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Marine litter at the seafloor – Abundance and composition in the North Sea and the Baltic Sea

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ABSTRACT

Litter is present in all marine waters around the globe. It consists of several compound classes of which plastic is of special interest because of its high abundance and possible threat to marine organisms. The regional distribution, composition and abundance of large litter items (LI) at the sea floor of the North Sea and the Baltic Sea were investigated based on 175 bottom trawls between 2013 and 2015. Different types of marine litter > 2.5 cm were classified according to the protocol of the ICES International Bottom Trawl Survey. The results showed considerable geographical variation: In the North Sea, a mean litter abundance of 16.8 LI/km^2 was found, whereas the litter abundance in the Baltic Sea was significantly lower (5.07 LI/km^2). In general, plastic represented 80% of the litter items. During the study, some methodical aspects with possible impact on the results were identified that need to be addressed in future sampling campaigns.

1. Introduction

The huge amount of man-made solid waste materials ending up in the oceans becoming marine litter was identified as one of the pressing global challenges (G7, 2015; G20, 2017). It was estimated that between 4.8 and 12.7 million tons of litter enter the oceans each year, but its continuance is not fully understood (UNEP, 2009; Watkins et al., 2015). Litter has already been determined everywhere in the marine environment, from remote areas such as in 4500 m deep basins (Pham et al., 2014) to Arctic areas (Bergmann and Klages, 2012) or floating at the surface (Cózar et al., 2015), drifting in the water column as well as lying on the sea floor or being covered with sediments. Deeper regions in the sea (Pham et al., 2014) as well as beaches (Zhou et al., 2011; Williams et al., 2016) may act as accumulation areas, but wind and water currents (Ramirez-Llodra et al., 2013) influence litter distribution. Finally, about 70% of marine litter reaches the sea floor (OSPAR, 2014). Levels of marine litter are presumed to be rising with the increasing global population densities and industrial production.

Marine litter comprises a wide range of materials such as glass, metal, wood, rubber and plastics. Plastic waste was already identified as special problem in the 1980s, because it represents the dominating category of marine litter and persists in the environment (Derraik, 2002; Barnes et al., 2009; Avio et al., 2017). It was recently determined that the character of the input source is determining the compartment of the ocean in which the plastic remains (Critchell and Lambrechts, 2016). Due to the material properties and the resulting persistence it is expected that the level of marine plastic litter at the seafloor will continue to rise in the future. Galgani et al. (2000) reported plastics to represent over 70% of marine litter items in the European marine regions. Plastic litter items related to fishing (e.g. net material, ropes, buoys) are reported as being one of the most common forms of litter in the marine seas (Galgani et al., 2000). Andrady, 2011 and Moriarty et al. (2016) reported between 18% and 51% of the total litter amount was related to fishery. The ingestion of larger plastic items probably affects the condition of animals negatively by e.g. leading to internal blockage of the digestive tract (Foekema et al., 2013). Furthermore, larger plastic items may be degraded and may finally end up as microplastic (< 5 mm), but there are also other direct sources for microplastic in oceans (GESAMP, 2010). It was found that microplastic is mistakenly ingested as food items by marine fish (GESAMP, 2010; Rummel et al., 2016), and therewith also enter the food chain at lower trophic levels (Cole et al., 2011). Observations of the ingestion of plastics by North Sea fish were made by Lusher et al. (2012), Foekema et al. (2013), Avio et al. (2015) and Rummel et al. (2016). It is still unknown to which extend microplastic in seafood may pose a risk to the consumer. Also entanglement of organism in plastic litter is a problem especially for cetaceans (Allen et al., 2012), turtles (Nelms et al., 2016) and birds (Katsanevakis et al., 2007).

To identify the extent of marine litter and its composition it was established as environmental indicator by international authorities such as the European Union, OSPAR and HELCOM. Furthermore, marine litter is included in the EU Marine Strategy Framework Directive

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(MSFD) as one of the eleven qualitative descriptors used to describe the good environmental status (GES) in the European seas (European Commission, 2008; Galgani et al., 2013). The MSFD implies an implementation of monitoring programs in order to assess and evaluate the state of the marine ecosystem on a regular basis. As no tools were available when the MSFD came into force, a joint protocol of the International Bottom Trawl Surveys (IBTS) (ICES, 2012; Moriarty et al., 2016) was set up to standardize the collected data. This included forms to record the identification code, material, weight, and size class of marine litter. Nevertheless, there is only a limited amount of data available so far and only few studies describe litter at the seafloor in European off-shore regions (Galgani et al., 2000; Moriarty et al., 2016; Pham et al., 2014; Rummel et al., 2016).

Therefore, the aims of the present study were 1) to bridge the gap in data by providing results from standardized observations on the abundance of marine litter at the sea floor of the North Sea and Baltic Sea, 2) to evaluate the data obtained for patterns of geographical distribution in litter composition, 3) to identify sources and source characteristics of marine litter, and 4) to provide suggestions for an improved design of sampling campaigns to include marine litter from the seafloor into existing monitoring programs like the IBTS. These aims are essential to overcome the problem of marine litter and conclude whether a good environmental status is reached in European Seas.

2. Material and methods

2.1. Collection of litter

Marine litter > 2.5 cm (GESAMP, 2016) was collected from the sea floor during cruises of the fisheries research vessel Walther Herwig III, conducted by the Thünen Institute of Fisheries Ecology between August 2013 and September 2015. Litter items found inside the net during 175 fishery trawls were included in the evaluation.

Locations of the sampling areas are shown Table 1 and in Fig. 1. Cruise details are given in Table S1. Typically, four trawls were made per area and cruise to repeat sampling. Two different bottom trawl types, both with otter boards and a mesh size of 20 mm in the cod-end were used: a Grande Ouverture Verticale bottom trawl (GOV) in standard ICES IBTS configuration (ICES, 2012) was used in the North Sea, while a 140 ft. bottom trawl with rock hoppers was used in the Baltic Sea. The towing time was 60 min at a towing speed between 3.0 and 3.7 kn (mean 3.5 kn). Wind speed was always below 7 bft during sampling (data not shown). After hauling, the debris in the net was sorted from the catches and classified in different categories and sub categories according to ICES, (2012; see below). Only litter items falling out of the net together with the fishery catch were counted.

2.2. Calculation of litter abundance

Litter > 2.5 cm (GESAMP, 2016) abundance was calculated as number of litter item (LI) per hour trawling time [LI/h] for the major litter categories in all regions. In addition, the results were related to the area covered [LI/km^2] using the mean ship speed recorded by GPS sensors during trawling time when the net had contact to the ground of 3.5 kn (6.5 km/h) with a standard deviation of 0.16 kn between trawls. Furthermore, the mean distance between the tips of the net wings (= wing spread) was used as a measure of the area swept. The wing spread varies depending on water depth, the warp length used for trawling and the resulting door spread, but, on average, the wing spread for the GOV measured using Scanmar ® sensors is 18.5 m (A. Sell, April 2017, personal communication) and for the 140 ft. bottom trawl 18.85 m (B. Mieske, April 2017, personal communication). Therefore, during 1 h trawling at 6.5 km/h, litter items from approximately 0.12 km^2 sea floor were collected.

Table 1
Sampling positions, sampling area and depth, litter abundance (litter items [LI]/h trawling time) per area and cruise of the Baltic Sea (BS) and North Sea (NS) based on 175 trawls from 2013 to 2015. Numbers are calculated as mean of up to 4 replicate trawls (60 min). "n.a.": not accessed.

Ocean	Area	Trawls	Mean Depth	Latitude	Longitude	Box area	Cruise WH0367	Cruise WH0370	Cruise WH0377	Cruise WH0380	Cruise WH0387
		n	**m**	**Degree min**		**km^2**	**LI/h**				
BS	B01	19	19	54 25.00 N – 54 45.00 N	010 07.00 E – 011 00.00 E	6650	1.19	2.00	0.67	0.55	2.00
BS	B09	19	70	55 04.00 N – 55 16.00 N	018 09.00 E – 018 35.00 E	1900	0	0	0	1.42	0
BS	B10	14	29	54 34.00 N – 55 00.00 N	013 55.00 E – 014 20.00 E	3900	0.50	0.67	0.25	n.a.	0
BS	B11	17	35	54 40.00 N – 54 55.00 N	013 00.00 E – 013 55.00 E	4900	0.75	0.33	0	0.67	1.01
BS	BHB	10	70	55 30.00 N – 56 00.00 N	014 12.00 E – 015 40.00 E	17,850	n.a.	n.a.	1.01	0.33	0
BS	**Mean**						**0.61 ± 1.13**	**0.60 ± 1.35**	**0.41 ± 0.72**	**0.82 ± 1.04**	**0.71 ± 1.08**
NS	GB1	17	37	54 03.00 N – 54 09.00 N	007 43.00 E – 007 55.00 E	400	2.25	4.75	3.27	3.52	0.33
NS	GB3	17	42	54 55.00 N – 55 02.00 N	006 15.00 E – 006 24.00 E	400	1.00	3.67	1.75	3.67	1.75
NS	GB4	13	45	55 22.00 N – 55 25.00 N	004 25.00 E – 004 34.00 E	200	1.33	3.90	1.50	n.a.	0
NS	N01	18	39	54 14.00 N – 54 26.00 N	007 22.00 E – 007 41.00 E	1500	0.60	2.50	1.35	1.34	0.67
NS	N04	8	29	54 25.00 N – 54 52.00 N	001 59.00 E – 002 32.00 E	5300	n.a.	n.a.	0.76	n.a.	2.28
NS	N06	5	53	56 15.00 N – 56 24.42 N	001 44.00 W – 002 10.00 W	1500	n.a.	n.a.	1.56	n.a.	n.a.
NS	N11	7	25	55 29.00 N – 55 41.00 N	006 49.00 E – 007 39.00 E	3550	n.a.	1.50	n.a.	n.a.	2.11
NS	P02	10	68	56 16.00 N – 56 42.00 N	002 39.00 E – 003 26.00 E	7100	n.a.	2.33	2.76	n.a.	3.67
NS	**Mean**						**1.27 ± 1.83**	**3.12 ± 2.65**	**1.86 ± 1.56**	**2.76 ± 1.90**	**1.62 ± 2.58**
all	**Mean**						**0.91 ± 1.50**	**2.10 ± 2.53**	**1.31 ± 1.48**	**1.49 ± 1.66**	**1.23 ± 2.11**