Overview of available methods to monitor marine plastic litter

Incl. method for riverine litter monitoring developed within BLASTIC

Project	BLASTIC - Plastic waste pathways into the Baltic Sea
Work package	WP3 Monitoring of plastic litter
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Contents

1. The BLASTIC project

This document is prepared within the BLASTIC project (Plastic waste pathways into the Baltic Sea). The project was supported by EU Interreg Central Baltic (2016-2018). The overall aim is, by mapping and monitoring marine plastic litter, to facilitate the reduction of the inflows of plastic litter and of hazardous substances into the Baltic Sea. The results of the project included a compiled list of sources and pathways of marine plastic littering, and recommendations/action plants to reduce plastic marine litter in the Baltic Sea.[1] A methodology suited for riverine litter monitoring of litter was also developed, and described in this document.

The present document is one of the outputs of Work Package 3: Monitoring of plastic litter. The document compiles existing methods for monitoring plastic litter in rivers and the coastal waters/areas of the Baltic Sea in general, and the method for monitoring plastic litter developed within Blastic in particular. The focus in the document is on beach litter, floating litter and seafloor litter, and also on monitoring plastic macro-litter (>2.5 cm), although some methods/principles could be used for monitoring litter other than plastic and of smaller sizes.

The target group for the document is municipalities with the main objective to give an overview of available methods to facilitate the choice of monitoring method, provide basic information on monitoring methodology, resources required and illustrate with examples. For each section we provide a short description of strengths and weaknesses related to each specific monitoring method. The information presented for each method is based on literature, and has not been tested in practice. The only exception is the method for monitoring plastic litter in rivers, which was developed and tested in Blastic project.

2. Reading guide

This overview is based on 7 sections/chapters:

Section 3 – **Introduction: plastic litter – why monitor?** Shortly introduces plastic marine litter, its sources, main factors influencing its distribution/allocation and presents the main reasons for monitoring plastic litter.

Section 4 – **Methodology for monitoring plastic litter in rivers developed within Blastic**

Section 5 - **Local conditions facilitate the choice of monitoring method –** focuses on how to select monitoring method.

 Section 6 – **Beach litter monitoring methods** – describes the application of two commonly used methods for beach monitoring of plastic litter (MARLIN and OSPAR), including examples.

Section 7 – **Floating litter monitoring** - describes the monitoring of floating litter: (1) riverine litter monitoring in the water body, and (2) visual monitoring for both marine and riverine litter on the water surface (ship-based and on shore), including examples of monitoring protocols/data sheets.

Section 8 – **Sea floor litter monitoring** – describes the monitoring of sea floor litter by trawling, scuba divers and video cameras, including examples of monitoring protocols/data sheets.

Section 9 – **Summary of monitoring methods – what to consider?** – provides a summary of monitoring methods and the main "do's and don'ts".

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[1] See the official project website, URL: https://www.blastic.eu/about-blastic/

The presentation of each monitoring method is structured as follows:

- Explanation of the content in each chapter;
- Description of site selection and observation timing with references to protocols and data sheets;
- Description of plastic litter collected (type, size, etc.);
- Examples of method applications;
- Resources required incl. costs, time estimates and equipment used;
- The methods' strengths and weaknesses.

3. Introduction: plastic litter, origins, distribution and why to monitor?

3.1. Why monitor plastic litter?

Monitoring of plastic marine litter is important for different reasons. It can help to identify pollution sources and access and control the efficiency of implemented pollution prevention measures. Monitoring can facilitate awareness-raising campaigns by means of e.g. organising specific events for monitoring, attracting the attention of the public, generating rich information about the problem of marine littering, etc.

3.2. Plastic marine litter

Many studies show that the majority of marine litter (60-80%) consists of plastic. In the Baltic Sea region plastics constitute ca. 60% of marine litter.[2] This litter can endanger the aquatic environment as it is durable, can float and travels long distances. Moreover, larger plastic items can slowly degrade into smaller items and therefore could be mistaken for food by the aquatic fauna and/or even enter into human food chains. Many plastic types contain harmful substances and toxic additives that may leak into environment. It is also known that small plastic item (micro-plastic) tend to absorb other hazardous substances from environment.

Plastic litter could range from micro-size to large items. The litter is usually categorized into micro- (<2-5 mm), meso- (5-25 mm) and macro (>25 mm) plastics. The focus in the Guidelines is on monitoring macro-plastics litter.

3.3. Sources

The marine plastic litter can originate from multiple sources, both land- and sea-based. Land sources can be households, towns, beach/coast, harbours/ports, agricultural activities and landfills. Plastics can end-up in marine environments due to improper waste management, littering, illegal dumping and/or improper plastic disposal in toilets. Sea-based sources are mainly related to recreation, fishing and shipping as well as aquaculture activities. The litter from these sources is generated mainly by ship passengers, improper disposal of gallery waste and abandoned maritime and fishing gear.[3] Due to hydrodynamics, whether conditions and surface run-off, the litter could be transferred long distances from its sources of origin.

3.4. Distribution/location

Marine plastic litter could be located on coastlines, floating on the surface and in the water column or sunk onto the seafloor. The location of plastic debris depends on many factors, such as pollution sources, local weather, site and water conditions (e.g. currents), as well as the type of plastic.

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[2] Source URL: http://www.hsr.se/sites/default/files/marlin-baltic-marine-litter-report.pdf
[3] https://www.blastic.eu/knowledge-bank/knowledge-bank-distribution/fate-marine-litter/

Litter allocation in the water column depends mainly on plastics density, water salinity, temperature gradients and water currents. The salinity and thus the density of the Baltic Sea (ca. 1.03 g/cm^3) is considerably lower compared to other seas and oceans, which facilitates the sinking of the majority of plastics. For instance, polycarbonate (PC), polybutylene terephthalate (PBT), polyvinyl chloride (PVC), acrylonitrile butadiene styrene (ABS) sink very easily as they have densities higher than water.[4] Polypropylene (PP) tends to float (approx. 0.83-–0.85 g/cm^3), but can sink due to bio-fouling. In rivers and river estuaries plastic litter is more prone to sinking as the densities of fresh or brackish waters are low. The temperature also affects water density (colder water has higher density). The Baltic Sea has a great seasonal variation of surface water temperatures making plastic litter sink slower in the winter and faster in the summer. The size, shape and geometry of items can also affect the distribution of marine litter. Some items (e.g. foamy plastic or bottles) could be in shapes suitable to trap air and float easily despite higher density. When plastic litter is submerged, the litter distribution will depend mainly on the currents and partly - on bio-foliage.[5]

4. Local conditions facilitate the choice monitoring method

The municipalities should clearly define the aim of monitoring and resources available before selecting a method and starting the monitoring procedures. The resources required may depend on whether it is possible to involve volunteers and combine monitoring with other activities, such as fish stock monitoring, recreational and/or scientific activities (e.g. using the same vessel). Some monitoring methods could require specific and specialised equipment.

If the aim with the monitoring is to generate comparable results and to re-do the monitoring on a regular basis as part of a monitoring program, it is important to choose an established methodology. Using an established, detailed methodology may also allow comparison of results with different municipalities or regions. If the aim of the monitoring for example is to create increased awareness, and not generate comparable results, the importance of choosing an established and detailed method decreases.

Each monitoring approach starts with the selection and description of suitable sites. Most monitoring methods suggest selecting sites that are prone to accumulation of marine litter. Such sites usually are:

- coastal areas;
- areas close to land-based pollutions sources (e.g. river, sewage waste water);
- depressions on the seafloor;
- sites with slow hydrodynamics (e.g. weak circulation, low currents).[6]

In this document s we present three types of monitoring methods designed for litter measurements in different areas:

(1) coastlines (for beach litter monitoring)
(2) floating litter on the water surface and column in riverine and marine waters

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[4] UNEP/IOC (2009): *Guidelines on Survey and Monitoring of Marine Litter*, Regional Seas Reports and Studies No 186 IOC Technical Series No 83. United Nations Environment Program (UNEP) and Intergovernmental Oceanographic Commission (IOC). Nairobi, Kenya. http://wedocs.unep.org/bitstream/handle/20.500.11822/13604/rsrs186.pdf?sequence=1&isAllowed=y

[5] https://www.blastic.eu/knowledge-bank/knowledge-bank-distribution/fate-marine-litter/
[6] LC&P and IMO, 2016. Review of the current state of knowledge regarding marine litter in wastes dumped at sea. Under the London convention and protocol. Final report.

(3) sea-floor monitoring

We describe the most commonly applicable methods that could be suitable for both riverine and marine litter monitoring in the Baltic Sea region. Within each method there could be several specific monitoring protocols, data sheets and procedures available. There is no standardized monitoring method specifically for the Baltic Sea region (except probably MARLIN for beach monitoring). The selection of concrete monitoring protocols could/should depend on whether (or how often) the method/protocols are practiced locally or regionally, which could give more information for reference and benchmarking. The municipalities should also consider that monitoring methods require finding specific information about the measurement area (e.g. length of beaches, local current and circulation patters, width of rivers, observer's elevation above the water level etc.).

5. Monitoring floating plastic with litter booms in rivers – method from BLASTIC

Floating litter booms can be used to collect and identify floating marine and riverine litter for item sizes down to at least 2.5 cm. The floating litter booms monitoring is preferably performed in a narrow river with a continuous water flow[7]. Examples and scientific information on visual monitoring of riverine litter are scarce besides the BLASTIC-project. However, plastic litter monitoring has been performed by similar litter retention devices in Seine[8,9] and Thames[10].

5.1. The litter booms

The floating litter boom creates a barrier where floating litter is trapped as the current drives the litter inside the floating boom (Figure 1). As over 2/3 of all produced plastics have lower density than water[11] it has the potential to float. However both the shape and density of the plastic will affect the plastic items buoyancy and hence affect where in the water column of the river that the litter will be. For example flexible, film-like litter, tends to stay mixed in with the water column while more dense plastics without trapped air pockets may sink and travel along the river bottom if not completely embedded in sediment. However if the more dense plastic package has air trapped in it (like a PET bottle) then it may float on the surface. The floating litter boom method focuses mainly on measuring the surface water (top 0.5m) but the boom can advantageously be supplemented with different net curtains to increase the sampling depth[7]. In the BLASTIC project different kind of set-ups where tested.

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[7] BLASTIC (2018): Pilot area Plastic litter monitoring results. Interreg Central Baltic. BLASTIC WP3: Results from plastic litter monitoring in the pilot areas, Final Report.

[8] Gasperi, J., R. Dris, T. Bonin, V. Rocher and B. Tassin (2014). "Assessment of floating plastic debris in surface water along the Seine River." Environmental pollution 195: 163-166.

[9] Dris, R., J. Gasperi, V. Rocher, M. Saad, N. Renault and B. Tassin (2015). "Microplastic contamination in an urban area: a case study in Greater Paris." Environmental Chemistry 12(5): 592-599.

[10] Morritt, D., P. V. Stefanoudis, D. Pearce, O. A. Crimmen and P. F. Clark (2014). "Plastic in the Thames: a river runs through it." Marine Pollution Bulletin 78(1): 196-200.

[11] Yeo, J. C. C., J. K. Muiruri, T. Warintorn, Z. Li and C. He (2017). "Recent advances in the development of biodegradable PHB-based toughening materials: Approaches, advantages and applications." Materials Science and Engineering: C. Volume 92, 1 November 2018, Pages 1092-1116
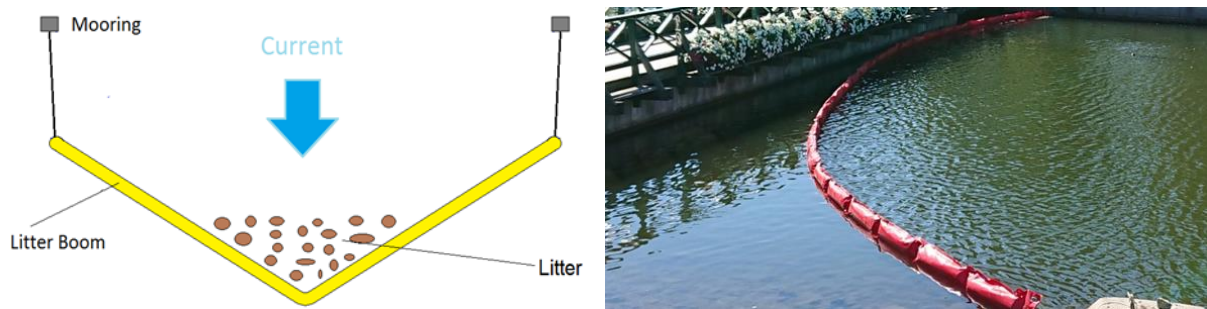
Figure 1. Set-up of the floating litter boom[7].

The floating litter booms creates a physical barrier where floating litter is captured. The litter can then be collected, quantified, categorised and analysed, which is considered to be a major strength of the litter booms. It is designed with the intention of producing high quality, robust data sets. The method is flexible in regards to the purpose of the monitoring, it can be for scientific purposes if standardizing the sampling or it can be simplified to work in e.g. awareness projects[7]. Also the litter booms stop the litter from reaching the ocean, in contrast to e.g. visual surveys. Litter/trash/debris-retention booms are already being used in some rivers to stop litter from reaching the ocean[8,9,10]. The floating litter boom methodology described within BLASTIC project[7] relatively cost efficient (compared to large litter retention devices), easy to deploy, easy to scale in size, flexible in regards to where it can be placed and easily moved.

5.1.1. Net curtains

Net curtains with different mesh size can be connected if one wants to monitor other size fractions of plastic litter. In the BLASTIV project the mesh size of about 8 mm was chosen so that the nets would catch cigarette buds and that mesh size was not expected to clog too fast with organic material. That mesh size was adequate to catch a good sample of cigarette butts, candy wrappers etc. while allowing a longer sampling time than a net with smaller mesh size. The height of the net curtain can be modified to suit the monitoring site[7].

5.2. Sample size and duration

Depending on what the results of the monitoring are to be used for (quantitative scientific data. monitoring the results of implemented measures towards reducing riverine litter or public awareness), the setup may vary greatly. The more variable the data is the more repetition is needed to achieve an acceptable level of accuracy and precision. If the monitoring is to be used for a scientific publication or to monitor the effects of implemented measures against litter, multiple sampling sessions are needed in order to produce high quality data. But if the monitoring is to be used to raise awareness in an environmental campaign then fewer samples may suffice[7].

When starting to monitor in a specific area that has no prior monitoring, the general lack of quantitative data regarding litter quantities makes it difficult/impossible to predict how long sampling duration and sampling repetition is needed to obtain high quality results. The needed sampling repetition and sampling duration will be site specific which means that pilot sampling is recommended. Frequent sampling is recommended to increase the representativeness of monitoring[7].

5.3. Site selection

The physical conditions of the monitoring site are of great importance when monitoring with floating litter booms. The monitoring is affected by the width of the river, weather conditions such as wind and/or water flow rate/direction. Based on the experiences from the BLASTIC project the recommendations for site selection are:

- Narrow rivers with a continuous water flow, or in narrow parts of a wider river.
- A site where a large part (preferably the entire width) of the river that the boom can block the more reliable results can be obtained.
- Select a sampling site with minimal influence of the tidal currents or counter currents as these can push away already captured litter.
- The site selection also could depend on available information on potential litter emitters or convenience of the sampling locations.
- A site where at least one fixed mooring point is available is recommended.

5.4. Assessment and documentation

The collected litter can be counted, weighed and categorized according to the BLASTIC protocol for categorization of marine plastic litter. This includes the specific information about the dates of the monitoring, number of collection days, weight of the total collected amount litter, weight of the collected amount of plastic items and total number of items collected. The data should, if possible be reported as the number of items per volume of water passing the litter boom. The categories for plastic litter include 37 types of floating plastic litter.

5.5. Necessary resources

The floating litter boom is a low-tech and low-cost monitoring option. However an initial cost for the boom is required. Cylindrical containment booms can be used with success. These booms might need some modification depending on the initial design and if net curtains are to be used on the booms. Other costs depend on the deployment and retrieval of the booms and the collection and categorization of the collected litter. The deployment and retrieval of one boom requires 2 man-days, excluding the travel time. The monitoring does not require any specific skills, although some experience in the field is recommended.

5.6. Monitoring recommendations

Before starting to monitor in a specific site there are several factors that needs to be examined in order to succeed with the monitoring.

- Examine the flow pattern and speed of the water before performing any monitoring. If the flowrate is too slow or the flow direction is unstable then another site or method should be considered.
- The method (boom/net collection) is more suitable for narrow rivers or narrow parts of a wider river.
- Fixed mooring points for the boom ends are recommended and a mooring point in the middle of the boom is recommended.
- Investigate the upcoming weather conditions. Strong winds increase the risk of changing the shape and position of the booms and litter can be blown away from the boom. Rain and other precipitation can affect the results if there is an increased flow of storm water.
- Periods with heavy water discharge (early spring an autumn) are associated with much organic material in the water. Leaves, branches and other organic material will get trapped in the boom and might clog net curtains. This could overflow the litter booms and it can result

in difficulties to separate the litter from the organic material. However, frequent litter collection from the booms can reduce this issue.

- If possible use a boom that covers the entire width of the river. If this is not possible due to e.g. boat traffic then it's recommended to sample both sides of the river. Check with the relevant authorities if monitoring is allowed

5.7. PROS & CONS of floating litter boom litter monitoring

Advantages

- Cost effective and simple monitoring option for floating litter;
- Simple and direct method that can be used as a proxy in the short term;
- Collects litter so that it can be counted, weighed and categorized;
- Submerged litter items can be captured by net curtains.

Disadvantages

- Frequent observations are recommended for representative monitoring;
- The monitoring is easily influenced by external circumstances such as weather conditions and flowrate/direction;
- Not suitable in wider rivers or in rivers with boat traffic as it is recommended to block the entire width of the river;
- Monitoring can be affected by the discharge of organic material. Monitoring during spring and autumn floods is not recommended.
- Susceptible for environmental factors such as wind and precipitation.

6. Visual monitoring of floating litter

Visual monitoring can be used to visually identify floating marine and riverine litter for item sizes larger than 2.5 cm. The visual marine litter monitoring is usually performed from a vessel. Examples and scientific information on visual monitoring of riverine litter are scarce. The existing examples are mainly conducted from an elevated spot on the river.

6.1. Visual ship-based marine litter monitoring

There are many ways of visual ship-based marine monitoring but the basic principles of different methods are similar and as presented below. Here we also summarise some of the existing guidelines and their main differences. The method is well developed for the monitoring of marine litter, but the same principals could be used for monitoring rivers.

6.1.1. Generic application of visual ship-based litter monitoring

The majority of existing guidelines for visual monitoring the marine debris address ship-based monitoring, although it can also be also performed directly from viewing platforms, aircrafts,[12] or bridges (in rivers) or indirectly through video equipment. The monitoring from a ship does not have to be a dedicated activity as it can be done in parallel with other on-going scheduled activities (e.g.

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[12] For detection of large litter items (> ca. 30-40 cm) such as derelict floating nets or large litter accumulation spots.

fisheries, other research, tourist cruises etc.). Such observations from the so-called "ships of opportunities" could significantly reduce the costs of marine litter monitoring[13].

Visual observations are usually used for monitoring and counting large floating debris. Here, "large" is usually a fluid term, but frequently marine debris larger than 2.5 cm fall under this category. All visual observations usually undergo several generic steps described below.

6.1.2. Site selection

The UNEP guidelines**Fel! Bokmärket är inte definierat.** recommend selecting sites, which accumulate or generate marine litter (e.g. areas with concentrated commercial activities or major shipping lines). In such areas the selection of a site could be done randomly, although a stratification of observation site is recommended in accordance with possible sources of littering. These could be, for instance:
- urban coasts (most of the litter sources are likely to be terrestrial),
- rural coasts (most of the sources are likely to be from open sea),
- vicinity of riverine inputs (identifiable catchment area of a specific river or a point source upstream), or
- open sea areas (most likely sources are from fisheries, commercial activities, accumulation in connection to major currents etc.)**Fel! Bokmärket är inte definierat.**.

In a region with no or little data available MSFD (2013)[14] recommends to start with selections of two extremums: (1) areas with low expected quantities of littering (such as open sea), and (2) areas with high expected accumulation of littering (such as nearby ports or other point-source commercial activities). Such approach will contribute to the training of an observer and provide an understanding of the variability of litter, its sources and distribution. The vicinity of touristic or commercial activities, cities, proximity to estuaries or dynamics of currents should be also considered.[15]

However, as "ships of opportunity" are often used for visual ship-based surveys, a structured design of the survey (as well as its timing and frequency) is unlikely[16].

6.1.3. Zoning for observations

If observation is performed from vessel, the observation zone is usually delimited by an imaginary (not necessarily straight) line on the surface of the sea. A vessel then moves from the point of departure towards that line until it crosses it, which marks the boundary of the observation. The litter in this zone can be observed from one or both sides of a vessel. Ideally, the mapping of the zone should be assisted by a GPS system including a log of vessel directions and movements. This is important in determining the length of the transect and taking into account the force of winds and currents. If a GPS-assisted system is not available, the movements and the length of the transect can be approximated form compass readings, vessel velocity and observation time.**Fel! Bokmärket är inte definierat.**

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[13] UNEP/IOC (2009): *Guidelines on Survey and Monitoring of Marine Litter*, Regional Seas Reports and Studies No 186 IOC Technical Series No 83. United Nations Environment Program (UNEP) and Intergovernmental Oceanographic Commission (IOC). Nairobi, Kenya. URL: http://wedocs.unep.org/.

[14] MSFD Technical Subgroup on Marine Litter (2013). "Guidance on Monitoring of Marine Litter in European Seas." Joint Research Centre Scientific and Policy Reports, European Commission. URL: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC83985/lb-na-26113-en-n.pdf

[15] UNEP/IOC (2009): *Guidelines on Survey and Monitoring of Marine Litter*, Regional Seas Reports and Studies No 186 IOC Technical Series No 83. United Nations Environment Program (UNEP) and Intergovernmental Oceanographic Commission (IOC). Nairobi, Kenya. URL: http://wedocs.unep.org/.

[16] NOAA (2013). "*Marine Debris Monitoring and Assessment: Recommendations for Monitoring Debris Trends in the Marine Environment*". Marine Debris Program, Office for Response and Restoration, National Oceanic and Atmospheric Administration (NOAA). U.S. Department of Commerce. Technical Memorandum NOS-OR&R-46. URL: https://marinedebris.noaa.gov/sites/default/files/publications-files/TM_NOS-ORR_46.pdf.

The direction of observation must be perpendicular *(Fel! Hittar inte referenskälla.)* to the vessel track and glare-free side must be selected to avoid poor quality of visibility (reflections and/or glare).[17] The width of the area observed should be recorded (note that the observation area depends also on observer's position above the sea level). The approximate widths of observation corridors in relation to observer's elevation and the speed of the vessel are presented in *Fel! Hittar inte referenskälla.*.[18]

In order to avoid bias by observers due to fatigue the recommended time of a visual survey is 2 hours per person.[Fel! Bokmärket är inte definierat.] The UNEP's guidelines[Fel! Bokmärket är inte definierat.] recommend the width of the typical measurement area to be 50-100 m and at least 1 km distance between transects in order to avoid overlaps. A minimum of 20 transects (sampling units) should be randomly selected, but the stratification according to possible source of littering (urban, rural coast, river input as well as open seas) is highly recommended by UNEP's guidelines[Fel! Bokmärket är inte definierat.].

Figure 2. The position of the observation.[19]
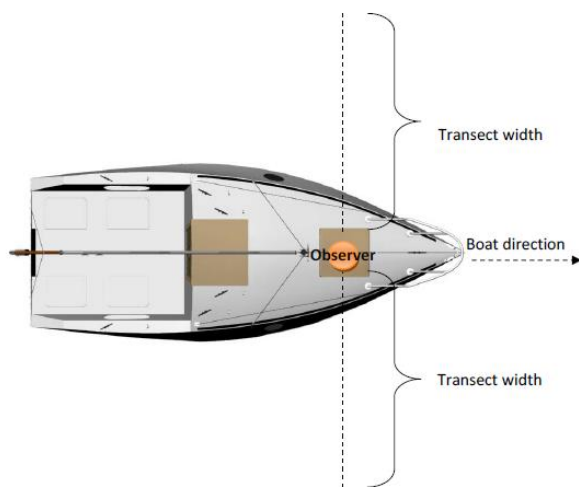
Table 1. Indicative width of transect based on height of observation and vessel speed.

Observer's elevation above the sea level	2 knots (3.7 km/h)	6 knots (11.1 km/h)	10 knots (18.5 km/h)
1 m	6 m	4 m	3 m
3 m	8 m	6 m	4 m
6 m	10 m	8 m	6 m
10 m	15 m	10 m	5 m

Source: MSFD (2013).

6.1.4. Assessment and documentation

As the litter is observed remotely and no collection is involved, the assessment and categorisation of litter is quite simple and, in many cases, it is impossible to determine the composition of material of litter items. The unit for quantification usually is the quantity of items per square kilometre (items/km^2)[20][21] (although other studies may use the unit "item/km", which makes different studies

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[17] DeFishGrear (2015). "*Methodology for Monitoring Marine Litter on the Sea Surface Visual observation*". DeFishGear project. The European Uninio and the Adriatic IPA. URL: http://mio-ecsde.org/wp-content/uploads/2014/12/Floating-litter_monitoring-methodology_complete.pdf.

[18] MSFD Technical Subgroup on Marine Litter (2013). "Guidance on Monitoring of Marine Litter in European Seas." Joint Research Centre Scientific and Policy Reports, European Commission. URL: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC83985/lb-na-26113-en-n.pdf

[19] DeFishGrear (2015). "*Methodology for Monitoring Marine Litter on the Sea Surface Visual observation*". DeFishGear project. The European Union and the Adriatic IPA. URL: http://mio-ecsde.org/wp-content/uploads/2014/12/Floating-litter_monitoring-methodology_complete.pdf.

[20] Ibid.

[21] MSFD Technical Subgroup on Marine Litter (2013). "Guidance on Monitoring of Marine Litter in European Seas." Joint Research Centre Scientific and Policy Reports, European Commission. URL: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC83985/lb-na-26113-en-n.pdf

difficult to compare).[22] As items are not collected only the quantity of each litter category is counted[23].

6.1.5. Monitored plastic litter

Visual monitoring is not suitable for deeper water column and usually covers mainly items larger than 2.5 cm floating close to the water surface, although some other methods suggest identifying the classes for different size of litter items (see **Fel! Hittar inte referenskälla.**).

There are several guidelines and recommendations, including protocols available for visual ship-based observation of litter. The generic application of visual ship-based floating litter monitoring methods is rather similar, but the existing examples/recommendations may differ slightly in terms of their recommendations for the frequency of measurements, the length and width of the transects, the classification systems for the litter, etc.

Fel! Hittar inte referenskälla. lists four dominant methods and their methodological differences.

Although a litter classification system for all surveys (including beach monitoring) might be selected with its 77 categories of plastics, the plastic categories used in visual monitoring are usually not very broad. A simplistic classification of litter items is used, as it is difficult to collect accurate and detail information. For instance, the UNEP method for remote visual observations suggests using Remote Litter Classes (RLC) based on 29 types of object instead of material. The DeFishGear project defines 20 categories of products made of plastics, while the Master List of Categories gives 23 items made of plastics for floating litter monitoring (**Fel! Hittar inte referenskälla.**).

6.1.6. Necessary resources

No specialty equipment is required for the monitoring based on the "ships of opportunity", where GPS systems to record transect location and ship speed are usually available. However, a pair of binoculars could be used to improve the quality of litter identification. According to JRC guidance[24] a tablet PC (with GPS) may facilitate the work. Other possible equipment indicated by different guidelines is listed in **Fel! Hittar inte referenskälla.**.

If the visual monitoring is considered as a dedicated activity, the costs could be very high due to the operational costs of the vessels involved. If the monitoring is performed parallel to other shipping activities and there is no need to dedicate costs for the monitoring activity, the visual monitoring could be low-cost (e.g. in conjunction with research on marine ecosystems, ferries, coast guard patrols, fisheries etc.). According to JRC[25], visual floating litter monitoring has low to medium costs[26] (if operational costs for vessel excluded). Indicative costs for floating litter monitoring are estimated to require 0.5 man-day/transect, including transfers. It also requires ac. 5 man-days for data preparation for measurements in whole region and some costs for additional equipment (e.g. 250

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[22] NOAA (2013). "*Marine Debris Monitoring and Assessment: Recommendations for Monitoring Debris Trends in the Marine Environment*" Marine Debris Program, Office for Response and Restoration, National Oceanic and Atmospheric Administration (NOAA). U.S. Department of Commerce. Technical Memorandum NOS-OR&R-46. URL: https://marinedebris.noaa.gov/sites/default/files/publications-files/TM_NOS-ORR_46.pdf

[23] UNEP/IOC (2009): *Guidelines on Survey and Monitoring of Marine Litter*, Regional Seas Reports and Studies No 186 IOC Technical Series No 83. United Nations Environment Program (UNEP) and Intergovernmental Oceanographic Commission (IOC). Nairobi, Kenya. URL: http://wedocs.unep.org/.

[24] JRC (2013). "Guidance on Monitoring of Marine Litter in European Seas". MSFD GES TG on Marine Litter. Joint Research Centre. The European Union. URL: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC83985/lb-na-26113-en-n.pdf

[25] Ibid.

[26] The costs are categorized as: *Low:* 1-10 k€; *medium:* 10 – 50 k€.

EUR for a tablet PC).[27] However, although the visual observations could be performed by voluntaries, dedicated personnel with proper training is preferable.

6.1.7. Example of visual monitoring of floating litter, existing guidelines and recommendations

There are several guidelines and recommendations, including protocols available for visual ship-based observation of litter. The generic application of visual ship-based floating litter monitoring methods is rather similar, but the existing examples/recommendations may differ slightly in terms of their recommendations for the frequency of measurements, the length and width of the transects, the classification systems for the litter, etc. The **Fel! Hittar inte referenskälla.** lists four dominant methods and their methodological differences.

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[27] JRC (2013). "Guidance on Monitoring of Marine Litter in European Seas". MSFD GES TG on Marine Litter. Joint Research Centre. The European Union. URL: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC83985/lb-na-26113-en-n.pdf

Table 2. Compilation of examples of dominant methods/guidelines for visual observations/monitoring of floating marine litter.

	JRC	UNEP	DeFishGear Project	NOOA
Short description of guidance or project	*Guidance on Monitoring of Marine Litter in European Seas* by MSFD group, is a guidance document within the Common Implementation Strategy (CIS) for the Marine Strategy Framework Directive (MSFD)	*UNEP/IOC Guidelines on Survey and Monitoring of Marine Litter* that assist policy makers and support efforts by regions, countries and other relevant organizations (e.g. the Regional Seas Programme) to help in monitoring and assessment of marine litter.	*Methodology for Monitoring Marine Litter on the Sea Surface Visual observation* by the DeFishGear project. Aimed to facilitate litter monitoring in the Adriatic Sea.	*Marine Debris Monitoring and Assessment: Recommendations for Monitoring Debris Trends in the Marine Environment*, is a guidance document by the by the National Oceanic and Atmospheric Administration (NOAA), US
Site selection	Targets coastal surveys. Sites with two extremums: low and high expected littering	Sites that accumulate litter or are close to the source of littering; stratification according the source of littering.	Sites should include low and high litter density areas, as well as other areas near cities, touristic or commercial activities and high intensity traffic. The dynamics of the currents should be considered.	No strict recommendations. The method recommended as a complement to other on-going surveys, thus survey design partly depends on the ongoing activities on the "ships of opportunity".
Frequency and timing of measurements	Not specified, recommended to take into account the conditions of the observations and the purpose of monitoring.	Min. once per year, but four times/year is recommended as optimal.	At least 2 times per year (autumn, spring), but recommended to take into account the conditions of the observations.	Not specified
Measurements	Transect widths based on vessel speed and height of the observer above the sea level. Transects length ca. 1hour/observer	Typically, 50-100 m length per transects and at least 1 km distance between transects. Transects width not specified	Transects width of 10m, ship speed of max. of 3knots with length of transects of 1 h/survey	Transects at least 0.5 nmi (ca 1 km) in length, widths (ranging from 3 to 15 m) based on vessel speed and the height of the observer above the sea level.
Plastic litter categories	The Master List includes 23 categories for floating plastic litter	The classification for Remote Litter based on object types rather than material	20 groups of categories for plastic litter (44 in total including other material litter).	6 groups for plastics (13 in total including other material litter).
Size of litter items	**5 sizes classes:**	Not specified, but the method	**6 sizes classes:**	> 2.5 cm

	JRC	UNEP	DeFishGear Project	NOOA
	2.5-5 cm 5-10 cm 10-20 cm 20-30 cm 30-50 cm > 50 cm (may be reported but not required)	aims larger litter items (>2.5 cm)	A. 2.5cm-5cm B. 5 cm-10cm C. 10 cm-20cm D. 20 cm-30cm E. 30 cm-50cm F. >50 cm	
Equipment	GPS units, tablet PC Systems for visually marking the observation area, and for training and calibrating size classification	GPS units, binoculars	Digital camera, binoculars, GPS unit, extra batteries, clipboard, recording sheets (waterproof), pencils, first aid kit (incl. sunscreen, bug spray, water)	Clipboard, pencil, survey forms printed on waterproof paper, a GPS unit, binoculars, digital camera
Links to the guidance/recommen dations	URL: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC83985/lb-na-26113-en-n.pdf	http://wedocs.unep.org/bitstream/handle/20.500.11822/13604/rsrs186.pdf?sequence=1&isAllowed=y	http://mio-ecsde.org/wp-content/uploads/2014/12/Floating-litter_monitoring-methodology_complete.pdf	https://marinedebris.noaa.gov/sites/default/files/publications-files/TM_NOS-ORR_46.pdf

6.1.8. PROS & CONS of visual ship based monitoring

Advantages

- Simplicity and cost-effectiveness (if "Ships of opportunity" and/or voluntaries involved) as the method does not require high level of expertise or advanced equipment;
- A large marine area can be covered in a short period of time;
- Avoids some of the complications of beach dynamics and contamination by beach users.[28]

Disadvantages

- The identification of litter items is prone to subjectivity. As visual monitoring does not include the collection of items, the remote identification of plastics (by kind or material) may be difficult, especially for smaller items;
- Visual surveys account for litter items that are visible on the surface, the data should be interpreted as a low-end estimate of the total concentration of the floating litter items[29];
- Objects may be missed or included by mistake due to factors such as weather conditions, amorphous shape, vessel speed and surveyor's experience[30];
- If measurements are to be performed repeatedly, it is difficult to get representative samples, due to winds and currents;
- Changes from the same sampling area do not necessarily show the efficiency of prevention measures to reduce plastic littering, rather than show the balance between input and losses.[31]

6.2. Visual riverine litter monitoring

A considerable share of marine floating litter is from riverine inputs. To monitor this litter visual observation methods in rivers are used (suitable only for macro-size litter over 2.5 cm). In 2016, JRC published guidelines for riverine visual observation methods[32]. According to the guidelines, the monitoring can be performed both stationary and dynamically. In stationary observations, an observer/ device is stationed in a fixed spot on the river (e.g. a bridge). Dynamic riverine observations, similarly to ship-based marine monitoring, rely on boats and use similar protocols.[33]

Examples and scientific information on visual monitoring of riverine litter are scarce.[34] One of the best examples of methodology for visual riverine monitoring of floating litter was developed within the JRC research project RIMMEL (Riverine and Marine floating macro litter Monitoring and

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[28] Ryan P, G., Moore C. J., van Franeker J. A. and Moloney C. L. (2009). Monitoring the abundance of plastic debris in the marine environment. *Phil. Trans. R. Soc. B*: 364, 1999–2012. doi:10.1098/rstb.2008.0207

[29] NOAA (2013). "*Marine Debris Monitoring and Assessment: Recommendations for Monitoring Debris Trends in the Marine Environment*" Marine Debris Program, Office for Response and Restoration, National Oceanic and Atmospheric Administration (NOAA). U.S. Department of Commerce. Technical Memorandum NOS-OR&R-46. URL: https://marinedebris.noaa.gov/sites/default/files/publications-files/TM_NOS-ORR_46.pdf

[30] Ibid.

[31] Ryan P, G., Moore C. J., van Franeker J. A. and Moloney C. L. (2009). Monitoring the abundance of plastic debris in the marine environment. *Phil. Trans. R. Soc. B*: 364, 1999–2012. doi:10.1098/rstb.2008.0207

[32] JRC (2016). "Riverine Litter Monitoring - Options and Recommendations". MSFD GES TG Marine Litter - Thematic Report. Joint Research Centre. The European Union. URL: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC104194/lb-na-28307-en-n%20.pdf.

[33] JRC (2016). "Riverine Litter Monitoring - Options and Recommendations". MSFD GES TG Marine Litter - Thematic Report. Joint Research Centre. The European Union. URL: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC104194/lb-na-28307-en-n%20.pdf.

[34] Ibid.

Modelling of Environmental Loading).[35] The project established a Riverine Litter Observation Network - a collaborative activity of 36 participating institutions including authorities, research institutes, NGOS and SMEs from 17 countries. So far, 58 rivers have been registered for observation by the network, in countries sharing marine basins within the EU (Mediterranean Sea, Black Sea, North Easts Atlantic Ocean and Baltic Sea) during the monitoring period of 2016-2017.

Below we will present the main provisions of the guidelines developed by the RIMMEL project.

6.2.1. Site selection

For the selection of monitoring sites there are no strict recommendations. JRC recommends choosing sampling site(s) right upstream from the estuaries, as here the rivers usually widen and the currents slow down. Another guiding principle is to select the sampling site to minimise the influence of the tidal currents.[36] The site selection also could depend on available information on potential litter emitters or convenience of the sampling locations.

The monitoring should take place from an elevated position (e.g. bridges, quays, pier, quay wall, etc.). The observation point should provide a wide field of view, not disturbed by light conditions. The height of the observation point should be in such a range from the litter which allows litter larger than 2.5 cm to be visible. The use of binoculars is also recommended.

6.2.2. Zoning for observations and timing

JRC (2016) recommends frequent observations to increase the representativeness of monitoring. Stationary monitoring involves observations from one side of a river with 30-60 min sampling duration and the total of ca. 30 visual observations over 15 days. Automatic cameras for long-term observations have also been proposed combined with image recognition technology.[37]

The time for monitoring should take into account the light conditions of the geographical region(s) to avoid poor visibility (e.g. light reflections or shades). The observer needs to face upstream flow and have an unobstructed view (**Fel! Hittar inte referenskälla.**).

Several parameters are important to identify:

- the observation height and the width of the track width (a section where the litter items are observed);
- the total width of the river (in the selected area);
- weather description (state of the river surface flow, light conditions, visibility etc.).

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[35] More information about RIMMEL and the Network is available from JRC's website, URL:
http://mcc.jrc.ec.europa.eu/dev.py?N=simple&O=380&titre_chap= &titre_page=RIMMEL
[36] JRC (2016). "Riverine Litter Monitoring - Options and Recommendations". MSFD GES TG Marine Litter - Thematic Report. Joint Research Centre. The European Union. URL: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC104194/lb-na-28307-en-n%20.pdf.

[37] Ibid.

Figure 3. Visual litter observation from the bridge over the river by the RIMMEL project.

6.2.3. Assessment and documentation

The collected data can be reported through JRC's specially developed Floating Litter Monitoring application. This includes the specific information about the observation site and river characteristics and litter categories. The categorisation is based on the same categories as marine litter monitoring[38], i.e. the Master List of Categories of Litter Items[39]. The data should be reported as the number of items per unit of time along with the width of each observation track and the speed of the surface water.

6.2.4. Monitored plastic litter

The categories for plastic litter are based on the Master List of Categories. It includes 23 types of floating plastic litter and 5 classes of different litter sizes.

6.2.5. Necessary resources

An observer should use a tablet computer with the JRC's app installed for data records. The tablet should have a GPS access to record the position of litter tracking. The monitoring does not require any other specific equipment or skills, although it should be performed by trained observers.

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[38] JRC (2013). "Guidance on Monitoring of Marine Litter in European Seas". MSFD GES TG on Marine Litter. Joint Research Centre. The European Union. URL: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC83985/lb-na-26113-en-n.pdf

[39] The Master List can be found here:
http://www.ramoge.org/documents/MSFD%20Guidance%20on%20Monitoring%20Marine%20Litter_2013_online.pdf#page25

However, special equipment is needed for the measurements or estimates of the river flow if the data is not available from gauge stations.[40] Direct observations may be replaced by video cameras.

The visual observation of riverine litter is a low-tech and low-cost monitoring option. The costs largely depend on the duration and frequency of measurements. For instance, with a minimum survey time of 0.5 hour/survey and 30 times, the survey would require 2 man-days, excluding the travel time.

6.2.6. PROS & CONS of visual riverine litter monitoring

Advantages

- Very cost effective and simple monitoring option for floating litter, useful when low costs and high frequency monitoring for many sites are required;
- Simple and direct method that can be used as a proxy in the short term;[41]
- Camera-assisted observations with image recognition technology are less tedious and can provide a less subjective survey.

Disadvantages

- Frequent observations are needed for a representative monitoring;
- Just like visual marine litter monitoring (no need to collect the litter), the remote identification of plastics (by kind or material) may be difficult, especially for smaller items;
- The detection is affected by weather conditions and litter characteristics (e.g. color, size) and largely depends on observers' skills and experience;[42]
- Submerged litter items are difficult to identify in turbid waters.

7. Beach litter monitoring methods

Monitoring marine litter in open waters could be complicated and expensive. Alternative methods, such as beach monitoring could offer cheaper and still effective solutions for information collection. Below is a summary of different beach litter monitoring methods. This includes an overview of MARLIN and OSPAR, two monitoring methods commonly used in the Baltic region, as well as a short description of HELCOM's marine litter monitoring recommendations and a method used in Poland.

7.1. MARLIN/UNEP method

Historically, marine litter measurements in the Baltic Sea have been random, intermittent and based on different assessment methods, which generated poorly comparable data. During 2011-2013, a research project MARLIN[43] on marine littering was launched. The aim was to get uniform data, support measures for litter prevention and raise public awareness about the negative impacts on marine ecosystems. The project selected 23 reference beaches around the Baltic Sea for monitoring in Sweden, Finland, Estonia and Latvia. For the first time comparable results on beach litter were gathered. This also enabled the development of a monitoring program based UNEP/IOC guidelines

[40] JRC (2016). "Riverine Litter Monitoring - Options and Recommendations". MSFD GES TG Marine Litter - Thematic Report. Joint Research Centre. The European Union. URL: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC104194/lb-na-28307-en-n%20.pdf.

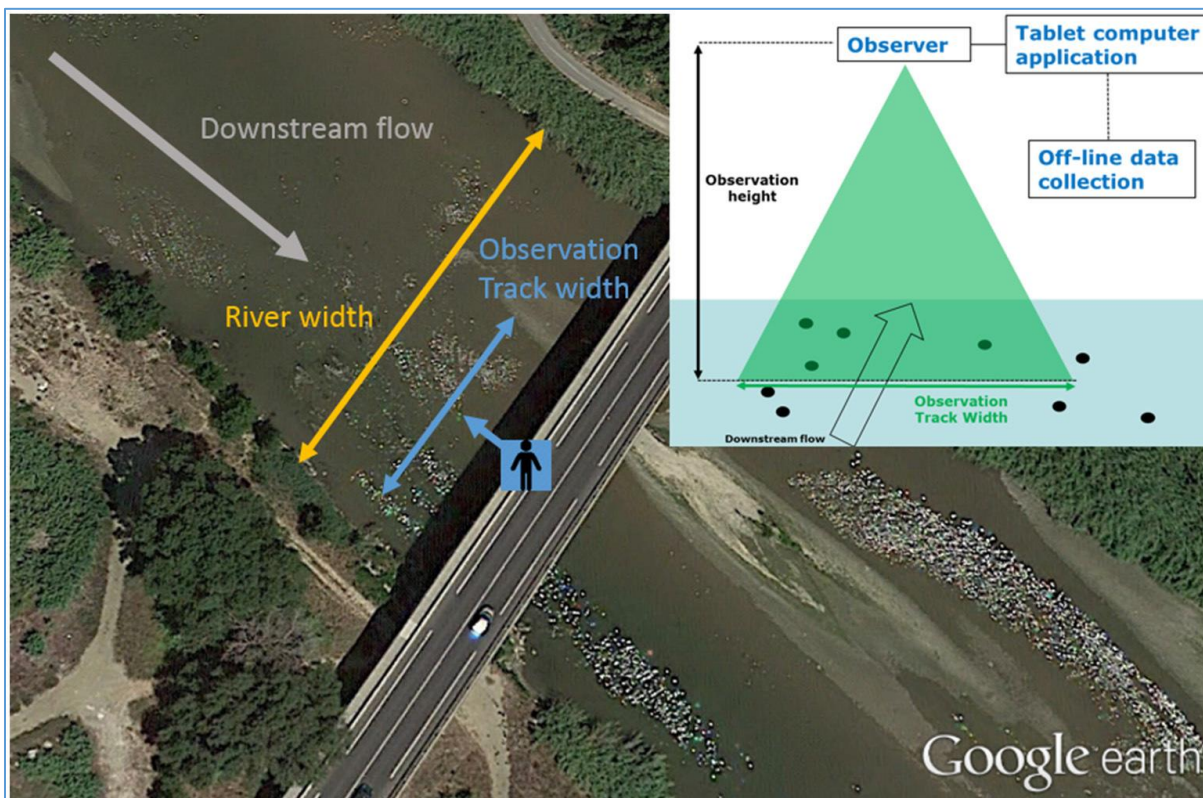[41] González-Fernández D., Hanke G. (2017). Toward a Harmonized Approach for Monitoring of Riverine Floating Macro Litter Inputs to the Marine Environment. Frontiers in Marine Science, Vol. 4, article 86. doi: 10.3389/fmars.2017.00086

[42] González-Fernández D., Hanke G. (2017). Toward a Harmonized Approach for Monitoring of Riverine Floating Macro Litter Inputs to the Marine Environment. Frontiers in Marine Science, Vol. 4, article 86. doi: 10.3389/fmars.2017.00086

[43] For more information, see URL: http://www.cbss.org/wp-content/uploads/2012/08/marlin-baltic-marine-litter-report.pdf.

and adapted for the conditions of the Baltic Sea.[44] The MARLIN method is still, in 2018, used by these countries for monitoring beach litter at a national level.

7.1.1. General application

The MARLIN method for a beach observations-based assessment of marine litter is simple and can be applied for identifying the sources of littering.[45] As for all monitoring methods the main principle of MARLIN monitoring is that the negative impact on the protected or endangered flora and fauna should be avoided during the monitoring.

The MARLIN beach monitoring program comprises several basic steps.

7.1.2. Site selection

A general recommendation is to select **a** mix of urban, rural and peri-urban beaches, but the selection may depend on local specifics (e.g. in the Swedish monitoring program two of these beach types are used). The selected beaches should be at least 100 m long (up to 1,000 m), have a clear access to the sea and slope between 1° and 45° in order to include very shallow areas. Beaches subjected to other monitoring actions or/and regular cleaning are undesirable. If such beaches are included, the cleaning date must be known.

7.1.3. Zoning for observations.

Each sample beach should be divided into three overlapping measurement areas: Area 1 (10 m stretch), Area 2 (100 m stretch) and Area 3 (1 km stretch) (

Figure 4) More detailed information on how to measure the selected areas is available here[46].
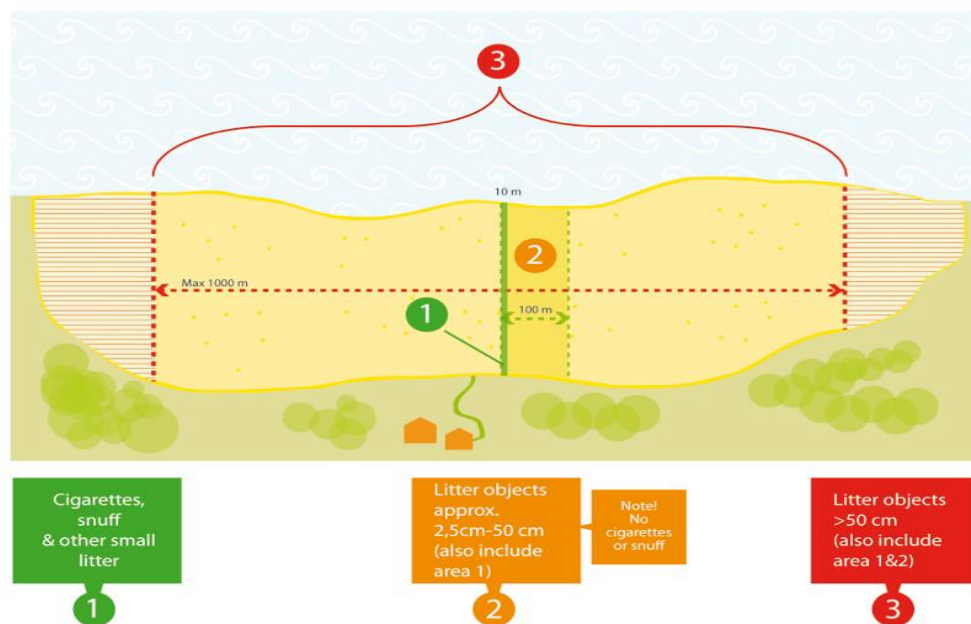
Figure 4. Measurements area for Marlin monitoring[47]

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[44] UNEP/IOC (2009): *Guidelines on Survey and Monitoring of Marine Litter*, Regional Seas Reports and Studies No 186 IOC Technical Series No 83. United Nations Environment Program (UNEP) and Intergovernmental Oceanographic Commission (IOC). Nairobi, Kenya.
[45] The method is less suitable for monitoring rocky coastlines or lake beaches.
[46] Source: URL: http://www.hsr.se/sites/default/files/appendix1_measurement_method.pdf
[47] Source: URL: http://www.hsr.se/sites/default/files/appendix1_measurement_method.pdf

7.1.4. Observation timing

The measurements should be carried out three times a year during each season except winter (i.e. weeks 13-20, 28-31 and 37-46). The monitoring should take place during the same period. MARLIN's monitoring program recommends three annual measurements (in the UNEP/IOC guidelines these are four) to take into account the climate specifics of the Baltic Sea.[48] It is important to use same areas for follow-up observations in the future. Therefore, the use of GPS coordinates, photos and/or permanent reference points are recommended.

7.1.5. Assessment

Marine litter in each selected zone is collected for analysis which includes counting, classification and categorisation of materials. This analysis is sequenced by starting first from Area 1, then Area 2 and finally Area 3.

MARLIN monitoring method categorizes 80 different litter items grouped into 8 material types:

- plastic/foamed plastic (29 items)
- cloth (6 items)
- glass and ceramics (8 items)
- metals (9 items)
- paper/cardboard (5 items)
- rubber (8 items)
- wood (8 items)
- others (5 items).

Items that do not fall under any of these categories should be categorised as "other" together with a short description. For categories see:

 https://www.hsr.se/sites/default/files/protokoll_bc02_3_eng.pdf

Different sizes of litter items are of interest in each of areas. The sizes are classified as follows[49]:

1) All large litter raging in size over 50 cm litter items are counted in Area 3;
2) Litter ranging in size 2.5-50 cm are counted in Area 2;
3) Cigarette butts and snus are counted in Area 1.

7.1.6. Documentation and registration

For each area different protocols are filled in. The documentation includes: (1) number of litter items/100 m, (2) total amount of litter/ area; and (3) litter items/10 m^2. The last parameter was chosen as additional to UNEP guidelines due to the fact that area 1 influence the results on urban beaches were most of the litter is expected to come from visitors. However, since the units have to be comparable the last two ways of presenting results are used very rarely. Once the measurement process is completed the data are send for registration (in the project web-based database at http://hsr-beach.herokuapp.com/login [50].
More detailed description of the MARLIN method is available at
http://www.hsr.se/sites/default/files/appendix1_measurement_method.pdf

Further explanation of the MARLIN method versus UNEP/IOC guidelines and an evaluation of the method is available here http://www.hsr.se/sites/default/files/appendix2.pdf .

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[48] Source: URL: http://www.hsr.se/sites/default/files/appendix2.pdf
[49] Source: Marine litter in the Baltic Sea (MARLIN), Beach litter measurements method description. URL: http://www.projectmarlin.eu/ .
[50] The database is open for anyone, but requires log-in credentials provided by site administrator (Eva Blidberg, 2018-09-18).

7.1.7. Human resource estimate

According to the guidelines[51] at least 4 persons are required for the measurement and counting of items at the beach. However, in practise not more than 1-2 persons are needed, although this depends on littering degree.[52]

7.1.8. Monitored plastic litter

The bulk of marine beach litter in terms of both volume and number is usually of plastic origin. The monitoring procedures of MARLIN address macro-litter (over 25 mm in size). The results from 2011-2013 of MARLIN project showed similar results to other cases of littering from other seas, in terms of plastics turned to be the dominant material (62% of all litter). Unidentified plastic and small plastic items were among the most common litter (25 % of the items in total). Other plastic types as plastic bottle caps and lids (4.8 %), plastic bags (4.3%) and foamed plastic (4.2%) were also among a top 5 list of litter.[53] Cigarette was one of the most common form of beach litter in the Baltic Sea, as up to 300 cigarette butts per 100 m were observed on urban beaches during the monitoring.[54]

7.1.9. Results of monitoring method

The MARLIN project has been effective in describing the *litter situation* on different beach types, identifying litter *composition*, its *seasonal variations* and possible *sources* of littering. For instance, the project showed that more litter is present on urban beaches than on rural beaches with up to three times difference (e.g. 237 and 76 items per 100 m respectively). Most of the litter on urban beaches originate from visitors (e.g. bottle caps, plastic packaging for take away food). On rural beaches most of the litter is industrial (e.g. constructions materials or plastic ropes). Litter produced from marine sources (e.g. shipping, fishing) does not end up on the beaches of the Baltic Sea to the same extend as in the North East Atlantic Area.

7.1.10. Necessary resources

The method does not require numerous staff with high expertise or advanced equipment[55].

According to JRC[56], visual beach litter monitoring has low to medium costs[57]. Monitoring coordination and measurements execution comprise the main costs. The time costs for the measurements should be similar to OSPAR monitoring method (see section **7.2**). Monitoring could sometimes be time-consuming. Beach specific costs will depend on country, location, accessibility of sample sites, etc.

7.2. OSPAR method

The OSPAR Convention is a regional seas convention, in which 15 governments[58] and the EU cooperate to protect the marine environment of the North-East Atlantic. OSPAR started in 1972 with the Oslo Convention against dumping and was broadened to cover land-based sources of marine pollution and the offshore industry by the Paris Convention of 1974. In 1992 the two conventions were unified by OSPAR Convention. [59]

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[51] http://www.hsr.se/sites/default/files/appendix1_measurement_method.pdf
[52] Personal communication, Eva Bildberg, Keep Sweden Tidy, 2018-09-18.
[53] cigarette butts were not included in the top list due to small size and low weight
[54] URL: https://www.hsr.se/sites/default/files/marlin-baltic-marine-litter-report.pdf
[55] URL: http://www.cbss.org/wp-content/uploads/2012/08/marlin-baltic-marine-litter-report.pdf
[56] URL: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC83985/lb-na-26113-en-n.pdf
[57] The costs are categorized as: *Low:* 1-10 k€; *medium:* 10 – 50 k€.
[58] Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.
[59] URL: http://www.hsr.se/sites/default/files/marlin-baltic-marine-litter-report.pdf

OSPAR measures marine litter since 1998 and today monitors 100m stretches on ca. 70 beaches in the North-East Atlantic[60]. Currently, the survey sites of the OSPAR monitoring programme are situated in 11 countries all situated on the North-East Atlantic coastlines (Belgium, Denmark, France, Germany, Ireland, the Netherlands, Norway, Portugal, Spain, Sweden and the UK).

The most recent monitoring action was in 2017 as part of OSPAR's Intermediate Assessment of the state of the marine environment of the North-East Atlantic (see map in Figure 5). The monitoring, for instance, revealed how abundant marine litter is on the beaches and that in some areas by 90% comprises of plastic material. The most common litter items are fragments of building materials, fishing gear and packaging[61]. Details of the 2017 monitoring are published in report "*Beach Litter - Abundance, Composition and Trends*".[62]

Figure 5. The assessed area of the most recent OSPAR litter monitoring assessment (blue area).[63]

7.2.1. General application

Similar to MARLIN, the OSPAR beach monitoring program comprises some basic provisions.

1. Provisions to site selection. The OSPAR method describes litter counting on standardised stretches of coastline. The reference beaches must be (i) *minimum* 100 meters long (if possible even larger – up to 1 km), (ii) exposed to the open sea, and (iii) preferably comprised of sand or gravel. Other beach types are also included in the OSPAR Litter Monitoring Programme, including rocky, boulder and shingle beaches and other beaches with different levels of pebble, rock and vegetation coverage.

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[60] URL: https://www.ospar.org/work-areas/eiha/marine-litter/beach-litter
[61] Ibid.
[62] URL: https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/pressures-human-activities/marine-litter/beach-litter/
[63] URL: https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/pressures-human-activities/marine-litter/beach-litter/

The selected beaches must be free of buildings and not subjected to regular litter removing activities. The beaches should be chosen with the guidance of expert judgement and local knowledge of coastal areas. The beaches should also be accessible to surveyors and for litter removal all year round[64].

2. Observation timing. Normally, the sites are monitored *four times a year* and the start and end points of the sites are clearly marked to ensure the exact same area is monitored for all surveys. The four occasions for the monitoring is normally conducted in winter (from mid-December to mid-January), spring (April), summer (mid-June to mid-July) and autumn (mid-September to mid-October)[65]. Within a given survey period the surveys on all reference beaches should be carried out within the shortest timeframe possible.

4. Assessment. The assessment of marine litter is similar to of MARLIN program. This involves counting, classification and categorisation of materials. The monitoring method categorizes 112 pre-defined litter items. These are included in 11 types of items:

- plastic/polystyrene (54 items)
- metal (15 items)
- paper and cardboard (9 items)
- wood (9 items)
- sanitary waste (6 items)
- cloth (5 items)
- rubber (4 items)
- glass (3 items)
- pottery/ceramics (3 items)
- medical waste (3 items) and faeces (1 item).[66]

Some items are listed as separate categories to facilitate the linkage to littering sources and help the development of appropriate mitigation measures. For example, cotton bud sticks are categorized as sanitary waste although plastic is usually the dominant part of this litter item.

5. Documentation and registration. The data about beach litter is recorded at item levels that are pre-defined, see section 7.2.2 Monitored plastic litter. The collected data is entered in a survey form[67] with a specific OSPAR identification number, preferably also with a short description. Prior to issuing the survey forms, information about the location and physical and geographical characteristics of the selected beaches should be fil in. During the survey, information is gathered by filling-in a questionnaire, which includes information regarding possible sources for marine litter, factors that help explain the amounts, types, and litter composition on a specific beach[68]. The collected data is sent to national coordinator for control and then entered into the central database within a month of surveying[69].

7.2.2. Monitored plastic litter

Surveyors using the OSPAR method are guided with photo guides to identify and categorize litter items. Items that do not fall under any of the aforementioned categories will fall under the category "other" together with a short description.

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[64] Ibid.
[65] Ibid.
[66] URL: https://www.ospar.org/work-areas/eiha/marine-litter/beach-litter
[67] The survey form can be found here:
https://www.housing.gov.ie/sites/default/files/migrated-files/en/Publications/Environment/Water/FileDownLoad%2C39586%2Cen.pdf
[68] URL: http://www.housing.gov.ie/sites/default/files/publications/files/annex_1_-_ospar_guideline.pdf
[69] Ibid.

7.2.3. Results of the monitoring method

OSPAR has a long application record as it monitors about 70 beaches in the North-East Atlantic.[70] Many OSPAR monitoring sites are present in the Baltic Sea region. For instance, the method was applied in 31 beaches in Germany (2011-2015) and 4 in Lithuania (2012-2014)[71].

In the North-Eats Atlantic no general trends in the abundance of beach litter items have been established yet. However, decreasing trends have been observed for individual litter items. For instance, the abundance of cotton bud sticks has decreased by 12% in the north-western coast of Spain[72]. Results of the OSPAR monitoring will show the abundance of beach litter items in various geographical areas and identify the most prevailing materials. It is already now clear that, for instance, plastic fragments, food and drink packaging and fishing gear are the most frequent types of litter across all OSPAR survey sites.[73] Although the generic sources of marine litter (e.g. fishing gear) are identifiable, a more detailed information about the sources on a sub-regional level is required. [74]

The results of OSPAR monitoring are intended to provide necessary information to guide the development of appropriate actions for reducing marine litter in the OSPAR Regional Action Plan.

7.2.4. Necessary resources

Although no information has been found on the required monitoring equipment, it should be similar to MARLIN. The only difference is that OSPAR guidelines do not specify the need for a GPS equipment, pointing to insufficient accuracy of the publicly available GPS networks. The total costs of OSPAR beach litter monitoring comprise of time for coordination and surveys. The costs largely depend on personnel employment costs and can vary from country to country. Coordination usually requires costs for transportation and office including the costs of regular communication facilities (phone, Internet access).

The coordination of monitoring includes selection of surveys sites, communication with surveys companies, development of the survey system, training of surveyors, maintenance of database, analysis of data, reporting and the development of survey methodology.

The costs of execution the surveys depend on whether professional staff of surveyors will be hired or volunteer surveyors (e.g. NGOs) will carry out the measurements. Professional surveyors would increase the costs of personnel, while the involvement of volunteers would increase the load on regional coordinators, as more training would be required. For instance, it has been estimated that ca. 48 person-hours would be necessary to carry out four measurements a year for 2 persons. Additional costs will occur for litter removal and disposal as well as travel and lodging costs depending on location of sample sites[75]. For reference, the Netherlands and Germany spend between ca. 10 – 20 k€/year to run the monitoring of 4 sample sites, 4 times/year, including project coordination, analysis of data and reporting[76].

Following the methodology of OSPAR the JRC created the so-called TG Master List[77] of marine litter containing in total ca. 160 of different litter categories. The TG Master List was instrumental in the development of the Polish monitoring method (see next section) [78].

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[70] URL: https://www.ospar.org/work-areas/eiha/marine-litter/beach-litter
[71] URL: https://link.springer.com/article/10.1007/s11852-016-0489-x
[72] URL: https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/pressures-human-activities/marine-litter/beach-litter/
[73] URL: https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/pressures-human-activities/marine-litter/beach-litter/
[74] Ibid.
[75] URL: https://circabc.europa.eu/sd/a/ace0bf3c-9044-48b7-bd95-210abe8fab32/CHAPTER%203-%20DRAFT%20MSFD%20Monitoring%20Guidance%20TSG-ML%2011072013.pdf
[76] URL: http://www.ramoge.org/documents/MSFD%20Guidance%20on%20Monitoring%20Marine%20Litter_2013_online.pdf#page25
[77] The TG MASTER List is under revision, but should be completed shortly (Eva Blidberg, Keep Sweden Tidy, 2018-09-17)
[78] Personal communication with Arunas Balciunas, Klaipeda University (2018-06-06).

7.3. Differences between OSPAR and MARLIN methods

The MARLIN and OSPAR methods are very similar, however there are some differences:

- MARLIN was first experimental monitoring method applies specifically for the Baltic Sea.
- MARLIN is specific that it has a 10 m zone were cigarette butts and snuff waste are counted.
- MARLIN requires only 3 times annual measurements, while OSPAR requires 4;[79]
- OSPAR it has become a more or less widely applied method for the monitoring of North-East Atlantic coastlines;
- OSPAR covers more litter categories in general including more plastics categories than MARLIN. MARLIN was adjusted for the Baltic Sea conditions, where compared to other regions fewer littering originates from the fishing industry.[80] However, owing to fewer material categories present in MARLIN's methodology, many kinds of plastics end up being classified as "other plastics".
- MARLIN monitors only litter larger than 2.5 cm, while OSPAR is intended to capture all litter (although this is not often practised). Nevertheless, MARLIN needs more details on certain plastic litter items in line with OSPAR categories to be able trace the litter to its sources. On the other hand, MARLIN separates plastics from EPS, which has shown to be practical when the questions about the dynamics of EPS litter is of interest.[81]
- The costs of both methods are similar and largely depend on litter density.

7.4. Other beach litter monitoring

7.4.1. Poland's version of beach litter monitoring

In January 2018 Poland finished its 3-year pilot program for beach litter monitoring. The program is not significantly different from the methods used in other Baltic countries. The main change is the extension of the monitored section, from 100 m to 1 km. This improves the statistics, but requires much more work. In Poland, the monitoring is carried out on 15 one-kilometre beach sections chosen to reflect the state of the entire coast and represent diverse beaches ranging from urban to rural with various tourist intensities. The observations are carried out 4 times a year: in April, at the turn of June and July, at the turn of September and at the turn of December and January.

On each section, all litter items are counted along the entire width of the monitored section, from the water line to the beach border. Each type of litter item is identified in accordance with the accepted classification by JRC, TG Master List[82]. Information on the number of litter items and types is entered into unified surveys that also contain information on weather conditions, the condition of the shore and possible information on the condition and development of infrastructure[83].

7.4.2. HELCOMs recommendations

In 2008 HELCOM has released the Recommendation, which suggests the use of unified beach litter monitoring method, including method of sampling and reporting in order to get comparable results in the Baltic Sea region. The Recommendation suggests the monitoring on open sand or gravel beaches which should be preferably at least 1,000 m long. The sample beaches should be visually and frequently exposed to littering, accessible for litter removal, not located near to other than marine

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[79] For instance, in Sweden OSPAR is practiced 3 times per year. Source: Eva Blidberg, Keep Sweden Tidy, 2018-09-17
[80] Personal communication, Eva Blidberg, Keep Sweden Tidy, 2018-09-17.
[81] Personal communication, Eva Blidberg, Keep Sweden Tidy, 2018-09-17.
[82] http://mcc.jrc.ec.europa.eu/documents/201702074014.pdf
[83] Personal communication, Tamara Zalewska (2018-06-04).

sources of littering (e.g. not selected near river estuaries). The measurements/surveys should be carried out on at least 100 m. The parameters of litter measurement should include number of items and if possible the weight unit (kg) in each litter category. A survey form with categories of litter is available here:
http://www.helcom.fi/Documents/Action%20areas/Monitoring%20and%20assessment/Manuals%20and%20Guidelines/Guidelines%20for%20monitoring%20beach%20litter.pdf

7.5. PROS & CONS of generic beach litter monitoring

Beach litter monitoring is a commonly used method for measuring the amounts and the frequency of litter in coastal and/or the marine environment. It also improves the understanding about the type of materials and sometimes the sources of littering, which may facilitate preventative actions.

Advantages:

- Simplicity as the method does not require high level of expertise or advanced equipment.
- Cost-effectiveness.
- The data show geographical and seasonal variations.
- Useful in collecting information to facilitate preventative actions.

Disadvantages:

- Not very suitable for monitoring rocky shores as well as beaches with regular cleaning routines, e.g. in Germany.[84]
- Not very practical for extremely polluted coastlines as the time input for collection, counting and classification would become prohibitively expensive[85]. This could be solved by sub-sampling practised by OSPAR and other technologically advanced methods (e.g. using drones) can overcome the issue in the future.[86]
- Beach monitoring provides only a snapshot picture in sample areas, might not be accurate for scaling up the estimates on the total amounts of litter.
- The amounts and the frequency of beach litter usually correlates with the distances from urban areas, population density and the patterns of marine currents.[87]

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[84] URL: https://link.springer.com/article/10.1007/s11852-016-0489-x
[85] URL http://www.hsr.se/sites/default/files/appendix1_measurement_method.pdf
[86] Personal communication, Eva Blidberg, Keep Sweden Tidy, 2018-09-17
[87] URL: http://www.ivl.se/webdav/files/Rapporter/C183.pdf

8. Marine litter monitoring on the sea floor

A significant proportion of plastic litter that enters the sea eventually sinks and accumulates on the seabed. Most of the plastic litter can sink as plastic constituents consist of e.g. Polycarbonate PC, Polybutylene terephthalate PBT, Polyvinyl chloride PVC, Acrylonitrile butadiene styrene ABS with higher than water densities.[88] Low density plastics can also sink due to biofouling. The litter that accumulates on the bottom of the sea floor is *sea-floor* or *benthic litter* and is found in and on sediment and the close-to-bottom part of the water column. Sea currents, water salinity and temperatures gradients can contribute to localized accumulations of different density benthic litter.[89] Bottom topography can also play an important role.[90] Macro-sized plastic items dominate on the sea floor at the similar level as they dominate among floating or beach litter. [91]

Relatively little is known about benthic litter, as it is rarely visible and does not draw much attention from the public.[92] Benthic litter can be monitored in three different ways, partly depending on depth of the monitoring:

- Trawls or towed equipment including benthic trawls (depth 20-800 m);

- Visual assessments/surveys by divers in shallow water, near shore areas (< 20 m of depth);

- Remotely operated vehicle (ROV) or cameras for visual direct and indirect assessment surveys. ROV – for deep waters and towed cameras - for shallow water.

Below the three methods are presented shortly with some details.

8.1. Monitoring by benthic trawling

Bottom trawls can collect all large size litter located both on the sea floor and approximately one meter above it. Litter monitoring by means of trawling (and counting) is probably one of the accurate (though potentially expensive and laborious) method. It has been in use since 2011. Since 2015 marine litter from the Baltic Sea are agreed to be collected regularly in connection to evaluation of fish stock by the Baltic International Trawl Survey (BITS). The generic principles of application of the benthic trawl monitoring with short description of BITS monitoring are summarised below.

8.1.1. Environmental considerations

Sea-floor surveys that utilize trawls or towed equipment need to take into account potential environmental impacts e.g. by-catch and physical damage to benthic environments.

8.1.2. Site selection

The selection of monitoring site can be guided following the recommendations of the United Nations Environmental Program (UNEP).[93] Following principles apply:

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[88] UNEP/IOC (2009): *Guidelines on Survey and Monitoring of Marine Litter*, Regional Seas Reports and Studies No 186 IOC Technical Series No 83. United Nations Environment Program (UNEP) and Intergovernmental Oceanographic Commission (IOC). Nairobi, Kenya. http://wedocs.unep.org/bitstream/handle/20.500.11822/13604/rsrs186.pdf?sequence=1&isAllowed=y

[89] Ryan P, G., Moore C. J., van Franeker J. A. and Moloney C. L. (2009). Monitoring the abundance of plastic debris in the marine environment. *Phil. Trans. R. Soc. B*: 364, 1999–2012. doi:10.1098/rstb.2008.0207

[90] Ibid.

[91] Ibid.

[92] Galgani, F., Leaute, J.P., Moguedet, P., Souplet, A., Verin, Y., Carpentier, A., Goraguer, H., Latrouite, D., Andral, B., Cadiou, Y., Mahe J.C., Pouland, J.C. and Nerisson, P. (2000). Litter on the sea floor along European coasts, *Marine Pollution Bulletin* 40: 516-527.

- Sea bottom areas should preferably have a uniform substrate (ideally sand/silt bottom);

- The depth should be more or less uniform for the entire observation area;

- Focus should be given to areas, which accumulate or generate marine litter;

- Avoid areas with a risk of unexploded munitions;

- Avoid destroying of sensitive and/or pristine habitats;

- Avoid damaging any endangered or protected flora and/or fauna.

A stratification of sampling site is recommended in accordance with possible sources of littering (urban, rural, in vicinity of riverine inputs) or impacted open sea areas (most likely sources are from fisheries, commercial activities, accumulation in connection to major currents etc.).**Fel! Bokmärket är inte definierat.**

8.1.3. Zoning for observations

The UNEP suggests selecting a site measuring 5 × 5 km[94]. The area should be pre-controlled by sonars or using cameras to test if it is suitable for trawling. Area should be divided into 25 sub-blocks, 1 x 1 km each. Three sub-blocks should be selected randomly for trawling. In each of the selected 3 sub-blocks, 5 trawl shots spaced 800 m should be performed keeping a distance of 200 m between the shots.[95]

The benthic survey typically recommended to be conducted annually.[96]

8.1.4. Assessment and documentation

The collected litter is counted, weighed and recorded. The units of measurement can be either kg/km per km of distance, items/ha or item/km^2.

8.1.5. Necessary resources

Highly specialized and extensive equipment required.
- Trawl equipment, grapples or hooks;
- Specialist advice on setting a trawl is required (e.g. to determine the length of the rope);
- Side rollers are needed to take sea-floor litter on board;
- Facilities to count and weigh litter items.

Given the specialized nature of equipment and the technical expertise required, the use of volunteers cannot be extensive.

According to JRC[97], the sea-floor monitoring by trawling has low/medium total costs (indicatively, the costs of 10-50 k€ per site per year are considered medium). Litter surveys by trawl can be conducted

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[93] UNEP/IOC (2009): *Guidelines on Survey and Monitoring of Marine Litter*, Regional Seas Reports and Studies No 186 IOC Technical Series No 83. United Nations Environment Program (UNEP) and Intergovernmental Oceanographic Commission (IOC). Nairobi, Kenya. http://wedocs.unep.org/bitstream/handle/20.500.11822/13604/rsrs186.pdf?sequence=1&isAllowed=y

[94] UNEP/IOC (2009): *Guidelines on Survey and Monitoring of Marine Litter*, Regional Seas Reports and Studies No 186 IOC Technical Series No 83. United Nations Environment Program (UNEP) and Intergovernmental Oceanographic Commission (IOC). Nairobi, Kenya. http://wedocs.unep.org/bitstream/handle/20.500.11822/13604/rsrs186.pdf?sequence=1&isAllowed=y

[95] Ibid.

[96] Ibid.

[97] JRC (2013). "Guidance on Monitoring of Marine Litter in European Seas". MSFD GES TG on Marine Litter. Joint Research Centre. The European Union. URL: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC83985/lb-na-26113-en-n.pdf

parallel to evaluations of fish stock in the North Sea (International Bottom Trawl Survey, IBTS) and in the Baltic Sea (Baltic International Trawl Survey, BITS). Litter monitoring performed alongside these existing bottom-trawling programs (BITS and IBITS) has considerably lower costs than stand-alone surveys.[98]

8.1.6. Example **of trawling monitoring in the Baltic Sea (BITS)**

Benthic litter surveys (BITS) in the Baltic Sea have been conducted since 2011 and from 2015 are performed regularly. The BITS survey is recommended twice a year and in the first and second quarters. The geographical coverage is decided based the evaluations of fish stocks. The number of litter items per km^2 is counted and categorized into 6 broad material categories (plastic, metal, rubber, glass/ceramics, natural items, others). These categories are further divided into 40 different types of litter, out of which 14 categories are used for plastic litter. The 6 material categories of all litter are also classified by two-dimensional size categories[99]:

- A: < 5 x 5 cm, (25 cm^2),
- B: < 10 x 10 cm (100 cm^2),
- C: < 20 x 20 cm (400 cm^2),
- D: < 50 x 50 cm (2,500 cm^2),
- E: < 100 x 100 cm (10,000 cm^2).

Other information collected about the litter includes the weight of the litter items and the degree of fouling.

The data is sent to the International Council for the Exploration of the Sea (ICES), and accumulated in their database called DATRAS. As the monitoring is conducted using an international standard, the data can be used to evaluate common indicators on a regional level for both the North Sea and the Baltic Sea.[100]

A recent example of sea-floor monitoring within BITS program in the Southern Baltic[101] is from 2015-2016. Surprisingly it showed low concentrations of sea-floor litter. The mean litter density of 0.20 items/ha were recorded, which are not very dense compared to e.g. the Mediterranean (0.4 items/ha). The majority (67%) of the collected litter were plastics (mainly plastic bags, foils and bottles), half of it was colonized by fauna, which partly explains why the litter sinks.

8.1.7. Pros & cons of litter monitoring by trawling

Advantages

- The method is relatively accurate for large size litter items and can present rich multi-parameter data;
- The method is fully compatible with the existing bottom-trawling programmes, such as the observations of fish stocks;

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[98] Ibid.

[99] Ibid.

[100]ICES Baltic International Fish Survey Working Group (WGBIFS) (2017). Manual for the Baltic International Trawl Surveys (BITS). Version 2.0. ISBN 978-87-7482-202-8. DOI: http://doi.org/10.17895/ices.pub.2883

[101] Urban-Malinga B, Wodzinowski T., Witalis B., Zalewski M., Radtke K., Grygiel W (2018). Marine litter on the seafloor of the southern Baltic. Marine Pollution Bulletin 127 (2018) 612–617.

- The method is relatively inexpensive when combined with planned fish stock observations.

Disadvantages

- The method is restricted to smooth and flat bottoms, which are not indicative of typical litter accumulation areas;[102,103]
- The monitoring not possible for restricted and/or protected areas;[104]
- Litter concentration are likely be underestimated with trawl surveys, as not all litter items are captured and some might be lost while the net is returned to the vessel;[105]
- Extensive and specialized equipment required;
- The accuracy of measurements may be affected by the type of vessel's nets, the operations of the crew, trawling depth and weather conditions;
- The method accounts only the litter that can be cached by the nets (small litter can potentially evade the nets).[106]

8.2. Monitoring by scuba divers (<20 m)

Visual surveys of benthic litter by scuba-divers are useful and effective for the quantification of marine bottom litter near the shores in shallow waters. Here the litter is regularly entangled in different benthic structures such as rocky reefs and vegetation. A crucial factor for the effectiveness of such visual observations is sub-surface visibility so that the transects do not become too narrow. The limited visibility in murky waters (e.g. in the estuaries of a river) obstructs observations. The scuba diver-based monitoring method aims only macro-sized litter items (> 2,5 cm).

The typical methods for visual surveys of the benthic litter are based on recommendations provided by UNEP[107] and by JRC (the Marine Strategy Framework Directive (MSFD) Technical Subgroup)[108]. The main provisions are summarized below.

8.2.1. Site selection
The site for monitoring by scuba diving should be selected considering:

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[102] JRC (2013). "Guidance on Monitoring of Marine Litter in European Seas". MSFD GES TG on Marine Litter. Joint Research Centre. The European Union. URL: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC83985/lb-na-26113-en-n.pdf

[103] NOAA (2013). "*Marine Debris Monitoring and Assessment: Recommendations for Monitoring Debris Trends in the Marine Environment*". Marine Debris Program, Office for Response and Restoration, National Oceanic and Atmospheric Administration (NOAA). U.S. Department of Commerce. Technical Memorandum NOS-OR&R-46. URL: https://marinedebris.noaa.gov/sites/default/files/publications-files/TM_NOS-ORR_46.pdf.

[104] JRC (2013). "Guidance on Monitoring of Marine Litter in European Seas". MSFD GES TG on Marine Litter. Joint Research Centre. The European Union. URL: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC83985/lb-na-26113-en-n.pdf

[105] NOAA (2013). "*Marine Debris Monitoring and Assessment: Recommendations for Monitoring Debris Trends in the Marine Environment*". Marine Debris Program, Office for Response and Restoration, National Oceanic and Atmospheric Administration (NOAA). U.S. Department of Commerce. Technical Memorandum NOS-OR&R-46. URL: https://marinedebris.noaa.gov/sites/default/files/publications-files/TM_NOS-ORR_46.pdf.

[106] Ibid.

[107] UNEP/IOC (2009): *Guidelines on Survey and Monitoring of Marine Litter*, Regional Seas Reports and Studies No 186 IOC Technical Series No 83. United Nations Environment Program (UNEP) and Intergovernmental Oceanographic Commission (IOC). Nairobi, Kenya. http://wedocs.unep.org/bitstream/handle/20.500.11822/13604/rsrs186.pdf?sequence=1&isAllowed=y

[108] JRC (2013). "Guidance on Monitoring of Marine Litter in European Seas". MSFD GES TG on Marine Litter. Joint Research Centre. The European Union. URL: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC83985/lb-na-26113-en-n.pdf

- Select areas, which are likely to accumulate or generate marine litter;

- Select areas with max. depth of 20 m (beyond this depth remote methods (e.g. camera) should be used).

- Secure access from shore or support ship;

- Avoid potentially hazardous areas for divers;

- Avoid impact on endangered flora or fauna.

Sampling units should be stratified according to the relative to sources within a region such that there are samples obtained from: (1) urban coasts (i.e. mostly terrestrial littering source); (2) rural coasts (i.e. sources from open sea inputs); (3) in vicinity of major riverine inputs.

8.2.2. Zoning for observations

A transect of 4 x 100 m (at fixed depth) should be selected. The coordinates for the beginning and the end of the transect should be recorded using GPS and marked with marker buoys. As it could be challenging to locate and to dive across the transect, it should be marked by laying either a 100 m long tape measure, weighted rope, or string lines for cave diving. Two divers swim along the tape/rope/string (Figure 6) and collect small litter items found within the transect. Large items should be recorded or marked for further collection. The survey should be cancelled when the visibility is less than 2 m.
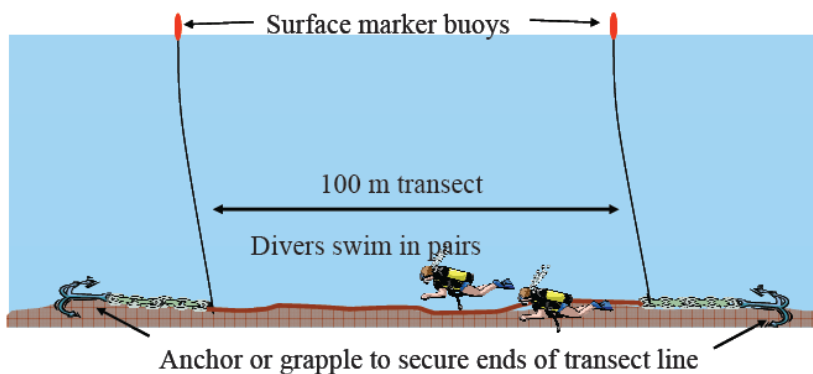
Figure 6. Marking the transect for diving monitoring [109]

It is recommended to select 20 sampling units per region. In case of more than one transect is selected within the area, then the minimum distance between the transects should be at least 50 m.

MSFD TG suggests a different range of transects size depending on environmental conditions of the sea and littering concentration (Table 3).

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[109] UNEP/IOC (2009): *Guidelines on Survey and Monitoring of Marine Litter*, Regional Seas Reports and Studies No 186 IOC Technical Series No 83. United Nations Environment Program (UNEP) and Intergovernmental Oceanographic Commission (IOC). Nairobi, Kenya. http://wedocs.unep.org/bitstream/handle/20.500.11822/13604/rsrs186.pdf?sequence=1&isAllowed=y

Table 3. Size of sampling units on a sea-floor depending on density of litter items and water conditions.[110,111]

Litter density, items/m^2	Conditions	Transect size (length x width)
0.1 - 1	Low turbidity- high habitat complexity	20 x 4 m
0.1 - 1	High turbidity	20 x 4 m
0.01 -0.1	For every case	100 x 8 m
<0.01	For every case	200 x 8 m

8.2.3. Observation timing

The surveys should be conducted at least annually. Ideally – every three months to accommodate seasonal changes.

8.2.4. Assessment and documentation

All collected/observed litter items should be classified, counted and/or weighted. The results are typically expressed in litter density (items/m^2 or items/100 m^2)

The UNEP's guidelines provide three data sheets for characterisation of the litter, the sites (with information about benthic environment and proximity to potential source of litter) and items that cannot be removed.

8.2.5. Necessary resources

Diver safety must be the highest priority, therefore licensed dive operators or logistic support to field team is recommended. The list of equipment includes: [112]

- Vessel of an appropriate size and capacity for all dive operations;
- Proper diving gear, clothing and footwear for divers;
- First aid kit, including oxygen resuscitation equipment and access to decompression facilities;
- Safety protocols and manuals;
- Communications equipment including marine radio;
- Tape, anchored ropes and marker buoys (for marking transects);
- GPS or digital camera (for relocation is diving conducted close to the shore);
- Scale (if weighing required);
- Calculator, collection bags, clip-boards for documentation and data recording;
- Knifes, bolt cutter, scissors or shears.

According to MSFD [113], seafloor monitoring with diving has more or less medium costs[114] compares to other methods. However, the costs depend on regulations and requirements. For instance, in Swedish regulations require at least 3 divers involved in a diving team. All of them must have diving

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[110] JRC (2013). "Guidance on Monitoring of Marine Litter in European Seas". MSFD GES TG on Marine Litter. Joint Research Centre. The European Union. URL: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC83985/lb-na-26113-en-n.pdf

[111] Katsanevakis, S., (2008): Marine debris, a growing problem: sources, distribution, compositioin and impacts, Marine Pollution: New Research, Editor: Hofer, N. T., pp. 53-100, ISBN: 978-1-604556-242-2

[112] UNEP/IOC (2009): *Guidelines on Survey and Monitoring of Marine Litter*, Regional Seas Reports and Studies No 186 IOC Technical Series No 83. United Nations Environment Program (UNEP) and Intergovernmental Oceanographic Commission (IOC). Nairobi, Kenya. http://wedocs.unep.org/bitstream/handle/20.500.11822/13604/rsrs186.pdf?sequence=1&isAllowed=y

[113] JRC (2013). "Guidance on Monitoring of Marine Litter in European Seas". MSFD GES TG on Marine Litter. Joint Research Centre. The European Union. URL: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC83985/lb-na-26113-en-n.pdf

[114] The costs are categorized as: *Medium:* 10 – 50 k€.

certificates and a diving plan with risk evaluation.[115] The costs for monitoring could be reduced by volunteer divers[116] (e.g. project AWARE, see **Table 4**) or if combined with existing other monitoring efforts (e.g. benthic ecology monitoring).[117]

8.2.6. Examples of sea-floor litter surveys, existing guidelines and recommendations

There are several guidelines and recommendations available for benthic litter monitoring by divers. The **Table 4** lists four methods used by JRC, UNEP, AWARE (an NGO project) and NOWPAP (Northwest Pacific Action Plan) for visual monitoring by scuba diving including their main methodological differences.

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[115] Lundqvist J. (2013). Quantification of debris on the seafloor in shallow (<20 m) areas using a towed video camera system. Department of Marine Ecology University of Gothenburg. URL: https://portal.helcom.fi/workspaces/MARINE%20LITTER-92/Litter%20on%20the%20seafloor%20candidate%20indicator/Quantification%20debris%20seafloor%20shallow%20areas%20using%20towed%20video%20camera_2016.pdf

[116] JRC (2013). "Guidance on Monitoring of Marine Litter in European Seas". MSFD GES TG on Marine Litter. Joint Research Centre. The European Union. URL: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC83985/lb-na-26113-en-n.pdf

[117] NOAA (2013). "*Marine Debris Monitoring and Assessment: Recommendations for Monitoring Debris Trends in the Marine Environment*". Marine Debris Program, Office for Response and Restoration, National Oceanic and Atmospheric Administration (NOAA). U.S. Department of Commerce. Technical Memorandum NOS-OR&R-46. URL: https://marinedebris.noaa.gov/sites/default/files/publications-files/TM_NOS-ORR_46.pdf.

Table 4. Compilation of examples of dominant methods/guidelines for visual monitoring by scuba diving.

	JRC	UNEP	AWARE	NOWPAP
Short description of guidance or project	*Guidance on Monitoring of Marine Litter in European Seas* by MSFD group, is a guidance document within the Common Implementation Strategy (CIS) for the Marine Strategy Framework Directive (MSFD)	*UNEP/IOC Guidelines on Survey and Monitoring of Marine Litter* that assist policy makers and support efforts by regions, countries and other relevant organizations (e.g. the Regional Seas Programme) to help in monitoring and assessment of marine litter.	Project AWARE is NPO working with volunteer scuba divers. *Dive Against Debris*, is a litter survey on voluntary bases to engage scuba divers in shallow water litter removal, survey and record.	*Guidelines for Monitoring Marine Litter on the Seabed in the Northwest Pacific Region* Designed as a tool to assist the NOWPAP (Northwest Pacific Action Plan) Members, including local governments, volunteers and NGOs, in litter monitoring on the seafloor.
Monitoring sites	Sites in shallow coastal areas	Areas that accumulate litter or are close to the source of littering; stratification according the source of littering. Areas potentially dangerous for divers should be avoided.	Areas: that could be observed regularly, with the presence of litter, where removal of litter and diving is in accordance with the law.	Areas close to the potential source of littering (in vicinity of ports, harbours, other fishing-related littering). Potentially dangerous areas for divers should be avoided
Measurement area	A range of transects length (20-200m) and width (4-8m) depending on depth, depth gradient, the turbidity, litter density and the habitat complexity	A transect of 100x4m (on each side of transect line two divers observe the whole width of the path)	No specific requirements for transect length or width; the same area is recommended for observations on regular basis.	Not specified, as an example area of 10 x 10 m is given.
Frequency	At least annually, ideally every 3 months	At least annually	No requirement on frequency, but regular surveys encouraged (e.g. monthly or once in 2 months)	At least annually, preferably together the existing monitoring surveys and/or clean-up events.
Plastic categories	Either from the Master List: 20 plastic items categories (52 categories in total) Or refers to IBTS for Baltic with 14 plastic categories	29 plastic categories (77 material categories in total)	43 plastic categories (100 categories in total)	7 plastic categories (41 material categories in total)

	JRC	UNEP	AWARE	NOWPAP
Human resources (for diving)	Not specified	At least 2 divers one on each side of transect line	Not specified	At least 2 divers
Equipment	Not specified	Appropriate equipment, closing and footwear for divers; safety equipment and protocols, appropriate size and capacity of vessel for all dive operations, communications equipment, ape, anchored ropes and marker buoys, GPS, weight, collection bags, clip-boards, tape measures, calculator, a sharp knife or shears.	Appropriate equipment, clothing and footwear for divers; bags, mesh nets, dive tool/knife, gloves, scissors, GPS, scales, underwater camera, harps container, blank slate and pencil	Appropriate equipment, closing and footwear for divers; compass, pressure gauge, fins, gloves, knife, mesh sack, rope, ruler, cutter, dive flag, dive slate, float tube, and pelican float; underwater camera, lift bag, and floating fence; GPS.
Links	http://www.ramoge.org/documents/MSFD%20Guidance%20on%20Monitoring%20Marine%20Litter_2013_online.pdf#page25	http://wedocs.unep.org/bitstream/handle/20.500.11822/13604/rsrs186.pdf?sequence=1&isAllowed=y	https://issuu.com/projectaware/docs/dad_survey_guide_v2-2_en/24	http://dinrac.nowpap.org:8080/documents/NOWPAP_MERRAC_Marine_Litter_Monitoring_Seabed.pdf

8.2.7. Pros & cons of litter monitoring by divers

Advantages

- Simplicity and cost-effectiveness (in case if volunteers divers involved) as the method does not require high level of expertise (except special skills needed for diving);

Disadvantages

- Feasibility depends on accessibility to the diving areas;[118]
- Not appropriated in case of poor visibility (if less than 2 m);
- Diver experience may affect the degree of detection;
- There is always an element of risk for the divers.

8.3. Monitoring by video cameras/ROVs

The monitoring on benthic litter might not always be possible using diver or trawling. In these cases, specialty equipment, such as submersibles or remote operated vehicles (ROVs), could be used. However, as the Baltic Sea has mostly shallow waters, some simple towed video camera may be a good option.

8.3.1. Application of monitoring by towed camera for shallow waters

The principles of monitoring using towed video cameras are quite similar to the diving protocol, the main difference is that the data are either analysed immediately during the filming or records are analysed later on shore.[119]

There are limited described examples of monitoring protocols for litter survey based on towed cameras. For instance, Lundqvist (2013)[120] proposed and tested benthic litter monitoring with a towed camera on the Swedish northwest coast in Skagerrak. This method was included in JRC report[121] and considered as advantageous for surveys in shallow waters (<20 m). The equipment includes a rig, reminding a sleigh carrying a frame with two consumer type cameras (e.g. GoPro) mounted in waterproof housings (Figure 6). One camera is pointed forward and the other - straight down. The rig is towed from a boat. The images are recorded and saved in memory cards and data analysed afterwards.[122] The cameras could be used to survey litter in depth ca. 20 m deep without any additional lighting. The results of the monitoring are presented as the number of per hectare (ha) or square kilometre (km^2) if the measure of area is possible. Otherwise, the litter items are measured per unit of distanced (per 100m or per 1 km).

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[118] The costs are categorized as: *Medium:* 10 – 50 k€.

[119] JRC (2013). "Guidance on Monitoring of Marine Litter in European Seas". MSFD GES TG on Marine Litter. Joint Research Centre. The European Union. URL: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC83985/lb-na-26113-en-n.pdf

[120] Lundqvist J. (2013). Quantification of debris on the seafloor in shallow (<20 m) areas using a towed video camera system. Department of Marine Ecology University of Gothenburg. URL: https://portal.helcom.fi/workspaces/MARINE%20LITTER-92/Litter%20on%20the%20seafloor%20candidate%20indicator/Quantification%20debris%20seafloor%20shallow%20areas%20using%20towed%20video%20camera_2016.pdf

[121] JRC (2013). "Guidance on Monitoring of Marine Litter in European Seas". MSFD GES TG on Marine Litter. Joint Research Centre. The European Union. URL: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC83985/lb-na-26113-en-n.pdf

[122] Lundqvist J. (2013). Quantification of debris on the seafloor in shallow (<20 m) areas using a towed video camera system. Department of Marine Ecology University of Gothenburg. URL: https://portal.helcom.fi/workspaces/MARINE%20LITTER-92/Litter%20on%20the%20seafloor%20candidate%20indicator/Quantification%20debris%20seafloor%20shallow%20areas%20using%20towed%20video%20camera_2016.pdf

In order to determine the area of the observed bottom one needs to know both the distance covered by the sledge and the width of camera's visual field. To determine the latter the easiest is to place markers left and right of the screen and measure the width between them. The area covered by the camera's visual field will be the product of distance covered and the width of the visual field.

Figure 7. The equipment for benthic litter monitoring by towed camera developed by Lundquist[123]

For the identification of the litter the same classification systems as for sea-floor litter may be used. For instance, the widely used classification of IBTS for the Baltic Sea consists of 14 categories for plastic litter.[124]

8.3.2. Necessary resources

The method requires relatively inexpensive equipment (<1,000 €). It takes ca. 60 min to perform one transect and the time for data analysis on land as well as the preparation of the equipment should be counted. It requires 1-2 persons in the field to cover ca. 2,900 m^2/day, including boat transport, analysis etc.[125]

8.3.3. Pros & cons of litter monitoring by towed camera

Advantages
- Simplicity and cost-effectiveness, since the method does not require high level of expertise or expensive equipment;
- Low demands for human resources (1-2 persons in the field);

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[123]Lundqvist J. (2013). Quantification of debris on the seafloor in shallow (<20 m) areas using a towed video camera system. Department of Marine Ecology University of Gothenburg. URL: https://portal.helcom.fi/workspaces/MARINE%20LITTER-92/Litter%20on%20the%20seafloor%20candidate%20indicator/Quantification%20debris%20seafloor%20shallow%20areas%20using%20towed%20video%20camera_2016.pdf

[124]JRC (2013). "Guidance on Monitoring of Marine Litter in European Seas". MSFD GES TG on Marine Litter. Joint Research Centre. The European Union. URL: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC83985/lb-na-26113-en-n.pdf

[125]JRC (2013). "Guidance on Monitoring of Marine Litter in European Seas". MSFD GES TG on Marine Litter. Joint Research Centre. The European Union. URL: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC83985/lb-na-26113-en-n.pdf

- Video materials can be analysed by others, which brings more objectivity; the materials can also be used for other purposes (e.g. mapping of underwater habitat, research, etc.);
- The surveyor does not know the benthic environment before the monitoring, this enables less biased sampling;
- Towing cameras could be substitutes to divers when legal requirements or other conditions restrict diving monitoring.[126]

Disadvantages
- Requires a boat, is limited only to good weather conditions;
- Not suitable in areas with thick bottom vegetation or rugged terrain;
- Technical failures are observed only afterwards (in the office/lab).

8.4. Deep sea-floor monitoring with video

For deeper water (>200 m) data collection on benthic litter are usually performed on irregular basis and aims macro litter (>2.5 cm) along submersibles/ROVs. Priority for the sampling typically is given for sites that known to accumulate or generate litter. However, the method requires very specialised and expensive equipment as well as high level of expertise, thus making the costs of survey high compared to other methods (> 50 k€)[127].

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[126] JRC (2013). "Guidance on Monitoring of Marine Litter in European Seas". MSFD GES TG on Marine Litter. Joint Research Centre. The European Union. URL: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC83985/lb-na-26113-en-n.pdf

[127] JRC (2013). "Guidance on Monitoring of Marine Litter in European Seas". MSFD GES TG on Marine Litter. Joint Research Centre. The European Union. URL: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC83985/lb-na-26113-en-n.pdf

9. Summary of monitoring methods – what to consider?

Marine litter can be found on beaches and shorelines, floating on the surface, submerged in the water column or sunk to the bottom. Most of the floating litter is made of plastic and there are several methods available for its monitoring.

The majority of litter monitoring methods are not standardized specifically for the Baltic Sea. It is useful to opt for a monitoring method which is commonly practiced in a given locality or region. This helps harmonising data collection, gives more information for reference, improves comparability of results and allows benchmarking. It is also advantageous to consider selecting the place and time for monitoring in such manner that it would be suitable for continuous monitoring, especially when litter preventive measures are to be evaluated.

Monitoring organisations should be aware that each monitoring method targets different kinds of litter and yields different results. Therefore, before selecting a concrete method an observer should clearly define the intended aim of the monitoring, resources needed, site characteristics and be aware about the nature and the reliability of monitoring results.

Beach monitoring is a commonly used method to measure the littering in coastal and partly marine environments. The method is simple, cost-effective and effective for understanding littering levels facilitating preventive actions. The method relies on several methodologies, most of which involve area gridding, manual collection, counting and categorising litter by size, materials and/or type of items. The method is also instrumental in supporting awareness raising campaigns as it yields rich data regarding the nature of litter and its origins. However, the method is not universal and is less suitable for regularly cleaned beaches, rocky shores or extremely polluted areas. The method also provides only a snapshot picture, so scaling-up sample data and estimating of the total amounts of litter might not be very accurate.

Floating litter booms and nets can be used to measure litter floating on the surface and litter suspended in the first meters of the water column in rivers. The litter booms can be useful for high frequency monitoring in riverine sites and can e.g. be used before and after litter reducing actions have been implemented in a specific area. Monitoring with floating litter booms can give very accurate result as the litter is collected and can be counted, categorised and weighed. The method is susceptible to weather conditions as the litter booms positioning and form can be altered depending on e.g. wind and currents. No special skills are required for personnel working with the litter booms however the choice of monitoring site is crucial in order to get representative results. The method gives a snapshot of what litter was the part of the river that was being monitored at that specific period of time. In order to get high quality data that shows the variation of the litter discharged in the river, frequent monitoring is recommended.

Litter floating on the surface could be monitored by *visual observations*. They are especially useful for high frequency monitoring in many sites. Quick observations of large marine areas are usually performed from ships. To reduce costs, it is recommended to use the called "Ships of opportunities". Visual observations from ships are less practical and are usually performed from shores. Both ship-based and on shore monitoring methods are not very accurate and are prone to subjectivity, since they do not involve waste collection, depend on weather and water conditions, vessel speed, observation angle (elevation) of observers and their experience. Camera-assisted observations facilitate less subjective surveys.

The monitoring of benthic plastic litter trawls, scuba divers and video cameras could be used. *Monitoring by trawls* should be considered when existing bottom-trawling programmes for assessing

fish stocks (such as BITS in the Baltic Sea) should be performed. This allows avoiding additional environmental damage to the benthic ecosystems as well as reducing observation costs. The method is relatively accurate for large size litter and yields rich multi-parameter data, although covering only the litter that could be cached by the nets.

Monitoring by *scuba divers* can also be useful, although in some countries it could be expensive, as national regulations require several divers due to safety requirements (e.g. in Sweden). The costs could be reduced if volunteer divers are available (e.g. AWARE). The feasibility of this method depends on the accessibility of diving areas and it is prone to subjectivity as divers experience.

Compared to trawling- and scuba diving-based, litter monitoring with the help of *towed-cameras* is potentially more accurate. It allows avoiding bias in sampling and assessment and allows more flexibility as visual records could be analysed after the survey. The method is simple, costs effective and does not require high level of expertise or expensive equipment. It requires a frame and following some simple instructions for camera placement and observation angles. However, the method is restricted to areas with good water visibility and not applicable in areas with thick vegetation or rugged terrain.

In deeper waters (>200 m) the data on benthic litter can be collected using *submersibles or remotely operated vehicles*. The method requires specialised and expensive equipment as well as high level of expertise.

Table 5. *Summary of plastic litter monitoring methods.*

Kind of litter targeted	Monitoring method	Does	Does not/is not
Beach litter	Beach litter monitoring (Marlin/OSPAR/Others)	Does not require high expertise or advanced equipment. Cost effective. Data captures geographical and seasonal variations.	Not very suitable for rocky shores or beaches by lakes, beaches with regular cleaning routines. Not practical for extremely polluted coastlines. Usually detailed information on litter composition is not collected making it difficult to identify the sources of littering. Provides only a snapshot picture in sample areas, might not be accurate for scaling up the estimates on the total amounts of litter. Beach monitoring does not prove an accurate measure of the amounts and the sources of littering. The amounts and the frequency of beach litter usually correlates with the distances from urban areas, population density and the patterns of marine currents.
Floating litter	Floating booms and nets	Cost effective and simple monitoring option for floating litter; Data can capture geographical and seasonal variations; Accurate for small and large size items as the litter is captured. Can present rich multi-parameter data Submerged litter items can be captured by net curtains. Stops the discharge of riverine litter to the oceans.	Frequent observations are recommended for representative monitoring; The monitoring is easily influenced by external circumstances such as weather conditions and flowrate/direction; Not suitable in wider rivers or in rivers with boat traffic as it is recommended to block the entire width of the river; Monitoring can be affected by the discharge of organic material. Monitoring during spring and autumn floods is not recommended. Susceptible for environmental factors such as wind and precipitation.

Kind of litter targeted	Monitoring method	Does	Does not/is not
	Visual ship-based	Applicable for both marine and riverine waters (but more common for marine litter). Simplicity and cost-effectiveness (if "Ships of opportunity" and/or voluntaries involved). A large marine area can be covered in a short period of time. Avoids some of the complications of beach characteristics Avoids accounting the litter of local beach users.	Does not include any collection of litter items. Identification of plastics (by kind or material) from a distance may be difficult, especially for smaller items. Visual surveys account for litter items that are visible on the surface, the data should be interpreted as a low-end estimate of the total concentration of the floating litter items. Objects may be missed or included by mistake due to factors such as weather conditions, amorphous shapes, vessel speed and surveyor's experience. If measurements are to be performed repeatedly, it is difficult to get representative samples, due to winds and currents. Changes from the same sampling area do not necessarily show the efficiency of prevention measures to reduce plastic littering, rather than show the balance between input and losses.
	Visual off shore	Highly cost-effective and simple, useful when budget monitoring of multiple sites are required at high frequency. Simple and direct method that can be used as a proxy in a short term. Camera-assisted observations with image recognition technology are less tedious and can provide a less	Frequent observations are needed for a representative monitoring. Like visual marine litter monitoring (no need to collect the litter), the remote identification of plastics (by kind or material) may be difficult, especially for smaller items. The detection is affected by weather conditions and litter characteristics (e.g. color, size) and largely depends on observers' skills and experience. Submerged litter items are difficult to identify in turbid waters.

Kind of litter targeted	Monitoring method	Does	Does not/is not
		subjective survey.	
Benthic plastic litter	By trawling	The method is relatively accurate for large size items and can present rich multi-parameter data. The method is fully compatible with the existing bottom-trawling programmes, such as fish stock observations. Relatively inexpensive when combined with the existing observations.	Accounts only the litter that can be cached by the nets (small litter can potentially evade the nets). Restricted to smooth and flat bottoms, which are not characteristic for typical accumulation areas of bottom litter. Not possible in restricted and/or protected areas. Litter concentrations are likely be underestimated, as not all litter items are captured and some are lost while the nets are returned to a vessel. Expensive and specialized equipment required. The accuracy of measurements may be affected by the type of vessel's nets, the operations of the crew, trawling depth and weather conditions.
	By scuba divers	Simplicity and cost-effectiveness (in case if volunteers divers involved) as the method does not require high level of expertise (except special skills needed for diving) Feasibility depends on accessibility to the diving areas	Not appropriated in low visibility areas (typical for depths over 2 m). Diver experience may affect the degree of detection. There is always an element of risk for the divers. Could become expensive due to local legal requirements (mainly due to prescriptions for equipment standards and human resources needed).
	By towed camera	Enables less biased sampling compare to monitoring with direct observations Does not require high level of expertise or expensive equipment	Requires a boat, is limited only to good weather conditions Not suitable in areas with thick bottom vegetation or rugged terrain; Technical failures are usually noticed only afterwards (in the office/lab).

Kind of litter targeted	Monitoring method	Does	Does not/is not
		Low demand of human resources

Video materials can be analysed by others, which brings more objectivity;

Recorded materials can also be used for other purposes | |