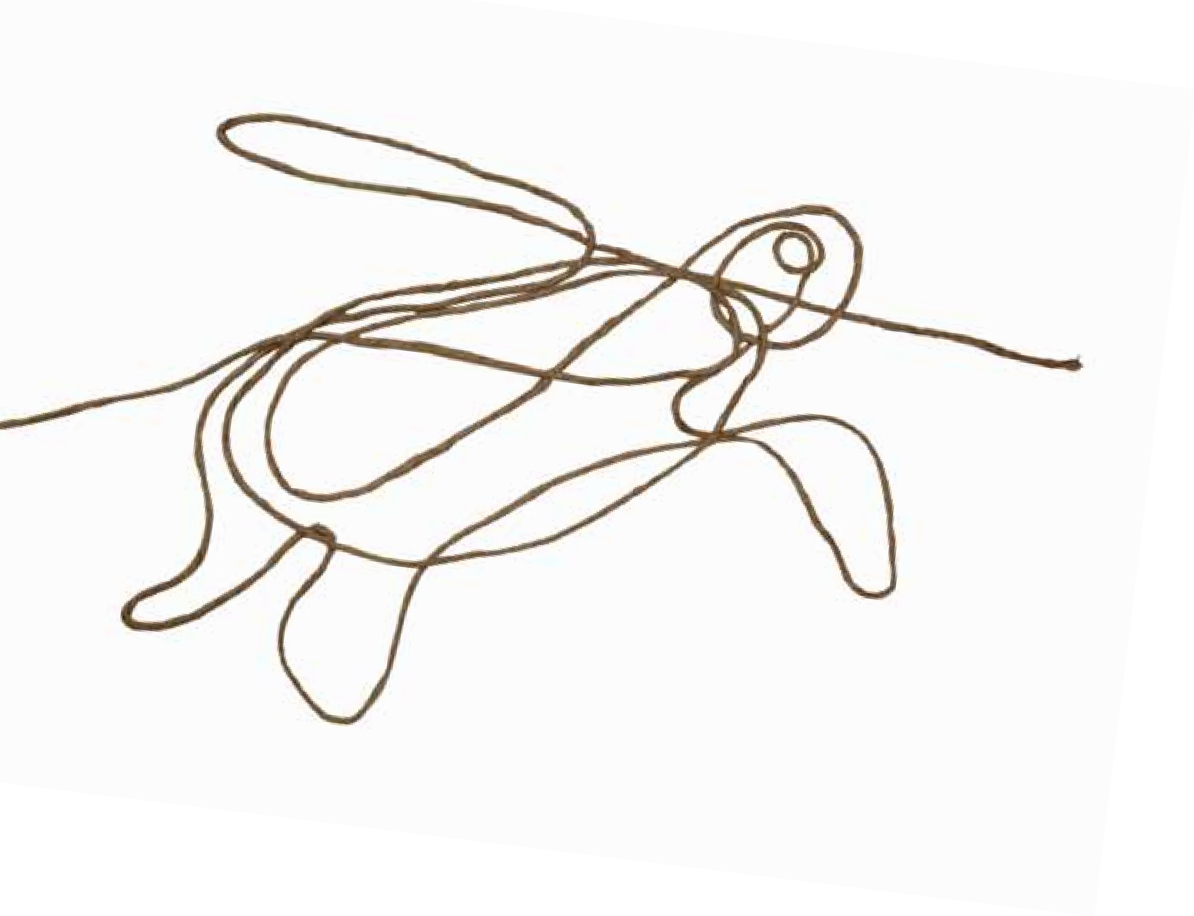
Untangled

Marine debris: a global picture of the impact on animal welfare and of animal-focused solutions

World Society for the Protection of Animals

WSPA



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- helping people understand the critical importance of good animal welfare
- encouraging nations to commit to animal-friendly practices
- building the scientific case for the better treatment of animals
- encouraging a worldwide movement to further animal welfare.

Locally, we improve animals' lives by working directly with communities and owners. Working on the ground with local partners, we are active in more than 50 countries.

Globally, we introduce animals into the most pressing debates. We have special consultative status with the United Nations and consultative status at the Council of Europe; we collaborate with national governments and global bodies including the World Organisation for Animal Health (OIE).

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Right: Sea turtle entangled in a ghost net

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Introduction

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1 Introduction

Each year, millions of the animals that live in our oceans are debilitated, mutilated and killed by marine debris. Reports from across the world indicate that hundreds of species of marine animals routinely become entangled in or ingest lost or discarded fishing nets, monofilament line, ropes, packing bands, plastic packaging and bags, with grave consequences for their welfare.

Marine debris is a truly global problem. Often travelling long distances from its origin and now found even in the remote waters around Antarctica, no ocean habitat is free from this pollution. In addition to the increasingly well-recognised problems that marine debris causes to the environment, coastal communities and marine industries, there is now compelling evidence of the large-scale and serious threat that it poses to the welfare of wild marine animals.

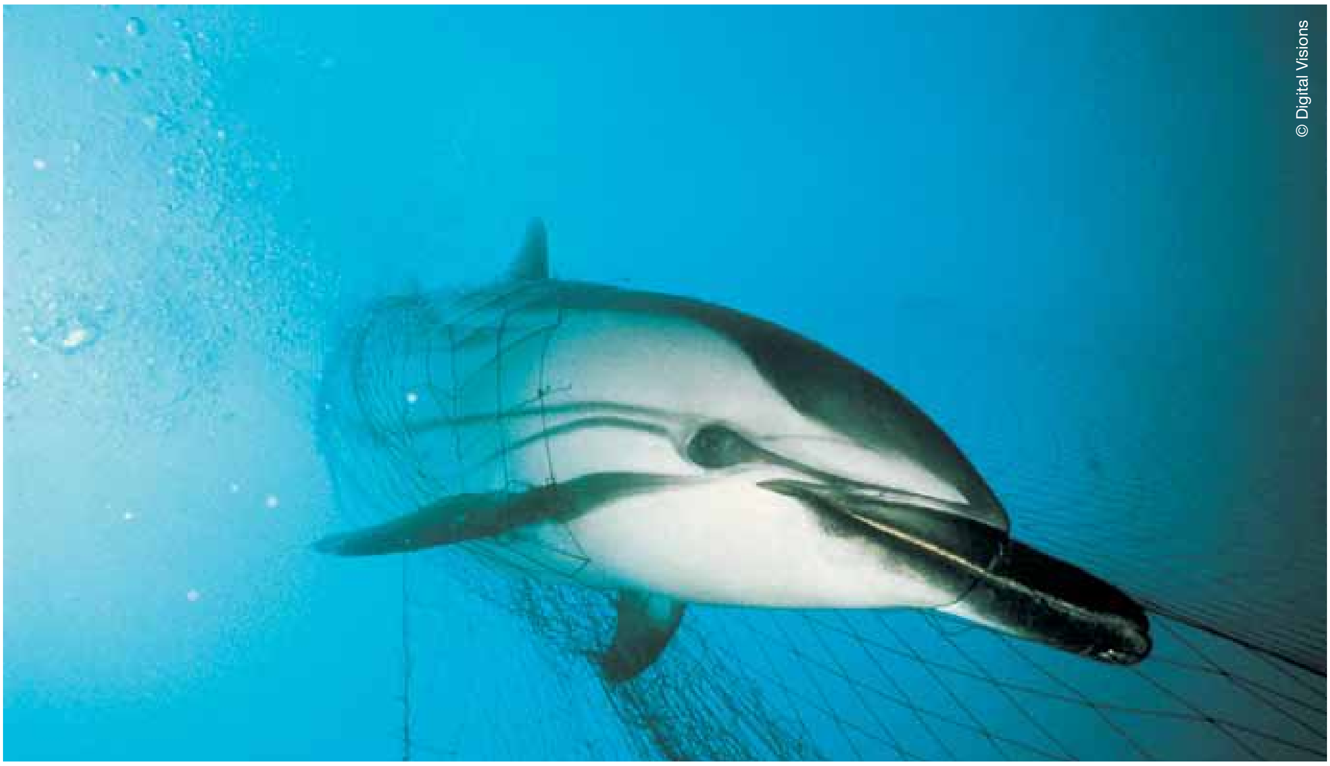
This report is unique in that it focuses on the animal suffering caused by marine debris. Marine mammals, birds, turtles, sharks and other large fish species are all documented to have ingested or become entangled in human-originated debris that has either been deliberately discarded or lost in the oceans. Here, for the first time, we summarise the considerable literature which describes and, to an extent, quantifies the problem globally.

The report has four aims. First, it reviews the published papers and grey literature that identify and describe animal entanglement in and ingestion of marine debris and from this summarises the likely welfare impact of key debris types on the affected species. Secondly, it provides a very broad estimate of the numbers of animals affected by different debris. It then discusses the nature and abundance, where known, of the key types of debris which adversely affect animals, including geographic hotspots. Finally, it discusses the efforts being made around the world to reduce the volume of dangerous debris entering the marine environment, as well as to remove existing debris and to rescue, treat and release trapped and entangled animals.

Although a wide range of animals can experience the effects of marine debris, some species appear much more significantly affected than others. Based on the available literature, it appears that the animals most frequently affected by entanglement are pinnipeds (in particular species of fur seals and sea lions), humpback and right whales, and many species of turtles and marine birds; the animals most frequently affected by the ingestion of marine debris are marine bird and turtle species. Our findings indicate that between 57,000 and 135,000 pinnipeds and baleen whales are entangled each year, in addition to the inestimable – but likely millions – of birds, turtles, fish and other species affected by entanglement in and ingestion of marine debris.

Although marine debris is now found in every ocean, its effects are not uniformly spread. It is true that the observer effort and reporting of the effects of marine debris on animals is uneven, with almost no reporting in some parts of the world. But even taking this into account, the frequency of sightings and reports from some regions suggest that they present a higher risk of entanglement and ingestion hazards, and that it may be helpful, as part of targeted action, to focus resources in these areas.

Far too frequently, animals who become entangled by, trapped in, or who ingest marine debris cannot cope with the trauma, damage, pain, infection and compromised ability to feed, move and carry out their normal behaviours. The resulting poor welfare, outlined and summarised in this report, creates a compelling argument that marine debris must be viewed not only as a serious environmental, conservation, human health and economic issue, but also as a significant global animal welfare issue that requires urgent action. Untangling and tackling the problem effectively will require the proactive cooperation of governments, industry, relevant intergovernmental bodies and agencies, and the public worldwide.



Top: Catshark (deceased) entangled in fishing net, Croatia, Adriatic Sea
Bottom: Striped dolphin entangled in net, North East Atlantic Ocean

1.1
Marine debris: the background

When Norwegian explorer Thor Heyerdahl crossed the Atlantic Ocean in 1970, the amount of debris, litter and waste that he saw left him sufficiently concerned to submit a report to the United Nations Conference on the Human Environment (held in Stockholm in 1972). Since that time, a huge swell of reports, government actions and specific studies have shown that the marine environment is accumulating an increasing volume of human-originated debris. Estimates of the volume of marine debris vary, but some indicate that up to 300,000 items of litter and waste can be found per sq kilometre of ocean surface (National Research Council [NRC], 2008). An estimated 8 million items of litter enter the ocean every day, and about 6.4 million tonnes of marine litter are disposed of in the oceans and seas each year (United Nations Environment Programme, 2005).

An internationally agreed definition of marine litter, adopted by the United Nations Environment Programme (UNEP), is “any persistent, manufactured or processed solid material discarded, disposed or abandoned in the marine and coastal environment”. Marine debris includes items made from plastics, glass, metals and rubber. Plastic has come to dominate marine litter, due to its long lifespan and buoyancy, but the prevalence of different types of debris varies from location to location, depending on the nature of the shore-based waste handling, the type and extent of fishing activity, and the nature of the topography and currents in the marine environment. Derelict and abandoned fishing gear – including nets, lines, traps and floats lost or abandoned at sea – is a major source of marine debris, and is of particular concern for animal welfare due its capacity to entangle and trap animals in the sea.

Types of marine debris include:

- **fishing industry debris** – rope, fishing net, fishing line, lost fishing traps and pots
- **food-related waste –** plastic bags, plastic bottles, cans, plastic bottle and container lids, plastic straws, food packaging
- **smoking-related waste** – cigarette filters, cigar tips, disposable lighters
- **manufacturing and shipping-related waste** – plastic resin pellets, pallets, plastic sheeting, strapping bands, straps.

Figure 1. The ten most prevalent marine debris items (from 103,247,609 items collected), 1989–2007

Source: Sheavly (2007)

Other common items identified in beach surveys include balloons, metal beverage cans, rope fragments, fishing line, cotton swabs, tampon applicators, packing straps (both open and closed), floats and buoys, nets of more than five meshes, plastic bleach or cleaning product bottles, traps and pots, gloves, light sticks, plastic sheets, motor-oil containers, six-pack rings, pipe-thread protectors, condoms, light bulbs and tubes, oil and gas containers, syringes, salt bags and fish baskets.

The results of a study commissioned by the United States National Marine Debris Monitoring Program (Sheavly, 2007) showed that 32.3 per cent of beach litter resulting from dedicated clean-ups across the United States 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 per cent); balloons (7.8 per cent); rope longer than one metre (5.5 per cent); fishing line (3.4 per cent); and fishing nets (1.4 per cent). In the United Kingdom, fishing debris including line, nets, buoys and floats is the second biggest source of marine debris after beach visitors' litter (Marine Conservation Society [MSC], 2007), representing about 11.2 per cent of total beach litter (MSC, 2007).

1.1.1 The problem of plastics

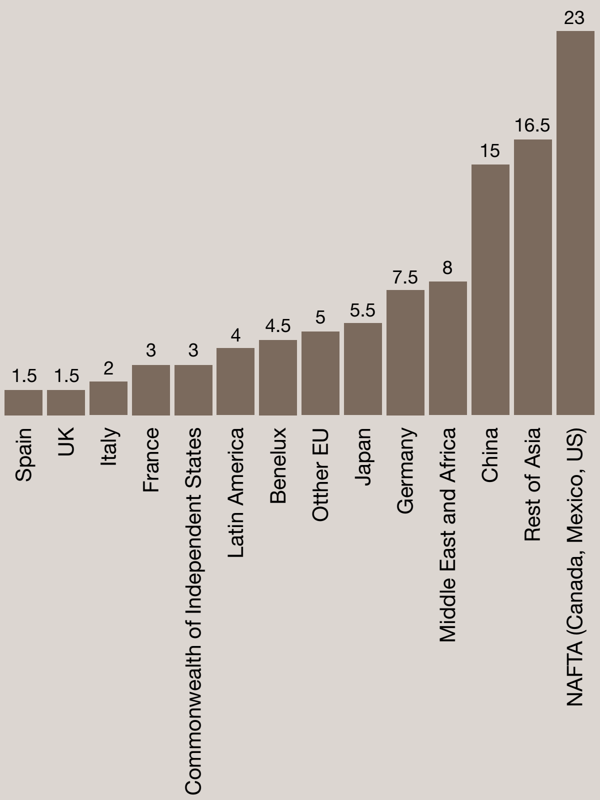
Plastics are a major source of marine debris. The mass production of plastics soared after the Second World War – items from that period are still being retrieved from the oceans today. Many plastics – including polypropylene, polyethylene, nylon, polystyrene, polycarbonate and polyvinyl chloride (PVC) – are very durable; some are predicted to persist in the marine environment for up to 600 years. At the same time, many plastics are buoyant, or very close to the density of seawater, and so either float at the surface, sink only very slowly in the sea, or are easily carried by currents. Ocean modelling and the tracing of barcodes on plastic items shows that marine debris can be found 10 years later 10,000 km away from its country of origin (Barnes et al., 2009).

Much of the debris originating from land (rather than from boats) has now found its way, via prevailing winds and currents, into the ocean gyres – systems of rotating ocean currents (Law et al., 2010). These 'plastic gyres' contain items of large plastic-based waste such as abandoned fishing nets. They float around trapping litter and animals alike (in a process known as 'ghost fishing'), and also accumulate vast soups of small plastic particles. Plastic debris in the oceans slowly breaks down to become the size of grains of sand. These broken-down plastics can now be found in both the water and sediments across the world's oceans, along with small plastic particles called 'scrubbers' which are included in hand cleaners and cosmetic products and used as air-blasted abrasives to remove paint from ship hulls.

The recent rise in plastics production has been very steep (EC DG ENV, 2011), with the total global production estimated at 230 million tonnes in 2009. The European Union (EU) accounts for around 25 per cent of world production. Figure 2 shows the percentage of production by key countries.

The EU report describes key trends in relation to plastics. It assumes that the production of plastic and generation of plastic waste will increase, but that we will also see increases in recycling (primarily mechanical) and energy recovery (but in a more limited way than recycling levels, due to the lead time). The major plastic-consuming countries in the EU are Germany and Italy, which together account for around 40 per cent of the EU market (EC DG ENV, 2011).

Figure 2. Plastics production by key countries (global percentage)



Source: EC DG ENV (2011)

1.1.2 Where does marine debris come from and where does it end up?

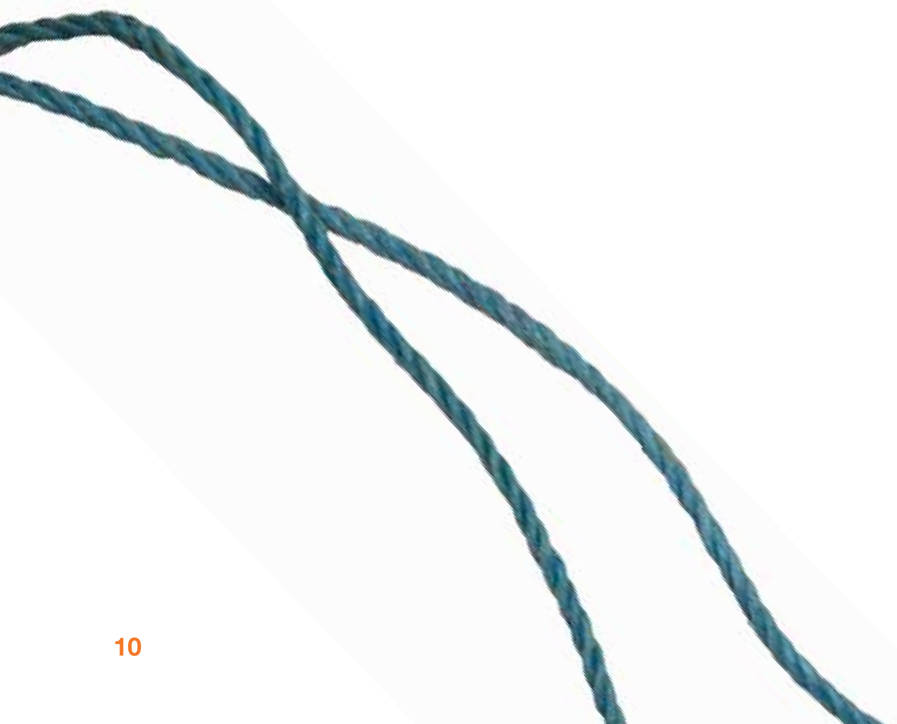
Marine debris derives from a wide range of human activities:

- accidental or deliberate dumping of commercial, industrial and domestic waste in the sea from the land (for example, sewage or factory outfalls)
- windblown waste from the shore or from boats
- intentional and unintentional losses from shipping, including fishing vessels
- land-based items moved by storm and flood damage.

Marine debris may be produced in one part of the world and end up in another. Oceanic currents and winds can carry debris thousands of miles, and have accumulated large densities of debris in five major ocean gyres (there are also other smaller ones). The Great Pacific Oceanic Gyre (also known as the Great Pacific Garbage Patch) contains plastic, chemical sludge and debris with an estimated mass of 100 million tonnes (Environmental Graffiti, 2012), covering an area as large as France and Spain combined (Derraik, 2002; Sheavly, 2005).

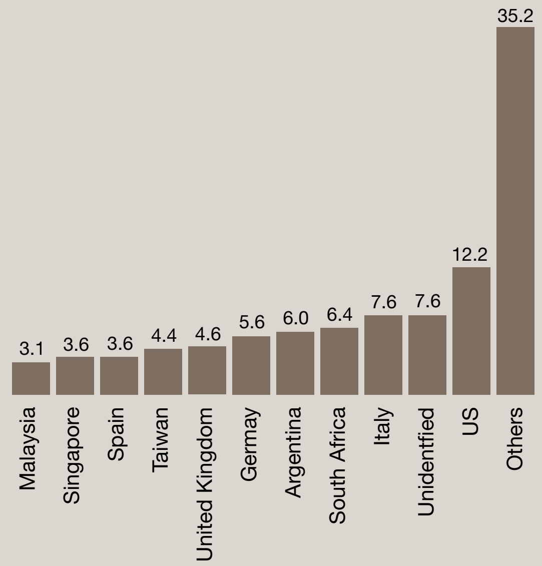
It is possible to identify the origin of plastic waste and packaging from barcodes (the first three letters indicate the manufacturing country). Using this approach, Santos et al. (2005) identified the sources of debris on beaches in Brazil. The Costa dos Coqueiros beaches yielded containers from diverse nations, see Figure 3.

At the Asia Pacific Economic Cooperation (APEC) Marine Debris Seminar, held in Hawaii in 2004, Australian delegates described a significant marine debris problem along the sparsely populated northern Australian coast. Some areas record up to 4,100 items counted per mile, with up to 99 per cent of this debris derived from marine-related sources. They explained that 13,800 tonnes of waste were generated by ships each year in Australian waters, but only 9,800 tonnes of waste were returned to shore for disposal – leaving up to 4,000 tonnes lost or discarded by ships each year, along with 2,400 tonnes of lost or discarded gear from fishing vessels. Meanwhile, the Japanese delegates described how approximately 50 per cent of surface marine debris collected in Japanese waters was made up of plastics, styrofoam and petrochemical products. In Japan, only about 12 per cent of debris was derived from fishing nets and other derelict gear.



Before the 1980s, marine litter had reached only the most remote island shores of the Southern Ocean in only small quantities. However, there is now a clear trend toward the accumulation of plastic debris across the entire southern hemisphere; survey data show an increased rate of accumulation on remote shores, with plastics pushing toward the Antarctic (Barnes, 2005). A 2009 report commissioned by the Oslo and Paris Conventions for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) paints a clear picture: that the overall amount of marine debris is consistently high and not yet reducing, despite recent efforts. It documented the highest levels in the greater North Sea Region, with 600–1,400 items per 100 metres (m) of beach surveyed in the northern North Sea and 200–600 items per 100m in the southern North Sea. Levels were also high in the Celtic Seas, with some 600–800 items per 100m. The report estimates that there are 250 billion pieces of plastic currently in circulation in the Mediterranean (OSPAR, 2009).

Figure 3. Origin of plastic waste found on Costa dos Coqueiros beaches, Brazil (in per cent)



Source: Santos et al. (2005)

Table 1. Beach items recorded per sq km

Location	Survey period	Mean number of beach items per sq km	Range (items per sq km, lowest to highest)
Pitcairn Island (South Pacific)	1991–1993	230,000	120,000–350,000
Indonesia	1994	27,100,000	700,000–53,400,000
Red Sea, Jordan	1994–1995	4,026,100	2,436,800–6,171,000
Eastern Australia	2000	133,200	34,000–298,000
Sea of Japan	2000	-----	207,000–3,410,000
Argentina	2000	62,462	9,462–150,900
Mexico	2000	1,525,000	1,238,800–1,829,700
Brazil	2001	137,580	33,700–233,300
Scotland	2001–2003	989,189	160,000–3,060,000

Source: OSPAR (2009)

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Plastic pollution washed up on a beach after a storm, Cape Town, South Africa

1.1.3 What problems can marine debris cause?

Marine debris has a wide range of adverse impacts which are of relevance to many stakeholders. The UNEP Regional Seas Programme summarises the areas of concerns in relation to marine debris as:

- the environment
- conservation of species
- human health
- tourism
- local economies.

Expanding on the social and economic cost of marine debris, UNEP (2001) further defines that it can:

- spoil the beauty of the sea and the coastal zone
- interfere with fishing and damage fishing boats and gear
- block cooling water intakes in power stations
- contaminate beaches, commercial harbours and marinas
- injure livestock on coastal grazing land
- interfere with ships, causing accidents at sea
- be a serious hazard to human health, particularly when composed of medical and sanitary waste
- damage local economies by contaminating fish catches and driving away tourists
- cost a significant amount to clean up.

UNEP (2001) also describes the diverse impacts of marine debris on marine flora and fauna, including:

- harm to wildlife directly through entanglement and ingestion – the two main types of direct harm to animals, and the major focus of this report
- smothering of the seabed and habitat disturbance
- as a source of persistent toxic chemical pollution in the ocean – particularly from plastics
- transportation of invasive species between countries, and between seas.

At present, there is little international focus on marine debris in relation to the specific threat that some types of debris pose to animal welfare, which this report seeks to begin to remedy.

1.2
What is animal welfare?

Animal welfare is an area of significant scientific and societal interest. The term refers to the physical and psychological wellbeing of an animal. The welfare of an animal can be described as good or high if the individual is fit, healthy, free from suffering and in a positive state of wellbeing.

The 'five freedoms' provide valuable general guidance on the welfare of an individual animal. The freedoms were first codified in the 1970s by the UK government's Farm Animal Welfare Council (FAWC, 1979).

The five freedoms promote freedom from: hunger, thirst and malnutrition; fear and distress; physical and thermal discomfort; pain, injury and disease; and promote the freedom to express normal patterns of behaviour.

These measures of animal welfare have since been endorsed and expanded on by the World Organisation for Animal Health (OIE) who, in 2008, agreed a definition that an animal can be said to be in a good state of welfare if it is: "healthy, comfortable, well nourished, safe, able to express innate behaviour, and if it is not suffering from unpleasant states such as pain, fear and distress" (OIE, 2010).

Entanglement in, trapping by or ingestion of marine debris clearly has the potential to negatively impact on some or all of the freedoms, leaving the animal in a state of poor welfare. This poor welfare – both physical and psychological – is the subject of this report.

Humpback whale breaching, North Atlantic Ocean

1.3
About this report

This report presents a review of a large body of published literature on marine debris, its impacts on the welfare of animals, and mitigation efforts already in place. The literature reviewed ranges from scientific journals to government papers, reports by non-governmental organisations (NGOs), websites of beach clean-up organisations and presentations given by researchers at conferences on marine debris. This breadth in terms of sources is a strength – it has enabled us to collect information globally, rather than just from the centres of academic research, which tend to cluster in the developed world.

It is important that the findings summarised in this report come from a wide spread of countries and origins, as marine debris is truly an international problem. Many sources describe the extent and spread of debris – particularly of plastics – and a number describe its effects on populations of specific animal groups, such as seals, turtles, whales and birds. But very few make reference to the potential or actual suffering of the animals on which they report; they usually present numeric data on how many are affected without comment on the severity or likely duration of suffering.

1.3 About this report

1.3.1 Limitations of the report

There are clear variations in the geographical spread of research into the impact of marine debris on animals. The Convention on Biological Diversity's 2012 status report (CBD, 2012) highlights and describes this geographical imbalance by noting the number of reports it has reviewed from different regions: Americas (117), Australasia (56), Europe (52), Africa (12), Antarctic (7), Asia (6), and the Arctic (5).

The majority of the literature available on animal entanglement in marine debris discusses the problem with regard to marine mammals, birds and turtles. However, it is also known that many fish and other marine animal species are affected by entanglement/entrapment in debris – particularly in the form of 'ghost fishing' by abandoned, lost or discarded fishing gear. The available literature's focus on quantifying the impacts of marine debris on charismatic megafauna (such as the larger whale species) may be in part due to conservation drivers (for example, in the case of the endangered North Atlantic right whale), as well as a need to demonstrate adherence (or otherwise) to legislation that protects these animals from harm, such as the US Marine Mammal Protection Act. The literature reviewed in this report therefore reflects a tendency for research to focus on the more charismatic marine species. However, this does not mean that marine debris does not also represent a significant welfare problem for fish and other marine animals.

Given the regional and species-based variability in the number of entanglements and ingestion events recorded, it is important to be cautious when scaling up or extrapolating figures on marine debris based animal impacts. Similarly, when considering estimates of the numbers of animals affected, it is important to be aware of the following:

- Estimates based on published reports can reflect only the areas where the reports were carried out; the level of research and interest is not uniformly spread across the globe.

- Estimates of animal entanglement and ingestion generally rely on reports of animals seen alive (or recently deceased), and so are likely to seriously underestimate the scale of the problem. If animals are affected and die unseen (as is likely to be common), then they are not reported. As Cole et al. (2006) state, "Our greatest concern remains the number of animals we never saw … Evidence suggests that only 3 to 10 per cent of entanglements are witnessed and reported."

- Estimates for the number of animals affected at any point in time rely on an understanding of how long the animals in the survey period were likely to be affected. However, this is often not clear, since the time over which an animal is affected is highly variable. Some animals will be affected acutely and very severely, and die after a relatively short period, whereas others – for example, the large baleen whales – may be adversely affected by entanglement for many months or even years.

In combination, these 'estimates of estimates', the inevitably patchy geographical nature of reporting of effects of marine debris on animals, and uncertainty about the duration of the effects of different types of debris on different species, lead to a high degree of uncertainty in estimating overall numbers of animals affected. It is therefore possible that the animal welfare impacts of marine debris are even more significant than existing reports indicate.

Right: Californian sea lion entangled in monofilament gill net, Gulf of California, Mexico

2
How are animals affected by marine debris?

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2
How are animals affected by marine debris?

Not all species of marine animals are equally likely to be affected by entanglement in marine debris. One recent literature review found that entanglement in or ingestion of marine debris affected all known species of sea turtles, about one-half of the species of marine mammals and one-fifth of all species of sea birds (CBD, 2012). In one of the most comprehensive reviews to date of the impacts of marine debris on marine fauna, Laist (1997) estimated that 100,000 marine mammals died every year from entanglement in or ingestion of fishing gear and related marine debris.

Whether entanglement happens, how it takes place and with what debris, how severely, and the outcome for different species will depend on a number of factors. These include the animal's physiology, feeding habits, size, locality, and behaviours, and the types of marine debris found in the animal's environment. Tables 2 and 3 provide an overview of the common types of entanglement and ingestion for some key species (pp. 21 and 27).

Northern gannets breeding on plastic waste, Germany, North Sea


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2.1 Entanglement

Entanglement in marine debris is the cause of widespread animal suffering, resulting in the deaths of at least hundreds of thousands of marine animals and birds each year. Abandoned, lost or discarded fishing gear (including monofilament line, nets and ropes), as well as other ropes, netting and plastic packaging, can be a cause of entanglement for fish, turtles, birds and marine mammals. One hundred and thirty-six marine species have been reported entangled, including six species of sea turtles, 51 species of seabirds and 32 species of marine mammals (Marine Mammal Commission, 1996).

The way in which a marine animal is entangled and the type of debris involved varies by species, largely according to the animal's body shape and behaviours. For example, young seals may accidentally put their heads through plastic, rope or monofilament loops, which then become firmly fixed onto the neck or around the body close to the forelimb flipper. On the other hand, baleen whales and turtles may swim through a section of ghost fishing line or net that initially becomes snagged around the mouth, flippers or (in the case of whales) fluke, and may subsequently become wrapped around the whole body. Meanwhile, birds may ingest baited hooks and lines and become entangled in the portion of the line that remains outside the body.

Entanglement may be acute, causing an immediate and severe welfare problem such as asphyxiation through drowning, or chronic, where the welfare impacts may increase over time.

The effects of chronic entanglement are varied. Debris may restrict feeding to the point of starvation. It can create large energetic burdens through additional drag, restrict movement, and may ultimately exhaust or drown the animal. Rope and line ligatures can cause amputation or wounds that leave sites open to infection, further reducing the likelihood of survival. Loops cut into the skin, muscle and sometimes even bone as the animal grows. The constriction can become severe enough to sever arteries and finally cause strangulation. Plastic is so durable in the marine environment that when an entangled animal dies, the debris may return to the sea with the potential to entangle another animal.

The following sections describe in more detail the impacts of entanglement in marine debris on different species groups.

2.1 Entanglement

2.1.1 Pinnipeds

Animals affected

A large number of seal and sea lion species have been recorded as entangled, and the available literature reflects the global nature of this problem. Entanglement has been noted in 58 per cent of all species of seals and sea lions (Boland & Donohue, 2003). Some regions report a particularly wide range of species affected. For example, one study found that of the pinniped species found around the coast of British Columbia, northern elephant seals, Steller sea lions and harbour seals are all known to become entangled, as well as sea otters and a large number of cetacean species (Williams et al., 2011). However, it is important to acknowledge that observer effort and reporting in this region appears relatively high compared with many other parts of the world.

From the literature reviewed, the global entanglement incidence rate for seal and sea lion species is estimated at 0.001–5 per cent of the population (see Table 2, p.21), with the exception of particularly high levels of up to 7.9 per cent for California sea lions in Mexico (Harcourt et al., 1994). Another study on northern fur seals in the Bering Sea estimated that 40,000 seals a year were being killed by plastic entanglement (Derraik, 2002). The incidence rates of entanglement already observed suggest that the number of animals affected may be significant. Harcourt et al. point out that most entanglement incidence rates are likely to be conservative because they only register animals on shore, and do not account for those that die and remain at sea.

Causes and welfare impacts

Pinniped entanglement usually involves a ring of packing strap, rope, fishing net or monofilament line forming a collar around the neck or a flipper, which the animal is unable to remove. The loop effectively tightens as the animal grows or, if the animal is adult, the loop cuts into the tissues and becomes firmly embedded in skin, muscle and fat. The level of risk to seals posed by a piece of looped material depends on the size of the loop, the material in question and how attractive the item appears to a playful and inquisitive animal. Indeed, the majority of seal entanglements seem to involve young animals, which is likely to be because they are curious or even simply naïve feeders.

Entangled pinnipeds need to increase their metabolism to compensate for increased drag during swimming (Boland & Donohue, 2003). For northern fur seals, it is estimated that dragging a net weighing more than 200g could cause a four-fold increase in the quantity of food needed (Derraik, 2002). Taking into consideration the number of seals affected, and the chronic long-term discomfort, pain and infection caused, it is evident that plastic debris collars represent a significant welfare impact.

The following sections include examples of ‘internal entanglement’, where pinnipeds such as Steller sea lions in Alaska and British Columbia ingest fishing gear with hooks or flashers that can lodge, with part of the gear inside the animal and part remaining in the mouth. This can physically damage the mouth and lower digestive system, as well as reducing the animal’s capacity to forage and feed effectively.

Table 2: Overview of literature containing data on the entanglement of pinnipeds

Species/ Sub-species	Region (FAO statistical areas [FAO 2012])	Entanglement rate (incidence in population, %)	Types of debris (%)			Mortality estimate (%)*	Source
			Plastic	Net	Fishing Line		
Kaikoura fur seal	South West Pacific	0.6-2.8	31	42			Boren et al. (2006)
Australian fur seal	Eastern Indian Ocean	1.9	30	40		73	Pemberton et al. (1992)
New Zealand fur seal	Eastern Indian Ocean	0.9	30	29	3	57	Page et al. (2004)
Australian sea lion	Eastern Indian Ocean	1.3	11	66	6	44	Page et al. (2004)
Antarctic & Sub-Antarctic fur seal	Western Indian Ocean	0.24	41	17	c. 10		Hofmeyr et al. (2002)
Antarctic fur seal	South East Atlantic	0.024-0.059	18	48		50	Hofmeyr et al. (2006)
Antarctic fur seal	South West Atlantic	0.4	46-52			80	Arnould & Croxall (1995)
Cape fur seal	South East Atlantic	0.1-0.6	50				Shaughnessy (1980)
Californian sea lion	Eastern Central Pacific	3.9-7.9		50	33		Harcourt et al. (1994)
Hawaiian monk seal	Eastern Central Pacific	0.7	8	32	28	16	Henderson (2001)
Steller sea lion	North East Pacific	0.26	54	7	2		Raum-Sayuran et al. (2009)
California sea lion	Eastern Central Pacific	0.08-0.22	25	19	14		Stewart & Yochem (1987)
Northern elephant seal	Eastern Central Pacific	0.15	36	19	33		Stewart & Yochem (1987)
Harbour seal	Eastern Central Pacific	0.09	33				Stewart & Yochem (1987)
Northern fur seal	Eastern Central Pacific	0.24		50			Stewart & Yochem (1987)
Steller sea lion	Eastern Central Pacific		0	4	4	23	Hanni & Pyle (2000)
Northern fur seal	North East Pacific	0.40	19	65		61	Fowler (1987)
Northern fur seal	North East Pacific	0.08-0.35	37	39	9		Zavadil et al. (2007)
Grey seal	North West Atlantic	3.1-5				64	Allen et al. (2012)
Southern elephant seal	South West Atlantic	0.001-0.002	c. 36		c. 64	28	Campagna et al. (2007)

* Percentage of entangled animals estimated to be killed by their entanglement

2.1 Entanglement

Monk seals

The Hawaiian monk seal is a critically endangered species, with breeding colonies limited to six small islands and atolls in the north-western Hawaiian Islands. From 1982 to 1998, the entanglement incidence rate rose from 0.18 per cent to 0.85 per cent (Donohue et al., 2001). To help solve the problem of entanglement in monk seals, a multi-agency effort was funded between 1996 and 2000 to remove derelict fishing gear from the reefs of the north-western Hawaiian Islands and reefs and areas close to breeding sites were cleaned (Boland & Donohue, 2003). By 2003, a total of 195 tonnes of derelict fishing gear had been removed from this area.

Entanglement rates can also be influenced by weather changes and storms. One study (Donohue & Foley, 2007) highlights the impact of these factors on monk seal entanglement in the North Pacific Ocean. It shows that for the 23 years recorded up to 2007, entanglement rates were elevated during periods characterised by the changes in weather and ocean flows associated with El Niño. It proposes that weather and the physical oceanographic processes linked with this recurrent climate pattern contribute to changes in entanglement incidence rates.

An earlier report (Karamanlidis, 2000) found that entanglement in static fishing gear and abandoned nets had an effect on the population of critically endangered monk seals in the Mediterranean, and argued that the widespread use of gill nets has threatened the small surviving monk seal colony in the Desertas Islands of Madeira.

Sea lions

In Australia, an estimated 1,500 pinnipeds (mostly sea lions) die annually from entanglement, mostly as a result of being trapped in monofilament gill nets from the shark fishery that operates in the area where the sea lions forage (Page et al., 2003). The California sea lion population extends from British Columbia to Mazatlan in Mexico, and includes the Gulf of California. The sea lion population in the Mexican region has been estimated at 74,467 along the Pacific coast and 28,220 in the Gulf of California. Annual entanglement rates in the Gulf ranged up to 2.24 per cent (Zavala-González & Mellink, 1997), whilst very high entanglement rates of up to 7.9 per cent were reported in studies in the Baja California region (Harcourt et al., 1994). A more recent study commissioned by the National Oceanic and Atmospheric Administration (NOAA) found that packing bands cause more than 50 per cent of neck entanglements of Steller sea lions in Alaska (NOAA, 2012a).

In a survey of 386 Steller sea lions entangled in Southeast Alaska and northern British Columbia, Raum-Suryan et al. (2009) looked at causes of entanglement. The most common neck-entangling material was packing bands (54 per cent), followed by large rubber bands (rubber packing bands) (30 per cent), net (7 per cent), rope (7 per cent) and monofilament line (2 per cent). The entanglement incidence rate in the population was 0.26 per cent. Examples of ingested entangling fishing gear in these animals included salmon fishery flashers (80 per cent of which were lures), longline gear (12 per cent), hook and line (4 per cent), spinners or spoons (2 per cent) and bait hooks (2 per cent). Local campaigns to ‘Lose the loop!’ promoted simple procedures, such as cutting entangling loops of synthetic material and eliminating packing bands to help prevent entanglements.

A further study, which described bird and pinniped entanglement cases in California during a six-year study period, found that 1,090 (11.3 per cent) of entanglements were related to fishing gear. The highest prevalence of fishing gear-related injury in pinnipeds was seen in the San Diego region (Dau et al., 2009).

Fur seals

In a 10-year study at Marion Island in the Southern Ocean, Hofmeyr et al. (2002) recorded 101 fur seals and five southern elephant seals entangled in debris, and estimated that 0.24 per cent of the populations of fur seals were entangled annually. The study described how 67 per cent of materials causing entanglement originated from the fishing industry; polypropylene packaging straps were the most common cause, followed by trawl netting. Longline hooks embedded in animals and fishing line only started to be encountered after the start of longline fishing in the waters around Marion Island in 1996. In New Zealand, fur seals are most commonly entangled in loops of packing tape and trawl net fragments suspected to derive from rock lobster and trawl fisheries (Page et al., 2004).

In the Antarctic, the entanglement of Antarctic fur seals halved over a five-year period (1990–1994) after the International Convention for the Prevention of Pollution from Ships (MARPOL) introduced Annex V (Regulations for the Prevention of Pollution by Garbage from Ships). However, polypropylene packing straps, fishing net fragments and synthetic string were still found to be common debris items entangling seals in all years (Arnould & Croxall, 1995).

Shaughnessy (1980) describes the number of Cape fur seals recorded as entangled in several colonies between 1972 and 1979. Most of the entangling objects were found around the seals' necks. The highest incidence among seals was recorded at the Cape Cross colony, at 0.56–0.66 per cent between 1977 and 1979. The entanglements were caused by string, monofilament line, fishing net, rope, plastic straps, rubber O-rings and wire.

In a study of fur seals in South Georgia in the Southern Ocean, Croxall et al. (2006) reported several thousand Antarctic fur seals being entangled, mainly in derelict fishing gear. The rate of entanglement in the population was calculated to be 0.4 per cent and it was estimated that up to 15,000 seals could be entangled each year, of which 5,700 would be expected to die as a consequence.

Another study looked at the entanglement of Australian sea lions and New Zealand fur seals in lost fishing gear and other marine debris, both before and after government and industry attempts to reduce the problem (Page et al., 2004). In 2002, the Australian sea lion entanglement rate was at 1.3 per cent – which according to the authors was the third highest reported for any seal species. The authors concluded that rates had in fact not declined in response to government mitigation efforts. Australian sea lions were most frequently entangled in monofilament gill nets, most probably originating from the shark fishery.

In the Kaikoura region of New Zealand, fur seals breed near a town with expanding tourist and fishing industries. They commonly become entangled in nets and plastic debris. The entanglement rates of seals in the Kaikoura region are listed as being in the range of 0.6–2.8 per cent; the most common causes are green trawl net (42 per cent) and plastic strapping tape (31 per cent) (Boren et al., 2006). Nearly half of the entangled seals were successfully treated and released (43 per cent). Post-release monitoring showed that with appropriate intervention there was a strong likelihood that an animal would survive, even with a significant entanglement wound (Boren et al., 2006).

On St Paul Island, in the Alaskan Pribilof Islands, northern fur seals have been documented with various objects caught around their necks, shoulders and, less frequently, flippers (Fowler, 1987). The incidence of entanglement observed among sub-adult males at that time was about 0.4 per cent; almost all resulted from trawl netting and plastic packing bands. Entanglement involved both sexes and more commonly affected young animals, which were sometimes observed entangled in groups attached to the same large items of debris. On nearby St George Island, nearly 20 years later, Zavadil et al. (2007) observed the entanglement of northern fur seals to consist primarily of net, plastic packing bands and line related to the fishing industry. They estimated a mean entanglement rate of 0.06–0.08 per cent for pups, with a maximum rate of up to 0.11 per cent in October before weaning. The 2005/06 rate for juvenile male entanglement was particularly high, at between 0.15 and 0.35 per cent.

On south-east Farallon Island, north California, 914 pinnipeds (California sea lions, northern elephant seals, Steller sea lions, Pacific harbour seals and northern fur seals) were recorded as being entangled between 1976 and 1998 (Hanni & Pyle, 2000). The most common entangling materials were monofilament line and net, trawl (heavy fishnet material), unknown net material, salmon fishing lure and lines, fish hooks and lines, packing straps, other miscellaneous marine debris, and ‘constriction’ (where no material was observed but a circular indentation was present around the head, neck or torso, the encircling material presumably deeply embedded in the tissues).

Grey seals and common seals

Allen et al. (2012) describe the entanglement rates of grey seals in Cornwall, UK, with a range from 5 per cent in 2004 to 3.1 per cent in 2011. Entangled seals account for 8.7 per cent of the seals on the Cornish photo ID database (as of the end of 2011). Of the 58 seals identified, 37 (64 per cent) had injuries that were causing a constriction, had formed an open wound, or both. The authors note that one impact of entanglement that may be overlooked is the effect on animal welfare of the increased drag caused by trailing material and the increased foraging times needed to meet raised metabolic demands.

In a study of entanglement on the Dutch coast between 1985 and 2010, entanglement was more prevalent in grey seals than common seals (39 versus 15 respectively). For both species, a slight (non-significant) majority of the entangled seals were males, with entanglements most frequently found in juveniles (Hazekamp et al., 2010). Seals were entangled in pieces of ghost trawl nets and gill nets. The authors suggest that the numbers found were likely to be just a fraction of the true extent of morbidity and mortality due to the probable low rate of recovery of stranded animals when compared to those lost at sea.

Elephant seals

In southern elephant seals, signs of entanglement include fresh wounds around the neck caused by monofilament lines (Campagna et al., 2007). The elephant seals were caught, when possible, to remove the material. In every case, the material removed was a monofilament line, 1.3–1.5 mm thick, typically tied in a circle with a knot. In some animals, the line had jigs attached (coloured lures armed with a crown of hooks) – gear typically used by squid fisheries. Observations of three to five new entangled animals per breeding season indicated that the rate of incidence of entanglement could be as low as 0.001 per cent. However, this was likely to be an underestimate, since observations took place during a period when juveniles – the most affected group – were not present.

The study highlighted that entanglements can turn into chronic wounds that often bleed and become infected, with debilitating consequences. Judging from the depth of the wounds, entangled seals can live for years with a line cutting the skin and muscles of the neck. The wounds limit the movement of the neck and rest of the body, and can impair diving ability (Campagna et al., 2007).

Entangled grey seal, Cornwall, UK

2.1.2 Cetaceans

Animals affected
Whales, dolphins and porpoises of all sizes can become entangled in and killed by fishing gear, floating rope, ghost nets and lines attached to pots and creels, though the problem is more widely reported for large whales. As with the findings for pinnipeds, the reviewed literature (see summary in Table 3, p. 27) shows that entanglement affects cetaceans all over the world. Coastal species of cetaceans appear particularly vulnerable as their habitats are affected by human activities – notably, fisheries. The large whales most commonly recorded as being entangled are the North Atlantic right whale and the humpback whale. However, observer effort and monitoring of affected species has tended to focus on those populations that are threatened with extinction due to entanglement, such as the North Atlantic right whale.

Scar-based studies suggest that non-lethal entanglements are extremely common in some species of large whales. Observation shows that about one-half (48–65 per cent) of Gulf of Maine humpback whales have been entangled at least once in their lifetime, while 8–25 per cent sustain new injuries each year (Robbins, 2009). However, humpback whale scar evidence suggests that only 3–10 per cent of entanglements are witnessed and reported (Robbins & Mattila, 2000, 2004). This indicates that, like other species, whales may succumb to entanglement and sink after death, before the event can be detected.

Reports also exist of small cetacean entanglements in ghost fishing gear. For example, in April 2002, 35 harbour porpoises were entangled in 30.2km of abandoned gill and trammel nets off the coast of Romania. In the Atlantic pelagic longline fishery, pilot whales interact with fishery operations; in the Pacific, false killer whales interact with the Hawaii-based pelagic longline fishery. Of the species found around the coast of British Columbia, those that are known to become entangled are the harbour porpoise, Dall's porpoise, Pacific white-sided dolphin, minke whale, humpback whale, fin whale, and orca (Williams et al., 2011).

By-catch or debris?
It may be questioned whether an animal has been caught in active fishing gear ('by-catch') or ghost gear or debris. Because of their size and mass, the larger whales may be able to break away from an anchoring entanglement in fixed fishing lines and gear, but may then remain entangled in thin but strong ropes, net and lines – effectively having turned active, human-controlled fishing gear into marine debris. Cetaceans may also become entangled in ghost gear – that is, gear that has been abandoned, lost or discarded.

Causes
Cetaceans may become entangled in a range of different gear types. Johnson et al. (2005) studied the entanglements of 31 right whales and 30 humpback whales to assess the types and parts of fishing gear involved. They found that 81 per cent involved entanglements in buoy lines or groundlines from pots. Other materials known to cause entanglements include: rope, traps and floats from fixed gear – especially lobster pots – as well as gill nets, monofilament line, hook and line gear, and mobile trawl nets (Moore et al., 2006).

Commercial fishing ropes of all diameters and breaking strengths can lead to severe injuries for whales, according to the Consortium for Wildlife Bycatch Reduction. Its study observed younger right whales entangled in ropes of lower breaking strength, with adults entangled in ropes of higher breaking strength. However, this trend applied only to the observed cases – as with other studies, animals that were not observed may have died. The study suggests that to lessen the severity of entanglements in juvenile whales, rope-breaking strength would need to be reduced to less than 1,000lbs (450kg). However, this strength is not considered a realistic option for some fishing gear and boat rigging (Werner, 2011).

Welfare impacts

In some cases of acute entanglement, death will be relatively rapid (taking place over a number of minutes or hours), usually when asphyxiation prevents the animal from resurfacing. If the animal can surface but remains anchored to the gear, it may be unable to move to feed, or to defend itself from predators, causing death within hours or days. In a study of baleen whales in the north-western Atlantic, Cassoff et al. (2011) describe acute cases of drowning from entanglement involving multiple body parts. They also describe the more protracted causes of death caused by chronic entanglement, resulting in poor welfare and death caused by impaired foraging (resulting in starvation) and systemic infection arising from open open entanglement wounds. Other whales experienced haemorrhage or debilitation due to severe damage to tissues, including laceration of large blood vessels and rope and line being embedded into growing bone. The study also found massive periosteal proliferation of new bone in an attempt to wall off constricting, encircling lines. In one entangled and growing whale, the radius bone in the flipper (incised by an entangling line) grew in such a way that it was notched by encircling rope (Moore et al., 2006). In another case, a simple loop of line cutting into the peduncle lacerated two superficial veins. In cases of chronic entanglement, death may take many months or even years (Moore et al., 2005).

In baleen whales, entanglement can involve the rostrum, baleen, flipper and peduncle (Moore et al., 2006). Oral entanglement (a common site of entanglement in baleen whales) may have a significant impact on the animal's hydrostatic oral seal – a critical adaptation that enables the whale to seal and close its mouth with little or no effort by the craniomandibular muscles, even when swimming (Lambertsen et al., 2005). If the seal and the ability to fully close the mouth is compromised by entanglement with rope, the animal's capability to effectively dive, feed, and breed are severely affected, leading to depletion of energy reserves, reproductive failure, and death.

Entanglement can also cause hormonal changes. A whale's physiological response to tissue damage includes increased secretion of glucocorticoids. This suppresses lymphocytes and, if sustained (due to chronic destruction of tissue by gear), compromises the animal's ability to fight other infections. Loosely wrapped gear does not appear to elicit as much stress, and some whales have been found to carry loose wraps for years (Cole et al., 2006).

Table 3: Overview of literature containing data on entanglement of cetaceans

Species/ Sub-species	Region (FAO statistical areas [FAO 2012])	Entanglement rate (% become entangled each year)	Entanglement rate (by animal or by % of population observed with entanglement scars)	Types of debris (%)		Mortality estimate (%)*	Source
				Fishing pot gear	Net (derelict)		
Humpback whale	Western Central Atlantic			41	50	10	Johnson et al. (2005)
Humpback whale	North West Atlantic	2.4	17 whales become entangled each year			26	Cole et al. (2006)
Humpback whale	North West Atlantic	8-10.4	48-57				Robbins & Mattila (2004)
Humpback whale	North East Pacific	8	52-78				Neilson et al. (2007)
Western grey whale	North West Pacific		18.7				Bradford et al. (2009)
Minke whale	North East Atlantic		5-22				Northridge et al. (2010)
Minke whale	North West Pacific			31	69	0.9	Song et al. (2010)
Minke whale	North West Atlantic	2.6	7 whales per year			37	Cole et al. (2006)
North Atlantic right whale	North West Atlantic		57	25	67	12	Kraus (1990)
North Atlantic right whale	North & Central West Atlantic	1.6 (2 from IWC 2010 population estimate of 300)	6 whales per year			27	Cole et al. (2006)
North Atlantic right whale	North & Central West Atlantic	1.15 (IWC 2010 population estimate: 300)		71	14	29	Johnson et al. (2005)
Fin whale	North East Atlantic		5				Sadove & Morreale (1990)
Fin whale	North West Atlantic	0.8	2 whales per year			44	Cole et al. (2006)
Blue whale	North West Atlantic		<1 whale per year				Cole et al. (2006)
Bryde's whale	North West Atlantic	0.2	<1 whale per year				Cole et al. (2006)

* Percentage of entangled animals estimated to be killed by their entanglement

Right whales

The North Atlantic right whale has an estimated population of only 400 in the western North Atlantic. The apparent failure of the population to recover has in part been attributed to mortality from collisions with ships and entanglements in fixed fishing gear (Kraus, 2008). One study, which summarised necropsy reports for lethally entangled western North Atlantic right whales over a 30-year period, found that every single whale examined had sustained entanglement and fishing gear wounds (Moore et al., 2005). In one case, fishing line had entangled the flippers and had cut through all of the soft tissues, embedding several centimetres into the bone. In another case, line had become anchored to both flippers and had cut a 1.5m-wide section of blubber from across the dorsum. Johnson et al. (2005) found that, for right whales, the most common point of gear attachment was the mouth (77.4 per cent). The average time to death is estimated at 5.6 months (Moore et al., 2006), but some whales with potentially fatal entanglement injuries have survived considerably longer – up to 1.5 years (Knowlton & Kraus, 2001).

Humpback whales

In 2006, Neilson assessed the prevalence of non-lethal entanglements of humpback whales in fishing gear in the northern part of south-eastern Alaska. The study, using a scar-based method, found that 52–78 per cent of whales had become entangled. In Glacier Bay or Icy Strait, 8 per cent of the whales acquired new entanglement scars each year, and males seemed to be at higher risk than females. Calves were less likely to have entanglement scars than older whales, perhaps because young animals are more likely to die from entanglement than to survive and show scars. According to Johnson et al. (2005), common points for gear attachment in humpback whales are the tail (53 per cent) and the mouth (43 per cent).

Humpback whales also become entangled in Canadian and US Atlantic waters (Robbins & Mattila, 2001), with 48–65 per cent of the whales photographed every year bearing some evidence of previous entanglement.

About 12 per cent of the humpback whales in the Gulf of Maine appear to become non-lethally entangled, and on average 19–29 humpback whales may die as a result of entanglement annually, affecting 2–5 per cent of the local population (Robbins, 2009).

In northern Southeast Alaska, caudal peduncle scars reveal that the majority of humpback whales have been entangled, with the lowest scarring percentage (17 per cent) being in calves (Neilson et al., 2009). Neilson suggests that calves and juveniles have a higher mortality rate from entanglement than adult whales for two reasons. Firstly, because they are growing, gear is more likely to become embedded and lead to lethal infections or restricted circulation. Secondly, because of their smaller size, calves and juveniles may not have the strength necessary to break free from entangling gear.

False killer whales

False killer whales interact with the Hawaii tuna and swordfish longline fishery in offshore Hawaiian waters. In an examination of the rate of dorsal fin disfigurements of false killer whales (2000–2004), 80 distinctive individuals were photographically documented. Of these, 3.75 per cent had major dorsal fin disfigurements apparently caused by entanglement (Neilson et al., 2009).

Bottlenose dolphins

One study describes observations of a bottlenose dolphin calf becoming entangled in monofilament line during a play bout with another juvenile (Mann et al., 1995). For about 90 minutes, the mother and calf leapt and travelled rapidly. The following day, the calf was seen again, no longer entangled, although she had some small lacerations, which developed into permanent scarring on the anterior edge of her dorsal fin. More recent studies on entangled bottlenose dolphins have shown that some newly developed (and very abrasive) fishing lines cut deep wounds into their tissues (Barco et al., 2010).

Minke whales

A study of the entanglement of minke whales in the East Sea of Korea found a total of 214 incidences between 2004 and 2007 (Song et al., 2010). Two hundred and seven of these (96.7 per cent) were caused by fishing gear such as set nets, pots, and gill nets. The others were associated with bottom trawls, purse seines and trawls. The most common body part to become entangled was the mouth (in 63 cases – 30.4 per cent).

According to Northridge et al. (2010), entanglement in fishing gear, primarily creel lines, is the most frequently documented cause of mortality in minke whales in Scottish and UK waters. The same study asserts that roughly one-half of all examined dead baleen whales from Scotland are thought to have died due to entanglement.

Of animals photographed off the island of Mull, as many as 22 per cent of the minke whales bear some scar evidence of previous entanglement (Gill et al., 2000). Gill also reports on two whales, photographed in May 1997 and May 1999, which had plastic packing straps wrapped around their rostrums, apparently cutting into the skin. In 1999, another whale was photographed with a white scar thought to be caused by a packing strip or twine.

2.1.3 Turtles

In Cape Arnhem, northern Australia, 29 dead turtles were found in ghost fishing nets over a four-month period. The threat to marine turtles posed by fishing debris is thought to be equivalent to that posed by active fishing efforts prior to the introduction of turtle exclusion devices in the region (Kiessling, 2003).

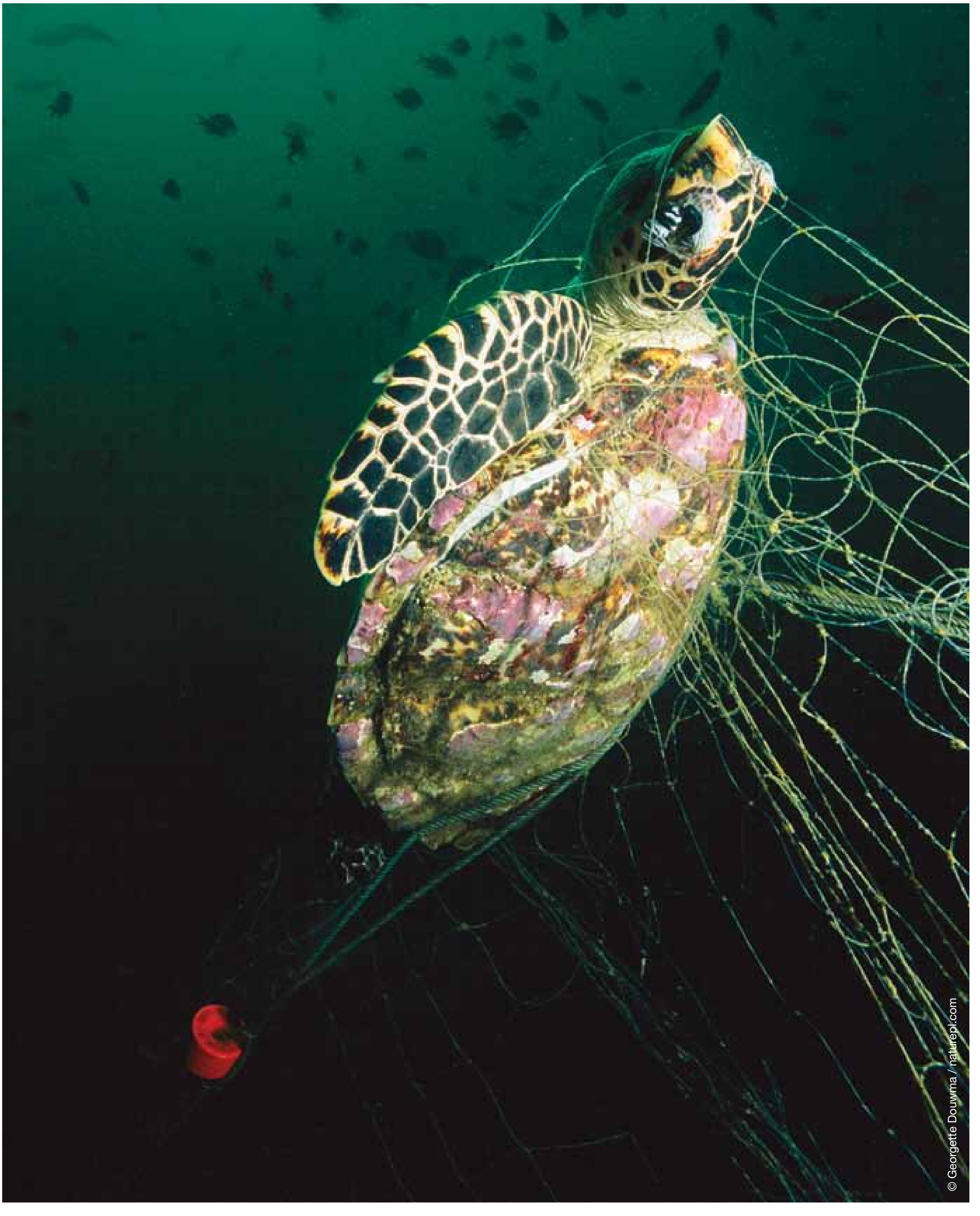
In the Canary Islands, between January 1998 and December 2001, 88 loggerhead, three green, and two leatherback sea turtles were studied postmortem; 69.89 per cent appeared to have died from human-induced causes. These included boat-strike injuries (23.66 per cent), entanglement in derelict fishing nets (24.73 per cent), ingestion of hooks and monofilament lines (19.35 per cent), and crude oil ingestion (2.15 per cent). Skin lesions with ulceration were the most common gross lesions caused by entanglement. In 10.75 per cent of the studied animals, necrotising myositis (death of local areas of muscle) had been caused by entanglement in fishing nets, and in 25.81 per cent of animals either one or two flippers had been amputated through entanglement in netting (Orós et al., 2005).

2.1.4 Sharks

Entanglement in lines and net can have serious welfare impacts on sharks. Wegner and Cartamil (2012) report a mature male shortfin mako shark that was captured with a three-strand twisted natural-fibre rope wrapped around its body, causing deep abrasions, scoliosis (twisting) of the back and undernourishment. Barnacle growth suggested that the rope had been around it for at least 150 days. An earlier study on the effects of plastic debris on sharks in the KwaZulu Natal area of South Africa found that of 28,687 large sharks caught between 1978 and 2000 in the shark-attack nets that protect swimming beaches, 53 (0.18 per cent of the catch) had polypropylene strapping bands around the body (Cliff et al., 2002). The most frequently entangled species was the dusky shark, comprising 0.47 per cent of the species catch. Of those whose stomach contents were recorded, 60 (0.38 per cent) had ingested plastic debris.

Another study (Sazima et al., 2002) necropsied three juvenile Brazilian sharpnose sharks from south-east Brazil. All three had plastic gill net collars which had caused severe cutting trauma to their tissues as they grew. This was thought to have hampered normal feeding and/or ventilation, since two of the collared individuals were emaciated. The plastic rings were identified as lid parts from plastic bottles, suggesting that the impact of discarded plastic debris is likely to be greater on sharks which inhabit shallow coastal waters. As with pinnipeds and cetaceans, a plastic collar around a shark's gill slits or body can cause traumatic cutting into tissue and chronic infection, and may compromise its ability to feed and to grow. The number of sharks that become entangled and die undetected could be much greater than those reported since they will invariably die at sea and very likely be rapidly consumed.

2.1
Entanglement



Young hawksbill turtle (deceased) entangled in fishing net, Andaman Sea, Thailand

2.1.5 Sirenia

For manatees, entanglement usually involves monofilament line wrapped around one or both pectoral flippers. The line incises the tissues of the flipper root, which can cause partial or complete amputation. Some manatees survive with a compromised ability to swim, while others succumb to infection. Crab traps represent a particular hazard to manatees, which feed in the waters where the buoy lines run between the traps and the surface.

Manatees in Florida have been observed with scars and missing flippers – the consequences of entanglement. In one study in the southern USA, of 940 carcasses recovered 1.7 per cent had flippers that were scarred, missing or entangled in monofilament line, rope or crab trap lines. In 1.2 per cent of the cases, entanglement in line or netting was identified as the cause of death (Laist, 1997). Less commonly, manatees have been found with rope tangled around the pectoral flippers and cranial thoracic region. Ingestion of plastic material, found in the stomach and intestines, is also a problem and can cause death (Attademo et al., 2008).

Dugongs are also known to be victims of entanglement in the Asia-Pacific region – the Australian government states that entanglement in net fragments (in particular gill nets) are a key threat. Incidents involving entanglement in plastic debris were recorded for 56 dugongs between 1996 and 2007. Of these, only one dugong was recorded as having been freed and released alive, while 14 died and the fate of 41 individuals was not reported (Ceccarelli, 2009).

2.1.6 Birds

Birds that become compromised by entanglement in marine debris may not be able to dive, nest or fly and may suffer from incisions into their limbs by rope, line or plastic, potentially leading to infection or eventual amputation.

More than 1 million birds are estimated to die each year from entanglement in or ingestion of plastics (Laist, 1997). However, the impacts of entanglement in marine debris at a species level are not very clear because for most seabird species – particularly procellariiform seabirds, penguins, grebes and loons – there is only patchy information, and reports of rates of entanglement and ingestion are infrequent. The species most commonly reported as entangled include the northern fulmar, horned puffin, greater shearwater, sooty shearwater, common guillemot and laysan albatross (CBD, 2012).

In a study on efforts to remove derelict nets, Good et al. (2009) report that more than 1,200 derelict fishing nets have been recovered from areas throughout Puget Sound and the Northwest Straits, United States. Of the 870 gill nets recovered, 50 per cent had been derelict for at least one year, but many that seemed much older were still entangling birds. Of the marine organisms recovered from these ghost gill nets, 514 were marine birds, representing at least 15 species – all of which were recovered dead. Overall, dead marine birds occurred in 14 per cent of recovered gill nets.

In April 2010, a paper was presented to the meeting of the Agreement on Conservation of Albatrosses and Petrels held in Argentina. It indicated that the widespread adoption of a new longline fishing system (known as the Chilean mixed system) has caused a significant increase in the number of albatrosses affected by multifilament snood (gangion) entanglement. Meanwhile, a report on mortality rates among cormorants by the Northwest Straits Initiative (2008) shows that hooked lines from fishery caught about one cormorant every four days, resulting in death.

The situation is compounded by the fact that northern gannets and other seabirds incorporate marine debris into their nests, which can result in entanglement. A study by Votier et al. (2011) found that the proportion

of nests that incorporated marine debris decreased following the fishery closure, and that the proportion of nests incorporating fishing gear was related exponentially to the number of gill nets set around breeding colonies. On average, the gannet nests contained 469.91g (range 0–1293g) of plastic, equating to an estimated colony total of 18.46 tonnes (range 4.47–42.34 tonnes) of plastic material. The majority of nesting material was synthetic rope, which the cormorants seemed to prefer. On average 62.85 (with range of 33–109) birds were entangled each year, with a total of 525 individuals seen entangled over eight years – mostly nestlings. Anecdotal evidence and grey literature suggests that other bird species are also using large quantities of plastic in their nests. This is a very recent development, and one that is costing a significant numbers of birds their lives through entanglement.

A paper from the Common Wadden Sea Secretariat (cited in OSPAR, 2009) showed that nylon fishing lines, ropes and lines, and pieces of fishing nets were the most common litter items. It reported that 48 per cent of beached birds were entangled in line or rope, 39 per cent in nets and 7 per cent with fishing hooks. Meanwhile in California, of 9,668 brown pelican, gull, and pinniped entanglement cases recorded during a six-year study period (2001–2006), 1,090 (11.3 per cent) were fishing gear related. The highest prevalence of fishing gear-related injury in gulls was documented in the Los Angeles/Orange County region (16.1 per cent).

Of the literature reviewed for this report, most relating to the entanglement of birds cited fishing debris as the major cause. However, UNEP (2001) states that many birds, such as gulls and cormorants, are entangled in six-pack rings and other encircling pieces of litter.


© David Cayless / Marine Photobank

Lesser black backed gull (deceased) entangled in plastic ring, Isles of Scilly, UK

2.2
Ingestion

Some marine animals will eat marine debris, either intentionally, or sometimes, it is believed, because they mistake it for food. The effects of the ingested debris will depend on the size, shape and volume of the material, relative to the animal. This report focuses on debris ingestion that clearly and immediately causes a welfare problem through asphyxiation or starvation, such as turtles ingesting plastic bags. It also considers cases where there is clear evidence that the volume of debris consumed has resulted in compromised animal welfare – for example, if the stomach is perforated or if digestion is prevented, leading to starvation.

Some literature – for example, that with reference to deep-diving beaked whales – cites animals having ingested a small volume of debris relative to their size, but is unable to ascertain whether the debris has definitely caused a welfare problem or death. It is widely acknowledged that ingesting small volumes of debris and/or microplastic particles may carry as-yet unknown risks to the animal's welfare. For example, Mato et al. (2001) note that plastic marine debris may contain toxic chemicals such as polychlorinated biphenyls, which might act as endocrine disruptors or may even cause infertility in some species. However, in this report we focus on ingestion events where the poor welfare outcome can be clearly described.

Once ingested, plastic materials are not digested, and can cause obstruction of the stomach or intestine, or take up valuable space in the gut. This can reduce the area available for food and reduce absorption, or may cause inflammation and ulceration of the gut. Eating plastic waste may also alter the buoyancy of the animal, making diving more difficult (Beck & Barros, 1991; Bjorndal et al., 1994; Sloan et al., 1998).

Ingestion of plastic is a welfare problem for a wide range of marine animals, with different species ingesting different sorts of debris. For example, sea turtles may confuse plastic bags for jellyfish, while birds may confuse scraps of plastic bag for fish or other prey. Fish are also known to eat plastic pellets (Derraik, 2002; Gregory, 2009).

2.2 Ingestion

2.2.1 Cetaceans

Filter-feeding baleen whales can ingest marine debris as they feed, while the toothed whales and dolphins can ingest plastic and other waste either in play or exploration, or as part of feeding behaviours. Jacobsen et al. (2010) discuss the cases of two male sperm whales that were stranded along the northern California coast with large amounts of fishing net scraps, rope and other plastic debris in their stomachs. One animal had a ruptured stomach, while the other was emaciated and in poor condition. The suspected cause of death in both cases was impaction of the stomach. At necropsy, 134 different types of net pieces were found in just these two animals, all made of floating material and varying in size from 10 sq cm to about 16 sq m. The authors suggest that the variability in size and age of the pieces indicates that the ingested material was from the surface, rather than bitten off from active fishing gear. The strandings indicate that ingesting marine debris can be fatal to large whales, alongside the more commonly discussed entanglements that are known to impact these species.

Gomerčić et al. (2009) carried out a study into the link between gill net parts and larynx strangulation in bottlenose dolphins. Of 120 dead stranded bottlenose dolphins found along the Croatian coast of the Adriatic Sea from 1990 to March 2008, 12 (10 per cent) had been affected by larynx strangulation with gill net parts. The larynx of all the affected animals showed some or all of the following: oedema (fluid swelling), mucosal injury, and hypergranulation (thickening). Larynx strangulations were found only in adult animals, and in most cases there was evidence that the injury was a chronic condition.

Ten years earlier a study described the post-mortem findings of a Blainville's beaked whale washed ashore in Brazil (Secchi & Zarzur, 1999). The post-mortem revealed a bundle of plastic threads occupying a large part of the main stomach chamber (35 cm^3 in terms of displaced liquid). The authors conclude that this obstruction had prevented the whale from holding food in the stomach, which may have contributed to the animal's death.

Again in Brazil, an adult male rough-toothed dolphin was found stranded in Fortaleza, Ceará state. The animal was emaciated, and the necropsy revealed two plastic bags in the fore-stomach chamber, where the mucosa had several ulcers (Meirelles & Barros, 2007).

2.2.2 Turtles

In data gathered from the Canary Islands between January 1998 and December 2001, Orós et al. (2005) describe how oesophagitis and traumatic oesophageal perforation were the most frequently observed lesions. These lesions are associated with ingestion of fishing hooks, occurring in 23 of the 88 animals studied post-mortem. Another report found that of 590 turtles found entangled in line and ghost nets, 280 were discovered alive and 310 dead (CRC, 2009).

In a study of 54 loggerhead sea turtles found stranded or incidentally captured dead by fisheries in the Adriatic Sea, 35.2 per cent had marine debris in their gastrointestinal tracts (Lazar & Gracan, 2011). The debris included soft plastic (68.4 per cent), ropes (42.1 per cent), styrofoam (15.8 per cent) and monofilament lines (5.3 per cent).

In an earlier study in Latin America and the wider Caribbean region, plastics were by far the most common item found in turtle necropsies, at more than 60 per cent (Ivar do Sul & Costa, 2007). Plastic ropes were also found in the oesophagus and stomach of dead turtles, and were estimated to account for the deaths of 13.2 per cent of the green turtles examined. In a further study on stranded green turtles from Brazil, Tourinho et al. (2010) found that all 34 of the animals examined had ingested plastic debris.

From the reviewed literature, it appears that a variety of turtle species ingest (and are sometimes killed by) plastics – often in the form of plastic bags. It has been suggested that turtles mistake plastic bags for jellyfish and plants. It is unlikely that this can be categorically proven, but there is strong post-mortem evidence that intestinal obstruction by plastics, alongside drowning in active and ghost fishing nets, is a widespread welfare problem and cause of death in turtles.

2.2.3 Birds

A number of species of seabirds ingest significant and potentially damaging quantities of plastic, while some birds ingest fish hooks and line when they scavenge from fisheries (OSPAR, 2009). The number of animals affected is only likely to be estimated very generally, with many causes for inaccuracy (for example, birds lost before reporting and patchy areas of study). However, survey figures indicate that large numbers (the majority, in some species and some areas) carry loads of plastic in their intestines that are likely to compromise feeding behaviour. This can give the animal the effect of feeling full, compromise their ability to hold and digest food, and may eventually result in starvation. Birds that become compromised through ingesting marine debris may be unable to feed, dive, nest or fly effectively, and their welfare will be strongly adversely affected.

One ingestion risk that is widely recognised is the eating of offal from fishing boats (particularly longline fishing) that contains discarded hooks. Albatrosses are regularly found with hooks embedded in their mouthparts or intestines. Although these may eventually be digested, there is a serious risk of oesophageal damage, as well as heavy metal poisoning.

The northern fulmar has been extensively studied in relation to the ingestion of plastic debris. Over 95 per cent of birds washed ashore dead contained plastic in their gut, many having ingested large volumes (Ryan et al., 2009). The amounts of plastic in the intestines of birds reflect regional differences in the abundance of marine debris (Gregory, 2009). For example, the amount of ingested plastic in northern fulmars in the North Atlantic is greatest in the highly contaminated waters of the North Sea, where almost all birds contain plastic. However, among birds of the same species in Arctic Canada, the figure decreases to 36 per cent. Young birds often have more plastic in their guts than adults, perhaps as a result of transfer from parents to their offspring during feeding, or due to poor discrimination of suitable food items by naive juvenile birds (Ryan, 1988; Mallory et al., 2006).

The 2009 OSPAR report describes how quantitative data on the environmental impact of marine litter is based on the background study of plastic particles in fulmars' stomachs. For the whole North Sea, 94 per cent of birds investigated contained plastic. On average, 34 pieces of plastic with a mass of 0.3g were found, and 55 per cent of all examined birds exceeded OSPAR's 0.1g 'Ecological Quality Objectives' level. If 0.3g of plastic were scaled up to size, this would equate to an average portion of lunch for a human adult.

Marine debris and fishing gear scattered among albatross nesting habitat, north-western Hawaiian Islands, Pacific Ocean

2.3
How many animals are likely to be affected?

2.3.1 Entanglement estimates

This section presents estimates of the number of entanglements affecting the two marine animal groups for which data is most readily available: pinnipeds and baleen whales (see Table 4, opposite). Please note: Section 1.3.1 lays out some very important caveats to be taken into consideration regarding these estimates.

The calculations have produced two totals:

- a sum total of the marine animals affected (pinnipeds and baleen whales), derived from annual entanglement figures provided in the reviewed published studies (57,000 animals)

- an extrapolated total, derived by multiplying the recorded percentage entanglement rates (of pinnipeds and baleen whales) by population estimates (135,000 animals).

We propose that these figures represent a range, with the lower figure (57,000) being a conservative estimate and 135,000 being an upper-level estimate, based on calculations that extrapolate entanglement rates from published studies to the wider estimated population.

We have made no attempt to calculate the number of birds or other marine animals that are entangled. The patchy nature of the data and the wide geographical spread of the most commonly affected species make it very difficult to give meaningful estimates of the numbers affected by entanglement, although it is very clear that these are significant.

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Nurse shark (deceased) entangled in plastic fishing net and washed onto rocks, Jamaica

2.3 How many animals are likely to be affected?

Table 4: Data used to estimate sum total of pinniped and baleen whale species affected by marine debris

Species/ Sub-species	Entanglement rate (incidence in population, % [if range then mean appears in brackets])	Population estimates (where multiple estimates mean is adopted)	Extrapolation: estimated animals affected by entanglement per annum (entanglement rate x population estimate, rounded to nearest whole number)	Sum: number of animals affected by entanglement annually, from specific studies and from specific restricted localities (if range given mean adopted)	Source of entanglement rate estimation
Kaikoura fur seal	0.6-2.8 (1.7)			19	Boren et al. (2006)
Australian fur seal	1.9				Pemberton et al. (1992)
Antarctic & Sub-Antarctic fur seal	0.24			10	Hofmeyr et al. (2002)
New Zealand fur seal	0.9			15	Page et al. (2004)
Antarctic fur seal	0.024-0.059 (0.041)			15,000	Boren et al. (2006)
Cape fur seal	0.1-0.6 (0.35)			84	Shaughnessy (1980)
Northern fur seal	0.08-0.32 (0.2)			40,000	Derraik (2002) (Bering sea total); Zavadil et al. (2007) (entanglement rate)
Australian sea lion	1.3			1,500	Page et al. (2003)
Californian sea lion	3.9-7.9 (5.9)				Harcourt et al. (1994)
Steller sea lion	0.26				Raum-Sayuran et al. (2009)
California sea lion	0.08-0.22 (0.15)			28	Stewart & Yochem (1987)
TOTAL (otariid seals)	**Mean entanglement rate for otariid seals = 2.21%**	**Combined Fur and Seal Lion population estimate = 238,8000 (Trites et al., 1997)**	**52,774**	**56,656**	
Hawaiian monk seal	0.7			215	Henderson (2001)
Northern elephant seal	0.15			14	Stewart & Yochem (1987)
Southern elephant seal	0.001-0.002 (0.0015)				Campagna et al. (2007)
Harbour seal	0.09			2	Stewart & Yochem (1987)
TOTAL (phocid seals)	**Entanglement rate for phocid seals = 0.24%**	**Phocid seal population estimate = 22,070,500 (Trites, 1997)**	**52,969**	**231**	
Humpback whale	9.2	63,600 (IWC 2010)	5,851	54	Robbins & Mattila (2004)
Western grey whale		26,400 (IWC, 2010), 21,100 (Trites et al., 1997)		19	Bradford et al. (2009)
Minke whale	2.6	970,000 (IWC 2010, 860,000 (Trites et al., 1997)	23,790	7	Cole et al. (2006)
North Atlantic right whale	1.6	300 (IWC 2010)	5	6	Cole et al. (2006)
Fin Whale	0.8	33,200 (IWC, 2010), 12,000 (Lowry et al., 2007)	181	2	Cole et al. (2006)
Bryde's Whale	0.2	20500 (IWC 2010), 11200 (Trites et al., 1997)	32	1	Cole et al. (2006)
TOTAL (baleen whales)			**29,859**	**89**	
		Totals (pinniped and baleen whale species combined)	**135,602**	**56,976**	

2.3
How many animals are likely to be affected?

2.3.2 Ingestion estimates

No attempt is made to calculate the total number of animals affected by ingestion. Sections 2.2.2 and 2.2.3 detail some of the recognised effects of ingestion in turtles and birds. However, the patchy nature of the data and the wide geographical spread of the species most commonly affected make it impossible at this time to give meaningful estimates for the global number of turtles, birds and other marine animals affected by ingestion. However, it is very clear – particularly for birds – that the numbers are significant and likely to be at least in the hundreds of thousands annually.

Right: Abandoned fishing net entangling 17 deceased sea turtles (discovered days after a storm) is removed by boat; off the coast of Bahia, Brazil

3
Measuring animal welfare impacts

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3.1
Animal welfare assessment scoring

For many species of animal, the welfare impacts of farming practices, laboratory procedures, training and zoo captivity are starting to be assessed using increasingly complex behavioural and physiological measures. For farmed animals, a large EU initiative resulted in an assessment system called 'Welfare Quality'. For laboratory animals, there are a number of assessment systems in place that score the responses of animals to the environment in which they are kept and the procedures that they are subjected to (Goulart et al., 2009; Moreira et al., 2007).

Similarly, in human medicine, wound scoring is a well-established practice, enabling clinicians to communicate the severity of wounds and gauge how they are healing. The Red Cross classification of war wounds is used internationally to describe wounds based on their appearance, rather than on what caused them (Coupland, 1992).

In a related way, some effort has been made to assess the severity of marine mammal entanglements. The box below presents an example of a hierarchical descriptive scale for injuries to marine mammals.

Injuries to marine mammals: hierarchical descriptive scale
Gear-related injuries
Serious injury Ingestion of gear; trailing gear (e.g. flasher), when it has the potential to anchor or drag, or when it is wrapped around the animal; gear attached to the body with the potential to wrap around flippers, body, or head; foreign bodies penetrating into a body cavity; multiple wraps; missing flippers – front and back flipper (serious), for both otariids or phocids; deep external injuries.
Non-serious Hooked in the lip; hooked in flipper, etc. with minimal trailing gear that does not have the potential to wrap around body parts, accumulate drag, or anchor; freely swimming animals encircled by purse seine nets.
Grey area Hooked in head (serious injury could be assumed, but it depends on several factors, including where on the head the hooking took place, the depth of the hooking, the type of hook, etc.); animals stressed by being encircled or trapped (e.g. purse seine); animals released without gear following entanglement (this designation depends on the extent of the injury or how long the animal was submerged, how long the gear was on the animal, and the degree of restraint).
Other impacts of interactions with humans
Pinniped brought on vessel (this was considered in the report to be non-serious, and the severity dependent on how the animal was brought up, e.g. in net or a roller, or through the power block).

This kind of severity scoring scale may be of value to create a system for the reporting of entanglement by fishermen and other observers which would allow comparisons to be made between different areas and different fisheries, as well as allowing the effects of mitigation efforts to be assessed.

In whales, entanglement has the potential to cause prolonged suffering, and Knowlton et al. (2012) propose a severity index for entanglement lesions in North Atlantic right whales.
Low severity Skin abrasions that do not appear to extend into the blubber or cartilage.
Medium severtiy Broad areas of abrasion, and/or injuries that extend into blubber but do not penetrate muscle, and/or lacerations on appendages that extend beyond the skin but have a total estimated depth of less than 8cm.
High severity Injuries extending into muscle or bone, and/or appendage lacerations >8cm in depth, and/or significant deformity. Source: adapted from report of the NOAA/NMFS Serious Injury Technical Workshop (2007)

3.2 Marine debris animal welfare impact: comparative assessment

The lack of data and of consistency in data presentation on the animal welfare impacts of marine debris mean it has not been possible for this report to present a comparative scale or index of 'severity' or 'intensity' of suffering across different animal species or their interactions with different debris types.
However, Figure 4 presents a graphical representation of the major animal welfare impacts of marine debris, split by the main types of marine debris known to affect animals. It provides an indication of which animals are known to be affected by different debris types, and over which timeframes the adverse welfare effects may be felt.

For example:

- A fur seal entangled in a submerged and anchored ghost net, which prevents it from surfacing to breathe, will suffer intense distress, panic and suffering before drowning after a period of minutes. The duration of suffering is short when compared to that experienced by the same species if entangled in a monofilament noose, which may cause an increasingly severe wound, resulting in pain, distress and possible infection over a period of months or years.

- A turtle that has wholly ingested a plastic bag or bags may experience a long duration of adverse welfare effects if the plastic obstructs the gut and causes starvation over a period of days or weeks. Though much longer in duration, the severity of suffering may arguably be less intense than that of a turtle that is immediately asphyxiated by a plastic bag.

- A whale entangled in a long rope may suffer a lengthy period of chronic and increasingly intense pain and distress (over months, or even years), as a result of the line cutting into its body and compromising feeding, locomotion and diving.

- A bird ingesting small plastic items may not suffer intense immediate distress, but the duration of the effects of accumulating plastic may be long term. The intensity of suffering is likely to increase over time, with an end result of slow starvation through compromised gut function. This starvation (possibly over months or years) is distinct from the shorter duration starvation (over days or weeks) that would result when a bird's mouth, wings or legs become entangled in (for example) plastic packaging or fishing line, preventing it from feeding at all.

It should be noted that Figure 4 is a graphic depiction of the major known impacts as identified from the reviewed literature. The text provided in boxes are examples of known welfare impacts at either end of the duration spectrum of a given debris type. Many other impacts may also result from the debris type, with effects lasting as long as, or anywhere between, the two examples provided.

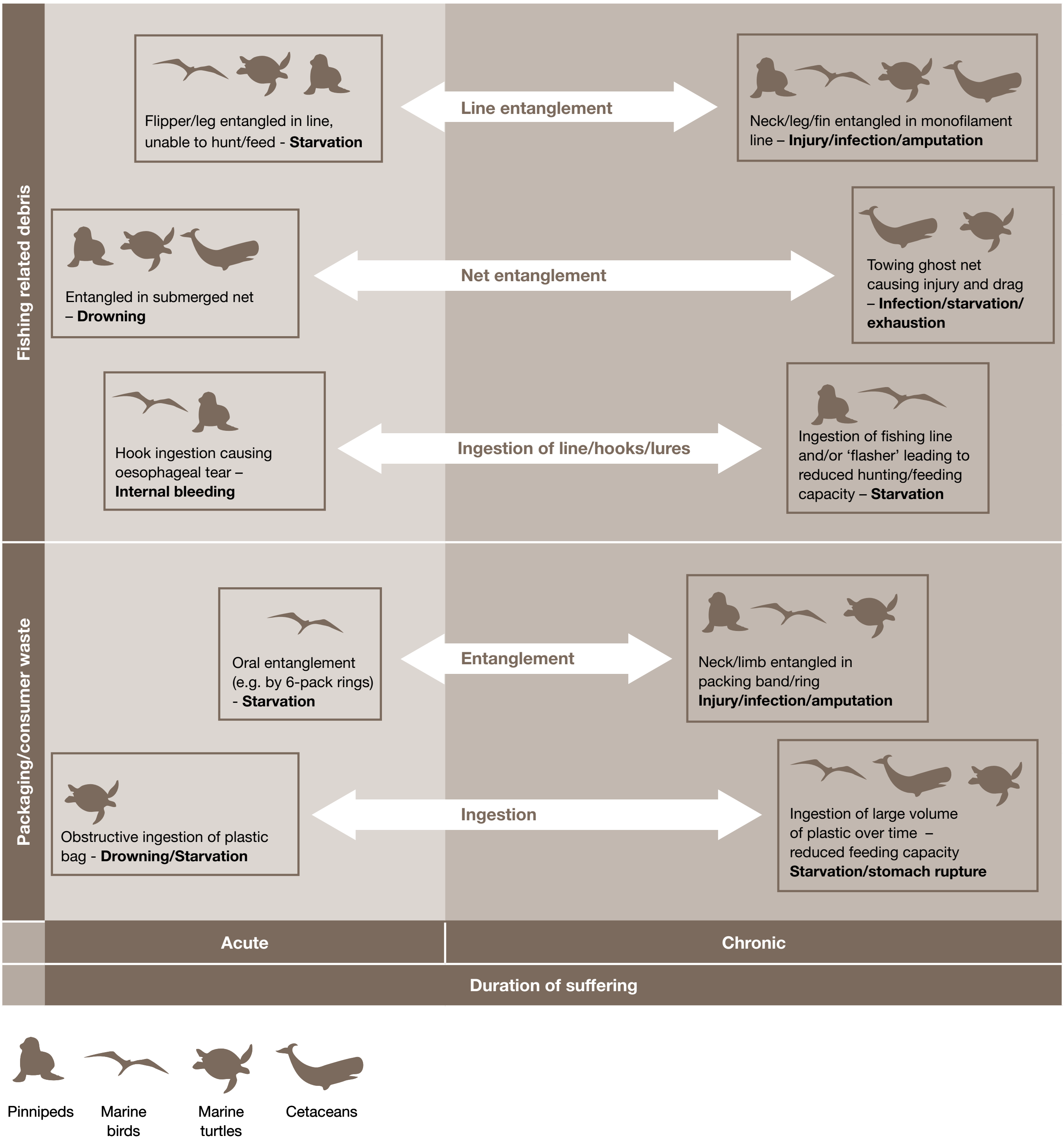
As a very broad illustration of the problem of marine debris for animal welfare, Figure 4 shows that the major types of debris affecting animals cause problems for a wide range of species. It demonstrates that the same debris can cause a range of physical impacts, and that these physical impacts can result in poor animal welfare experiences over a range of timeframes; acute impacts may cause suffering and distress for minutes while chronic impacts may be cumulative, causing increasing suffering over periods as long as years.

In order to present a more quantitative scoring index to describe the severity and duration of suffering caused to animals by marine debris, a concerted effort would need to be made to build a comprehensive species- and debris-type specific dataset which allowed comparative scoring of welfare impacts. From the available literature it does not appear that detailed information on injury type and welfare impacts – to allow such scoring – is collected as standard by researchers investigating the impacts of marine debris on animals.

As a broad illustration of the problem marine debris presents for animal welfare, Figure 4 shows that very substantial numbers of animals – likely hundreds of thousands annually – are suffering the effects of entanglement in, or ingestion of, marine debris over periods of weeks, months or even years.

3.2
Animal welfare impact of marine debris: comparative assessment

Figure 4: Major types of marine debris causing animal welfare problems, key species affected and range of likely duration of suffering. Text in boxes are examples of the known welfare impacts at either end of the spectrum of duration of suffering, for each given debris type. At their shortest, acute effects may be experienced over minutes, whilst chronic effects may be experienced over years.



Right: Northern gannets breeding on plastic waste (one has been strangled), Germany, North Sea

4
Major types of debris affecting animal welfare

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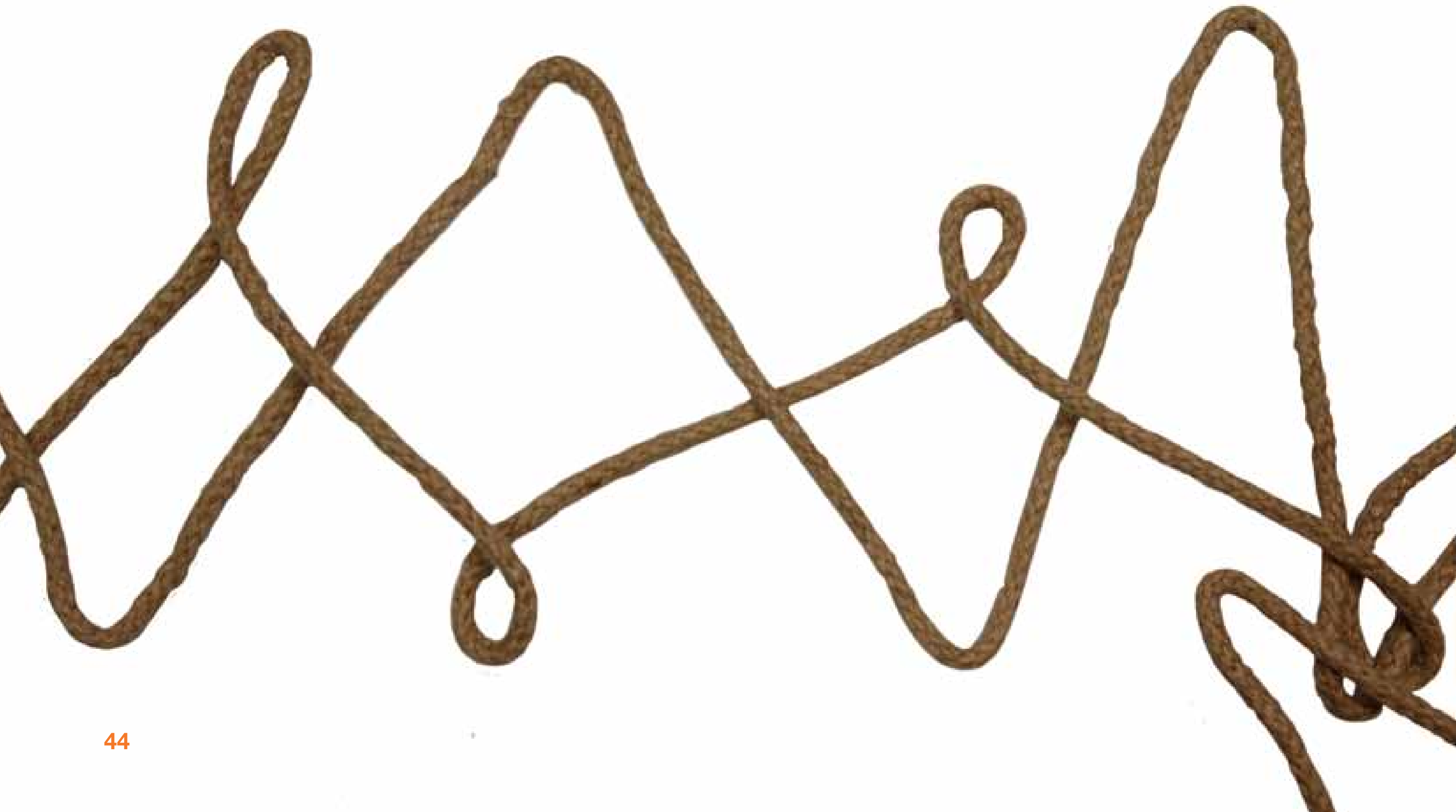
4

Major types of debris affecting animal welfare

Based on the reviewed literature, this section describes the nature and, where possible, frequency of the five key types of debris reported to affect the welfare of marine animals. These are:

- abandoned, lost or discarded fishing pots, traps and nets
- fishing lines and hooks
- rope and line
- packing bands
- plastic bags.



4.1 Abandoned, lost or discarded fishing pots, traps and nets

Fishing nets and lines, mostly made of synthetic fibres, are very persistent in the sea. Abandoned, lost or otherwise discarded fishing gear can continue to catch fish – ‘ghost fishing’ – for long periods. Over time, the weight of animals caught can cause the net to collapse and/or fragment. They tend to float slightly below the surface, making it challenging to spot and recover them, and can affect large numbers of marine animals by posing entanglement hazards. Furthermore, the nets smother the substrate if and when they settle.

Fishing gear may be lost if it is caught on an obstruction on the seabed, if it becomes tangled with another fleets’ fishing gear, or through storms or strong ocean currents. Fishermen have been known to dispose of damaged fishing gear at sea if there are charges for disposal onshore, though the scale and frequency of deliberate abandonment is not known. A global hotspot for lost nets is the Hawaiian Archipelago, due to its proximity to the North Pacific Subtropical Gyre, where ocean currents accumulate abandoned, lost or discarded fishing gear from the North Pacific Ocean (McElwee & Morishige, 2008).

Various studies have assessed and quantified the problem of ghost nets and other fishing gear, and some have also attempted to quantify the damage they cause to marine life.

4.1.1 European waters

Around 25,000 nets may be lost or deliberately discarded in European fisheries each year, with a total length of around 1,250km (Brown et al., 2005).

A study by Macfadyen et al. (2009) describes the recovery of 6,759 gill nets from Norwegian waters and the loss of 263 nets per year from 18 vessels in the United Kingdom, where, on average, one-third of the lost nets were recovered. In these fleets, the whole fishing gear was seldom lost, rather it was common for portions of net sheets and segments to be lost after snagging (884 incidences from a fleet of 26 vessels). In a study on the Cantabrian region of northern Spain (around 645 vessels), an average annual loss of 13.3 nets per vessel was recorded.

4.1.2 Northwest Straits

A study in Puget Sound and Northwest Straits (USA) recorded the recovery of 481 lost gill nets during a cleanup operation (Good et al., 2007). Most of the nets were still in good condition and were open, rather than folded or rolled up, and so capable of fishing. More than 7,000 animals were found trapped in these nets at the time of recovery.

4.1.3 Washington state

In 2010, Good et al. reported the recovery of more than 32,000 marine animals from 870 gill nets recovered from Washington’s inland waters – many of the nets had been at sea for many years. The marine animals comprised 31,278 invertebrates (76 species), 1,036 fish (22 species), 514 birds (16 species), and 23 mammals (4 species). Fifty-six per cent of the invertebrates, 93 per cent of the fish, and all the birds and mammals were dead when recovered. These figures are an underestimate as they only represent a snapshot of the loss of animals at the specific time of recovery, rather than reflecting the true long-term losses and animal suffering caused over the years.

4.1.4 Ghost nets in South-East Asia and the western-central Pacific

Ghost nets and ghost fishing are a significant issue in the Republic of Korea, Japan and Australia (Raaymakers, 2007). In 2003, an estimated 10,000 lost nets – around 250kg of fishing net per kilometre – were littering the Queensland coastline in the Gulf of Carpentaria, between the Torres Strait and the Northern Territory border (Kiessling, 2003). During a 29-month recovery programme (the Carpentaria Ghost Net Programme), 73,444m of net was collected by November 2007. The net was analysed for its origin. Although 41 per cent was of unknown origin, 17 per cent was identifiable as of Taiwanese origin, 7 per cent of Indonesian and Taiwanese or Indonesian origin, and 6 per cent from the Republic of Korea.

4.1.5 Ghost nets in the north-western Pacific

A survey in the Republic of Korea (Chang-Gu Kang, 2003) identified an estimated 18.9kg of marine litter per hectare, 83 per cent of which was composed of fishing nets and ropes. Another survey, of Korea's Incheon coastal area, identified 194,000 sq m of marine debris over a six-month period, weighing 97,000 tonnes (Cho, 2004). A follow-up programme resulted in the annual recovery of 91 tonnes of debris per sq km, of which 24 per cent was of marine (as opposed to coastal) origin. Over the six-year period 2000–2006, 10,285 tonnes of fishing-related debris was recovered from coastal areas through coordinated coastal clean-up campaigns (Hwang & Ko, 2007).

Table 5. Global statistics for lost fishing gear

Summary of gear loss/abandonment/discard indicators from around the world		
Region	**Fishery/gear type**	**Indicator of gear loss (data source)**
North Sea & NE Atlantic	Bottom-set gill nets	0.02-0.09% nets lost per boat per year (EC contract FAIR-PL98-4338 (2003))
English Channel & North Sea (France)	Gill nets	0.2% (sole & plaice) to 2.11% (sea bass) nets lost per boat per year (EC contract FAIR-PL98-4338 (2003))
Mediterranean	Gill nets	0.05% (inshore hake) to 3.2% (sea bream) nets lost per boat per year (EC contract FAIR-PL98-4338 (2003)
Gulf of Aden	Traps	c. 20% lost per boat per year (Al-Masroori, 2002)
ROPME Sea Area (UAE)	Traps	260,000 lost per year in 2002 (Gary Morgan, personal communication, 2007)
Indian Ocean	Maldives tuna longline	3% loss of hooks/set (Anderson & Waheed, 1988)
Australia (Queensland)	Blue swimmer crab trap fishery	35 traps lost per boat per year (McKauge, undated)
NE Pacific	Bristol Bay king crab trap fishery	7,000 to 31,000 traps lost in the fishery per year (Stevens, 1996; Paul et al,; 1994; Kruse & Kimker, 1993)
NW Atlantic	Newfoundland cod gill net fishery	5,000 nets per year (Breen, 1990)
	Canadian Atlantic gill net fisheries	2% nets lost per boat per year (Chopin et al., 1995)
	Gulf of St Lawrence snow crab	792 traps per year
	New England lobster fishery	20-30% traps lost per boat per year (Smolowitz, 1978)
	Chesapeake Bay	Up to 30% traps lost per boat per year (NOAA Chesapeake Bay Office, 2007)
Caribbean	Guadeloupe trap fishery	20,000 traps lost per year, mainly in the hurricane season (Burke & Maidens, 2004)

Source: taken from Macfadyen et al. (2009)

4.1.6 Pots and traps

Lost pots and traps can pass through cycles of ghost fishing. If they contain bait or lost catch, this can attract animals, which may become entrapped and subsequently die, forming new bait. One study in the United Arab Emirates estimated that approximately 260,000 traps were being lost per year (cited in Macfadyen et al., 2009). The United Arab Emirates authorities have since made degradable panels in traps mandatory.

Of the 40,000 Caribbean traps around Guadeloupe, approximately 20,000 are lost each year during hurricane season, but continue to catch fish for many months (Burke & Maidens, 2004). In the Northwest Atlantic, in the Gulf of St Lawrence snow-crab trap fishery alone, an estimated 800 traps are lost each year. It is suggested that each fisherman may lose up to 30 per cent of his traps over the course of one year (NOAA Chesapeake Bay Office, 2007). This would equate to losses of around 150,000 traps annually just in this one large bay.

Similarly, in the Gulf of Mexico, of the 1 million traps fished commercially, there is an estimated 25 per cent loss rate (Guillory et al. 2001). This suggests that 250,000 traps are lost in the Gulf of Mexico each year, contributing to the 4–10 million blue crabs each year lost to ghost fishing in Louisiana alone (GSMFC, 2003). Meanwhile, in the Florida Keys, an estimated 10–28 per cent of lobster traps are lost each year (Matthews & Uhrin, 2009). Fishermen reported losing even more of their traps than usual as a result of Hurricanes Katrina, Rita, and Wilma, suggesting trap losses of 50,000–140,000 annually.

4.2
Fishing lines (including monofilament) and hooks

Dupont first sold nylon monofilament fishing line in 1938. Since then, there has been a range of developments in line, including Stren (a thinner, softer line that is easily knotted), Spectra, Dyneema, and polyvinylidene fluoride (PVDF) lines. With each generation, the lines become stronger, less visible in water (low optical density) and, in general, denser (in order to sink faster). Discarded line is very difficult to see in water, very strong, and very resistant to biting and chewing by trapped animals. Indeed, monofilament line is so strong that many human divers are caught in line each year, and trainee divers are often taught how to release themselves from line entanglements using a diving knife.

Not only are fishing lines very strong in relation to their thickness, but their thin diameter can readily cut and damage tissues if an animal becomes entangled. For example, here is the sales presentation for one brand of fishing line, Spectra:

High Tensile Strength – the fiber is so strong that it is used in bulletproof vests; replacing Kevlar in that application. It is about 10 times as strong as steel, pound for pound. The finished line has a tensile strength of about 600,000 pounds per square inch versus monofilament which has a tensile strength of about 100,000 pounds per square inch.

Long Life – the line has a very long life, it does not rot, and is not readily damaged by ultraviolet rays in sunlight, as is monofilament, it does not swell in water, nor does it lose strength when wet.

Source: http://www.fishermansoutfitter.com/c-39-Spectra.aspx

4.3
Rope and line

Boat-based rigging and lines used to secure nets, pots and creels and shore operations can be lost into the sea, either from boats or from the shore. Ropes for marine use are designed to be strong and rot-resistant, and are usually made from polypropylene, polyester, nylon, polyethylene or Kevlar, or mixtures of these fibres. They can be extremely strong: a piece of 14m-diameter braided polyester rope can have a breaking load of 9,000kg.

4.4
Packing bands

Packing and shipping bands made of rubber or plastic are a common cause of entanglement, particularly for pinniped species. Polypropylene bands – some with metal hasps, some bonded into loops – are very strong, quite resistant to seawater, light and heat, and universally used to wrap boxes (such as bait boxes) and goods during shipping and transportation.

4.5
Plastic bags

The concept and production of the first plastic bags date to the 1950s. Their use has been widespread in the developed world from the 1980s. In 2002, an estimated 4–5 trillion bags were produced globally (WorldWatch, 2004). Plastic bags are usually made from polyethylene, though they may also be made from vegetable-based bioplastics, which degrade naturally.

The results of various beach clean-up exercises put plastic bags among the 10 most commonly found items along the coast, and in an extensive US-based study plastic bags comprised 12 per cent of the calculated total of beach litter collected (Sheavly, 2007). In countries where land-based waste disposal or sewerage systems are inadequate or non-existent, plastic bags can reach the sea through rivers, open sewers or other drainage. In other parts of the world, bags may be blown from land-based waste disposal towards the sea, or be accidentally or deliberately lost from marine or coastal industries (for example, bags containing fishing materials such as salt or bait).

4.6
Harm hotspots

The box below highlights the key harm hotspots, listing the debris that is most frequently associated with entanglement or ingestion and the locations where particular species are most at risk. This draws on the findings highlighted elsewhere in this report. Please note the comments on analysing the data that appear in Section 1.3.1.

Debris most frequently associated with entanglement

- net fragments
- rope and line (for example, gill nets, trawl nets, lost or discarded line for pots and traps)
- monofilament line
- packing bands
- plastic circular rings and packaging such as multipack can rings.

Debris associated with ingestion

- small plastic fragments of sufficiently small size to be taken into the mouths of birds and turtles, capable of either obstructing the gut or replacing space, causing starvation
- plastic bags by turtles
- plastic bags and plastic waste (including net fragments) taken in by baleen whales during filter feeding.

Entanglement hotspots	
Western coast USA	Fur seals, sea lions, humpback whales
Eastern coast USA	Humpback whales, North Atlantic right whales
Eastern coast Australia	Fur seals
Southern African coast	Fur seals
North Sea	Grey seals, minke whales, gannets
California, USA	Pelicans
Northern coast Australia	Turtles
Northern Pacific and Sea of Japan	Grey whales, minke whales

Ingestion hot spots

The geographical spread of marine birds (numerous species) that are recorded to ingest plastic is global. It is probable that perceived ingestion rates are influenced by location of study rather than true geographical differences as many of the species affected have huge intercontinental ranges.

The reports of plastic ingestion by turtles are sporadic and widely spread; it is probably appropriate to assume that the same species will ingest plastic waste wherever they are found and where waste is present floating in the sea.

Right: Government-recruited volunteers and divers clean up the coastline, Phi Phi Island, Krabi, Thailand

5
Solutions

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5 Solutions

This section considers three possible approaches to effectively eliminating the marine debris that has the most significant negative impacts on marine animal welfare:

- reducing the amount of harmful debris entering the marine environment
- removing harmful debris that is already in the marine environment
- rescuing (and, where possible, rehabilitating and releasing) animals that are already entangled in marine debris.

Three biologists on a coral reef survey work to free a green sea turtle entangled in fishing net, Tamuning, Guam, Philippines


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5.1 Reduction

Marine debris and waste management is complicated. Waste that originates in one place can do harm somewhere quite different, spanning geographical and policy boundaries. Then, which area of responsibility and action does marine debris fall under: marine management, coastal management, waste management, production and manufacturing regulation, labelling and traceability, recycling and waste collection, or accountability for the destination and distribution of waste? Realistically, a range of approaches is needed to ensure that harmful debris does not reach marine habitats.

The Convention on Biological Diversity's 2012 report on marine debris cites the following potential reduction strategies (CBD, 2012):

eco-labelling; green procurement; extended producer responsibility (EPR); deposit return programs; fees charged on single use plastic bags; education to promote the viewing of wastes as resources; engaging with corporations and industry associations on sustainability; encouraging reuse and reduction through 'green chemistry'; encouraging better product and packaging design; and supporting marine debris awareness.

Some of these are expanded upon here.

5.1.1 Education

Targeting learning resources at fishermen and boat owners could increase awareness of the effects of fishing line, rope, ghost nets, lost fish hooks and tipping of waste at sea. Natural history programmers and filmmakers could identify the impacts of marine litter as an interesting and influential topic.

A number of programmes have been established to reduce the impact of discarded monofilament line on Florida's manatees. One encourages recycling of fishing line through a network of line recycling bins and drop-offs, with the following long-term goals:

1) **Heighten awareness about the negative impacts that fishing line debris has on human welfare, marine life, and water quality.**

2) **Decrease the amount of fishing line entering and remaining in the natural environment.**

3) **Increase the amount of fishing line being recycled. The group works to decrease entanglements in fishing gear through education and outreach efforts, gear recovery and clean-up, entanglement research, and development of potential technique and gear modifications.**

(Interagency Manatee Entanglement Working Group/Monofilament Recovery and Recycling, 2005)

At APEC's 2004 meeting in Honolulu, proposals to establish "net collection points" on a national or regional basis were outlined (APEC, 2004). It was suggested that recycling programmes could support other entrepreneurial activities, such as selling the recycled material to be converted into items including bicycle seats and office furniture. Part of the proposal was to establish centres for repairing, re-using and recycling fishing gear at key ports or nodes of fishing activity throughout the Pacific, such as resupply, landing, off loading or trans-shipment sites. The proposal included establishing a fund to support derelict fishing gear and marine debris clean-ups, similar to that developed for oil-spill disasters.

5.1.2 Market-based instruments

The United Nations Environment Programme has proposed harnessing market-based instruments (MBIs) in order to combat the problem of marine litter (UNEP, 2009). Examples include:

- **Deposit-refund programmes.** These programmes increase the incentive to reuse plastic and glass bottles and reduce the temptation to litter. They have been shown to reduce roadside litter and are applicable in most countries.

- **Plastic bag tax.** Taxes on bags increase the incentive to reduce their use. Many countries and regional governments are applying MBIs of this type, while others are pursuing outright bans on some packaging types.

- **Product charges.** Extra charges can be applied to the sale, distribution or use of products such as fishing line, fishing floats and foamed plastic food containers. This can reduce the incentive to litter while raising funds for cleanup activities or to improve coastal waste management infrastructures.

- **Liability for pollution or marine litter.** Where the source of marine debris can be identified, it is possible to introduce liability for the cost of the clean-up. This may be linked to a compensation scheme for those whose livelihoods are compromised by the impact of marine litter. This requires an established legal system and capacity to be effective. It may prove impossible for certain international sources of marine pollution and could be difficult to apply in some countries.

- **Fines for litter and illegal disposal of waste items.** Many communities impose fines to discourage improper disposal of waste and rubbish. Revenues could be used to fund education campaigns or provide additional waste receptacles and infrastructure.

- **Port reception, ship berthing and commercial and recreational fishing fees.** These fees could be partly designated to improving waste management infrastructure and to launch innovative programmes that remove marine litter from the ocean.

- **Award-based incentives for coastal villages with integrated waste management systems.** These programmes reward or provide incentives to promote policies, programmes, and technologies that manage and reduce marine debris. The mix and emphasis of approaches varies from region to region.

- **Financial and technical support.** This involves supporting those fishing vessels, leisure crafts and larger ships that currently have inadequate facilities to install waste management systems on board.

5.1.3 Working with industry

More plastics have been produced in the first decade of the present century than in the entire preceding century. Plastic production is growing at around 9 per cent annually, and plastics comprise about 60 per cent of the debris found on beaches and about 90 per cent of the debris found floating in the ocean. So, cooperating with industry – especially companies whose products are ending up on the shores and in the oceans – may present a key opportunity to reduce marine debris by reducing plastic waste and encouraging greater recycling rates.

Developed countries in Europe, Northern America and Japan account for about 60 per cent of global production, and have the highest rate of plastic consumption. However, the increasing demand for plastics is creating a shift in production to developing countries, with Asian countries having the highest potential for growth.

Some companies are supporting marine debris clean-up and education efforts. The Coca-Cola Company, Dow Plastics and Philip Morris have helped sponsor the International Coastal Cleanup. Morton Salt, the maker of shrimp-boat products, took action after blue plastic bags with the Morton Salt label started washing up on Gulf of Mexico beaches. The company started printing reminders such as ‘Stow it, don’t throw it’ on its bags, and fewer Morton Salt bags have been sighted on shores.

Manufacturers of fishing gear, rope and line

Another sector worth engaging is the manufacturers of fishing gear, rope and line. These companies could play a very significant role in both the development of new, less dangerous gear and in educating fishermen and boat owners about the impacts of derelict gear. The Consortium for Wildlife Bycatch Reduction (2012) has proposed adjustments to fishing gear that may reduce entanglement. These include 'pingers': alarms that can be attached to lines and nets to alert dolphins and porpoises to the presence of fishing gear. It has also designed whale-safe fishing hooks that will straighten out if ingested by whales. These are already being used in the North Carolina-based and Hawaii-based pelagic longline fisheries.

Another entanglement risk for whales is posed by ropes in the water column that tether pots and traps. To address this, the consortium has proposed the use of 'stiff rope'. This rope, which has reduced ability to bend, allows animals to slide off it before they became entangled. Non-buoyant 'sinking groundlines' are now mandatory in the Gulf of Maine pot fishery for lobster, in order to reduce the entanglement of whales. A glow rope has also been developed to increase rope visibility to whales, and another initiative has involved treating polypropylene rope with barium sulphate so that they are strong enough for fishing but will break under the pull of an entangled whale.

Some commentators, such as Moore et al. (2006), argue that although the current measures to weaken fixed gear to avoid anchoring entangled animals may reduce the risk of progressive, constrictive rope damage, they will not completely remove it. Moore et al. call for a combination of measures that reduce or eliminate the use of line in the fisheries that affect these animals, or work to make rope and line that will not lead to serious injury. Significantly, fixed-gear fisheries must be modernised to enhance their efficiency and substantially reduce the amount of rope in the water column in habitats of large whales (Moore et al., 2006).

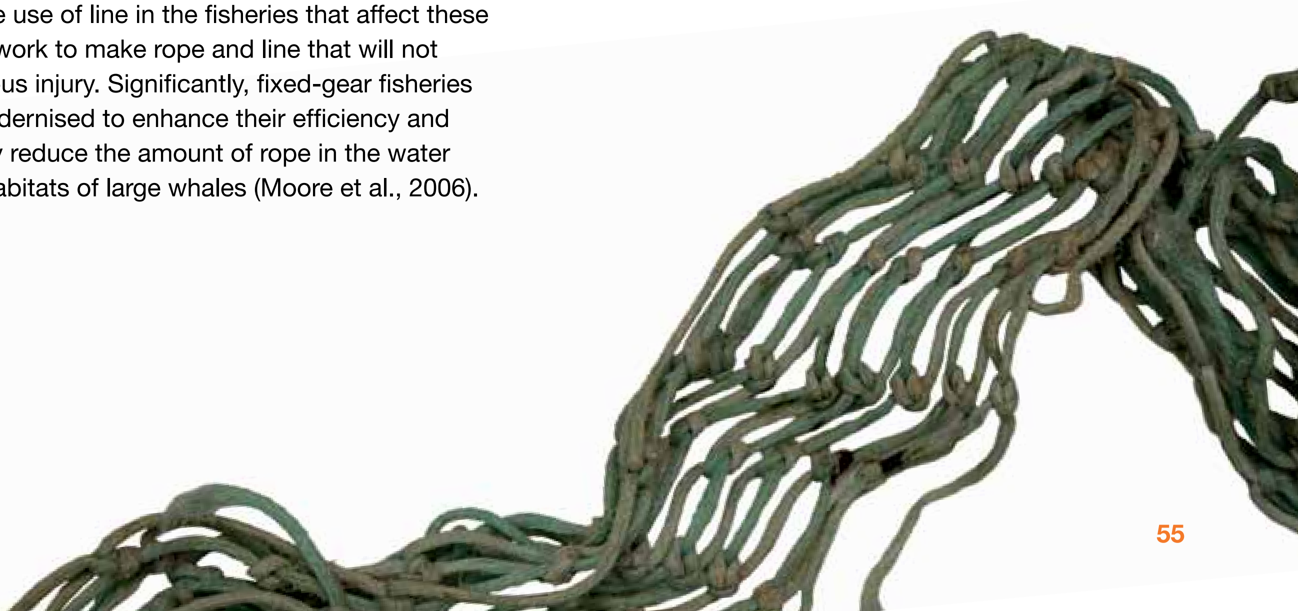

Table 6. Examples of initiatives to reduce the volume of dangerous debris in the marine environment

Project name	Location	Project description	Targeted debris
Marine Litter Treatment	Republic of Korea: Nakdong River	Cost-sharing programme between areas (municipals and government) along the Nakdong River for the treatment of marine debris at the river mouth.	Land-based debris, domestic refuse and lumber, along with plant material generated during the rainy season
Floating Receptacles for Marine Litter	Republic of Korea: Haenam-gun, Cheollanam-do (province)	Placing dedicated floating marine debris receptacles in port areas to collect derelict fishing gear.	Derelict fishing gear, ship-generated waste, plastic bags
Monofilament Recycling	United States: nearly all coastal states	Nationwide network of fishing line recycling bins to help anglers dispose of used fishing line.	Recreational monofilament fishing line
Nets to Energy	United States: Hawaii	Public–private partnership to use derelict fishing net, line, and rope to create electricity.	Derelict fishing nets and line, longline monofilament, nylon rope
Pier 38 port reception	United States: Hawaii	Port receptacle for derelict nets, line, and rope. Debris from this receptacle goes through the Nets to Energy programme (see above).	Derelict fishing nets and line, longline monofilament, nylon rope
Fishing for Energy	United States: states along the north-east and west coasts	A partnership that provides fishermen with a no- cost disposal service for old or derelict fishing gear and coverts it into clean, renewable energy, using state-of-the-art energy-from-waste technology.	Fishing gear (used or derelict) including traps, nets, line, buoys and floats
Hawaii Marine Debris Action Plan	United States: Hawaii	A state-wide planning process and action plan to reduce marine debris in Hawaii collaboratively and effectively.	All types
Marine Debris 101	United States: nationwide	A web-based outreach and education campaign to promote marine debris prevention.	All types

5.1.4 International agreements and commitments

In June 2005 Member States of the United Nations (UN) began discussions on marine debris as part of the Open-ended Informal Consultative Process on Oceans (UNICPO). The UN Meeting of the Open-ended Informal Consultative Process on Oceans and the Law of the Sea (2005) proposed that the UN General Assembly (UNGA) encourage collaborative work between agencies to address the issue of lost and discarded fishing gear and related marine debris through initiatives such as:

(d) Regular, long-term collection, collation and dissemination of information on derelict fishing gear found within national jurisdictions;

(e) Development and implementation of targeted studies to determine the socio-economic, technical and other factors that influence the accidental loss and deliberate disposal of fishing gear at sea;

(f) Assessment of preventive measures, incentives and disincentives relating to the loss and disposal of fishing gear at sea.

(UN, 2005)

The issue of marine litter was then also recognised by the UNGA, in a resolution (A/60/L.22 Nov. 2005) which called for national, regional and global actions to address the problem. The resolution noted the lack of information and data on marine debris; encouraged Member States to develop partnerships with industry and civil society; urged States to integrate the issue of marine debris within national strategies dealing with waste management; encouraged the development of appropriate economic incentives to address this issue; and encouraged States to cooperate regionally and sub-regionally to develop and implement joint prevention and recovery programmes for marine debris.

More recently, at its 65th session in 2010, the UNGA again urged States to cooperate regionally and sub-regionally on this issue and to support measures aimed at preventing, reducing and controlling sources of marine debris (STAP, 2011). At the UN Conference on Sustainable Development (Rio+20) in 2012, ocean pollution (and plastic marine debris in particular) was identified as a global priority for sustainable development (CBD, 2012).

The United Nations Convention on the Law of the Sea (UNCLOS) represents an overarching legal framework for addressing the issue of marine debris. It acknowledges the terrestrial waste sources for marine debris, calling for Member States to pass national legislation to combat pollution from rivers, estuaries and pipelines. However it is not any more specific than this.

The rest of this section details a number of specific international initiatives, agreements and commitments aimed at reducing the impacts of marine debris.

Initiatives of the United Nations Environment Programme (UNEP)

The Global Initiative on Marine Litter was created in 2003 by UNEP's Regional Seas Programme and the Coordinating Office for the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA). It is intended as a platform for managing the marine debris problem through partnerships, cooperative arrangements and joint activities. Regional Seas Conventions and GPA are the main implementing partners and twelve Regional Action Plans are currently in place as a result of the Global Initiative.

The Global Partnership on Waste Management (GPWM) was launched in 2010 with marine debris as one of its six focal areas.

In June 2012, at Rio+20, UNEP and the United States National Oceanic and Atmospheric Administration (NOAA) launched the Global Partnership on Marine Litter. The purpose of this new partnership is to bring together stakeholders committed to implementing the Honolulu Strategy.

The Honolulu Strategy

The Honolulu Strategy was developed from the Fifth International Marine Debris Conference (5IMDC) in 2011, organised by NOAA and UNEP. It outlines three overarching goals within a global framework for the prevention and management of marine debris:

Goal A: Reduced amount and impact of land-based litter and solid waste introduced into the marine environment.

Goal B: Reduced amount and impact of solid waste, lost cargo, derelict fishing gear, and abandoned vessels introduced at sea.

Goal C: Reduced amount and impact of accumulated marine debris on shorelines, in benthic habitats, and in pelagic waters.

(UNEP/NOAA, 2011)

UNEP is an implementing agency of the Global Environment Facility (GEF) and provides the Secretariat of the GEF's Scientific and Technical Advisory Panel (STAP). Under strategic guidance from UNEP, the STAP has published two recent scientific reports on marine debris: Marine Debris as a Global Environmental Problem (November, 2011) and Impacts of Marine Debris on Biodiversity: Current Status and Potential Solutions (October, 2012). Both present status reports as well as potential solutions to inform policy makers at national and international level.

The International Convention for the Prevention of Pollution from Ships (MARPOL)

MARPOL prohibits the disposal of all plastics, including fish nets, from vessels, with exemption for certain accidental losses. It stipulates that vessels over a certain size (400 gross tons) must have garbage management plans and report all at-sea disposals. The Annex V Guidelines encourage technological development to minimise losses and maximise recoveries, including gear identification systems and the use of degradable materials, and also recommends increasing shore-based disposal facilities. Annex V has recently been comprehensively revised, and the new Guidelines will be in operation as of 1 January 2013 (MARPOL, 2011). From this date the discharge of all garbage into the sea will be prohibited except for, under special circumstances, food wastes, animal carcasses, cargo residues and cleaning agents and additives that are not harmful to the marine environment. Under the revised Annex V Guidelines, any waste that poses an entanglement risk to animals is prohibited. The success of this regulatory regime will lie in its enforcement by UN Member States.

Convention on Biological Diversity (CBD)

Although the Convention on Biological Diversity (CBD) has an overarching framework to address threats to marine biodiversity, it has not, historically, specifically addressed the issue of marine debris and its impacts on biodiversity. However, in 2012, the Convention adopted a decision to include marine debris in their working portfolio.

The Convention on the Conservation of migratory Species of Wild Animals (CMS)

In 2012, the Convention on the Conservation of Migratory Species of Wild Animals (CMS) adopted a specific resolution on marine debris, submitted by the government of Australia. Resolution 10.4 highlights the negative impacts of marine debris on migratory species and recommends the Parties identify geographical hotspots, collaboratively assess the impacts, develop and implement national plans of action, and produce national reports on amounts, impacts and sources of debris within their waters.

The Food and Agriculture Organization (FAO) Code of Conduct for Responsible Fisheries

The FAO Committee on Fisheries (COFI) is the only intergovernmental forum on fisheries and it looks at fisheries-specific marine debris issues. The Code of Conduct encourages states to fulfil the requirements of MARPOL (CBD, 2012).

The UN Fish Stocks Agreement (UNFSA)

The agreement is an elaboration of the more general provisions of UNCLOS and obligates Member States to minimise pollution, wastes, discards and catches by lost or abandoned fishing gear.

Regional Fishery Management Organisations (RFMOs)

These are treaties which regulate fishing in different ocean regions. Two of the RFMOs, the Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean and the Inter-American Tropical Tuna Convention, both contain specific obligations to minimise catches by lost or abandoned fishing gear. The UN Fish Stocks Agreement (see above) provides the more general duties that RFMOs have for the conduct of responsible fishing operations, including marine debris.

In addition to global-level agreements and commitments, it is also important to note that there are a large number of regional and national initiatives in place, including regulations and legislation.

5.2 Removal

5.2.1 Fishing gear and litter recovery programmes

There have been a number of programmes aimed at recovering fishing gear.

In one study, Kiessling (2003) identified around 10,000 lost nets (about 250kg of fishing net per km) on the Queensland coastline in the Gulf of Carpentaria (between the Torres Strait and the Northern Territory border). A recovery programme was carried out (the Carpentaria Ghost Net Programme) and after 29 months of collection (until November 2007), 73,444m of net had been collected from the region. The net was analysed for its origin, and although 41 per cent could not be identified, 17 per cent was identifiable as of Taiwanese origin, 7 per cent of Indonesian or Taiwanese origin, and 6 per cent from Korea.

Around the same time, in the Republic of Korea, a survey identified an estimated 18.9kg of debris per hectare of marine litter, 83 per cent of which comprised fishing nets and ropes (Cho, 2004).

Five years later, another survey in the Republic of Korea – this time a six-month study of the Incheon (Korea) coastal area – identified 194,000 sq m of marine debris, weighing 97,000 tonnes. A follow-up programme resulted in annual recovery of 91 tonnes of debris per sq km, of which 24 per cent was of marine origin. Between 2000 and 2006, 10,285 tonnes of fishing-related debris was recovered from coastal areas through coordinated coastal clean-up campaigns (UNEP, 2009).

Table 7. Examples of initiatives to remove debris from the marine environment

Project name	Location	Project description	Targeted debris
Coastal Clean-up Programme	Republic of Korea: 162 sites in 42 administrative units along the coast	Coastal clean-up programme to provide paying jobs for the removal of marine debris on the coast.	All types
KIMO's Fishing for Litter	Netherlands, United Kingdom (Scotland and South West England), Baltic Sea	Fishing vessels are provided with large bags, which are filled with marine-based litter, and when full deposited on the quayside and collected for disposal.	Marine-based
Ocean Conservancy's International Coastal Cleanup	More than 150 countries and locations worldwide	One day, every September, hundreds of thousands of people remove litter from coastlines and waterways around the world.	All types
Norsk Fiskeriretur AS	Various sites along the Norwegian coastline	A nationwide recycling scheme to collect discarded plastic equipment from the fishing industry. All collected equipment is dismantled, packed and sold to recycling companies in Europe.	Fish farming nets, cages, ropes and feeding tubes
South Korea's marine debris buyback program	South Korea	Fishermen are paid a small incentive fee by the government to collect and bring entangled, derelict fishing gear and other marine debris back to port.	All types

5.2.2 Beach clean-ups

There are numerous beach clean-up and beach survey programmes in operation around the world. One organisation working in this field is US-based Ocean Conservancy, which co-ordinates an annual international beach clean-up operation. In 2011, it enlisted some 600,000 volunteers, who collected more than 4,100 tons of litter and together covered more than 20,000 miles of coastline around the world. The clean-up also recorded a range of wildlife affected by debris, including 27 marine mammals, 49 birds and 18 reptiles, all entangled in debris including rope, fishing nets, lobster traps and plastic bags (Ocean Conservancy, 2012).

This widespread activity has huge potential to not only clean beaches, but to educate and involve people in the issues arising from marine litter. People especially need to understand that debris may have travelled wide distances before it makes landfall, and that debris can cause serious and significant effects to the welfare and health of wild animals.

University of Cape Town students survey a beach for plastic debris (and clean up as they go along), South Africa

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5.3
Rescue

Seal entangled in fishing net is rescued

5.3
Rescue

Where the necessary resources and infrastructure are in place, there are various programmes and training schemes that promote the rescue and disentanglement of trapped marine animals. There can be some difficulties and dangers associated with disentangling large, frightened animals, and professional rescue organisations, such as those mentioned below, are at pains to point out that rescue should only be attempted by properly trained individuals operating with the appropriate equipment.

Specific programmes

The International Fund for Animal Welfare (IFAW) trains volunteers in using equipment (such as grappling hooks, floating buoys, long cutting poles and special cutting knives and shears) to restrain and untangle trapped cetaceans and seals (IFAW, 2012).

Similarly, the British Divers Marine Life Rescue (BDMLR, 2012) runs training in how to use cutting and restraint gear for entangled animals as part of its rescue and rehabilitation training, and has trained more than 400 volunteers.

Meanwhile, NOAA (2012b) provides guidance to members of the public who find trapped or entangled animals, including the challenges of untangling a large whale. It also shares information about the work of the Alaska Response Network, which uses telemetry to track and relocate entangled whales that cannot be immediately untangled due to limited resources or poor weather. Responses of this nature are costly but clearly of great advantage.

Finally, the Whale and Dolphin Conservation Society (WDCS, 2012) uses whale watching as a platform for research and to monitor the health of populations. This enables it to actively report animals suspected to be entangled or trailing ropes or net, feeding into other rescue and untangling activity.

Rehabilitation centres

Many marine rehabilitation centres for cetaceans, seals and birds are experienced in untangling animals, either that they themselves have rescued or that others bring to them. The overall number of animals treated and returned across the globe is hard to ascertain because of the piecemeal nature of the reporting, usually found on websites and in newsletters produced by the many marine rescue and rehabilitation organisations. However, this work is essential. It is the active intervention of these organisations that results in many marine animals being disentangled.

Coastguards and marine agencies

Around the world, coastguard and other marine agencies are asked to attend to animals trapped in nets or entangled in ropes or lines. Many individual reports of coastguard action to release trapped animals can be seen on the internet. Some such agencies have demonstrated a willingness to formalise this role, though arguably many would require greater support such as the provision of specialist equipment for freeing animals and the training of staff.

5.4
Integrating the three Rs: reduction, removal and rescue

Sections 5.1–5.3 have looked at a number of initiatives that focus on either the reduction or removal of marine debris or on the rescue of affected animals. However, to be most effective a multi-faceted approach is necessary. One example of this approach in action is Australia's 'Threat Abatement Plan' which provides a coordinated national approach to preventing and mitigating the impacts of harmful marine debris on vertebrate marine life (CRC, 2009). The plan focuses on three areas of debris:

- land-sourced waste and refuse
- abandoned fishing gear from recreational and commercial fisheries (such as strapping bands, synthetic ropes, derelict fishing nets, floats, hooks, fishing line and wire trace)
- ship-sourced solid, non-biodegradable floating materials disposed of at sea (such as fibreglass or insulation).

The main objectives of the plan are to:

- contribute to the long-term prevention of the incidence of harmful marine debris
- remove existing harmful marine debris from the marine environment
- mitigate the impacts of harmful marine debris on marine species and ecological communities
- monitor the quantities, origins and impacts of marine debris and assess the effectiveness of management arrangements over time for the strategic reduction of debris.

This five-year project is due to be fully evaluated in 2015, but initial reports are positive and can be viewed as encouraging for future integrated work.

Right: Juvenile grey whale entangled in fishing gear, North Pacific Ocean

6
Conclusion

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6
Conclusion

Juvenile fur seal, South Island, New Zealand

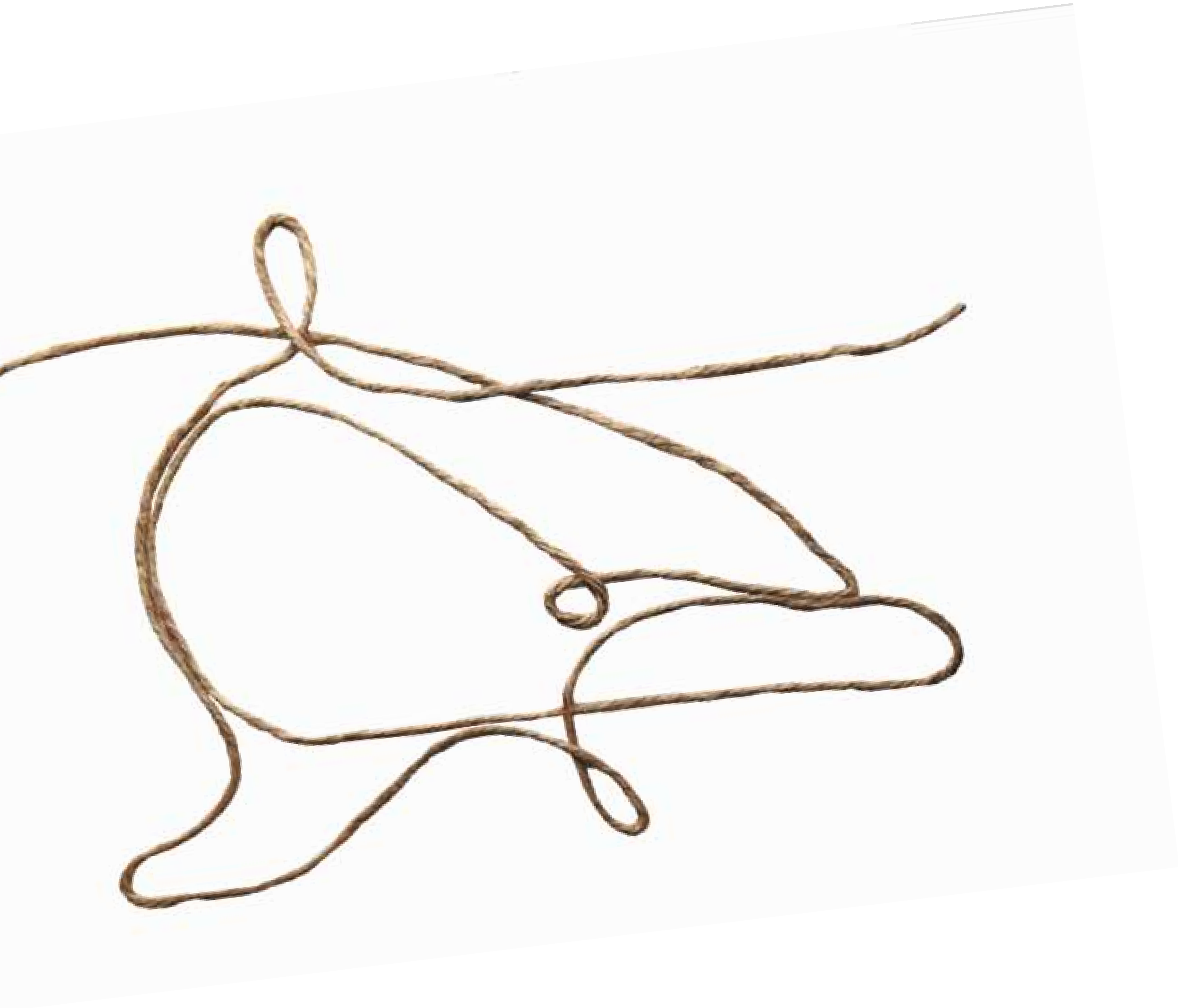
As the literature on marine debris grows, so does our insight into its impact. We can now see clearly that the effects of marine debris are not only aesthetic and environmental, but that it is also a cause of significant, large-scale and wholly avoidable animal suffering.

Every day, marine mammals, birds, turtles, sharks and other large fish species become entangled in ropes, nets, packing bands and straps, plastic packaging and fishing line, or ingest harmful debris. The consequences are severe; many fail to cope with the trauma, damage, pain, infection or compromised ability to feed, move and carry out their normal behaviours. Every year, millions of marine animals die a painful death, often prolonged over a period of months, or are condemned to a lifetime of suffering. Moore et al. (2006) describe this suffering as 'one of the grossest abuses of wild animals in the modern world.'

As this report shows, although a wide range of animals is affected, there are some particular species and locations where the effects seem to be amplified. The species most affected by entanglement are fur seals, monk seals, the California sea lion, humpback whales, turtles and marine birds, while the key species affected by ingestion are marine birds and turtles.

Despite the scale of their suffering, there is cause for hope. The number of organisations and agencies with a mandate for addressing the problem has expanded, and reporting and training networks to aid affected animals are increasingly in place. Local organisations that are involved in beach cleaning, recovering marine debris, or rescuing marine animals are exploiting modern communications to gain a clearer picture of the global nature of the problem and learn from each other's experiences. Public awareness of the problem of marine debris is also increasing and, with it, the demand for our political leaders to take action.

Yet, while there is hope, there is also urgency. Despite work being done in many regions to combat marine debris, the overall global trend in waste and plastic production is almost certain to result in more waste being either deliberately or accidentally released into the oceans in the future. Ever-greater accumulations of plastic will endanger ever-greater numbers of animals. The mounting evidence of the global nature of marine waste – and its potential to affect the lives and welfare of animals in every wild corner of the planet – should be a cause for international concern. Governments, industry, intergovernmental bodies and agencies, and the public worldwide; we all must act now to untangle the problem of marine debris and end the needless suffering of millions of marine animals.



Right: Lost and discarded fishing nets collected
from the Wadden Sea, Netherlands

References

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References

Agreement on Conservation of Albatrosses and Petrels (ACAP). (2010). Retrieved 10 October 2012 from http://www.acap.aq/2009-news-archive/fifth-meeting-of-the-acap-advisory-committee-to-meet-in-argentina-in-april-2010.

Asia-Pacific Economic Corporation (APEC). (2004). *Derelict Fishing Gear and Related Marine Debris: An Educational Outreach Seminar Among APEC Partners*. Seminar Report. APEC Seminar on Derelict Fishing Gear and Related Marine Debris, 13–16 January 2004, Honolulu, Hawaii, USA.

Al-Masroori, H.S. (2002). *Trap ghost fishing problem in the area between Muscat and Barka (Sultanate of Oman): an evaluation study* (M.Sc. thesis). Sultan Qaboos University, Sultanate of Oman.

Anderson, R. C. & Waheed, A. (1988). Exploratory fishing for large pelagic species in the Maldives. Main Report. Bay of Bengal Programme BOBP/REP/46 – FAO/TCP/ MDV/6651.

Allen, J. A., Sayer, S. Jarvis, D., & Mills, C. (2012). *A welfare issue: entanglement of Cornish grey seals.* Presentation. Cornwall College, Newquay, Cornwall Seal Group, BDMLR, University of Exeter. Abstract retrieved 10 October 2012 from http://www.cornwallsealgroup.co.uk/.

Arnould, J. P. Y., & Croxall, J. P. (1995). Trends in entanglement of Antarctic fur seals (Arctocephalus gazella) in man-made debris at South Georgia. *Marine Pollution Bulletin, 30*(11), 707-712.

Attademo, F. L. N., Alencar, A. E., Nobre, J. K., Lopes, L. J., & Severo, M. M. (2008). *Ingestion of plastic debris by marine manatees (Trichechus manatus manatus) reintroduced on the coast of Paraiba/Brazil: Case report.* The Third Florida Marine Mammal Health Conference. April 22-25, Florida. Abstract retrieved 10 October 2012 from http://www.conference.ifas.ufl.edu/marinemammal/pdfs/abstract_book.pdf.

Barco, S. G., D'Eri, L. R., Woodward, B. L., Winn, J. P., & Rotstein, D. S. (2010). Spectra® fishing twine entanglement of a bottlenose dolphin: A case study and experimental modeling. *Marine Pollution Bulletin, 60*(9), 1477-1481.

Barnes, D. K. A. (2005). Remote islands reveal rapid rise of Southern Hemisphere sea debris. *The Scientific World Journal*, *5,* 915-921.

Barnes, D. K. A., Galgani, F., Thompson, R. C., & Barlaz, M. (2009). Accumulation and fragmentation of plastic debris in global environments. *Philosophical Transactions of the Royal Society B, 364*(1526), 1985-1998.

Beck, C., & Barros, N. (1991). The impact of debris on the Florida Manatee. *Marine Pollution Bulletin, 22*(10), 508-510.

Bjorndal, K., Bolten, A., & Lageaux, C. (1994). Ingestion of marine debris by juvenile sea turtles in coastal Florida habitats. *Marine Pollution Bulletin, 28*(3), 154-158.

Boland, R. C. & 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, 46,* 1385-1394.

Boren, L. J., Morrissey, M., Muller, C. G., & Gemmell, N. J. (2006). Entanglement of New Zealand fur seals in man-made debris at Kaikoura, New Zealand. *Marine Pollution Bulletin, 52,* 442-446.

Bradford, A., Weller, D., Ivaschenko, Y., Burdin, A., & Brownell, R. (2009). Anthropogenic Scarring of Western Gray Whales *(Eschrichtius robustus). Marine Mammal Science, 25*(1): 161-175.

Breen, P. A. (1990). A review of ghost fishing by traps and gillnets. *Proceedings of the 2nd International Conference on Marine Debris,* 2–7 April 1989, Honolulu, Hawaii, USA. NOAA Technical Memorandum *154*: 561-599.

British Divers Marine Life Rescue (BDMLR). (2012). *British Divers Marine Life Rescue Training.* Retrieved 10 October 2012 http://www.bdmlr.org.uk/index.php?page=training-course.

Brown, J., Macfadyen, G., Huntington, T., Magnus J., & Tumilty, J. (2005). Ghost fishing by lost fishing gear. *Final Report to DG Fisheries and Maritime Affairs of the European Commission.* Fish/2004/20. Institute for European Environmental Policy/ Poseidon Aquatic Resource Management Ltd joint report.

Burke, L., & Maidens, J. (2004). *Reefs at Risk in the Caribbean.* Report by the World Resources Institute, Washington D.C. Retrieved 10 October 2012 from http://www.wri.org/publication/reefs-riskcaribbean.

Campagna, C., Falabella, V., & Lewis, M. (2007). Entanglement of southern elephant seals in squid fishing gear. *Marine Mammal Science, 23*(2), 414-418.

Cassoff, R. M., Moore, K. M., McLellan, W. A., Barco, S. G., Rotstein, D. S., & Moore, M. J. (2011). Lethal entanglement in baleen whales. *Diseases of Aquatic Organisms, 96,* 175-185.

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

Chang-Gu Kang (2003). *Marine litter in the republic of Korea.* Retrieved 10 October 2012 from http://marine-litter.gpa.unep.org/documents/marine-litter-Korea-Kang.pdf.

Cho, D. O. (2004). *Case study of derelict fishing gear in Republic of Korea.* Paper presented at the APEC Seminar on Derelict Fishing Gear and Related Marine Debris, 13-16 January, Honolulu, Hawaii, USA.

Chopin, F., Inoue, Y., Matsuhita, Y., & Arimoto, T. (1995). Sources of accounted and unaccounted fishing mortality. In B. Baxter & S. Keller (Eds.), *Proceedings of the Solving Bycatch Workshop on Considerations for Today and Tomorrow* (pp.41-47). University of Alaska Sea Grant College Program Report No. 96–03.

Cliff, G., Dudley, S. F. J., Ryan, P. G., & Singleton, N. (2002). Large sharks and plastic debris in KwaZulu-Natal, South Africa. *Marine and Freshwater Research, 53*(2), 575-581.

Cole, T., Hartley, D., & Garron, M. (2006). *Mortality and serious injury determinations for baleen whale stocks along the Eastern Seaboard of the United States, 2000-2004.* US Department of Commerce, Northeast Fisheries Science Center Reference Document: 06-04.

Consortium for Wildlife Bycatch Reduction. (2012). *Fishing Technique Modifications.* Retrieved 10 October 2012 from http://www.bycatch.org/research/consortium/fishing-gear-modifications.

Convention on Biological Diversity (CBD). (2012). Secretariat of the Convention on Biological Diversity and the Scientific and Technical Advisory Panel—GEF (2012). *Impacts of Marine Debris on Biodiversity: Current Status and Potential Solutions,* Montreal, Technical Series No. 67. Retrieved 12 November 2012 from http://www.cbd.int/doc/publications/cbd-ts-67-en.pdf.

Convention on Migratory Species (CMS). (2012). *Cop10 Outcome: Marine Debris.* Retrieved 12 November 2012 from http://www.cms.int/news/PRESS/nwPR2012/02_feb/nw_100212_marine_debris.htm.

Coupland, R. M. (1992). The Red Cross classification of war wounds: The E.X.C.F.V.M. scoring system. *World Journal of Surgery, 16*(5), 910-917.

C&R Consulting for the Department of the Environment, Water, Heritage and the Arts (CRC). (2009). *Australian work on debris abatement – Threat Abatement Plans.* Australian Government. Retrieved 10 October 2012 from http://www.environment.gov.au/coasts/pollution/marine-debris/index.html.

Croxall, J. P., Rowell, S., & Boyd, I. L. (2006). Entanglement in man-made debris of Antarctic fur seals at Bird Island, South Georgia. *Marine Mammal Science, 6*(3), 221-233.

Dau, B. K., Gilardi, K. V., Gulland, F. M., Higgins, A., Holcomb, J. B., Leger, J. S., & Ziccardi, M. H. (2009). Fishing gear-related injury in California marine wildlife. *Journal of Wildlife Diseases, 45*(2), 355-362.

Derraik, J. G. B. (2002). The pollution of the marine environment by plastic debris: a review. *Marine Pollution Bulletin, 44*(9), 842-852.

Donohue, M. J., Boland, R. C., Sramek, C. M., & 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*(12), 1301-1312.

Donohue, M. J., & Foley, D. G. (2007). Remote sensing reveals links among the endangered Hawaiian monk seal, marine debris, and El Niño. *Marine Mammal Science, 23*(2), 468-473.

Environmental Graffiti. (2009). *North Pacific Gyre: The Ocean's Hidden Garbage Dump.* Retrieved 15 November 2012 from http://www.environmentalgraffiti.com/waste-and-recycling/news-plastic-graveyard-soup-unwanted-junk-our-ocean#4qbxIel7QMgFLS2U.99.

European Commission Contract FAIR PL98 4338 (Fantared 2). (2003). Retrieved 10 October 2012 from http://www.seafish.org/media/Publications/FANTARED_2_COMPLETE.pdf.

European Commission DG ENV. (2011). *Plastic waste in the environment*. Revised final report. Specific contract 07.0307/2009/545281/ETU/G2 under Framework contract ENV.G.4/FRA/2008/0112.

Farm Animal Welfare Council (FAWC). (1979). *Press Statement.* Retrieved 8 November 2012 from http://www.fawc.org.uk/pdf/fivefreedoms1979.pdf.

Fowler, C. W. (1987). Marine debris and northern fur seals: A case study. *Marine Pollution Bulletin, 18*(6b), 326-335.

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. *European Research on Cetaceans, 14,* 173–178.

Gomerčić, M., Galov, A., Gomerčić, T., Škrtić, D., Ćurković, S., Lucić, H., Vuković, S., Arbanasić, H., & Gomerčić, H. (2009) Bottlenose dolphin *(Tursiops truncatus)* depredation resulting in larynx strangulation with gill-net parts. *Marine Mammal Science, 25*(2), 392-401.

Good, T. P., June, J. A., Etnier, M., & Broadhurst, G. (2007). Quantifying the impact of derelict fishing gear on the marine fauna of Puget Sound and the Northwest Straits. *Proceedings of the International Council for the Exploration of the Sea Annual Science Conference.* September 17-21, Helsinki. Retrieved 10 October 2012 from http://www.ices.dk/products/cmdocsindex.asp.

Good, T. P., June, J. A., Etnier, M., & Broadhurst, G. (2009). Ghosts of the Salish Sea: threats to marine birds in Puget Sound and the Northwest Straits from derelict fishing gear. *Marine Ornithology, 37*, 67-76.

Good, T. P., June, J. A., Etnier, M., & Broadhurst, G. (2010). Derelict fishing nets in Puget Sound and the Northwest Straits: patterns and threats to marine fauna. *Marine Pollution Bulletin, 60,* 39-50.

Goulart, V. D., Azevedo, P. G., van de Schepop, J. A., Teixeira, C. P., Barcante, L., Azevedo, C. S. & Young, R. J. (2009). GAPs in the Study of Zoo and Wild Animal Welfare. *Zoo Biology, 28,* 561-573.

Gregory, M. R. (2009). Environmental implications of plastic debris in marine settings – entanglement, ingestion, smothering, hangers-on, hitchhiking and alien invasions. *Philosophical Transactions of the Royal Society B, 364*(1526), 2013-2025.

Guillory, V., McMillen-Jackson, A., Hartman, L., & Perr, H. (2001). *Blue Crab Derelict Traps and Trap Removal Programs.* Publication 88, Gulf States Marine Fisheries Commission. Retrieved 10 October 2012 from http://www.gsmfc.org/pubs/ijf/derelicttraps.pdf.

Gulf States Marine Fisheries Commission (GSMFC). (2003). *Derelict crab trap removal program: Programs in other gulf states.* Retrieved 10 October 2012 from http://www.derelictcrabtrap.net/background5.html.

Hanni, K. D., & Pyle, P. (2000). Entanglement of Pinnipeds in Synthetic Materials at South-east Farallon Island, California, 1976-1998. *Marine Pollution Bulletin, 40*(12), 1076-1081.

Harcourt, R., Aurioles, D., & Sanchez, J. (1994). Entanglement of California sea lions at Los Islotes, Baja California Sur, Mexico. *Marine Mammal Science, 10,* 122-125.

Hazekamp, A.A.H., Mayer, R., Osinga, N. (2010). Flow simulation along a grey seal; the impact of an external device. *European Journal of Wildlife Research, 56,* 131-140. Retrieved 10 October 2012 from http://www.zeehondencreche.nl/wb/pages/wetensch.-onderzoek/wetenschappelijke-publicaties.php.

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.

Hofmeyr, G. J. G., De Maine, M., Bester, M. N., Kirkman, S. P., Pistorius, P. A., & Makhado, A. B. (2002). Entanglement of pinnipeds at Marion Island, Southern Ocean: 1991-2001. *Australian Mammalogy, 24,* 141-146.

Hofmeyr, G. J., Marthán, N. B., Kirkman, S. P., Lydersen, C., Kovacs, K. M. (2006). Entanglement of Antarctic fur seals at Bouvetøya, Southern Ocean. *Marine Pollution Bulletin, 52*(9): 1077-80. DOI:10.1016/j.marpolbul.2006.05.003.

Hwang, S. T., & Ko, J. P. (2007). *Achievement and progress of marine litter retrieval project in near coast of Korea, based on activities of Korea Fisheries Infrastructure Promotion Association.* Presentation to Regional Workshop on Marine Litter, June 2007, Rizhao, The People's Republic of China. North West Pacific Action Plan.

Interagency Manatee Entanglement Working Group of the US Fish and Wildlife Service. (2005). *Monofilament Recovery and Recycling Working Group.* Retrieved 10 October 2012 from http://florida-offshore.com/article2019.html.

International Fund for Animal Welfare (IFAW). (2012). *Learning to rescue whales from entanglements.* Retrieved 13 November 2012 from http://www.ifaw.org/united-kingdom/node/2472 .

International Whaling Commission (IWC). (2010). IWC/62/Rep 1 (Inc Annex A-C). *Report of the Scientific Committee International Whaling Commission.* Agadir, 30th May-11th June.

Ivar do Sul, J. A., & 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, 1*(8), 1087-1104.

Jacobsen, J. K., Massey, L., & Gulland, F. (2010). Fatal ingestion of floating net debris by two sperm whales *(Physeter macrocephalus). Marine Pollution Bulletin, 60*(5), 765-767.

Johnson, A., Salvador, G., Kenney, J., Robbins, J., Kraus, S., Landry, S., & Clapham, P. (2005). Fishing gear involved in entanglements of right and humpback whales. *Marine Mammal Science, 21*(4), 635-645.

Karamanlidis, A. A. (2000). Monitoring human and Mediterranean monk seal activity in the National Marine Park of Alonnissos and Northern Sporades, Greece. *The Monachus Guardian, 3*(1).

Kiessling, I. (2003). *Finding Solutions: Derelict fishing gear and other marine debris in Northern Australia.* Report prepared for the National Oceans Office for the Key Centre for Tropical Wildlife Management. Darwin, Australia: Charles Darwin University.

Knowlton, A. R., & 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,* Special Issue 2, 193-208.

Knowlton, A. R., Hamilton, P. K., Marx, M. K., Pettis, H. M., & Kraus, S. D. (2012). Monitoring North Atlantic right whale *Eubalaena glacialis* entanglement rates: a 30 yr retrospective. *Marine Ecology Progress Series, 466,* 293-302.

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

Kraus, S. D. (2008). The urban life of the North Atlantic right whale: The cumulative effects of traffic, fishing, noise, pollution, and disease in the coastal zone of North America. *The Third Florida Marine Mammal Health Conference.* April 22-25, Florida. Abstract retrieved 10 October 2012 from http://www.conference.ifas.ufl.edu/marinemammal/pdfs/abstract_book.pdf.

Kruse, G. H. & Kimker, A. (1993). *Degradable escape mechanisms for pot gear: a summary report to the Alaska Board of Fisheries.* Regional Information Report 5J93-01. Alaska Department of Fish and Game (ADFG).

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. In J. M. Coe & D. B. Rogers (Eds.), *Marine debris, sources, impacts, and solutions* (pp. 99-139). New York, NY: Springer-Verlag.

Lambertsen, R. H., Rasmussen, K. J., Lancaster, W. C., & Hintz, R. J. (2005). Functional morphology of the mouth of the Bowhead whale and its implications for conservation. *Journal of Mammalogy, 86*(2), 342-352.

Lazar, B. & Gracan, R. (2011). Ingestion of marine debris by loggerhead sea turtles, Caretta caretta, in the Adriatic Sea. *Marine Pollution Bulletin, 62,* 43-47.

Macfadyen, G., Huntington, T., & 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.

Mallory, M. L., Robertson, G. J., & Moenting, A. (2006). Marine plastic debris in northern fulmars from Davis Strait, Nanavut. *Marine Pollution Bulletin, 52*(7), 800-815.

Mann, J., Smolker, R .A., & Smuts, B. B. (1995). Responses to calf entanglement in free-ranging bottlenose dolphins. *Marine Mammal Science, 11*(1), 100-106.

Marine Conservation Society (MCS). (2007). *Beachwatch 2006: The 14th annual beach litter survey report.* Ross on Wye, UK: Marine Conservation Society. Summary data available at http://www.mcsuk.org/press/view/183. Retrieved 9 November 2012.

Marine Mammal Commission. (1996). *Annual Report.* Retrieved 10 October 2012 from http://mmc.gov/reports/annual/pdf/1996annualreport.pdf.

MARPOL (International Convention for the Prevention of Pollution from Ships) Annex V, resolution MEPC.201(62). Comes into force 1 January 2013. Retrieved 10 October 2012 from http://www.imo.org/OurWork/Environment/PollutionPrevention/Garbage/Documents/Annex%20V%20discharge%20requirements%20for%20website%203.pdf.

Mato, Y., Isobe, T., Takada, H., Kanehiro, H., Ohtake, C., & Kaminuma, T. (2001). Plastic resin pellets as a transport medium for toxic chemicals in the marine environment, *Environmental Science and Technology, 35*(2), 318-324.

Matthews, T. R., & Uhrin, A. V. (2009). Lobster trap loss, ghost fishing, and impact on natural resources in Florida Keys National Marine Sanctuary. In Morison, S. and Murphy, P. (Eds.), *Proceedings of the NOAA Submerged Derelict Trap Methodology Detection Workshop.* June 2-4. NOAA Technical Memorandum NOSOR&R-32.

McKauge, K. (Undated). *Assessing the Blue Swimmer Crab Fishery in Queensland.* Retrieved 15 November 2012 at www2.dpi.qld.gov.au/extra/pdf/fishweb/blueswimmercrab/GhostFishing.pdf.

McElwee, K., & Morishige, C. (Eds.). (2008). *Proceedings of the Workshop on At-Sea Detection and Removal of Derelict Fishing Gear.* December 9-10, 2008. NOAA Technical Memorandum NOS-OR&R-34. Retrieved 10 October 2012 from http://marinedebris.noaa.gov/projects/pdfs/atsea.pdf.

Meirelles, A. C. O., & Barros, H. M. D. R. (2007). Plastic debris ingested by a rough-toothed dolphin, *Steno bredanensis,* stranded alive in northeastern Brazil. *Biotemas, 20*(1), 127-131.

Moore, M., Knowlton, A., Kraus, S., McLellan, W. and Bonde, R. (2005). Morphometry, gross morphology and available histopathology in Northwest Atlantic right whale *(Eubalaena glacialis)* mortalities (1970 to 2002). *Journal Cetacean Research and Management, 6*, 199-214.

Moore, M. J., Bogomolni, A., Bowman, R., Hamilton, P. K., Harry, C. T., Knowlton, A. R., Landry, S., Rotstein, D. S., & Touhey, K. (2006). *Fatally entangled right whales can die extremely slowly.* OCEANS Conference, 18-21 September, Boston, MA.

Moreira, N., Brown, J. L., Moraes, W., Swanson, W. F., & Monteiro-Filho. E.L.A. (2007). Effect of housing and environmental enrichment on adrenocortical activity, behavior, and reproductive cyclicity in the female Tigrina *(Leopradus tigrinus)* and Margay *(Leopardus wiedii). Zoo Biology, 26,* 441-460.

National Oceanic and Atmospheric Administration (NOAA) Chesapeake Bay Office. (2007). *NOAA Chesapeake Bay Office Partners with Maryland Department of Natural Resources in Study of Derelict Fishing Gear.* Retrieved 10 October 2012 from http://dnr.maryland.gov/fisheries/crab/derelictfactsheet.pdf.

NOAA/NMFS. (2007). Workshop Summary. *Serious Injury Technical Workshop,* Seattle, September 10-12 2007. Retrieved from: http://www.nmfs.noaa.gov/pr/interactions/injury/pdfs/workshop_summary.pdf on 8 November 2011

NOAA. (2012a). *Marine Mammal Entanglement: Pinniped.* Retrieved 15 November 2012 from http://www.fakr.noaa.gov/protectedresources/entanglement/pinnipeds.htm

NOAA. (2012b). *Marine Mammal Entanglement: Large Whale.* Retrieved 15 November 2012 from http://www.fakr.noaa.gov/protectedresources/entanglement/whales.htm

NOAA. (2012c). *International Efforts to Reduce Marine Debris and Build Capacity.* Retrieved 12 November 2012 from http://marinedebris.noaa.gov/about/international.html.

National Research Council (NRC). (2008). *Tackling marine debris in the 21st Century.* Committee on the Effectiveness of International and National Measures to Prevent and Reduce Marine Debris and its Impacts. Retrieved 10 October 2012 from http://docs.lib.noaa.gov/noaa_documents/NOAA_related_docs/marine_debris_2008.pdf.

Neilson, J. L. (2006). Humpback whale *(Megaptera novaeangliae) entanglement in fishing gear in northern southeastern Alaska* (Unpublished master's thesis). Fairbanks, University of Alaska.

Neilson, J. L., Gabriele, C. M., Straley, J. M. (2007). Humpback Whale Entanglement in Fishing Gear in Northern Southeastern Alaska. *Proceedings of the Fourth Glacier Bay Science Symposium.* October 26-28, 2004: U.S. Geological Survey Investigations Report 2007-5047, p. 204-207.

Neilson, J. L., & Gabriele, C. M. (2007). R*esults of humpback whale population monitoring in Glacier Bay and adjacent waters.* Glacier Bay National Park & Preserve. Gustavus, AK, 20pp. Abstract retrieved 10 October 2012 from http://digitalcorpora.org/corp/nps/files/govdocs1/372/372142.pdf.

Neilson, J. L., Straley, J. M., Gabriele, C. M., & Hills, S. (2009). Non-lethal entanglement of humpback whales *(Megaptera novaeangliae)* in fishing gear in northern Southeast Alaska. *Journal of Biogeography, 36,* 452-464.

Northridge, S., Cargill, A., Coram, A., Mandleberg, L., Calderan, S., & Reid, B. (2010). *Entanglement of minke whales in Scottish waters: An investigation into occurrence, causes and mitigation.* Sea Mammal Research Unit. Final report to the Scottish Government CR/2007/49.

Northwest Straits Initiative. (2008). *Rates of marine species mortality caused by derelict fishing nets in Puget Sound, Washington.* Final report, prepared by Natural Resources Consultants, Inc. Retrieved 10 October 2012 from: http://www.nwstraits.org/Uploads/pdf/DG-MortalityRates.pdf.

Ocean Conservancy. (2012). *International Coastal Clean Up: 2012 data release.* Retrieved 10 October 2012 from http://www.oceanconservancy.org/our-work/marine-debris/2012-data-release.html.

Orós, J.,Torrent, A., Calabuig, P., & Déniz, S. (2005). Diseases and causes of mortality among sea turtles stranded in the Canary Islands, Spain (1998–2001). *Diseases of Aquatic Organisms, 63,* 13-24.

Oslo and Paris Conventions for the Protection of the Marine Environment of the North-East Atlantic (OSPAR). (2009). *Marine litter in the North-east Atlantic region.* London: OSPAR Commission. Publication number 386/2009. Retrieved 10 October 2012 from http://www.ospar.org/documents/dbase/publications/p00386_marine%20litter%20in%20the%20north-east%20atlantic%20with%20addendum.pdf.

Page, B., Welling, A., Chambellant, M., Goldsworthy, S. D., Dorr T., & van Veen, R. (2003). Population status and breeding season chronology of Heard Island fur seals. *Polar Biology, 26,* 219-224.

Page, B., McKenzie, J., McIntosh, R., Baylis, A., Morrissey, A., Calvert, N., Haas, T., Berris, M., Dowie, D., Shaughnessy, P. D., & Goldsworthy, S. D. (2004). Entanglement of Australian sea lions and New Zealand fur seals in lost fishing gear and other marine debris before and after Government and industry attempts to reduce the problem. *Marine Pollution Bulletin, 49,* 33-42.

Paul, J. M., Paul, A. J., & Kimker, A. (1994). Compensatory feeding capacity of two Brachyuran crabs, Tanner and Dungeness, after starvation periods like those encountered in pots. *Alaska Fishery Research Bulletin, 1,* 184-187.

Pemberton, D., Brothers, N. P., & Kirkwood, R. (1992). Entanglement of Australian fur seals in man-made debris in Tasmanian waters. *Wildlife Research, 19,* 151-159.

Raaymakers, S. (2007). *The Problem of Lost and Abandoned Fishing Gear - Global Review and Proposals for Action.* Draft report to the Food and Agriculture Organization (FAO) of the United Nations and the United Nations Environment Programme (UNEP). EcoStrategic Consultants, Cairns.

Raum-Suryan, K. L., Jemison, L. A., & Pitcher, K. W. (2009). Entanglement of Steller sea lions (Eumetopias jubatus) in marine debris: Identifying causes and finding solutions. *Marine Pollution Bulletin, 58,* 1487-1495.

Robbins, J., and D. K. Mattila. (2000). *Monitoring entanglement scars on the caudal peduncle of Gulf of Maine humpback whales: 1997-1999.* Center for Coastal Studies. Order number 40ENNF900253. 24 p.

Robbins, J., & Mattila, D. (2001). *Monitoring entanglements of humpback whales (Megaptera novaeangliae) in the Gulf of Maine on the basis of caudal peduncle scarring.* Unpublished report to the Scientific Committee of the International Whaling Commission: SC/53/NAH25.

Robbins, J., & Mattila, D. (2004). *Estimating humpback whale (Megaptera novaeangliae) entanglement rates on the basis of scar evidence.* Report to the Northeast Fisheries Science Centre National Marine Fisheries Service, Woods Hole, MA 02543 43EANF030121.

Robbins, J. (2009). *Scar-based inference into Gulf of Maine humpback whale entanglement: 2003-2006.* Report to the National Marine Fisheries Service. Provincetown (MA): Provincetown Center for Coastal Studies.

Ryan, P.G. (1988). Effects of ingested plastic on seabird feeding: Evidence from chickens. *Marine Pollution Bulletin, 19,* 3, 125-128.

Ryan, P. G., Moore, C. J., van Franeker, J. A., & Moloney, C. L. (2009). Monitoring the abundance of plastic debris in the marine environment. *Philosophical Transactions of the Royal Society B: Biological Sciences, 364,* 1999-2012. doi: 10.1098/rstb.2008.0207.

Sadove, S. S., & Morreale, S. J. (1990). Marine mammal and sea turtle encounters with marine debris in the New York Bight and the Northeast Atlantic. In R. S. Shomura & M. L. Godfrey (Eds.). *Proceedings of the Second International Conference on Marine Debris,* 2-7 April 1989, Honolulu, Hawaii. NOAA TM NMFS SWFSC 154.

Santos, I. R., Friedrich, A. C., & Barretto, F. P. (2005). Overseas garbage pollution on beaches of northeast Brazil. *Marine Pollution Bulletin, 50*(7), 782-786.

Sazima, I., Gadig, O. B. F., Namora, R. C., & Motta, F. S. (2002). Plastic debris collars on juvenile carcharhinid sharks *(Rhizoprionodon lalandii)* in southwest Atlantic. *Marine Pollution Bulletin, 44(*10), 1149-1151.

Scientific and Technical Advisory Panel (STAP). (2011). *Marine Debris as a Global Environmental Problem: Introducing a solutions based framework focused on plastic.* A STAP Information Document. Global Environment Facility, Washington, DC. Retrieved 10 October 2012 from http://www.thegef.org/gef/sites/thegef.org/files/publication/STAP%20MarineDebris%20-%20website.pdf.

Secchi, E. R., & Zarzur, S. (1999). Plastic debris ingested by a Blainville's beaked whale, *Mesoplodon densirostris,* washed ashore in Brazil. *Aquatic Mammals, 25*(1), 21-24.

Shaughnessy, P. D. (1980). Entanglement of Cape fur seals with man-made objects. *Marine Pollution Bulletin, 11,* 332-336.

Sheavly, S. B. (2005). *Marine debris – an overview of a critical issue for our oceans.* Paper presented at the sixth meeting of the UN Open-ended Informal Consultative Process on Oceans and the Law of the Sea. June 6-10, 2005. New York, NY. Retrieved 9 November 2012 from http://www.un.org/Depts/los/consultative_process/consultative_process.htm.

Sheavly, S. B. (2007). *National Marine Debris Monitoring Program: Final Program Report, Data Analysis and Summary.* Prepared for U.S. Environmental Protection Agency by Ocean Conservancy, Grant Number X83053401-02. 76 pp. Retrieved 10 October 2012 from http://act.oceanconservancy.org/site/DocServer/NMDMP_REPORT_Ocean_Conservancy__2_.pdf?docID=3181.

Sloan, S., Wallner, B., & Mounsey, R. (1998). *Fishing debris around Groote Eylandt in the Western Gulf of Carpentaria.* Report on the Groote Eylandt Fishing Gear Debris Project 1998. Australian Fisheries Management Authority. Canberra: Australia.

Smolowitz, R. J. (1978). Trap design and ghost fishing: an overview. *Marine Fisheries Review, 40*(5-6), 2-8.

Song, K., Kim, Z. G., Zhang, C. I., & Kim, Y. H. (2010). Fishing gears involved in entanglements of minke whales *(Balaenoptera acutorostrata)* in the East Sea of Korea. *Marine Mammal Science, 26*(2), 282-295.

Stevens, B. G. (1996). *Crab bycatch in pot fisheries. Solving bycatch: considerations for today and tomorrow,* pp.151–158. Alaska Sea Grant Program Report 96-03. University of Alaska, Fairbanks, Juneau, Alaska.

Stewart, B. S., & Yochem, P. K. (1987). Entanglement of pinnipeds in synthetic debris and fishing net and line fragments at San Nicolas and San Miguel Islands, California, 1978–1986. *Marine Pollution Bulletin, 18,* 336-339.

Tourinho, P. S., Ivar do Sul, J. A., & Fillmann, G. (2010). Is marine debris ingestion still a problem for the coastal marine biota of southern Brazil? *Marine Pollution Bulletin, 60*(3), 396-401.

Trites, A. W., Christensen, V., & Pauly, D. (1997) Competition Between Fisheries and Marine Mammals for Prey and Primary Production in the Pacific Ocean. *Journal of Northwest Atlantic Fisheries Science, 22,* 173-187.

United Nations (UN). (2005). *Report on the work of the United Nations Open-ended Informal Consultative Process on Oceans and the Law of the Sea at its sixth meeting.* United Nations document number A/60/99.

UNEP. (2001). *Marine Litter: trash that kills.* Retrieved 10 October 2012 from http://www.unep.org/regionalseas/marinelitter/publications/docs/trash_that_kills.pdf.

UNEP. (2005). *Marine litter: An analytical overview.* Retrieved 10 October 2012 from http://www.unep.org/regionalseas/marinelitter/publications/docs/anl_oview.pdf.

UNEP. (2009). *Marine Litter: A Global Challenge.* Nairobi: UNEP.

UNEP/NOAA. (2011). The Honolulu Strategy. *5th International Marine Debris Conference,* 2011, Honolulu, Hawaii. Retrieved 12 November 2012 from http://5imdc.files.wordpress.com/2011/03/honolulustrategy.pdf.

Votier, S. C., Archibald, K., Morgan, G., & Morgan, L. (2011). The use of plastic debris as nesting material by a colonial seabird and associated entanglement mortality. *Marine Pollution Bulletin, 62,* 168-172.

Wegner, N. C., & Cartamil, D. P. (2012). Effects of prolonged entanglement in discarded fishing gear with substantive biofouling on the health and behavior of an adult shortfin mako shark, *Isurus oxyrinchus. Marine Pollution Bulletin, 64*(2), 391-394.

Werner, T. (2011). *Preliminary Report of the Dynamics of Large Whale Entanglements in Fishing Gear Workshop.* Retrieved 15 November 2012 from http://www.nero.noaa.gov/whaletrp/trt/meetings/day1/r-whaleEntanglementWorkshop_PRELIMFINAL.pdf.

Whale and Dolphin Conservation Society (WDCS). (2012). *Entanglement.* Retrieved 10 October 2012 from http://us.wdcs.org/wap_blog/index.php?/categories/7-Entanglement/P2.html.

Williams, R., Ashe, E., & O'Hara, P. D. (2011). Marine mammals and debris in coastal waters of British Columbia, Canada. *Marine Pollution Bulletin, 62*(6), 1303-1316.

World Organisation for Animal Health (OIE). (2010). *Introduction to the Recommendations for Animal Welfare.* Retrieved 7th November 2012 from http://web.oie.int/eng/normes/mcode/en_chapitre_1.7.1.pdf.

WorldWatch. (2004). *State of the World 2004: Special Focus: The Consumer Society.* Retrieved 10 October 2012 from http://www.worldwatch.org/node/1043.

Zavadil, P. A., Robson, B. W., Lestenkof, A. D., Holser, R., & Malavansky, A. (2007). *Northern Fur Seal Entanglement Studies on the Pribilof Islands in 2006.* For National Oceanic and Atmospheric Administration Prescott Stranding Grant Program and Alaska Regional Stranding Network Coordinator.

Zavala-González, A., & Mellink, E. (1997). Entanglement of California sea lions, *Zalophus californianus californianus,* in fishing gear in the central-northern part of the Gulf of California, Mexico. *Fishery Bulletin, 95,* 180-184.

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