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Large amounts of marine debris found in sperm whales stranded along the North Sea coast in early 2016

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ABSTRACT

30 sperm whales (*Physeter macrocephalus*) stranded along the coasts of the North Sea between January and February 2016. The gastro-intestinal tracts of 22 of the carcasses were investigated. Marine debris including netting, ropes, foils, packaging material and a part of a car were found in nine of the 22 individuals. Here we provide details about the findings and consequences for the animals. While none of the items was responsible for the death of the animal, the findings demonstrate the high level of exposure to marine debris and associated risks for large predators, such as the sperm whale.

1. Introduction

Marine debris is defined as "any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment" (UNEP, 2009). It is a serious threat to marine life. Marine debris can be found in all of the world's oceans (Barnes et al., 2009; Thompson et al., 2004). It can be ingested (internal findings) (de Stephanis et al., 2013) or cause entanglement which may lead to lesions or even strangulation (external findings) (Gregory, 2009). Furthermore, if too much debris is swallowed, stomach fullness can be reached without obtaining nutrients (Sheavly and Register, 2007) and might lead to starvation and death (Page et al., 2004; Allen et al., 2012; Moore et al., 2013). Marine debris may consist of many different materials. Due to their characteristics, such as durability, synthetic materials (plastics) constitute the highest proportion of marine debris (Barnes et al., 2009).

Depending on the size of the organism and its habitat, different debris items are of concern. Marine debris findings are recorded in many different marine biota, including copepods (Cole et al., 2015), bivalves (Cole and Galloway, 2015), fish (Lusher et al., 2013), birds (Van Franeker and Law, 2015) and seals (Bravo Rebolledo et al., 2013). Occurrence and impacts in cetaceans were recently summarized by Baulch and Perry (2014) and Kühn et al. (2015). For sperm whales, 17 cases of debris ingestion have been documented worldwide between 1895 and 2009 (listed in de Stephanis et al., 2013). Debris findings in marine mammals raising concerns also for deep diving cetaceans, such as sperm whales (Simmonds, 2012). Another recent case was a plastic bottle found in a sperm whale stranded in Denmark (Hansen et al., 2015). Among the effects of marine debris ingestion in cetaceans, gastric ruptures, pylorus blockage and gastric obstruction were identified as fatal consequences (Tarpley and Marwitz, 1993, Jacobsen et al., 2010). The negative impact of marine debris was also observed during an endoscopic procedure of a pygmy sperm whale (*Kogia breviceps*), where removal of a plastic piece found between the main and pyloric stomach healed the previous lack of appetite in the animal (Stamper et al., 2006). These findings demonstrate that ingested marine debris may severely affect cetaceans.

Information on debris ingestion in cetaceans can usually only be obtained from necropsies. Thus, stranding events provide a valuable source of information on ingested debris. Sperm whales live in deep-water habitats of depths ≥1000 m (Rice, 1989; Whitehead, 2003). Strandings of sperm whales are occasional events, that seem to occur clustered in a few places around the world, one of them being the North Sea (Jauniaux et al., 1998; Pierce et al., 2007; Vanselow et al.,

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2009); a shallow marginal sea that is also referred to as the "sperm whale trap" (Smeenk, 1997). Sperm whales of the North Atlantic population migrating from the Norwegian shelf edge to the Azores sometimes swim into the North Sea, for reasons that are still hypothesized about (Vanselow and Ricklefs, 2005; Pierce et al., 2007). This shallow water habitat is highly unsuitable for a deep-diver like the sperm whale. Sandbanks, mudflats and tides make the coastline of the southern North Sea prone to sperm whale strandings (Camphuysen, 1995; Smeenk, 1997; Jauniaux et al., 1998). Strandings of sperm whales in the North Sea have been reported for centuries and well documented in the past (Camphuysen, 1995; Smeenk, 1997; Pierce et al., 2007).

In early 2016, 30 sperm whales stranded in the North Sea (IJsseldijk et al., 2016, submitted). In this paper we report on the findings of marine debris in the necropsied animals, describe the debris items in detail and suggest conclusions about potential origin and risks associated with ingestion.

2. Material and methods

Between 8th January and 24th February 2016, 30 sperm whales stranded on different locations along the North Sea coast (IJsseldijk et al., 2016, submitted; Fig. 1). A total of 14 sperm whale stranding events of groups of up to 8 individuals were recorded along the coasts of Germany, The Netherlands, the United Kingdom, France and Denmark. The gastro-intestinal tract (GIT) of 22 of these animals was opened from stomach to anus and investigated for debris (Table 1). Seven of these GITs were additionally rinsed and the contents were sieved over 500 and 1000 μm mesh. Five of the obtained sieve fractions were machine-washed (following Bravo Rebolledo et al., 2013, online supplement) to dissolve organic materials and isolate hard prey remains (bones, otoliths and beaks) and foreign objects (such as plastic particles). For details on GIT treatment see Table 1. Prey remains found in the GITs were preserved for further analysis. Additionally, faeces samples of 12 animals were taken and stored in glass jars for later analyses on the presence of microplastics. The nutritional status of each whale was judged according to the blubber thickness and muscle condition. Samples for histopathological examinations were taken from most stomachs and intestines in which marine debris was found (Table 1).

Any debris items found were isolated and most were measured and photographed. All measurements were conducted with a folding rule and a calliper. The floating capacity of objects was tested if uncertain (netting, rope, car part, bucket, foil). Thin plastic pieces (mostly transparent) were categorized as "foil" when no suture was discovered to classify it as "plastic bag". Thicker, black foil, which is mostly used in agriculture for protecting e.g. hey bails is categorized as "agricultural foil".

Findings were classified into fishing related and general debris objects. Items were grouped according to the material they were made of (plastic, wood, etc.), and evaluated visually. Where appropriate, details were obtained from manufacturers. Monofilaments (net remains after netting is unravelled) were counted and listed as "bundle".

3. Results

Marine debris was found in nine out of 22 dissected sperm whales. In total, 322 debris items of varying sizes were collected (Table 2) from the GITs of these animals. Among the collected items, 250 (78%) were classified as fishing related including monofilaments (Fig. 4d), nets (Fig. 2, Fig. 7b), ropes (Fig. 2, Fig. 6b), pieces of netting yarn (Fig. 4a, Fig. 7a) and a fish hook. The remaining 72 (22%) were classified as general debris. In this category were two chocolate/cereal bar-wrappings (Fig. 4f), a coffee capsule (Fig. 4c), foils, duct tape, parts of plastic bags, agricultural foils, strapping tapes, a screw-cap (Fig. 4e), a plastic bucket (listed as two objects, since one part was discovered in the pharynx, the other in the stomach) (Fig. 5a and b) and a plastic part of a car engine cover (Fig. 5c). All debris items were made of synthetic materials, apart from six pieces of wood and a fish hook. For netting and yarn, the fabric was identified as Polyethylen/Polypropylene. Based on expert opinion the nets from sperm whales (GER-02, GER-06, GER-15) were recognised as fishing nets, likely "protection nets" from shrimp fisheries. Protection nets are rather solid nets placed around the actual

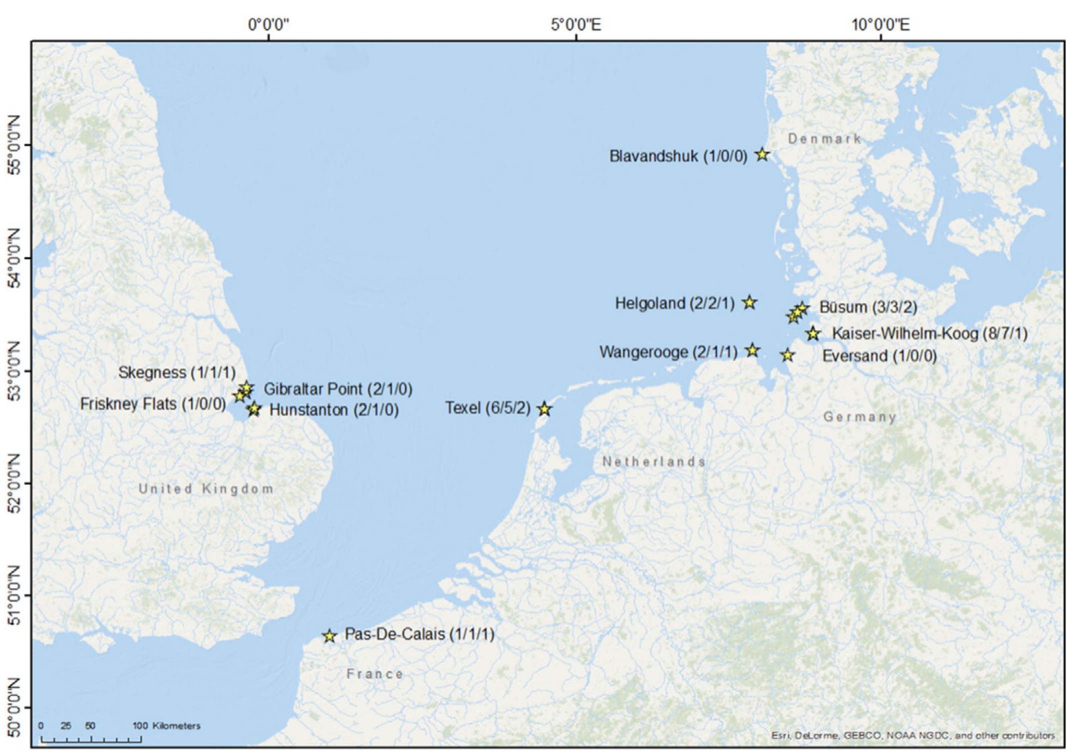

Fig. 1. Stranding locations of all 30 sperm whales. Numbers of stranded animals/investigated gastro-intestinal tracts/animals with debris findings are listed in brackets behind each stranding location.

Table 1
Overview of all stranded sperm whales and information on treatment of the gastro-intestinal tract (GIT).

ID	Stranding location	GPS Position		Stranding date	GIT investigated	Additional treatment (rinsed/samples washed in washing machine)	Debris found	Histopathological samples from the GIT	Sample holder
		Lat	Lon						
GER-01	Wangerooge	53.7806	7.9757	08.01.2016	n	/		n	/
GER-02	Wangerooge	53.7806	7.9757	08.01.2016	y	/	y	y	ITAW Büsum
GER-03	Eversand	53.7412	8.5111	12.01.2016	n	/		n	/
GER-04	Helgoland	54.2146	7.9131	12.01.2016	y	/	y	y	ITAW Büsum
GER-05	Helgoland	54.2146	7.9131	12.01.2016	y	/		y	ITAW Büsum
GER-06	Büsum	54.0852	8.5889	13.01.2016	y	Rinsed	y	y	ITAW Büsum
GER-07	Kaiser-Wilhelm-Koog	53.9426	8.9002	31.01.2016	y	/	y	y	ITAW Büsum
GER-08	Kaiser-Wilhelm-Koog	53.9426	8.9002	31.01.2016	y	/		y	ITAW Büsum
GER-09	Kaiser-Wilhelm-Koog	53.9426	8.9002	31.01.2016	y	/		y	ITAW Büsum
GER-10	Kaiser-Wilhelm-Koog	53.9426	8.9002	31.01.2016	y	/		y	ITAW Büsum
GER-11	Kaiser-Wilhelm-Koog	53.9426	8.9002	31.01.2016	y	/		y	ITAW Büsum
GER-12	Kaiser-Wilhelm-Koog	53.9426	8.9002	31.01.2016	y	/		y	ITAW Büsum
GER-13	Kaiser-Wilhelm-Koog	53.9426	8.9002	31.01.2016	y	/		y	ITAW Büsum
GER-14	Kaiser-Wilhelm-Koog	53.9426	8.9002	31.01.2016	n	/		n	ITAW Büsum
GER-15	Büsum	54.0852	8.5889	03.02.2016	y	/	y	y	ITAW Büsum
GER-16	Büsum	54.0852	8.5889	03.02.2016	y	/		y	ITAW Büsum
NET-01	Texel	53.1841	4.8472	12.01.2016	y	Rinsed/washed	y	y (intestine)	Faculty of Veterinary Medicine, Utrecht/IMARES
NET-02	Texel	53.1841	4.8472	12.01.2016	y	Rinsed/washed	y	y (intestine)	Faculty of Veterinary Medicine, Utrecht/IMARES
NET-03	Texel	53.1841	4.8472	12.01.2016	y	Rinsed/washed		n	Faculty of Veterinary Medicine, Utrecht
NET-04	Texel	53.1841	4.8472	12.01.2016	y	Rinsed/washed		y (intestine)	Faculty of Veterinary Medicine, Utrecht
NET-05	Texel	53.1841	4.8472	12.01.2016	y	Rinsed/washed		n	Faculty of Veterinary Medicine, Utrecht
NET-06	Texel	53.1841	4.8472	14.01.2016	n	/		n	Faculty of Veterinary Medicine, Utrecht
UK-01	Hunstanton	52.9473	0.4887	22.01.2016	n	/		n	Institute of Zoology, London
UK-02	Gibraltar Point	53.0940	0.3373	24.01.2016	y	/		n	Institute of Zoology, London
UK-03	Gibraltar Point	53.0940	0.3373	24.01.2016	n	/		n	Institute of Zoology, London
UK-04	Skegness	53.14	0.3496	24.01.2016	y	/	y	n	Institute of Zoology, London
UK-05	Friskney Flats	53.0481	0.2632	25.01.2016	n	/		n	Institute of Zoology, London
UK-06	Old Hunstanton	52.9592	0.5030	04.02.2016	y	/		n	Institute of Zoology, London
FRA-01	Pas-De-Calais	50.9864	1.9593	02.02.2016	y	Rinsed	y	n	Observatoire PELAGIS, La Rochelle
DK-01	Blåvand	55.5621	8.073	24.02.2016	n	/		n	/

fishing nets to protect the more delicate shrimp nets from scrubbing and to prevent fish from entering the shrimp net. The complete number and description of all debris items per animal are listed in detail in Table 2.

It has to be taken into account that not all gastro-intestininal tracts in which debris was found were rinsed (Table 1). Therefore, the number of smaller items might be underestimated.

The amount and weight of ingested marine debris differed greatly between the individuals.

FRA-01 had the highest burden of marine debris concerning the summed weight (24.84 kg; Table 2), and the number of swallowed items were highest in GER-06 (78, excluding single monofilaments). The lightest burden of all affected individuals was observed in UK-01 (<1 g), where only two small plastic sheets were found.

In FRA-01 netting pieces with a total length of 13.01 m were found. GER-06 had ingested a large net with a total length of 13.5 m and a width of 1.2 m, which was found (Fig. 3a, b) in the first stomach compartment. Additionally, monofilaments were found in the same compartment varying between 0.9 cm and 16.6 cm of length. The debris filled most of the stomach in both cases.

The largest hard pieces of debris were found in GER-15: one piece of a broken blue plastic bucket was found in the pharynx (Fig. 5a, red square) and two bigger pieces in the first compartment of the stomach. Moreover, a black car part was found in the first compartment of the stomach (Fig. 5c) with a size of 68 × 23.5 cm. A closer examination by the manufacturer revealed that it was a a part of an engine cover of a ©Ford SUV (Fig. 5, magnification).

Other prominent findings included a fish hook likely used in longline fishery found in NET-01 (Fig. 6a), three longlines (Fig. 6b) and agricultural foil (Fig. 6c) in NET-02.

None of the marine debris findings could be identified as the cause of death. All dissected animals were well nourished, which was underlined by the high count of squid beaks, fish bones and otoliths found in the animals stomachs, indicating that they had fed shortly before stranding. No internal injuries, which could be attributed to swallowed marine debris items, were discovered. The gastro-intestinal tracts investigated displayed no macroscopic or histopathologcial lesions to indicate that the objectives were causing any impact to the digestive process or health of the animals.

4. Discussion

In this study, marine debris items were found in nine out of 22 necropsied sperm whales. This is a high proportion of the total number and points to a high susceptibility of sperm whales to ingestion of debris. However, it remains unclear, if the fact that ending up in a foreign habitat, without access to their natural food, led to an increased uptake of unusual items of assumed prey.

Until recently, few findings of debris in sperm whales have been reported (cases listed in de Stephanis et al., 2013) and so the threat may have been assumed to be low. Since discovery of marine debris in marine mammals requires both, the washing ashore of the dead animal and the state of decay being sufficient enough for a full necropsy, the number of incidents may be underestimated (Williams et al., 2011).

Table 2
List of all marine debris findings in sperm whales stranded in Germany (GER), The Netherlands (NET), the United Kingdom (UK) and France (FRA). In some cases the material could be identified: Polyethylene (PE), Polypropylene (PP), Polyvinyl chloride (PVC) and Polyamide (PA).

Animal no.	Locality in body	Debris items	Size (cm)/diametre (cm)	Material	Comment	Total weight (kg)
GER-02	Stomach (1. Compartement)	Net	250 × 150/0.4: mesh size: 8	PE		2
		Foil	0.9 × 0.2			
		Wood (3)	Between 0.8 × 0.25–0.13 × 0.6			
GER-04	Stomach (1. Compartement)	Rope	98 × 1.5	PP, PE		0.22
		Foil	9 × 9			
		Duct tape	2.9 × 1.6			
		Thread	3.3			
GER-06	Stomach (1. Compartement)	Net	1355 × 1.2/0.3; mesh size: 5	PE	Most likely protection net (shrimp fishery)	
		Net	156 × 0.51/0.1; mesh size: 3		Most likely protection net (shrimp fishery)	10.53
		Net	42/0.2; mesh size: 8	PE	Most likely protection net (shrimp fishery)	
		Netting yarns (30)	Between 5.4 × 0.4 and 169 × 0.6			
		Rope	441 × 0.4		Longline rope	
		Strapping tapes (3)	between 5 and 15 × 0.5 and 20 × 0.5			
		Coffee capsule	Diametre: 3			
		Monofilaments (66)	Between 1.1 and 16.6			
		Foil	8.6			
	Stomach (2. Compartement)	Net	46.5 × 24.5/0.6; mesh size: 10	PE	Most likely protection net (shrimp fishery)	0.078
		Foils (9)	Between 3.3 × 2.3 and 26 × 14.7			
		Screw-cap	Diametre: 7	PP		
		Plastic tube	18.1 × 1			
		“Snickers” wrap	13.4 × 9.3			
		Netting yarn	43.3 × 0.3			
		Strapping tape	30.7			
		Monofilaments (64)	Between 0.9 and 15.9			
		Plastic piece	1 × 0.6			
	Stomach (n.d.)	Plastic cap	1.7/0.7			0.016
		Netting yarn	5.7 × 0.1			
		Woods (3)	0.7–1.5 × 0.3			
		Plastic bag	3.3 × 1.2	PE	Part of a plastic bag (suture)	
		Plastic pieces (8)	Between 2 × 2.1 and 8.3 × 0.1			
		Netting yarns (4)	Between 13 × 0.3 and 21.5 × 0.4/0.5			
		Rope	9.3/1.4			
GER-07	Jaw/Mouth	Thread	161		Synthetic material (flame test)	0.002
GER-15	Stomach (1. Compartement)	Car part	68 × 23.5	PP	Engine protection (against wind, ©Ford), one strapping tape and one rope attached	0.66
		Plastic bucket	Diametre: 32			
		Foils (3)	Between 31 × 32.5 and 101.5 × 96	PVC	Agricultural foil	
		Plastic bag	32 × 19	PE	Part of a plastic bag (suture)	
	Pharynx	Plastic part of a bucket	10.8 × 14.5			
NET-01	Stomach (n.d.)	Fish hook	5.6 × 2.1 × 0.18		Used in longline fishery	0.001
NET-02	Stomach (n.d.)	Fragment plastic	13.5 × 7 × 2			0.453
		Ropes (3)	381–1314 × 0.5		Longline ropes	
		Ribbon	7.3 × 0.46		Used for ballons or present wrapping	
		Ropes (7)	Between 22.3 × 0.25 and 168.2 × 0.05		Most likely fishery related	
		Threadball	3.4 × 3.2			
		Foil	17 × 13		Accumulation of foils and bags (suture)	
		Strapping tape	53.4 × 0.51			
		Packaging material	n.a.		Sutures	
		Foil	n.a.		Agricultural foil	
		Sheetlike plastic (4)	Between 28 × 28 × 0.05 and 188 × 83 × 0.02			
UK-01	Stomach	Plastic pieces (2)	2–3			<0.001
FRA-01	Stomach	Plastic bags (2)	55 × 55 and 75 × 30			24.84
		(Cereal bar) wraps	10 × 3			
		Plastic cable	10 × 0.1			
		Strapping tape (4)	Between 4 × 2 and 140 × 1			
		Jute canvas	75 × 60			
		Plastic sheeting	130 × 115			
		Textile lifting strap (3)	Between 170 × 7 and 600 × 7			
		Ropes (13)	Between 45 × 0.8–2000 × 0.8		Rope with plastic sleeve	
		Netting yarns (39)	Between 8 × 0.4 and 280 × 0.5			
		Net (2)	45 × 10 mesh size: 1 - 35 × 8 mesh size: 0.5			
		Bundle of monofilament		PA		

(continued on next page)

Table 2 (*continued*)

Animal no.	Locality in body	Debris items	Size (cm)/diametre (cm)	Material	Comment	Total weight (kg)
		(3)				
		Net	105 × 22/1; mesh size: 5			
		Net	200 × 10/0.4; mesh size: 7			
		Net	140 × 50/0.4; mesh size: 14			
		Nets (4)	(total) 466 × 170/0.3 mesh size: 15			
		Net	300 × 140/0.3; mesh size: 15			

The data in this study represent additional valuable information on the ingestion of marine debris by sperm whales. The high rate of debris ingestion found in this study, however, may not be representative of population level, since the stranded sperm whales died in a foreign habitat and it remains unclear whether they ingested the debris items prior to entering the North Sea or while in the North Sea. Nevertheless, the fact that the debris objects were exclusively found in the upper digestive system and stomach, with no items found in the intestine, suggests that debris was ingested shortly before stranding. Otherwise, objects small enough for gastro-intestinal passage would have been expected to be present in the intestine. Moreover, analyses of the net types found in the stomachs, taking mesh size and thickness of the netting yarn into account, indicate that the nets most likely originated from the local North Sea shrimp fishery. This also suggests ingestion in North Sea waters. However, discarded parts of netting may also drift over considerable distances; therefore no final conclusion about a possible area of intake of the nets can be drawn.

Depredation by the sperm whales in shrimp trawl fishery is highly unlikely and incidents would have likely been reported. Possibly the nets were discarded or lost at sea and then ingested by the whales. However, the longlines found (GER-06, NET-01 and NET-02) and the fish hook (NET-01) may be the result of a depredation event. Sperm whales are known to take fish from active long lines (Straley et al., 2014; O'Connell et al., 2015). While longline fishery is more common in the Atlantic, it is also carried out to a small extent in the North Sea haddock fishery (Food Certification International Ltd, 2014).

Monofilaments as found in the stomachs are used in fisheries e.g. as set nets, but can also be the result of the degradation of ropes or larger nets. The fact that the monofilaments were found in GER-06, together with the large pieces of nets, allow the conclusion that they are the result of the netting being unravelled due to the peristaltic movements. In addition, it remains unclear if the gastric acid in the stomach promoted the detachment since no information is available on the properties and effects on synthetic materials of the gastric acid in cetaceans. Nevertheless, it is more likely that the monofilaments originated from the netting material rather than having been taken up independently.

Fig. 2. Rope found in GER-04 in the first stomach compartment.
©ITAW.

All of the animals had healthy nutritional statuses and recent food consumption was evident from squid beaks in the stomachs. The good nutritional status of the animals with large amounts of ingested debris, especially animals FRA-01, GER-06 and GER-15, suggests a rather recent uptake of the marine debris items. These items would likely have hampered food intake and digestion in the long term (Jacobsen et al., 2010). While none of the ingested items led to the death of the animals, it can be assumed, that over time, especially the larger swallowed items, might have caused health issues for the respective animals, as seen in other cases, such as two stranded sperm whales in northern California where netting caused a rupture in the stomach and blocked the pylorus (Jacobsen et al., 2010). This can be considered as another argument for debris uptake during the last days they spent in the North Sea.

Sperm whales are deep water suction feeders and feed on squid (cephalopods) for which they forage during their deep dives (Whitehead, 2003). In canyons off the west coast of Portugal, debris was encountered in depths up to 4.574 m (Mordecai et al., 2011). Thus, sperm whales, as a deep diving and teutophageous species, could be valuable sentinels of the marine debris presence in deep water habitats. It is assumed that sperm whales also plough through the sediment with their lower jaws during their dives in search for benthic food (Heezen, 1957; Walker and Coe, 1989). The assumption that debris is incidentally ingested during capturing prey (Walker and Coe, 1989) is amplified by the fact that even stones were found in the GIT's

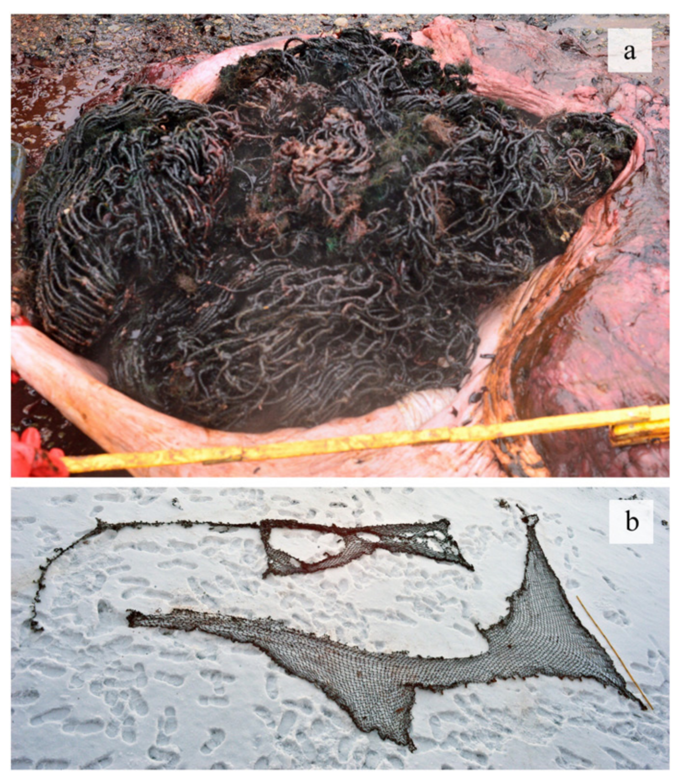

Fig. 3. Netting in GER-06; a) netting in the stomach during necropsy; b) netting enrolled after removal.
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during stranding events (de Stephanis et al., 2013). Stones were found in three animals and sand could be identified in another individual (pers. Comm. Uwe Piatkowski). Findings of marine debris with floating properties in sperm whales provides evidence for capture from the water column or maybe even from the sea surface, (de Stephanis et al., 2013; Jacobsen et al., 2010) using both visual and acoustic abilities (Whitehead, 2009). The objects found in this study mainly showed floating characteristics (e.g. netting, rope, car part, bucket, foil). The fact that no growth potentially causing sinking of the nets could be identified, lead to the suggestion that the sperm whales captured these items in the water column. Whether they mistook these items for prey or captured them in lack of any other available prey, remains speculative. Walker and Coe (1989) suggested that mistaken ingestion of debris items due to resemblance to prey is unlikely in odontocetes because of their echolocation ability and that ingestion is more likely to happen incidentally during feeding or may be part of the stranding process.

No debris items were found in the intestines. However, faeces samples were taken and will be analysed for microplastics. This will give some indication about the burden of sperm whales concerning microplastics.

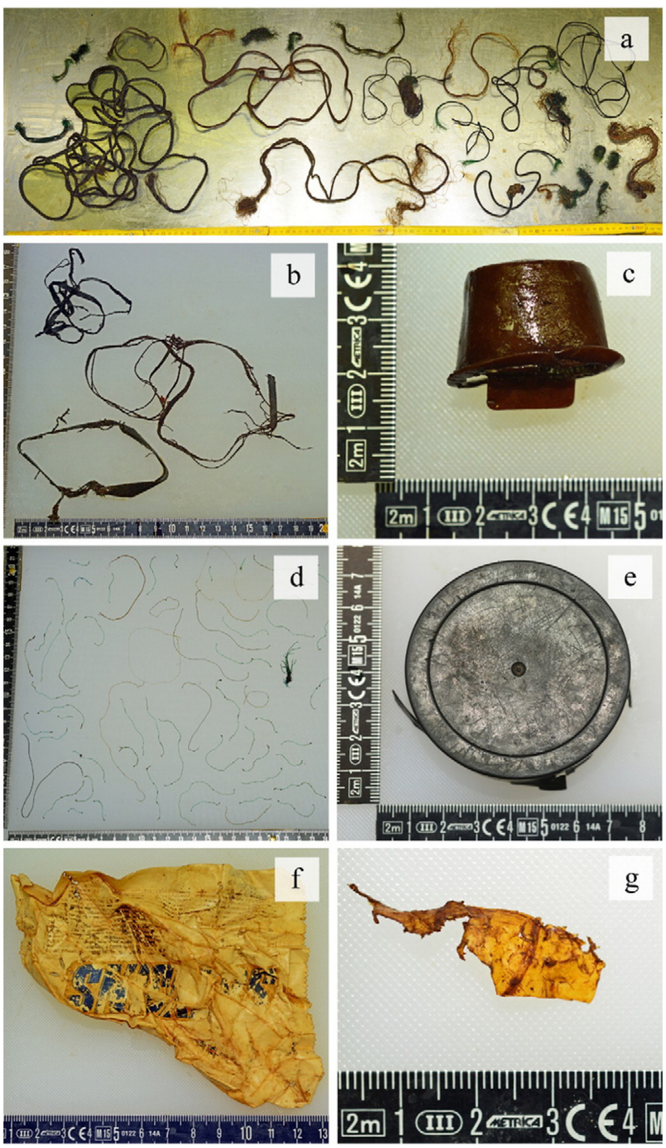

Fig. 4. Findings in GER-06: first stomach compartment: a) netting yarn; b) strapping tape; c) coffee capsule; d) monofilaments; second stomach compartment: e) screw-cap; f) ©Snickers-wrap; compartment not definable: g) plastic bag (suture). ©ITAW.

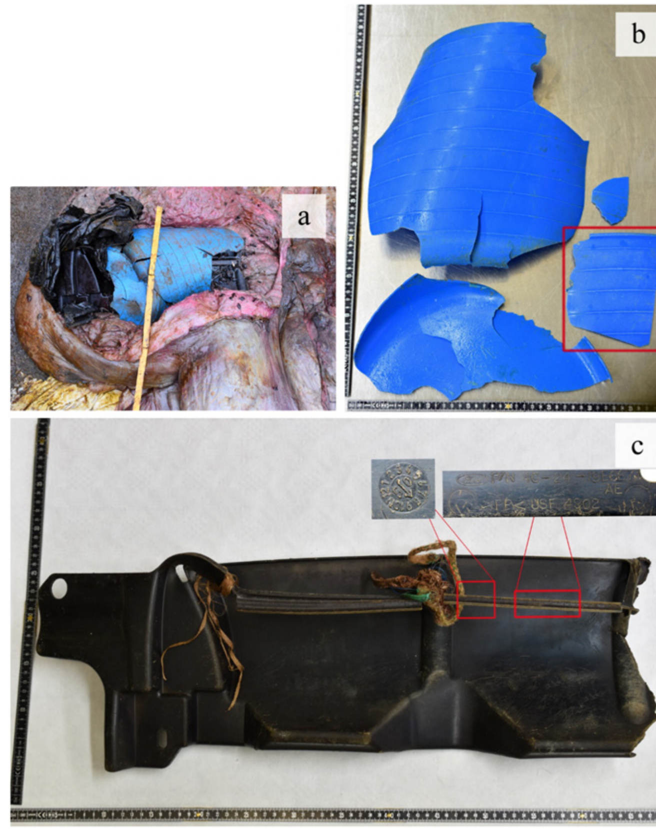

Fig. 5. Debris from GER-15: a) in situ-localization of the found debris items; b) blue plastic bucket found in the first compartment of the stomach. The part in the red square was found in the pharynx and belongs to the rest found in the stomach; c) Car part (engine cover) found in the first compartment of the stomach.
This car part was used in a ©Ford SUV. ©ITAW.

In Europe, the Marine Strategy Framework Directive (MSFD) aims to maintain or restore the good environmental status of marine ecosystems (European Parliament and Council, 2008). One specific target of MSFD is to limit the amount of marine debris ingested by marine species. Some species, such as fulmar (*Fulmarus glacialis*) or sea turtles, have already been identified and used as tools to quantify trends in marine debris (van Franeker et al., 2011; Galgani et al., 2014). However, research on alternative indicator species is still required to monitor the various ecosystems across European waters, and evaluate the adverse effects of debris on a wider range of marine organisms (Bravo Rebolledo et al., 2013; Galgani et al., 2014). The Scientific Committee of the International Whaling Commission (IWC) demands further effort on this topic for intensifying the understanding of the interaction between marine debris and cetaceans (IWC, 2016). Our study contributes important information on this matter.

Although no associated injuries could be detected in this study, the risk of severe consequences by marine debris ingestion was clearly demonstrated by the quantity and quality of the found items. The findings of this study prove a high susceptibility of sperm whales towards the ingestion of marine debris and associated risks. Moreover, the results point to a high marine debris burden in the North Sea and North Atlantic where items are likely to have been ingested. They provide insight into the composition of marine debris and underline the high share of fishing related debris as well as plastics. Efforts to reduce marine debris in our environment must be continued and intensified to decrease pollution burdens for marine life, especially in a highly exploited

Fig. 6. Debris items found in the animals from The Netherlands: a) NET-01: fish hook; b) NET-02: long line; c) NET-02: agricultural foil.
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area like the North Sea, to achieve the good environmental status of marine ecosystems required by the European Marine Strategy Framework Directive.

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Fig. 7. Debris items found in FRA-01: a) overview of all items; b.) netting.
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