Pilot: collecting Marine litter during regular fish surveys

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Summary

The European Marine Strategy Framework Directive (MSFD, 2008/56/EC) obliges EU Member States to establish and implement the necessary measures to achieve and/or maintain good environmental status (GES) in their marine waters. Marine litter is one of the aspects mentioned in the directive and monitoring plans should be implemented soon.

This report presents the results of a pilot to monitor marine litter on the sea-floor using regular bottom trawl fish surveys. In the last years registration of marine litter became common practice on some international bottom trawl fish surveys, however it was implemented differently on the participating international vessels. The pilot study gave special attention to the registration of litter caught during the Dutch IBTS Q1 in 2013. This meant that the catch was searched with more detail, the net on the deck was inspected and cleaned, descriptions of each item were given and photos were taken.

The main goal was to evaluate the possibilities to continue this detailed registration in the coming years, e.g. the number of staff needed and the amount of time it consumes. The other goal was to give an overview of the collected data, and to show the relevance of collecting this data in relation to the MSFD objectives. To support this also the French data of the IBTS Q1 2013 and data on marine litter collected by the Dutch surveys, IBTS Q1 and BTS, in 2012 are presented.

The conclusion is that detailed registration of marine litter during the surveys is possible. Without much effort the catch can be searched thoroughly and descriptions can be given of each litter item. Extra effort is needed to search and clean the net and these activities can be hampered by the weather conditions. Overall the activities needed for monitoring the marine litter are unlikely going to delay the main objectives of the survey. However, priority issues have to be solved: the survey is financed to perform the fish survey and does work for a lot of side request of which marine litter is one.

The efficiency of monitoring the marine litter could be improved by implementing the registration in the same program which is used to enter the catch data. Furthermore the guidelines on registration of marine litter should be extended as many arbitrary choices are made at the moment which result in discrepancies between different staff members but even more between the different vessels participating in the survey.

The overview of the datasets indicates that the number of items and distribution of the items over the different categories is reasonably consistent between the years and the vessels. The spatial analysis indicate potential understandable hotspots. However, these results might be flawed due to limited cleaning of the net after each tow.

Overall the practical and the scientific part of the pilot paint a positive picture. Limited funding is needed for implementing the monitoring of marine litter deposited on the sea-floor for the MSFD in regular IMARES fish surveys and the data collected can be used to describe the composition and spatial distribution of marine litter.

More information about marine litter could be obtained from these existing surveys. Biota from the same surveys could be used for analysis of macro- and micro-plastics in digestive systems of different organisms. Micro-plastics in the water column and sediment could be monitored by making use of other types of regular IMARES surveys.

1 Introduction

The European Marine Strategy Framework Directive (MSFD, 2008/56/EC) obliges EU Member States to establish and implement the necessary measures to achieve and/or maintain good environmental status (GES) in their marine waters. The GES to be achieved and the associated targets and indicators are or will be decided upon soon. By 2014 at the latest, the Netherlands must report on the monitoring program that will become active to monitor the good environmental status.

Good Environmental Status is described by 11 descriptors, one of these, Descriptor 10, is Marine Litter. To achieve GES in 2020 for this descriptor it is necessary that "Properties and quantities of marine litter, including their degradation products such as small plastic particles down to micro-plastics do not cause harm to the coastal and marine environment and their volume decreases over time."
The descriptor is split in two aspects 1) characteristics of the litter and 2) impact on marine life. The first is split in three sub-aspects of which the second is most relevant for this report (MSFD, 2008/56/EC):

- **Trends in the amount of litter in the water column (including floating at the surface) and deposited on the sea- floor, including analysis of its composition, spatial distribution and, where possible, source (10.1.2).**

The other two sub-aspects relate to litter washed ashore and trends in micro-particles.

Monitoring trends in the amount of litter in the water column and deposited on the sea-floor is one of the aspects that could be proposed for the 2014 MSFD monitoring program. It is considered to combine this monitoring with regular fish surveys in the North Sea.

Running ahead of this, possibilities for it were considered internationally by working groups of the International Council for the Exploration of the Sea (ICES) (e.g. WGISUR, IBTSWG, WKMAL). This resulted amongst others in a protocol for collecting data on marine litter. This protocol was included in the latest manual of the International Bottom Trawl Survey (IBTS) (The International Bottom Trawl Survey Working Group, 2012). Despite this fact the actual implementation of monitoring litter is not mandatory and as a result monitoring of litter is done differently and with a varying priority by each country participating in the IBTS survey.

The Netherlands, IMARES, started the collection of marine litter on demersal fish surveys done with the R.V. Tridens II in 2011, using a much simpler separation sheet than in the current protocol and the actual registration of litter was of low priority compared to the main activities of the survey.

Prior to the IBTS survey in the first quarter of 2013, RWS asked to give the registration of litter a higher priority and to follow the method described in the IBTS manual. A pilot study was designed to investigate how much time following the protocol consumes, how much litter per type is caught during the survey and also to investigate the difference between quickly sorting the catch and more precisely sorting the catch and checking the net for litter. Besides the data and results of the pilot study also the data of the French IBTS survey in the first quarter and the litter data collected earlier by IMARES are presented.

2 Materials and Methods

2.1 IBTS

The International Bottom Trawl Survey goes back to 1960 and 1961 when a series of four large international trawl surveys were organised under the auspices of ICES to map the distribution of juvenile herring (*Clupea harengus*) in the North Sea, Skagerrak and Kattegat, the International Young Herring Survey (IYHS) (Heessen *et al.*, 1997). Gradually more countries participated and the focus on herring

alone, shifted to other species as whiting (*Merlangius merlangus*), cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*). Laterally the area surveyed extended northward to cover the entire distribution of juvenile haddock and later also Norway pout (*Trispoterus esmarki*). In 1990, the survey got its current name, IBTS, and at that time the survey was run quarterly. From 1997 onward most countries have only carried out a survey twice a year, a first quarter survey (January-February) and a third quarter survey (August-September). Since 2006, the French vessel started additional tows in the Eastern English Channel, from 2010 onward this area is covered by the French and the Dutch vessel.

As the survey developed over time, also the gear changed. From 1978 onward a multipurpose fishing gear started to be used and by 1983 all countries participating in the quarter 1 survey used this gear. Since 1992 the gear is used by all countries in both quarters. This gear is the GOV “Grand Ouverture Verticale” 36/47, a (semi-pelagic) bottom trawl. The mesh size of the net is 100 mm and 10 mm in the codend. The headline of the net is about 5 m above the seafloor, which is particularly convenient to fish pelagic species and those species which dwell just above the bottom. Compared to a beam trawl, the GOV is not particularly suited and designed for sampling flatfish as the groundrope of the GOV only touches the bottom, flatfish, benthic organisms and bottom litter might go underneath it. The only parts of the GOV that slightly penetrate the sea-floor are the two doors, on each side of the net one. The pressure against these doors determines the horizontal opening of the net and this varies with depth. Compared to a beam trawl the width of the gear, and related the surface fished is variable. The width between the doors is therefore measured continuously during each haul.

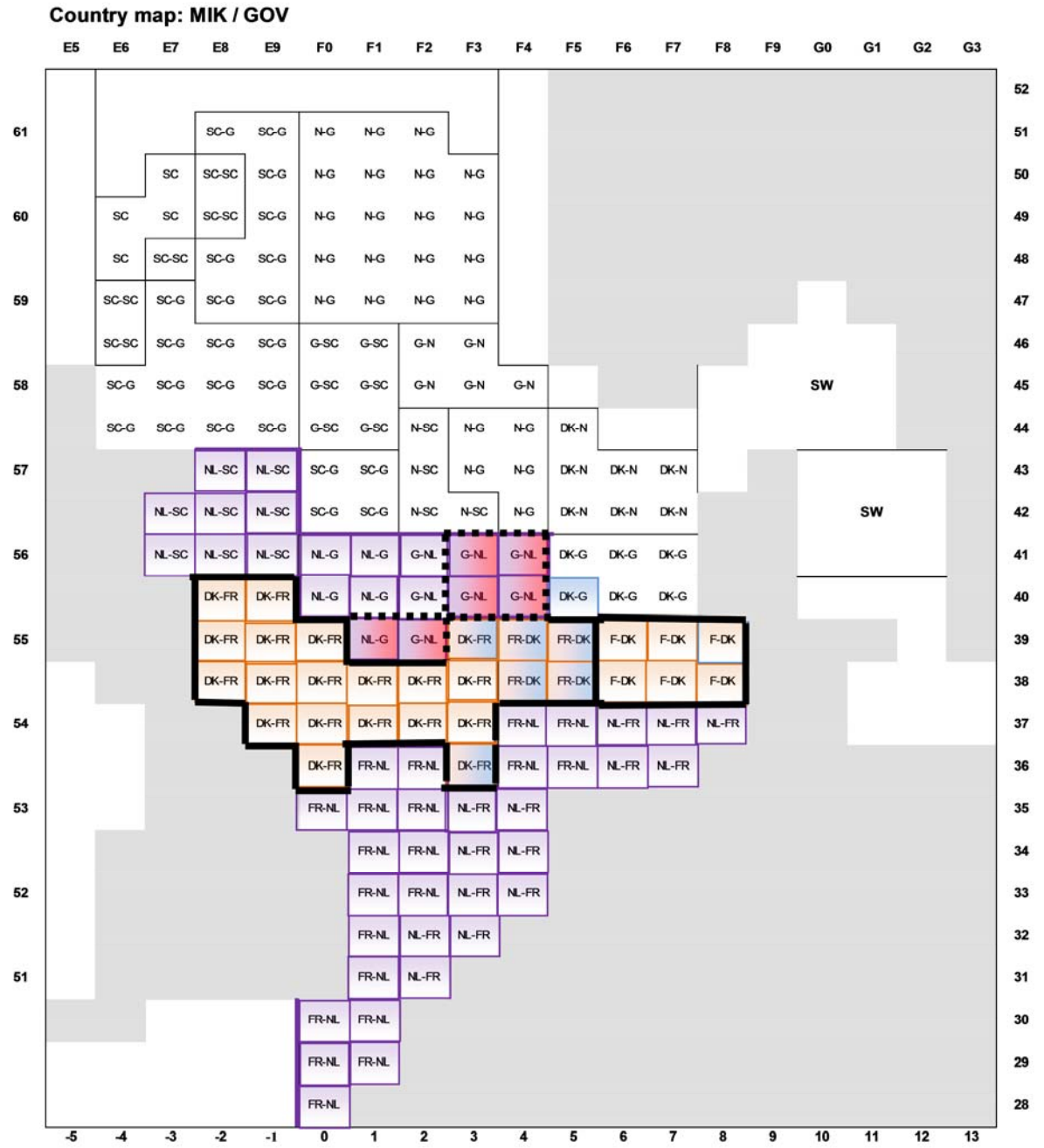
The standard fishing practice is a tow duration of 30 minutes, with a fishing speed of 4 knots. Trawling is carried out only during daylight hours. Of each haul information on location, date, weather, current and depth are recorded. During the haul the gear geometry is monitored and an average doorspread is stored.

The IBTS in the first quarter takes place in January and February. The exact dates differ between the nations participating in the survey. The Dutch did their survey in the period from 21 January till 22 February 2013.

The survey is designed such that each ICES rectangle is fished twice, the rectangles are distributed over the countries such that each rectangle is fished by two countries each fishing one haul. The Netherlands covers the Southern North Sea, the English Channel, the German Bight and a northern part in front of the Scottish coast (Purple in fig 1). Due to weather conditions the Danish and the Dutch had to swap some rectangles in 2013. The reddish rectangles were not fished by the Dutch in 2013 instead the blue-ish rectangles were fished by the Dutch. In total 60 hauls with the GOV were done by the Dutch Tridens.

In the Dutch situation: at the end of each haul the net is hoisted on deck (photo 1), however a part of it is still overboard (photo 2) and stays there. Then the codend is hoisted on deck (photo 3) and emptied (photo 4). The catch falls directly below deck (photo 5), where it is transported by a conveyor belt (photo 6). On this belt the fish and benthos species are taken out (photo 7 & 8). Small catches are fully sorted, in case of larger catches 1 or 2 fish species are not taken from the belt (photo 9) but are collected at the end of the belt in large buckets of about 35kg (photo 10). From very large catches, only a part of the catch is collected in the buckets while the rest is weighed and put overboard directly. When everything is handled on the belt one or two of the collected buckets are sorted. If the content of the bucket is only part of the catch, the contents are registered as subsample of the total catch. All or a subsample of the fish are measured and benthic species are counted (photo 12). This data is stored directly on the computer using an IMARES developed program Billie Turf that creates files that can easily be transferred to the IMARES database. From individuals of the target species, length, weight, gender and maturity are

recorded and the otoliths are collected. This information is put on paper first and later transferred to the same file as the length measurements.



SC=Scotland, G= Germany, N= Norway, DK= Denmark, FR/F= France, NL= The Netherlands, SW=Sweden.

Figure 1: distribution map of the IBTS, purple the planned Dutch part, Orange (within de dark line) the French extension beyond the Dutch section, reddish the 6 Dutch rectangles swapped with the Danish (within the dashed lines, text G-NL), blue-ish the 7 Danish rectangles taken over by the Dutch (FR-DK and DK-G).

Photo 1 to 4: 1) the net hoisted on deck; 2) part hanging over board; 3) hoisting the codend, 4) emptying the codend.




Photo 5 to 8: 5) largest catch of IBTS 2013, mainly whiting; 6) the working deck with the conveyor belt and IMARES staff sorting fish; 7) sorting the catch on the belt, 8) taking out all other species than the dominant species.

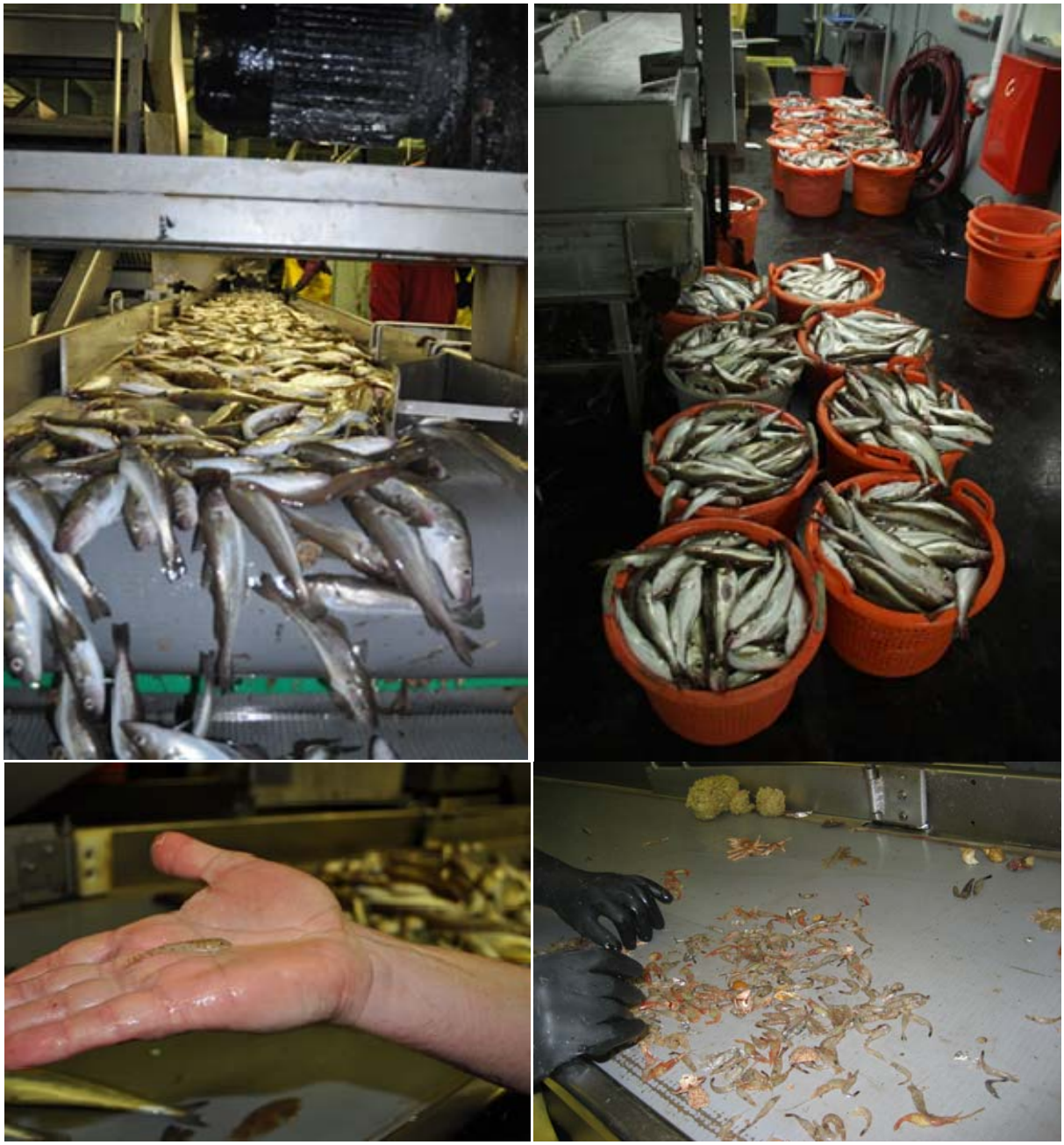


Photo 9 to 12: 9) dominant species is not taken from the belt; 10) all or with really large catches part of the catch is collected in buckets; 11) even the smallest species are taken out, 12) benthic species (shrimps in this case) are sorted to species level.

2.2 Sampling litter

The current manual of the IBTS states litter has to be collected each haul and recorded as one of the categories (table 1) with an estimate of the size. There is no guidance on how detailed the catch should be sorted or on visual inspection of the net. The data collected prior to 2013 (see 2.4) only reflects the litter that is seen on the belt and taken from there.

During this pilot the collection of litter was intensified. One crew member went on deck at the end of each haul and inspected the part of the net that was on deck. The litter stuck to or entangled in the net or the ground rope was collected. Separately from this the visual litter on the conveyor belt was collected following the same method as used during earlier surveys.

In the first three weeks the crewmember that had inspected the net was also at the end of the conveyor belt specifically there to find litter in the catch. This crewmember helped with sorting the (subsample) bucket that was collected at the end of the conveyor belt. In this way the catch was inspected twice, except for the largest catches as then a part was transported overboard directly and only a subsample of the buckets was inspected.

The two sources of litter, the net and the conveyor belt were recorded separately. Each item was assigned to one of the categories (table 1), weighed (after removing attached organisms and debris) and the size was estimated. In the first three weeks of the survey pictures were taken of most of the litter per haul and an extended description was given for each litter item. When organisms were attached to the litter this was recorded as well.

Table 1: Classification of marine litter items and the related size categories (The International Bottom Trawl Survey Working Group, 2012).

A: Plastic	B: Sanitary waste	C: Metals	Related size category
A1. Bottle	B1. diapers	C1. Cans (food)	A: <5*5 cm= 25 cm^2
A2. Sheet	B2. cotton buds	C2. Cans (beverage)	B: <10*10 cm= 100 cm^2
A3. Bag	B3. cigarette butts	C3. Fishing related	C: <20*20 cm= 400 cm^2
A4. Caps/ lids	B4. condoms	C4. Drums	D: <50*50 cm=2500 cm^2
A5. Fishing line (monofilamen	B5. syringes	C5. appliances	E: <100*100 cm= 10000 cm^2= 1 m^2
A6. Fishing line (entangled)	B6. sanitary towels/tampon	C6. car parts	F: >100*100 cm = 10000 cm^2= 1 m^2
A7. Synthetic rope	B7. other	C7. cables	
A8. Fishing net		C8. other	
A9. Cable ties			
A10. Strapping band			
A11. crates and containers			
A12. other			
D: Rubber	**E: Glass/ Ceramics**	**F: Natural products**	**G: Miscellaneous**
D1. Boots	E1. Jar	F1. Wood (processed)	G1. Clothing/ rags
D2. Balloons	E2. Bottle	F2. Rope	G2. Shoes
D3. bobbins (fishing)	E3. piece	F3. Paper/cardboard	G3. other
D4. tyre	E4. other	F4. pallets	
D5. glove		F5. other	
D6. other			

2.3 French data

The 2013 litter data collected on the French research vessel Thalassa is provided by Yves Verin, IFREMER's cruise leader on the French IBTS, and used in this report. The French covered the English Channel, the Southern North Sea, the German Bight (the same rectangles as the Dutch), but also covered a subsequent section more northward (orange figure 1). In total the French vessel fished 86 locations.
Fishing by Thalassa is done in the same way with the same net according to the IBTS protocol. Sorting the catch is however done slightly different from the Dutch situation as the working decks of the two ships differ. For the collection of the litter the French followed the description and classification in the IBTS manual.

2.4 Earlier collected data

IBTS 2012

Marine litter was recorded on the Tridens during the IBTS 2012. However, this was done on major categories, rather than the categories specified in the current manual. In 2012, the categories were: 1) plastic; 2) paper/cardboard; 3) wood-industrial; 4) metal; 5) glass/ceramics; 6) cloth; 7) rubber; 8) fishing-gear and 9) miscellaneous. The litter was collected from the belt and only in special occasions, a very large metal spiral and a lobster cage, taken from the deck. The accuracy of the sampling was limited compared to 2013 and the preferred sampling accuracy. There is a reasonable chance that litter items have been missed even as they came down on the conveyor belt.
The litter items were grouped per category per haul and weighed. Thus even when multiple plastic objects were caught, it resulted in a single registration of plastic in that haul. Due to this a comparison with the 2013 data is nearly impossible.
In 2012, 57 hauls were sampled all taken in the area planned to be covered by the Dutch, which is the same area as planned to be covered by the Dutch in 2013 (figure 1).

BTS 2012

The Beam Trawl Survey in August-September 2012 also collected marine litter on the part of the survey done on board of the Tridens. The Tridens covers the western en northern part of the North Sea (figure 2, red dots). The beam trawl survey uses another net than the IBTS. The BTS uses a beam trawl with a fixed width of 8 meter. A beam trawl is designed to catch flatfish and therefore has more bottom contact than the GOV. However, due to its width the surface fished is smaller. The fished surface is 8 times the fished distance. On average a haul of the BTS covers 0.03 km^2 (about 0.07 km^2 in the IBTS) and this single haul represents the catch in an ICES-rectangle of 1° longitude by 0.5° latitude.

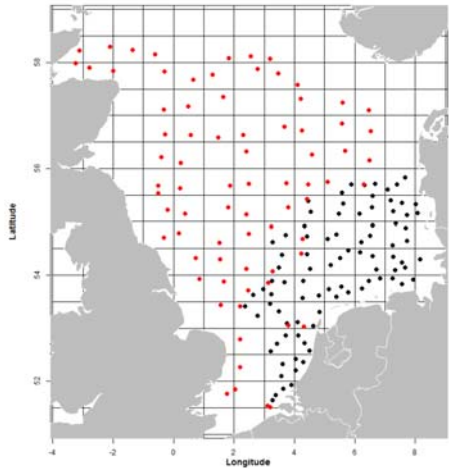


Figure 2.: Distribution map of the BTS, the red dots are the locations of the hauls with the Tridens

3 Results

3.1 Dutch data

The Dutch 2013 IBTS Q1 performed 60 hauls in total. In 56 of these hauls at least one litter item was found, meaning that only 4 hauls were without marine litter. In total 220 litter items were registered of which 147 were found during sampling on the belt and 73 were attached in the net. Thus a third of the litter items got stuck in the net or to the groundrope and was not emptied in the fish bin. Difficulty with the litter entangled in the net or groundrope is that it is difficult to find everything and in some cases it is difficult to get it loose. Especially the monofilament/nylon wires (photo 14) get entangled in the groundrope and are than difficult to spot and retrieve.

A separate issue regarding the number of items is the difficulty to discriminate litter items. In many cases this has been an arbitrary choice (photo 13-14). Monofilament/nylon wire was sometimes split into different items based on color, while in other cases a number of wires together was registered as a single item (little incentive to collect all pieces from the net) or if these wires were entangled they were recorded as a single item 'Fishing line entangled'. Similar arbitrary decisions had to be made for example for separate pieces of glass, wood or plastic (photo 13). Do they belong to a single item or did they come from different sources? In previous marine litter studies of IMARES on organisms, this type of decisions needed to be made too (Bravo Rebolledo *et al.*, 2013, Foekema *et al.*, 2013 (Accepted Manuscript), Van Franeker and The SNS Fulmar study group, 2010), therefore this study could build upon the previous experience of IMARES on breaking of particles inside samples.

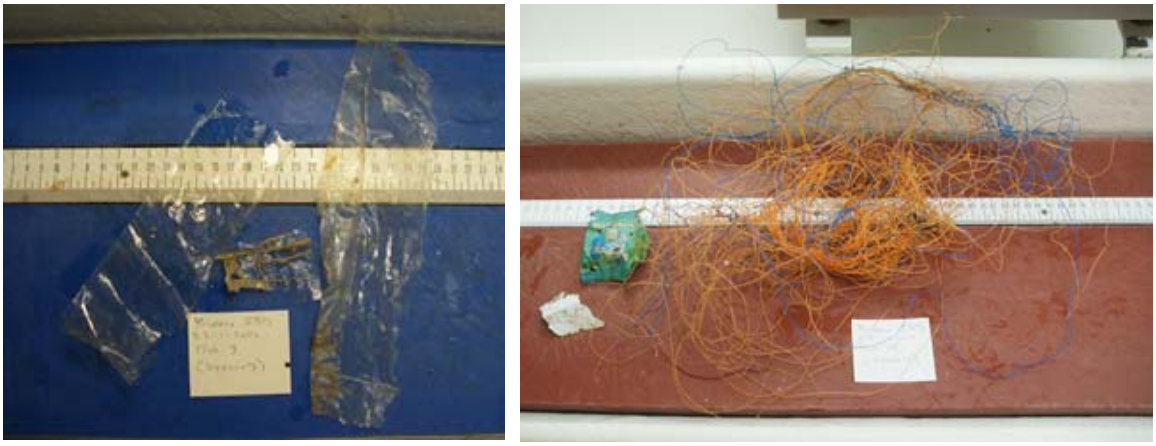


Photo 13-14: Litter collected in haul 7 and in haul 15. Haul 7) three separate plastic sheet (A2) items; haul 15) single item Fishing line entangled (A6) and two separate pieces of plastic sheet (A2).

If we consider the recorded number of items as the absolute number, most litter items found fall under category A: Plastic, this is about 87% of the total number of litter items found. The other items were divided over the other six categories:

Category		number	%	description
A	Plastic	192	87	
B	Sanitary waste	1	0.5	Cotton bud
C	Metals	3	1.5	Coca cola can; oil can; small metal bar
D	Rubber	3	1.5	Glove, balloon, rubber band
E	Glass/Ceramics	7	3	3 beer bottles, 1 vase, 1 Sweps bottle, white glass, a ceramic plate
F	Natural products	9	4	7 pieces of wood, 2 cardboard pieces
G	Miscellaneous	5	2	Shoe sole, coal, part of a T-shirt, sock, white cloth

These findings are similar to the results of Maes (Maes, 2013), who found a 76% dominance of plastic (figure 3). The data of Maes (2013) were collected at least on various UK surveys, including the IBTS.

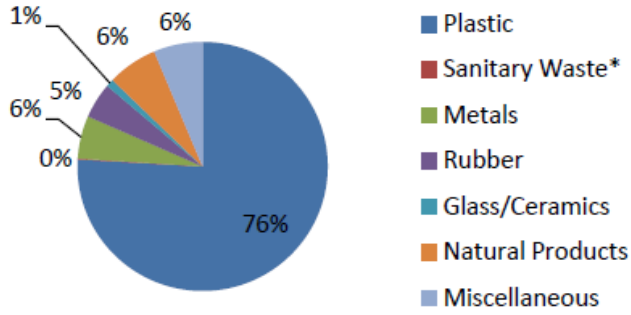


Figure 3.: Distribution of the litter items over the categories as reported by Maes (2013).

Photo 15-16: Litter collected in haul 28, one of the most diverse hauls. Determined as 1) plastic (A2), 2) rope (A6), 3) bottle (E2), 4) shoe sole (G2), 5) glove (D5), 6) cardboard (F3), and 7) wood (F5). The wood contains metal as well, but is only placed in F5 as the main part was wood.

The plastic category (A) exists of 12 sub-categories, of which 11 were found. Crates/containers, sub-category A11, were not caught. Of the 11 plastic categories A2 (Sheet, photo 13) was most dominant followed by A5 (Fishing line, monofilament, photo 21) (figure 4).

The items in category A2 vary a lot. This is because the interpretation of plastic sheet is not straightforward, many items might be named as such, and the categorization is arbitrary in many cases. We included all kinds of wrapping material and various flexible plastic pieces of which the origine was not clear. The pieces in photo 13 were considered as a single A2 item, and the three pieces from haul 33 (photo 17 and 18) were considered as three separate A2 items. The black plastic in haul 33 (photo 17) was considered a garbage bag and was recorded as a single A3 item. The plastic item in haul 29 (photo 19) might be a part of a similar garbage bag but was considered a single A2 item. While the Disco chips bag in that haul was labeled A3.

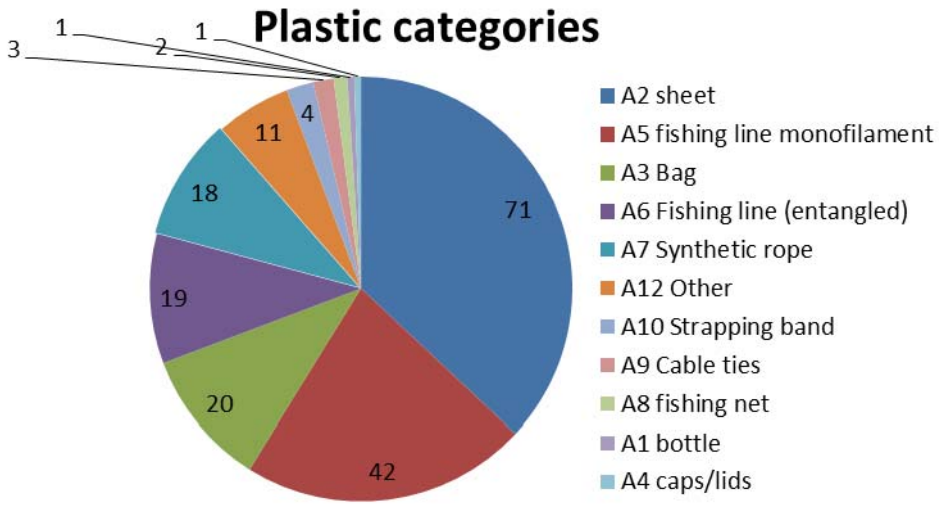


Figure 4.: Number of litter items per sub-category of Plastic.

The second biggest category in number of items was A5 fishing line monofilament. This was a difficult category as well. If all single strings of line were registered as separate items, this category would have dominated. However, in many cases all lines were registered as a single item. Furthermore the discrepancy between A5 and A6 is arbitrary. Some pieces are clearly entangled (photo 14), while for other parts it is an arbitrary choice. A5 and A6 could just as well be grouped as it is very likely to be the same source and the question is when it became entangled. When it was lost, later on the seafloor when the current brought it together or in our net.

Photo 17-18: Litter from haul 33, A plastic garbage bag (A3) and three pieces of plastic sheet (A2).
19: Litter from haul 29, black plastic sheet (A2) and a Discos chips bag (A3)

Synthetic rope (A7) was also often caught. The main question here is if it is actually caught or is it part of our own material. Many of the A7 items were small cuttings of netting material very similar to our own net. Repairs of the net are done almost after every haul, resulting in small piece of rope that fall on the deck. These are found when checking the net for litter, but also fall down when the fish is dropped to the lower deck. In microplastic studies, similar self-contamination errors are discussed. Clothing fibres in these studies play a similar role too synthethic rope pieces in this survey. These types of particles therefore need to be treated with great care in data interpretation (Foekema *et al.*, 2013 (Accepted Manuscript)), especially when sterile working is impossible like in trawl surveys. We excluded very white and clean items as being our own waste, but included the greenish older looking items as being marine litter. All other rope types were also included in this category.

Other plastic items (A12) were for example a medicine strip, a couple of festival drinking cups, a button and a yellow fishing net float (photo 21). The drinking cups might be a group on their own as these can be clearly distinguised.

Net versus belt

About 33% of the litter items was taken from the net. Most of these items from the net were entwined in the groundrope, while some, mainly larger, items became stuck somewhere in the net (photo 20). In more detail at sub-category level, 65% of the Bags (A3) were taken from the deck. Of the categories A2, A5 and A7 a quarter to nearly half of the items is collected from the net (table 2).

Table 2: Number of items per sub-category found on the belt or on the net.

	Belt	net	% in net
A2	42	29	41
A5	32	10	24
A7	15	4	21
A12	10	1	9
A6	10	8	44
A3	7	13	65
F1	5	1	17

Size of the litter

The majority of the items were estimated to be of size class A (115), with 56 items being size class B the litter caught is small. There were 21 items classified as C and 26 as D, only two items were E and a single item was F. This largest item was a large piece of fishing net of a trawled gear which was so big that it had to stay on deck and is not weighed. The two E items were a large white rag and a larger plastic sheet. The smallest items were the monofilament lines. Due to the mesh size of the trawl, smaller individual plastic particles in the water column will not be found. Micro-plastics could have been found during this survey when analysing gut contents of biota. For studying micro-plastic in the water column other sampling techniques could be used.

The heaviest item was most likely the fishing net followed by some wooden items (photo 20). Followed by the metal oil drum of about 2kg and the yellow floater of about 1.5kg (photo 21).

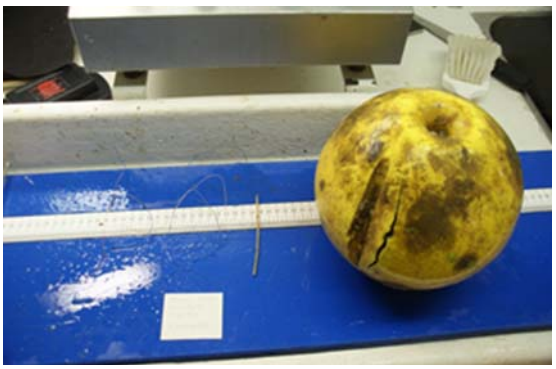


photo 20-21: Litter from haul 10, a wooden piece (F1) unable to get it out of the net, estimated at 3kg. Litter from haul 22L yellow fishing float (A12) and monofilament (A5), the straw is organic (*Hyalinoecia tubicola*).

Distribution of litter

For analysis on the distribution of the litter, the Dutch IBTS data is combined with the French IBTS data. The mapping results are presented in paragraph 3.2.

Organisms attached

About 47 items were overgrown with at least some organic material. In many cases this was algal material (photo 21 and 23) or various types of hydrozoa. Only in a small number of cases the attached

organisms were recognizable. Some objects had barnacles attached to them or anemones (photo 15). The clearest were the eggs of the common whelk attached to a beer bottle (photo 22).

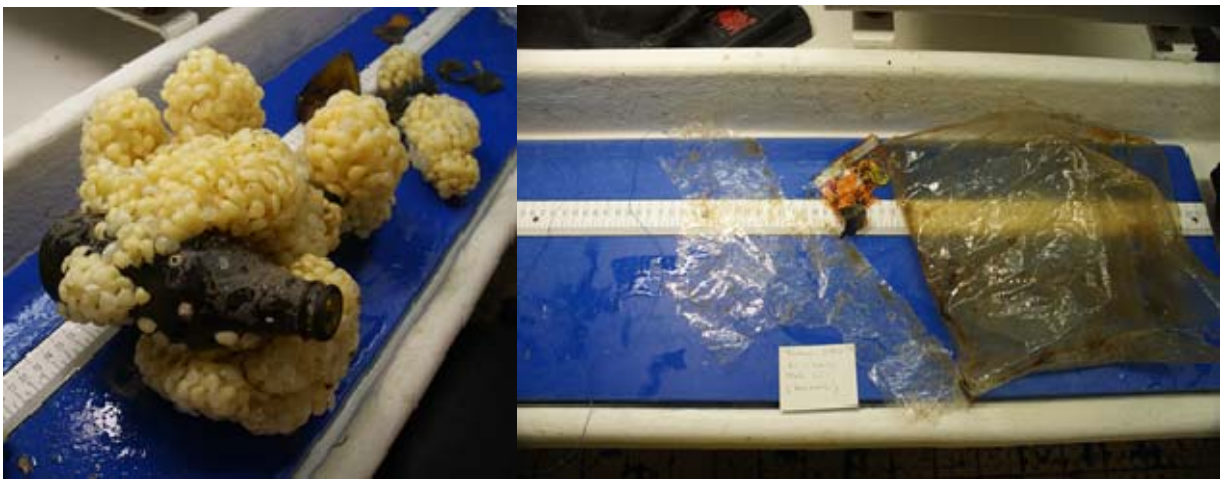


photo 22-23: A part of the litter from haul 10, Glass bottle (E2) with common whelk eggs. The litter from haul 21, two pieces of plastic sheet (A2) with some organic material, a plastic bag (A3) full of organic material and a blue monofilament wire (A5).

3.2 French data

Amount of litter

The French did a larger number of hauls, in total 86. In these hauls they recorded 179 litter items. They however did not separate it by source (belt or net), but they did a visual inspection of the net. Six of the hauls were situated further south/west than shown in figure 1, these hauls were left out of the spatial analyses.
The distribution of the items over the categories is very similar to the other two datasets as 86% was plastic (A). Looking at the description of these items, we however think that the French also recorded real natural products as branches and peat. Leaving out those recordings would reduce their number of natural products considered as marine litter.

Category		number	Percentage
A	Plastic	154	86%
B	Sanitary waste	3	2%
C	Metals	2	1%
D	Rubber	2	1%
E	Glass/Ceramics	3	2%
F	Natural products	11	6%
G	Miscellaneous	4	2%

Splitting plastic in sub-categories gives a different picture than the Dutch 2013 results. Similar is that the sheet (A2) category is dominant. The largest difference is in 'Bag' (A3), which is only a very small category in the French data. The other difference is that A6 and A7 are more dominant in the French data compared to the Dutch data. A part of these differences might be due to checking the net for litter. If the French did this differently, they might have underestimated especially A3. Another part might be due to differences in categorizing the items especially the difference between monofilament (A5) or entangled monofilament (A6) or synthetic rope (A7). In total these tree sub-categories contained 80 items in the French, and 79 items in the Dutch data. Thus combined the picture is similar between the surveys.

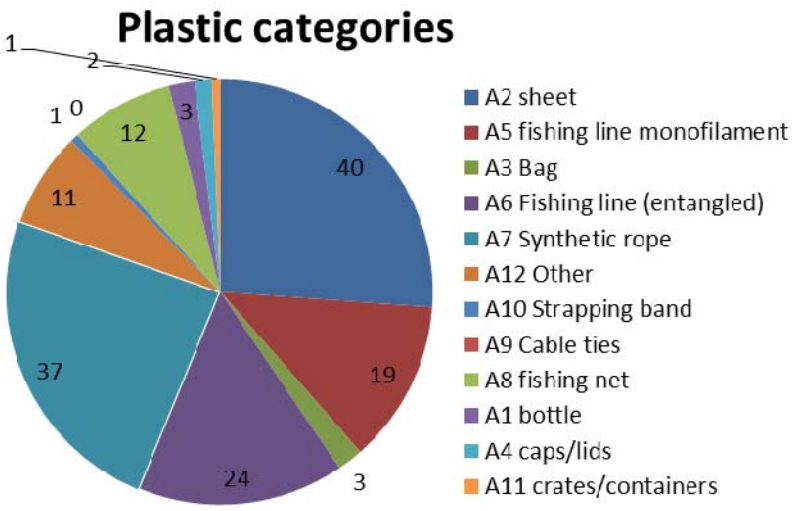


Figure 5.: Number of litter items per sub-category of Plastic in the French data.

Distribution of litter

The French and the Dutch data are combined in a single distribution map (figure 6). The data is presented in number of items per km^2. This is the same measure as used by Maes (Maes, 2013) for the data collected by CEFAS (Figure 7).
The map by Maes shows a concentration of litter north of the Dutch islands following the current up north to the Skagerrak. Some darker blue spots are found there in our maps as well. However, we also see a concentration of blue to dark blue spots in front of the Scottish coast, while no such concentration is seen in the data by Maes. Both data sets show higher values in front of the Thames. In our data this is based on only a single haul with a lot of litter. This single dark blue spot is surrounded by the darkest green, hauls with the lowest amount of litter.
Even though the spatial coverage is limited and it is only data from a single year, the survey seems to be able to show expected hotspots, amongst others the discharge area of the Thames, the Elbe and the Béthune.

The kriging map underlying the haul data is very basic. The current kriging map represents the average of the hauls up to a circular distance of 0.5 degree away from its position. A statistical approach by fitting a variogram did not result in a sound solution. The variogram indicated that hauls close to each other do not explain more about the amount of litter found there, than hauls far from each other. This is most likely caused by the large distances between the hauls. It is to be expected that there is spatial correlation on a smaller spatial scale than present in the current data. Another explanation might be the differences in the collection of the data between the French and the Dutch.

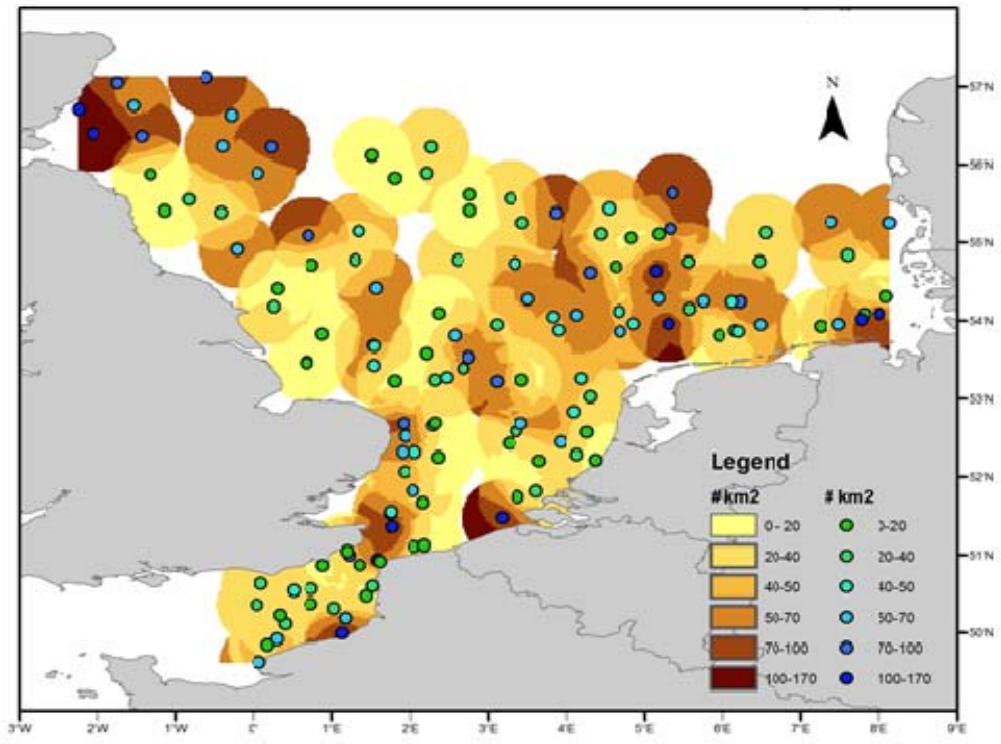


Figure 6. : Number of litter items per km^2 per haul in the Dutch and French IBTS of 2013. The underlying kriging map is very basic.

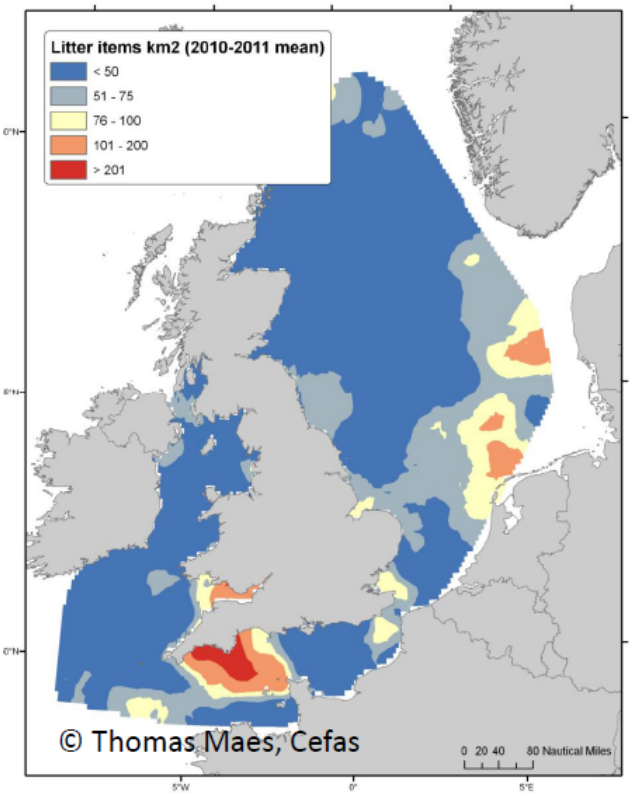


Figure 7. : Number of litter items in km^2 based on the UK 2010-2011 data (Maes, 2013).

3.3 Earlier data

IBTS 2012

In 57 hauls litter was sampled, with a lower accuracy then in 2013. In total, in 40 hauls litter items were found, thus 17 hauls were considered empty. As the items were combined per category rather than recorded as separate items it is impossible to say how many items were found. It is only possible to state that plastic was found in 29 hauls, fishing gear (without the lobster cage) in 23 hauls, Miscellaneous (including the lobster cage) in 12 hauls, wood in 1 haul and metal in 3 hauls.

BTS 2012

In 74 hauls litter was sampled during the BTS in 2012. 6 hauls did not contain any litter items. All other hauls contained at least one litter item. The litter was again dominated by plastic (176; 61%), the dominance was however lower than in the IBTS samples. In the BTS besides plastic a reasonable number of 'Natural products' (F) was found, which was dominated by processed wood. Followed by the category 'Miscellaneous', with most items in G3 (others) being items that could not be classified or contained multiple materials.

Category		number
A	Plastic	176
B	Sanitary waste	3
C	Metals	16
D	Rubber	17
E	Glass/Ceramics	10
F	Natural products	43
G	Miscellaneous	26

Splitting plastic in sub-categories gives similar results as the other data sources, A2 sheets as most dominant litter item. In the BTS, the number of items assigned to A5 and A6 (fishing lines) is very small, while A7 synthetic rope is the second largest group. Reading some of the BTS descriptions of litter items, it is very likely that a number of the items in A7 would have been placed in A5 if these had been caught during the IBTS 2013 survey. The sub-category 'Other plastics' (A12) also contains a part of the litter items. According to the descriptions, these include the drinking cups as caught in the IBTS, but also a lot of hard plastics not belonging to caps or bottles.

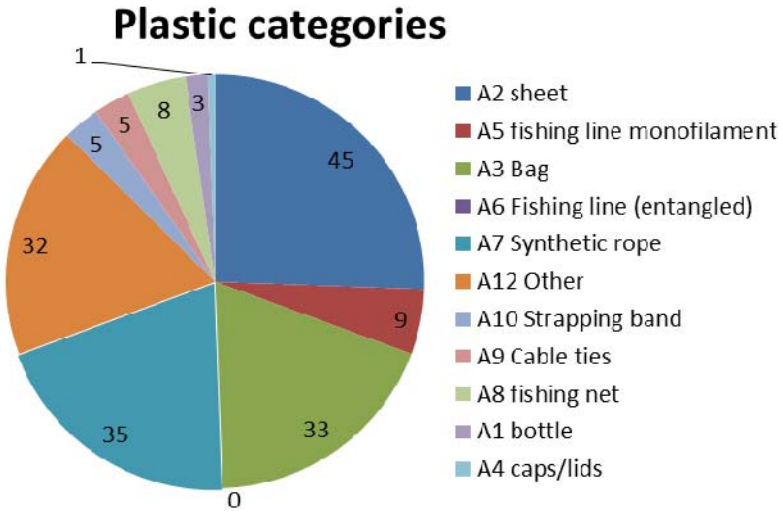


Figure 8.: Number of litter items per sub-category of Plastic in the BTS data.

Distribution of litter

The BTS in 2012 covered a large part of the North Sea. The sampling design of 1 haul per ICES-rectangle gives a very course coverage. This course coverage limits the possibilities to produce a kriging map. The variogram of the data does not support a statistical kriging approach for this data. Now the data is averaged over a maximum of 5 hauls within the distance of 0.75 degree around each location. The result and the absolute numbers of items in km^2 are given in figure 9.
Similar as in the IBTS map, hotspots are shown in the Thames discharge area. Surprisingly, in contrast to the IBTS map the hauls in front of the Voordelta show no litter items.

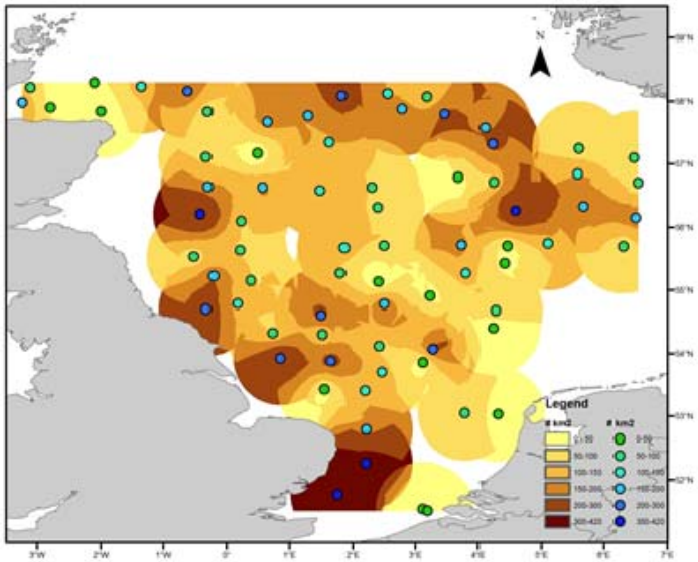


Figure 9.: Number of litter items in km^2 per haul in the BTS of 2012. The underlying kriging map is very basic.

4 Discussion

Pilot

This study is a pilot to test the possibilities to monitor marine litter deposited on the sea floor as part of regular Dutch fish surveys. Overall the pilot has been successful and has shown that it is possible to collect information on marine litter in the detail requested, at least on board of the Tridens. A second question was to estimate the extra time needed to collect the requested data. This depends a lot on the requested accuracy and will depend on the used vessel.

The current IBTS manual only specifies that marine litter data has to be collected and has to be identified to sub-category level (Table 1) no further detail on the accuracy is given. There are a number of steps in the process that can all have a different level of accuracy.

Step 1: Collecting the litter
- From the catch
- From the net

Step 2: Identifying the litter
- Category level
- Sub-category level
- Polymer level

Step 3: Registering the litter

- Grouping items
- Detailed description
- Measuring/weighing
- Photo
- Attached benthos

Step 4: Storing the data

- On paper
- Digital

The Dutch IBTS 2012 collected data from the catch and identified it on category level, items were grouped per category and weighed. The results were stored in an Excel-sheet.

The Dutch BTS 2012 collected data from the catch and identified it on sub-category level, in some cases items were grouped as similar types within a sub-category, a detailed description was given and an estimate of the size was given and the item was weighed. The results were stored in an Excel-sheet.

The Dutch IBTS 2013 collected data from the catch, the net and the groundrope and identified it on sub-category level, in some cases items were grouped as similar types within a sub-category, a detailed description was given, during part of the trip a photo was taken and an estimate of the size was given and the item was weighed. The results were stored in an Excel-sheet.

Step 1:
Sampling the catch from the conveyor belt is feasible and does not result in extra time needed. The accuracy of this is similar to the accuracy used in the fish and benthos sampling. A question for the manual is, in case litter is collected from a subsample from the catch, should this be registered as subsample similar as is done with the fish catch?
In the IBTS 2013, it is clearly shown that a significant part of the litter items, at least in the GOV, is entangled in the gear. Taking larger entangled items, e.g. plastic bags, is feasible but takes about 5 to 10 minutes. Collecting smaller items and especially all the monofilament lines is difficult in the first place, but also takes much more time (estimated 15-30 min). These monofilament lines become entangled in the net and the groundrope, taking all these single lines out of the net is a time consuming job. However, if this is not done properly, these monofilament lines will be found each haul without being certain that they were caught in that transect. For distribution maps as made in this report and requested as one of the outputs of this project, it is necessary to take all the monofilament lines out of the net after each haul or the lines should be neglected completely.
Searching the net has to be done outside on the deck. Due to safety issues this can only start when the net is hoisted in completely. For the same reasons, it should be done by an experienced member of the crew as working on the deck requires some experience with working at sea. In difficult conditions e.g. wind force 8 to 9 Bft as experienced this year, or in heavy rain and snow the risks of working on deck increase. This might in some cases limit the precision of searching the net for litter.

Step 2:
Identifying the litter should be done on sub-category at least for plastic. This results in interesting data that can be used to better understand the source of the litter. Identifying the litter items on sub-category does not take much time, however better guidelines for the different sub-categories are needed. Additionally there might be options to further divide at least the plastic category, suggestion is to include a sub-category for drinking cups.
A better guideline on the sub-categories is needed to be able to divide the litter items to the right category. The difference between fishing line (A5), fishing line entangled (A6), synthetic rope (A7),

fishing net (A8) and rope (F2) is difficult and in many cases arbitrary. Part of the differences in results between the two Dutch surveys and also the French data might be related to this issue. But also differences between sheets (A2) and bags (A3) need to be clarified. This clarification includes the need for more categories. For example do 'Plastic bottles' only include drinking bottles or also the flacons of shampoos et cetera? If the flacons do not belong to bottles, a new group should be created or they are all recorded under Other (A12).
A further division of the plastic category would be on polymer level. Different types of polymer act differently in the environment, for example degradation, transport or binding poisonous substances. The current crew does not have the knowledge to make this division. Therefore, this year all the litter items caught are taken to the lab, where if time allows they will be further divided to polymer level.

Step 3:
In the Dutch data sets at least a part of the items were grouped. Stricter guidelines are needed for this, as the results presented in this report depend a lot on this choice. In our opinion it is nearly impossible to separate all the lines/ropes as separated items. The same applies to pieces of wood, plastic sheets, coal or glass. When they are broken into pieces but originate from one marine litter item, they should be grouped, but clearly distinguishable sources of the same type should be separated. From the lines and especially the monofilament the source is difficult to determine so these might be grouped by color.
Giving a detailed description of each item takes time and is difficult to store in a database. It also is an arbitrary choice of the crewmember what he/she considers important as detail (color, brand, shape) and the descriptions vary between crewmembers and between nations. In the datasets with descriptions (BTS 2012, Dutch and French IBTS 2013) items with similar descriptions were placed in different categories. This might be related to the issue discussed in step 2, but could also be due to lacking guidelines on the descriptions.
All the Dutch items are weighed, which gives an overestimation of many items because these absorb debris or water. However, for most of the plastic, glass, rubber and metal items it is a more precise estimate than the size estimation used in the manual. The other categories absorb more water and for these the weight is less informative.
In the first three weeks of the Dutch IBTS 2013, photos were taken of most catches. These were very useful in determining how the categorization of the items was done. However, with better guidelines and more experience of the crew the necessity of the photos will reduce (confirmed by Thomas Maes based on his experience with the English data collection). Then photos need only be taken from items of which the crew doubts the identification. These items could also be collected for identification in the lab as is done with fish and benthos species for which doubts arise.
Attached benthos is nice to record, however difficult for the crew and detailed determination takes time. The level of determination could follow the level used in the survey itself. For the BTS and IBTS this would mean plant material and the organic material in photo 23 would not be identified, only the larger benthic species, photo 22 and 15, would be identified.

Step 4:
The data was registered on paper first and typed in an Excel-sheet later or the data was stored in the Excel-sheet directly. On board of the Tridens this is possible and does not take a considerable amount of time. However, it creates a separate sheet in a different format than in which the other data of the survey are stored. IMARES prefers that the data are included and stored in the same format as the fish data. In that way all the data from the survey is combined and can be checked for errors in an automatic way (e.g. sub-categories that do not exist). When the data is needed it could easily be taken from the institute's database rather than looking for the separate Excel-sheets. From the database it could be exported to every requested format and thus also to a joined database similar to the ICES DATRAS database in which the fish and benthos data of the participating countries are stored. At ICES

developments are ongoing to make it possible to include this type of data in the ICES DOME database (http://ices.dk/marine-data/data-portals/Pages/DOME.aspx) .

Time needed

Collecting the litter from the catch on the conveyor belt takes only a limited amount of time and can be done without problems by the regular crew on board.
Collecting litter from the net means that a (experienced) crew-member is on deck instead of sorting the catch. A simple inspection costs 5 to 10 minutes, but a detailed inspection collecting all monofilament will take longer. In that case the working pressure on the regular crew sorting the catch increases and the time needed to fully handle a haul increases.
Registration of the items, weighing and estimating the size takes only limited time. However, as still arbitrary choices are made it should be done by the same person the whole trip and preferably photos should be taken which take more time.

Overall it is possible to collect litter information following the pilot protocol with the current crew on board as an extra project of which there are many others. This means it has low priority and in case time becomes limited or other requests (for example a project on collecting stomachs) are made the collection of litter might be skipped that haul or for a longer period.

Results on litter

The litter items show a very similar result between the various data sources, showing that plastic and then specifically 'plastic sheets' are the most dominant litter items found. That the surveys produce such a consistent picture indicates that they can at least be used to monitor the composition of the sea-floor litter. Even though the gear is not design for catching marine litter and it is currently impossible to give an idea on the representativeness of the litter items caught in relation to the actual litter deposited.

The number of litter items per km^2 results in similar values comparing the Dutch and the French IBTS and also comparing it with the UK data. The results from the BTS show higher values per km^2, which is not a surprise as this gear has a higher bottom impact, less debris can go underneath the gear. The catchability of the beam trawl for real sea-floor litter is higher than that of the GOV. However, the GOV is likely to have a higher catchability for litter floating near the bottom. This explainable difference and the agreement in n/km^2 between the three data sources indicates that the survey could be used to monitor the sea-floor litter also in relative numbers. This enables the creation of time series of the amount of litter and potentially see the effect of implemented measures on the amount of litter on the sea-floor.

Limitations are the size of the litter items, many of the litter items caught are small. And probably a large number of items is even smaller than presented here, for example the micro-plastics. The mesh size (1 cm IBTS and 4 cm BTS) determines the minimum size that be caught. Other techniques are needed to monitor the small marine litter, for example the MIK-larvae sampling or water sampling performed during the IBTS as well or the high speed manta-trawl tested.

The spatial resolution of the surveys is coarse and multiple years of data from multiple vessels and surveys are needed to make a reasonable picture of the distribution of litter on the sea-floor of the North Sea. However, with a single year of data of two countries it was already possible to show likely hotspots of litter, which supports the usefulness of this type of data and the possibility to use the surveys even for monitoring the litter on a spatial scale.

Other surveys

IMARES performs more than the two surveys described here. Regarding the distribution of litter deposited on the Dutch Continental Plate, surveys that are of interest are the coastal surveys (SNS and

DFS) and the part of the BTS carried out by RV Isis. These surveys are all done with the Isis, a much smaller vessel than the Tridens with less facilities. The number of IMARES crew is two or could be maximum three, in contrast to the Tridens were 5 to 9 persons are on board. Owing to these two aspects the sampling of the catch is more often done in sub-samples and there is less time available to do extra work.
However, possibilities are there to collect litter information during these surveys as well. It could be that this is done by registering litter from the sub-samples rather than from the complete catch (larger items will come from the whole catch). The implementation on board of these surveys would be simplified when better guidelines are available and data storage is merged with the registration of the fish catch. Instead of registering the required information on board, all the litter items per haul could be stored and brought to the lab. Identification and registration can then be done in the lab, which would require hours for lab staff doing this after the survey but would decrease the workload on board and so, increase the amount of data collected.
The collection of deposited litter could also be broadened to benthic surveys. But also litter in the water column could be collected during larvae and egg surveys and floating litter might be registered during aerial marine mammal or bird surveys.

MSFD related
The method and data presented in this report might be suggested for monitoring the sea-floor litter as requested in the MSFD. However, the MSFD also requires monitoring litter floating on the surface or in the water column. Observers are allowed to join the surveys to monitor the floating litter, but there might also be possibilities to install camera's on board of the research vessels to monitor floating litter or to install these camera on planes used to monitor marine mammals and birds. Litter in the water column might be covered by pelagic surveys, however none of these are performed on the Dutch Continental Plate, or larvae and egg surveys.
The MSFD also requires the monitoring of micro-plastics in the water column as well as in organisms, as small plastics might have specific size related effects on the marine ecosystems. Recent micro- and nano-plastic studies from IMARES are effect studies with mussels and lugworms, including the effect of small plastic particle ingestion on contaminant transfer to/from organisms (Besseling *et al.*, 2013, Wegner *et al.*, 2012, Koelmans *et al.*, 2013 (Accepted Manuscript)). Similar to the macro plastic analyses like the surveys in this report, IMARES could do fate and distribution analyses for micro-plastics by combining them with existing survey programs. For micro-plastics in the water column, there might be possibilities in the regular survey programs to include sampling. Like the IBTS and BTS for macro plastic, the samples of fish larvae surveys (for example the HALA) might be useful for analysis of micro plastic. Next to that, the high-speed manta trawl tested on the Zirfea in autumn 2012 could be used on the Tridens as well, and thereby added to another survey specially for plastic sampling. While steaming from one fish station to the next, the manta trawl could be used to sample the surface waters for micro plastics. Depending on the ability to use the manta trawl with maximum steaming speed, this might cost extra time. Additional to water sampling, sediment and biota could be analysed on occurrence of (micro) plastic. In 2010 already several fish species from IMARES surveys where analysed (Foekema *et al.*, 2013 (Accepted Manuscript)) and also during the IBTS in January biota could be collected as was done this year already for the IMARES PhD project by Ellen Besseling, for further lab analyses on micro plastics in their digestive system. This could be done on a regular basis during existing surveys. Afterwards this would require hours for lab staff ashore.

5 Recommendations

- Extend the manual of the IBTS on sampling marine litter.
    - The accuracy of searching the catch
    - The accuracy of searching the net
        - Excluding monofilament from the analysis when the net cannot be fully cleaned.
- Clarify the definition of the sub-categories
    - What kind of items belong to which group, especially the very similar sub-groups as fishing line, entangled fishing line, synthetic rope, fishing net.
    - Include a sub-group plastic drink cups
- Clarify the description on how to register the items
    - Grouping items or registering everything separate
- Continue monitoring of litter at least on the IBTS and BTS on board of the Tridens
    - Make it an official yearly monitoring program (stand alone or as part of the upcoming MSFD monitoring requirements (potentially included in the DCF, WOT program)
- Extend the current survey program intensifying monitoring for litter in expected hotspots.
- Improve the registration system on board, by making the import program ready for litter information.
- Create possibilities to store the data in the IMARES database
- Support the activities for the inclusion of marine litter data in the ICES DOME database.
- Investigate possibilities to extend monitoring litter to the surveys on the Isis or other regular survey programs, similar to the CEFAS situation where litter is recorded on most if not all sea-going surveys.
- Investigate possibilities to combine other litter-related issues of the MSFD with regular monitoring programs, e.g. using samples from fish larvae surveys, using the high speed manta trawl on board of the Tridens during fish surveys, or collecting samples for analysing the digestive system of biota and sediments on micro-plastics.

The manual on monitoring litter needs to be extended. This is in the first place a recommendation to the ICES groups IBTSWG and WGBEAM to work on this in an international context. This could also be done by IMARES for only the Dutch monitoring program, in that case it could be incorporated in the “handboek bestandsopnames en routinematige bemonsteringen op het water” (van Damme *et al.*, 2013).

The data presented in this report look promising to be used in monitoring not only the composition and amount of litter but even the spatial distribution. Continuation of this work would improve the spatial work as combining multiple years would improve the spatial coverage. Continuation of the work will result in a time series that potentially can be used to monitor the effect of measures taken to reduce marine litter. Funding needed for this work is limited. As it can profit from the on-going surveys, the yearly costs could be further decreased when a single investment is made in improving the storage on board and in the lab of this type of data. This means some alterations of the current database and registration program. In that case the recurring budget (depending on the accuracy requested) needs to cover data management and possibly a yearly report. In case litter samples from the RV Isis are requested, budget is needed for sorting and registration of those samples.
Related to the spatial distribution of litter, it might be worthwhile to invest in a more intensified program that covers the expected hotspots at a smaller spatial scale. This will give a better idea of the distribution of litter on the sea-floor. Similar kind of information could be retrieved from continuing the monitoring for a couple of years, however in that case the effects of measures taken could hamper conclusions on the spatial distribution.

Improving the current database will make the storage of this type of data at IMARES easier and with that also retrieving data and producing reports on it. Besides that, IMARES is in favour of an international database that stores this type of data from all countries participating in litter monitoring. Such a database is of much more value for all kinds of investigations in relation to the MSFD. The fish and benthos data from the IBTS and BTS survey are stored in such an international database at the ICES Data Centre. That DATRAS database contains all the data of the hauls made in these surveys including the information on the catches. Litter could become part of the catch data and be stored as such in this or a similar type of database.

6 Conclusions

Overall the pilot has been successful and has shown that it is possible to collect information on marine litter in the detail as requested. It was possible to collect litter with the current crew on board of the Tridens as an extra project. However, that means it has low priority and in case time becomes limited or other requests (for example a project on collecting stomachs) are made the collection of litter might be skipped that haul or for a longer period. If the collection could be done on the smaller vessel Isis is still questionable.

The results of the pilot show very similar results between the various data sources (countries, and surveys), showing that plastic and specifically 'plastic sheets' are the most dominant litter items found. This consistent picture indicates that monitoring litter in this way can be used to get an impression of the composition of the sea-floor litter.

7 Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 124296-2012-AQ-NLD-RvA). This certificate is valid until 15 December 2015. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Fish Division has NEN-EN-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 1th of April 2017 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

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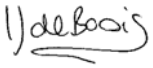
Justification

Rapport C112/13
Project Number: 4302505401

The scientific quality of this report has been peer reviewed by the a colleague scientists and the head of the department of IMARES.

Approved: Ingeborg de Boois
Scientist and Cruiseleader BTS

Signature: 

Date: July 4th 2013

Approved: John Schobben
Head of Department Vis

Signature: 

Date: July 4th 2013

Appendix A: Suggestions to be included in the survey manual(s).

Suggestions for the survey manual(s), at least to be included in the Dutch manual as long as it isn't included in the international manual:

Collect all items from the catch and search the net on the deck for at least the items of size class D or larger. Collect the smaller items, but record these as items from the net. (Thus an extra column is added to the recording sheet).

Register all items as individual pieces, unless they are clearly from a single source item (however include an extra column to the registration sheet to include the number of items).

Assign each item to one of the sub-categories of the table in the IBTS manual. This table is extended with the suggestions below. In case, items exist out of multiple material record them as G3, and give a description of the various materials in the description column.

A1 Bottle: all drinking bottles, but also packaging like shampoo flask. Not included boxed juices.
A2 Sheet: all types of flexible plastic including parts of (garbage, chips) bags, candy wrappings.
A3 Bags: Shopping, garbage, chips, seal bags that could still be used as such.
A4 Caps\lids: Recorded separately if still attached to the bottle. However, combined with the bottle considered it as a single litter item. Register it as 0 in the newly included "number of items column".
A5 fishing line, monofilament: Combine all the monofilament lines as a single item. If possible to count the single lines include this value in the newly included "number of items column".
A6 fishing line, entangled: report this as single item. However if single monofilament lines are recorded, report A5 and A6 together or record A6 as 0 in the newly included "number of items column".
A7 synthetic rope: All plastic none monofilament single lines/ropes.
A8 fishing net: None monofilament fishing net.
A9 Cables ties
A10 Strapping band: All types of adhesive tapes, duct tapes, isolation tape.
A11 crates/containers: larger object as jerry canes, beer crates....
A12 others: all other plastics. In this case write an extensive description or make a picture.