European Marine Strategy Framework Directive
Working Group on Good Environmental Status
(WG-GES)

Monitoring Guidance for Marine Litter in European Seas

Draft Report

CHAPTER 2
General Approaches & Strategies for Marine Litter Monitoring

July 2013

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Draft Guidance Report:

TSG-ML was tasked to deliver guidance so that European Member States could initiate programmes for marine litter monitoring. As monitoring must be operational by 2014, first guidance was required by mid-2013. The draft Guidance report provides the basis for the marine litter programme however since new information continues to be compiled TSG -ML can review and update this guidance later in 2013.

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2. General Approaches & Strategies for Marine Litter Monitoring

An important milestone in the implementation of the Marine Strategy Framework Directive (MSFD – 2008/56/EC) is the establishment of monitoring programmes by 15 July 2014. This chapter describes general issues associated with monitoring of marine litter. This includes advice on setting up monitoring approaches/strategies to be used for monitoring planning, taking into account knowledge development and costs of monitoring. It does not include advice on assessment, scaling and aggregation. This will be prepared at a later stage.[1]

The aims of monitoring in the MSFD are related to the GES, indicators and targets. Article 11 of the MSFD regarding monitoring programmes from Member States provides legally binding requirements to establish and implement coordinated monitoring programmes for the on-going assessment of the environmental status of EU waters. WG GES initiates the development of a framework for coordinated monitoring programmes, which will deliver data to assess whether GES and associated environmental targets are being achieved, in close cooperation with WG DIKE.

The monitoring requirements for implementing the MSFD-Descriptor 10 successfully are directly dependent upon available measurement techniques of demonstrated quality, which will be able to deliver reliable data at affordable costs. Besides the already available monitoring methods, novel methods and automated monitoring devices can play a complementary role by improving the quality of monitoring results. The MSFD will only be a powerful management tool if monitoring data are appropriate for the purpose, reliable and of comparable quality.

There are different aims for monitoring, including assessing the environmental status, the temporal and spatial trends, and the level of achievement of environmental targets, the identifications of sources and their strength or the effectiveness of measures. Different aims imply different approaches when designing a monitoring program.

2.1. Monitoring requirements of the MSFD and the Common Implementation Strategy

In this chapter, we take one step back and look at the purpose of monitoring in general, and assess the level of suitability of the different monitoring methods to achieve the different monitoring purposes.

According to the monitoring requirements of the MSFD, in **Article 11 (1)** it is specified that "*on the basis of the initial assessment made pursuant to Article 8(1), Member States shall establish and implement coordinated monitoring programmes for the ongoing assessment of the environmental status of their marine waters on the basis of the indicative lists of elements set out in Annex III [of the MSFD] and the list set out in Annex V, and by reference to the environmental targets establish pursuant to Article 10.*" Furthermore, "*Monitoring programmes shall be compatible within marine regions or subregions and shall build upon, and be compatible with, relevant provisions for assessment and monitoring laid down by Community legislation, including the Habitats and Birds Directives, or under international agreements.*" In addition, **Article 11 (2)** indicates that "*Member States sharing a marine region or subregion shall draw up monitoring programmes in accordance with paragraph 1 and shall, in the interest of coherence and coordination, endeavour to ensure that: (a) monitoring methods are consistent across the marine region or subregion so far as to facilitate comparability of monitoring results; (b) relevant transboundary impacts and transboundary features are taken into account.*"

Moreover, Annex V of the MSFD sets out a list of needs for monitoring programmes. Elaborating on this, during the 10th meeting of the MSCG (6-7 May 2013) a set of key principles and messages that should be taken into consideration in planning the MSFD monitoring programmes have been identified. These were summarized as 7 recommendations in the MSCG report (MSCG/10/2013/5rev). These are listed below, with comments on how the TSG-ML addresses these issues with the protocols listed in chapters 3-7 in the present report.

[1] After discussions on sources in TSG ML and advice on scaling and aggregation prepared for MSCG by a contractor , commissioned by DG ENV.

Recommendation 1: The core purpose for the establishment and implementation of coordinated monitoring programmes is the "on-going assessment of the environmental status" and related environmental targets in accordance with the MSFD strategies and management cycles. All other elements of Article 11 (1) and (2) and Annex V are detailed specifications or conditions.

How this relates to the proposed protocols:

All protocols suggested are mainly aimed at assessing environmental status and environmental targets. All protocols can supply quantitative data, and allow the assessment of trends. The beach litter protocol is also designed to identify sources by using a detailed list of identifiable items, while other protocols can do this to some extent through their lists of items, but also by modifying the sampling strategy (where and when to sample) to match the likely effects of specific measures. This is discussed further in section 2.3.2 below.

Recommendation 2: The monitoring programmes have to be "coordinated", "compatible", "coherent", "consistent" and "comparable"

How this relates to the proposed protocols:

In our analysis of the protocols, the issue of compatibility and coherence has been important. Most of the protocols proposed can be applied across the European scale (see "Geographic Applicability" in Table 2). However, some of the protocols for litter in biota cannot be identical across Europe, for the simple reason that the proposed species do not all occur across Europe. For those protocols, we try to emphasize how to develop regional (or sub-regional) approaches that can be comparable. Coordinated coherent monitoring effort, especially where lab analysis of samples is involved, is practically and financially most efficiently set up when regional parties jointly assign and fund a coordinating research organisation.

Recommendation 3: Build upon and integrate as much as possible, existing well-established monitoring programmes and relevant guidance under Habitats and Birds Directives, the Water Framework Directive and other relevant EU legislation as well as under Regional Sea Conventions and other international agreements.

How this relates to the proposed protocols:

As marine litter monitoring has not been addressed previously by other EU directives (and only in few regional or national programmes), the direct integration with existing monitoring programmes is difficult. However, there is much to be gained by combining the collection of marine litter related data for the MSFD with other existing monitoring programmes, both for other descriptors in the MSFD and for other Directives. We refer to such combination as "windows of opportunity" and this is discussed further in section 3.2.2 below (see also "windows of opportunity" in the Table 2).

Recommendation 4: Data and information resulting from the monitoring programmes should be made available in a comparable format and for interoperable use and feed into the "Marine Knowledge 2020" process.

How this relates to the proposed protocols:

Many of the issues of data handling are the same for marine litter as for other MSFD descriptors. However, the use of common or at least compatible lists of item categories across protocols and environmental compartments is considered important by the TSG-ML. For this purpose, the TSG-ML has developed a "master list" of item categories, and although many of the protocols assessing macro litter can only identify a subset of these item categories, these should be coherent with the master list. This is further discussed in sections 2.3.3 and 2.3.5 below. It needs to be ensured, through the use of these harmonized protocols, that the reporting units are compatible and that a common set of metadata is supplied. The availability of joint databases or portals is important in the process of harmonization and for an efficient use of the data.

Recommendation 5: Monitoring programmes need to be adaptive to enable appropriate reaction on e.g. changes in the marine environment, new understanding and emerging issues.

How this relates to the proposed protocols:

The proposed protocols cover several environmental compartments (beach, water surface, seafloor, sediment and biota). From that point of view, emerging issues across a wide geographical and environmental range could in theory be detected, depending on how member states choose to design their monitoring programmes. Most protocols are non-selective in what they can detect, i.e. although there are lists of item categories to be quantified, any other items found should also be noted and specified as much as possible. If a new item becomes common, this will thus probably be picked up by the monitoring. This has indeed happened several times within the OSPAR beach litter monitoring protocol. Procedures for incorporating new item categories into the master list could be developed but this is of course dependent on how member states choose to administrate this list. With marine litter being an emerging issue, it can be expected that initial monitoring efforts are needed in order to assess the extent, variability and spatial distribution of marine litter. Within the adaptive MSFD framework these monitoring efforts can then be adjusted in an iterative way in order to provide the necessary data in the most efficient way.

Recommendation 6: Linking monitoring to assessment needs, including the use of risk-based approach as basis of a flexible monitoring design.

How this relates to the proposed protocols:

A complete analysis of risk should ideally include quantitative knowledge of harm. An analysis of harm will be a focus area for the work by the TSG-ML during 2013-2014. In the event of insufficient quantitative data availability on harm, we choose to address the risk-based approach by assessment of where the amounts of litter are likely to be highest or the type of litter has the largest impact (e.g. microplastics).[2] Already in the selections of protocols, a degree of risk-based approach is used. For example, we propose to measure litter on the sea surface rather than in the whole water column, because pilot studies indicate that litter quantities are higher on the sea surface. Similarly, the protocols for monitoring on the sea floor propose to assess where litter tends to accumulate (e.g. through pilot studies or oceanographic modelling), and then to direct monitoring towards such areas. While there may be problems to generalize the results from this kind of monitoring to other areas (see section 2.3.4 on site selection strategies below), such strategies are in line with a risk-based approach.

Recommendation 7: Take account of the differences in scientific understanding for each descriptor in the monitoring programmes and apply the precautionary principle[3].

How this relates to the proposed protocols:

We acknowledge in our descriptions of protocols that there are different levels of maturity of different protocols. While, e.g., the beach litter protocol or the protocol for ingested litter in birds (applied to fulmars-*Fulmarus glacialis)* have been used for many years. On the other hand, methodologies such as ones for microparticles are currently an area for intense research. This is reflected upon in the different chapters in this report (see also section 2.3 below and "Level of Maturity" in the Table 2).

2.2. Monitoring marine litter under the Regional Seas Conventions

MSFD Article 11 describes the need to develop coordinated monitoring and assessment programmes.

Article 6 of the MSFD recommends Member States to use existing regional institutional cooperation structures, such as those under the Regional Sea Conventions (RSCs), in order to achieve coherence and coordination of their marine strategies and build upon relevant existing programmes and activities. The RSCs have developed monitoring guidance and environmental assessment schemes according to their current programs and recommend contracting parties to use them for their monitoring and assessment.

A summary of the monitoring guidance related to marine litter developed by the RCSs is given below:

2 The master list does include some information on the potential "harm" single litter items can cause (e.g. ingestion, smothering, entanglement)

3 See COM (2000) 1 on the precautionary principle
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2000:0001:FIN:en:PDF

2.2.1. OSPAR Convention

OSPAR is in the process of developing a Monitoring Framework combining monitoring for the MSFD with complementary "regular" OSPAR monitoring. The effectiveness of collective action in OSPAR can be enhanced by managing the entire chain of monitoring and assessment in a more streamlined way so that resources are allocated to those activities which result in the greatest overall net benefit. The Monitoring Framework is intended to aid in the identification of main areas for development and provides overviews of thematic priorities and how certain common monitoring questions are addressed under various themes. At this moment coordinated monitoring is being carried out under the Coordinated Environmental Monitoring Programme that includes beach litter. A special arrangement is in place for monitoring on plastic particles in stomachs of fulmars in the North Sea region. Further (Common) indicators are under development (e.g. IBTS seabed monitoring).

With regard to the process of identification of 'common indicators and associated monitoring needs' OSPAR CoG in May 2013 noted that the objective is to agree at OSPAR Commission 2013 on a combined list of common indicators across OSPAR, including their monitoring requirements, with an indication of (sub-) regional importance and/or applicability to feed into the review of the Joint Assessment and Monitoring Programme (JAMP) by 2014. To achieve this, OSPAR will differentiate between 'common indicators' and 'candidate indicators' with clear associated implications as regards (a) inclusion in the next JAMP and (b) concomitant implications for Contracting Parties' monitoring commitments and requirements;

In principle 'common indicators' should be implemented by all Contracting Parties that are coastal states of the OSPAR maritime area where they are scientifically relevant. Certain indicators may need to be regionally adapted to specific environmental conditions or pressures. Specific indicators may be applicable to only one or more particular OSPAR Regions;

Contracting Parties retain the option to 'opt out' on the application of a common indicator within their waters. Contracting Parties should be invited to explain the reasons and provide justification of their opting out within the relevant Committee where that particular indicator is made operational (monitoring and assessment) (e.g. where there is no significant risk to the marine environment or where the costs would be disproportionate taking account the risks to the marine environment; the CEMP opting out conditions, …);

CoG advised to use the following concepts and understanding across all Committees working on indicators:

i) an indicator qualifies as a 'common indicator' if its application is considered feasible either on the basis of on-going monitoring or after a relatively short period of development and testing (i.e. within a period not exceeding 1-2 years so that it can still be operationally used by 2016 within the JAMP); and

ii) an indicator qualifies as a 'candidate indicator' if further development is required before a decision can be taken to adopt them as a "common indicator", with the intention that it becomes operational as soon as possible once adopted;

Contracting Parties are recommended to take into account the current state of the work on common indicators in the drafting of their national MSFD monitoring programme.

OSPAR Contracting Parties are discussing how to prepare their monitoring programs in a coordinated way including:

a) feasibility and coordination aspects of national monitoring, including the question of practical implications for transboundary cooperation for features and metrics covered by an OSPAR draft common indicator;
b) the reporting of regionally coordinated elements of monitoring, and possible joint reporting on monitoring programmes;
c) early opportunities for coordination of monitoring, what benefits can be derived from wider EU developments such as the JPI Oceans, and any project in the OSPAR maritime area that is started under the EC DG Environment New Knowledge call for projects.

In 2013, OSPAR decide to adopt beach litter has a common indicator, ingestion in fulmars as a common indicator in the Greater North Sea area, while for other areas other species are candidate indicators. Seafloor is also a candidate indicator.

2.2.2. Barcelona Convention

Within the framework of the Barcelona Convention, a Policy Document and the associated Strategic Framework for Marine Litter management was adopted in 2012. One of the main objectives of this Framework is to follow the trends of marine litter generation and distribution through the establishment of a monitoring programme for marine litter in the Mediterranean Sea based on the Ecosystem Approach. In addition, these monitoring programmes should indicate sources and activities which lead to marine litter production and, most importantly, should indicate if the adopted litter management/mitigation strategies are effective or need further adaptation. Furthermore, monitoring should facilitate the assessment of the ecological, financial and social impact of litter (threats to marine biota and damage to health, tourism, recreation, etc.).

A monitoring programme for litter is expected to be developed during the biennium 2014-2015, in the framework of the new integrated monitoring programme for the application of the Ecosystem Approach. The recently developed "UNEP/IOC Operational Guidelines on Survey and Monitoring of Marine Litter" is going to be used in order to adopt a useful standardised methodology. At the regional level MED POL will coordinate this activity and promote the appropriate methodologies. It will be responsible for the evaluation and dissemination of marine litter related information which has been provided by designated national agencies. At the national level, it is proposed that the main institutions or groups involved in marine litter data collection: NGOs, Local/Port Authorities and universities, set up a simple coordination structure and select one of them to act as the designated focal point/national agency for collecting the data and keeping record of the carried out marine litter monitoring activities.

One of the most recent developments has been the elaboration of a draft Regional Action Plan on Marine Litter (May 2013, Barcelona) which will be legally binding once adopted by the Contracting Parties of the Barcelona Convention (planned in December 2013 in Istanbul). Article 12 of the Regional Action Plan refers to a Mediterranean Marine Litter Monitoring Programme which will be in synergy with the relevant international and regional guidelines including the ones produced by the TSG ML and will be prepared by 2014/2015.

2.2.3. Helsinki Convention (HELCOM)

Within the HELCOM convention area in the Baltic Sea the coordinated joint monitoring programme COMBINE is under review with the aim to revise and agree on it by 2013. The revised HELCOM Monitoring and Assessment Strategy will focus on aligning the monitoring with the HELCOM ecological objectives in order to follow up the effectiveness of the implementation of the Baltic Sea Action Plan. One of the key changes in the monitoring programme will be the focus on the core indicators. The monitoring requirements arising from the EU Marine Strategy Framework Directive, e.g. new indicators such as litter and noise will be included in the revised monitoring strategy. Of the HELCOM projects, CORESET is dealing with indicators in the context of determination of GES for the marine environment and HELCOM MORE is dealing with the revision of the HELCOM monitoring strategy and gap analysis. Within this work it has been recognized that marine litter needs to be addressed as well.

At the moment, no country in the Baltic Sea conducts systematic coast-wide[4] monitoring of marine litter. HELCOM made a questionnaire of the national monitoring for the purpose of the monitoring review process. According to the questionnaire, several countries are starting surveys by making pilot studies or participating in various regional or European wide projects. New information is also generated by research projects (e.g. MARLIN project).

HELCOM has the Recommendation 29/2 for a common methodology for monitoring of beach litter (HELCOM, 2008). It recommends the Governments of the Contracting Parties to recognize one unified method of sampling and reporting of marine litter found on beaches and to call upon different marine litter survey initiatives to use it in order to achieve comparable results. The method, which focuses on at

4 Germany conducts systematic surveys but not coast-wide.

least 1 km long and exposed sand or gravel beaches with at least 100 meters surveys, is described in the Recommendation. There are no commonly agreed methods for monitoring of other kinds of litter, but HELCOM has decided to follow the development of methods on the European level and agree on the methods during the revision process of the monitoring programme.

However, there have been very few initiatives in the Baltic Sea to survey sources, amounts or impacts of litter. The HELCOM-UNEP report from 2007 and also the HELCOM GEAR document 2/2012 gives an overview of some sources and amounts of beach and floating litter.

For the HELCOM 2013 Ministerial Conference 3 October 2013 the aim is to get agreement on common indicators and associated targets by 2015 to collect scientific data on quantities of marine litter, its impacts, composition, sources and pathways, and monitor the progress towards achieving the agreed goals, with the aim to review the effectiveness of the measures by (2025/2020).

2.2.4. Bucharest Convention

Currently the Black Sea Commission elaborates on the new text of the Black Sea Integrated Monitoring and Assessment Program (BSIMAP) for the years 2013-2018. Development and implementation of the BSIMAP is stipulated in Article XV of the Convention on the Protection of the Black Sea Against Pollution (Bucharest Convention) and its Protocols. BSIMAP is based on national monitoring programs, financed by the Black Sea states. Outside of national monitoring programs, thematic scientific surveys related to various environmental problems are carried out in the framework of different projects, financed by national authorities and/or donors.

Traditionally the BSIMAP employs the DPSIRR (Drivers, Pressures, State, Impact, Response and Recovery) approach allowing detection of negative impacts as well as the effects of measures taken, thereby enabling the necessary corrective actions to be decided on and introduced in a timely manner[5]. The choice of parameters to monitor is related to the main environmental problems recognized in the Black Sea region and re-evaluated every 5 years based on important reports – State of the Environment of the Black Sea (SoE Report) and Report on the Implementation of the Strategic Action Plan for Environmental Protection and Rehabilitation of the Black Sea (BS SAP) initially adopted in 1996 and later amended in 2009.

The updated BSIMAP for the years 2013-2018 has been drafted in the framework of the EU funded project "Support to the Black Sea Commission for the Implementation of the MSFD" (MSFD Project) which was finalized in 2012 and will undergo the national consultations. The main approaches of the updated draft BSIMAP are harmonized with the MSFD as well as aimed to be compliant with relevant assessment processes within the Black Sea SoE Report. These include BSIMAP 2006-2011, Guidelines and manuals (adopted or under development) supporting the implementation of the provisions of Bucharest Convention and the BS SAP 2009 and reporting templates to be filled in with the national statistical and monitoring data.

The process of the 3rd Scientific Assessment for the SoE Report has been launched in November, 2012 in which the relevant approaches of the MSFD were also taken into account.

At the same time, since only two countries (Romania and Bulgaria) out of the six Contracting Parties to the Bucharest Convention - are implementing the provisions of the EU MSFD Directive, the main source of monitoring in the Black Sea Basin is the one described in the BSIMAP and based on the parameters, introduced by the BS SAP 2009.

The BS SAP (2009) addresses the main areas of concern, and their causes, through the aims of four Ecosystem Quality Objectives (EcoQOs). The four EcoQOs are: EcoQO 1: Preserve commercial marine living resources; EcoQO 2: Conservation of Black Sea Biodiversity and Habitats; EcoQO 3: Reduce eutrophication; EcoQO 4: Ensure Good Water Quality for Human Health, Recreational Use and Aquatic Biota.

Marine litter is only mentioned as one of the descriptors as well as the parameter of discharges under the EcoQO 4. Nevertheless, the methodology of its assessment (together with the assessment of marine noise)

[5] The BSIMAP for 2006-2007 was taking into consideration the DPSIRR model to the extent possible and aimed at future development and publication of the Second SoE Report for years 2001-2006/7.

is to be further developed as soon as the updated BSIMAP for 2013-2018 will be adopted by the Black Sea Commission.

One of the relevant initiatives, the Regional Activity on Marine Litter, supported by UNEP, was launched in 2005. The main outputs of this activity, completed in mid-2007, were the documents "Marine Litter in the Black Sea Region: A Review of the Problem" and a "Draft Strategic Action Plan for Management and Abatement of Marine Litter in the Black Sea Region". The first report evaluated existing data, policies, activities, and institutional arrangements concerning marine litter in the Black Sea region and proposed several actions to deal with the problem, which eventually led to the adoption of a BS SAP 2009.

Thus, there is an urgent need to work on the elaboration of the methodology for requirements of assessment and monitoring of marine litter in the Black Sea and to develop the set of indicators for marine litter to be included in the SoE Report and annexes to draft BSIMAP 2013-2018.

2.3. Establishing a monitoring framework for marine litter

In order to provide concrete and useful recommendations on for the implementation of the MSFD Descriptor 10 and the establishment of appropriate monitoring strategies, there is a need to make an analysis/evaluation of different parameters and to respond to a series of questions.

First of all a comparison and final assessment of the different existing monitoring methods is needed, in terms of suitability to achieving the aims of the monitoring programmes. This requires some type of criteria. The identification of these criteria is not an easy task, given that some can both be qualitative (e.g. “can this method be used to provide early warnings of major changes?”) and quantitative (e.g. “Is this method cost-efficient?”, which ideally should contain some quantitative measure of precision/cost unit). Other crucial issues to be addressed and clarified are the spatial distribution of survey sites, the frequency of sampling, the QA/QC needs, the arrangements for management/handling of the monitoring metadata at local, national (and/or regional level), etc..

The COM DEC identifies indicators to characterize marine litter, including microparticles, in the different marine environmental compartments (beach, water column, water surface and seafloor) and one indicator to determine impacts of litter on marine life (biota) ,emphazising that this indicator needs to be further developed.

Fulfilling the monitoring requirements of the MSFD is a major undertaking and resources for monitoring can be limited. Member States are therefore faced with the decision of what to monitor, and whether it is essential to assess litter amounts in all of the environmental compartments mentioned above. It is then important to remember that these different compartments can indicate different pathways and sinks for marine litter, and do not necessarily substitute each other.

Our present understanding of litter in the marine environment, which is based on information for only a subset of these compartments, is not sufficient to draw conclusions about the trends and amounts of litter in the various size categories in the total marine environment. Biota indicators have a different but not less important function: they give an indication of possible harm. Furthermore, the compartments selected for monitoring should also provide information for the identification of sources, not only in terms of nature and purpose of the items but also their original source (which can be related to incorrect or accidental disposal) and possibly the pathway through which the item entered the marine environment. Again, this may vary among the different environmental compartments. At the same time, we acknowledge that the protocols/methods listed in this report have different degrees of maturity, i.e. what extent they are tested in the field and in common use.

Member States may feel hesitant to embark on full-scale monitoring programmes based on methods/protocols that may need further testing. We strongly recommend Member States, which currently only have plans to monitor in a subset of environmental compartments, to start at least with small pilot, research or development projects in other compartments, in order to get baseline data to be able to make an informed decision about future full-scale monitoring programmes. Without some information about trends and amounts in all the marine compartments, a risk-based approach to litter monitoring and measures is not possible.

2.3.1. Defining the aim and objectives of monitoring

Defining the aim and objectives of monitoring should precede any selection of protocols and has profound consequences for the decision on what to measure, where and when to monitor, the number of replicates to take and so on. The basic aims of monitoring for the MSFD is set up in the Directive itself, as outlined in section 2.1 of the present report. The report by the MSCG (MSCG/10/2013/5rev) makes an interpretation of monitoring needs to primarily address:

1) Assessment of whether GES has been achieved or maintained, and if environmental status is improving, stable or deteriorating;
2) Assessment of the progress towards achievement of environmental targets;

Monitoring may have different aims and purposes in different stages of the management cycle. As discussed above, the maturity of monitoring protocols for marine litter varies, and member states may not choose to presently initiate full-scale monitoring programmes in all compartments of Descriptor 10. However, if no baseline exists (yet) research monitoring should be undertaken.

A similar typology of monitoring programmes to the WFD could be used: surveillance, operational and investigative. In the surveillance monitoring, it has to be defined what is needed: monitoring of state, against impacts, of pressures, of activities/measures. There may be also be other types of monitoring such as "supportive" monitoring, e.g. for pressures and impacts.

2.3.2. Assessment of monitoring tools/methodologies

All methods/protocols suggested in this report are primarily designed to monitor environmental status, and to measure progress towards GES. They can also be used to measure the achievement of environmental targets. The present lack of knowledge about harm levels of litter is such that absolute targets are difficult to set, and therefore many Member States instead formulate trend targets. An example of how absolute targets can be formulated relates to the protocol for litter ingested by fulmars, where a quantitative level target has been formulated by OSPAR as an EcoQO ("less than 10% of beached Fulmars has more than 0.1g of plastic in the stomach over a continuous period of at least 5 years in all North Sea region" (OSPAR, 2008)).

The usefulness of the methods/protocols for assessing the effectiveness and impact of measures depends on the characteristics of the measures. If measures can be expected to have differential impacts in space or time (e.g. measures will lead to decreased amounts of litter in some geographical areas or during some seasons), then the design of most protocols suggested here can be modified to address this, *e.g.* by focussing monitoring in areas where litter amounts are expected to change as a result of the measures. A possible exception is when protocols are tied to other monitoring, programmes, such as the seafloor monitoring done during scientific trawl programmes (IBTS, MEDITS etc.), because that would require that other programmes are changed accordingly. The resource efficiency of combined programmes comes with the cost of decreased flexibility of individual programmes.

Another way that these protocols can address measures is if such measures will lead to changes in the composition of litter, perhaps in the decrease of a particular suite of items (e.g. measures within the recreation sector should lead to a decrease in items related to recreational activities). This will be most easily picked up in protocols with a high level of detail in the categorization of items. Beach litter monitoring is the protocol that would most likely be useful for such an approach (with the very detailed categorisation used in most beach litter protocols). Most other protocols allow for less detailed discrimination of litter items or as in the case of micro-particles only for an identification of the material (e.g. type of plastic used), and are thus less likely to detect such changes. However, all protocols have some kind of categorization, and could be used for some forms of assessment of measures. For example, monitoring of litter in fulmar stomachs has shown decreasing trends in industrial plastic pellets, a likely indication of successful measures to decrease spillage of such items. Another example could be the ability to identify plastic water bottles when monitoring litter on the seafloor using trawls: measures against improper disposal of plastic water bottles could potentially be evaluated with seafloor monitoring.

For an overview of the different protocols (in the 4 different compartments) regarding their maturity, level of detail generated, costs, geographic applicability, main limitations and potential to use "windows of opportunity" to increase cost-effectiveness, please see Table 2, under section 2.6.

Brief overview is provided below about the maturity of protocols. More details in the following chapters.

Maturity of protocols - general overview:

Beach-visual: Beach litter monitoring is a well-developed monitoring tool to determine trends of litter in the environment. It can also supply detailed information on composition and amount of litter, which can provide an indication of sources of litter and the potential impact of measures. Further development of this protocol includes the development of a standard statistical analyses method and a refined method for the identification sources.

Floating-Visual: Monitoring by visual observation is being done but without a harmonized protocol. The protocol developed by the TSG-ML provides comparability by use of a common approach and harmonized categories for reporting.

Floating – manta trawl: This protocol for monitoring of micro litter has been subject to testing in several pilot projects in North East Atlantic and Mediterranean waters.

Sea-Floor-IBTS: The sea-floor-IBTS is a protocol that is combined with existing trawling programs for the assessment of fish stocks. The sampling protocols are well developed, and recently standardized protocols for categorization of Items have been added to the manuals for the IBTS. Harmonized protocols are also currently used in the Mediterranean, and is planned to be incorporated as standard protocols in the MEDIT program too.

Sea-Floor–Video on deep sea-floor: The video protocols for seafloor litter in deep areas have been employed in several projects in e.g. France. Similar techniques are used for other types of monitoring (e.g. for seafloor biota), and there are possibilities for coordination with monitoring for other descriptors and other directives.

Sea-floor-Divers: The protocols for monitoring litter on shallow seafloor using divers are also using techniques commonly used for other types of monitoring, and also for this protocol there are possibilities for coordination with monitoring for other descriptors and other Directives.

Sea-floor –Video in shallow waters: This protocol is tested in a pilot project, and can therefore be regarded as less mature than e.g. the diving protocol. On the other hand, it shares essential characteristics with both the diving protocol, and with the video protocol for deep sea-floor. It can be a viable alternative to the diving protocol when conditions prohibit diving. There are also possibilities for coordination with monitoring for other descriptors and other directives.

Micro particles - there is a range of existing methods to sample beaches, these do provide standard methods to give comparable index of contamination but recent reviews have identified some limitations of these approaches. New methods are also being developed. There is a need for optimization and comparison of methods in the near future but this is not considered essential prior to initiating monitoring via existing approaches. Sub-tidal sediments have been less extensively sampled but in principle could be sampled using similar methods to intertidal sediments. A range of methods are also available for sampling the water column but again there is a need for optimization and inter calibration. However, the TSG-ML considers there are sufficient reliable approaches to initiate monitoring at the present time. There are only a limited number of reports on sampling microparticles in biota. Approaches for monitoring can be suggested at this time, but it is thought the most cost effective approach is to extend existing monitoring of biota (e.g. in fulmars or fish) to incorporate and quantify any micro particles present.

Biota-Birds (ingestion): Based on the fulmar litter monitoring, is a well-developed monitoring tool to determine trends in the amount and composition of litter ingested by marine birds and thus impacts on marine life. It is also suitable to be used as a floating litter indicator. Trends can be tested in a standard way, however, it only partly fulfills the need for a Community-wide standardized method since its use depends on the geographic distribution of the species selected. It can, however, be applicable at a regional or sub-regional level.

Biota-Turtles (ingestion): The turtle protocol has recently been developed, based on the protocol for fulmars. As for the Birds-protocol, its use depends on the distribution of the species considered.

Biota-Fish (ingestion): This is presently an area of intense research activity. The TSG-ML has decided to recommend a general protocol for application to measure trends and regional differences in ingested litter in benthic and pelagic fish. Its application depends on the distribution of the species considered. **Biota-plastic litter in nests and entanglement :** The use of marine litter (especially plastic) by birds as building material for their nests is quite widespread in some species and leads to entanglement and mortality of adult birds, their young and visiting immature birds. A protocol for application was recently developed.

Biota-Entanglement: Entangled birds and marine mammals are recorded during some beached animals monitoring programs. However, where measured, the incidence of entanglement of beached birds is quite low for most species. In marine mammals, numbers of beached animals and especially cetaceans are often high and many have body marks suggesting entanglement. Although it can be difficult from looking at the animal to distinguish between fisheries by-catch and entanglement in litter items, pathologists are able to predict for this difference. The TSG-ML has concluded that the assessment of entangled animals requires further development before it can be suggested as a monitoring method.

2.3.3. Quality Assessment /Quality Control approaches & needs

Since important decisions will be taken based on the results obtained by monitoring programmes it is important that the data generated will be of acceptable quality. In order to ensure an adequate quality and integrity of marine litter monitoring data, investments must be made in capacity-building of the regional, national and local survey coordinators and managers.

The use of quality control/quality assurance measures such as intercalibrations, use of reference material where appropriate and training for operators should accompany the implementation of the monitoring protocols. These approaches should be developed in the context of dedicated research.

The value of the results of monitoring programmes implemented to assess litter in the different regional seas and in the various compartments of the marine environment (beach, seafloor, sea-surface etc.) can be enhanced if a standard list of litter items is used as a basis for preparing assessment protocols. A master-list of categories of litter items has been prepared (See further in Chapter 8 on categories). The use of appropriately developed field guides (such as the one to be developed for monitoring litter on beaches) with examples of each litter type, will assist survey team members (particularly volunteers) to be consistent in litter characterization. Such field guides should be coupled to the master list of litter items and be made available over the web to increase consistency between survey teams working at more distant (remote) locations.

The use of standard lists and definitions of items will enable the comparison of results between regions and environmental compartments. Items can be attributed to a given source e.g. fisheries, shipping etc. or a given form of harm e.g. entanglement, ingestion etc. The value of monitoring results can be increased further by facilitating the identification of the main sources of marine litter pollution and the potential level of harm litter encountered in the marine environment might have. This will enable a more target-orientated implementation of measures. Throughout the period 2013-2014, the TSG-ML will further elaborate on approaches to link detailed categories of items to the most probable source and to other important strategic parameters that can help to design and monitor measures.

2.3.4. Spatial distribution of survey sites: site selection strategies

The strategy used to select sites is partly a statistical/technical issue, but foremost it is related to the purpose of monitoring, i.e. a decision to be taken when a monitoring strategy is decided. The site selection strategy has as fundamental consequences for the monitoring analysis as has the selection of the survey method. Two monitoring programmes are not compatible and comparable if they use exactly the same survey methods, but use different site selection strategies (e.g. special site selection on the basis of litter pollution levels or a randomised selection of sites.

The principles for strategies of site selection are described in many handbooks on statistics or monitoring. On a fundamental level, one can either choose sites individually because they have certain characteristics of interest or through a representative strategy using a random selection of sites meeting certain characteristics (a randomised selection strategy):

a) Choosing special sites: Here sites are chosen because they are examples of certain characteristics. This can be because they are considered to have certain environmental or societal values – for example, beaches that have the highest number of visitors, because they are situated in certain areas or because they have certain characteristics in the variable that the monitoring programme uses (e.g. sites that tend to have heavy litter loads). Usually the same sites are revisited during subsequent surveys in order to assess trends.
   The advantage of this approach is that because sites are chosen for certain characteristics, the litter load they receive will probably be similar, and the variation between sites in the monitoring programme will be low. If so, the ability to detect statistically significant trends will be higher.. The main disadvantage of the strategy is that the sites represent nothing else other than themselves, as they are deliberately chosen, and are therefore different from other sites. In other words, we cannot use them to make statements about other sites or average litter pollution levels

for a given region. Statistical results may also be difficult to interpret, both for technical and philosophical reasons.

b) The representative strategy. Here sites are chosen randomly among a large number of possible sites meeting certain criteria decided by the method and the monitoring purpose. Sites may be revisited or changed for each monitoring occasion; the important issue is how they were selected in the first place.
The main advantage of this strategy is that results can be extrapolated to other possible sites, i.e. we can use the results to make statements of larger areas. An obvious disadvantage is that the variation among sites usually will be higher than when choosing individual sites, making it difficult and costly to find statistically significant trends.

In practice, these two strategies are rarely used in their pure form, instead a combination is used: stratified randomised sampling (e.g. OSPAR beach litter protocol). Here certain criteria (more or less strict) are set up, and sites meeting these criteria are (more or less) randomly chosen. The criteria may include geographic, environmental, societal and other factors. This is also compatible with a risk-based approach: priority should be given to monitoring programmes that measure environmental status and trends in sites where the risk of harm is greatest. The selection criteria for the site selection should then be based on prediction of potential harm. Potential harm could be based on actual knowledge of which environmental values are most sensitive to harm. However, the current knowledge of how different species or biotopes react to litter is insufficient, and this should be an area of further research. Another approach to harm may be values that are specifically "valuable" to society for other reasons i.e. economically, socially or environmentally. A third approach is to assume that harm is more likely to occur in areas/environments where there is much litter, and therefore select sites based on screening monitoring to identify them. While this option may be practical and make sense in terms of societal needs, it is important to remember that we do not know if statistical trends from such sites are representative of other sites (probably not), but represents a "worst case" scenario.

One way to make best use of limited resources is to take advantage of other studies to add on litter monitoring (what we call "windows of opportunity"). An example that we advocate is to combine monitoring for litter on the sea bed with scientific trawling for fish stock biomass estimation (IBTS, BITS, MEDITS). In such a case, the selection of sites is presumably designed for the purpose of the original monitoring programme, and the possibilities for representation of other areas are already defined. If attempting to use such a scheme, it is important to analyse the sampling strategy for the original programme to assess if this is suitable for litter monitoring too.

For marine litter, we advocate a stratified randomised sampling strategy where such a strategy is possible. We also advocate that the purposes of the monitoring programmes define the criteria for selecting sites. Simplification is necessary when resources are limiting, and concentration of monitoring effort the logical result.

Monitoring for trend analysis: Statistical power or how many sampling stations are needed to detect a change?

The ability of a monitoring programme to show a statistically significant trend or difference, if such a trend really exists, is called statistical power. Statistical power is influenced by the magnitude of the trend, the variation among replicates, and the number of replicates.

The *magnitude of the trend* is a characteristic of the combined system of the environment and our (mis-) handling of litter. In that sense, the magnitude of the trend is dependent on the actions we take against litter. When designing a monitoring programme an important decision is related to the magnitude of change we wish to detect. From a statistical perspective, it is of course easier to detect a large trend than a small trend. The smaller the magnitude we want to detect, the more extensive and expensive the monitoring programme needs to be. If the action plans to tackle marine litter are ambitious aiming to reduce litter amounts significantly, then monitoring programmes will have a greater chance to detect real changes than if action plans are less ambitious (and the expected trends thus less strong).

The *number of replicates* is something that at least theoretically is easy to change (if not in reality due to limited resources). Replicates in the case of litter trends are a combination of monitoring sites and monitoring occasions. Using the same amount of sites, the ability to detect a significant trend is increasing with time. In monitoring programmes, which often are complex with multiple temporal and spatial layers, the actual number of replicates is less intuitive.

The variation among replicates is a characteristic of the system studied. All biological systems tend to be very variable. To a certain extent we can influence this by having well defined monitoring protocols and quality assessments, to minimize the added variation due to handling. More important, however, is the ability to decrease variation by limiting variation among sites, by introducing criteria for the sampling sites as described in the section on site selection strategies above. This is not cutting corners or cheating, but it is important to realize that it comes with a price, that the possibility to extrapolate to un-sampled sites decreases.

A common thing to all three factors influencing statistical power is that it is case specific. It is not possible to give general advice on how many replicates are adequate (except stating the obvious but unhelpful that the more the better). Firstly, decisions about the purpose of a specific monitoring programme and what the sites should represent has to be made, then some estimate of variation is necessary. The data on variation should ideally come from a pilot study using the same sites, but otherwise data from similar programmes can be used. Only thereafter can actual calculations of statistical power (and thus the necessary amount of sites to fulfil the aim of the monitoring programme) be made.

An important and encouraging fact is also that it is of value to start a monitoring programme also if the initial resources are small/limited. The first dates of monitoring can nevertheless be used for subsequent trend analysis (albeit perhaps not with full statistical power), and more importantly, the data collected can be used to refine the design of the programme, including power calculations.

Power calculations for litter monitoring using methods suggested in this report have been done for some protocols, e.g. the Sea-bird litter ingestion protocol applied to Fulmars.

A possible challenge in monitoring of time trends of microparticles

Microparticles may enter the marine environment either as microparticles from the beginning (e.g. from textile fragments or plastic particles in cleaning chemical, etc.), or be produced from larger particles that are fragmenting. If the former case is the dominant source, it is relevant to draw conclusions on detected increasing or decreasing trends. If the latter source (degradation of larger particles) is the main source it is more problematic. Then it is possible to interpret increasing or decreasing trends as a net input of microparticles in the marine environment, when in fact the increase may be caused by changes in the rates of breakdown of larger particles, i.e. not be caused by a change in the total amount of marine litter. In another hypothetical scenario, we might through measures be able to decrease the amount of new particles entering the sea, but will not detect a decreasing trend in microparticles because new microparticles are being produced from degradation of remaining old macrolitter. Studies on the degradation of macrolitter and studies on the release of microparticles from land to the sea are important to solve this possible problem.

2.3.5. Data handling & Reporting

Data handling and reporting of marine litter data refers to raw data and to interpreted data (information): data on the occurrence and composition of litter, on progress towards GES and targets, on sources and on the impact of measures and actions. No specific data handling and reporting recommendations are presented in the thematic protocols.

Data handling and reporting (for the MSFD) are still under consideration both at EU level as well as at Regional Sea level. However, data analysis of litter (as other descriptors of the MSFD) will need to be done at different spatial scales (national, sub-regional, regional and European scales). A data collation system through an online European-wide, relational database management system under the control and direction of the local managers would facilitate such analyses. Responsibility for review and approval of uploaded data should be undertaken by the regional/national coordinator who will clarify any issues with local managers. This would ensure a high level of consistency within each region as well as create a hierarchy of quality assurance on data acquisition. The use of such a system would also support comprehensive analysis of the data providing the opportunity to undertake statistically robust comparisons through time and between survey locations.

The reporting process of data and information under the MSFD (Art 19.3) is being addressed by the Working Group DIKE (Data, Information Knowledge Transfer) and steered by DG ENV and the EEA. The separation between primary data and interpreted information offers a basis for interpreting the Directive's phrase 'data and information' in Art 19.3. The 'information' will be captured in the reporting sheets, whilst the underlying data will largely be made available via other mechanisms, including INSPIRE

and EMODNET, with GMES as a potential source of data. Both elements (data and information) will fall under the auspices of WISE-Marine.

While the linkages between the different existing data systems relevant for the MSFD (at national, regional or other levels) and how they will operate within WISE are still being defined, WISE is moving towards a distributed network system, with the intention that the data will be held at national level.

Special attention should be given to the position and role of the Regional Sea Conventions, both with respect to storage of ML data, QA/QC procedures as well as with respect to (coordinated) reporting and (sub) regional assessments - e.g. a central database for the OSPAR beach litter data already exists. Data input is carried out through the internet.

2.3.6. Knowledge development and research needs

Recommendation 7 from the MSCG Monitoring and Reporting Guidance report states that MS should take account of the differences in scientific understanding for each Descriptor in the monitoring programme and apply the precautionary principle. This is especially valid for Marine Litter, as this is a relatively new field of monitoring (at least for many of the protocols proposed in this report).

The TSG ML report from 2011 summarizes the Research Needs to understand the mechanisms and processes associated with litter at sea. The following research strategy was defined in the 2011 report:

- Clarify any fundamental research gaps required to link quantities of litter and associated harm in the context of GES.
- Within the MSFD context, research must be conducted at the region/sub region level to give a scientific and technical basis for large scale monitoring.
- Research must define priority (highly affected) areas. [6]
- Harmonisation and coordination of common and comparable monitoring approaches are required. [6]
- Research will support guidelines to assess GES on a regional/European scale.

The following short term research priorities to support the start of monitoring by 2014 had been identified in the 2011 TSG-ML report:

1) Evaluate behaviour (floatability, density, effects of wind, fouling, degradation rates) and factors affecting the fate of litter (weather, sea altitude, temperature driven variations, slopes, canyons, bays, etc.) affecting transport.
2) Develop or use existing comprehensive models to define source and destination regions of litter (especially accumulation areas, permanent gyres, deep sea zones), estimated residence times, average drift times and must consider trans-border transportation, from/to MSFD region/sub regions.
3) Evaluate rates of degradation of different types of litter, quantify degradation products (to nanoparticles) and evaluate environmental consequences of litter related chemicals (Phthalates, bisphenol A, etc.) in marine organisms.
4) Identify sources for direct inputs of industrial microlitter particles.
5) Establish the environmental consequences of microlitter to establish potential physical and chemical impacts on wildlife, marine living resources and the food chain.
6) Evaluate effects (on metabolism, physiology, on survival, reproductive performance and ultimately affect populations or communities).
7) Evaluate the risk for transportation of invasive species.
8) Study dose/ response relationships in relation with types and quantities of marine litter to enable science-based definition of threshold levels.
9) Evaluate direct costs to industry, fishing industry, local authorities and governments to ecosystems goods and services.
10) Develop automated monitoring systems (ship-based cameras, microlitter quantification etc.) and impact indicators (aesthetic impact, effects on human health, and harm to environment).
11) Rationalisation of monitoring (standards/baselines; data management/quality insurance; extend monitoring protocols to all MSFD sub regions)

6 See discussion in the present report

Amongst these priorities, point 10 and 11 have partially been researched during 2012/13 and described in this report. Many of the other research points are part of on-going national and (sub) regional research. Two emerging issues are (i) the development of monitoring and assessment tools for riverine litter and (ii) relation between harm and risk. These research questions have been added to the tasks of TSG ML, to be further analyzed during 2013-2014.

A number of European projects have started in 2012/2013, some have been finalized (pilot projects and case studies on loopholes in plastic cycles), most are still under way with projected results in 2014-2015, so after finalizing MSFD Monitoring plans. These EU projects address common marine litter issues (occurrence of litter, loopholes in plastic cycles, awareness campaigns) and specific research questions (fate of litter; degradation; hotspot research; contaminants): MICRO, CLEANSEA, ECsafeFood, BIOCLEAN, STAGES, HERMIONE, PERSEUS, MARLISCO and MARELITT.

The STAGES project: STAGES (Science and Technology Advancing Governance of Good Environmental Status) aims to improve the scientific knowledge base to support the implementation of the MSFD. The STAGES project will bridge the science-policy gap and improve the current scientific knowledge base to allow Member States to achieve a Good Environmental Status (GES) in marine waters. Main lines of activities include: providing a comprehensive characterization and analysis of the marine litter problem (biological, chemical, social, economic, legislative and policy-oriented) in the EU's four main marine regions; proposing innovative monitoring tools and standard protocols to facilitate monitoring marine litter in a harmonized way; presenting cost-effective management measures and policy options to meet the MSFD and other international objectives regarding marine litter. (More info: http://www.stagesproject.eu)

JPI OCEANS: The Joint Programming Initiative Healthy and Productive Seas and Oceans (JPI Oceans) is a coordinating and integrating platform, open to all EU Member States and Associated Countries. The main aim of JPI OCEANS is to increase the value of relevant national and EU R&D and infrastructure investments through a concerted effort achieved by jointly planning, implementing and evaluating national research programmes (more info: http://www.jpi-oceans.eu).

Some of the monitoring protocols as presented in this report still need further development. Specific development steps have been identified in the thematic chapters.

Regional research strategies are being developed. E.g. OSPAR is developing a Science (needs) agenda including science needs for marine litter. Liaising takes place with the STAGES project and JPI Oceans with the aim of communicating OSPAR science needs to EU research projects. For Marine litter an inventory has been made of (future) R&D by Contracting Parties. A (TSG ML wide) update is currently underway.

In conclusion, although a lot of (EU funded) R&D is taking place, many of the knowledge gaps presented above still need to be addressed. At present, the EC is defining the research programs for Horizon 2020. Research needs associated to MSFD marine litter should be known in order to allow appropriate consideration for the programme.

2.4. Cost of marine litter monitoring

2.4.1. Cost-effectiveness of different approaches

Prioritising the monitoring programmes to address the most significant risks, and finding more innovative and efficient ways of doing the monitoring will be key assets to meeting the MSFD monitoring requirements in an environment of economic constraints. One criterion for prioritisation is the relevance of criteria and indicators for measures / pressures as they directly link back to management.

One of the elements in this is the possibility for Member States to cooperate in the execution of the monitoring programme to reduce efforts and costs. There is opportunity for the EU to contribute to cost-efficiency through the Copernicus marine core services by offering data products in relevant resolutions for national and regional uses in support of the MSFD. Another element could be the development and use of models which are based on ground-truth monitoring but cover a much wider area and reduced costs.

The potential to collaborate with industry on marine litter monitoring (e.g. by providing "windows-of-opportunity") can be an effective way to assess the nature and extent of environmental impacts within marine waters. If such monitoring is done to specified standards, is quality assured and provides data that

are compatible with other MSFD monitoring programmes, then it could reduce the costs to Member States. Such approaches are in place for some sectors in some countries.

Integrated multi-disciplinary monitoring programmes should aim to maximise the use of existing resources (e.g. ship time), by improving the efficiency of existing programmes (i.e. use of spare capacity). In support of integration and cost-efficiency, existing monitoring requirements of EU legislations should be explored for streamlining and adjustment. Furthermore, the current and future Marine Research Infrastructure can be used more efficiently and there are EU programmes in place to support this[7].

Moreover, joint monitoring programmes in (sub) regions may help forge synergies between Member States on the ways in which they are monitoring and assessing the marine environment, and which can potentially reduce overall costs.

Decision-making tools may also help design effective and efficient monitoring programmes (e.g. to determine the spatial and temporal resolution needed or possibilities for integration of techniques). This is part of several pilot projects or research projects that are currently delivering where this concept could be tested.

Finally, it should be clear how the governance of monitoring programmes is organised (e.g. clear attribution of responsibilities, allocation of resources etc…). There should be also clear coordination arrangements in case of various administrations playing a role in the implementation of the monitoring programmes. The answer to these questions will allow streamlining existing resources, increase transparency and enhance accountability amongst other benefits.

In the sections below ways for more cost effective monitoring of marine litter are presented.

2.4.2. Factors that influence cost

A great number of factors influence the cost of monitoring (and assessing) marine litter. Cost of labour, cost of laboratory analyses, cost of equipment and cost of shipping to name a few. Indications of these costs have been included, as far as possible and/or known, in the thematic protocols.

Important ways to reduce monitoring cost are related to technical/methodological developments, joint monitoring and windows of opportunity, refining monitoring programmes and the use of volunteers.

2.4.2.1. Technical/methodological means

Technical/methodological improvements could lead to faster and less expensive monitoring, but also to more exact analyses (less added variation due to handling inaccuracies), which would increase the statistical power of analyses.

All litter protocols proposed in this report could of course be made more efficient by technical and methodological development. Some indicators (e.g. microlitter and litter in the water column) are still in such a stage of development that we can expect new methods to be developed and tested in the coming years. Improvements in this case may include more rapid and simple analysis both in the field and in the lab. Other protocols (e.g. beach litter) are essentially low tech, and it is less easy to see how technology could be improved. However, also for beach litter monitoring there are possibilities for developing more precise source detection, statistical analysis, standardizing of litter item categories for specific monitoring purposes but also the development of electronic tools to simplify recording (tablet computers, counting Apps) etc.

In addition, analyzing emissions into and modeling dispersal of plastic litter in aquatic systems from local to global scales by applying current data from remote sensing via satellite has the potential to become an efficient and reliable tool to monitor large marine areas. In situ observations made during field campaigns and Lagrangian transport modeling (Pelets-2D, Helmholtz Centre Geesthacht, Germany) can validate results derived from satellite imaging. The advantages of this method are high temporal and spatial resolutions and automated evaluations of image data. This method needs to be validated by means of macroscopic observations and transport model simulations.

7 For more detail, refer to the Final Report of the MRI Expert Group "Towards European Integrated Ocean Observation", January 2013.

2.4.2.2. Integration with other descriptors ("Windows of opportunity")

Most of the Marine Litter protocols can be integrated with other MSFD descriptors, to varying degrees:

i. *Monitoring of litter on (deep) seafloor.* In many countries this is already integrated with trawling for monitoring fish stocks (International Bottom Trawl Survey, Regional Trawl Survey such as BITS etc.). Both sampling and analysis can be made by the personnel doing the fish monitoring, i.e. complete integration is possible
ii. *Monitoring of litter on shallow seafloor.* Whether done by diving or using video techniques, there should be possibilities to integrate this with e.g. monitoring programmes for biotopes (descriptor 1 descriptor 6, monitoring for favourable conservation status for NATURA 2000 habitats). Also here both sampling and analysis of litter could be made by the same persons doing the biotope monitoring, i.e. complete integration.
iii. *Monitoring of litter on the water surface.* Here it could be possible to integrate this with hydrographic/plankton monitoring programmes (e.g. Descriptor 1, descriptor 4, Water Framework Directive). Costs for monitoring of floating litter could be decreased if using a "windows of opportunity" such as ferries or other regular cruises.
iv. *Monitoring of litter in biota.* Depending on the organism used for litter monitoring, there could be possibilities for integration with other programmes collecting fauna, e.g. collection programmes for dead seals or beached birds, collection programmes for fish and existing study birds colonies on breeding pairs/success etc. (e.g. descriptor 1, descriptor 8, descriptor 9).

Another type of integration which is possible for several litter indicators is to integrate monitoring with measures (e.g. clean-up campaigns). This has to be planned with care to achieve proper design for monitoring purposes (e.g. our view that fishing for litter programmes usually are difficult to combine with monitoring because of their non-systematic sampling), but such integration could be relevant for beach litter monitoring in some cases (i.e. if the sole aim is to assess composition and sources of beach litter).

2.4.2.3. Refining monitoring programmes (replication, statistical power)

It is perhaps in this field that the greatest gains in terms of cost-efficiency can be made. Most of the monitoring protocols suggested here are quite new, and have not been tested in monitoring programmes at such a large scale as will be necessary for the MSFD. Within a few years, information on trends and variation could make it possible to redesign the programme (e.g. where to sample, how often, how many sites) to be more cost-efficient.

2.4.2.4. Use of volunteers

Most litter indicators are not suited to use volunteers because of the need for ships, sophisticated equipment and/or specialist knowledge. In that case, the work is carried out by specialised agencies, scientist and consultants. However, cost of monitoring can be greatly reduced by using volunteers. In addition, use of volunteers may increase the possibility for the monitoring programme to act as an early warning system and awareness and public engagement tool essential to marine litter prevention.

Beach litter monitoring is particularly well suited for use of volunteers and shallow water litter surveys can be done with the aid of volunteer scuba divers. Many countries (e.g. UK, Spain, France) already use volunteers to monitor beach litter. The existence of clear, simple yet comparable protocols is essential in this respect. The Marine Litter Watch from the European Environment Agency is based on a simple Beach Litter Counting App tool on an Electronic Tablet. Volunteers/citizens can count litter on beaches and upload these data on a regional DataBase (Citizens Science). Thus more data series are generated that can also fill in gaps of the more official monitoring activities. Project AWARE's *Dive Against Debris*, is a litter survey designed to engage volunteer scuba divers in shallow water litter removal, recording and reporting. As with any citizen science based program, thoughtful design and on-going quality control are essential elements to success.

2.4.2.5. Refining questions

The cost of a monitoring programme is of course dependent on the scope of the programme, i.e. the questions asked. Large questions (e.g. "does litter decrease over the European scale?") require larger and thus more expensive programmes than small questions (e.g., "does plastic litter decrease on certain types of beaches in the Netherlands?"). Of course, the fundamental purposes of the MSFD ultimately guides the questions to be asked but it may be cost-efficient to carefully assess any additional aspects that are

suggested to be included in a monitoring programme. More questions, larger ambitions, come with a price also in monitoring.

2.5. Assessing actual costs of different protocols

The protocols contain estimations of the cost. The estimates include cost of labour in different phases of monitoring, cost of equipment and other running costs (ship time, etc.). Table 1 below provides an overview of estimation of costs, level of expertise required and potential performers, in the different stages of data collection and analysis, for the different protocols. Please note that these are very rough estimates, as the staff-costs vary considerably across countries.

Estimated Costs and Level of Expertise															
Compart-ment	**Beach**	**Sea-floor**			**Water**		**Biota**				**Microlitter**			
Protocol	**Visual**	**Diving** (Shallow)	**Trawling** (20-800m)	**ROV** (Deep)	**Manta-trawl**[8]	**Visual ship surveys**	**Birds-ingestion**	**Turtles-ingestion**	**Fish-ingestion**	**Nest/entanglement**	**Inter tidal**	**Sub-tidal**	**Water**	**Biota**
<u>Cost</u>														
Cost categories	**L – L**OW: € 1-10k; **M** – **M**EDIUM: €10 - 50k; **H** – **H**IGH: €50-100 k; **VH** – **V**ERY **H**IGH: > € 100k													
Collection of samples	L/M[9]	M/H[10]	L/M[11]	H/VH[11]	M/V[12]	L[13]	L/M[14]	M	L[10]	M	L/M	M	M[12]	M[15]
Analysis of samples	L	M	L	M	L	M/H	M	M	M	L	VH	VH	VH	VH
Protocol	**Visual**	**Diving** (Shallow)	**Trawling** (20-800m)	**ROV** (Deep)	**Manta-trawl**	**Visual ship surveys**	**Birds-ingestion**	**Turtles-ingestion**	**Fish-ingestion**	**Nest/entanglement**	**Inter tidal**	**Sub-tidal**	**Water**	**Biota**

[8] Manta-trawl is applied for collection of Microlitter

[9] No expensive equipment, but could be time-consuming; cheap when carried out by volunteers

[10] Depending on regulations for diving etc.

[11] If combined with fish trawl surveys

[12] Depending on to what extent you can combine the sampling with other monitoring

[13] If ships of opportunity are used

[14] Depends on if sampling is opportunistic (send a bird if you find one) or if it is regular/systematic

[15] If existing monitoring of biota (e.g. Fulmar) is extended

Estimated Costs and Level of Expertise														
Compart-ment	**Beach**	**Sea-floor**			**Water**		**Biota**				**Microlitter**			
Statistical analysis	H	M	L	M	L	M	L	M	M	L	M	M	M	M
Equipment	L	M	L/M[11]	VH	M	L/H[16]	M	L[17]	M	L	VH	VH	VH	VH
Overall	**L/M**	**M**	**L/M**	**H**	**M**	**L/M**	**M**	**M**	**M**	**L/M**	**M/H**	**H**	**H**	**H**
Required expertise														
Expertise categories	**L** – **L**OW: *Trained personnel without specific professional formation*; **M** – **M**EDIUM: Trained personnel with specific professional formation; **H - H**IGH: High expertise and special skills required.													
Sampling	L/M	H/M	L/M	H	H	L/M	M	L/M	L	L	H	H	H	H
Analysis	M	M	L	M	L	H	V	M	M	L	H	H	H	H
Statistical analysis	M	M	M	M	M	M	M	M	M	M	M	M	M	M
Performers	**V** – VOLUNTEERS and ORGANISATIONS; **C – C**ONSULTANTS**;** **A - A**GENCIES; **S - S**CIENTISTS													
Possible performers	V, C, A, S	V, C, A, S	A, S	C, A, S	C, A, S	C, A, S	C, S, V	C, S, V	C, S	C, S, A, V	S	S	S	S

Table 1: Overview of estimated costs and expertise needed for the different protocols

[16] High when cameras are being used, needing processing

[17] Assuming lab with standard equipment is available (freezers, microscope, electronic weighing equipment etc.)

2.6. Overview of protocols regarding strategic criteria

Table 2 below presents an overview of the different protocols and methodologies, regarding a series of criteria that can support the decision of which compartments to monitor and which protocols to adopt.

The protocols highlighted in colour refer to those that have been sufficiently tested across Europe and/or elsewhere (Maturity *High* or *Medium*) and are therefore the ones proposed for a consistent/harmonised approach, within the 2014 Monitoring Programme. For the other ones, the TSG ML considers that there is not yet sufficient data to support the proposal of a specific methodology but further R&D is needed.

DEFINITION OF THE DIFFERENT CRITERIA USED

Level of maturity – It refers to the extension to which the protocol has been tested and applied and thus its robustness to be used in the 2014 Monitoring Programme: *HIGH* – when the tool has been systematically applied for > 1 decade, extensively in 1 or more regions; *MEDIUM* – when it's been applied systematically in a few countries/ regions, for less than 1 decade; *LOW* - when the tool is under development/has been only test in a couple of pilots, and therefore needs further R&D.

Technical/Equipment– Requirements for technical equipment in terms of costs (for details, please see Table 1): *LOW – €1.000-10.000; MEDIUM - €10.000 – 50.000; HIGH - >€50.000*

Expertise– Level of expertise required for sampling, analysis and data interpretation (for details, please see Table 1). *LOW - trained personnel without specific professional formation*; *MEDIUM – trained personnel with specific professional formation; HIGH - high expertise and special skills required.* For more details on level of expertise required for the different stages of data collection and analysis, please see table 1.

Cost– Total costs incurred. *LOW: €1.000-10.000; MEDIUM: €10.000 – 50.000; HIGH : >€50.000.* Please note that these are only approximate estimations, as they depend greatly on staff costs, existing equipment and whether or not the protocol makes use of existing monitoring programmes and/or maritime operations; For more details see break-down of costs in Table 1.

Level of detail generated – potential of the protocol to generate details and information in terms of material, nature and purpose of the items sampled, which can be attributed to specific and distinct sources.

Geographic applicability– potential of the protocol to be applied in any geographic area/region

Limitations– key aspects inherent to the protocol and/or factors that can limit its applicability and/or generation of reliable & comparable data.

"Windows of opportunities" to reduce costs – opportunities that can increase the cost-effectiveness by making use of other monitoring programmes (e.g. for other MSFD descriptors) and/or maritime operations, in which the protocol can be integrated.

SUMMARY OF MONITORING PROTOCOLS										
Indicator *Code*	**Environ. matrices**	**Method/ protocol**	**Level of maturity**	**Technical/ Equipment**	**Expertise needed**	**Cost**	**Level of detail generated**	**Geographic applicability**	**Limitations**	**"Windows of Opportunities" to reduce costs**
10.1.1	**Beach**	**Visual/ Collection**	**HIGH** Extensively applied in NEA and Baltic but further R&D needed on statistical analysis	**LOW**	**LOW/ MEDIUM**	**L/M**	**HIGH** Size ≥ 2.5 cm	**HIGH** but depending on site availability (e.g. problems with remote or inaccessible beaches)	Great variability among sites; Amount of items deposited can be affected by weather/sea conditions	Potential to make use of (trained) volunteers
10.1.2	**Floating**	**Visual**	**HIGH** Extensively used in several parts of the world	**LOW**[1]	**LOW/ MEDIUM**	**L/M**[2]	**MEDIUM** Size ≥ 2.5 cm	**HIGH**	Observation may be affected by weather/sea conditions and must be adapted so the item's minimum size is detected;	Can be integrated in on-going operations with vessels (e.g. cruises, maritime authorities) or/and other monitoring programmes on the sea-surface (e.g. marine mammals)
10.1.2	**Floating**	**Aerial Survey**	**LOW**	**HIGH**[3]	**MEDIUM**	**H**[3]	**LOW**	**HIGH**	Expensive, unless coupled with existing aerial surveys; Mainly sensitive to large, floating items	Aerial surveys e.g. cetaceans – potentially Biological Diversity (D1)
10.1.2	**Floating**	**Automated camera survey**	**LOW** *In development*	**MEDIUM**	**HIGH**	**M**	**MEDIUM**	**HIGH**	Still in development, needs to be adapted for routine use. Depends on good sea conditions.	Can be integrated in on-going operations with vessels (e.g. cruises, maritime authorities)

[1] Considering "windows of opportunity" with existing vessel operations and excluding video

[2] Can increase if video is used (extra time for processing)

[3] Can be considerably reduced if coupled with other aerial surveys

SUMMARY OF MONITORING PROTOCOLS										
Indicator *Code*	**Environ. matrices**	**Method/ protocol**	**Level of maturity**	**Technical/ Equipment**	**Expertise needed**	**Cost**	**Level of detail generated**	**Geographic applicability**	**Limitations**	**"Windows of Opportunities" to reduce costs**
10.1.2	**Sea-floor** (20-800m)	**Bottom-trawl** (video optional)	**MEDIUM/HIGH** (NE Atlantic – IBTS and Med - MEDITIS)	**LOW/ MEDIUM**	**LOW/ MEDIUM**	**L/M**[4]	**MEDIUM** Size ≥ 2.5 cm	**MEDIUM** (not possible in restricted/protected areas)	Restricted to flat/smooth bottoms	Can be fully coupled with existing bottom-trawling programmes (e.g. IBTS, MEDITIS); Commercial Fish (D3); Biological Diversity (D1)
10.1.2	**Sea-floor** (Deep)	**ROV/Video**	**MEDIUM**	**HIGH**	**HIGH**	**H**	**MEDIUM** Size ≥ 2.5 cm	**MEDIUM** (only for countries with Deep Seas)	Expensive, unless coupled with existing deep-sea bottom surveys	Commercial Fish (D3); Biological Diversity (D1); Sea-floor Integrity (D6)
10.1.2	**Sea-floor** (Shallow)	**Diving** (video optional)	**MEDIUM** (LOW for video)	**MEDIUM** (LOW for video)	**MEDIUM**	**M**	**MEDIUM** Size ≥ 2.5 cm	**HIGH**	Depends on accessibility to diving areas	Commercial fish (D3); Biological Diversity (D1) Potential to make use of volunteer divers and awareness- raising campaigns (e.g. Project AWARE)

[4] Can increase if video is used (extra time for processing)

SUMMARY OF MONITORING PROTOCOLS										
Indicator *Code*	**Environ. matrices**	**Method/ protocol**	**Level of maturity**	**Technical/ Equipment**	**Expertise needed**	**Cost**	**Level of detail generated**	**Geographic applicability**	**Limitations**	**"Windows of Opportunities" to reduce costs**
10.2.1	**Biota**	**Sea-birds (ingestion)**	**HIGH** (extensively used in some Northern countries of NEA for Fulmars)	**LOW**[5]	**MEDIUM**	**M**	**MEDIUM** Size ≥ 1mm	**MEDIUM** (*e.g.* Fulmars restricted Northern countries of the NE Atlantic)	Depends on geographic coverage of species and their feeding behaviour; depends on availability of dead birds	Ingestion in Fulmars is already a EcoQO Indicator in OSPAR North Sea sub-region; Detection and collection of specimens can be part of collaboration with several entities (e.g. coastal authorities) and coastal programmes
10.2.1	**Biota**	**Turtles (ingestion)**	**MEDIUM/ LOW**	**LOW**[5]	**MEDIUM**	**M**	**MEDIUM** Size ≥ 1mm	**MEDIUM** (*e.g. Caretta caretta* occurs in Med and part of NEA but not in Northern areas or Black Sea)	Depends on geographic coverage of species; depends on availability of animals	Potential to collaborate with Recovery Centres for Turtles
10.2.1	**Biota**	**Fish (ingestion)**	**LOW** *In development*	**MEDIUM/ HIGH**	**MEDIUM-HIGH**	**M/H**	**MEDIUM/ LOW**	**HIGH**	Depends on geographic coverage of species; Costs and expertise of analysis depends on sizes of species, size of particles analysed and methodologies used	Commercial fish (D3); Biological Diversity (D1); IBTS, MEDITIS or any other programmes were fish are collected for analysis

[5] Assuming lab with standard equipment is available

SUMMARY OF MONITORING PROTOCOLS										
Indicator *Code*	**Environ. matrices**	**Method/ protocol**	**Level of maturity**	**Technical/ Equipment**	**Expertise needed**	**Cost**	**Level of detail generated**	**Geographic applicability**	**Limitations**	**"Windows of Opportunities" to reduce costs**
10.2.1	**Biota**	**Sea-birds (Plastic as nest material & entanglement)**	**LOW** *In development*	**LOW**	**MEDIUM**	**L**	**LOW/ MEDIUM**	**MEDIUM**	Depends on geographic coverage of birds breeding colonies; Focus on marine sources (e.g. ropes/nets)	Can be used during surveys for other studies on bird-colonies
10.2.1	**Biota**	**Entanglement (beached-animals)**	**LOW** *In development*	**LOW**	**MEDIUM**	**L/M**	**LOW/ MEDIUM**	**MEDIUM**	Low occurrence rates in sea-birds. Numbers of beached cetaceans often high. Pathologists may be able to distinct if animal died in active or lost/discarded fishing gear	Pathologic investigations of dead mammals need to include assessment for cause of death
10.2.1	**Biota**	**Marine Mammal (ingestion)**	**LOW** *In development*	**MEDIUM**	**MEDIUM/ HIGH**	**M**	**MEDIUM**	**MEDIUM** (depends on occurrence of species)	Known rates of ingested litter are low but number of pathologic investigated animals is also low – needs further development	Can be applied as part of necropsies procedures of marine mammals
10.2.1	**Biota**	**Marine invertebrates (ingestion)**	**LOW** *In development*	**MEDIUM/ HIGH**	**MEDIUM/ HIGH**	**H**	**LOW/ MEDIUM**	**HIGH**	Insufficient data to support recommendation as an indicator	Potentially coupled with Monitoring of Contaminants (D8) if filtering/detritivores organisms are used?

SUMMARY OF MONITORING PROTOCOLS										
Indicator *Code*	**Environ. matrices**	**Method/ protocol**	**Level of maturity**	**Technical/ Equipment**	**Expertise needed**	**Cost**	**Level of detail generated**	**Geographic applicability**	**Limitations**	**"Windows of Opportunities" to reduce costs**
10.1.3	**Micro**	**Beach**	**LOW**	**HIGH**	**HIGH**	**M/H**	**MEDIUM** Size ≤ 5 mm	**HIGH**	Probably the most widely sampled compartment but approaches to date have been variable, which limits comparability	Sampling can be coupled with Beach protocol for macro-litter or in parallel with any other routine intertidal monitoring (for chemical contaminants, biota)
10.1.3	**Micro**	**Sub-tidal**	**LOW** (very limited use to date)	**HIGH**	**HIGH**	**H**	**MEDIUM** Size ≤ 5 mm	**HIGH**	Equipment is only available/used in the EU by one organisation and used along standard shipping routes so limited flexibility in terms of options for spatial monitoring	Can be coupled with other monitoring programmes that involve sampling the sea-floor
10.1.3	**Micro**	**Water** MANTA-TRAWL	**LOW** (several pilots in NEA and Med)	**MEDIUM**	**MEDIUM/ HIGH**	**H**	**MEDIUM** Size ≤ 5 mm	**HIGH**	Can be insensitive to fraction < 3mm	Can be coupled with other monitoring programmes that involve sampling the sea-surface
10.1.3	**Micro**	**Water** *Continuous Plankton Recorder* (CPR)	**LOW**	**HIGH**	**HIGH**	**H**	**MEDIUM** Size ≤ 5 mm	**HIGH**	Can be insensitive to fraction > 3mm	Can be fully coupled with surveys involving CPR. Possibly Biological Diversity (D1)

SUMMARY OF MONITORING PROTOCOLS										
Indicator *Code*	**Environ. matrices**	**Method/ protocol**	**Level of maturity**	**Technical/ Equipment**	**Expertise needed**	**Cost**	**Level of detail generated**	**Geographic applicability**	**Limitations**	**"Windows of Opportunities" to reduce costs**
10.1.3	**Micro**	**Biota** If sampling for macro-litter ingestion is conducted	**LOW** *In development*	**HIGH**	**HIGH**	**H**	**MEDIUM** Size ≤ 5 mm	**MEDIUM** Depends on the species	No indicator species is recommended for micro-litter, only protocol to analyse this fraction as part of Protocol to analyse ingestion of litter	Can be part of the analysis on biota ingestion of macro-litter

Table 2: Summary of Monitoring Protocols

2.7. Conclusions: Key messages to MSFD implementation process

In conclusion, the TSG-ML highlights the following messages that should be considered and lead the process towards the implementation of monitoring of marine litter in the European Seas:

- ✓ Protocols are available for all indicators but with different levels of maturity;
- ✓ Protocols are available for most geographical areas. Greatest difficulty is with:
  - Litter in biota, where protocols have to be adjusted to match regional distribution of species
  - Microlitter, where much research is currently going on, and we consider it premature to suggest any protocol currently;
- ✓ For indicators where no mature protocol can be recommended, pilot studies using one of the less mature protocols are recommended. Our knowledge about the amount and distribution of ML in many of the environmental compartments is still insufficient. Pilot studies could guide us towards better design of future monitoring, and thus be cost-efficient in the long run;
- ✓ Data acquisition should be organized effectively and between MS authorities and scientific research projects;
- ✓ Data acquisition through research, beyond on-going research projects and monitoring efforts need to be identified and implemented;
- ✓ Although a lot of (EU funded) R&D is taking place, many of the knowledge gaps on marine litter need to be closed. MSFD Marine litter Research needs should be included in the further EU knowledge development programming (e.g. Horizon 2020).

2.8. References

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