009).

For cetaceans, the threats posed by marine debris are multiple and range from direct health impacts and mortality to potential secondary effects as a result of habitat degradation, transfer of chemical pollutants and effects on prey populations. While impacts are predominantly documented at the individual level, due to the low detection probability of debris interactions, there remains a high risk that population level effects are occurring but are not detected.

The nature of the marine environment makes it intrinsically difficult to measure and monitor the quantity of marine debris. Estimates indicate that approximately 6.4 million tonnes (the equivalent of 40,000 Boeing-747 airplanes) of marine litter is dumped in oceans every year, resulting in an estimated 13,000 pieces of litter per square kilometre of ocean (UNEP, 2005). Highly uneven in its distribution, hotspots exist with an excess of 3.5 million pieces of litter per square kilometre (Yamashita and Tanimura, 2007). Marine debris has pervaded all levels of the water column and quantities are increasing in even the most remote areas, far removed from source locations (Derraik, 2002; Barnes *et al*., 2009). There is general consensus that land-based sources are the dominant source of origin of marine debris, contributing up to 80%, with marine or undetermined sources contributing the remainder (Sheavly and Register, 2007). Plastics, which constitute between 60-80% of marine debris, persist in the marine environment (Derraik, 2002). They may fragment, but do not biodegrade and therefore persistence rates of marine debris are estimated to be in the region of hundreds to thousands of years (Barnes *et al*., 2009).

Over the last 25 years, there have been efforts to tackle the problem through international, regional and national level legal and policy instruments as well as non-governmental initiatives. The recent Honolulu Strategy (2011) invites international organizations, governments, industry, NGOs and other stakeholders, to commit to a series of actions, including developing global, regional, national and local targets to reduce marine debris and facilitating technical, legal, policy, community and market-based solutions that will help prevent, reduce and manage marine debris. This has led to the 2012 Manila Declaration, with 65 signatories reaffirming their commitment to develop policies to reduce and control marine debris.

Despite the widespread global adoption of a number of international laws covering both land and marine sources of pollution (see Appendix 1), almost thirty years on there remains mixed evidence regarding any change in the rate of debris accumulation in the marine environment, with strong indications from many regions that quantities are conversely on the rise (Johnson, 1994; Henderson, 2001; UNEP, 2005). This paper builds on previous reviews undertaken (Walker and Coe, 1990; Laist, 1997; Katsanevakis, 2008; Cornish *et al*., 2011; Simmonds, 2011) and represents an initial effort to collate an up to date overview of the number of species and, for the first time, an inventory of the number of cases in which impacts have been documented. It is hoped that this review can help form the basis for a coordinated effort to produce a comprehensive global database of the documented impacts of marine debris on cetaceans, in order to better evaluate conservation concerns resulting from population level impacts and inform the development of appropriate mitigation, preventative measures and timely action on this issue.

Methods

Data collection

We reviewed the published literature documenting impacts of marine debris on marine mammals, using Laist (1997) and other reviews conducted to date (Walker and Coe, 1990; Katsanevakis, 2008; Simmonds, 2011; Cornish *et al*., 2011) as valuable resources for historical incidences dating back to 1960. In addition, data requests were posted to two academic mailing lists – 'marmam' and 'marinedebris' – and representatives from strandings networks were contacted for additional records of ingestion and entanglement. We have included details of the number of individual animals, species, type of debris and the associated types and rates of pathology and mortality observed, although, in many cases, such information was not available.
We collated 80 references from published literature or personal communications (see Table 1). Data were provided by strandings networks in the UK, New Zealand, Israel, Canary Islands, Madeira, Belgium, Reunion Island, Venezuela and Brazil. Whilst every effort was made to include all available data and data sources, the information presented here cannot be considered comprehensive. Records received from strandings networks indicate that many cases never make it into the public domain. Furthermore, many strandings networks record information in a format that prohibits the required data queries.

Data analysis

Data analysis was carried out separately for ingestion of debris and entanglement. For cetaceans and other marine mammals we calculated the total number of reported cases of each type of debris interaction for each taxonomic group. This was undertaken at the level of species, family, sub-order and order. We also calculated the proportion of each taxonomic group that was recorded with debris interactions at the levels of sub-orders and families to examine whether prevalence varied among particular taxonomic groups.

To identify the prevalence of different types of debris in cases of ingestion and entanglement, debris was assigned to discrete categories and the frequency with which different debris types were encountered was calculated. Three categories were used both for ingestion and two for entanglement.

Ingestion categories:

- Fishing gear, including nets, lines, ropes, traps and all other types of fishing gear;
- Plastic items; and
- Miscellaneous debris, including fabric, rubber, paper, balloons, polystyrene, glass and unidentified items.

Entanglement categories:

- Fishing gear, including nets, lines, ropes, traps and all other types of fishing gear; and
- Miscellaneous debris including including packing bands, fabric, rubber, paper, balloons, polystyrene, glass and unidentified items.

For most instances of entanglement in fishing gear, reports do not determine which were due to active fishing gear and which were due to abandoned, lost or otherwise discarded fishing gear (ALDFG). More often than not this differentiation was not or could not be determined at the data gathering stage. As bycatch is not a focus of this paper, our principal analysis includes only those reports in which ALDFG was identified as likely to be responsible. Reports in which only active gear was identified as likely to be responsible were excluded from all analyses. In a separate analysis, we included cases where the origin of gear was unknown, or likely included both active gear and ALDFG.

In some cases with historic data sources, it was not possible to access the original paper. Where this was the case, we have included the relevant data used within the reviews conducted to date (e.g. Laist, 1997). However, as these previous reviews did not detail the number of individual animals per species with debris interactions, the species referred to were assigned only a value of more than zero to avoid over-reporting the total number of cases. In addition, some references included in these previous reviews were included on the basis that they reported a total number of entanglement cases, with the assumption that a subset of these would be due to marine debris (Laist, 1997). Most notably Kraus (1990) and the Humpback Whale Recovery Team (1991) detail a total of approximately 70 North Atlantic right whale (*Eubalaena glacialis*) and 600 humpback whale (*Megaptera novaeangliae*) entanglements in fishing gear, respectively. As an unknown proportion of these were derived from marine debris, we have included these references in recognition that a proportion are likely to result from ALDFG, but again have assigned them only a value of more than zero to avoid over-reporting the prevalence of debris entanglement in these two species.

In order to determine mortality rates resulting from debris interactions, each instance was classified according to whether the interaction was identified as the likely cause of mortality, whether mortality was due to other factors or unknown, where the cause of mortality was undetermined, or the relevant information was not available.

In order to investigate the number of species reported over time, our analysis was compared to three reviews that have taken place (Walker and Coe, 1990; Laist, 1997; Katsanevakis, 2008). To examine temporal changes in the number of reported cases each reference was assigned to a decadal period. A finer-scale temporal evaluation was not possible as publications often document data which span several years or decades and do not give the specific year in which each interaction took place. Where reported instances spanned two decades, they were assigned to the decade that the majority of the date span fell within. Where they spanned three or more decades they were assigned to the decade in which the mid-point of the data span fell.

Finally, international and regional legislation, policy and voluntary initiatives currently focused on tackling marine debris are reviewed, a summary of which is included within Appendix 1.

Results

Ingestion

Ingestion of debris was documented in 252 individuals, representing 38 cetacean species (see Table 1). This represents 44% of cetacean species. This is an additional 15 cetacean species since Laist's review in 1997, and demonstrates a progressive increase in the number of species affected over the last 15 years (see Figure 1). The decadal rate of recorded cases of debris ingestion by cetaceans has risen relatively steadily from the 1960s to 2012, with a slight decrease in 1990-2000 before peaking in the last decade (2000-2010) (see Figure 2).

Figure 1: Number of cetacean species recorded with debris interactions.

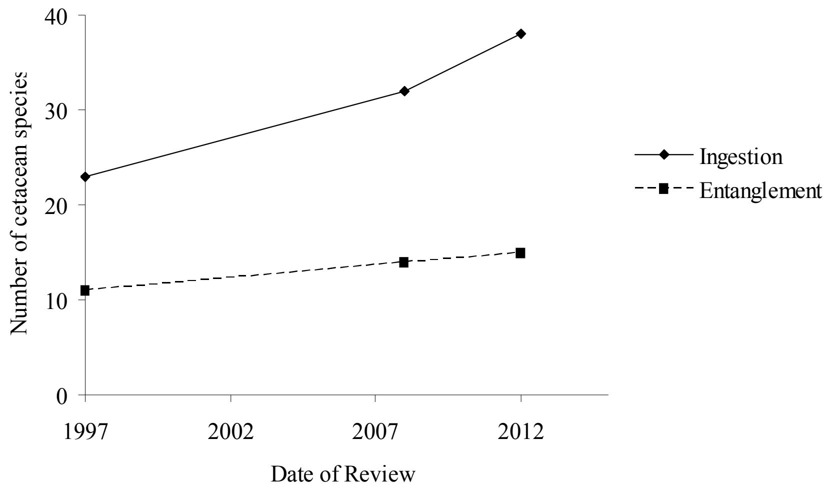
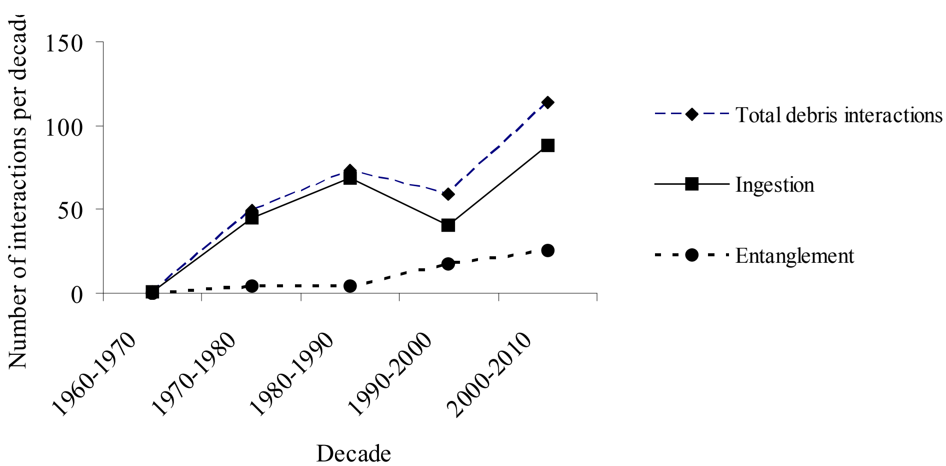


Figure 2: Decadal rates of debris interactions involving cetaceans between 1960 and 2010.



Recorded rates of debris ingestion differed between families and sub-orders, with a higher proportion of mysticete species (57%) compared to odontocete species (42%) recorded ingesting debris. Items ingested by cetaceans were most commonly plastic (47%), with fishing gear (e.g. nets, hooks, lines etc) (25%) and miscellaneous items (28%) constituting the remainder (see Figure 3). Debris items ingested range in size from small particles (<5mm) to large plastic sheeting or netting. Exceptional examples included 134 different net types of up to 16m^2 documented in one Pygmy sperm whale (*Kogia breviceps*) and 378 items recorded in a Cuvier's beaked whale (*Ziphius cavirostris*) with a collective weight of 33kg (Jacobsen *et al*., 2010; Poncelet *et al*., 2000).

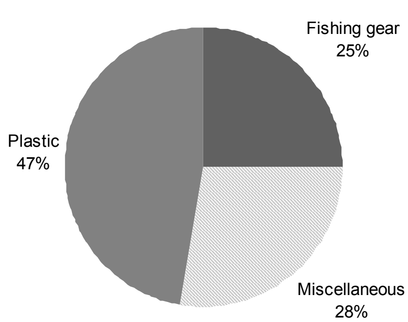


Figure 3: Debris types ingested by cetaceans.

The pathology associated with ingestion of debris was similar across species groups and ranged from no discernible pathological effects through to internal injuries or complete blockage of the digestive tract, with associated malnutrition, starvation and mortality. In addition, heightened pollutant loads have been documented in fin whales, hypothesised to be a result of ingestion of micro-plastics that adsorb and concentrate hydrophobic pollutants (Fossi *et al*., 2012). In the majority of cases (62%) the cause of death was unknown. In cases of ingestion where a cause of death could be determined, ingestion was identified as the likely cause of 34% of these mortalities (32 individuals), with 66% being attributed to another cause. Of these 32 mortalities due to debris ingestion, 58% were due to ingestion of fishing gear and 39% due to ingestion of plastic.

Entanglement

Entanglement in debris was documented less frequently and in a smaller number of cetacean species than ingestion, with 15 species recorded in this review (see Table 1). Nonetheless, the decadal rate of entanglements increased by a factor of 6.5over the 40 year period (1960-2010), with a total of 57 individual entanglement cases documented in this review (see Figure 2).

A larger proportion of mysticete species were recorded entangled in debris (43% as opposed to only 12.5% of odontocete species). Almost all of the entanglements of cetaceans were caused by fishing gear (98%), with the exception of one case of a bottlenose dolphin (*Tursiops truncatus*) with a rubber strap wrapped around its head (Science Daily, 2008). The rate of known mortality resulting from entanglement was 56%; 25% of cases did not result in mortality and in 19% of cases the outcome was unknown. This mortality rate would be higher without human intervention, which occurred in 14% of cases.

In a separate analysis, additional records of cetacean entanglement where the origin of fishing gear was unknown or likely included both active gear and ADLFG provided an additional 2281 cases of cetacean entanglement, including six additional species not previously identified as entangled in known debris; the blue whale (*Balaenoptera musculus*), Bryde's whale (*Balaenoptera edeni*), common dolphin (*Delphinus delphis*), dusky dolphin (*Lagenorhynchus obscurus*), Hector's dolphin (*Cephalorhynchus hectori*) and long-finned pilot whale (*Globicephala melas*).

Discussion

Temporal trends

The first cases of ingestion of debris and entanglement in debris were recorded in the 1960s; 10 years after mass-production of synthetic materials began. From the 1970s to 2010 there has been an increase in decadal rates of recorded debris interactions, and the number of cetacean species affected. Recorded debris interaction rates (ingestion and entanglement events combined) reached an unprecedented high in the last decade, at a level more than double that of 1970-1980 (see Figure 1). When considered independently, recorded rates of ingestion have increased by a factor of 1.9 over the last forty years (1970-2010), entanglement rising by a factor of 6.5. Both indicate a progressive increase in debris interaction rates over the last forty years.

Rates of debris interactions in different taxonomic groups

Both ingestion of debris and entanglement in debris occur within a higher proportion of species within the mysticete family compared to the odontocete family (e.g. 43% of mysticete species reported entangled in debris as opposed to 13% of odontocetes; see Table 2). However, higher absolute numbers of both types of debris interactions have been reported in odontocete species (e.g. 237 instances of ingestion of debris in odontocetes, as opposed to 15 in mysticetes; see Table 1). Neither the higher proportion of mysticete species affected nor the higher number of interactions in odontocete species necessarily indicate a higher susceptibility to ingest or become entangled within debris, given the differences in detection and reporting rates that may occur between the two sub-orders. Mysticete and odontocete species have widely differing geographical distributions, relative abundance and likely differential stranding tendencies that may bias detection and reporting rates. A truly independent comparison of the relative rates of debris interactions between species could only be gained by strategic experimental sampling of different species. Thus, the incidental nature of the source data prevents any firm conclusions regarding which species or taxonomic groups have the highest interaction rates. What is clear is that ingestion of marine debris occurs in a large number of cetacean species that employ a variety of foraging strategies at different levels of the water column. Indeed, the only families which have not been recorded with debris interactions are those with freshwater or polar distributions.

Types of debris

Plastic is estimated to contribute between 60% and 80% of the debris in the marine environment and constituted 47% of the debris ingested (Derraik 2002). Derelict fishing gear (ALDFG) was also a dominant component of the debris ingested by cetaceans (25%). In entanglement, debris of marine origin appears to play a larger role, with entrapment in ALDFG responsible for almost all cases (98%) of entanglement of cetaceans. ALDFG therefore clearly poses the greatest risk of entangling cetaceans compared to other debris types, presumably due to its size, structure and coincidence with key cetacean habitat. It also presents a high risk of repeated 'ghost-fishing' where nets and lines ensnare multiple individuals. Mitigation measures for ALDFG will need to be area and fishery-specific and tailored to address the key causes of lost gear. These could include measures to reduce dumping and loss of gear, increase recovery of lost gear and promote the deployment of technology specifically targeted to reduce entanglement in ALDFG, such as passive acoustic beacons ("pingers"), acoustic reflectors and 'weak' rope linkages (Macfayden *et al*., 2009). Avoiding the loss of gear will likely provide a more cost-effective and long-term solution than clean-up operations, although both have their role to play in restoring the marine environment.

Individual-level effects of debris interactions

Pathological affects of debris interactions are hard to measure. Stranded specimens are often in poor condition with a clear cause of death difficult to determine (Williams *et al*., 2011). Nonetheless, a variety of impacts resulting from debris interactions have been documented to date. In entanglement cases, effects range from immediate mortality through drowning to progressive debilitation over a period of months or years (Laist, 1997). Ensnaring debris frequently causes injury, with progressive constriction and tissue damage as individuals grow, impairing movement, limiting foraging ability and increasing energy expenditure, often ultimately leading to starvation (Knowlton and Kraus, 2001). This can result in a painful and prolonged progression to death. For example, in lethally-entangled North Atlantic right whales the average time to death was 5.6 months but in some individuals up to 1.5 years (Moore *et al.,*2006; Knowlton and Kraus, 2001). The welfare implications are therefore severe, representing "one of the worst forms of human-caused mortality in any wild animal" (Cassoff *et al.,*2011).

In cases of debris ingestion there are often no obvious external signs that items have been ingested. Its occurrence therefore has a high potential to remain undetected (Derraik, 2002). Ingestion and its associated effects are only discovered when stranded or bycaught animals are subject to a comprehensive necropsy involving examination of stomach contents. In this review, acute symptoms recorded most frequently comprised internal injury and blockage of the digestive tract. In cases of ingestion where a cause of death could be determined, ingestion was identified as the likely cause of 34% of mortalities with 66% being attributed to other causes. Ingestion of marine debris is therefore a significant cause of pathology and mortality in cetaceans. Moreover, whilst the detection rate of acute pathology is likely to be low, the likelihood of detecting chronic symptoms resulting from dietary dilution or debris-induced disease is almost non-existent. These have been suggested to include decreased growth rates, longer developmental periods, reduced reproductive output and decreased life expectancy (McCauley and Bjorndal, 1999; Katsanevakis, 2008).

In addition to physical trauma caused by ingestion, there is now evidence corroborating the hypothesis that ingestion of plastic debris represents a significant additional source of pollutants for cetaceans (Fossi *et al*., 2012). Plastic particles carry chemical additives and adsorb and concentrate hydrophobic pollutants such as polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs) at concentrations several orders of magnitude higher than those of the surrounding sea water or sediments (Andrady, 2011). In particular, fin whales have been found to have elevated phthalate concentrations (a chemical additive added to plastic products), thought to be a result of both direct consumption of micro-plastics when filter-feeding and consumption of plankton that have assimilated micro-plastics (Fossi *et al*., 2012). This secondary ingestion of micro-plastic via prey species has also been recorded in Antarctic fur seals (*Arctocephalus gazella*) (Eriksson and Benton, 2003). Ingestion of plastic particles by organisms at the base of the food chain provides an additional mechanism for transfer of contaminants into the marine food web, with bioaccumulation and biomagnification amplifying pollutant loads at the top of the food chain (Teuten *et al*., 2007). Given the high contaminant load already observed in some cetacean populations, and its positive correlation with cancer rates as well as likely immuno-suppression, endocrine disruption and reproductive failure, this additional vector for pollutants should be a cause for concern (Martineau *et al.,*2002). Quantities of microplastics have increased 100-fold over the last forty years and present an insidious threat due to the even greater difficulty of removal and their potential to enter the food chain at virtually all levels (Barnes *et al*., 2009; Goldstein *et al*., 2012).

Population-level effects of debris interactions

The number of recorded instances of debris interactions involving cetaceans, although increasing, remains relatively low, comprising a total of 252 cases of ingestion of debris and 57 cases of entanglement in debris over the last fifty years (see Table 1). If taken at face value, these numbers of confirmed debris interactions, and the resulting mortality rates, would represent an insignificant threat to cetacean populations. However, the vast majority of published cases document single stranding events. Stranding rates of cetaceans are low, with only 2-6% of individuals dying at sea thought to be likely to strand (Fisheries and Oceans Canada, 2008; Williams *et al*., 2011). Thus, as Williams *et al.* (2011) extrapolate, "*the true death toll could be 50 times the number of carcasses recovered"*. In addition, carcasses must be found sufficiently intact to detect evidence of harm caused by marine debris, and a full necropsy must be carried out while the specimen is sufficiently fresh, meaning there is a very low likelihood of detecting sub-lethal or lethal affects at the individual level. It can therefore be presumed that the numbers of animals affected are far higher than the numbers detailed here. In entanglement cases, an added problem is that the origin of gear is not, or cannot, be determined. Even when entangling gear was examined, the type of fishery responsible could not be determined in 20% of cases, and no assessment was made as to whether gear was active or derelict at the time of entanglement (Johnson *et al*., 2005; Laist, 1997). It is therefore highly likely that under-detection of entanglement in debris occurs due to mis-identification of ALDFG as active gear.

Given its limitations, strandings data cannot be relied upon to measure the impact that debris interactions are having on cetacean populations. Neither do current monitoring levels of most species allow us to detect population-level impacts. The "current investment in surveys, and current survey technology and design" are so low that we are unlikely to detect even the most "precipitous declines" (Taylor *et al*., 2007; Williams *et al*., 2011). Studies which have been able to employ a less biased sampling technique, such as stomach content analyses of bycatch specimens, report prevalence rates of debris ingestion between 10 and 27% (Evans *et al*., 2002; Gomerčić *et al*., 2009; Tonay *et al*., 2007; Walker and Coe, 1990). This is suggestive of a far higher rate of debris ingestion than strandings-based evidence indicates, and represents a large additional source of mortality to cetacean populations that are already facing multiple anthropogenic threats. Moreover, whilst increased population mortality rates are the principal concern, multiple chronic fitness-reducing effects are also likely to occur as a result of debris ingestion, further threatening the viability of cetacean populations (McCauley and Bjorndal, 1999).

Despite such limitations with the available data, there is evidence indicating that entanglement is a significant cause of mortality in seven marine mammal species. Population impacts have been best documented in other marine mammal orders, where entanglement is easier to detect due to animals returning to land to breed. For example, annual entanglement rates of < 2% of the Hawaiian monk seal (*Monachus schauninslandi*), Northern fur seal (*Calorhinus ursinus*), Antarctic fur seal and Australian fur seal (*Arctocephalus pusillus*) have been identified as an important factor in population declines (Fowler, 1987; Croxall *et al.,*1990; Henderson, 2001; Derraik, 2002; National Research Council, 2008). This indicates that population-level impacts can occur even with very low debris interaction rates.

In cetaceans, entanglement of the endangered North Atlantic right whale in fishing gear has been identified as a factor inhibiting recovery of the species, with studies indicating entanglement rates as high as 57% of the population. However, the relative proportion that ALDFG as opposed to actively deployed gear contributes to this mortality is not clear, with many likely caused by interactions with active gear (Laist, 1997). In Hawaii, the majority of entangling gear removed from humpback whales originates from Alaska and studies are underway to determine whether this is active or derelict at the time of entanglement (IWC, 2010). In the Alaskan bowhead whale (*Balaena mysticetus*) population, ALDFG is thought to be the main cause of entanglement, with approximately 10% of the population suffering from entanglement in fishing gear (Citta *et al.,*2011). However the resulting mortality rates in bowhead whales and its potential population impacts are not yet known.

Population-level impacts have not been documented as a result of debris ingestion. However, across the study period reported debris ingestion rates were consistently higher than entanglement rates and affected a greater proportion of species. In order to gain a more accurate measure of population level impacts of both ingestion and entanglement interactions, information on (a) the rate of interactions, (b) resulting rates of mortality and other fitness-related pathology, and (c) the demographic structure of populations is required.

Whilst ingestion of debris and entanglement in debris are the key mechanisms by which marine mammal populations are impacted, impacts on marine habitats and prey populations may have secondary repercussions for cetacea. Debris can smother or damage flora and fauna and impede gas exchange, thereby altering community composition (Backhurst and Cole, 2000; Donohue, *et al*., 2001; Goldberg, 1997; Gregory, 2009; Katsanevakis and Verriopoulos, 2007). Similarly, ghost-fishing by ALDFG can reduce stocks of prey species (Laist, 1995). Whilst the implications of this for marine mammals have not been studied, there is evidently the potential for significant impacts on breeding, foraging and migratory habitats and the food supplies upon which they depend (Gregory, 2009).

Conclusions

Our review finds that the proportion of cetacean species ingesting debris or becoming entangled in debris is increasing, as are decadal rates of reported debris interactions. Debris interactions have been documented in cetacean species that occupy a range of habitats and employ a variety of foraging strategies at different levels of the water column. Indeed, the only families which have not been recorded with debris interactions are those with freshwater or polar distributions, where quantities of marine debris are expected to be lower. Marine debris and its effects are increasing, persistent, global in distribution, and could affect the entire spectrum of marine species and habitats (UNEP, 2005). As such, mitigation measures will need to target all strata of the marine environment. Debris from both marine-based and land-based sources is responsible, although marine-based debris in the form of ALDFG is the main cause of reported entanglement cases.

Monitoring of the scale of impacts on cetacean species unavoidably relies on opportunistic stranding data. Such data represents an unknown but likely low proportion of actual mortalities and is further limited by geographic differences in coverage, lack of standardized reporting and storage of information, under-reporting and time-lags before publication. Hence, whilst useful for comparative and temporal analysis, it cannot be taken as indicative of the absolute scale of debris interactions. This, taken together with the fact that current levels of population surveillance of most species are insufficiently powerful to detect even precipitous declines, means that there is no mechanism by which population-level effects of marine debris would be detected (Taylor *et al.,*2007).

Despite the adoption of a number of international laws and other initiatives dating from 1973 that are aimed at reducing inputs of waste into the marine environment, evidence suggests that quantities of debris and debris interaction rates are continuing to increase (UNEP, 2005). International legislation is expected to provide a 'thirty percent solution', with "politics, economics, technology [and] public awareness" expected to provide the remainder (Trouwborst 2011). Regional intergovernmental actions have made good progress in monitoring quantities of marine litter but have achieved less success in preventative and remedial actions (Trouwborst, 2011).

Tackling marine debris presents multi-faceted challenges, requiring coordination from all sectors. The IWC Scientific Committee has an important role to play in evaluating the risk that ingestion of and entanglement in marine debris poses to cetacean populations, identifying populations of highest concern and recommending areas for further research. More data is required to understand which types of marine debris (including different types of fishing gear) are most likely to result in morbidity and mortality of cetaceans.

An IWC workshop would be a valuable tool to coordinate the development of a research programme aimed at determining how marine debris is affecting cetaceans and how best to monitor and mitigate for these effects. Actions could initially include development of a centralized database to collate historic and new cases of debris interactions. Better standardisation of data from strandings networks would allow more certain identification of types of fishing gear and whether gear is active or derelict (i.e. debris) at the time of impact. This would facilitate further research on the rate of interactions, resulting rates of mortality and other fitness-related pathology that is required to evaluate population level impacts. Research should also focus on the incidence of plastic ingestion, which appears to be a growing concern, including further examination of the potential toxicological impact of micro-plastic in cetaceans. The results of this research would inform the development of actions to prevent and mitigate for the impacts of marine debris on cetaceans.

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Table 1: Number of reported instances of debris interactions in cetacean species

Order	Family	Species	Number of instances (Number of instances where interaction likely cause of mortality) Ingestion	Entanglement	Reference(s)
Mysticete	Balaenidae	Bowhead whale (*Balaena mysticetus*)	>0 (0)	3 (0)	(Philo *et al*., 1992; Lowry, 1993)
		North Atlantic right whale (*Eubalaena glacialis*)	1 (1)	>0	(Kraus, 1990; Johnson *et al*., 2005)
		Southern right whale (*Eubalaena australis*)	0	1 (1)	(Cawthorn, 1985)
	Balaenidae Total		1 (1)	4 (1)	
	Balaenopteridae	Blue whale (*Balaenoptera musculus*)	1 (0)	0	(Baxter, 2009)
		Bryde's whale (*Balaenoptera edeni*)	1 (0)	0	(Haines and Limpus, 2001)
		Fin whale (*Balaenoptera physalus*)	6 (0)	0	(Sadove and Morreale, 1990)
		Humpback whale (*Megaptera novaeangliae*)	0	6 (2)	(Mate, 1985; Humpback Whale Recovery Team, 1991; Mattila and Lyman, 2006; Moore *et al.,*2009; Marcondes pers. comm. 13/04/12)
		Minke whale (*Balaenoptera acutorostrata*)	4 (1)	9 (8)	(Cawthorn, 1985; Mate, 1985; Hare and Mead 1987, Tarpley and Marwitz, 1993; Gill *et al*., 2000; Mauger *et al*., 2002; De Pierrepont *et al.,*2005)
	Balaenopteridae Total		12 (1)	15 (10)	
	Eschrichtiidae	Gray whale (*Eschrichtius robustus*)	1 (0)	4 (0)	(Hare and Mead, 1987; Heyning and Lewis, 1990; Cascadia Research, 2010; Barboza, 2012)
	Eschrichtiidae Total		1 (0)	4	
	Neobalaenidae	Pygmy right whale (*Caperea marginata*)	1 (0)	0 (0)	(Ceccarelli, 2009)
	Neobalaenidae Total		1 (0)	0	
Mysticete Total			**15 (2)**	**23 (11)**	
Odontocete	Delphinidae	Bottlenose dolphin (*Tursiops truncatus*)	35 (15)	9 (1)	(Barros *et al.,*1990; Walker and Coe, 1990; Schwartz *et al.,*1991; Mann *et al.,*1995; Gorzelany, 1998; Ceccarelli, 2009; NEFSC, 2009; Levy *et al.,*2009; Gomerčić *et al.,*2009; Deaville and Jepson, 2010; FAU, 2012; Lelis, 2012; Nicolau pers. comm. 12/04/12)
		Common dolphin (*Delphinus delphis*)	8 (1)	0	(Deaville and Jepson, 2010; Walker and Coe, 1990; Nicolau pers. comm. 12/04/12)
		False killer whale (*Pseudorca crassidens*)	1 (0)	0	(Barros *et al*., 1990)

Order	Family	Species	Number of instances (Number of instances where interaction likely cause of mortality)		Reference(s)
			Ingestion	Entanglement	
		Fraser's dolphin (*Lagenodelphis hosei)*	1 (0)	0	(Fernández *et al*., 2009)
		Guiana river dolphin (*Sotalia guianensis)*	1 (0)	0	(Geise and Gomes, 1992)
		Indo-pacific bottlenose dolphin (*Tursiops aduncus*)	0	1 (0)	(Chatto and Warneke, 2000; Bossley, 2005)
		Killer whale (*Orcinus orca*)	1 (0)	1 (0)	(Cawthorn 1985; Baird and Hooker, 2000)
		Long-finned pilot whale (*Globicephala melas*)	1 (0)	0	(Laist, 1997)
		Northern right whale dolphin (*Lissodelphis borealis*)	2 (0)	0	(Walker and Coe, 1990)
		Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)	5 (0)	0	(Caldwell *et al.,*1965; Cowan *et al.,*1986; Walker and Coe, 1990)
		Pantropical spotted dolphin (*Stenella attenuata)*	1 (0)	0	(Baird and Hooker 2000)
		Risso's dolphin (*Grampus griseus*)	4 (0)	1 (1)	(Walker and Coe, 1990; Shoham-frider *et al.,*2002; Frantzis, 2007; Bermudez-Villapol *et al.,*2008)
		Rough toothed dolphin (*Steno bredanensis*)	4 (1)	0	(Meirelles and Barros, 2007; Walker and Coe, 1990)
		Short-finned pilot whale (*Globicephala macrorhynchus*)	2 (0)	1 (0)	(Walker and Coe, 1990; Barros *et al.,*1997; Carillo pers. comm. 02/05/12)
		Striped dolphin (*Stenella coeruleoalba*)	2 (0)	13 (13)	(Walker and Coe, 1990; Frantzis, 2007; Fernández *et al.,*2009)
		Tucuxi (*Sotalia fluviatilis)*	1 (0)	0	(Laist, 1997)
		White-beaked dolphin (*Lagenorhynchus albirostris*)	1 (0)	0	(Baird and Hooker, 2000)
	Delphinidae Total		70 (17)	26 (15)	
	Kogiidae	Dwarf sperm whale (*Kogia sima*)	2 (0)	0	(Barros *et al*., 1990; Walker and Coe, 1990)
		Pygmy sperm whale (*Kogia breviceps*)	16 (3)	0	(Walker and Coe, 1990; Tarpley and Marwitz, 1993; Laist *et al.,*1999; Stamper *et al.,*2006; Fernández *et al.,*2009; Jacobsen *et al.,*2010; Marcondes pers. comm. 13/04/12)
	Kogiidae Total		18 (3)	0	
	Phocoenidae	Dall's porpoise (*Phocoenoides dalli*)	3 (0)	1 (0)	(Degange and Newby, 1980; Jones and Ferrero, 1985; Walker and Coe, 1990)

Order	Family	Species	Number of instances (Number of instances where interaction likely cause of mortality) Ingestion	Entanglement	Reference(s)
		Finless porpoise (*Neophocoena phocaenoides*)	1 (0)	0	(Baird and Hooker, 2000)
		Harbour porpoise (*Phocoena phocoena*)	19 (3)	4 (4)	(Hare and Mead, 1987; Walker and Coe 1990; Kastelein and Lavaleije, 1992; Baird and Hooker, 2000; Tonay *et al.,*2007; Deaville and Jepson, 2010; Bogomolni *et al.,*2010; Northwest Straits Initiative Project, 2012)
	Phocoenidae Total		23 (3)	5 (4)	
	Physeteridae	Sperm whale (*Physeter macrocephalus*)	43 (5)	3 (0)	(Mate, 1985; Martin and Clarke, 1986; Lambertsen, and Kohn, 1987; Sadove and Morreale, 1990; Walker and Coe, 1990; Lambertsen 1990; Viale *et al.,*1992; Spence, 1995; Laist, 1997; Evans and Hindell 2004; International Whaling Commission, 2008; NMFS, 2009; Fernández *et al.,*2009; Moore *et al.,*2009; Mazzariol *et al.,*2011; Carillo pers. comm. 02/05/12; Haelters pers. comm. 24/04/12)
	Physeteridae Total		43 (5)	3 (1)	
	Pontoporiidae	Franciscana dolphin (*Pontoporia blainvillei*)	30 (0)	0	(Pinedo, 1982; Bassoi, 1997; Denuncio *et al.*, 2011)
	Pontoporiidae Total		30 (0)	0	
	Ziphiidae	Baird's beaked whale (*Berardius bairdii*)	31 (0)	0	(Walker and Coe, 1990)
		Blainville's beaked whale (*Mesopledon densirostris*)	2 (0)	0	(Secchi and Zarzur, 1999; Walker and Coe, 1990)
		Cuvier's beaked whale (*Ziphius cavirostris*)	12 (2)	0	(Foster and Hare, 1990; Walker and Coe, 1990; Fertl *et al.,*1997; Poncelet *et al.,*2000; Santos and Pierce 2001; Gomerčić *et al.,*2006; Santos *et al.,*2007; Kerem pers. comm. 12/04/12)
		Gervais' beaked whale (*Mesopledon europaeus*)	4 (0)	0	(Fernández *et al.*, 2009; Walker and Coe, 1990)
		Northern bottlenose whale (*Hyperoodon ampullatus*)	2 (0)	0	(Baird and Hooker, 2000; Deaville and Jepson, 2010)
		Sowerby's beaked whale (*Mesoplodon bidens*)	1 (0)	0	(Deaville and Jepson, 2010)
		Stejneger's beaked whale (*Mesopledon stejnegeri*)	1 (0)	0	(Walker and Hanson, 1999)
	Ziphiidae Total		53 (2)	0	

Order	Family	Species	Number of instances (Number of instances where interaction likely cause of mortality)		Reference(s)
			Ingestion	Entanglement	
Odontocete Total			**237 (30)**	**34 (20)**	
Cetacea Total			**252 (32)**	**57 (31)**	

Table 2: Number of species per family and order reported with debris interactions.

Sub-order	Family	Ingestion		Entanglement	
		Number of species	Proportion of family (%)	Number of species	Proportion of family (%)
Mysticetes	Balaenidae	2	50	3	75
	Balaenopteridae	4	50	2	25
	Eschrichtiidae	1	100	1	100
	Neobalaenidae	1	100	0	0
	Sub-total for sub-order	**8**	**57**	**6**	**43**
Odontocetes	Delphinidae	16	44	6	17
	Kogiidae	2	100	0	0
	Phocoenidae	3	43	2	29
	Physeteridae	1	100	1	100
	Pontoporiidae	1	100	0	0
	Ziphiidae	7	0	0	0
	Sub-total for sub-order	**30**	**42**	**9**	**13**
Cetacea Total		**38**	**44**	**15**	**17**

References

Andrady, A. L. 2011. Microplastics in the marine environment. *Marine Pollution Bulletin* 62:1596-1605.

Backhurst, M. and Cole, R. 2000. Subtidal benthic marine litter at Kawau Island, north-eastern New Zealand. *Journal of Environmental Management* 60:227-237.

Baird, R. W. and Hooker, S. K. 2000. Ingestion of plastic and unusual prey by a juvenile harbour porpoise. *Marine Pollution Bulletin* 40:719-720.

Barboza, T. 2012. Team attempting to free gray whale entangled in fishing gear. *L A Times*. [Available at http://latimesblogs.latimes.com/lanow/2012/03/team-to-attempt-rescue-of-gray-whale-tangled-in-fishing-gear.html; accessed May 2012]

Barnes, D. K., Galgani, F., Thompson, R. C. and Barlaz, M. 2009. Accumulation and fragmentation of plastic debris in global environments. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences* 364:1985-98.

Barros, N. B., Gasparini, J. L., Barbosa, L. A., Netto, R. F. and Moraes. S. 1997. Ingestão de plástico como provável causa mortis de uma baleia-piloto-de-peitorais-curtas, Globicephala macrorhynchus Gray, 1846, no litoral do estado do Espírito Santo. Page 336 in Anais do 7o Congresso Nordestino de Ecologia. Ilhéus, Bahia, Brazil.

Barros, N. B., Odell, D. K. and Patton, G. W. 1990. Ingestion of plastic debris by stranded marine mammals from Florida. Page 746 in R. S. Shomura and M. L. Godfrey (eds). Proceedings of the Second International Conference on Marine Debris. U. S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154, Honolulu, Hawaii.

Bassoi, M. 1997. Avaliação da dieta alimentar de toninha, Pontoporia blainvillei (Gervais and D' Orbigny, 1844), capturadas acidentalmente na pesca costeira de emalhe no sul do Rio Grande do Sul. FURG, Rio Grande, Bachelor Thesis, 68p.

Baxter, A. 2009. Blue whale reveals a sobering reminder about the threats of marine debris. *Bycatch Communication Network Newsletter*:5-6.

Bermudez Villapol, L., Sayegh, A., Rangel, M., Camila, M., Londoño, R., Vera, N. 2008. Notes on the presence of Risso's dolphin, *Grampus griseus*, in Venezuelan waters. *Revista Científica UDO Agrícola* 1812:163-170.

Bogomolni, A., Pugliares, K., Sharp, S., Patchett, K., Harry, C., LaRocque, J., Touhey, K. and Moore, M. 2010. Mortality trends of stranded marine mammals on Cape Cod and south eastern Massachusetts, USA, 2000 to 2006. *Diseases of Aquatic Organisms* 88:143-155.

Bossley, M. (2004/5). The last word: tangled up in blue. *Nature Australia* 28.

Fertl, C. , Schiro, A. J., Collier, S. and Worthy, G. A. J. 1997. Stranding of a Cuvier's beaked whale (*Ziphius cavirostris*) in southern Texas, with comments on stomach contents. *Gulf of Mexico Science* 2:92-93.

Caldwell, M. C., Caldwell, D. K. and Siebenaler, J. B. 1965. Observations on captive and wild Atlantic bottlenosed dolphins, *Tursiops truncatus*, in the northeastern Gulf of Mexico. *Los Angeles City Museum Contributions in Science* 91:1-10.

Cascadia Research. 2010. Examination of gray whale from west Seattle reveals unusual stomach contents but no definitive cause of death. [Available at http://www.cascadiaresearch.org/WSeattle-ER.htm., accessed May 2012]

Cassoff, R., Moore, K., McLellan, W., Barco, S. Rotsteins, D., Moore, M. and Rotstein, D. 2011. Lethal entanglement in baleen whales. *Diseases of Aquatic Organisms* 96:175-85.

Cawthorn, M. W. 1985. Entanglement in, and ingestion of, plastic litter by marine mammals, sharks, and turtles in New Zealand waters. Pages 336-343 in Shomura, R. S. and Yoshida, H. O. (eds). Proceedings of the Workshop on the Fate and Impact of Marine Debris. National Marine Fisheries Service, NOAA, Honolulu, Hawai'i.

Ceccarelli, D. M. 2009. Impacts of plastic debris on Australian marine wildlife. 83pp. Report by C&R Consulting for the Department of the Environment, Water, Heritage and the Arts.

Chatto, R., and R. M. Warneke. 2000. Records of Cetacean Strandings in the Northern Territory of Australia. The Beagle, Records of the Museum and Art Galleries of the Northern Territory. 16:163.

Citta, J., Quakenbush, L., George, J., Brower, H., Small, R. and Heidi-Jorgensen, M. 2011. Does the winter range of bowhead whales overlap commercial fisheries in the Bering Sea? 19th Biennial Conference on the Biology of Marine Mammals.

Cornish, V., Willig, J. and Senner, S. 2011. Marine debris: more than a low-grade fever for marine mammals and sea turtles. Pages 604-608 in Carswell, B., McElwee, K., Morison, S., (eds). Technical Proceedings of the Fifth International Marine Debris Conference. National Oceanic and Atmospheric Administration Technical Memorandum NOS-OR&R-38, Honolulu, Hawaiʻi.

Cowan, D. F., Walker, W. A. and Brownell, R. L. 1986. Pathology of small cetaceans stranded along southern California beaches. Pages 323-367 in Bryden, M. M. and Harrison, R., (eds). Research on Dolphins. Clarendon Press, Oxford.

Croxall, J. P., Rodwell, S. and Boyd, I. L. 1990. Entanglement in man-made debris of Antarctic fur seals at Bird Island, South Georgia. *Marine Mammal Science* 6:221-233.

Deaville, R. and Jepson, P. D. 2010. Final Report for the period 1st January 2005 – 31st December 2010: UK Cetacean Strandings Investigation Programme. 98pp.

Degange, A. R., and T. C. Newby. 1980. Mortality of seabirds and fish in a lost salmon driftnet. *Marine Pollution Bulletin* 11:322-323.

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* 62:1836-41.

De Pierrepont, J., Dubois, B., Desormonts, S., Santos, M. and Robin, J. 2005. Stomach contents of English Channel cetaceans stranded on the coast of Normandy. *Journal of the Marine Biological Association of the UK* 85:1539-1546.

Derraik, J. G. B. 2002. The pollution of the marine environment by plastic debris: A review. *Marine Pollution Bulletin* 44:842-52.

Donohue, M. J., Boland, R. C., Sramek, C. M. and Antonelis, G. A. 2001. Derelict fishing gear in the northwestern Hawaiian Islands: Diving surveys and debris removal in 1999 confirm threat to coral reef ecosystems. *Marine Pollution Bulletin* 42:1301-12.

Eriksson, C. and Benton, H. 2003. Origins and biological accumulation of small plastic particles in fur seals from Macquarie Island. *Ambio* 32:380-384.

Evans, K., and M. Hindell. 2004. The diet of sperm whales (*Physeter macrocephalus*) in southern Australian waters. *ICES Journal of Marine Science* 61: 1313-1329

Fernández, R., Santos, M.B., Carrillo, M., Tejedor, M., Pierce, G. J. 2009. Stomach contents of cetaceans stranded in the Canary Islands 1996–2006. *Journal of the Marine Biological Association of the UK* 89:873.

Fisheries and Oceans Canada, 2008. Recovery Strategy for the Northern and Southern Resident Killer Whales (*Orcinus orca*) in Canada. Species at Risk Act Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa, ix+81pp

Florida Atlantic University. 2012. Dolphins entangled in fishing line increasingly common in Indian River Lagoon. [Available at http://www.fau.edu/hboi/irldolphinentanglements.php; accessed May 2012]

Fossi, M. C., Guerranti, C., Coppola, D. Panti, C., Gianetti, M., Maltese, S., Marsili, L. and Minutoli, R. 2012. Preliminary results on the potential assumption of microplastics by Mediterranean Fin whale: the use of phthalates as a tracer. SETAC World Congress. Berlin.

Foster, N.R. and Hare, M. P. 1990. Cephalopod remains from a Cuvier's beaked whale (*Ziphius cavirostris*) stranded in Kodiak, Alaska. *Northwestern Naturalist* 71:49-51.

Fowler, C. W. 1987. Marine debris and northern fur seals: a case study. *Marine Pollution Bulletin* 18:326-335.

Frantzis, A. 2007. Fisheries interaction with cetacean species in Hellas. Pages 274-278 in Papaconstantinou, C., Zenetos, A., Tserpes, G. and Vassilopoulou, V., (eds). *State of the Hellenic Fisheries*. Athens Hellenic Centre for Marine Research.

Geise, L. and Gomes, N. 1992. Ocorrência de Plástico no estômago de um golfinho, Sotalia guianensis (Cetacea, Delphinidae). Pages 26-28 Proceedings of the Tercera Reun. Trab. Esp. Mam. Aquat. Am. del Sur. Montevideo.

Gill, A., Reid, R. J. and Fairbairns, B. R. 2000. Photographic and strandings data highlighting the problem of marine debris and creel rope entanglement to minke whales (*Balaenoptera acutorostrata*) and other marine life in Scottish waters. Pages 173-178 in Evans, P. G. H., Pitt-Aiken, R. and Rogan, E., (eds). *European Research on Cetaceans*. European Cetacean Society, Cork, Ireland.

Goldberg, E. D. 1997. Plasticizing the seafloor: An overview. *Environmental Technology* 18:195-201.

Goldstein, M. C., Rosenberg, M. and Cheng, L. 2012. Increased oceanic microplastic debris enhances oviposition in an endemic pelagic insect. *Biology Letters*. Published online before print. Available at http://rsbl.royalsocietypublishing.org/content/early/2012/04/26/rsbl.2012.0298; accessed May 2012]

Gomerčić, H. D., Gomerčić, M. D., Gomerčić, T., Luci, H., Dalebout, M., Galov, A., Škrti, D., Urkovi, S. Vukovi, S. and Huber, Đ. 2006. Biological aspects of Cuvier's beaked whale (*Ziphius cavirostris*) recorded in the Croatian part of the Adriatic Sea. *European Journal of Wildlife Research* 52:182-187.

Gomerčić, M., Galov, A., Gomerčić, T., Škrtić, D., and H. Ćurković, S., Lucić, H., Vuković, S., Arbanasić, H., Gomerčić. 2009. Bottlenose dolphin (*Tursiops truncatus*) depredation resulting in larynx strangulation with gill-net parts. *Marine Mammal Science* 25:392-401.

Gorzelany, J. 1998. Unusual deaths of two free-ranging Atlantic bottlenose dolphins (*Tursiops truncatus*) related to ingestion of recreational fishing gear. *Marine Mammal Science* 14:614-617.

Gregory, M. R. 1996. Plastic "scrubbers" in hand cleansers: a further (and minor) source for marine pollution identified. *Marine Pollution Bulletin* 32:867-871.

Gregory, M. R. 2009. Environmental implications of plastic debris in marine settings -entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences* 364:2013-25.

Haines J. A. and Limpus C. J. (2000) Marine wildlife stranding and mortality database annual report 2000. II. Cetaceans and pinnipeds. Research Coordination Unit, Parks and Wildlife Strategy Division, Queensland Parks and Wildlife Service, Brisbane

Hare, M. P., and Mead, J. G. 1987. Handbook for determination of adverse human-marine mammal interactions from necropsies. Seattle. U.S. Department of Commerce, Northwest and Alaska Fisheries Center. NWAFC Processed Report 87-06:35.

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* 42:584-589.

Heyning, J. E. and Lewis, T. D. 1990. Entanglements of baleen whales in fishing gear off southern California. *Report of the International Whaling Commission*:427-431.

Humpback Whale Recovery Team. 1991. Final recovery plan for the humpback whale *Megaptera novaeangliae*. 115pp.

International Whaling Commission. 2008. Annex J: Report of the sub-committee on estimation of bycatch and other human- induced mortality. *Report of the International Whaling Commission*:8pp.

International Whaling Commission. 2010. Report of the workshop on welfare issues associated with the entanglement of large whales. *Report of the International Whaling Commission*:1-33.

Jacobsen, J. K., Massey, L. and Gulland. F. 2010. Fatal ingestion of floating net debris by two sperm whales (*Physeter macrocephalus*). *Marine Pollution Bulletin* 60:765-7.

Johnson, A. J., 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* 21:635-645.

Johnson, S. W. 1994. Deposition of trawl web on an Alaska beach after implementation of MARPOL Annex V legislation. *Marine Pollution Bulletin* 28:477-481.

Jones, L. L. and Ferrero, R. C. 1985. Observations of net debris and associated entanglements in the North Pacific Ocean and Bering Sea, 1978-84. Pages 183-196 in Shomura, R. S. and Yoshida, H. O. (eds). Proceedings of the Workshop on the Fate and Impact of Marine Debris. National Marine Fisheries Service, NOAA, Honolulu, Hawai‘i.

Kastelein, R. A. and Lavaleije, M. S. S. 1992. Foreign bodies in the stomach of a female harbour porpoise (*Phocoena phocoena*) from the North Sea. *Aquatic Mammals* 18:40-46.

Katsanevakis, S. 2008. Marine debris, a growing problem: Sources, distribution, composition and impacts. Pages 53-100 in T. N. Hofer, (ed.). Science. Nova Science Publishers Inc.

Katsanevakis, S., and Verriopoulos, G. 2007. Effect of marine litter on the benthic megafauna of coastal soft bottoms: A manipulative field experiment. Marine Pollution Bulletin 54 (6): 771-8

Knowlton, A. R., and Kraus, S. D. 2001. Mortality and serious injury of northern right whales (*Eubalaena glacialis*) in the western North Atlantic Ocean. *Journal of Cetacean Research and Management*:193-208.

Kraus, S. D. 1990. Rates and potential causes of mortality in North Atlantic right whales (*Eubalaena glacialis*). *Marine Mammal Science* 6:278-291.

Laist, D. W. 1995. Marine debris entanglement and ghost fishing: A cryptic and significant type of bycatch. Pages 33-39 in Proceedings of the Solving Bycatch Workshop: Considerations for Today and Tomorrow, 25-27 September 19995, Seattle WA. Report No. 96-03. Alaska Sea Grant College Program, Fairbanks AK.

Laist, D. W. 1997. Impacts of Marine Debris: Entanglement of marine life in marine debris, including a comprehensive list of species with entanglement. Pages 99-139 in Coe, J.M. and Rogers, D. B. (eds). Marine Debris - Sources, Impacts and Solutions. Springer-Verlag, New York.

Laist, D. W., Coe, J. and O'Hara, K. 1999. Marine debris pollution. Page 342-366 in Twiss, J.R. and Reeves, R. R. (eds). *Conservation and Management of Marine Mammals*. Smithsonian Institution Press.

Lambertsen, R. H. 1990. Disease biomarkers in large whales of the North Atlantic and other oceans. Pages 395-417 in McCarthy, J. F. and Shugart, L.R., (eds). *Biomarkers of environmental contamination*. Lewis Publishers, CRC Press, Florida.

Lambertsen, R.H. and Kohn, B. A. 1987. Unusual multisystemic pathology in a sperm whale bull. *Journal of Wildlife Diseases* 23:510-514.

Lelis, L. 2012. Discarded fishing line threatens dolphins, other animals. Orlando Sentinel. [Available at http://articles.orlandosentinel.com/2012-01-11/news/os-dolphin-fishing-line-entanglement-20120111_1_wendy-noke-durden-bottlenose-dolphin-monofilament; accessed May 2012]

Levy, A. M., Brenner, O., Scheinin, A., Morick, D., Ratner, E., Goffman, O. and Kerem, D. 2009. Laryngeal snaring by ingested fishing net in a common bottlenose dolphin (*Tursiops truncatus*) off the Israeli shoreline. *Journal of Wildlife Diseases* 45:834-838.

Lowry, L. 1993. Foods and feeding ecology. Pages 201-238 in Bums, J. J., Montague, J. J., Cowles, C.J., (eds). *The Bowhead Whale.* The Society for Marine Mammology.

Macfayden, G., Huntinton, T. and Cappell, R. 2009. Abandoned, lost or otherwise discarded fishing gear. *UNEP Regional Seas Reports and Studies,* No.185;FAO Fisheries and Aquaculture Technical Paper, No. 523. Rome, UNEP/FAO. 115p.

Mann, J., Smolker, R. A. and Smuts, B. B. 1995. Responses to calf entanglement in free-ranging bottlenose dolphins. *Marine Mammal Science* 11:100-106.

Martin, A.R. and Clarke, M. R. 1986. The diet of sperm whales (*Physeter macrocephalus*) captured between Iceland and Greenland. *Journal of the Marine Biological Association of the UK* 66:779-790.

Martineau, D., Lemberger, K., Dallaire, A., Labelle, P., Lipscomb, T., Michel, P., Mikaelian, I. 2002. Cancer in wildlife, a case study: Beluga from the St. Lawrence estuary, Québec, Canada. *Environmental Health Perspectives* 110:285-92. National Institute of Environmental Health Science.

Mate, B. R. 1985. Incidents of marine mammal encounters with debris and active fishing gear. Pages 453-458 in Shomura, R. S. and Yoshida, H. O. (eds). Proceedings of the Workshop on the Fate and Impact of Marine Debris. National Marine Fisheries Service, NOAA, Honolulu, Hawai'i.

Mattila, D. K. and Lyman, E. 2006. A note on the entanglement of large whales in marine debris. Unpublished report to the Scientific Committee of the International Whaling Commission: SC/58/BC2.

Mauger, G., Kerleau, F., Robin, J.P., Dubois, B., De Pierrepont, J.F., De Meersman, P. and Custers, I. 2002. Marine debris obstructing stomach of a young minke whale (*Balaenoptera acutorostrata*) stranded in Normandy, France. American Cetacean Society International Conference. Seattle.

Mazzariol, S., Guardo, G., Petrella, A. 2011. Sometimes sperm whales (*Physeter macrocephalus*) cannot find their way back to the high seas: a multidisciplinary study on a mass stranding. *PLoS ONE* 6(5): e19417. doi:10.1371/journal.pone.0019417

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* 13:925-929.

Meirelles, A. C. and Barros, R. 2007. Plastic debris ingested by a rough-toothed dolphin, *Steno bredanensis*, stranded alive in northeastern Brazil. *Biotemas* 20:127-131.

Moore, E., Lyday, S., Roletto, J., Litle, K., Parrish, J., Nevins, H., Harvey, J., Mortenson, J., Greig, D., Piazza, M., Hermance, A., Lee, D., Adams, D., Allen, S. and Kell, S. 2009. Entanglements of marine mammals and seabirds in central California and the north-west coast of the United States 2001-2005. *Marine Pollution Bulletin* 58:1045-51.

Moore, M., Bogomolni, A., Bowman, R., Hamilton, P., Charles, T., Knowlton, A., Landry, S., Rotstein, D. and Touhey, K. 2006. Fatally entangled right whales can die extremely slowly. *Oceans'06 MTS/IEEE-Boston, Massachusetts September 18-21, 2006 - ISBN: 1-4244-0115-1*, 3 pp

National Marine Fisheries Service. 2009. Sperm whale (*Physeter macrocephalus*), 5-year review: Summary and Evaluation. 44pp [Available at http://www.nmfs.noaa.gov/pr/pdfs/species/spermwhale_5yearreview.pdf; accessed May 2012]

National Marine Fisheries Service Center, 2009. Bottlenose dolphin (*Tursiops truncatus*): Indian River Lagoon Estuarine System Stock. 9pp. [Available at http://www.nmfs.noaa.gov/pr/pdfs/sars/ao2009dobn-irles.pdf; accessed May 2012]

National Research Council. 2008. *Tackling Marine Debris in the 21st Century*. The National Academies Press. Washington, D. C. 206pp.

Northwest Straits Initiative Project. 2011. Numbers of live and dead animals by species encountered in derelict fishing gear in the Puget Sound. [Available at http://www.derelictgear.org/uploads/pdf/Derelict%20Gear/DGSpecies.pdf; accessed May 2012]

Philo, L., George, J. and Albert, T. 1992. Rope entanglement of bowhead whales (*Balaena mysticetus*). *Marine Mammal Science* 8:306-311.

Pinedo, M. C. 1982. Análises dos conteúdos estomacais de Pontoporia blainvillei e Tursiops gephyreus na zona estuarial e costeira de Rio Grande, RS, Brazil. Universidade do Rio Grande, Brasil.

Poncelet, E., van Canneyt, O. and Boubert, J. J. 2000. Considerable amount of plastic debris in the stomach of a Cuvier's beaked whale (*Ziphius cavirostris*) washed ashore on the French Atlantic coast. *European Research on Cetaceans* 14:44–47.

Sadove, S., Morreale, S. 1990. Marine mammal and sea turtle encounters with marine debris. Pages 2-7 in Shomura, R. S. and Godfrey, M. L. (eds). Proceedings of the Second International Conference on Marine Debris. U . S . Dep. Comer., NOM Tech Memo. NMFS, NoAA-YH-NMFS-S~FSC-1541.9 90, Honolulu, Hawai'i.

Santos, M., Martin, V., Arbelo, M., Fernández, A., Pierce, G. 2007. Insights into the diet of beaked whales from the atypical mass stranding in the Canary Islands in September 2002. *Journal of the Marine Biological Association of the UK* 87:243.

Santos, M., Pierce, G., Herman, J., Lopez, A., Guerra, A., Mente, E., Clarke, M. 2001. Feeding ecology of Cuvier's beaked whale (*Ziphius cavirostris*): A review with new information on the diet of this species. *Journal of the Marine Biological Association of the UK* 81(4): 687-694

Schwartz, M., Hohn, A. and Bernard, H. 1991. Stomach contents of beach cast cetaceans collected along the San Diego county coast of California, 1972-1991. *Fisheries Science*: 1972-1991.

Secchi, E. and Zarzur, S. 1999. Plastic debris ingested by a Blainville's beaked whale, *Mesoplodon densirostris*, washed ashore in Brazil. *Aquatic Mammals* 25:21-24.

Sheavly, S. B. and Register, K. 2007. Marine Debris & Plastics: Environmental concerns, sources, impacts and solutions. *Journal of Polymers and the Environment* 15:301-305.

Shoham-frider, E., Amiel, S., Roditi-elasar, M. and Kress, N. 2002. Risso's dolphin (*Grampus griseus*) stranding on the coast of Israel (eastern Mediterranean). Autopsy results and trace metal concentrations.*The Science of the Total Environment* 295:157-166.

Simmonds, M. P. 2011. Eating plastic: A preliminary evaluation of the impact on cetaceans of ingestion of plastic debris. Submission to the IWC Scientific Committee: 1-14.

Spence, L. 1995. The death of a whale: using a stranding incident for public education. Pages 36-37 in J. C. Clary (ed). Third International Conference on Marine Debris. NOAA-TM-NMFS- AFSC-51, Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Miami, Florida.

Stamper, M. A., Whitaker, B. and Schofield, T. 2006. Case study: Morbidity in a pygmy sperm whale (*Kogia breviceps*) due to ocean-bourne plastic. *Marine Mammal Science* 22:719-722.

Tarpley, R. J. and Marwitz, S. 1993. Plastic debris ingestion by cetaceans along the Texas coast: two case reports. *Aquatic Mammals* 19:93-98.

Taylor, B., Martinez, M., Gerrodette, T., Barlow, J. and Hrovat, Y. 2007. Lessons from monitoring trends in abundance of marine mammals. *Marine Mammal Science* 23:157-175.

Teuten, E., Rowland, S., Galloway, T. and Thompson, R. 2007. Potential for plastics to transport hydrophobic contaminants. *Environmental Science & Technology* 41:7759-7764.

Tonay, A. M., Dede, A., Öztürk, A. and Öztürk, B. 2007. Stomach content of harbour porpoises (*Phocoena phocoena*) from the Turkish western Black Sea in spring and early summer. *Rapp. Comm. int. Mer Medit.*:616.

Trouwborst, A. 2011. Managing marine litter: Exploring the evolving role of International and European Law in confronting a persistent environmental problem. *Merkourios: Utrecht Journal of International and European Law* 27:4-18.

UNEP. 2005. Marine Litter, An analytical overview.

Viale, D., Verneau, N and Tison, Y. 1992. Stomach obstruction in a sperm whale beached on the Lavezzi islands: Macropollution in the Mediterranean. *Journal de Recherche Océanographique* 16:100-102.

Walker, W. A. and Coe, J. M. 1990. Survey of Marine Debris Ingestion by Odontocete Cetaceans. Pages 2-7 in Shomura, R. S. and Godfrey, H. L., (eds). Proceedings of the Second International Conference on Marine Debris. U.S. Dep. Comer., NOAA Tecli. Memo. NNFS. NOM-TH-NHFS-SWFSC-15, Honolulu, Hawai'i.

Walker, W. and Hanson, M. 1999. Biological observations on Stejneger's beaked whale *Mesopledon stejnegeri*, from strandings on Adak Island, Alaska. *Marine Mammal Science* 15:1314-1329.

Williams, R., Ashe, E. and O'Hara, P. 2011. Marine mammals and debris in coastal waters of British Columbia, Canada. *Marine Pollution Bulletin* 62:1303-16.

Williams, R., Gero, S., Bejder, L., Calambokidis, J., Kraus, S., Lusseau, D., Read, A. and Robbins, J. 2011. Underestimating the damage: Interpreting cetacean carcass recoveries in the context of the Deepwater Horizon/BP incident. *Conservation Letters* 4:228-233.

Yamashita, R. and Tanimura, A. 2007. Floating plastic in the Kuroshio current area, western North Pacific Ocean. *Marine Pollution Bulletin* 54:485-8.

Appendix 1: Summary of international and regional mandates relating to marine debris and sector-specific initiatives

Law/Agreement/Resolution	Description
INTERNATIONAL	
IMO Convention (1948) and the IMO Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (1975)	Established the United Nations International Maritime Organisation (IMO) with the purpose of facilitating the "*general adoption of the highest practicable standards in matters concerning … prevention and control of marine pollution from ships*". The convention and its protocol focus on preventing the dumping of wastes and other materials into the sea, including dumping from vessels. However, discharging items from vessels at sea is not considered as dumping if the items concerned are wastes generated during "*normal operations*"; it is considered dumping if the discharged materials were transported for the express purpose of disposal at sea.
MARPOL Convention (1973) and Protocol (1997)	Main international convention covering prevention of pollution of the marine environment by ships. Imposes a complete ban on the dumping of all forms of plastic (under Annex V) and restricts dumping of other synthetic materials such as fishing gear. Ships of signatory nations have to abide by this in all waters while ships from non-signatory nations must follow this when in waters of signatory countries. Also requires ports and terminals to provide garbage reception facilities and provides for designation of Special Areas where controls are stricter. Amended in 2010 to apply a general prohibition of discharge of any garbage into the ocean.
UN Convention of the Law of the Sea (UNCLOS) (1982)	Calls upon states to adopt laws and regulations to prevent, reduce and control pollution of the marine environment from vessels and land-based sources.
UNEP Montreal Guidelines for the Protection of the Marine Environment against Pollution from Land-based Sources (1985)	Recommendations to governments to assist them in the process of developing appropriate bilateral, regional and multilateral agreements and national legislation for the protection of the marine environment against pollution from land-based sources. One of the recommendations is that "*States should adopt, individually or jointly, and in accordance with their capabilities, all measures necessary to prevent, reduce and control pollution from land-based sources*".
Basel Convention (1992)	Designed to reduce the movements of hazardous waste (e.g. explosive, flammable, toxic, or corrosive) between nations, particularly from developed to less developed countries. Imposes conditions on the import and export of hazardous wastes with requirements for notice, consent and tracking for movement of wastes across national boundaries.
Convention on Biological Diversity (1992), and the Jakarta Mandate (1995)	The Jakarta Mandate on Marine and Coastal Biodiversity is part of the UN Convention on Biological Diversity (CBD), and includes targets in relation to action to reduce and control marine pollution.
UNEP Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA) and the Washington Declaration (1995)	Framework for action to mitigate and prevent the degradation of the coastal and marine environment caused by land-based activities, highlights the need for action to reduce the pollutant load to the seas from land-based sources. One of the objectives is to "*reduce significantly the amount of litter reaching the marine and coastal environment by the prevention or reduction of the generation of solid waste and improvements in its management, including collection and recycling of litter.*"
The London Dumping Convention and Protocol (1996)	Restricts all deliberate dumping of waste at sea, except for a permitted list. Applies to vessels, aircraft, and platforms but does not cover discharges from land-based sources.
Agenda 21 and the Johannesburg Plan of Implementation (2002)	Agenda 21 is a comprehensive plan for global, national and local action by organizations of the United Nations system and governments. It includes chapters on protection of the oceans and environmentally sound management of solid wastes & sewage. The Johannesburg Plan of Implementation emphasises the importance of the UNEP GPA and the ratification of relevant conventions in regard to marine pollution from shipping.

Law/Agreement/Resolution	Description
UNEP Global Initiative on Marine Litter (2003)	Initiative to concentrate on the establishment and development of pilot activities in regions that are particularly affected by marine litter. Also provides a global platform for the establishment of partnerships, co-operation and co-ordination of activities for the control and sustainable management of marine litter.
Global Partnership on Waste Management (GPWM, 2010)	GPWM is an open-ended partnership for international agencies, governments, businesses, academia, local authorities and NGOs. It facilitates the implementation of integrated solid waste management at a national and local level, facilitating policy dialogues and other activities to exchange experiences and practices.
Manila Declaration on Furthering the Implementation of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (2012)	Adopted at the Third Intergovernmental Review Meeting on the Implementation of the GPA. Signatories reaffirmed their commitment to develop policies to reduce and control wastewater, marine litter and pollution from fertilizers.
REGIONAL	
UNEP Regional Seas Programme (1974)	Legal, administrative, substantive and financial framework for implementation of Agenda 21, in particular chapter 17 regarding Oceans. The Regional Seas Programme is based on regional Action Plans which relate to a common body of water. They provide a platform for regional implementation of global conventions and programmes and coordination of activities. These are adopted at intergovernmental meetings and largely implemented under a legally binding Convention and associated protocols. A number of these are directly administered by UNEP, whilst the others are independently administered by regional secretariats. Details of the action plans are given below.
UNEP Regional Action Plans	
Baltic Sea	Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention, 1974)
Black Sea	Convention for the Protection of the Black Sea against Pollution (Bucharest Convention, 1992)
Caspian Sea	Caspian Environment Program (CEP) and Framework Convention for the Protection of the Maritime Environment of the Caspian Sea (Tehran Convention, 2003)
East Asia	No regional convention. Instead, the programme promotes compliance with existing environmental treaties and is based on member country goodwill. Prepared Action Plan for the Protection and Development of the Marine and Coastal Areas of the East Asian Region (1981). Published "Marine litter in the East Asian Seas Region (UNEP, 2008)".
East Africa / West Indian Ocean	Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern African Region (Nairobi Convention, 2010). UNEP prepared "A Regional Overview and Assessment of Marine Litter Related Activities in the West Indian Ocean Region".
Mediterranean	Convention for the Protection of the Mediterranean Sea against Pollution (the Barcelona Convention) and the Athens Protocol for the Protection of the Mediterranean Sea against Pollution from Land-based Sources. Activities coordinated by the Mediterranean Action Plan (MAP).
Northeast Atlantic	Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) (1992). Combines and replaces the 1972 Oslo Convention on dumping waste at sea and the 1974 Paris Convention on land-based sources of marine pollution, with the intention of providing a comprehensive and simplified approach to addressing all sources of pollution which might affect the maritime area. Sets Ecological Quality Objectives, such as reducing quantities of marine litter ingestion below set levels within indicator species.

Law/Agreement/Resolution	Description
Northeast Pacific	Convention for Cooperation in the Protection and Sustainable Development of the Marine and Coastal Environment of the Northeast Pacific (Antigua Convention, 2002).
Northwest Pacific	Action Plan for the Protection, Management and Development of the Marine and Coastal Environment of the Northwest Pacific (NOWPAP, 1994). NOWPAP Marine Litter Activity (MALITA) has been initiated in 2005, as part of the UNEP Global Initiative on Marine Litter, with the goal of developing a NOWPAP Regional Action Plan on Marine Litter (RAP MALI).
West and Central Africa	Convention for Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African (Abidjan Convention, 1984).
Red Sea and Gulf of Aden	Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment (Jeddah Convention, 1982). Have prepared the Regional Action Plan (RAP) for Sustainable Management of marine litter in the PERSGA Region (PERSGA/UNEP, 2007).
Kuwait	Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution, 1978 (Kuwait convention, 1978)
South Asian Seas	South Asian Seas Action Plan (SASAP) adopted in 1995. Published "Review of marine litter in the SAS Region and Framework for Marine Litter Management in the South Asian Seas Region."
Southeast Pacific	Southeast Pacific Action Plan adopted in 1981 together with the Convention for the Protection of the Marine Environment and Coastal Zones of the Southeast Pacific (Lima Convention, 1981). Published "Marine litter in the Southeast Pacific Region: a review of the problem (CPPS, 2007)".
South Pacific	Convention for the Protection of Natural Resources and Environment of the South Pacific Region (SPREP Noumea Convention, 1986).
Wider Caribbean	Caribbean Environment Programme (CEP, 1976) managed through the Caribbean Action Plan (1981). The Action Plan led to the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region (Cartagena Convention, 1983) and the Protocol Concerning Pollution from Land-Based Sources and Activities (LBS Protocol).
Other Regional Directives / Programmes	
Convention on Migratory Species Resolution (CMS/Bonn Convention) (1979)	Intergovernmental treaty that aims to conserve terrestrial, aquatic and avian migratory species throughout their range. UNEP/CMS Resolution 10.4 adopted in 2011 which deals specifically with marine debris and includes recommendations to parties to identify hotspots, address sources and impacts and develop action plans.
Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) (1981)	Monitoring of marine debris and its impact on marine taxa is a permanent item on the Commission agenda.
Protection of the Arctic Marine Environment (PAME) (1991)	The PAME working group addresses pollution prevention issues associated with protection of the Arctic marine environment from land and sea-based sources.
UN General Assembly resolutions: Resolution A/RES/59/25 (2004) Resolution A/60/L.22 (2005) Resolution A/RES/60/30 (2006) Resolution A/RES/60/31 (2006) Resolution A/RES/61/222 (2007) Resolution A/RES/61/105 (2007)	Call for national, regional and global actions to address the problem of marine litter, including integrating the issue of marine debris within national strategies, the development of appropriate economic incentives and regional prevention and recovery programmes for marine debris.

Law/Agreement/Resolution	Description
Intergovernmental Oceanographic Commission of UNESCO & NEP/RSP Guidelines on Survey and Monitoring of Marine Litter (2009)	Recognised that one of the significant barriers to addressing marine litter is the absence of adequate science-based monitoring and assessment programmes. Produced guidelines to support efforts by regions, countries, regional seas programmes and other relevant organizations to monitor and assess marine litter.
Honolulu Strategy and Commitment (2011)	Introduced by UNEP to Third Intergovernmental Review Meeting on the Implementation of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (January 2012). The Honolulu Strategy is a planning tool for marine debris programs and projects. The Honolulu Commitment invites international organizations, governments, industry, NGOs, and other stakeholders, to commit to a series of actions, including developing global, regional, national and local targets to reduce marine debris and facilitating technical, legal, policy, community-based and economic / market-based solutions that will help prevent, reduce and manage marine debris.
EC Urban Waste Water Treatment Directive (1991)	Introduced to ensure that sewage was properly treated before discharge. Sets treatment standards. Under this, combined sewer overflows, which transport domestic sewage and rainwater run-off out of flooded sewer systems and discharge it, untreated into rivers or the sea, are restricted in use to periods of unusually heavy rain.
EC Habitats Directive (1992)	Implemented to meet obligations under the Bern Convention. Member states required to introduce measures to maintain or restore European protected habitats and species listed in the Annexes at a favourable conservation status. This includes a number of coastal and marine habitats and species. All cetaceans are strictly protected species under the Habitats Directive and as such all incidental catches or killings of cetaceans (such as those from marine debris) need to be examined to address obligations under the Habitats Directive.
EC Directive on the Landfill of Waste (1999)	Introduced to prevent or reduce as far as possible negative effects on the environment from the landfilling of waste, by introducing stringent technical requirements. The Directive is applicable to garbage from the landfills entering the seas and becoming marine litter.
EC Water Framework Directive (2000)	Commits member states to make their inland and coastal waters free from human influence. Required to establish river basin districts and for each of these a river basin management plan.
EC Directive on Port Reception Facilities for Ship-Generated Waste and Cargo residues (2000)	Established to reduce the discharges of ship-generated waste and cargo residues into the sea. Requires that all ports provide facilities to meet the needs of those vessels normally calling in at them.
EC Directive on Packaging and Packaging Waste (2004)	Aim is to prevent packaging waste by encouraging packaging re-use and recycling. Requests that Members States introduce systems for the return and/or collection of used packaging and defines specific targets for packaging waste recovery and recycling.
EC Environmental Liability Directive (2004)	Aims to make those causing damage to the environment legally and financially responsible for that damage. Covers environmental damage caused by occupational activities to species and natural habitats protected under the 1992 Habitats Directive and waters covered by the 2000 Water Framework Directive.
EC Directive on Waste (2006)	Prohibits the abandonment, rejection and uncontrolled elimination of waste. Member states must promote the prevention, recycling and transformation of waste.
EC Marine Strategy Framework Directive (MSFD) (2008)	Legislative framework for an ecosystem-based approach to the management of human activities, which supports the sustainable use of marine goods and services. The overarching goal of the Directive is to achieve 'Good Environmental Status' (GES) by 2020 across Europe's marine environment. Requires member states to develop and implement marine strategies to protect and conserve the marine environment, prevent its deterioration, and, where practicable, restore marine ecosystems in areas where they have been adversely affected. These are expected to produce results by 2020. One of the eleven descriptors that must be met to achieve GES is that "*Properties and quantities of marine litter do not cause harm to the coastal and marine environment*".

Law/Agreement/Resolution	Description
SECTOR SPECIFIC INITIATIVES	
FAO's Code of Conduct for Responsible Fisheries (1995)	Includes recommendations that management objectives should provide that "*pollution, waste, discards, catch by lost or abandoned gear…are minimised*" and that states should introduce and enforce laws and regulations based on MARPOL. Measures on the code (such as gear marking) are aimed at reducing ALDFG.
Regional Fisheries Management Organisations (RFMOs) resolutions	CCAMLR Conservation Measure 10-01 requires marking of all fishing gear with the aim of reducing ALDFG. ICCAT Contracting Parties must mark gear in accordance with industry standards. NOAA Fisheries Service has adopted federal regulations which expressly prohibit the disposal or abandonment of fishing gear and require reporting of accidental loss.
International Whaling Commission	In 2011 the IWC agreed to: 1. Endorse the Honolulu Commitment; 2. Establish a standing item on marine debris on the Conservation Committee agenda; and 3. Request the Scientific Committee continue reviewing potential threats to cetaceans arising from marine debris.
International Council of Cruise Lines	Mandatory standards for cruise ships with a goal of zero discharges of MARPOL Annex V solid waste products.
Declaration of the Global Plastics Associations for Solutions on Marine Litter (2011)	Signatory organisations commit to: 1. Contribute to solutions by working in public-private partnerships aimed at preventing marine debris; 2. Work with the scientific community and researchers to better understand and evaluate the scope, origins and impact of and solutions to marine litter; 3. Promote comprehensive science-based policies and enforcement of existing laws to prevent marine litter; 4. Help spread knowledge regarding eco-efficient waste management systems and practices, particularly in communities and countries that border our oceans and watersheds; 5. Enhance opportunities to recover plastic products for recycling and energy recovery; and 6. Steward the transport and distribution of plastic resin pellets and products from supplier to customer to prevent product loss and encourage customers to do the same.
Ocean Conservancy: International Coastal Cleanup (ICC)	Global project co-ordinated by the Ocean Conservancy NGO. ICC is an international network of environmental and civic organizations, government agencies, industries, and individuals working to remove marine litter and collect information on the amounts and types of litter.