Amount and composition of litter on the seafloor (seafloor litter)

Indicator type: HELCOM Pre-core indicator
Indicator category: Pressure indicator
BSAP segment: Hazardous substances & litter
MSFD Descriptor: 10
MSFD Criteria: 1

Table of Contents

1. Key message

Note: There is no operational indicator for litter on the seafloor in the HELCOM area, but an indicator based on data of marine litter collected in trawls during fish stock surveys is proposed. The indicator concept is the amounts of litter (unit: items per km² seafloor) in different categories of litter items (plastic, glass/ceramics, metals, natural products, rubber and miscellaneous; for further details see below), distributed in different *sub-basins. It is important to note that the number of litter items recovered in trawls is only an indication of the true amount of litter on the seafloor. An interim definition of Good Environmental Status (GES) is proposed in the section on GES. The section on results includes a brief summary of data and information available in the Baltic Sea area, but the status is not assessed due to lack of agreement on GES.*

Marine litter is widely recognised as a serious global environmental concern as the increased use of single use plastics, mismanagement of waste and insufficient recycling practices all contribute to increasing amounts of litter ending up in the marine environment. Marine litter can have a variety of environmental impacts: marine animals can ingest litter and thereby the litter can enter the food web, or become entangled in litter resulting in death or injury and containers and plastic items are potential sources of contaminants. Larger litter items that move in currents can cause habitat damage by scouring or smothering at the seafloor but may also potentially provide habitat as they increase habitat rugosity. Benthic trawl surveys are a convenient way to monitor seafloor litter on the continental shelf, because they are already in use and financed for fish stock assessments, cover a wide area of seafloor using standardised methods and routinely register litter.

Table 1. Assessment of the preliminary threshold of no significant increase from 2015 to 2021.

HELCOM Assessment unit name (and ID)	Threshold value achieved/failed	Distinct trend between current and previous assessment	Description of outcomes, if pertinent
Baltic Sea	Achieved for glass, metal, natural litter, fisheries related litter (numbers only) rubber and SUP	Stable/decreasing	Indicator evaluation failed to achieve the threshold value for some litter categories. Long natural recovery times for most litter types.
	Failed for plastic, fisheries related (weight only) and other litter.	Increasing	

When litter density was measured in weight, the categories “other”, plastic and fisheries related litter increased significantly in the period from 2015 to 2021 whereas when density was measured in numbers, “other” and plastic litter increased significantly and thereby failed the preliminary threshold of no significant increase from 2015 to 2021 in both weight, numbers and probability of catching litter. Fisheries related litter passed the threshold when measured in numbers per km^2 but not when measured in weight per km^2. The categories glass, metal, natural, rubber and single use plastics (SUP) showed no significant increase in weight and numbers per km^2 and hence passed the preliminary threshold of no significant increase.

Data on the amount of litter collected in trawls during fish stock surveys is only available for some Baltic Sea regions. The data set covers years from 2012 and forward in areas from the Northern Baltic proper and south, see map below in the section on current monitoring. Other methods for monitoring litter on the seafloor, e.g., in areas not covered by fish stock surveys, are still in the form of pilot studies.

1.1 Citation

HELCOM (2023). Litter on the seafloor. HELCOM core indicator report. Online. [Date Viewed], [Web link].

2 Relevance of the indicator

Once litter is introduced in the marine environment it can be transported long distances by water currents and accumulate on the seafloor far away from its original source. Recent reviews indicate that the density of macro-scale (>2 cm) litter items is higher on the seafloor than floating on the sea surface (Galgani *et al.*, 2015), suggesting that a large part of the total amount of litter in the marine environment is deposited on the seafloor. The negative impacts of litter that is deposited on the seafloor are wide ranging including death of marine organisms by entanglement and lack of oxygen, ingestion, contamination, smothering and other damage to habitats, and can also have socioeconomic impacts, and may pose navigational hazards.

2.1 Ecological relevance

Litter on the seafloor can cause anoxia to the underlying sediments, which alters biogeochemistry and benthic community structure (Goldber, 1994). Furthermore, litter (such as glass bottles, tin cans) may provide substrata for the attachment of sessile biota in sedimentary environments and increase local diversity (Mordecai *et al.,* 2011; Moret-Ferguson *et al.*, 2010; Pace *et al.*, 2007) although this replaces existing species and leads to non-natural alterations of faunal community composition (Bergmann & Klages, 2012). Heavy plastic items are colonized by bacteria or loaded with sediments and sink to the seafloor (Thompson, 2006; Ye & Andrady, 1991) where they can persist for centuries (Derraik, 2002), be ingested by organisms or cause ghost fishing for long periods. Litter containing hazardous substances can act as source to these, and thereby contribute to pollution effects in the ecosystem. The monitoring of seafloor litter is required to close the loop of marine litter monitoring in the aquatic environment.

2.2 Policy relevance

At this moment in time, there is no doubt that marine litter is on top of the global agenda. The historic agreement at the resumed Fifth Session of the United Nations Environment Assembly (UNEA 5-2) in March 2022 to develop an international legally binding agreement to end plastic pollution by 2024 is the best exponent of such global commitment. HELCOM is committed to support the development of the global instrument, as stated in a voluntary commitment on the matter at the UN Ocean Conference held in Lisbon in June 2022. In alignment with such commitment, the updated Baltic Sea Action Plan contains, for the first time, a dedicated section on marine litter including both ecological and managerial objectives to achieve. The fulfilment of these objectives will count with the revised Regional Action Plan on Marine Litter, adopted in the 2021 Ministerial Meeting as HELCOM Recommendation 42-43/3, as its instrumental tool containing almost thirty regional actions addressing sea-based and land-based sources of marine litter (HELCOM, 2021a). Moreover, in its preamble, the Action Plan states HELCOM ambitions towards development of additional core indicators and associated definition of GES and improved coordinated monitoring programmes. Such work is to be conducted considering outcomes of the related work under the EU MSFD and involving close coordination with the EU TG Litter, as well as with similar work of the Russian Federation.

In that sense, recommendations for sampling seafloor litter (specifying shallow are deeper waters) are derived from the MSFD GES Technical Group on Marine Litter (JRC, 2013) to contribute to the monitoring of litter in the marine environment according to the MSFD requirements. Seabed litter is also a common indicator of the OSPAR area, as detailed in the Second Regional Action Plan for Prevention and Management of Marine Litter in the North-East Atlantic (OSPAR, 2022).

Table 2. Policy relevance of this specific HELCOM indicator.

	Baltic Sea Action Plan (BSAP)	**Marine Strategy Framework Directive (MSFD)**
Fundamental link	Ecological objective: No harm to marine life from litter. Management objectives: (i) Prevent generation of waste and its input to the sea, including microplastics; (ii) Significantly reduce amounts of litter on shorelines and in the sea.	Descriptor 10 Properties and quantities of marine litter do not cause harm to the coastal and marine environment. • Criteria 1 The composition, amount and spatial distribution of litter on the coastline, in the surface layer of the water column, and on the seabed, are at levels that do not cause harm to the coastal and marine environment. • Feature – Litter in the environment. • Element of the feature assessed – Beach litter - Marine Litter Categories.
Complementary link	Management objectives: (i) Minimize the input of nutrients, hazardous substances and litter from sea-based activities; (ii) Safe maritime traffic without accidental pollution	Descriptor 10 Properties and quantities of marine litter do not cause harm to the coastal and marine environment. • Criteria 2 The composition, amount and spatial distribution of micro-litter on the coastline, in the surface layer of the water column, and in seabed sediment, are at levels that do not cause harm to the coastal and marine environment. • Feature – Litter in the environment.

		• Element of the feature assessed – Marine Litter Categories.
Other relevant legislation	UN Sustainable Development Goal 14 (Conserve and sustainably use the oceans, seas and marine resources for sustainable development) is most clearly relevant, though SDG 12 (Ensure sustainable consumption and production patterns) and 13 (Take urgent action to combat climate change and its impacts) also have relevance.	

2.3 Relevance for other assessments

The indicator assesses the 2021 Baltic Sea Action Plan's (BSAP) (HELCOM 2021) Hazardous substances and litter's segment ecological objective of no harm to marine life from litter, as well as the management objectives to prevent generation of waste and its input to the sea, including microplastics, and significantly reduce amounts of litter on shorelines and in the sea. The indicator is relevant to the following specific BSAP actions:

- HL31: Improve the evidence base on the impact of marine litter on the Baltic Sea region in order to develop and agree on new measures by 2025.
- HL32 Agree on core indicators and harmonized monitoring methods to evaluate quantities, composition, distribution, and sources (including riverine input), of marine litter, including microlitter, by 2022, where applicable and for the rest no later than 2026. Work should be done in close coordination with work undertaken by Contracting Parties in other relevant fora, such as the Technical Group on marine litter under the Marine Strategy Framework Directive.

The indicator further supports the implementation of the HELCOM Recommendation 42-43/3 on the Regional Action Plan on Marine Litter, in particular action RL2 on the evaluation of top findings according to the knowledge available and recommendation of environmentally sound alternatives to phase out top plastic and rubber litter items.

The results of the indicator support an overall evaluation of pollution in the Baltic Sea.

Potential relevance for indicators for different types of hazardous substances, like flame retardants, used as plastic additives.

In addition, the indicator addresses descriptor 10 “Properties and quantities of marine litter do not cause harm to the coastal and marine environment” of the EU MSFD for determining good environmental status (European Commission 2008), and in particular criteria 1 and 2 of the Commission Decision on GES criteria (2017), “The composition, amount and spatial distribution of litter on the coastline, in the surface layer of the water column, and on the seabed, are at levels that do not cause harm to the coastal and marine environment”, and “The composition, amount, and spatial distribution of micro-litter on the coastline, in the surface layer of the water column, and in seabed sediment, are at levels that do not cause harm to the coastal and marine environment”, respectively.

3 Threshold values

Trend not significantly >0 (preliminary).

3.1 Setting the threshold value(s) (method/reference/logic)

The threshold was set as no significant increase over the observed time period in the monitored part of the Baltic Sea. The threshold is preliminary and for use only until further guidance is available.

4 Results and discussion

The temporal development in mass and number of litter items caught per km^2 and probability of catching litter in a haul in the surveyed area can be seen in figures 1, 2 and 3, respectively. By far the most numerous litter item in terms of number and probability was plastic, followed by natural litter (Table 3). The trend estimated for the different litter types differ depending on whether the early (poorly sampled) years are included as well as between densities measured by numbers and weight (Table 4). Among the plastic items counted, SUP accounted for 36% (32% by weight). As the changes in early years may be a result of differences in sample coverage and effort, the trends are examined from 2015 onwards. The spatial distribution of the assessed litter types can be seen in figure 4. The large differences in the distribution as measured by weight and numbers/probability of catch is likely due to differences in sample coverage and effort as all years are included in the estimation of the distribution of litter. Annual estimates from model 1 are given in Table 5.

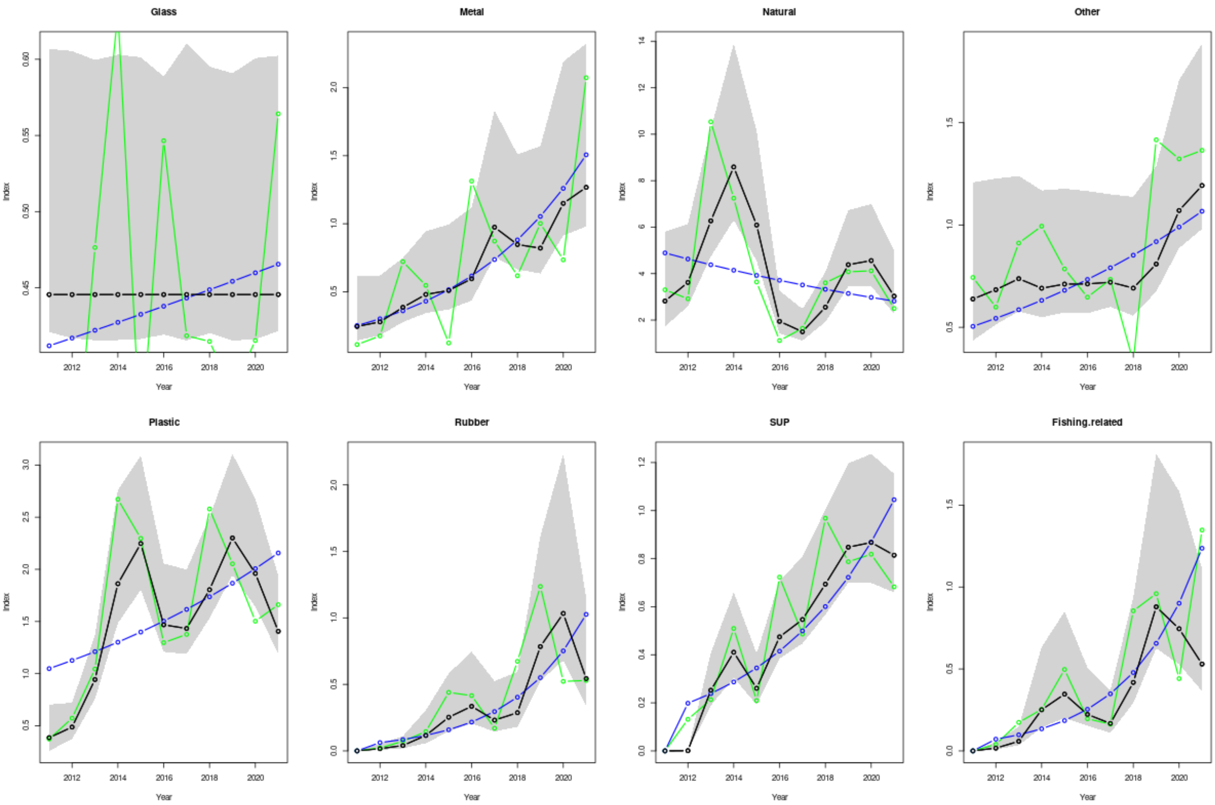

Figure 1. Temporal development in kg litter/km^2 as estimated by models 1 (black, grey is 95% confidence interval of the estimate), 2 (green) and 3 (blue). Top row from left to right: glass, metal, natural, other. Bottom row from left to right: plastic, rubber, SUP, fisheries related plastic. Note difference in scale of the y-axis.

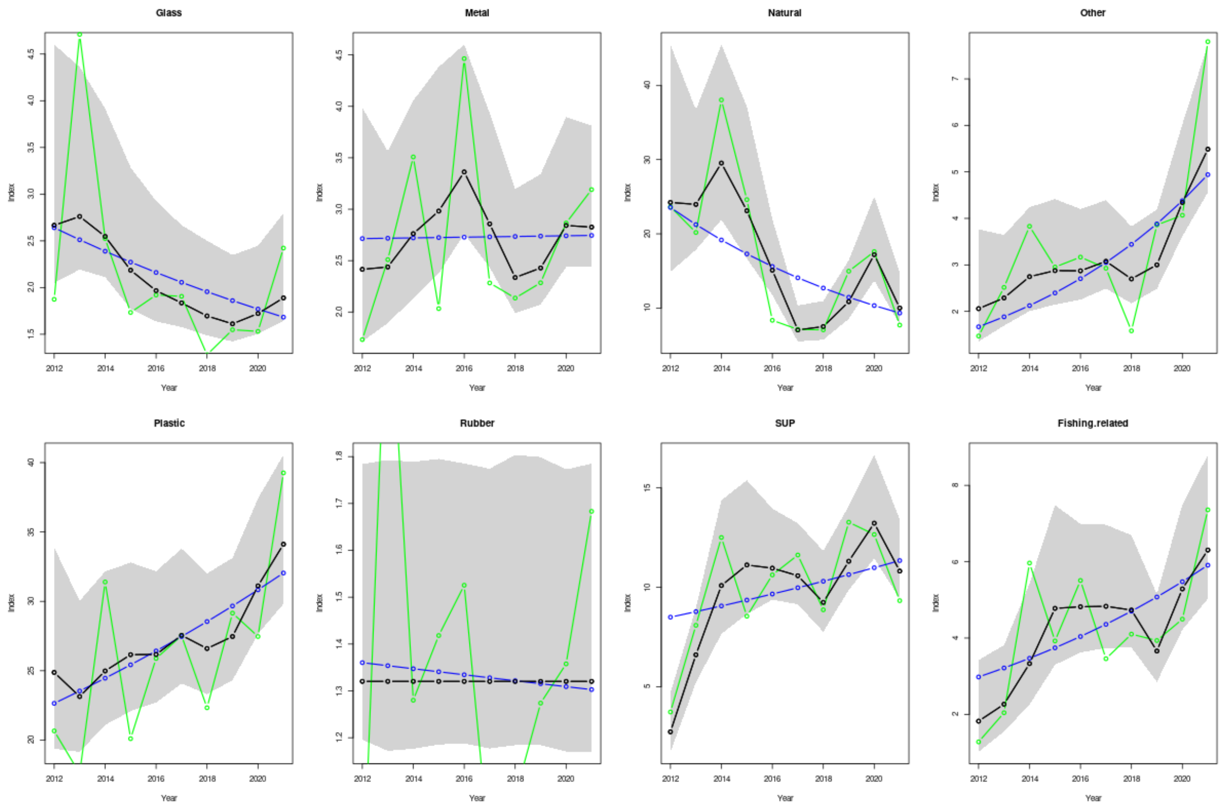

Figure 2. Temporal development in number of litter items/km^2 as estimated by models 1 (black, grey is 95% confidence interval of the estimate), 2 (green) and 3 (blue). Top row from left to right: glass, metal, natural, other. Bottom row from left to right: plastic, rubber, SUP, fisheries related plastic. Note difference in scale of the y-axis.

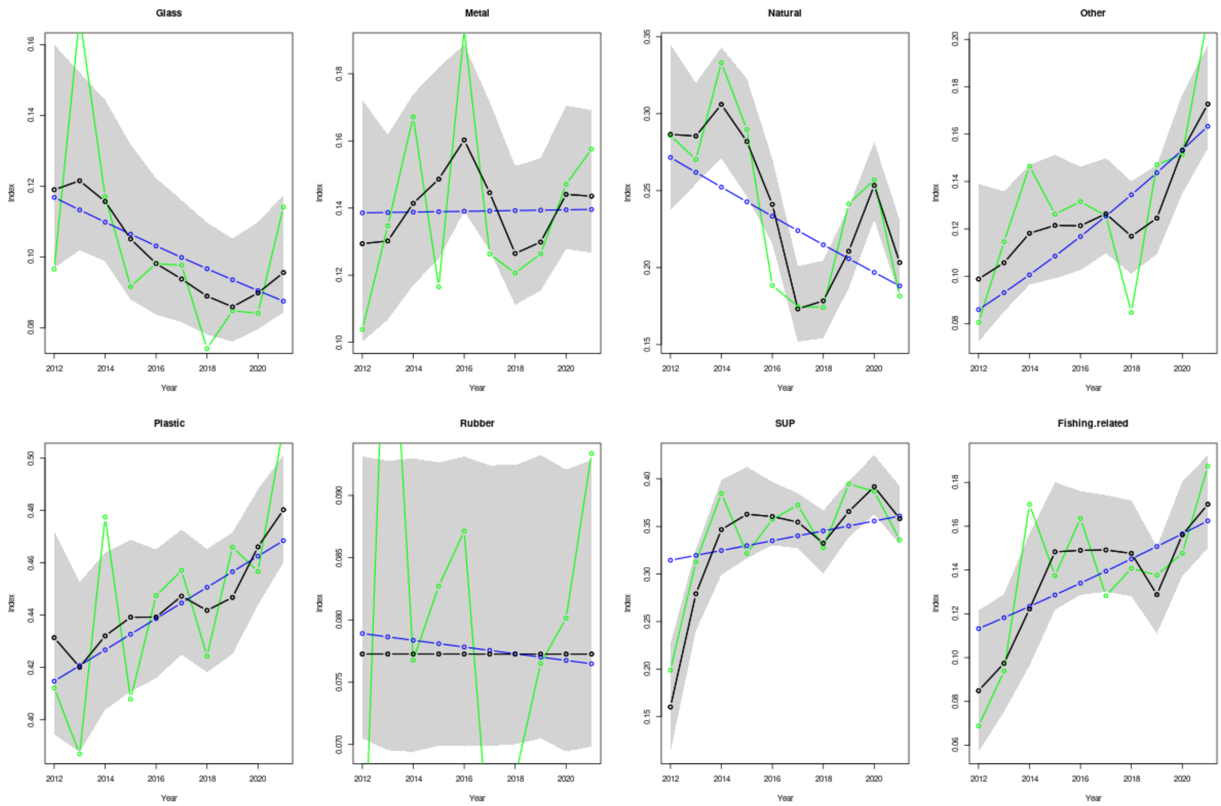

Figure 3. Temporal development in probability of catching litter as estimated by models 1 (black, grey is 95% confidence interval of the estimate), 2 (green) and 3 (blue). Top row from left to right: glass, metal, natural, other. Bottom row from left to right: plastic, rubber, SUP, fisheries related plastic. Note difference in scale of the y-axis.

Table 3. Average weight and number of litter items per km^2 and probability of non-zero catch across all years. Note that the number of hauls analysed for weight and number differs, and hence the numbers are not directly comparable.

	Average weight kg/km^2	*Average Probability/haul*	*Average Number/km^2*
Glass	0.45	0.101	2.09
Metal	0.73	0.140	2.72
Natural	4.25	0.242	16.86
Other	0.80	0.126	3.15
Plastic	1.59	0.444	27.22
Rubber	0.36	0.077	1.32
SUP	0.52	0.331	9.67
Fishing related	0.36	0.135	4.181
Total	1.13		8.40

Table 4. Trend and significance level of trend in weight and number of litter items per km^2. Trends in probability of non-zero catch are identical to trends in numbers. Effects greater than 0 indicate increase and effects smaller than 0 indicate decrease. Values in bold indicate significant trends.

	Weight				*Number*			
	All years		2015 onwards		All years		2015 onwards	
Litter type	effect	P	effect	P	effect	P	effect	P
Glass	0.012	0.563	0.0234	0.451	-0.05	**0.0438**	0.0169	0.642
Metal	**0.179**	**<0.0001**	-0.015	0.558	0.0013	0.952	-0.0217	0.476
Natural	**-0.550**	**0.007**	**-0.0654**	**0.0177**	**-0.103**	**<0.0001**	-0.0439	0.146
Other	**0.075**	**0.00454**	**0.153**	**<0.0001**	**0.1206**	**<0.0001**	**0.1532**	**<0.0001**
Plastic	**0.072**	**<0.0001**	**0.0935**	**<0.0001**	**0.0386**	**0.0021**	**0.0432**	**0.0131**
Rubber	**0.311**	**<0.0001**	0.039	0.272	-0.0048	0.868	0.00947	0.816
SUP	**0.185**	**<0.0001**	-0.015	0.36	**0.0321**	**0.01876**	-0.00179	0.924
Fisheries related	**0.317**	**<0.0001**	**0.102**	**0.0016**	**0.0761**	**0.00158**	0.04431	0.169

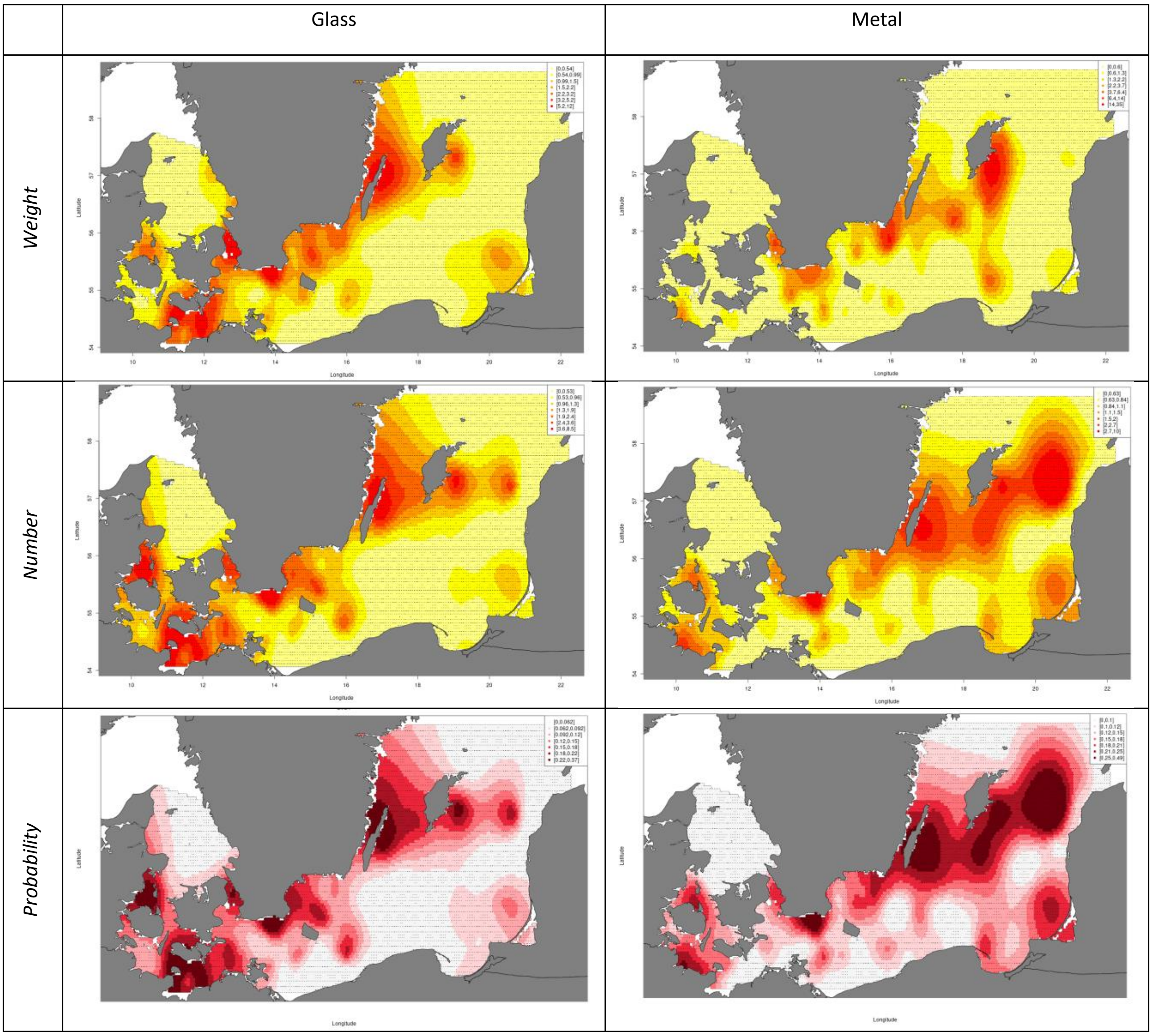

Figure 4a. Distribution of different litter types in weight, number and probability of catching litter. Colouring reflects amount relative to the mean, yellow/white is low amounts, red/dark red is high amounts. Note the limited sampling in deeper areas, see figure 3.

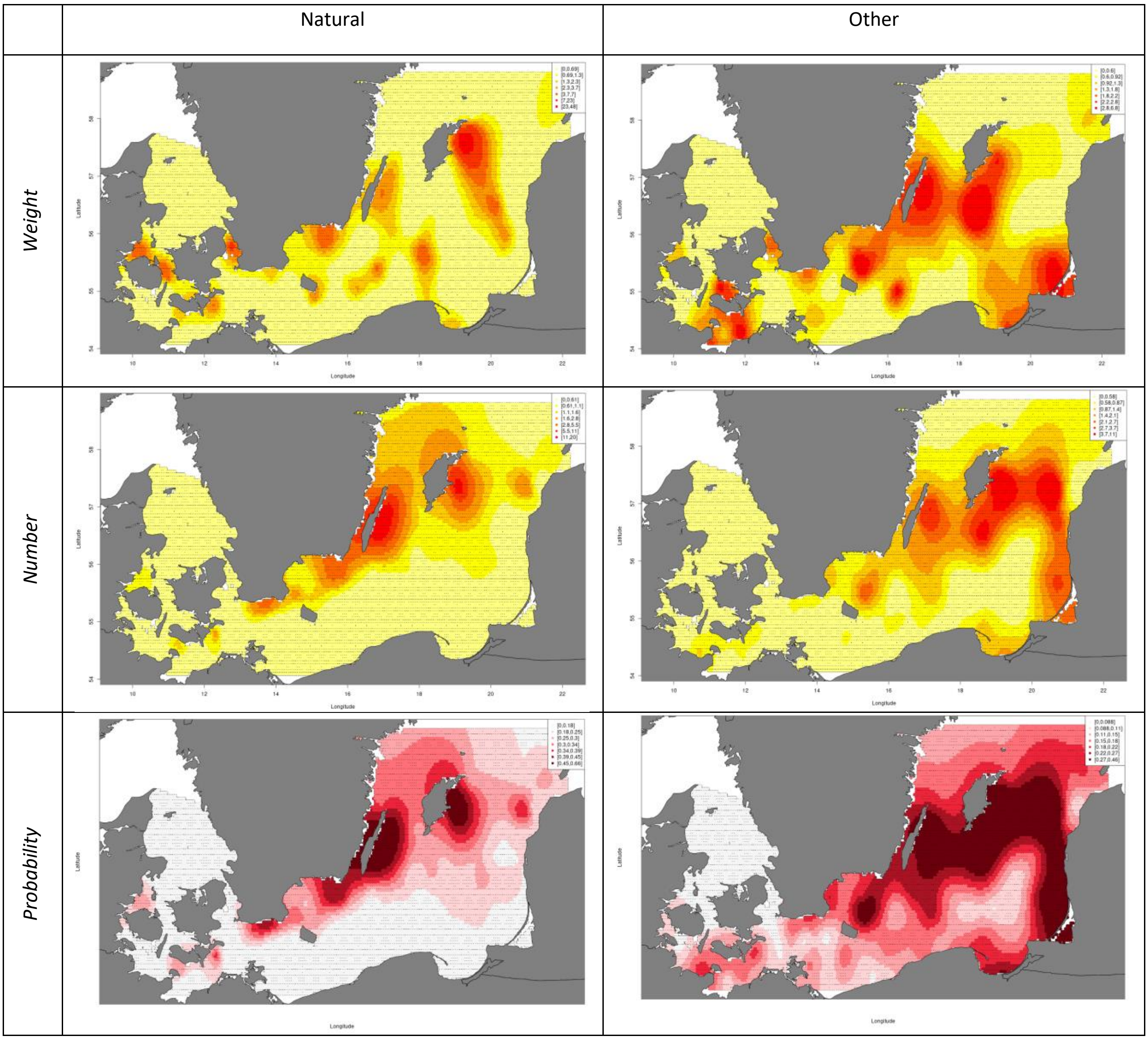

Figure 4b. Distribution of different litter types in weight, number and probability of catching litter. Colouring reflects amount relative to the mean, yellow/white is low amounts, red/dark red is high amounts. Note the limited sampling in deeper areas, see figure 3.

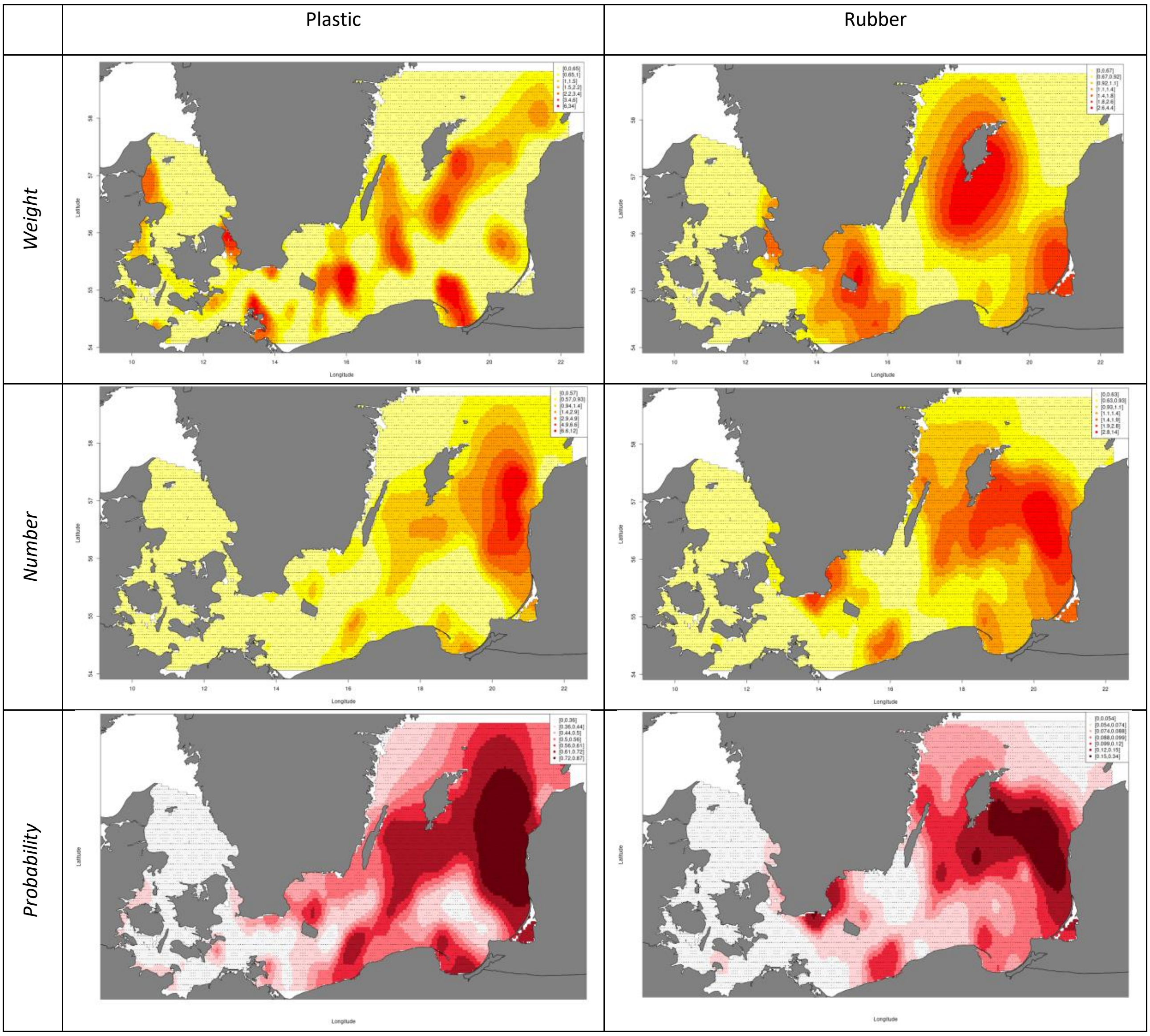

Figure 4c. Distribution of different litter types in weight, number and probability of catching litter. Colouring reflects amount relative to the mean, yellow/white is low amounts, red/dark red is high amounts. Note the limited sampling in deeper areas, see figure 3.

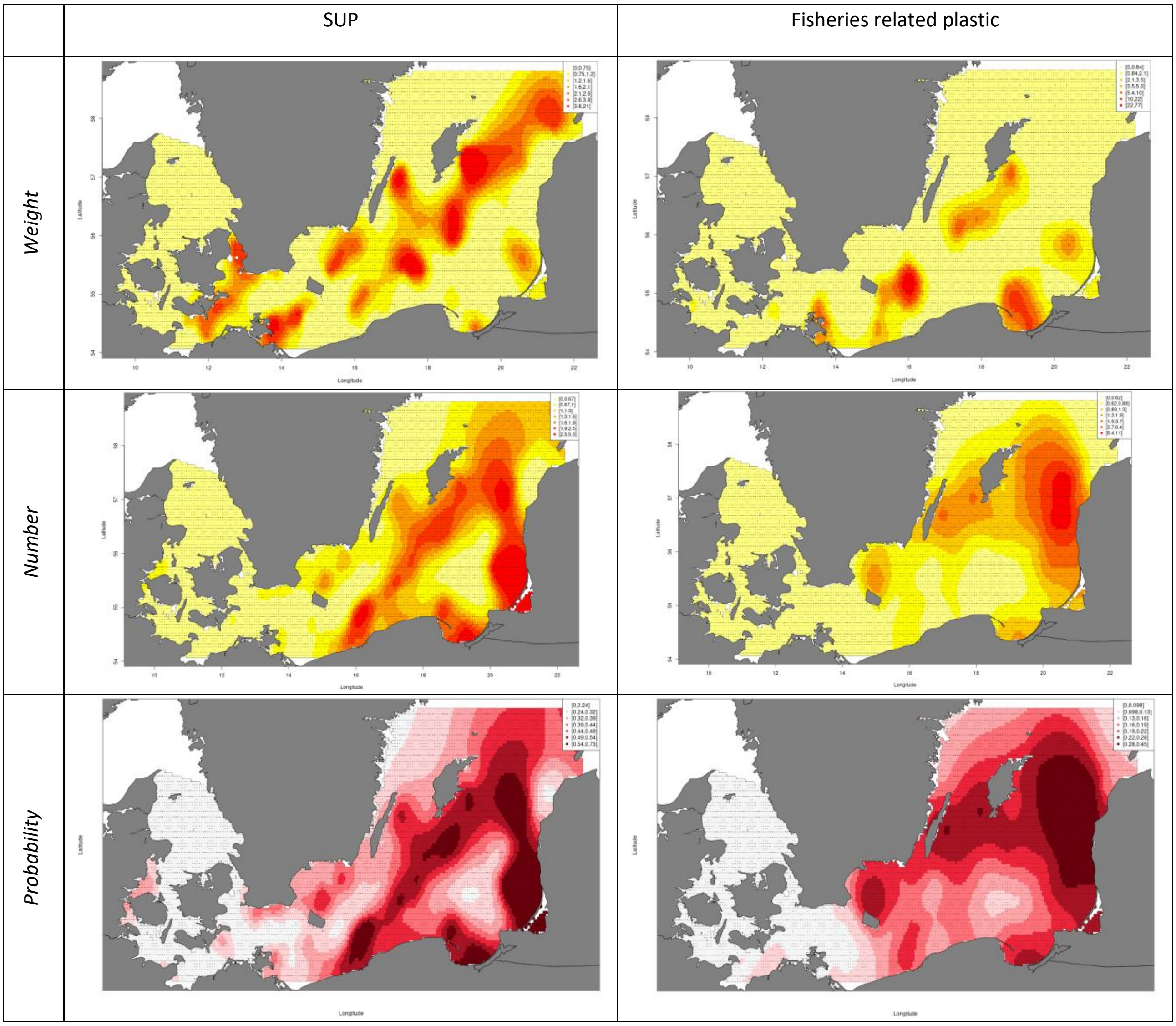

Figure 4d. Distribution of different litter types in weight, number and probability of catching litter. Colouring reflects amount relative to the mean, yellow/white is low amounts, red/dark red is high amounts. Note the limited sampling in deeper areas, see figure 3.

4.1 Discussion

When litter density was measured in weight, the categories “other”, plastic and fisheries related litter increased significantly in the period from 2015 to 2021 whereas when density was measured in numbers, only the categories “other” and plastic litter increased significantly (see Table 5 below). Hence, the categories “other” and litter failed the preliminary threshold of no significant increase from 2015 to 2021 in both weight, numbers and probability of catching litter. Fisheries related litter passed the threshold when measured in numbers per km^2 but not when measured in weight pr km^2. The categories glass, metal, natural, rubber and SUP showed no significant increase in weight and numbers per km^2 and hence passed the preliminary threshold of no significant increase.

Table 5. Assessment of the preliminary threshold of no significant increase from 2015 to 2021.

HELCOM Assessment unit name (and ID)	Threshold value achieved/failed	Distinct trend between current and previous assessment	Description of outcomes, if pertinent
Baltic Sea	Achieved for glass, metal, natural litter, fisheries related litter (numbers only) rubber and SUP	Stable/decreasing	Indicator evaluation failed to achieve the threshold value for some litter categories. Long natural recovery times for most litter types.
	Failed for plastic, fisheries related (weight only) and other litter.	Increasing	

5 Confidence

Confidence in the applied threshold value is high, given that the choice is based on a policy decision. The data coverage is good within the surveyed area and period, but the amount of litter observed varies greatly between trawl hauls and even after the addition of a state of the art-statistical model to account for this variability, the coefficient of variation (CV) around the annual estimates of litter on the seafloor remain high.

6 Drivers, Activities, and Pressures

As the deep seafloor is thought to constitute a sink/accumulation area also for marine litter, most sources for marine litter can probably contribute to litter on the seafloor. Recent reviews of the amount and composition of litter on the seafloor show that items associated with maritime activities (e.g., fishing, shipping) dominate in some areas, but that items form land-based sources also commonly occur (Galgani *et al.*, 2010; Galgani *et al.*, 2015; Pham *et al.*, 2014). In addition to that, seafloor litter originating from human activities can affect the ecosystem and its integrity, it should also be recognised that litter in the sea can have a socio-economic impact on human activities related to the sea, e.g., costs for damage or loss of fishing gear, obstruction of motors, beach cleanups then washed ashore and potential effects on tourism and recreation (Newman *et al*., 2015).

Fishing gear that has been lost, so called ghost nets, are a very special type of anthropogenic litter on the seafloor. Ghost nets are known to continue fishing and can be considered as posing an especially large risk to the environment compared to other types of litter. Static and bottom trawling fishing gear are known to be frequently lost and/or discarded. Studies have estimated the total catch of cod by ghost nets to 3-906 tonnes during a 28 month study period, amounting to 0.01-3.2% of the total weight of reported and landed cod catch from the same area and time period (Brown *et al.*, 2005).

The types of gear lost and the reasons for the gear being lost are believed to differ regionally in the Baltic Sea, however comprehensive statistics are currently not available. In 2011, WWF Poland together with fishermen, scientists and divers conducted a pilot project financed by Baltic Sea 2020, with a view to work out the methodology for net removal and carry out activities to clean the Polish territorial waters from ghost nets. As a result, 6 tonnes of ghost nets were retrieved from the Baltic during 24 days of actions at sea – from sea bottom and two ship wrecks. In 2014, a ghost net project was conducted by the Ozeaneum Stralsund, archeomare e.V., Drosos foundation and the WWF Germany on Rügen. Thereby divers removed around 4 tonnes of ghost nets from 2 wrecks.

New data on the occurrence of derelict fishing gear (DFG) in the Baltic were collected through MARELITT Baltic, an EU-supported project involving partners from Estonia, Germany, Poland and Sweden. Among the aims of the project were to develop cost-efficient methods for mapping the occurrence of DFG, and to develop cost-efficient and environmentally sound methods for collecting DFG. The project run for the period 2016-2019 (MARELITT, 2019).

7 Climate change and other factors

Climate change does not impact seafloor litter except through possible changes in transport of litter by e.g., wind, rivers or currents.

8 Conclusions

Litter in the categories "other", plastic and fisheries related litter failed the threshold of no increase but only "other" and plastic litter failed the threshold of no increase in both weight, numbers and probability of catching litter. Fisheries related litter passed the threshold when measured in numbers per km^2 but not when measured in weight per km^2. The categories glass, metal, natural, rubber and SUP showed no significant increase in weight and numbers per km^2 and hence passed the preliminary threshold of no significant increase. The confidence in the trend estimate from the model is high, but the high variability in the data decreases the confidence in the annual values.

8.1 Future work or improvements needed

Further improvements to the analysis could include monitoring of the amount of litter in categories more closely related to ingestion, entanglement and contaminants. Further, the issue of the source of litter items should be investigated in order to suggest appropriate management measures and likely impacts of these on the indicator.

9 Methodology

9.1 Scale of assessment

The indicator is assessed at HELCOM level 1 (entire Baltic Sea), with the caveat that it is based on ICES coordinated trawl surveys and that there is no sampling in coastal areas, on rough grounds, grounds with dumped munition and north of the Gotland basins (HELCOM Monitoring and Assessment Strategy Annex 4). There are no plans to expand the coverage of the currently used surveys.

9.2 Methodology applied

Benthic trawls such as the ones used in the Baltic Sea International Trawl Survey (figure 2) are designed to capture demersal fish species on the seafloor over a range of different seabed types that can be trawled. The trawl interacts with the seafloor in several places, potentially bringing litter into the water, and subsequently this litter pass to the meshes of the trawl where it may either pass through or be retained. In the Baltic, the TV3 trawl is used in a small and a large version which are effectively scaled versions of the same gear. The widest part of the trawl is between the trawl doors (figure 5). Trawl doors are heavy and effectively plough through the bottom, exposing litter in the upper layers depending on litter characteristics. Heavier litter falls to the ground next to the area that the doors passed whereas lighter litter depending on characteristics may remain in the water column long enough to potentially enter the path of the trawl net where it can be retained. The ground gear consists of a series of 10 cm wide rubber discs that roll over the bottom, creating turbulence that may cause the trawl to pass over or lift litter into the net. The turbulence differs between soft and harder bottom types. The initial part of the net has large meshes (8-12 cm) and only the very final part of the net has small meshes (2 cm). Hence, smaller litter can be carried through the meshes of the initial part of the trawl and thus not occur among the items brought to the vessel whereas larger litter once entering the trawl mouth will be retained. The water current will also affect how much of the litter is retained as a strong current may affect the amount of water passing through the trawl and hence the amount of floating litter encountered. The trawl is therefore likely to under-represent the number of small and heavy items as these pass through the meshes of the net or do not even enter the trawl. As bottom trawls of different types are dragged at different distances above the sediment it is still difficult to predict how much of the actual litter on the bottom that is caught by the trawl as this is not studied. Further, trawl surveys cover only sandy or muddy/clay areas and hence do not represent rocky substrates which may retain different amounts of litter. Finally, there are some concerns over the quality of the data submitted as the sampling guidelines and quality control have undergone continued development from the onset of litter sampling to today. The sampling protocol for the litter sampling can be found in ICES (2016).

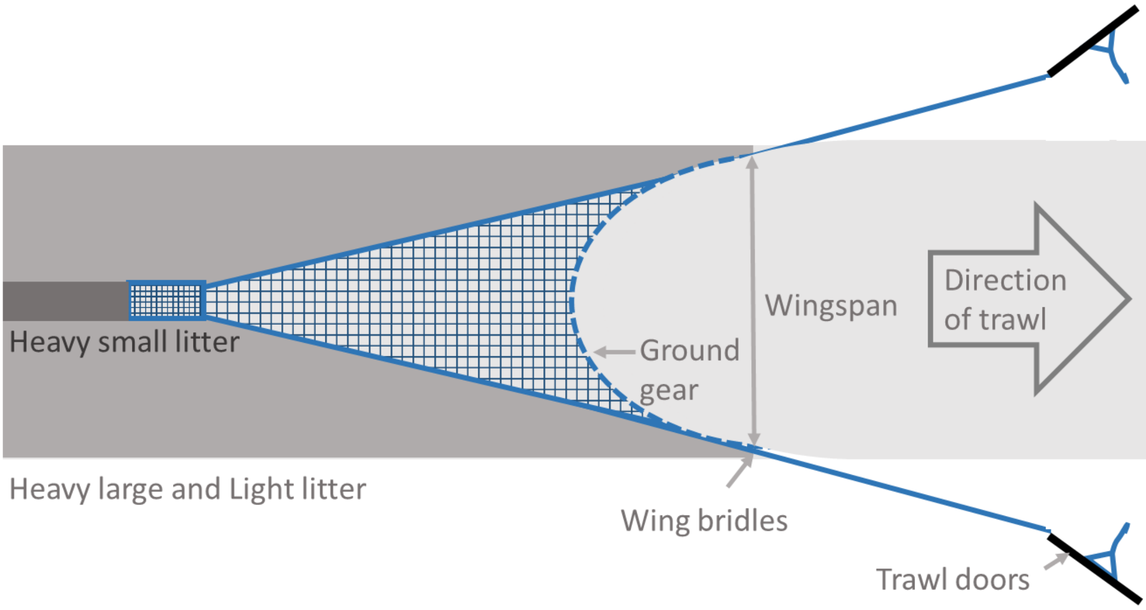

Figure 5. The active region of a benthic trawl net for light and heavy litter. See text for explanation.

9.2.1 Data preparation

Data for use in the analysis were extracted from the ICES website (https://datras.ices.dk/Data_products/Download/Download_Data_public.aspx). The methods outlined below are similar to methods used by OSPAR in the assessment of marine litter.

The sampling of litter in the Baltic Sea International Trawl survey commenced in 2011 but the manual describing the categories and sample codes was not fully standardised until 2015. A common description of how to sample litter did not appear until 2018. In the early years, some countries reported numbers while others reported weight. Further, the categories used initially were coarser than those currently used. As a result, data collected prior to 2015/2018 are considered less reliable. The locations sampled annually in the survey are shown in figure 6. There are minor variations in survey location within the surveyed area between years. The north-eastern Baltic is not covered by the available data. This area must therefore be monitored using other data if an assessment of the development over time in litter density is to be conducted.

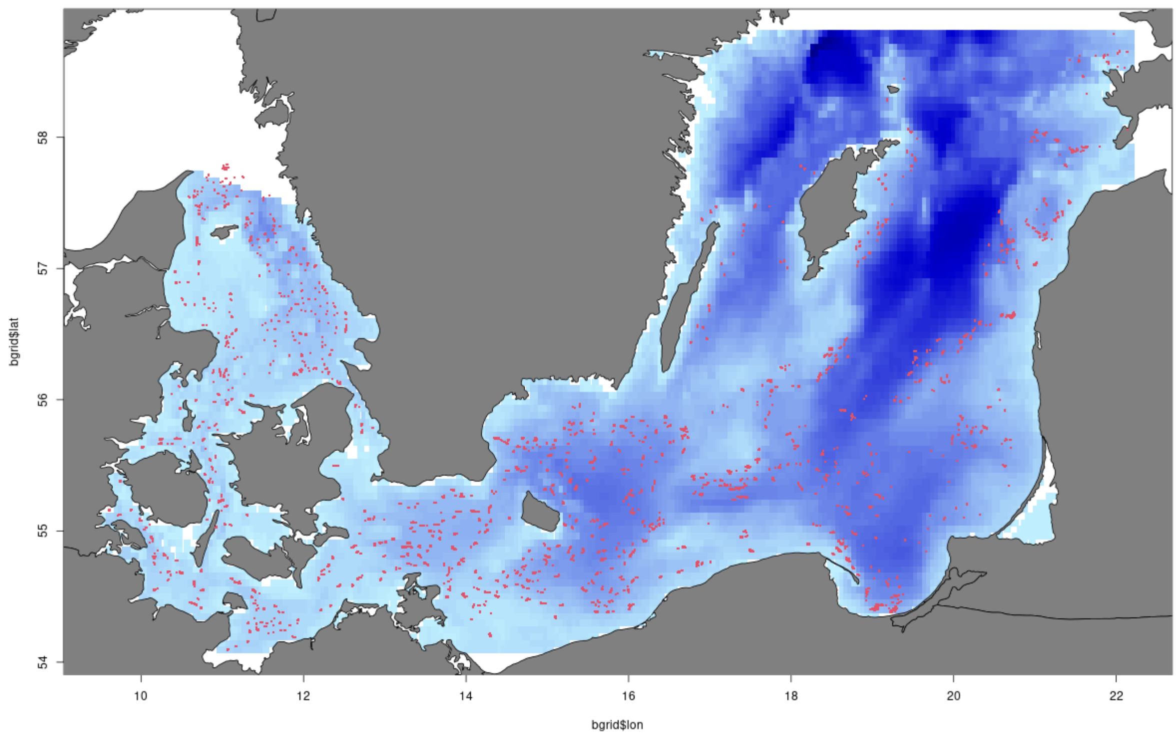

Figure 6. Sampling locations (red) and depth (shades of blue). Note that deep and north-eastern areas are not sampled.

Litter data are recorded in the database by Denmark, Estonia, Germany, Lithuania, Latvia, Poland, Russia and Sweden. The years sampled for litter weight and litter number varies between countries (Tables 6 and 7). From 2016 onwards, the proportion of hauls recording both litter weight and numbers has been above 85% (Figure 7).

Table 6. Number of hauls sampled by country for weight of litter.

Year	*Denmark*	*Estonia*	*Germany*	*Latvia*	*Lithuania*	*Poland*	*Russia*	*Sweden*
2011	194	0	0	0	0	0	0	0
2012	203	0	51	0	0	0	0	80
2013	192	0	104	0	0	0	0	74
2014	146	0	115	0	0	0	0	70
2015	169	9	107	14	2	31	0	78
2016	95	10	116	41	10	95	0	76
2017	91	10	108	49	11	136	0	78
2018	205	10	111	56	9	118	16	63
2019	157	6	98	44	12	127	0	68
2020	222	8	108	37	12	106	0	68
2021	235	7	103	43	0	119	14	72

Table 7. Number of hauls sampled by country for number of litter items.

	Denmark	*Estonia*	*Germany*	*Latvia*	*Lithuania*	*Poland*	*Russia*	*Sweden*
2012	52	0	51	0	0	0	0	60
2013	0	0	104	0	0	0	0	64
2014	0	0	115	0	0	0	0	57
2015	15	9	107	14	3	31	0	57
2016	95	10	116	41	10	95	0	57
2017	91	10	108	49	11	67	0	78
2018	205	10	111	56	9	84	16	63
2019	157	6	98	44	12	121	0	68
2020	204	8	108	37	12	106	0	68
2021	221	7	103	43	0	119	14	72

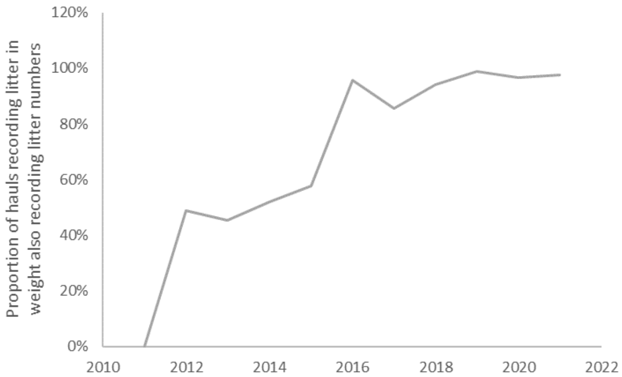

Figure 7. Development in the proportion of hauls recording litter in weight where number of litter items is also recorded.

Data are classified using one of the two formats C-TS (Original CEFAS trawl litter categories) and C-TS-REV (Revised CEFAS Trawl Litter Survey parameters). From 2019 onwards, only the latter of the two are used. The major categories are recorded in all years (plastic, metal, glass/ceramics, rubber, natural products and other) and are mutually exclusive (a litter item can only appear in one of these categories). Two further categories were also investigated (a litter item will appear in one of these categories only if it already appears in one of the above categories): Fisheries related plastic and Single Use Plastic (Table 8). The aim of this categorization is to reflect estimates of SUP and Fisheries related plastic as defined in EC (2019). As this represent a post hoc classification, the categories may contain litter that is not covered by the SUP Directive.

Table 8. Litter categorisation and assignment of categories to Single Use Plastic (SUP) and Fisheries related plastic. 'Yes' means the litter type is included in SUP or Fisheries related plastic. Litter categorised as SUP does not include Fisheries related plastic.

	C-TS	C-TS-REV	Type	SUP	Fisheries related plastic
Plastic	A	A	Plastic		
Plastic bottle	A1	A1	Plastic	Yes	
Plastic sheet	A2	A2	Plastic	Yes	
Plastic bag	A3	A3	Plastic	Yes	
Plastic caps	A4	A4	Plastic	Yes	
Plastic fishing line (monofilament)	A5	A5	Plastic		Yes
Plastic fishing line (entangled)	A6	A6	Plastic		Yes
Synthetic rope	A7	A7	Plastic		Yes
Fishing net	A8	A8	Plastic		Yes
Plastic cable ties	A9	A9	Plastic		
Plastic strapping band	A10	A10	Plastic		
Plastic crates and containers	A11	A11	Plastic	Yes	
Plastic diapers	B1	A12	Plastic	Yes	
Sanitary towel/tampon	B6	A13	Plastic	Yes	
Other plastic	A12	A14	Plastic		
Sanitary waste (unspecified)	B		Plastic	Yes	
Cotton buds	B2		Plastic	Yes	
Cigarette butts	B3		Plastic	Yes	
Condoms	B4		Plastic	Yes	
Syringes	B5		Plastic	Yes	
Other sanitary waste	B7		Plastic	Yes	
Metals	C	B	Metal		
Cans (food)	C1	B1	Metal		
Cans (beverage)	C2	B2	Metal		
Fishing related metal	C3	B3	Metal		
Metal drums	C4	B4	Metal		
Metal appliances	C5	B5	Metal		
Metal car parts	C6	B6	Metal		
Metal cables	C7	B7	Metal		
Other metal	C8	B8	Metal		
Rubber	D	C	Rubber		
Boots	D1	C1	Rubber		
Balloons	D2	C2	Rubber	Yes	
Rubber bobbins (fishing)	D3	C3	Rubber		Yes
Tyre	D4	C4	Rubber		
Glove	D5	C5	Rubber		
Other rubber	D6	C6	Rubber		
Glass/Ceramics	E	D	Glass		
Jar	E1	D1	Glass		
Glass bottle	E2	D2	Glass		
Glass/ceramic piece	E3	D3	Glass		
Other glass or ceramic	E4	D4	Glass		
Natural products	F	E	Natural		
Wood (processed)	F1	E1	Natural		
Rope	F2	E2	Natural		
Paper/cardboard	F3	E3	Natural		
Pallets	F4	E4	Natural		
Other natural products	F5	F5	Natural		
Miscellaneous	G	F	Other		
Clothing/rags	G1	F1	Other		
Shoes	G2	F2	Other		
Other	G3	F3	Other		

9.2.2 Swept area corrections

The area swept was defined as the distance trawled multiplied by the width of the trawl between the wings. Data on wingspan, doorspread and distance travelled were not consistently available. Given the low proportion of hauls containing the necessary information to estimate the swept area for each haul, it was decided to instead assume that all hauls of a specific gear type covered the median of the swept areas estimated for all hauls with TVL and TVS, respectively (87163 m^2 and 68184 m^2, respectively).

9.2.3 Estimation of the indicator

Three metrics were investigated, the proportion of trawl hauls containing litter, the average catch of litter in number and the average catch of litter in weight, both per km^2.

The statistical properties of the data (large overdispersion and occasional very large catches) necessitated analysing the data in a statistical model (Stefánsson 1996, Berg *et al.*, 2014). Survey indices were therefore calculated using the methodology described by Berg *et al*. (2014). Three models were fitted for each type of litter to estimate the amount of litter caught. Model 1 assumes that the amount of litter develops smoothly from year to year as a result of litter deteriorating slowly in the wild. Hence, the model utilises the knowledge we have of the lifetime of litter on the sea bottom and is considered the most appropriate model. Model 2 allows the amount of litter to change freely between years, equivalent to the assumption that litter is removed from the surveyed area every year and replaced by new litter. This model is equivalent to estimating the annual amount independently of the previous year and is commonly used. Model 3 estimates a linear trend over the period and can be used to evaluate if there has been a significant steady increase from year to year within the sampling period. An alternative method to investigate the development in litter over time could be to compare the level in the period from 2016 to 2021 with that in the period from 2010 to 2015. However, this test is less strong statistically than model 3 as it does not utilise the information present in the development within assessment periods and further is complicated by the sampling only beginning midway in the first assessment period for most countries.

The spatial distribution of litter was assumed constant over time due to the sparsity of data. The following equations describe the models:

$$g(\mu_i) = f_1(time_i) + f_1(lon_i, lat_i) + log(effort_i) \qquad (1)$$

$$g(\mu_i) = Year_i + f_1(lon_i, lat_i) + log(effort_i) \qquad (2)$$

$$g(\mu_i) = \alpha time_i + f_1(lon_i, lat_i) + log(effort_i) \qquad (3)$$

Effort is the swept area and amount caught is assumed to be directly proportional to this (i.e., if the area swept is doubled, the average amount caught is doubled). The swept area for a 30 min haul is assumed to be 68184 m^2 for the TVS gear and 87163 m^2 for the TVL (approx. 0.78 ratio, see above). All *f*-functions are Duchon splines with first derivative penalization. The models are fitted using both proportion of non-zero catches, numbers and mass as the response variable. For models using mass the Tweedie distribution (compound Poisson-Gamma) is used, because it is simple and easy to work with (see e.g., Thorson 2017). For models using numbers and to predict probability of catching litter the negative binomial distribution is used. Mass and number indices are standardized to a unit of kg / km^2 or numbers / km^2.

9.3 Monitoring and reporting requirements

There is wide experience and data collected on litter in the seafloor and fishing gear/lost fishing nets in the HELCOM area. Seafloor litter collection is integrated to bottom trawling for fish stocks assessment, so therefore the selection of the sampling stations as well as frequency is associated to the casuistic of the species of interest. Additional information can be found in the HELCOM Monitoring Programme on Litter on the Seafloor (HELCOM, 2020).

10 Data

The data and resulting data products (e.g., tables, figures and maps) available on the indicator web page can be used freely given that it is used appropriately, and the source is cited.

Data for use in the analysis were extracted from the ICES website (https://datras.ices.dk/Data_products/Download/Download_Data_public.aspx). The full code can be found here: https://github.com/DTUAqua/HELCOM-litter. The table below (Table 9) gives annual average values for each litter type and year.

Table 9. Annual model estimates of weight (mass) and number of litter items per km2 and probability of non-zero catch. Low and High denotes upper and lower 95% confidence intervals, respectively.

Type	Year	Mass	MassLow	MassHigh	Numbers	NumbersLow	NumbersHigh	Prob	ProbLow	ProbHigh
Glass	2012	0.44551	0.416846	0.605422	2.666697	2.049887	4.6012	0.118995	0.09691	0.159982
Glass	2013	0.445517	0.41552	0.599448	2.761062	2.193335	4.360735	0.121539	0.101878	0.152164
Glass	2014	0.445532	0.415663	0.603116	2.54682	2.11194	3.915167	0.115681	0.09878	0.144357
Glass	2015	0.445534	0.416347	0.601324	2.186015	1.773373	3.285524	0.105088	0.087959	0.131793
Glass	2016	0.445536	0.419242	0.58876	1.966743	1.637972	2.926399	0.098137	0.083707	0.122263
Glass	2017	0.445535	0.415385	0.610315	1.835458	1.576828	2.667841	0.093763	0.081616	0.11607
Glass	2018	0.44553	0.420258	0.595185	1.695945	1.487631	2.500857	0.088922	0.078073	0.109695
Glass	2019	0.445532	0.415355	0.590818	1.611645	1.422667	2.347476	0.085892	0.076074	0.105202
Glass	2020	0.445538	0.41616	0.600752	1.721922	1.504383	2.447111	0.089839	0.079622	0.10981
Glass	2021	0.445547	4.22E-01	0.602379	1.889319	1.645482	2.794938	0.095578	0.084314	0.117541
Metal	2012	0.278817	1.80E-01	0.619785	2.415496	1.713901	3.985435	0.129375	0.100189	0.172186
Metal	2013	0.385755	2.77E-01	0.748509	2.438146	1.893202	3.562842	0.130191	0.106718	0.161811
Metal	2014	0.480457	3.44E-01	0.944424	2.761709	2.133311	4.056337	0.141405	0.117079	0.173939
Metal	2015	0.509614	3.70E-01	0.99481	2.981882	2.376366	4.382549	0.148597	0.124847	0.181899
Metal	2016	0.595644	4.36E-01	1.119444	3.362414	2.761102	4.600896	0.16029	0.139066	0.188664
Metal	2017	0.974351	0.755916	1.832887	2.857335	2.435354	3.933275	0.14457	0.127348	0.171623
Metal	2018	0.847165	0.665291	1.509748	2.335822	1.98884	3.196872	0.126469	0.111147	0.152462
Metal	2019	0.82085	0.634643	1.569859	2.428742	2.073584	3.340907	0.129853	0.115408	0.154867
Metal	2020	1.149734	0.913114	2.191056	2.841842	2.437988	3.894713	0.144061	0.127789	0.170499
Metal	2021	1.267442	0.980223	2.323725	2.825967	2.436667	3.814477	0.143539	0.126694	0.169204
Natural	2012	3.620196	2.599513	6.138473	24.2258	14.8885	45.47056	0.286578	0.237343	0.344819
Natural	2013	6.270533	4.736894	10.2066	23.96556	17.84683	36.68562	0.285521	0.254387	0.319997
Natural	2014	8.589439	6.307281	13.89984	29.52924	21.91464	45.49308	0.30604	0.27112	0.343083
Natural	2015	6.089038	4.543524	10.13452	23.10761	16.67773	37.11972	0.281958	0.246298	0.3228
Natural	2016	1.945149	1.430028	3.262926	15.09974	11.76824	21.96961	0.241077	0.215729	0.270829
Natural	2017	1.498057	1.120274	2.472038	7.054283	5.498965	10.34529	0.173207	0.151964	0.200975
Natural	2018	2.554178	1.920114	4.064253	7.510614	5.737608	10.9563	0.178453	0.154115	0.204517
Natural	2019	4.383652	3.43986	6.727153	10.86231	8.541077	16.44772	0.210678	0.186863	0.239442
Natural	2020	4.559681	3.463246	6.994008	17.20075	13.74693	24.98245	0.253434	0.231349	0.281524

Natural	2021	3.029851	2.26182	5.000387	10.00476	7.804954	14.84023	0.203311	0.18126	0.230849
Other	2012	0.683721	0.514082	1.226198	2.058694	1.352842	3.764506	0.098831	0.07242	0.138985
Other	2013	0.73759	0.578255	1.239436	2.289719	1.695162	3.641892	0.105713	0.085119	0.135802
Other	2014	0.691079	0.549337	1.168765	2.746594	2.006484	4.240254	0.118162	0.096492	0.146931
Other	2015	0.711197	0.572256	1.177047	2.877021	2.147301	4.415927	0.121471	0.099127	0.151216
Other	2016	0.711995	0.569006	1.165453	2.872077	2.254205	4.201782	0.121347	0.102645	0.146192
Other	2017	0.72062	0.600031	1.149793	3.077284	2.490435	4.390988	0.126364	0.109725	0.149881
Other	2018	0.691668	0.556739	1.137364	2.698058	2.174886	3.826251	0.116905	0.101081	0.140103
Other	2019	0.809193	0.674828	1.287875	3.001113	2.486058	4.190662	0.124528	0.109374	0.146998
Other	2020	1.070679	0.887234	1.708392	4.342105	3.617725	6.02614	0.153068	0.134946	0.176797
Other	2021	1.19268	0.980058	1.885985	5.488249	4.559938	7.738453	0.172689	0.154007	0.19773
Plastic	2012	0.487681	0.373777	0.7207	24.87626	19.37626	33.8751	0.431346	0.39436	0.472188
Plastic	2013	0.943495	0.756934	1.368186	23.13959	19.14885	30.03497	0.42008	0.387667	0.452542
Plastic	2014	1.861788	1.484654	2.76175	24.9822	21.09779	32.1469	0.432008	0.403797	0.463863
Plastic	2015	2.247397	1.804174	3.089645	26.15674	22.08642	32.79934	0.439155	0.41077	0.468749
Plastic	2016	1.468015	1.208997	2.055911	26.17116	22.70678	32.16642	0.43924	0.415873	0.46509
Plastic	2017	1.432806	1.18836	1.998389	27.55173	24.08117	33.79315	0.447229	0.424877	0.472641
Plastic	2018	1.804394	1.53211	2.497888	26.60067	23.31656	32.00716	0.441771	0.41812	0.46523
Plastic	2019	2.300702	1.944203	3.106164	27.46569	24.31907	33.13106	0.446743	0.425114	0.471559
Plastic	2020	1.960626	1.642817	2.676456	31.11393	27.6549	37.41644	0.466062	0.443813	0.488021
Plastic	2021	1.405809	1.191638	1.938309	34.11683	29.81748	40.55215	0.480251	0.460134	0.501182
Rubber	2012	0.016701	0.006594	0.052692	1.320374	1.19597	1.783939	0.077265	0.070489	0.093145
Rubber	2013	0.040161	0.019895	0.110751	1.320382	1.172056	1.79269	0.077265	0.069534	0.092778
Rubber	2014	0.1163	0.057237	0.305315	1.320377	1.176659	1.788766	0.077265	0.0694	0.092985
Rubber	2015	0.252998	0.146836	0.582245	1.320359	1.18573	1.794996	0.077264	0.069904	0.092653
Rubber	2016	0.334959	0.206005	0.745389	1.32034	1.18767	1.785075	0.077263	0.069849	0.093129
Rubber	2017	0.231329	0.14576	0.524223	1.320283	1.177214	1.774076	0.077261	0.069883	0.092427
Rubber	2018	0.28724	0.181615	0.594962	1.320263	1.184293	1.803505	0.07726	0.070016	0.09243
Rubber	2019	0.784377	0.525989	1.614402	1.32028	1.184322	1.798943	0.077261	0.070471	0.093248
Rubber	2020	1.033477	0.682844	2.232517	1.320312	1.170545	1.772362	0.077262	0.069443	0.09207
Rubber	2021	0.543547	0.337187	1.14843	1.320321	1.169866	1.784994	0.077263	0.069823	0.092858
SUP	2012	0.000839	0.000348	0.002243	2.733454	1.724973	4.700086	0.160279	0.112993	0.226453

SUP	2013	0.252307	0.189019	0.407648	6.605985	5.217605	8.963356	0.279195	0.240493	0.325725
SUP	2014	0.410478	0.304204	0.660197	10.08766	7.659662	14.37608	0.346741	0.299268	0.398796
SUP	2015	0.260502	0.192654	0.404333	11.12199	8.652187	15.38066	0.362867	0.316569	0.412637
SUP	2016	0.474416	0.384744	0.707176	10.96174	9.382525	13.95706	0.36046	0.330191	0.396746
SUP	2017	0.546632	0.446862	0.808481	10.58062	9.143428	13.2179	0.354605	0.327293	0.38498
SUP	2018	0.693842	0.567204	1.003291	9.241721	7.762919	11.82625	0.33241	0.300577	0.366714
SUP	2019	0.847749	0.70014	1.197004	11.31024	9.873038	14.08182	0.365653	0.338682	0.397834
SUP	2020	0.86729	0.69867	1.235669	13.22162	11.44637	16.65218	0.391722	0.362727	0.425082
SUP	2021	0.814305	0.659653	1.153089	10.81527	9.439988	13.41733	0.358232	0.33107	0.392356
Fishing.related	2012	0.016902	0.008027	0.053815	1.822417	1.017337	3.420608	0.084898	0.056947	0.12152
Fishing.related	2013	0.058469	0.034531	0.147072	2.266205	1.553602	3.814894	0.097413	0.075346	0.12901
Fishing.related	2014	0.25091	0.142648	0.633787	3.330431	2.256848	5.423839	0.1222	0.096323	0.156589
Fishing.related	2015	0.346305	0.202241	0.85014	4.777329	3.300204	7.479029	0.148297	0.121855	0.180101
Fishing.related	2016	0.222457	0.15339	0.508151	4.819838	3.620443	6.991735	0.14897	0.12868	0.176014
Fishing.related	2017	0.167531	0.110093	0.369704	4.83173	3.741497	6.968711	0.149157	0.13003	0.174202
Fishing.related	2018	0.417742	0.292502	0.936551	4.733385	3.749024	6.69322	0.147597	0.128089	0.171707
Fishing.related	2019	0.879136	0.626643	1.812058	3.659236	2.853184	5.14664	0.128757	0.110982	0.15063
Fishing.related	2020	0.74537	0.527651	1.584376	5.286768	4.219909	7.496612	0.156074	0.137205	0.180269
Fishing.related	2021	0.529883	0.365336	1.112158	6.305216	5.029919	8.796378	0.170013	0.150109	0.192499

11 Contributors

Anna Rindorf, Marie Storr-Paulsen

HELCOM Expert Group on Marine Litter (HELCOM EG Marine Litter).

HELCOM Secretariat: Jannica Haldin, Owen Rowe, Marta Ruis

12 Archive

This version of the HELCOM core indicator report was published in March 2023.

13 References

Barnes D.K.A, Galgani F., Thompson R.C, Barlaz M. 2009. Accumulation and fragmentation of plastic debris in global environments. *Philos. Trans. R. Soc. Lond. B Biol. Sci* 364: 1985–1998. doi: 10.1098/rstb.2008.0205.

Bergmann M., Klages M. 2012. Increase of litter at the Artic deep-sea observatory HAUSGARTEN. *Marine Pollution Bulletin,* 64, 2734-2741.

Brown, J, G. Macfadyen, T. Huntington, J. Magnus and J. Tumilty (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.

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

Galgani F., Leaute J.P., Moguedet P., Souplet A., Verin Y., Carpentier A., Goraguer H., Latrouite D., Andral F., Cadiou Y., Mahe J.C., Poulard J.C., Nerisson P. 2010. Litter on the Sea Floor Along European Coasts. *Marine Pollution Bulletin*, 40 (6) 516-527.

Galgani F., Hanke G., Maes T.. 2015. Global Distribution, Composition and Abundance of Marine Litter. In: Bergmann M. *et al* (eds): Marine anthropogenic litter. Springer Open. pp 29-56.

Goldberg E.D. 1994. Diamonds and plastics are forever? *Marine Pollution Bulletin* 28, 466.

HELCOM, 2013. HELCOM Copenhagen Declaration "Taking Further Action to Implement the Baltic Sea Action Plan - Reaching Good Environmental Status for a healthy Baltic Sea". Online August 2014 http://www.helcom.fi/Documents/Ministerial2013/Ministerial%20declaration/2013%20Copenhagen%20Ministerial%20Declaration%20w%20cover.pdf

HELCOM 2020. HELCOM Monitoring Programme on Litter on the Seafloor. https://helcom.fi/wp-content/uploads/2020/10/MM_Litter-on-the-seafloor.pdf

HELCOM Recommendation 42-43/3, 2021. Regional Action Plan on Marine Litter. https://helcom.fi/wp-content/uploads/2021/10/Rec-42-43-3.pdf

ICES. 2014. Manual for the Baltic International Trawl Surveys (BITS). Series of ICES Survey Protocols SISP 7 - BITS. 71 pp.

ICES. 2015. Manual for the International Bottom Trawl Surveys. Series of ICES Survey Protocols SISP 10 - IBTS IX. 86 pp.

ICES. 2016. Second Interim Report of the Baltic International Fish Survey Working Group (WGBIFS), 30 March-3 April 2016, Rostock, Germany. ICES CM 2016/SSGIEOM:07. 591 pp.

JRC, 2013. Guidance on Monitoring of Marine Litter in European Seas. Online August 2014 http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/30681/1/lb-na-26113-en-n.pdf.

Katsanevakis, S. 2008. Marine debris, a growing problem: Sources, distribution, composition, and impacts. In: Hofer TN (ed) Marine Pollution: New Research. Nova Science Publishers, New York. pp. 53–100.

Lundqvist, J. 2013 . Quantification of debris on the seafloor in shallow (<20 m) areas using a towed video camera system, Report of university of Gothenburg, Faculty of sciences, pp. 22.

Majaneva & Suonpää, 2015. Vedenalaisen roskan kartoitus Helsingin edustan merialueella – pilottiprojekti. http://www.hel.fi/static/ymk/julkaisut/julkaisu-02-15.pdfa

MARELITT, 2019. https://www.marelittbaltic.eu/

Mordecai, G., Tyler, P.A., Masson, D.G., Huvenne, V.A.I., 2011. Litter in submarine canyons off the west coast of Portugal. Deep Sea Res. Part II 58, 2489.

Moret-Ferguson, S., Law, K.L., Proskurowski, G., Murphy, E.K., Peacock, E.E., Reddy, C.M., 2010. The size, mass, and composition of plastic debris in the western North Atlantic Ocean. *Marine Pollution Bulletin* 60, 1873–1878.

Miyake H., Shibata H., Furushima Y. 2011. Deep-sea litter study using deep-sea observation tools. In: Omori K., Guo X., Yoshie N., Fujii N., Handoh I.C. *et al.*, editors. Interdisciplinary Studies on Environmental Chemistry-Marine Environmental Modeling and Analysis: Terrapub. pp. 261–269.

Newman S., Watkins E., Farmer A., ten Brink P., Schweitzer J.P. 2015. The Economics of Marine Litter. Chapter 14 in: Marine Anthropogenic Litter, Eds. Bergmann M., Gutow L., Klages M., Eprint ID 37207 of the Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Springer Open Publication, 447pp.

OSPAR, 2022. OSPAR's Second Regional Action Plan for the Prevention and Management of Marine Litter in the North-East Atlantic (2022-2030) http://www.ospar.org/documents?v=48461

Pace, R., Dimech, M., Camilleri, M., Schembri, P.J., Briand, F., 2007. Litter as a Source of Habitat Islands on Deepwater Muddy Bottoms. CIESM, Monaco.

Pham C.K., Ramirez-Llodra E., Alt C.H.S., Amaro T., Bergmann M., Canals M., Company J.B., Davies J., Duineveld G., Galgani F., Howell K.L., Huvenne V.A.I., Isidro E., Jones D.O.B., Lastras G., Morato T., Gomes-Pereira J.N., Purser A., Stewart H., Tojeira I., Tubau X., Van Rooij D., Tyler P.A. 2014. PLoS ONE 9(4): e95839. doi:10.1371/journal.pone.0095839.

Thompson R.C. 2006. Plastic debris in the marine environment: consequences and solutions. In: Krause, J.C., Nordheim, H., Bräger, S. (Eds.), Marine Nature Conservation in Europe. Bundesamt für Naturschutz, Stralsund, Germany, 107–115.

Ye S. & Andrady A.L. 1991. Fouling of floating plastic debris under Biscayne Bay exposure conditions. *Marine Pollution Bulletin* 22, 608–613.

14 Other relevant resources