Chapter 1
Marine Mammals and Interactions with Debris in the Northeastern Atlantic Region: Synthesis and Recommendations for Monitoring and Research

Neil A. James and Anika Große

Abstract Marine plastic pollution is a global problem, affecting a wide variety of marine organisms through the processes of ingestion and entanglement. Despite numerous reports of entanglement and ingestion of plastic debris by marine mammals, there is a lack of clear understanding regarding the spatial distribution and drivers of interactions between marine mammals and marine plastics in the northeastern Atlantic area. To address this, we undertook a synthesis of the published and grey literature in order to acquire information on known documented cases of ingestion of, or entanglement with, debris relating to marine mammals. We found that 62% of the 37 species present in the region were reported to have either ingested, or become entangled in, debris. There was a predominance of threadlike plastic related to entanglement, but it was also present in the ingestion data. However, we observed a great deal of inconsistency regarding the reporting of marine mammal–debris interactions. We therefore highlight the need for and recommend the development of a standardised approach to recording debris interacting with marine mammals.

Keywords Marine mammals · Entanglement · Ingestion · Fishing gear · Plastics · Northeastern Atlantic · Marine pollution

N. A. James (✉)
Environmental Research Institute, UHI North Highland, University of the Highlands and Islands, Scotland, UK
e-mail: Neil.James@uhi.ac.uk

A. Große
Helmholtz Centre for Environmental Research GmbH – UFZ, Magdeburg, Germany
e-mail: anika.grosse@ufz.de

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1.1 Introduction

The global production of plastics continues to increase year on year, with 460 million tonnes produced in 2019 (OECD 2022). This is likely to increase, with projections from a business-as-usual scenario predicting a threefold increase in the amount of plastics use, waste, and cumulative presence in aquatic environments (OECD 2022). The most recent comprehensive study estimates that in 2016, 19–23 million tonnes of plastics entered the aquatic environment (Borrelle et al. 2020). This is likely to at least double to 44 million tonnes per year by 2060 (OECD), but according to some projections may increase to 53 million tonnes per year by 2030 (Borrelle et al. 2020). Across the European Union, the proportion of collected plastics that are recycled is increasing each year as initiatives and legislation encourage the move to a more circular economy but approximately 23.4% of collected plastics in the EU still go to landfill (Plastics Europe 2021). However, due to both deliberate and unintentional mishandling and disposal of plastic waste, a significant proportion of that which is produced ends up in the environment. Due to waste mismanagement, plastics can be transported by wind or rain into river systems and subsequently be transported into the marine environment. In addition, plastic debris can enter the aquatic environment through direct dumping (intentional and accidental) and through wastewater treatment works, for instance in the form of microplastic fibres from textiles during domestic or industrial washing (Murphy et al. 2016).

Marine plastics are impacting a broad range of animals across the globe, including birds (Provencher et al. 2015; O'Hanlon et al. 2017), turtles (Schuyler et al. 2013), fish (Thiel et al. 2018), crustaceans (Lavers et al. 2020), and marine mammals (Gall and Thompson 2015). Further, the impacts of plastic debris are not experienced by a species in isolation but in combination with other significant pressures including oil pollution, habitat change/distribution, persecution, pathogens, and climate change. Plastic debris can cause harm to marine organisms through ingestion and entanglement (Weldon 2020) and can introduce invasive, non-native species by acting as rafts (Derraik 2002). Ingested plastics can cause death if feeding and/or breathing is restricted, can cause physical damage, for example through lacerations to the oesophagus or digestive tract, or impact mobility, for example, by increasing the mass of the individual and therefore their energetic requirements for swimming and/or flying. There is concern that ingested plastics may also transfer micropollutants, adsorbed from the environment to the detriment of an individual's health. Additionally, plasticisers, which are commonly added to plastics, often to increase flexibility and plasticity, can leach into the environment due to their unstable nature. They can cause significant biological effects, including impacting reproduction (invertebrates, fish and amphibians), development (crustaceans and amphibians), and changes in gene expression (Oehlmann et al. 2009). Entanglement can impact marine organisms by entangling part of the body such as a leg, wing, head or flipper, or trap the entire individual. Fishing nets which are lost or discarded at sea can continue to capture individuals long after they enter the environment and are so-called *ghost nets*. Abandoned, lost, or otherwise discarded fishing gear (ALDFG), including nets, rope and other associated equipment, are particularly problematic and harmful to a range of biota (Wilcox et al. 2016). There is a significant lack of data concerning the amount of ALDFG which enters the marine environment, within local, regional, and global scales.

Despite significant public awareness regarding plastic pollution, the impact of plastics on marine mammals is poorly understood, especially at the population level. There is an urgent need to quantify the impact of plastics to understand the most common impacts, the scale of these impacts, which species are most affected, which types of plastics are most harmful, and identify the geographical areas in which species are most affected. Reviews addressing the impact of marine mammal debris ingestion and entanglement (Laist 1997; Gall and Thompson 2015; Weldon 2020) have been invaluable in highlighting impacts across the globe and developing and understanding of the field. We are now in need of regionally specific information regarding the current state of knowledge of marine mammal–debris interactions in order to develop baseline data, to initiate regional coordinated efforts and to be able to monitor the severity of impacts over spatial and temporal scales.

Here, using peer-reviewed scientific studies and reports from the grey literature, we compile incidences of debris ingestion and entanglement in marine mammals within the northeastern Atlantic region. We assess the current state of knowledge regarding marine mammal–debris interactions and provide recommendations for monitoring and research.

1.2 Methods

We collated instances of entanglement in and ingestion of debris within the scientific and grey literature. We used the search terms *plastic entanglement* and *marine mammals*, and keywords *marine, mammals, northern, Atlantic, debris, northern, Atlantic*, at ScienceDirect (https://www.sciencedirect.com/) and included all articles. We examined papers for data on entanglements and ingestion and used the primary source for our study, following references to their source material. Where we were unable to source the original document referenced to verify reports, we did not include their data, even when other authors had used and referenced these sources. We collected data from published studies and reports up to and including 30 May 2018.

We determined 37 species of marine mammals to be present within the northeastern Atlantic region (Table 1.1). These species were deemed to regularly occur within the region, as determined using the occurrence dataset at the Global Biodiversity Information Facility (https://www.gbif.org/). Included in the region were 7 species of pinnipeds (walrus and seals) and 29 cetaceans. The cetaceans comprised 8 species of Mysticetes (baleen whales) and 21 species of Odontocetes (toothed whales, including dolphins). Polar bear, *Ursus maritimus*, was also included. Information on the health of the global population of each species in the form of conservation status was sourced from the IUCN Red List (IUCN 2022).

Table 1.1 Species present within the northeastern Atlantic region, with their IUCN red list status, a species-specific global health indicator (IUCN 2022)

Group	Sub-grouping	Family	Scientific name	Common name	IUCN red list status
Carnivora		Ursidae	*Ursus maritimus*	Polar bear	Vulnerable
Carnivora	Pinnipedia	Odobenidae	*Odobenus rosmarus*	Walrus	Vulnerable
Carnivora	Pinnipedia	Phocidae	*Cystophora cristata*	Hooded seal	Vulnerable
Carnivora	Pinnipedia	Phocidae	*Erignathus barbatus*	Bearded seal	Least concern
Carnivora	Pinnipedia	Phocidae	*Halichoerus grypus*	Gray seal	Least concern
Carnivora	Pinnipedia	Phocidae	*Pagophilus groenlandicus*	Harp seal	Least concern
Carnivora	Pinnipedia	Phocidae	*Phoca vitulina*	Harbor seal, common seal	Least concern
Carnivora	Pinnipedia	Phocidae	*Pusa hispida*	Ringed seal	Least concern
Cetecea	Mysticeti (baleen whales)	Balaenidae	*Balaena mysticetus*	Bowhead whale, greenland whale	Least concern
Cetecea	Mysticeti (baleen whales)	Balaenidae	*Eubalaena glacialis*	North Atlantic right whale	Endangered
Cetecea	Mysticeti (baleen whales)	Balaenidae	*Eubalaena australis*	Southern right whale	Least concern
Cetecea	Mysticeti (baleen whales)	Balaenopteridae	*Balaenoptera acutorostrata*	Common minke whale	Least concern
Cetecea	Mysticeti (baleen whales)	Balaenopteridae	*Balaenoptera borealis*	Sei whale	Endangered
Cetecea	Mysticeti (baleen whales)	Balaenopteridae	*Balaenoptera musculus*	Blue whale	Endangered
Cetecea	Mysticeti (baleen whales)	Balaenopteridae	*Balaenoptera physalus*	Fin whale	Endangered
Cetecea	Mysticeti (baleen whales)	Balaenopteridae	*Megaptera novaeangliae*	Humpback whale	Least concern

(continued)

Table 1.1 (continued)

Group	Sub-grouping	Family	Scientific name	Common name	IUCN red list status
Cetecea	Odontoceti (toothed whales)	Physeteridae	*Physeter macrocephalus*	Sperm whale, cachalot	Vulnerable
Cetecea	Odontoceti (toothed whales)	Kogiidae	*Kogia breviceps*	Pygmy sperm whale	Data deficient
Cetecea	Odontoceti (toothed whales)	Ziphiidae	*Hyperoodon ampullatus*	Northern bottlenose whale	Data deficient
Cetecea	Odontoceti (toothed whales)	Ziphiidae	*Mesoplodon bidens*	Sowerby's beaked whale	Data deficient
Cetecea	Odontoceti (toothed whales)	Ziphiidae	*Mesoplodon europaeus*	Gervais' beaked whale	Data deficient
Cetecea	Odontoceti (toothed whales)	Ziphiidae	*Mesoplodon mirus*	True's beaked whale	Data deficient
Cetecea	Odontoceti (toothed whales)	Ziphiidae	*Mesoplodon densirostris*	Blainville's beaked whale	Data deficient
Cetecea	Odontoceti (toothed whales)	Ziphiidae	*Ziphius cavirostris*	Cuvier's beaked whale, goose-beaked whale	Least concern
Cetecea	Odontoceti (toothed whales)	Monodontidae	*Delphinapterus leucas*	Beluga, white whale	Least concern
Cetecea	Odontoceti (toothed whales)	Monodontidae	*Monodon monoceros*	Narwhal	Least concern
Cetecea	Odontoceti (toothed whales)	Delphinidae	*Delphinus delphis*	Common dolphin, saddleback dolphin	Least concern
Cetecea	Odontoceti (toothed whales)	Delphinidae	*Globicephala macrorhynchus*	Short-finned pilot whale	Data deficient
Cetecea	Odontoceti (toothed whales)	Delphinidae	*Globicephala melas*	Long-finned pilot whale	Data deficient

(continued)

Table 1.1 (continued)

Group	Sub-grouping	Family	Scientific name	Common name	IUCN red list status
Cetecea	Odontoceti (toothed whales)	Delphinidae	*Grampus griseus*	Risso's dolphin, grampus	Least concern
Cetecea	Odontoceti (toothed whales)	Delphinidae	*Lagenorhynchus acutus*	Atlantic white-sided dolphin	Least concern
Cetecea	Odontoceti (toothed whales)	Delphinidae	*Lagenorhynchus albirostris*	White-beaked dolphin	Least concern
Cetecea	Odontoceti (toothed whales)	Delphinidae	*Orcinus orca*	Killer whale, orca	Data deficient
Cetecea	Odontoceti (toothed whales)	Delphinidae	*Pseudorca crassidens*	False killer whale	Data deficient
Cetecea	Odontoceti (toothed whales)	Delphinidae	*Stenella coeruleoalba*	Striped dolphin	Least concern
Cetecea	Odontoceti (toothed whales)	Delphinidae	*Tursiops truncatus*	Common bottlenose dolphin	Least concern
Cetecea	Odontoceti (toothed whales)	Phocoenidae	*Phocoena phocoena*	Harbour porpoise	Least concern

For each species, we recorded data on the number of individuals for which incidences of debris entanglement or ingestion were reported. We also record the year in which the individual was assessed, although this was not available for all reports, and in some instances only available as a date range. The type of debris (ingested or entangled) was recorded: we considered debris to be any item or material which does not naturally originate from the marine environment. We only included debris which were considered to be lost, abandoned, or derelict, and hence we omitted bycatch data which concerns active fishing efforts. Using the recommendations of Provencher et al. (2017) as a basis, we categorised debris as one of the following categories: threadlike (including ropes, nets, twine, and monofilaments), film (sheet-like plastics including single-use bags), hard (fragments and whole pieces), fishing hooks, and other (all other items including plastics and non-plastic items such as wood and metal). We included fishing hooks as a separate category following a review of the data and noticing multiple reports of this sector-specific debris. We did not find any reports of foam in our dataset, and therefore omitted this category from our study. Instances where the debris type was reported as unknown, where it was not reported, or we were unable to determine the type within the primary source, were categorised as unknown. The mass, size/dimensions, and colour of debris were very rarely reported and so we did not collate these metrics. Some studies omitted key information including the number of individuals affected and year of occurrence.

1.3 Results

1.3.1 Entanglement

Of the marine mammals occurring in the northeastern Atlantic, we found instances of entanglement in 38% of species (14 of 37 species; Table 1.2). 43% (3 of 7 species) of the pinniped species were recorded to have become entangled in debris (Fig. 1.1). When considering whales, we found reports of entanglement in debris within the region for approximately a third of species (34%; 10 of 29 species), with toothed whales displaying a higher abundance and proportion of entangled species (38%; 8 of 21 species) than baleen whales (25%; 2 of 8 species). The Polar bear was found entangled in debris in two studies, although it should be noted that for one of these reports debris was within the mouth, and may have been attempted ingestion, or exploratory behaviour.

In cases where entanglement was recorded, for most species it was from a single study or report (57%; 8 species), which included 1 species of pinniped, 1 baleen whale, and 5 toothed whales. There were 6 species for which entanglement was recorded in more than one study or report with species including 2 pinnipeds, 1 baleen whale, and 3 toothed whales.

Entanglement of marine mammals was predominantly and overwhelmingly a result of threadlike debris, in cases where the debris type was identified. Threadlike debris, which included ropes, nets, and monofilaments, was responsible for 97% (98 of 102 individuals) of entanglements and was reported for 14 different species. The remaining instances of entanglement were caused by film (1%, 1 individual, 1 species; Polar bear), and other types of debris (2%, 2 individuals, 2 species), whilst in 42 cases involving 1 species (Grey seal) the debris type was unknown.

Table 1.2 Summary information for marine mammal species where debris entanglement and/or ingestion have been reported in the northeastern Atlantic. Numbers indicate the number of individuals for which debris entanglement or ingestion was recorded

Species	Entanglement debris	Incidences of entanglement	Entanglement reference (s)	Ingested debris	Incidences of ingestion	Ingestion Reference(s)	Location	Total incidences	Year
Polar bear	Threadlike (1), Film (1)	2	Bergmann et al. (2017)	–	–	–	Svalbard	2	2016
Walrus	–	–	–	–	–	–	–	–	–
Hooded seal	–	–	–	–	–	–	–	–	–
Bearded seal	Threadlike (1)	1	Bergmann et al. (2017)	–	–	–	Svalbard	1	2016
Grey seal	Threadlike (33), Other (1), Unknown (42)	76	Allen et al. (2012), Unger et al. (2017), Sayer and Williams (2015)	Fishing hook (2), Other (1)	3	Unger et al. (2017)	UK, North Sea and Baltic Sea, Germany;	79	2004–2015
Harp seal	–	–	–	–	–	–	–	–	–
Harbour seal, common seal	Threadlike (6), Other (1)	7	Unger et al. (2017), Bergmann et al. (2017), Bravo Rebolledo et al. (2013)	Threadlike (2), Film (1), Hard (1), Fishing hook (3), Other (4)	10	Bravo Rebolledo et al. (2013)	North Sea and Baltic Sea, Germany, Svalbard	17	1997–2016
Ringed seal	–	–	–	–	–	–	–	–	–

(continued)

Table 1.2 (continued)

Species	Entanglement debris	Incidences of entanglement	Entanglement reference (s)	Ingested debris	Incidences of ingestion	Ingestion Reference(s)	Location	Total incidences	Year
Bowhead whale, Greenland whale	–	–	–	–	–	–	–	–	–
North Atlantic right whale	–	–	–	–	–	–	–	–	–
Southern right whale	–	–	–	–	–	–	–	–	–
Common minke whale	Threadlike (7)	7	Lusher et al. (2018), CSIP Annual Report (2015), CSIP Annual Report (2011), CSIP Annual Report (2010)	Film (1), Hard (1), Fishing hook (1), Unknown (1)	4	Baulch and Perry (2014), De Pierrepont et al. (2005), CSIP Annual Report (2011)	Ireland, Belgium, UK, France	11	1990–2015
Sei whale	–	–	–	Hard (1), Unknown (1)	2	Baulch and Perry (2014), CSIP Annual Report (2012)	UK	2	2005–2012
Blue whale	–	–	–	–	–	–	–	–	–
Fin whale	Threadlike (1)	1	Smiddy et al. (2002)	Threadlike (1)	1	Smiddy et al. (2002)	Ireland	1	2000

(continued)

Table 1.2 (continued)

Species	Entanglement debris	Incidences of entanglement	Entanglement reference (s)	Ingested debris	Incidences of ingestion	Ingestion Reference(s)	Location	Total incidences	Year
Humpback whale	–	–	–	Threadlike (1), Film (1), Hard (1), Unknown (1)	2	O'Brien et al. (2007), Besseling et al. (2015)	Ireland, Netherlands	2	2006–2012
Sperm whale, cachalot	Threadlike (2)	2	Lusher et al. (2018), CSIP Annual Report (2011)	Threadlike (1*), Hard (1*), Unknown (1)	3*	Baulch and Perry (2014), Martin and Clarke (1986), Lambertsen and Kohn (1987)	Belgium, Denmark Strait, Iceland	5*	1977–2015
Pygmy Sperm whale	–	–	–	Film (1), Hard (1)	2	CSIP Annual Report (2015), CSIP Annual Report (2014)	UK	2	2014–2015
Northern bottlenose whale	–	–	–	Threadlike (1), Film (1), Hard (4), Unknown (2)	7	Baulch and Perry (2014), CSIP Annual Report (2012), Fernández et al. (2014), Simmonds (2012)	UK	7	2005–2014
Sowerby's beaked whale	–	–	–	Hard (1), Unknown (1)	2	Berrow et al. (2010), Baulch and Perry (2014)	Ireland, UK	2	2005–2012

(continued)

Table 1.2 (continued)

Species	Entanglement debris	Incidences of entanglement	Entanglement reference (s)	Ingested debris	Incidences of ingestion	Ingestion Reference(s)	Location	Total incidences	Year
Gervais' beaked whale	–	–	–	–	–	–	–	–	–
True's beaked whale				Film (1), Hard (2) Unknown (1)	3	Gassner et al. (2005), Lusher et al. (2015)	Ireland	3	1997–2013
Blainville's beaked whale	–	–	–	–	–	–	–	–	–
Cuvier's beaked whale, goose-beaked whale				Threadlike (1), Film (4), Hard (1), Unknown (2)	7	Lusher et al. (2018), Baulch and Perry (2014), CSIP Annual Report (2015), CSIP Annual Report (2011), Santos et al. (2001), Simmonds (2012)	Ireland, UK	7	1999–2015
Beluga, white whale	–	–	–	–	–	–	–	–	–
Narwhal	–	–	–	–	–	–	–	–	–

(continued)

Table 1.2 (continued)

Species	Entanglement debris	Incidences of entanglement	Entanglement reference (s)	Ingested debris	Incidences of ingestion	Ingestion Reference(s)	Location	Total incidences	Year
Common dolphin, saddleback dolphin	Threadlike (22)	22	Lusher et al. (2018)	Threadlike (3), Film (1), Hard (11)	15	Lusher et al. (2018), CSIP Annual Report (2010)	Ireland, UK	37	2003–2015
Short-finned pilot whale	–	–	–	–	–	-	–	–	–
Long-finned pilot whale	Threadlike (3)	3	Lusher et al. (2018)	Film (1), Hard (1)	2	Laist (1997), CSIP Annual Report (2014)	Ireland, France, UK	5	1990–2015
Risso's dolphin, grampus	Threadlike (1)	1	Lusher et al. (2018)	Film (1), Fishing hook (1)	2	Lusher et al. (2018)	Ireland	3	1990–2015
Atlantic white-sided dolphin	Threadlike (1)	1	Lusher et al. (2018)	–	–	–	Ireland	1	1990–2015
White-beaked dolphin	–	–	–	Film (1), Unknown (2)	3	Baulch and Perry (2014), CSIP Annual Report (2015), CSIP Annual Report (2012)	UK	3	2005–2015

(continued)

Table 1.2 (continued)

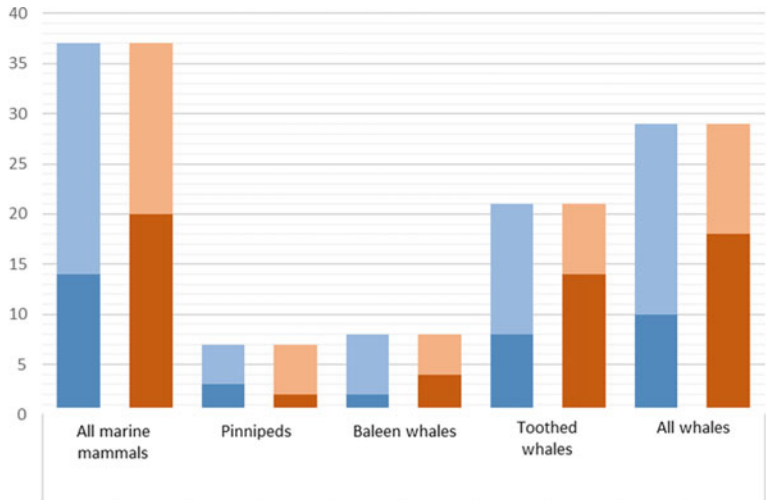
Species	Entanglement debris	Incidences of entanglement	Entanglement reference (s)	Ingested debris	Incidences of ingestion	Ingestion Reference(s)	Location	Total incidences	Year
Killer whale, orca	–	–	–	Threadlike (1), Film (1), Hard (1), Fishing hooks (2), Unknown (1)	3	Baulch and Perry (2014), CSIP Annual Report (2012), CSIP Annual Report (2014)	UK	3	2005–2014
False killer whale	–	–	–	–	–	–	–	–	–
Striped dolphin	Threadlike (4)	4	Lusher et al. (2018)	Threadlike (1), Film (2), Hard (3)	5	Lusher et al. (2018), Hernández-Milián (2014)	Ireland	9	2002–2014
Common bottlenose dolphin	Threadlike (3)	3	O'Brien and Berrow (2007), Lusher et al. (2018)	Film (1), Hard (2), Other (1), Unknown (1)	4	Lusher et al. (2018), Baulch and Perry (2014)	Ireland, UK	7	2005–2014

(continued)

Table 1.2 (continued)

Species	Entanglement debris	Incidences of entanglement	Entanglement reference (s)	Ingested debris	Incidences of ingestion	Ingestion Reference(s)	Location	Total incidences	Year
Harbour porpoise	Threadlike (14)	14	Unger et al. (2017), Marine Stranding Network (2015)	Threadlike (5), Film (5), Hard (13), Fishing hook (1), Other (1), Unknown (14)	33	Unger et al. (2017), Lusher et al. (2018), Baulch and Perry (2014), Kastelein and Lavaleije (1992), CSIP Annual Report (2011), CSIP Annual Report (2010), CSIP Annual Report (2009), Hernández-Milián (2014)	North Sea and Baltic Sea, Germany, Ireland, UK, Netherlands	47	1991–2015

The number of individuals that were reported to be entangled in, or having ingested, different types of debris (threadlike, film, hard, fishing hook, other, or unknown) is also presented. Individuals may have ingested more than one type of debris; hence, the total number of individuals is not necessarily equal to the sum of individuals per debris type. Asterisk (*) indicates that the number of individuals was likely higher, but the actual number was not reported in the source material



	All marine mammals		Pinnipeds		Baleen whales		Toothed whales		All whales	
No report	23	17	4	5	6	4	13	7	19	11
Incidence reported	14	20	3	2	2	4	8	14	10	18

Fig. 1.1 Number of species for which entanglement in (dark blue) and ingestion of (light orange) debris have been reported within the northeastern Atlantic region, using data compiled from studies in Table 1.2

The number of species for which there were no reports found are displayed for entanglement (light blue) and ingestion (light orange). Species are categorised as pinnipeds, baleen whales and toothed whales (Table 1.1), whilst all whale species (baleen and toothed whales) and all marine mammals are also displayed. At the bottom, the total number of species for which there was no report found, and where an incidence was reported for each category is displayed.

1.3.2 Ingestion

We found that just over half of marine mammal species in the northeastern Atlantic (54%; 20 of 37 species) were reported to have ingested debris. For 29% of pinnipeds (2 of 7 species) there were recorded instances of debris ingestion. Meanwhile 62% of whale species (18 of 29 species) had ingested debris within the region, which corresponds to half of baleen whales (50%; 4 of 8 species), and two-thirds of toothed whales (67%; 14 of 21 species). Although there was one report of a Polar bear with debris within its mouth, we could not ascertain whether the debris was ingested, either deliberately or accidently, and therefore this report was included within the entanglement category. Consequently, we did not find a report of Polar bears ingesting debris with the region.

Where species were recorded to have ingested debris, in the vast majority of cases there was more than one report (80%; 16 of 20 species), including for 3 baleen whales, 13 toothed whales, but no species of pinnipeds. There were 4 species (20%) where ingested debris was reported in a single study, including 2 pinnipeds, 1 baleen whale, and 1 toothed whale.

Individuals found to have ingested debris, and where debris type was identified, we found that plastic fragments were the dominant debris type, being present in 45% of cases (44 of 98 individuals). Film was found in 23% of individuals that ingested debris (23 individuals, 15 species), with threadlike debris in 17% (17 individuals, 10 species), fishing hooks in 8% (8 individuals, 6 species), and other debris types in 6% (6 individuals, 4 species). There were 29 cases where the debris type was not determined or reported.

1.3.3 Entanglement and Ingestion

There were 12 species for which there was evidence of debris ingestion and entanglement, including 2 pinnipeds (Grey seal and Harbour seal) and 10 cetaceans (baleen whales: Common minke whale, Fin whale; toothed whales: Sperm whale, Common dolphin, Long-finned pilot whale, Risso's dolphin, Atlantic white-sided dolphin, Striped dolphin, Common bottlenose dolphin, and Harbour porpoise). We found no reports of entanglement in, or ingestion of, debris in 38% (14 of 37) of species that occur in the northeastern Atlantic (Fig. 1.2). For 14% of species (5 of 37) entanglement or ingestion of debris was recorded in a single study or report within a single location, whilst in 19% of species (7 of 37) incidences were from more than one report, from a single location. The remainder of species (30%; 11 of 37) had multiple reports of entanglement and/or ingestion of debris from more than one location.

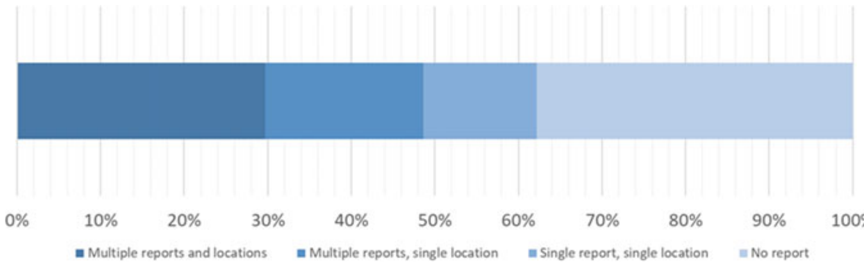


Fig. 1.2 Proportion of reports of debris entanglement or ingestion in marine mammals categorised according to the number of reports and locations for each of the 37 species in the northeastern Atlantic region, using data compiled from studies in Table 1.2

There were 11 distinct locations which were associated with reports of debris entanglement or ingestion by marine mammal species in the northeastern Atlantic region: UK, Ireland, Germany, Netherlands, Iceland, Denmark Strait, North Sea, Baltic Sea, Svalbard, Belgium, and France. Reports from both the UK and Ireland each included 13 species associated with entanglement or ingestion of debris, which were the joint equal, highest number of species across the 11 regions.

1.4 Discussion

Marine debris is having an impact on a significant proportion of marine mammal species within the northeastern Atlantic, with 62% of the 37 species present in the region reported to have either ingested or become entangled in debris. Marine mammals are facing a multitude of pressures including, but not limited to climate change, depletion of prey (e.g. through overfishing), habitat destruction, and noise and chemical pollution. Therefore, any impact of marine debris will add to the suite of pressures already faced by marine species, which is particularly important for the more highly endangered species. Both Sei whale and Fin whale are classified as endangered according to the IUCN Red List (IUCN 2022), and both were reported to have ingested and become entangled in debris. Meanwhile, Polar bears and Sperm whales are classified as vulnerable according to the IUCN Red List (IUCN 2022), with the latter species reported to have both become entangled in, and ingested debris. Given the evidence of interactions with debris and their conservation status, we recommend a comprehensive monitoring programme and assessment of the risk of debris to Sei whales, Fin whales, Sperm whales and Polar bears to better understand the level of impact with the northeastern Atlantic, and how this changes spatially and temporally.

The predominance of threadlike debris as the primary cause of marine mammal entanglements is unsurprising since nets, ropes, and monofilament are designed to capture marine biota. Presumably, the majority of this material is derived from fishing activity, which can enter the marine environment either deliberately or by accident. Threadlike debris has been assessed to be one of the most harmful types of marine litter and causing the most damage to marine animals (Wilcox et al. 2016). Our study reiterates the impact of threadlike debris on individuals, with reports of entanglement in more than a third of mammal species (14 of 37 species) in the northeastern Atlantic. To reduce the impact of threadlike debris, it is important to reduce the flow of material into the marine environment. Both behavioural and technological changes may be needed for a comprehensive reduction in both deliberate and accidental inputs. The marking of fishing gear to identify the user, and the introduction of European Union (EU) legislation, particularly around the extended producer responsibility (EPR) scheme of the EU Single Use Plastic Directive may assist efforts to reduce threadlike debris in the environment. In addition, organised and ad hoc volunteer beach clean efforts remove a significant mass of debris, including threadlike material. This helps prevent debris entering or reentering marine waters and particularly reduces the risk of seal species interacting with debris on beaches, for instance at haul out sites, and during pupping.

The dataset compiled in this study is likely to be an underestimate for several reasons. It is possible that studies and reports containing instances of debris ingestion or entanglement fell outside our search criteria. A limitation of our study is that it was conducted only in English, which potentially excludes those in one of the other primary languages within the region. The presence of marine mammal–debris interactions reported in languages other than English may be pertinent to the grey literature, where reports are frequently compiled for environmental charities, governmental departments, and non-governmental organisations (NGOs) in native languages. This represents a potential gap, and presents an opportunity for future studies. In addition, there are likely to be a significant number of ad hoc incidences of entanglement of marine mammals in non-published sources. For instance, volunteers beach clean-up programmes may record but not publish such incidences, whilst there may be a significant number of reports made by members of the public on social media. These sources could be used in the future to complement published data on marine mammal entanglements. To assist the collection of ad hoc data, we recommend the use of citizen/community science, which also has the benefit of raising awareness and public engagement. Crowdsourcing websites such as https://www.wildlifeanddebris.com can be used to collate reports of entanglement in debris across the globe. Although ingestion of debris by deceased and decomposing marine mammals may be observed, instances are likely to be fewer than for cases of entanglement, and more difficult to verify.

Ingestion of debris was reported in over half of the species present in the north-eastern Atlantic, and from our dataset appears to occur in more species that entanglements. The major difference here was the higher number of species of toothed whales reported to have ingested debris in comparison to those that have become entangled (14 and 8 respectively). It is perhaps surprising however that ingestion of debris was found in a higher proportion of toothed whales than baleen whales (67 and 50% respectively). Baleen whales are filter feeders, and so we might expect plastics and other debris to be ingested as they intake significant volumes of water during feeding. Toothed whales are carnivorous, active predators, whose diet consists primarily of fish, squid, and for some species other marine mammals such as seals and otters. We would perhaps expect toothed whales, with a selective feeding behaviour to ingest less debris than the more passive and indiscriminate feeding method of baleen whales. Although debris consumed by prey, such as fish, may be passed on to toothed whales when predated, we may expect this to occur to a greater extent with smaller items such as microplastics (items <5 mm in size). One possible explanation is that in some instances toothed whales intentionally consume debris after mistakenly identifying it as prey. Species of turtles known to consume gelatinous prey are also found to consume marine debris, especially film-type debris, such as plastic bags (Mrosovsky et al. 2009; Schuyler et al. 2013). Evidence suggests that turtles preferentially consume debris resembling jellyfish (Schuyler et al. 2014), with Green turtle (*Chelonia mydas*) and Loggerhead turtle (*Caretta caretta*) ingesting prey in 61.8 and 16.7% of encounters respectively (Fukuoka et al. 2016). Although toothed whales may mistake squid, a key prey for this group, for film debris, the use of sophisticated sonar in hunting is likely to reduce this rate of consumption. Other explanations for the greater number of species of toothed whales identified as ingesting debris in comparison to baleen whales is that toothed whales may feed in regions (either geographically or within the water column) within the northeastern Atlantic with higher densities of debris, or that they are more likely to die, and become available for necropsy, as a result of debris ingestion. We are currently unable to verify these suggestions, but these could form hypotheses for future studies.

Climate change is causing changes in the distribution of marine species including many fish, which require specific temperatures to live and breed in. The current and predicted northward shift of spawning grounds and distribution, for example of Atlantic cod (*Gadus morhua*) and Atlantic mackerel (*Scomber scombrus*) (Drinkwater 2005; Bruge et al. 2016), will consequently result in a shift in active fishing areas. Unless changes are implemented to further prevent the loss of ALDFG, then it is likely that we will observe more items of debris lost in more northernly regions. Therefore, entanglement of marine mammals may increase in the coming years and decades in the northeastern Atlantic region as their own distribution changes to track prey, and because of increased fishing and associated ADFLG loss in the region.

We observed a great deal of inconsistency regarding the reporting of marine mammal–debris interactions. In the majority of cases, information regarding debris colour, mass, and dimensions was absent. In addition, some reports omitted the number of individuals impacted, and/or the year in which the interaction was recorded. These omissions highlight the need for a standardised approach to recording debris interacting with marine mammals. We recommend following the suggested guidelines in Provencher et al. (2017), with the addition of fishing hooks as a separate category. We noted fishing hooks were ingested by 8 individuals from 6 species, and whilst this was not the most dominant type of debris ingested, we recommend its separate inclusion given the direct link to fishing and the potential for significant harm inflicted on individuals. Using a standardised approach to recording debris in interactions with marine mammals allows comparative studies across regions and time. Standardised approaches may allow an assessment of the effectiveness of initiatives and legislation aimed at reducing marine debris, and, potentially, of the effectiveness of clean-up operations. They also allow the identification and quantification of the most prevalent types of debris interacting with species and offers the potential for identifying the source of debris, which can be difficult given the distribution of debris through ocean currents. Indeed, even entangled individuals can travel large distances before stranding on shorelines. Figure 1.3 shows a dead juvenile Humpback whale entangled in ropes, with a buoy attached, which was associated with a lobster fishery in Nova Scotia, Canada. This individual washed up on the north coast of Scotland, and therefore may have travelled approximately 4000 km.

Whilst marine debris is impacting marine mammals, causing injury and death to individuals, it is difficult to ascertain population level effects. To better understand the severity of the threat to marine mammals, a coordinated and international monitoring and reporting scheme is needed. We support the approaches of collaborative projects

Fig. 1.3 A juvenile Humpback whale entangled in threadlike debris, Scrabster beach, Scotland, May 2019. The debris was identified as coming from a lobster fishery in Nova Scotia, Canada, approximately 4000 km away where the individual landed. Photograph by the author

such as the Global Ghost Gear Initiative, and Scottish Entanglement Alliance (SEA), which aims to understand, mitigate, and raise awareness of marine animal entanglements in Scotland, whilst engaging with the inshore fishing industry. It is important that approaches to reducing the quantity of marine debris, and the frequency of interactions with wildlife, are collaborative and include relevant stakeholders including fishers, port authorities, NGOs, government, scientists, and the community.

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