European Commission

JRC SCIENTIFIC AND POLICY REPORTS

Guidance on Monitoring of Marine Litter in European Seas

A guidance document within the Common Implementation Strategy for the Marine Strategy Framework Directive

MSFD Technical Subgroup on Marine Litter

2013

Report EUR 26113 EN

Joint Research Centre

European Commission
Joint Research Centre
Institute for Environment and Sustainability

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JRC83985

EUR 26113 EN

ISBN 978-92-79-32709-4 (pdf)
ISBN 978-92-79-32710-0 (print)

ISSN 1831-9424 (online)
ISSN 1018-5593 (print)

doi:10.2788/99475

Luxembourg: Publications Office of the European Union, 2013

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List of Acronyms and Abbreviations

AON	´apparently occupied nets´
BITS	Baltic International Trawl Survey
BS SAP	Report on the Implementation of the Strategic Action Plan for Environmental Protection and Rehabilitation of the Black Sea
BSIMAP	Black Sea Integrated Monitoring and Assessment Programme
Cefas	Centre for Environment, Fisheries and Aquaculture Science, UK
CEMP	Co-ordinated Environmental Monitoring Programme (OSPAR CEMP)
CNR-IAMC	Institute for Coastal Marine Environment of the National Research Council
CoG	Coordination Group (OSPAR)
COM DEC	Commission Decision
COMBINE	Cooperative Monitoring in the Baltic Marine Environment (HELCOM)
CPR	Continuous Plankton Recorder
DATRAS	Development of a central database for European trawl survey data
DCF	Data Center Framework
DG ENV	Directorate - General for the Environment (EC)
DG MARE	Directorate - General for Maritime Affairs and Fisheries (EC)
DPSIR	Driver, Pressure, State, Impact, Response
DSM	density surface modelling
ECOOCEAN	Marine Research and Education, Israeli
EcoQO	Ecological Quality Objective (OSPAR)
EEA	European Environment Agency
EMODNET	European Marine Observation and Data Network
FT-IR	Fourier Transform Infrared spectroscopy
FT-IR or Raman	Different spectroscopic analyse techniques
GES	Good Environmental Status
GI	gastrointestinal system; oesophagus, stomach, intestines
GMES	Global Monitoring for Environment and Security (*Copernicus*)
HELCOM	Helsinki Commission Baltic Marine Environment Protection Commission
HELMEPA	Hellenic Marine Environment Protection Association
Horizon 2020	EU Framework Programme for Research and Innovation
IBTS	International Bottom Trawl Survey
ICC	International Coastal Clean-up
ICES	International Council for the Exploration of the Seas (CIEM)
ICES/ IBTS WG	International Bottom Trawl Surveys Working Group
INSPIRE	Infrastructure for Spatial Information in the European Community
IOC	Intergovernmental Oceanographic Commission
ISPRA	Italian National Institute for Environmental Protection and Research
JAMP	Joint Assessment and Monitoring Programme
JPI Oceans	Joint Programming Initiative Healthy and Productive Seas and Oceans
JRC - IES	European Commission Joint Research Centre - Institute for Environment and Sustainability
MCS	Marine Conservation Society
MED POL	Programme for the Assessment and Control of Pollution in the Mediterranean Region
MEDITS	Mediterranean International Trawl Survey
MS	EU Member States
MSCG	Marine Strategy Coordination Group
MSFD	Marine Strategy Framework Directive (2008/56/EC)
MSFD COM DEC 2010/477/EU	Commission Decision on criteria and methodological standards on good environmental status of marine waters (2010/477/EU)
NATURA 2000	EU wide network of nature protection areas, started in 1992 with EU Habitats Directive
NGO	Non-Governmental Organisation
NMDMP	National Marine Debris Monitoring Programme

NOAA	National Oceanic and Atmospheric Administration (US)
NOWPAP	Northwest Pacific Action Plan (UNEP)
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
AWARE 2013	Programme of Scuba Divers of the Professional Association of Diving Instructors (PADI)
QA/QC	Quality assurance / Quality control
R&D	Research and development
ROV	Remote Operated Vehicle
RSC	Regional Sea Convention
SoE Report	State of the Environment
STAGES	Science and Technology Advancing Governance of Good Environmental Status
TSG-ML	Technical Subgroup on Marine Litter under the Marine Strategy Framework Directive
UNEP	United Nations Environment Programme
WFD	European Water Framework Directive
WG GES	Working Group on GES in relation to the MSFD
WG DIKE	Working Group on Data Information Knowledge and Exchange within the MSFD
WISE/EMODNET	Water Information System for Europe / European Marine Observation and Data Network
WISE-Marine	Water Information System for Europe

Research and Technological Development Projects:

MICRO	Micro-plastics in the North Sea
CleanSea	Towards a Clean, Litter-Free European Marine Environment through Scientific, Evidence, Innovative Tools and Good Governance
ECsafeFood	Project on contaminants in seafood and their impact on public health; especially micro-plastics as component of marine litter
BIOCLEAN	Biotechnological solutions for the degradation of synthetic polymeric materials
STAGES	Connecting Science to Policy for Healthy Seas
HERMIONE	Hotspot Ecosystem Research and Man's Impact on European Seas
PERSEUS	Policy-oriented marine Environmental Research for the Southern European Seas
MARLISCO	Marine Litter in European Seas - Social Awareness and Co-Responsibility
MARELITT	Pilot Project - Removal of marine litter from Europe’s four regional seas

Foreword

The Marine Directors of the European Union (EU), Acceding Countries, Candidate Countries and EFTA Countries have jointly developed a common strategy for supporting the implementation of the Directive 2008/56/EC, "the Marine Strategy Framework Directive" (MSFD). The main aim of this strategy is to allow a coherent and harmonious implementation of the Directive. Focus is on methodological questions related to a common understanding of the technical and scientific implications of the Marine Strategy Framework Directive. In particular, one of the objectives of the strategy is the development of non-legally binding and practical documents, such as this recommendation, on various technical issues of the Directive. These documents are targeted to those experts who are directly or indirectly implementing the MSFD in the marine regions.

The TSG-ML is led by DG ENV and chaired by IREMER, the EC Joint Research Centre (JRC) and the German Environment Agency. The group consists of MS delegates, relevant organizations and invited experts. The guidance document should support EU Member States in implementing harmonized monitoring programmes for marine litter. Dealing with a topic under development through research efforts and by fast growing experience this guidance should be regarded as a living document and be reviewed regularly. The Marine Strategy Coordination Group has agreed (in accordance with Article 6 of its Rules of Procedures) to publish this document as technical guidance developed in the MSFD Common Implementation Strategy. The participants of the Marine Strategy Coordination Group concluded:

"We would like to thank the experts who have prepared this high quality document. We strongly believe that this and other documents developed under the Common Implementation Strategy will play a key role in the process of implementing the Marine Strategy Framework Directive. This document is a living document that will need continuous input and improvements as application and experience build up in all countries of the European Union and beyond. We agree, however, that this document will be made publicly available in its current form in order to present it to a wider public as a basis for carrying forward on-going implementation work."

The Marine Strategy Coordination Group will assess and decide upon the necessity for reviewing this document in the light of scientific and technical progress and experiences gained in implementing the Marine Strategy Framework Directive.

Disclaimer:

This document has been developed through a collaborative programme involving the European Commission, all EU Member States, the Accession Countries, and Norway, international organisations, including the Regional Sea Conventions and other stakeholders and Non-Governmental Organisations. The document should be regarded as presenting an informal consensus position on best practice agreed by all partners. However, the document does not necessarily represent the official, formal position of any of the partners. Hence, the views expressed in the document do not necessarily represent the views of the European Commission.

1. Introduction

The Marine Strategy Framework Directive (MSFD) requires European Member States (MS) to develop strategies that should lead to programmes of measures to achieve or maintain Good Environmental Status (GES) in European Seas. As an essential step of this process, MS should establish **monitoring programmes for assessment**, enabling the state of the marine waters to be evaluated on a regular basis.

In 2010, following the Commission Decision on criteria and methodological standards on GES of marine waters (Commission Decision 2010/477/EU), the Marine Directors requested the Directorate-General for the Environment (DG ENV) to establish an Technical Subgroup on Marine Litter (TSG-ML) under the Working Group on GES (WG GES), to address these gaps and further develop Descriptor 10. The TSG-ML is led by DG ENV and chaired by IFREMER, the EC Joint Research Centre and the German Environment Agency. The group consists of MS delegates and invited experts from relevant organizations.

During 2011, the TSG-ML focused on providing advice through the report "Marine Litter – Technical Recommendations for the implementation of MSFD requirements", which described the options and tools available for the monitoring of marine litter in the different environmental compartments and a review of the existing monitoring programmes or surveys that generated data within Europe. MS have since requested a follow-up through an additional mandate of the TSG-ML.

The present document is the Final Report "**Guidance on Monitoring of Marine Litter in European Seas"**, the output of the work of the TSG-ML between 2012 and 2013. The objective of such Guidance is to provide MS with recommendations and information needed to commence the monitoring of the MSFD Descriptor 10. It describes specific protocols and considerations to collect, re**port and asses data on marine litter**, in particular **beach litter, floating litter, seafloor litter, litter in biota and microlitter**.

The Guidance document is divided in 8 sections:

- Chapter 2 – **General Approaches & Strategies for Marine Litter Monitoring**, addressing key aspects related to MSFD requirements, coordination at the Regional Level and general framework of a monitoring programme on marine litter;
- Chapter 3 – **Beach Litter**: guidance to monitoring litter deposited on the beach (Indicator 10.1.1);
- Chapter 4 – **Floating Litter**: guidance to monitoring litter on the water surface (Indicator 10.1.2);
- Chapter 5 – **Seafloor Litter**: guidance to monitoring litter in the seafloor (Indicator 10.1.2);
- Chapter 6 – **Litter in Biota**: guidance to monitoring litter ingested by marine organisms (Indicator 10.2.1) and other impacts of litter on biota;
- Chapter 7 – **Microlitter**: guidance to monitoring microlitter in the marine environment and biota (Indicator 10.1.3);
- Chapter 8 – **Litter categories**: guidance on categorization of litter for a harmonised, comparable approach.

The TSG-ML will keep working throughout 2014, to further elaborate on outstanding issues, such as: assessment of harm; approaches to identification of land and marine-based sources, including monitoring of riverine litter. A subsequent document is expected to be published at the end of 2014 covering these topics.

2. General Approaches & Strategies for Marine Litter Monitoring

An important milestone in the implementation of the Marine Strategy Framework Directive (MSFD – 2008/56/EC) will be 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 for establishing and implementing coordinated monitoring programmes for assessment of EU waters environmental status. WG GES initiates a framework for coordinated monitoring programmes, which will deliver data assessing whether GES, and associated environmental targets, are being achieved. This will work in close cooperation with the Working Group on Data, Information Knowledge Exchange (WG DIKE).

The monitoring requirements, for implementing the MSFD-Descriptor 10 successfully, are dependent upon measuring techniques of demonstrated accuracy. This must deliver reliable data at affordable costs. Besides present monitoring methods, new methods and automated monitoring devices can play a complementary role, by improving results. The MSFD can only be a powerful management tool if monitoring data is relevant, reliable and fit-for-purpose.

There are different aims for monitoring including: assessing the environmental status: the temporal and spatial trends; environmental target achievement levels; source identification; and the effectiveness of measures. Different aims require different approaches when designing a monitoring program.

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

In this chapter, we look back at the general purpose of monitoring, and assess the suitability of the different monitoring methods in achieving 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 requirements for monitoring programmes. Elaborating on this, at the 10th meeting of the MSCG (6-7 May 2013), a set of key principles and messages, to 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 of 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.

<u>Recommendation 1</u>: The core purpose 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 aimed mainly 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.

<u>Recommendation 2</u>: 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.

<u>Recommendation 3</u>: Build upon and integrate already established monitoring programmes already 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 “opportunities to reduce costs” and this is discussed further in section 3.2.2 below (see also “opportunities to reduce costs” in the Table 2).

<u>Recommendation 4</u>: Data and information, resulting from the monitoring programmes, should be made available 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 adapt with appropriate reaction to changes in the marine environment and understanding of 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 a basis for 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). 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: Taking into account the differences in scientific understanding for each descriptor in the monitoring programmes and applying the precautionary principle[2].

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 programmes and recommend contracting parties to use them for their monitoring and assessment.

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

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

2.2.1. OSPAR Convention

OSPAR is in the process of developing a Monitoring Framework complimenting monitoring for the MSFD with "regular" OSPAR monitoring. Collective action in OSPAR is enhanced through streamlining the management of the entire chain of monitoring and assessment so that resources are allocated most effectively. The Monitoring Framework is intended to identify the main areas for development, and to provide an overview of thematic priorities on how common monitoring questions are addressed on various themes. Presently, coordinated monitoring is carried out under the Coordinated Environmental Monitoring Programme, which includes beach litter. A special arrangement is in place for monitoring on plastic particles in stomachs of North Sea fulmars. Further, common indicators are under development (*e.g.* IBTS seabed monitoring).

With regard to the identification of 'common indicators and associated monitoring needs' OSPAR CoG noted, in May 2013, that the objective is to agree on a combined list of common indicators across OSPAR, at OSPAR Commission 2013 . This will include their monitoring requirements, with an indication of (sub-) regional importance and 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 associated implications as regards: (a) inclusion in the next JAMP; and (b) concomitant implications for monitoring commitments and requirements of Contracting Parties;

'Common indicators' should be implemented by all Contracting Parties which are coastal states of the OSPAR maritime area, where scientifically relevant. Certain indicators may need to be regionally adapted to specific environmental conditions or pressures. Specific indicators may be applicable to 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 for 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 into account the risks to the marine environment; the CEMP opting out conditions, …);

CoG advised the use of 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 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 is taken to adopt them as a "common indicator", with the intention 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 programmes in a coordinated way, including:

a) feasibility and coordination aspects of national monitoring, including the question of practical implications for trans-boundary 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, where benefits can be derived from wider EU developments such as the JPI Oceans, and any project in the OSPAR maritime area started under the EC DG Environment New Knowledge call for projects.

In 2013, OSPAR decided to adopt beach litter as 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 were adopted in 2012. One of its main objectives 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 leading 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, within 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 to be used, to adopt a standardised methodology. At the regional level MED POL will coordinate this and promote the appropriate methodologies. It will be responsible for the evaluation and dissemination of marine litter related information, provided by designated national agencies. It is proposed, at the national level, 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 data, and keeping record of the marine litter monitoring activities carried out.

One of the most recent developments has been the development 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, and will be agreed upon at the end of 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 GES determination for the marine environment. 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, also, needs to be addressed.

At the moment, no Baltic country conducts systematic, coast-wide monitoring of marine litter. HELCOM made a questionnaire for 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, projects. New information is also generated by research projects (e.g. MARLIN project, which has conducted beach litter surveys in 20 key areas in Sweden, Finland, Estonia and Latvia, with a total of 120 beach litter assessments).

HELCOM has the Recommendation 29/2, for a common methodology for monitoring of beach litter (HELCOM, 2008). It recommends that the Governments of the Contracting Parties 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 stretches of exposed sand or gravel beaches, at least a 1 km long ,with surveys of at least 100 meters, is described in the Recommendation. There are no commonly agreed methods for the monitoring of other kinds of litter, but HELCOM has decided to pursue 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 the HELCOM GEAR document 2/2012, give an overview of some sources and amounts of beach and floating litter.

Following the HELCOM Ministerial Conference on 3rd October 2013, it was agreed to “develop common indicators and associated targets related to quantities, composition, sources and pathway of marine litter, including riverine inputs, in order to gain information on long-term trends, and carry out the monitoring of the progress towards achieving the agreed goals and to gain an inventory of marine litter in the Baltic Sea as well as scientific sound evaluation of its sources.” Specific mention was made of the application of the protocols recommended by the EU Technical Subgroup on marine litter, to be used where possible.

In the Conference Declaration, the Ministers also decided to develop a regional action plan by 2015, at the latest, with the aim of achieving a significant, quantitative reduction of marine litter by 2025, and to prevent harm to the coastal and marine environment.

2.2.4. Bucharest Convention

Currently the Black Sea Commission elaborates on the new text of the Black Sea Integrated Monitoring and Assessment Programme (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 programmes, 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[3]. 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

[3] 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.

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) 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 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 achieve the aims of the monitoring programs. 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 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; and 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), emphasising 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 the nature and purpose of the items, but also their original source (which can be related to unsuitable or accidental disposal), and 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. to what extent they are tested in the field, and are 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 have plans to monitor only in a subset of environmental compartments, to start with small pilot, research or development projects in other compartments. This would provide baseline data to make an informed decision about future, full-scale monitoring programmes. Without information on 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 to 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 initiate full-scale monitoring programmes, in all compartments of Descriptor 10. However, where no baseline exists, research monitoring should be undertaken.

A similar typology of monitoring programmes, to the WFD, could be used regarding surveillance, both operational and investigative. The requirements of surveillance monitoring, should be defined, and address the monitoring of monitoring, of state, impacts, pressures, and activities/measures. There may 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. The present lack of knowledge about harm levels of litter is such that absolute targets are difficult to set, and therefore, many Member States formulate trend targets instead. 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 have more than 0.1g of plastic in their 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 progress towards targets, and effectiveness and impact of measures, depends on the characteristics of those targets and 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 where 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 leading 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.

When considering a particular compartment for monitoring, the nature and behaviour of the type of items should be taken into account. On the seafloor it is more likely to capture trends in items that tend to sink, while lighter, smaller items may tend to float. Therefore, the monitoring of different compartments should be seen as complementary rather than alternative – *e.g.* a plastic bottle with cap on will tend to float, while without cap will tend to sink.

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 " opportunities to reduce costs" to increase cost-effectiveness, please see Table 2, under section 2.6.

A brief overview is provided below on 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 use techniques commonly used for other types of monitoring, and there are possibilities for coordination with monitoring for other descriptors and other Directives.

Sea-floor –Video in shallow waters: This protocol was 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 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 available for sampling the water column, but again there is a need for optimization and inter calibration. However, the TSG-ML considers there to be sufficient reliable approaches to initiate monitoring, at the present time. There are only a limited number of reports on sampling microparticles in biota. New 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, this 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: A recorded of entangled birds and marine mammals, during beached animals monitoring programmes. However, where measured, the incidence of entanglement of beached birds is quite low for most species. In marine mammals, numbers of beached animals, 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 & requirements

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

The use of quality control and 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 monitoring programmes results, implemented to assess litter in the various regional seas and compartments of the marine environment (beach, seafloor, sea-surface etc.) This can be enhanced where 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). The use of appropriate field guides 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 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 identifying the main sources of marine litter pollution, and the potential level of harm that marine litter may inflict. 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 which can help 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, a decision to be taken when a monitoring strategy is defined. The site selection strategy has fundamental consequences for the monitoring analysis, as has the selection of the survey method. Monitoring programmes are not compatible or comparable if they use the same survey methods, but different site selection strategies (*e.g.* special site selection on the basis of litter pollution levels, or a randomised selection of sites.)

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

Sites can be chosen individually because they have certain characteristics. This may be because they are considered to have certain environmental or societal values. For example, a beach that has a high number of visitors, because the beach is situated in a certain area, or simply because the site has heavy litter loads. Usually, the site is revisited during subsequent surveys to assess trends. The advantage of this approach is, that if several sites are chosen for sharing the same characteristics, the litter load they receive is expected to be more similar than those chosen randomly and, therefore, the variation will be less than those chosen randomly. With this in mind, the ability to detect statistically significant trends will be increased. The main disadvantage of the strategy is that, as individual sites are chosen deliberately for special features, they are therefore different from other sites. Hence they may be less suitable for drawing conclusions about average litter levels etc. for a given region. It may add difficulty in interpreting statistical results for technical and philosophical reasons.

Sites may be chosen randomly from a large number of possible sites, meeting certain criteria based upon the method and the monitoring purpose. Sites may be revisited or chosen for each monitoring occasion; the important issue is how they were selected in the first place, *e.g.* a random selection from many possible sites. The main advantage of this strategy is that results can be extrapolated to other possible sites, i.e. we can use the results to draw conclusions about larger areas. Nevertheless, the variation among sites can be high, 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 which is sometimes referred to as, "stratified randomised sampling strategy" (*e.g.* OSPAR beach litter protocol). Sites meeting certain criteria are (more or less) randomly chosen. The criteria may include geographic, environmental, societal and other factors. An example would be to choose sites that are close to harbours, to monitor effects of pollution from harbours, and/or sites that are situated in relatively remote areas, to monitor large-scale pollution levels without strong influence from local sources. This is 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 criteria for the site selection should then be based on prediction of potential harm. Prediction of potential harm could be based on practical knowledge of which environmental values are most sensitive to harm. However, the current understanding of how different species or biotopes react to litter is insufficient, and should be further researched. Another approach to harm may be based on aspects that are particularly "valuable" to society for other reasons *e.g.* economically, socially or environmentally. A third approach is to assume that harm is more likely to occur in areas/environments where there is a lot of litter and 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 represent a "worst case" scenario.

One way to make best use of limited resources is to take advantage of other studies and programmes where litter monitoring can be integrated (what we call "opportunities to reduce costs"). An example we advocate is to combine monitoring for litter on the sea floor with scientific trawling for fish stock biomass estimation (IBTS, BITS, MEDITS). In such a case, the selection of sites is designed the original monitoring programme purpose, and representation of other areas are already defined. Where use of such a scheme is made, it is important to analyse the sampling strategy to assess if this is suitable for litter monitoring too.

For marine litter, we advocate a stratified, randomised sampling strategy where possible. Also, that the purposes of the monitoring programmes define the criteria for selecting sites. Simplification is necessary when resources are limited, and concentration of monitoring effort is 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, 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 effect of the environment and our (mis-) handling of litter. In that sense, the magnitude of the trend is dependent on the action we take against litter. When designing a monitoring programme an important decision is related to the magnitude of change we wish to detect. It is of course easier to detect a large trend than a small trend. The smaller the magnitude we want to detect, the more comprehensive the monitoring programme needs to be. If the action plans to tackle marine litter aim at reducing litter amounts significantly, then monitoring programmes can detect real changes.

The *number of replicates* is something that is easy to change given sufficient 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 increases with time. In monitoring programmes, which often are complex with multiple temporal and spatial layers, the actual number of replicates is less easy to define.

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 among sites, by introducing criteria for the sampling, as described in the section on site selection strategies above. This is not cutting corners or cheating, but it is important to realize that the possibility to extrapolate to un-sampled sites decreases.

Common to all three factors influencing statistical power is that they are case specific. It is not possible to give general advice on how many replicates are adequate, except to say the more the better. Firstly, decisions about the purpose of a specific monitoring programme, and what the sites should represent have 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. Otherwise data from similar programmes can be used. Only then can calculations of statistical significance be made, and thus the required number of sites for the monitoring programme be arrived at.

An important and encouraging fact is that it is of value to start a monitoring programme even if the initial resources are limited. The initial data from monitoring can nevertheless be used for subsequent trend analysis (albeit with reduced statistical power), but 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 made 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 in the marine environment may enter directly as such from synthetic textile fragments, plastic particles used in cosmetic, or industrial cleansers, etc.) but they can also result from the progressive fragmentation of larger pieces or items already present in the sea. If the former source is the dominant,, conclusions may be drawn from fluctuation of trends. If the latter is the main source it is more problematic. Then it is possible to interpret increasing or decreasing trends as a net input of fragments or microparticles into the marine environment, when the increase may be caused by changes in the rate of breakdown of larger particles, *i.e.* not caused by a change in the overall amount of marine litter. In another hypothetical scenario, we may be able to implement measures that will reduce the amount of new particles entering the sea, but not able to detect a decreasing trend of microparticles in the sea, as these may be a result of progressive fragmentation from existing marine litter items and bigger pieces. Studies on the degradation of macrolitter, and studies on the release of microparticles from land to the sea, are important to solve this problem. Monitoring the concentration of microparticles upstream to the point of entrance into the marine environment (*e.g.* urban and industrial effluents) may help to assess the input of this fraction of litter.

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. Except for the record of data and units (*i.e.* standard categories of items), it is beyond the scope of this Guidance to provide specific recommendations on data handling and reporting.

Data handling and reporting (for the MSFD) is 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 made 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 WG DIKE 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. [4]
- 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)

4 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 analysed 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 (*i.e.* models that are validated by actual field observations) but cover a much wider area and reduced costs.

The potential to collaborate with industry on marine litter monitoring (*e.g.* by providing "opportunities to reduce costs") 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[5].

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 other opportunities to reduce costs, 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, analysing emissions into and modelling 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

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

and Lagrangian transport modelling (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.

2.4.2.2. *Integration with other descriptors – opportunities to reduce costs*

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 other opportunities, 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 citizen-science based Marine LitterWatch from the European Environment Agency is a new monitoring tool developed to support these initiatives (and provide a setup for new ones to emerge) and collect beach litter data. It is based on a simple beach litter counting mobile app, which enables volunteers to count litter on beaches and submit the data on a central public data base that is hosted by the EEA. Thus more data series are generated that can also fill in gaps of the official monitoring activities (more information on the project in the beach litter section in chapter 3.8.3). 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**[6]	**Visual ship surveys**	**Birds-ingestion**	**Turtles-ingestion**	**Fish-ingestion**	**Nest/entanglement**	**Inter tidal**	**Sub-tidal**	**Wat er**	**Biota**
Cost														
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[7]	M/H[8]	L/M[9]	H/VH[11]	M/V[10]	L[11]	L/M[12]	M	L[12]	M	L/M	M	M[10]	M[13]
Analysis of samples	L	M	L	M	L	M/H	M	M	M	L	H	H	H	H
Protocol	**Visual**	**Diving**	**Trawling**	**ROV**	**Manta-**	**Visual**	**Birds-**	**Turtles-**	**Fish-**	**Nest/enta**	**Inter**	**Sub-**	**Wate**	**Biota**

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

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

[8] Depending on regulations for diving etc.

[9] If combined with fish trawl surveys

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

[11] If ships of opportunity are used

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

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

Estimated Costs and Level of Expertise														
Compart-ment	**Beach**	**Sea-floor**			**Water**		**Biota**				**Microlitter**			
		(Shallow)	(20-800m)	(Deep)	**trawl**	**ship surveys**	**ingestion**	**ingestion**	**ingestion**	**nglement**	**tidal**	**tidal**	**r**	
Statistical analysis	M	M	L	M	L	M	L	M	M	L	M	M	M	M
Equipment	L	M	L/M9	VH	M	L/H[14]	M	L[15]	M	L	H	H	H	H
Overall	**L/M**	**M**	**L/M**	**VH**	**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	**Vt** – VOLUNTEERS and ORGANISATIONS; **C – C**ONSULTANTS**;** **A - A**GENCIES; **S - S**CIENTISTS													
Possible performers	Vt, C, A, S	Vt, C, A, S	A, S	C, A, S	C, A, S	C, A, S	C, S, Vt	C, S, Vt	C, S	C, S, A, Vt	S	S	S	S

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

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

[15] 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 protocol 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.

Opportunities to reduce costs – opportunities that can improve 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**	**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 opportunities to couple efforts 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**	**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**	**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**	**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**	**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**	**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. 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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3. Beach Litter

3.1. Introduction to Beach Litter

Numerous reviews of monitoring methods for assessing litter in the marine environment have been published over the last decades (*e.g.* Dixon & Dixon 1981, Ribic *et al.*, 1992, Rees & Pond 1995, Ryan *et al.*, 2009, Cheshire *et al.*, 2009, Opfer *et al.*, 2012).

The recent overviews by UNEP, in Cheshire *et al.* (2009), and by NOAA, in Opfer *et al.* (2012), are the most comprehensive and useful overviews for monitoring methods on the coast. The UNEP overview includes a comprehensive comparison of existing marine litter survey and monitoring methods and protocols in which beach surveys were assessed (Cheshire *et al.,* 2009).

Much of the information included here is taken from the UNEP Operational Guidelines for Comprehensive Beach Litter Assessment (Cheshire *et al.,* 2009) and the NOAA Marine Debris Shoreline Survey Field Guide (Opfer *et al.,* 2012).

A minimum set of requirements for beach litter monitoring within the MSFD are recommended, which are based on the OSPAR (OSPAR Commission 2010a), UNEP and NOAA guidelines. When designing marine litter surveys it is necessary to differentiate between standing-stock surveys, where the total load of litter is assessed during a one-off count, and the assessment of accumulation and loading rates during regularly repeated surveys of the same stretch of beach with initial and subsequent removal of litter.

Both types of survey provide information on the amount and types of litter, however, only the accumulation surveys provide information on the rate of deposition of litter and trends in litter pollution. As the MSFD requires an assessment of trends in marine litter recorded on coastlines only methods for the assessment of accumulation are recommended in this protocol.

3.2. Scope and key questions to be addressed

The TSG-ML has evaluated existing methods for monitoring litter on the coastline with regard to their capacity to fulfil the requirements of the MSFD. The TSG-ML recommends a harmonised method that can be applied to assess litter on all (regional seas) coastlines, which will ensure comparability of the results of coastline assessments of litter within and between regions. In this chapter, the difficulties associated with applying the method and its limitations are presented. It also addresses data quality assurance and quality control for trend and other analyses.

3.3. Existing protocols

Litter monitoring on the coasts of the European seas has developed from a number of campaigns of mostly non-governmental organizations. Originally designed to heighten public awareness or to make a simple assessment of the magnitude of the problem, they have developed over a thirty-year period into a monitoring tool for litter occurring on beaches.

Most existing protocols that have been used on European coasts are based on simple counts of the number, in some cases also the measurement of the weight or volume, of litter items found on a given length of beach or water line. Such surveys have their limitations and are perhaps not a practical method for extremely litter-polluted coastlines and generally do not supply data on the amount of litter recorded for a given area of beach unless the area of beach being surveyed is measured. Because the abundance of beach litter is very much influenced by water currents, prevailing winds and the exposure of the beach, the use of exactly defined stretches of coast is vital when using this type of survey if trends in the amount of litter over time are to be measured.

3.4. Needs and requirements for MSFD monitoring

Monitoring of litter on the coastline should quantify and characterise litter pollution and provide comparable datasets to support national and regional assessments of marine litter. Consequently it should provide the basis for the development of management, control and enforcement measures and allow the effectiveness of mitigation strategies to be measured. It should also help us to understand the level of threat posed by marine litter to biota and ecosystems (Cheshire *et al.,* 2009).

The EC Decision of 1st September 2010 on criteria and methodological standards on good environmental status of marine waters established that the characteristics of litter in the coastal environment should be evaluated. The evaluation should allow for the assessment of trends in the amount of litter washed ashore and/or deposited on coastlines, including analysis of its composition, spatial distribution and, where possible, source.

The monitoring methods applied on the coastline should provide reliable and, if possible, easily understandable information on all of these factors.

3.5. Harmonised Protocol

The comparison of beach litter data between assessment programmes is the primary aim of a harmonised protocol. Comparison is difficult if different methods, different spatial and temporal scales, different size scales of litter items and different lists or categorisation of litter items recorded on beaches are used within the regional seas and the EU as a whole.

The type of survey selected depends on the objectives of the assessment and on the magnitude of the pollution on the coastline. A single survey method is recommended here – with different spatial parameters for light to moderately polluted coastline and for heavily polluted coastlines.

Amounts of litter on the shore can be relatively easily assessed during surveys carried out by non-scientists using unsophisticated equipment. Coastal surveys are thus a cost effective way of obtaining large amounts of information. The litter deposited on the coastline can vary greatly between sites and seasons, affected by hydrographical and geomorphological characteristics of the area (*e.g.* prevailing winds and currents, exposure of the beach to the sea) but also depending on the use of the coast (*e.g.* larger amounts can be deposited during the tourist season or during special events). Therefore, coastal surveys should focus on fixed sites, which fulfil the requirements of the protocol, and the timing of the survey (i.e. season) should take into account the potential sources of litter to the site (*e.g.* flooding in rainy seasons may increase the amounts). Sites can be placed far from known sources, in order to better reflect reference values for background litter pollution levels, or close to potential sources. By using temporal trends for assessments, both of the survey strategies give important information for managers.

3.5.1. Amounts, composition, distribution and sources of Beach Litter

Trends in amounts of litter

The variation in the amount of litter present on a given beach between surveys and the variation between beaches, even in the same region, can be extremely large. This makes the identification of trends difficult. In fact, a*nalyses of OSPAR beach data from 2001 to 2011 (Schulz et al., 2013) showed considerable seasonal variation partly masking long-term trends.* Moreover, as litter accumulates on beaches, surveys should be carried out at regular intervals in time so that the accumulation periods are approximately of the same length.

Composition of litter

The assessment of composition of litter is one of the great strengths of coastal assessments. A detailed assessment of litter composition provides information on potential harm to the environment and in some cases on the source of the litter found. The assessment of composition must follow commonly agreed categories in order to provide results which are comparable over larger regions.

Spatial distribution

Amount and composition of marine litter varies over geographical scales and reflects hydrographical (e.g. tides, currents, wave exposure, wind directions) and geomorphological (e.g. steepness of a shore, amounts of inlets islands) characteristics of the coast. Hydrographical characteristics determine the amount of litter accumulating in waters adjacent to the coast, whereas geomorphological characteristics determine how much of this litter becomes washed ashore.

Sources of marine litter

The source of litter found on the coast can be clearly identified for some litter items. These are mostly items which originate from fisheries, or debris flushed down sewerage systems. Even with these items some caution is needed *e.g.* a fish box may originate from a fishing vessel or from a fishing port.

A comprehensive master list of items and categories has been developed within the TSG-ML (see Chapter 8). The sources for some items need to be designated at a regional level, because initial assessments of litter on coastlines show that sources for a given item can be different between regions.

The master list will enable at least a rough estimate of the sources of litter found on coastlines, but it should be evaluated in survey sites against known local sources. If detailed information is required it will, be necessary to carry out detailed research into the sources involved *e.g.* to identify between litter deposited directly on the beach by tourists and litter arriving on the beach from adjacent waters. In addition drift analysis of litter in adjacent waters could provide valuable information on its geographical origin.

3.5.2. Strategy for monitoring beach litter

3.5.2.1. Selection of survey sites

Ideally the selected sites should represent litter abundance and composition for a given region. Not any given coastal site may be appropriate, as they may be limited in terms of accessibility, suitability to sampling (sand or rocks/boulders) and beach cleaning activities. If possible the criteria below should be used:

- A minimum length of 100m.
- Low to moderate slope (15 – 45º), which precludes very shallow tidal mudflat areas that may be many kilometres wide at low tide.
- Clear access to the sea (not blocked by breakwaters or jetties) such that marine litter is not screened by anthropogenic structures.
- Accessible to survey teams year round, although some consideration needs to be given to sites that are iced-in over winter and the difficulty in accessing very remote areas.
- Ideally the site should not be subject to any other litter collection activities, although it is recognized that in many parts of Europe large scale maintenance cleaning is carried out periodically; in such cases the timing of non-survey related beach cleaning must be known such that litter flux rates (the amount of litter accumulation per unit time) can be determined.
- Survey activities should be conducted so as not to impact on any endangered or protected species such as sea turtles, sea birds or shore birds, marine mammals or sensitive beach vegetation; in many cases this would exclude national parks but this may vary depending on local management arrangements.

Within the above constraints, the location of sampling sites within each zone should be stratified such that samples are obtained from beaches subject to different litter exposures, including:

- Urban coasts, may better reflect the contribution of land-based inputs;
- Rural coasts may better reflect background values for litter pollution levels

- Coasts close to major rivers, if downstream from the prevailing drift, may better reflect the contribution of riverine input to coastal litter pollution.

3.5.2.2. Number of sites

At present there is no agreed statistical method for recommending a minimum number of sites that may be representative for a certain length of coast. This depends greatly on the purpose of the monitoring, on the geomorphology of the coast and how many sites that meet the criteria described above are available. The representativeness of survey sites should be assessed in pilot studies, where initially a large numbers of beaches are surveyed. Subsequently, selection of representative beaches from these sites should be made on the basis of a statistical analysis.

3.5.2.3. Frequency and timing of surveys

At least four surveys per year in spring, summer, autumn and winter are recommended. However, because of the large seasonal variation in amounts of litter washed ashore, initially a higher frequency of surveys may be necessary in order to identify significant seasonal patterns, which can then be considered when treating raw data for long-term trend analyses.

The survey periods below are suggested:

1) Winter: Mid-December–mid-January
2) Spring: April
3) Summer: Mid-June–mid-July
4) Autumn: Mid-September–mid-October

Preferably, the surveys for all participating beaches in a given region should be carried out within the shortest timeframe possible within a survey period. Coordinators within these regions should try and coordinate the survey dates between beaches. Furthermore a given beach should be surveyed on roughly the same day each year if possible.

Monitoring should start about one hour after high tide to prevent surveyors being cut off by incoming tide. If working on remote beaches it is recommended to work with a minimum of two people.

It should be kept in mind that circumstances may lead to inaccessible and unsafe situations for surveyors: heavy winds, slippery rocks and hazards such as rain, snow or ice, etc. The safety of the surveyors **must** always come first. Dangerous or suspicious looking items, such as ammunition, chemicals and medicine should not be removed. Inform the police or authorities responsible.

3.5.2.4. Documentation and characterisation of sites

It is very important to document and characterise the survey sites. As surveys should be repeated on exactly the same site the coordinates of the site should be documented.

It is strongly recommended to use the Marine Litter Beach Documentation and Characterization Form of the OSPAR Marine Litter Beach Questionnaire (OSPAR Commission 2010b).

3.5.2.5. Sampling unit

Once a beach is chosen sampling units can be identified. A sampling unit is a fixed section of beach covering the whole area between the water edges (where possible and safe) or from the strandline to the back of the beach.

- At least 2 sections of 100m on the same beach are recommended for monitoring purposes on lightly to moderately littered beaches

- At least 2 sections of 50 m for heavily littered beaches

Permanent reference points must be used to ensure that exactly the same site will be monitored for all surveys. The start and end points of each sampling unit can be identified by different methods. For example numbered beach poles could be installed at the site or easily identifiable landmarks could be used. Coordinates obtained by GPS are useful for identifying the reference beaches especially where easily identifiable landmarks are lacking.

3.5.2.6. Units (quantification) of litter

The unit in which litter is assessed on the coastline can be number, weight or volume, or a combination of these units. Counts of items are recommended as the standard unit of litter to be assessed on the coastline.

The assessment of weight of litter is problematical because it is dependent on whether litter items are wet or dry and often whether they are covered with or full of sand and gravel (Jambeck & Farfour 2011). Some items are even too big to be weighed and their weight must be estimated. The results of weight-based surveys and number-of-item-based surveys cannot be compared directly. Estimates of the weight of items counted could be made if average weights of the litter items assessed are known. However, this would not be possible for all items *e.g.* nets, which occur on beaches in a wide range of sizes and weights.

The assessment of the volume of litter is also problematical because it depends on the level of compression of the litter involved. Measurements of litter volume are not easily reproducible and only give a rough idea of the amount of litter recorded.

3.5.2.7. Collection and identification of litter items

All items found on the sampling unit should be entered on the survey forms. On the survey forms, each item is given a unique identification number. Data should ideally be entered on the survey form while picking up the litter. Collecting the litter first and identifying it later may alter numbers as collected litter tends to get more entangled or broken.

Unknown litter or items that are not on the survey form should be noted in the appropriate “other item box”. A short description of the item should then be included on the survey form. If possible, digital photos should be taken of unknown items so that they can be identified later and, if necessary, be added to the survey form.

A master list of litter categories and items is included in Chapter 8. This master list includes a list of categories and items to be recorded during beach litter surveys. Please refer to this list.

It is strongly recommended to produce regional photo guides including pictures of all litter items on the regional survey protocol. This will assist in the correct identification and allocation of recorded items. The OSPAR photo guide 100m[21] (OSPAR Commission 2010c) can be used in some regions and modified for others.

3.5.2.8. Size limits and classes of items to be surveyed

There are no upper size limits to litter recorded on beaches.

If lower size limits are not set, the lower limit will be determined by the possibility of detection by the naked eye and depends on the visual perception (eyesight) of the surveyors and on the conspicuousness of the litter items, which in turn depends on their size, colour and form. The lower limit of detection, when walking a beach, is probably somewhere around 0.5 cm (plastic pellets), however, it is doubtful that such small items can be monitored effectively and in a repeatable fashion during beach surveys.

A lower limit of 2.5 cm in the longest dimension is recommended for litter items monitored during beach surveys. This would ensure the inclusion of caps & lids and cigarette butts in any counts.

[21] http://www.robindesbois.org/macrodechets/Ospar_Photo_100m_lr.pdf

3.5.2.9. *Removal and disposal of litter*

Removal of litter should be carried out at the same time as monitoring the litter. Coupling removal with monitoring ensures better accuracy of reporting and enables comparison of litter accumulation over time; It also has the added advantage of leaving a clean beach. It is important to note that only the 100m ref section(s) need to be monitored and cleaned. Further areas of a beach can be cleaned without monitoring if surveyors/volunteers wish to do so.

The litter collected should be disposed of properly. Regional or national regulations and arrangements should be followed. If these do not exist local municipalities should be informed.

Larger items that cannot be removed (safely) by the surveyors should be marked, with for example paint spray (for marking trees) so they will not be counted again at the next survey.

Many municipalities will have their own cleaning programme, sometimes regularly, sometimes seasonal or incident related. Arrangements should be made with the local municipalities so that they either exclude the reference beach from their cleaning scheme or they provide their cleaning schedule so surveying can be carried out a few days before the municipality will clean the beach.

Preferably a set time should be established for each beach between the date when the beach was last cleaned and the date when the survey is carried out. It is advisable to contact the municipality before starting a survey to obtain the latest information on beach cleaning activities. Sometimes an incident, for example a storm, will alter their cleaning programme.

3.6. Quality Assessment /Quality Control

Based on the UNEP Guidelines (Cheshire *et al.,* 2009), any long-term marine litter assessment programme will require a specific and focussed effort to recruit and train field staff and volunteers. Consistent, high quality training is essential to ensure data quality and needs to explicitly include the development of operational (field based) skills. Staff education programmes should incorporate specific information on the results and outcomes from the work so that staff and volunteers can understand the context of the litter assessment programme.

Quality assurance and quality control should be primarily targeted at education of the field teams to ensure that litter collection and characterization is consistent across surveys. Investment in communication and the training of the country/regional and local survey coordinators and managers is thus critical to survey integrity.

The quality assurance protocol of Ocean Conservancy's National Marine Debris Monitoring Program (USA) required a percentage of all locations to be independently re-surveyed immediately following the scheduled assessment of litter (Sheavly, 2007). The collected litter from the follow-up survey could then be added to that of the main collection and could be used to provide an estimate of the error level associated with the survey. This approach should be employed as a component of beach litter surveys.

3.7. Data Management

Data collation should be undertaken through an online, relational database management system under the control and direction of the local managers. Responsibility for review and approval of uploaded data should be undertaken by the regional/country 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 will also support comprehensive analysis of the data providing the opportunity to undertake statistically robust comparisons through time and between survey locations (Cheshire *et al.,* 2009).

Database structures are available for OSPAR litter data and could be used/adapted for other regions.

3.8. The costs of beach litter monitoring

Table 3 presents a breakdown of the estimated effort required for the different tasks associated to the setting-up and running of a beach monitoring programme. Effort is presented in man-hours and estimations are based on the OSPAR monitoring system of four surveys a year, on four permanent sites, surveying the number of all litter items on 100 meters of coastline.

The actual financial costs of the surveys will vary from country to country depending on the costs of employing personnel, on whether professional or volunteer surveyors are used, etc. As an illustration the Netherlands and Germany spend between € 10.000 and 20.000 per year to run the monitoring of 4 sites, 4 times/year, including data management, analysis and reporting.

TASK	Hours/year setting up the programme	Hours/year running the programme
Contact with the organizations who carry out the surveys*	65	30
Setting up and running the monitoring program	65	30
Training of surveyors **	65	40
Carrying out the surveys (4 sites x 4 times/year)		192
Data input		40
Running the database	30	5
Data analysis		30
Reporting	8	40
(Further) development of methods	40	10
Participation on national and international workshops, working groups, etc.	50	30
TOTAL	**327**	**439**
*** 4 for survey sites; ** Central training event**		

Table 3: Estimation of effort for beach litter monitoring

3.8.1. Coordination

Without coordination at a regional/national level, a monitoring system for beach litter cannot be permanently maintained.

Tasks of the regional coordinator are:

- identification and setting up of survey sites
- contact with the organizations/institutions carrying out the surveys
- development & maintenance of the survey system
- training of surveyors
- entering the data into the database/QA of data

- maintaining the database
- data analysis
- reporting
- (further) development of methodology
- participation in national and international workshops, working groups, etc.

The coordination requires an office with communication facilities (phone, e-mail, internet access) and transportation.

For the overall coordination of four survey sites ca. 330 hours will be necessary in order to set up the monitoring system and about 250 hours/year will be required to maintain the system (see Table 3 above).

3.8.2. Carrying out the surveys

The actual cost of carrying out the surveys will depend on whether professional surveyors are paid to do the work or whether a system of volunteer surveyors from for example nature or environmental groups and societies is used. Using volunteers will increase the work load of the regional coordinator using professional workers will increase the costs of the surveys themselves.

If the weight of the litter is to be recorded (*e.g.* HELCOM Recommendation) this will increase the cost of the surveys considerably, since the effort (= number of hours) is significantly larger.

For preparation and carrying out the surveys (2 persons) and reporting for 4 surveys/year it is estimated that ca. 48 person-hours will be required to actually carryout the surveys for each site.

Carrying out the survey	
Days/survey site/year	8
Person-hours/day	6
Hours/survey site/year	48
Total (4 sites/4 times/year)	**192**

When litter is removed during the survey additional costs for disposal of the litter will occur.

In addition costs for travel and if necessary for board and lodging will occur depending on the location and accessibility of the survey sites.

3.8.3. "Marine LitterWatch" – a mobile tool to collect beach litter data

In view of innovative and cost-efficient monitoring methods and tools the European Environment Agency (EEA) is offering the citizen science based *Marine LitterWatch (MLW).* It aims to help fill data gaps on beach litter relevant for MSFD purposes, at the same time as it explores the benefits of involving citizens in the collection and monitoring of marine litter.

Marine LitterWatch primarily consists in a mobile application. It allows users to conduct beach litter monitoring surveys and support national monitoring programmes. Marine LitterWatch builds on the TSGML beach litter monitoring guidelines and the proposed Master List of litter items (see Chapter 8). The app also enables the collection of data from popular clean-ups. Data from popular clean-ups are treated as a separate dataflow.

Marine LitterWatch also includes a public central database hosted by EEA. From this database, data can be retrieved and used in other databases and/ or further disseminated into a wider range of products (e.g. survey reports and maps). Marine LitterWatch is developed in accordance with the Shared Environmental Information System (SEIS) principles.

During the summer 2013, MLW was tested for in volunteer clean-ups and national beach litter monitoring surveys. The initial results showed that the mobile application is well suited for both of these purposes. With the inclusion of minor technical improvements, MLW has the potential to become a tool to perform proper beach litter surveys as well as popular clean-ups.

Marine LitterWatch will be publically available for Android devices in the Google app store by the end of 2013. The iOS version is expected in spring 2014. A phased public roll-out will also happen in the beginning of 2014. The aim is to reach target policy and public audiences. As Marine LitterWatch is an exploratory project, its wider uptake and use will be essential for further fine-tuning, and for filling-in data gaps on beach litter.

More information about the Marine LitterWatch and its further developments can be found on the dedicated EEA webpage http://www.eea.europa.eu/themes/coast_sea/marine-litterwatch/marine-litterwatch.

3.9. Conclusions

In order to enable temporal and spatial comparisons within and across regions, standard litter survey methods should, where possible, be applied at all levels (local to regional) and the assessment of its composition follows agreed categories of items.

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4. Floating Litter

4.1. Introduction to Floating Litter

The monitoring of floating marine litter corresponds to indicator 10.1.2 within Descriptor 10 of the Marine Strategy Framework Directive.

The occurrence of man-made objects, mainly plastic, floating at sea has been described since long time ago (Venrick 1972, Morris, 1980). While significant actions in waste management and disposal have been taken, floating litter is still a concern. It poses a direct thread to fishes, marine mammals, reptiles and birds. Harm can occur through ingestion of whole items or pieces or by feeding on larger litter items. Entanglement can occur by bags, nets and other fishing gear. It can be assumed that marine macro litter is a precursor of marine micro litter.

4.2. Scope and key questions to be addressed

This chapter compiles the existing protocols for the monitoring of floating marine macro litter. It then investigates their differences, applicability and other important elements. It identifies the needs for monitoring methods to be used for MSFD and analyses eventual shortcomings of the existing approaches in view of their application to monitoring under the MSFD. Following up on the tools developed in the TSG-ML 2011 report, it develops a proposal for a protocol, in order to fill the recognized gap under Tool Code 10.1.2_Water T1.

This protocol does not address the monitoring of litter at open sea and on long transects, as this requires different approaches, in particular regarding the observation conditions provided by the ships used for the surveys and regarding the possibility to monitor smaller items..

The protocols aim at harmonised monitoring approaches, in order to ensure data comparability between different programmes and across regions. This chapter also addresses the issue on data quality assurance and control for trend analysis. It elaborates on the possibility to use monitoring data deriving from the use of platforms of opportunity. Finally, it investigates and describes the recent development of new monitoring methods as follow-up of the MSFD TSG 2011 report.

The fraction of litter discussed here, includes the floating items in the water column close to the surface, as caused *e.g.* by the temporary mixing of floating particles under the water surface due to wave action. Litter in the deeper water column is currently not recommended for routine monitoring and should be subject of research efforts.

4.3. Existing approaches for visual ship-based observation of floating litter

An assessment of different methodologies currently employed approaches has been made. These are used by HELMEPA, ECOOCEAN, Chile/Germany, UNEP, NOAA and by scientific research groups.

While the approaches for the different monitoring schemes are listed shortly, more detailed information can be found in the cited references:

HELMEPA

HELMEPA uses a fleet of ocean going member vessels on a voluntary basis to obtain monitoring data through a reporting sheet.

EcoOcéan Institut

EcoOcéan Institut: EcoOcean Institut is performing monitoring of floating litter in parallel with monitoring of marine mammals in the North-western Mediterranean Sea.

UNEP

UNEP guidance considers both, sampling of an area through a dedicated observation pattern and transect sampling for monitoring of surface floating litter (UNEP, 2009).

NOAA

NOAA operates two approaches for voluntary observation of marine litter: one for yacht racers in the Pacific and a different one for use with the Office of Marine and Aviation Operation's fleet of ships (Arthur *et al*, 2011).

University of Coquimbo, Chile

Several scientific publications have been made by Martin Thiel and collaborators (*e.g.* Hinojosa & Thiel, 2009). A strip transect approach is followed through observation from a ship bow.

Other approaches

Other scientific research groups are using different protocols for their observation purposes (Ryan, 2013).

4.3.1. Discussion of observation protocol elements

The observation of floating marine litter from ships is subject to numerous variables in the observation conditions. They can be divided into operational parameters, related to the ship properties and observation location.

Operational observation parameters:

- Observation height
- Observation width
- Observation distance
- Observation angle
- Ship speed

Environmental parameters:

- Wind speed
- Sea state
- Light conditions
- Sun direction
- Viewing (quality of vision eventually impaired by fog, etc.)

Marine litter object properties:

- Location (INSPIRE compatible geographical coordinates)
- Lower size range (detection limit)
- Upper size range (detection probability)
- Categories
- Object properties
- Windage (protrusion from water surface)
- Object size
- Object shape
- Object description
- Object depth
- Source relations
- Ageing/weathering
- Biofouling
- Object colour

The processing of the collected information, starting from the documentation on board, its compilation, elaboration and further use should be part of a protocol in order to derive comparable final results. The format should allow a compilation across different observing institutes and areas or regions. This would allow a plotting of floating litter distribution over time and thus finally allow the coupling with oceanographic current models.

Documentation

- Datasheet
- Photographic
- App
- Data compilation

Data analysis

- Statistics
- Averaging
- Geostatistical analyses
- Modelling (with oceanographic current models)

Data presentation

- Map Plotting
- Graphs
- Density mapping

4.4. Strategy for monitoring of floating marine litter

4.4.1. Source attribution of floating marine litter

The MSFD COM DEC 2010/477/EU calls for the "…analysis of its composition, spatial distribution and, where possible, source (…)". Due to the observation methodology, the source attribution for floating litter is challenging. The type of marine litter objects can only be noted during very short visual observation. Therefore, in difference to beach litter, it is likely that only rough litter categories can be determined.

The spatial distribution of floating marine litter instead gives, in combination about currents, tides and river information indications about the physical source, i.e. the litter input zone and its pathway, which is very valuable information about source strength and may help to design appropriate measures and check their efficiency of.

The monitoring of floating litter is very likely to be an iterative process during which in an initial phase hot spots and pathways are determined, while in an evolving monitoring program selected transects help with the quantification of trends.

4.4.2. Spatial distribution of monitoring

The monitoring of floating marine litter by human observers is a methodology indicated for short transects in selected areas. In a region with little or no information about floating marine litter abundance it might be advisable to start by surveys in different areas in order to understand the variability of litter distribution. The selected areas should include expected low density areas (*e.g.* open sea) as well as expected high density areas (*e.g.* close to ports). This will help to obtain maximum/minimum conditions and train the observers. Other selected areas (*e.g.* in estuaries), in the vicinity of cities, in local areas of touristic or commercial traffic, incoming currents from neighbouring areas or outgoing currents should be considered.

Based on the experience obtained in this initial phase, a routing programme including areas of interest should then be established.

4.4.3. Timing of floating marine litter monitoring

The observation of floating marine litter is much depending on the observation conditions, in particular on the sea state and wind speed. The organization of monitoring must be flexible enough to take this into account and to re-schedule observations in order to meet (according to the protocols QA/QC section) appropriate conditions. Ideally the observation should be performed after a minimum duration of calm sea, so that there is no bias by litter objects which have been mixed into the water column by recent storms or heavy sea.

The initial, investigative monitoring should be performed with a higher frequency in order to understand the variability of litter quantities in time. Even burst sampling, *i.e.* high sampling frequency over short period, might be appropriate in order to understand the variability of floating marine litter occurrence.

For trend monitoring the timing will depend on the assumed sources of the litter, this can be *e.g.* monitoring an estuary after a rain period in the river basin, monitoring a touristic area after a holiday period.

The timing of the surveys will also depend on the schedule of the observation platforms. Regular patrols of coast guard ships, ferry tracks or touristic trips may offer frequent opportunities which thus also allow the use during the needed calm weather conditions. The sharing of information and experience from the investigative monitoring between local authorities, regions and at EU level will be important for the organization of a harmonized and cost effective monitoring of the European Seas.

4.5. Categories for floating marine litter

The reporting of monitoring results requires the grouping into categories of material, type and size of litter object. The approach for categories of floating litter is linked with the development of a "master list" with the categories for other environmental compartments (see Chapter 8). This allows cross comparisons.

4.5.1. Material and item categories

The categories of items for floating litter should be, as far as practical, consistent with the categories selected for beach litter, seafloor litter and others. There are limitations to this, but in principal the derived data should allow a comparison across different environmental compartments, in particular between beach and surface floating litter. Therefore the list of item categories that should be adopted for floating litter corresponds to the Master List of items. For the practical use during the monitoring the list has to be arranged by object occurrence frequency so that the data acquisition can be done in the required short time. Tablet computer applications for facilitating the data documentation are under development.

4.5.2. Size categories

As floating litter items will be observed but not collected, the size is the only indicative parameter of the amount of plastic material that it contains. The size of an object is defined here as its largest dimension, width or length, as visible during the observation.

The lower size limit for the observations is determined by the observation conditions. These should be harmonized so that a lower limit of 2.5 cm can be achieved. That size appears to be reasonable for observation from "ships-of-opportunity" and is in line with the size for beach litter surveys. This denotes that observations not achieving this minimum size limit cannot be recommended.

For reporting purposes size range classes must be introduced as visual observation will not permit the correct measuring of object sizes. Only the estimation of size classes is feasible.

The size determination/reporting scheme should enclose the following classes:

- 2.5 – 5 cm
- 5 - 10 cm
- 10 – 20 cm
- 20 – 30 cm
- 30 – 50 cm

While also wider size range classes (*e.g.* 2.5–10cm, 10–30cm, 30–50 cm) could be utilized, it will be important that a common approach is used, as the data will be combined in common data bases. The test phase of the protocol should allow the determination of overall accepted and final size range classes. The upper size limit will have to be determined by statistical calculations regarding the density of the object occurrence in comparison to transect width, length and frequency. In coherence with the beach litter surveys an upper limit of 50 cm is here provisionally proposed. It has to be evaluated in experiments and from initial data sets if items larger than 50 cm should be reported, as their relevance in the statistical evaluation of data from short and narrow coastal transects might be questionable.

4.6. Protocol for visual monitoring of floating litter

The protocol will provide a harmonized approach for the quantification of floating marine litter by ship-based observers. It has the scope to harmonize the monitoring of floating marine litter:

- In the size range from 2.5 to 50 cm,
- Observation width needs to be determined according to observation set-up,
- It is planned for use from ships of opportunity,
- It is based on transect sampling,
- It should cover short transects, and
- Also record necessary metadata.

4.6.1. Observation

The observation from ships-of-opportunity should ensure the detection of litter items at 2.5 cm size. The observation transect width will therefore depend on the elevation above the sea, the ship speed and the observation conditions. Typically a transect width of 10 m can be expected, but a verification should be made and the width of the observation corridor chosen in a way that all items in that transect and within the target size range, can be seen. Table 4 below provides a preliminary indication of the observation corridor width, with varying observation elevation and speed of vessel (kn = knot = nautical mile/h). The parameters need to be verified prior to data acquisition.

The ideal location for observation will often be in the bow area of the ships. If that area is not accessible, the observation point should be selected so that the target size range can be observed, eventually reducing the observation corridor, as ship induced waves might interfere with the observations. An inclinometer can be used to measure distances at sea (Doyle, 2007).

Observation elevation above sea	Ship speed 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	5m

Table 4: Width of "observation corridor" based on observation height and ship speed (to be reviewed)

The protocol will have to go through an experimental implementation phase during which it is applied in different sea regions by different institutions, its practicality is tested and feedback for definition of observation parameters is provided.

The observation, quantification and identification of floating litter items must be made by a dedicated observer who does not have other duties contemporaneously. Observation for small items and surveying intensively the sea surface leads to fatigue and consequently to observation errors. The transect lengths should therefore be selected in a way that observation times are not too long. Times of 1 h for one observer could be reasonable, corresponding to a length of a few kilometres.

4.6.2. Data and metadata reporting

A harmonized reporting of monitoring results is crucial for the comparison of data. The data output from the application of the protocol, when using a computer interface, is a list of georeferenced objects according to a list of categories. The use of a portable computer device for documenting marine floating litter has clear advantage over paper documents. A specific application, based on the MSFD protocol for the monitoring of floating macro litter will be developed by JRC and field tested within the PERSEUS project.

It is not uncommon that floating litter items appear grouped, either because they have been released together or because they accumulate on oceanographic fronts. The reporting system should acknowledge this and foresee a way to report such groups. The occurrence of such accumulation areas needs to be considered when evaluating the data.

For floating marine litter the unit of reporting will be: items/km^2. The data will be available for the different categories and size classes. They can then be aggregated at different levels for providing overview data.

Along with the litter occurrence data, a series of metadata should be recorded, including georeferencing (coordinates) and wind speed (m/s). This accompanying data shall allow the evaluation of the data in the correct context and should be compatible with the INSPIRE Directive in order to make data easily exchangeable and shareable.

4.6.3. Quality Assessment /Quality Control

The wide spread acquisition of monitoring data will need some kind of intercomparison or calibration in order to ensure comparability of data between different areas and over time, for trend assessments. Approaches for this should be developed and implemented. This can be *e.g.* hands (eyes)–on training courses with comparisons of observations). Such events should be organized at EU level with further implementation at national scale then being organized in the EU Member States.

A methodology for calibrating observation quality by artificial targets may be devised through research efforts.

4.6.4. Equipment

The equipment used for the monitoring of floating litter is very limited. Besides the transportation platform some instruments may facilitate the work:

- A system for visually marking the observation area,
- GPS for determination of ship speed and geographical coordinates,
- A tablet PC (with GPS) for documenting the results (including a dedicated application/program),

- A system for training and calibrating size classification.

4.7. Cost of monitoring of floating litter

Costs for the monitoring of marine litter by a dedicated activity could be high, due to the involvement of a vessel. Therefore it can be expected that the monitoring of floating litter will mostly be connected to other activities. Though this can drastically reduce the operational costs ("close to zero"), marine litter observation needs dedicated personnel on board of the ships. The work can be done by volunteers, but in this case the proper training and following of protocols must be ensured. As no specific skills are need for observation, it can be done by personnel with different occupations on board a ship. In practise such monitoring is *e.g.* done by researchers quantifying marine mammal's abundance. The observation itself should be done be dedicated operators. This requires careful planning, as the requirements for the two tasks might still deviate attention and may not be compatible *e.g.* because of different observation distances.

4.7.1. Using opportunities for observation

The monitoring of marine litter can be done from any ship of appropriate size and speed moving on transects which are suitable for a sustainable monitoring of trends.

The placing of a dedicated person on board of a ferry for a selected short coastal transect repeated in appropriate intervals appears to be a very cost effective methodology, which can in short time provide a quantification of floating marine litter.

Other opportunities for observation can be: scheduled coastal oceanographic cruises, associated or not with monitoring of other MSFD Descriptors, coast guard patrols, ferries, touristic cruises, etc. Of course the monitoring programme needs then to be adjusted to the available opportunities and some compromises for the ideal observation transect might be needed.

4.7.2. Cost estimate

Trying to quantify the costs could denote to calculate *e.g.* the ferry shipping cost for a person; though in reality this may often be an in kind contribution by the ship owner company. Added to this would be the staff cost for a day of work (in case of availability of an appropriate ferry transect). The number of sites obviously depends on the marine and coastal extension of the country and its topography, population density, number of estuaries, etc.

Type of Cost	
Manpower cost:	0.5 man day/transect (including transfers)
Equipment cost:	ca. 250 € for tablet PC
Processing cost:	only need to download data
Analysis cost:	Plotting of data with a simple tool
Reporting cost:	5 man days for data preparation for a whole regional data set
Note: The cost of manpower will vary significantly between countries and the available personnel.	

Table 5: Estimation of costs of the different phases of monitoring floating litter through visual observation and considering "platforms-of-opportunities" (*i.e.* no cost associated to vessel)

4.7.3. Implementation of the protocol

The finalization and wide acceptance of the proposed protocol will require an experimental testing period during which observation parameters and reporting approaches are being studied on a wide range of ships and conditions, covering different regional seas. This can be achieved through the MSFD implementation process and through dedicated activities in research projects, such as PERSEUS. Resulting data can be used for adjusting the protocol. Once the protocol parameters, such as standardized size ranges, categories and observation conditions are confirmed, a final version can be prepared. The final protocol should be widely disseminated and accompanied by activities for its implementation. Training courses and workshops can contribute to the harmonized acquisition of comparable datasets.

4.8. Other methodologies

Open sea surveys

While the proposed protocol is aiming at coastal surveys, there are also approaches for monitoring of litter from large, seagoing vessels. While covering large areas, these surveys face considerably different observation conditions and therefore different observation protocols.

Aerial surveys

The opportunistic use of aerial surveys (*e.g.* for marine mammal observation/monitoring) has been considered. The minimum size of observed objects is at ca. 30 cm, therefore this approach might be adequate to the size fraction above 30 cm (MSFD GES TSG Marine Litter, 2011).

Net tow surveys for macro litter

Physical sampling of floating macro litter requires large net openings operated at the sea surface. Given the density of larger macro litter items occurrence this would require significant dedicated ship time and specific equipment. This method is applicable for floating micro litter. There should be methodological research on how to cover the size range between 5 mm and 2.5 cm, which is very relevant to ingestion by marine biota.

Riverine litter monitoring

It should be mentioned that the protocol is as well applicable for the monitoring of floating litter on rivers by observation from bridges or similar. The comparability of data between riverine and marine monitoring is important for the quantification and budgeting of litter sources.

New methodologies

Closely related to the monitoring by human visual observation is the monitoring through image acquisition by digital camera systems and their subsequent analysis by image recognition techniques. The EC JRC is developing the JRC *Sealittercamera*, a system being temporarily deployed on Costa Crociere cruise ships in the Western Mediterranean Sea (Hanke, 2011, publication in preparation).

4.9. Conclusions

Key messages to MSFD implementation process:

- The monitoring of floating marine litter in selected coastal transects is recommended

- Monitoring Marine Litter suspended in the middle water column is not recommended
- Monitored size categories should include a range covering relevant small items
- Monitoring of floating litter should follow a specific protocol agreed on EU scale within the MSFD implementation process

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5. Seafloor Litter

5.1. Introduction to Sea-floor Litter

Indicator 10.1 (*Characteristics of litter in the marine and coastal environment*) of Descriptor 10 includes the trends in the amounts of litter deposited on the seafloor, with analysis of its composition, spatial distribution and, where possible, source according to the Commission Decision (2010/477/EU).

Coordinated national or regional monitoring programmes for litter on the sea-floor within Europe have started in 2013 through experimental monitoring. The most common approaches to evaluate sea-floor litter distributions use opportunistic sampling. This type of sampling is usually coupled with regular fisheries surveys (marine reserve, offshore platforms, etc.) and programs on biodiversity, since methods for determining seafloor litter distributions (*e.g.* trawling, diving, video) are similar to those used for benthic and biodiversity assessments. The use of submersibles or *Remotely Operated Vehicles* (ROVs) is a possible approach for deep sea areas although this requires expensive equipment. Monitoring programmes for demersal fish stocks, undertaken as part of the International Bottom Trawl Surveys (IBTS), operate at large regional scale and provide data using an harmonized protocol, which may provide a consistent support for monitoring litter at the European scale on regular basis and within the MSFD requirements (see the 2011 GES TG ML report, "Marine Litter Technical Recommendations for the Implementation of MSFD Requirements).

5.2. Scope and key questions to be addressed

This Chapter evaluates existing methods for monitoring litter on the sea floor with respect to their capacity to fulfil the requirements of the MSFD. It proposes harmonised methods that can be applied to assess litter on regional seas which will ensure comparability of the results of seafloor assessments of litter within and between regions and at European scale. It presents the difficulties associated with applying the method and its limitations. A strategy is proposed, listing criteria, sites of interest and constraints. Complementary methodologies are also proposed for specific questions. Finally, it addresses data quality assurance and quality control requirements for trend and other analyses.

For shallow waters, the monitoring of litter on seafloor may not be considered for all coastal areas because of limited resources. In these areas the strategy is to be determined by each MS at national level, depending on the priority areas to be monitored. Opportunistic approaches may be used to minimize costs. Valuable information can be obtained from on-going monitoring of benthic species in protected areas, during pipeline camera surveys, cleaning of harbours and through diving activities. Additional monitoring might have to be put in place to cover all areas creating a consistent monitoring network. The sampling strategy should enable the generation of good detail of data, in order to assess most likely sources, the evaluation of trends and the possibility of evaluating the effectiveness of measures. The TSG-ML proposes simple protocols based on existing trawling surveys and two alternative protocols based on diving and video imagery which fit with the MSFD requirements and support harmonisation at European level, if applied trans-nationally.

Trawling (otter or beam trawl) is an efficient method for large scale evaluation and monitoring of sea-floor litter. The monitoring strategy for sea-floor can efficiently be based on on-going monitoring already developed at European level. It must be noted, however, that the geomorphology may impact the accumulation of litter in the seafloor and some sampling restrictions in rocky areas (incompatible with trawling) may lead to underestimation of the quantities present. Designing a developing an adequate monitoring programme will have to take account of these limits. Existing fisheries stock assessment programmes are covering most European seas on an annual basis, facilitating the harmonization across member states and the management of data. Key information can be obtained on typology, sources, localisation and trends.

Only some countries will have to consider deep sea areas in terms of monitoring of sea-floor litter. The strategy is to be determined by each MS at national level, depending on affected areas but previous results indicate that priority should be given to coastal canyons. Protocols based on video imagery are the only approaches to monitor deep sea areas. These protocols are based on the use of (ROVs)/submersibles. Because litter are accumulating and degrading slowly in deep sea waters, a multiyear evaluation will be sufficient.

Finally, research has shown to be also important to support the evaluation of litter on sea-floor. The priority topics include (i) the localisation of accumulation areas and supporting tools such as modelling to identify possible priority areas and to enable backtracking transportation schemes and sources, (ii) an analysis of existing data to characterise the most important sources, and (iii) the improvement of imaging tools (automated analysis, image resolution, etc.) for the deep sea video protocol.

5.3. Background and state of the art

The sea-floor from inter-tidal to abyssal depths has been identified as an important sink for marine litter. With observations made by divers, through video footage from ROV's as well as sampling by bottom trawls, data has been obtained from varying depths and at many places, although the methodologies used were different.

The abundance and distribution of marine litter show considerable spatial variability. Near metropolitan areas, in the Mediterranean, densities may exceed 100.000 items/km^2. The geographical distribution of litter on the sea floor is strongly influenced by hydrodynamics, geomorphology and human factors. Litter made of high density polymers or, in some cases, under the weight of fouling by a wide variety of organisms, will sink to the bottom. In shallow coastal areas (< 30 m depth), the abundance of marine litter is generally much greater than on the continental shelf. In these coastal areas, activities related to fishing and tourism significantly contribute to littering of the seafloor with notable temporal, particularly seasonal, variations. Interpretation of temporal trends is therefore complicated by annual variations in litter transport, such as seasonal changes in flow rate of rivers and related turbidity currents. Other seasonal factors include the intensity of currents, swell and upwelling and the conformation of sea bed, which influence both the distribution and densities. Nevertheless, considering existing data, it would appear that the Mediterranean Sea may be the most affected part of the European Seas.

Due to the persistence of some litter materials, the monitoring of litter on the sea floor must consider accumulation processes for past decades. Timescales of observation should therefore be adapted, requiring multiannual frequencies for deep sea floor surveys. Finally, the data can be amalgamated to produce values for local, regional and European level.

In this chapter, protocols are provided for monitoring:

(i) Shallow coastal waters
(ii) Margin / continental plate (<800m)
(iii) deep sea floor

5.3.1. Shallow coastal areas

The abundance of marine litter is generally much greater in shallow waters than on the continental shelf or on the deep seafloor, with the exception of some accumulation zones in the open sea (Katsanevakis, 2008). This is especially true in bays due to weaker currents; litter disposed locally is more likely to accumulate on the bottom. Furthermore wave or upwelling-induced cleaning of the seafloor is of less importance in small bays, where usually there is much less transport (Katsanevakis & Katsarou, 2004).

The most commonly used method to estimate marine litter density in shallow coastal areas is to conduct underwater visual surveys with SCUBA, although snorkelling has also been applied for very shallow waters (usually < 10 m depth) and for larger forms of marine litter (nets/fishing gear). To overcome an underestimation of abundance, Distance Sampling, which is a group of methods for estimating abundance and/or population density (Buckland *et al.*, 2001) is more often applied. The most commonly used Distance Sampling method for underwater surveys is line transect sampling, with recent development enabling the modelling of detectability and the estimation of density/abundance (Thomas *et al.*, 2006). This approach is particularly efficient in areas with low litter densities , turbid waters, and/or high sea bottom complexity (*e.g.* rocky reefs, sea grass beds) when imperfect detectability should not be ignored;

The field protocols for line transect surveys of litter on the sea-floor are the same as those for benthic sessile fauna, described in detail in Katsanevakis (2009).

5.3.2. Continental Plate

Collection of data on litter on continental plate (0-200m) was started in the 1990's in both NE Atlantic (within IBTS program) and Mediterranean sea (within MEDITS program) but on experimental basis. The IBTS Working Group (ICES/ IBTS WG) has recently developed a unique protocol for marine litter assessments using trawling programmes, which was taken up by the International Council for the Exploration of the Sea in the IBTS programme in the NE Atlantic. This protocol harmonizes the procedures for collecting and reporting marine litter data which is collected on the back of existing fish stock surveys. This protocol has been discussed within the TSG-ML and modified to provide an accurate methodology applicable for MSFD monitoring (facilitating the evaluation of sources, trends, data analysis, etc.).

5.3.3. Deep Sea-floor

Only some areas/countries are concerned with deep sea floor along the European coasts including submarine canyons, seamounts, cold seeps, open slopes and deep basins, such as present in Norway, UK, Ireland, France, Spain, Portugal, Italy, and Greece. Monitoring in those deep sea areas is largely restricted by sampling difficulties and costs. Litter that reaches the seabed may already have been transported for considerable distances, only sinking when weighed down by fouling. The consequence is an accumulation in bays and canyons, often around large cities, rather than at open sea. These densities are a consequence of residual ocean circulation patterns and more locally to the morphology of the sea bed (around rocks and/or in depressions or channels) and the extension of deep submarine extensions of coastal rivers. For monitoring, the use of trawls in deep-sea areas is restricted to flat and smooth bottoms. For slopes and rocky bottoms, more specialised equipment is necessary. ROVs, which are less complicated than submersibles and generally cheaper, are recommended for litter surveys of deep see-floor.

Benthic litter assessments need to be planned with defined protocols, including the definition and specification of the survey location, choice of sampling units, methodology for collection, classification and quantification of litter and a process for data integration, analysis and reporting of results.

5.4. Protocol for shallow sea-floor (< 20m)

The most commonly used method to estimate marine litter density in shallow coastal areas is to conduct underwater visual surveys with SCUBA/snorkelling. These surveys are best based on line transect surveys of litter on the sea-floor, which is derived from UNEP (Cheshire, 2009). The protocol is actually in use for evaluation of benthic fauna. It requires SCUBA equipment and trained observers. Only litter items above 2.5 cm are considered, between 0 and 20 m (to 40 meters with skilled divers).

5.4.1. Technical requirements

Frequency

The minimum sampling frequency for any site should be annually. Ideally it is recommended that locations are surveyed every three months (allowing an interpretation in terms of seasonal changes).

Transects

Surveys are conducted through 2 line transects for each site. Unbiased design-based inference requires allocating the transects randomly in the study area or on a grid of systematically spaced lines randomly superimposed. However, with a model-based approach like density surface modelling (DSM), it is not required that the line transects are located according to a formal and restrictive survey sampling scheme, although good spatial coverage of the study area is desirable. Line transect are defined with a nylon line, marked every 5 meters with resistant paints, that is deployed using a diving reel while SCUBA diving.

Individual litter within 4 m of the line (half of the width –Wt - of the line transects) are recorded. For each observed litter item, when possible, the corresponding line segment of occurrence and its perpendicular distance from the line (yi - for the estimation of detection probability, measured with the use of a 2 m plastic rod), and litter size category (wi) are recorded. The nature of the bottom/habitat is also recorded. The length of the line transects vary between 20 and 200 m, depending on the depth, the depth gradient, the turbidity, the habitat complexity and the litter density (Katsavenakis, 2009). Results are expressed in litter density (items/m^2 or items/ 100 m^2).

Litter density	Conditions	Method	Sampling Unit (strips: length x width)
0.1-1 items/m2	Low turbidity - high habitat complexity	distance sampling	20 m x 4 m
0.1-1 items/m2	high turbidity	distance sampling	20 m x 4 m
0.01-0.1 items/m2	for every case	distance sampling	100 m x 8 m
<0.01 items/m2	for every case	distance sampling	200 m x 8 m

Table 6: Spatial sampling units for litter evaluation on the sea floor (shallow waters) depending on density of items and sea conditions (Katsanevakis, 2009)

Detectability

In distance sampling surveys, detectability is used to correct abundance estimations (Katsavenakis, 2009). The probability that any particular item that is in the covered region is detected, *i.e.*, the 'detection probability', is denoted by (*pa)*, and the estimator (d) of abundance becomes d = N/ Ac *pa*, where (N) is the number of detected items, and (Ac) is the surface area covered by the survey. The extra effort in a line transect survey is to record the perpendicular distance of each item from the line. This set of distances is used to estimate detection probability *pa* (Buckland *et al.*, 2001; Katsanevakis, 2009). The standard software for modelling detectability and estimating density/abundance, based on distance sampling surveys, is DISTANCE (Thomas *et al.*, 2006).

5.4.2. Use of volunteers in shallow waters surveys

Recreational and professional scuba divers can provide valuable information on litter they see underwater and they are uniquely positioned to support benthic litter monitoring efforts. They can access, have the skills and the equipment needed to collect, record, and share information about litter they encounter underwater. Many dive clubs and dive shops organize underwater clean-ups, often in partnerships with NGOs or local governments. Many of these events, when managed, can be a valuable source of information and possibly be a part of a regular survey, monitoring or even assessment efforts while using volunteers.

For example, Project AWARE's "Dive Against Debris" programme provides guidelines and field protocols for scuba divers on how to collect and report marine litter found underwater (Project AWARE 2013). Divers are encouraged, but currently not required, to conduct surveys at the same dive site on a regular (once a quarter/per season) basis. Divers remove the litter in a self-selected area within a site that they measured or estimate, they record information about types and amounts litter on a data card, and later report that information into a public, online database.

For some Member States use of volunteer divers might be a good opportunity for shallow-water litter monitoring but standardization and conformity with the common methodologies and tools proposed here should be achieved. Fixed sites, common frequency and sampling methodology can be easily established by each Member State and training, material distribution etc. can be done relatively easily when partner NGOs or research institutions are involved.

5.5. Protocol for Sea-floor (20-800m)

From all the methods assessed, trawling (otter trawl) has been shown to be the most suitable for large scale evaluation and monitoring (Goldberg, 1995, Galgani *et al.*, 1995, 1996, 2000). Nevertheless there are some restrictions in rocky areas and in soft sediments, as the method may be restricted and/or underestimate the quantities present. This approach is however reliable, reproducible, allowing statistical processing and comparison of sites. As recommended by UNEP (Cheshire, 2009), sites should be selected to ensure that they (i) Comprise areas with uniform substrate (ideally sand/silt bottom); (ii) consider areas generating/accumulating litter, (iii) avoid areas of risk (presence of munitions), sensitive or protected areas; (iv) do not impact on any endangered or protected species.

Sampling units should be stratified relative to sources (urban, rural, close to riverine inputs) and impacted offshore areas (major currents, shipping lanes, fisheries areas, etc.).

General strategies to investigate seabed litter are similar to methodology for benthic ecology and place more emphasis on the abundance and nature of items (*e.g.* bags, bottles, pieces of plastics) rather than their mass. The occurrence of international bottom trawls surveys such as IBTS (Atlantic), BITS (Baltic) and MEDITS (Mediterranean/Black Sea) provide useful and valuable means for monitoring marine litter. These are using common gears depending on region (GOV nets in Atlantic, MEDITS net in the Mediterranean) and provide some harmonized and common conditions of sampling (20 mm mesh, 30-60 min tows, large sampling surface covered) and hydrographical and environmental information (surface & bottom temperature, surface & bottom salinity, surface & bottom current direction & speed, wind direction & speed, swell direction and height). More than 20 sampling units are sampled within each region as recommended by UNEP (Cheshire, 2009).

Therefore, the TSG-ML strongly recommends using these on-going and continuous programmes to collect data on marine litter in the sea-floor. This will enable to compare data from one country to another and to evaluate transnational transportation.

5.5.1. Technical Requirements

The protocol for sampling and trawling margins (20-800m) has been standardized for each region:

Atlantic and Baltic Seas

For Atlantic and Baltic regions, the protocol is derived from the IBTS /BITS protocols (see the protocol manual, ICES/IBTS, 2012). The sampling grids are based on statistical rectangles of one degree longitude x 0.5 degree latitude (# 30 x 30 nautical miles). Each rectangle is usually fished by ships of two different countries (two hauls per rectangle) or a single country fishing more than once in every rectangle (Skagerrat and Kattegat, Sweden). All countries have a standard haul duration to 30 minutes (defined as the moment when the vertical net opening and door spread are stable), using the same 36/47 GOV-trawl with 20 mm mesh nets (ICES/IBTS, 2012) and sampling at 3.5-4 knots between 0 and 200 m depth.

Mediterranean and Black Seas

For the Mediterranean Region, the protocol is derived from the MEDITS protocol (see the protocol manual, Bertan *et al.*, 2007). The protocol is also a reference protocol for associated countries, including Romania and Bulgaria in the Black Sea. The hauls are positioned following a depth stratified sampling scheme with random drawing of the positions within each stratum. The number of positions in each stratum is proportional to the surface of these strata and the hauls are made in the same position from year to year. The following depths (10 – 50; 50 – 100; 100 – 200; 200 – 500; 500 - 800 m) are fixed in all areas as strata limits. The total number of hauls for the Mediterranean Sea is 1385; covering the shelves and slopes from 11 countries in the Mediterranean.

The haul duration is fixed at 30 minutes on depths less than 200m and at 60 minutes at depths over 200m (defined as the moment when the vertical net opening and door spread are stable), using the same GOC 73 trawl with 20 mm mesh nets (Bertran *et al*, 2007) and sampling between May and July, at 3 knots between 20 and 800 m depth.

Detecting trends

Consistency of results is based on sampling strategy and monitoring efforts. Long term monitoring of litter on the sea floor has been performed in some EU countries such as UK, Germany, Spain and France. In some cases such as the margins of gulf of Lion (France), trends studies (70 Stations, depth 40-800m,) indicated a statistically significant decrease [Abundance (10-4) = 0.038 x (Year) + 1.062 (R2 =0.36)] enabling the measurement of 15% decrease in 15 years.

However, Power Analysis of IBTS related sampling by Cefas indicates that detection of a 10% change over 5 or 10 years is unlikely without massive sample sizes. However, 50% changes over 5 or 10 years look to be readily detectable with current designs based on fish stock surveys such as IBTS.

Data recording and Management

Templates for data recording sheet based on this system have been integrated in both the IBTS[22] and MEDITS Manuals[23]. Data on litter should be collected these templates and the items categories listed for Sea-floor (Annex 5.1). Other elements from the haul operations should be also recorded – See ICES Survey Protocols for Atlantic/Baltic and MEDITS for the Mediterranean/Black Sea.

Data on litter should be reported as items/ha or items/km^2 before further processing and reporting. In some cases, when the horizontal opening of the trawl is not evaluated for each tow, it will be necessary to calculate surfaces using mean opening of the trawl, as provided by the technical manual.

Monitoring of litter on continental margins must be co-organized and coordinated within the two groups ICES/IBTS (NE Atlantic and Baltic Sea) and MEDITS (Mediterranean and Black Sea). Inclusion of litter monitoring through IBTS/MEDITS programmes will need to be organized within the EU through the STEFC (Scientific, Technical and Economic Committee for Fisheries) and its Subgroup on Research Needs (SGRN), with the support of the Data Center Framework (DCF) from DG MARE (Directorate-General for Maritime Affairs and Fisheries). The use of a central database for European trawl survey data (MEDITS, IBTS, ICES, DATRAS, etc.) may be used for collection of trawl survey data preceding a more specific litter data management system. Organisation of litter data management is still being considered at the EU level (WISE/EMODNET) or regional institution (OSPAR, HELCOM, BSC, MEDPOL).

5.6. Litter categories for Sea-floor

Because marine litter degradation is affected by light, oxygen and wave action, the persistence of marine litter on the sea floor and deep sea floor is increased with notable outcomes on the nature of litter found. Another important factor influencing the composition of benthic litter is related to the type of activity. Typically, the analysis of sources indicated the importance and differences between ship based litter, as in the Southern North Sea, and land based litter such as in the Mediterranean. The definition of categories will have to take this in account when defining a protocol. Although marine litter is strongly affected by transportation, fishing has been shown as a main source of litter in some fishing or aquaculture grounds. Similarly specific types of marine litter were also found in areas affected by tourism, around beaches, as in the Mediterranean Sea. This may affect the strategy for monitoring selected areas, such as shallow waters.

A standardized litter classification system has been defined before monitoring the sea floor (Annex 5.1; see also Chapter 8). These categories were defined in accordance with types of litter found at regional level, enabling common main categories for all regions. The main categories have a hierarchical system including sub categories. It considers 5 main categories of material (Plastics, metal, rubber, glass/ceramics, natural products) and additional ones: 1 for NE Atlantic (miscellaneous) or 4 for Mediterranean (wood, paper/cardboard, other, unspecific). There are various subcategories for a more detailed description of litter items. Other specific categories may be added by Member States and

[22] http://www.ices.dk/sites/pub/Publication%20Reports/ICES%20Survey%20Protocols%20(SISP)/SISP1-IBTSVIII.pdf (ANNEX 15)

[23] http://www.sibm.it/SITO%20MEDITS/principaleprogramme.htm

additional description of the item may provide added-value, as long as the main categories and sub-categories are maintained. Furthermore, the weight, picture and note of potential attached organisms may further complement the classification of items.

Other parameters

Site information and trawling sampling characteristics such as date, position, type of trawl, speed, distance, sampled area, depth, hydrographical and meteorological conditions should be recorded

Data-sheets should be filled out for each trawl and compiled by survey. If multiple counts (transects/observers) are run at any given site then a new sheet should be used for each trawl shot. After each survey data must be aggregated for analysis and reporting.

5.7. Complementary protocol for sea-floor – Video camera

Large-scale evaluations of marine litter in the deep sea-floor are scarce because of available resources to collect data. Special equipment is necessary including ROVs and/or submersibles that may be very expensive to operate, especially in deep sea areas.

Towed video camera for shallow waters (Lundqvist, 2013) or ROVs for deeper areas are simpler and generally cheaper and must be recommended for litter surveys. There are some available protocols where litter is counted on routes and expressed as item/km, especially when using submersibles/ROVs at variable depths above the deep sea floor (Galgani *et al.*, 1996) but technology enables the evaluation of densities trough video-imagery using a standardized approach especially for shallow waters.

5.7.1. Shallow sea-floor using towed video

During some circumstances diving may be unsuitable, difficult or impossible, *e.g.* because of inadequate conditions, such as intense boat traffic, cold water temperatures, etc., because the legal requirements for diving are very strict, or because there is a lack of diving personal with the proper scientific/technical requirements. Using towed video may then be suitable alternative.

The principles for monitoring with towed video are essentially the same as for the diving protocol, but transects are filmed and analysed either immediately during the filming or afterwards in the lab/office.

The method is based on the protocol developed by Lundqvist (2013), as tested for recording the number of litter objects on shallow (<20m) seafloor biotopes (soft, hard and sand/stone bottoms). The equipment used consisted of a steel rig with two consumer type video cameras (mounted for filming obliquely forward and straight down (see Photo 1). A *Gopro* type camera (Woodman Labs, Inc. 2012)[24] equipped with a waterproof camera house or other similar brands are recommended with filmed sequences stored on memory card, and analysed afterwards.

24 www.gopro.com

Picture 1: (Right) - The rig with two video cameras for monitoring seafloor litter. The rig was towed after a small open boat (after Lundqvist, 2013); (Left) **-** The method used by Lundqvist for estimating the width of a video transect. The arrow shows one of the markings (2 cm across) on the line used to calculate the width. The distance between two markings is 0.2 m and at the black line across the picture the estimated transect width is 2.55 m.

The width of the transect is estimated using a line placed perpendicular to the tow direction and marked at every 0.2 m (Pic.1 – left side). The types of litter must be then recorded using the categories defined for the sea-floor (Annex 5.1) but whenever possible, a more detailed description of the item should be added.

In turbid waters, cameras could be used down to approximately 20 m depth without any additional light source (Lundqvist, 2013). In total, it takes approximately 60 minutes to perform one transect in the field and then analyse it on land, including the preparation and disassembly of the system (camera and sleigh). The total area monitored during one workday (8h) (including boat transport, analysis, etc.) can be on average 2900 m^2/day. If the system has some limits (require access to a boat and it is weather sensitive, less suitable for habitats with thick vegetation coverage, technical malfunctions are only seen afterwards), this method has major advantages such as (1) the inexpensive and standard equipment (<1000 €), (2) the system does not require high technical expertise, (3) the method is fast and requires only 1-2 persons in the field, (4) it allows for independent analysis of videos and other uses of the same films (*e.g.* habitat mapping, estimation of resources), (5) enables random (non-biased) transect, as the operator does not see the actual transects until afterwards, and the analyse of only subset to meet basic monitoring requirements, and finally (6) the system is a viable option if legal requirements or conditions limit diving.

5.7.2. Deep sea-floor using video

For deep sea-floor, data collection is to be performed on irregular basis, using mainly opportunistic circumstances, considering and counting only litter larger than 2.5 cm, along submersibles/ROVs routes of minimum 0.5 km.

Bathymetrically, the proportion of area with anthropogenic litter may increase with increasing distance along a broad offshore front, from inner to outer shelf. Priority must then be given to coastal canyons, or on other areas that are known to generate or accumulate marine litter. Categories are recorded following the list of main categories provided in Annex 5.1 and the data-sheet mentioned in section 5.5.1 – Data Recording and Management.

For shallow waters and deep sea floor (range 200-4000m), results are expressed as items/ha or km2 when the measure of the surface is possible or items/100 m or items/km when length based measures are necessary.

5.8. Quality Assessment /Quality Control

Several contracting parties from OSPAR and MEDPOL have indicated they will use their fish stock surveys for benthic litter monitoring and thus this method might be adopted as a common indicator. This is considered to be an adequate approach although quantities of litter might be underestimated, given restriction ion some areas. The adoption of a common protocol will lead to a significant level of standardization among the countries that apply it as their sampling strategy.

Data on litter in shallow sea-floor are collected through protocols already validated for benthic species.

Data recording and management should be undertaken through an online, relational database system under the control and direction of local managers. The responsibility for review and approval of uploaded data should be than undertaken by regional/country coordinators. This would ensure a high level of consistency within each region as well as create a hierarchy of quality assurance on data acquisition. Until now, no quality assurance programme has been considered for litter monitoring on the sea-floor. For IBTS and MEDITS, sampling data are collected in the DATRAS database and participate in data quality checking for hydrographical and environmental conditions. This process may also support quality insurance for data on litter. Currently, there are on-going discussions on how to organize and harmonize a specific system to collect, validate and organize data through a common platform, enabling the review and validation of data. ICES is considering data for OSPAR area, while MEDITS has included litter data to be analysed within a specific sub-group. The occurrence of WISE/EMODNET with modules dedicated to MSFD indicators may also be considered to develop a specific module for indicators from descriptor 10, including litter on sea floor.

5.9. Conclusions

Considering opportunities to couple monitoring efforts may be the best approach to monitor litter on the sea-floor.

There may be other opportunities to couple marine litter surveys with other regular surveys (monitoring in marine reserve, offshore platforms, etc.) or programmes on biodiversity.

Monitoring programmes such as IBTS operate at larger, regional scale and not only may be a good opportunity to couple monitoring of marine litter but also provide a regional, comparable approach, as required by the MSFD.

5.10. References

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Annex 5.1 - Categories and sub-categories of litter items for Sea-Floor

Litter categories from the OSPAR/ICES / IBTS for North East Atlantic and Baltic

A: Plastic	B: Metals	C: Rubber	D: Glass/ Ceramics	E: Natural products/ Clothes	F: Miscellaneous
A1. Bottle	B1. Cans (food)	C1. Boots	D1. Jar	E1. Clothing/ rags	F1. Wood (processed)
A2. Sheet	B2. Cans (beverage)	C2. Balloons	D2. Bottle	E2. Shoes	F2. Rope
A3. Bag	B3. Fishing related	C3. bobbins (fishing)	D3. piece	E3. Other	F3. Paper/ cardboard
A4. Caps/ lids	B4. Drums	C4. tyre	D4. other		F4. pallets
A5. Fishing line (monofilament)	B5. appliances	C5. other			F5. other
A6. Fishing line (entangled)	B6. car parts				
A7. Synthetic rope	B7. cables				
A8. Fishing net	B8. other				
A9. Cable ties					
A10. Strapping band					
A11. crates and containers					
A12. Plastic diapers					
A13. sanitary towel/tampon					
A14. Other					

Related size categories

- A: <5*5 cm= 25 cm²
- B: <10*10 cm= 100 cm²
- C: <20*20 cm= 400 cm²
- D: <50*50 cm= 2500 cm²
- E: <100*100 cm= 10000 cm²= 1 m²
- F: >100*100 cm = 10000 cm2= 1 m2

Litter categories from MEDITS litter for Mediterranean and Black Sea

A. Plastic	B. Rubber	C. Metals	D: Glass/ Ceramics	E. textiles / natural fibers	F. Wood (processed)	G. Paper / cardboard	H. Other (specify)	I. Unspecified
A1.Bags	B1. Tyres	C1. Beverage cans	D1. Bottles	E1. Clothing (clothes, shoes)				
A2. Bottles	B2. Other (gloves, shoes, etc.)	C2. Other food cans/wrappers	D2. Pieces of glass	E2. Large pieces (carpets, etc)				
A3. Food wrappers		C3. Middle size containers	D3. Ceramic jars	E3. Natural ropes				
A4. Sheets		C4. Large metallic objects	D4. Large objects (specify)					
A5. Other plastic objects		C5. Cables						
A6. Fishing nets		C6. Fishing related						
A7. Fishing lines								
A8. Other fishing related								
A9. Ropes/strapping bands								
A10. Sanitaries (diapers, etc.)								

Related size category

A: <5*5 cm= 25 cm²

B: <10*10 cm= 100 cm²

C: <20*20 cm= 400 cm²

D: <50*50 cm= 2500 cm²

E: <100*100 cm= 10000 cm²= 1 m²

F: >100*100 cm = 10000 cm2= 1 m2

6. Litter in Biota

This Chapter focuses on indicator 10.2.1 of descriptor 10 MSFD "*Trends in the amount and composition of litter ingested by marine animals*." For this indicator the Commission Decision (2010/477/EU) expresses the need for further development based on the experience in some sub-regions (*e.g.* North Sea), to be adapted in other regions and on emerging knowledge about other impacts beside the ingestion of litter by marine organisms.

Therefore, the primary task for the implementation of appropriate monitoring for this indicator is to develop tools for investigating trends in ingested litter that cover all the MSFD marine regions. As no single species can provide full coverage over all Europe's marine sectors, a range of species is needed to monitor ingested litter. Some spatial overlap between regionally restricted monitoring species is desirable to link pollution measurements in the different areas.

In addition the issue of entanglement of marine organisms in litter is the second main impact to be considered when dealing with criteria 10.2. *Impacts of litter on marine life*.

Furthermore the COM Dec states that the improvement of knowledge concerning impacts on marine life (affected species, species used as indicators, the standardisation of methods and the determination of thresholds) is also needed. Hence, a next issue to be dealt with is the development of strategies for assessing harm/impacts, which will be done in the further run of the work of the TSG-ML.

6.1. Scope and key questions to be addressed

- In the North Sea, an indicator is available, which expresses the impact of marine litter (OSPAR EcoQO). It measures ingested litter in Northern Fulmar and it is used to assess temporal trends, regional differences and compliance with a set target for acceptable ecological quality in the North Sea area (Van Franeker *et al.*, 2011). A combined protocol is here proposed which can be used for seabirds in general and applied in most North-East-Atlantic countries, *e.g.* to be applied in regular monitoring for fulmars in areas that are currently not covered or for shearwaters in the Southern part of the NE Atlantic and in parts of the Mediterranean.
- Alternative tools for indicator 10.2.1 are needed for the Baltic Sea, the Mediterranean Sea, the Black Sea, and southern parts of the North-East-Atlantic.
- On the basis of available information and expertise, this report proposes a monitoring protocol for sea turtles with focus on relevant parameters for application in the Mediterranean and some parts of the Southern Atlantic. Another protocol is proposed for a MSFD marine litter monitoring of ingested litter in fish.
- Microlitter occurrence in Biota (birds, fish, and invertebrates) can be incorporated in the provided protocols as a complementary analysis (see Chapter 7).
- The approach taken for the development of the protocols for ingestion consists of the application of the same categorization of marine litter for all ingestion studies of vertebrates. The applied standard categories follow the existing fulmar methodology, in which a number of plastic categories is counted, and weighted as a unit.
- Additionally further knowledge is being compiled on the occurrence of entanglement events in marine organisms. Based upon these findings a harmonised protocol for the assessment of the use of plastic litter as nesting material and associated entanglement mortality in birds breeding colonies is proposed for immediate application.
- Additional paragraphs reflect on entanglement in beached animals, entanglement in live animals (others than in relation to seabird nests), ingestion of litter by marine mammals, ingestion of litter by marine invertebrates and research on food chain transfer. Only ingestion of and entanglement in marine litter by marine mammals are considered for further development whereas the other aspects are crucial issues for research but not suitable to be recommended for wide monitoring application at this stage. Ingestion protocols for invertebrates such as

crustaceans, shellfish, worm or zooplankton are not included in this report but should be guided by methodological details as outlined in chapter 7 on microlitter monitoring.

Further development of existing tool sheets are presented in the following protocols.

6.2. Seabirds

Protocol name

MSFD Protocol for the monitoring of litter ingested by seabirds (Procellariiformes, like fulmars or shearwaters). Based on tool 10.2.1_T1 – Fulmar and Tool 10.2.1_T2 – Shearwater.

Protocol description

The methodology of this tool follows the OSPAR Ecological Quality Objective (EcoQO) methods for monitoring litter particles in stomachs of northern fulmars (*Fulmarus glacialis*). The stomach contents of birds beached or otherwise found dead are used to measure trends and regional differences in marine litter. Background information and the technical requirements are described in detail in documents related to the fulmar EcoQO methodology. A pilot study evaluating methods and potential sources of bias was conducted by Van Franeker & Meijboom (2002). Bird dissection procedures including characters for age, sex, cause of death etc. have been specified in Van Franeker (2004). Further OSPAR EcoQO details were given in OSPAR (2008, 2010a, b) and in Van Franeker *et al.,* (2011a, 2011b).

Related marine compartments

Seabirds like fulmars or shearwaters are feeding on the surface of the sea. Therefore the water column and especially the water surface is the marine compartment addressed when quantifying litter in the stomachs of fulmars.

6.2.1. Technical requirements

Bird corpses are stored frozen until analysis. Standardized dissection methods for Fulmar corpses have been published in a dedicated manual (Van Franeker, 2004) and are internationally calibrated during annual workshops. Stomach content analyses and methods for data processing and presentation of results were described in full detail in Van Franeker & Meijboom (2002) and updated in later reports. The methodology has been published in peer reviewed scientific literature (van Franeker *et al., 2011*). For convenience, some of the methodological information is repeated here in a condensed form.

At dissections, a full series of data is recorded to determine sex, age, breeding status, likely cause of death, origin, and other issues. Age, the only variable found to influence litter quantities in stomach contents, is largely determined on the basis of development of sexual organs (size and shape) and presence of *Bursa of Fabricius* (a gland-like organ positioned near the end of the gut which is involved in immunity systems of young birds; it is well developed in chicks, but disappears within the first year of life or shortly after). Further details are provided in Van Franeker 2004.

After dissection, stomachs of birds are opened for analysis. Stomachs of Fulmars have two 'units': initially food is stored and starts to digest in a large glandular stomach (the *proventriculus*) after which it passes into a small muscular stomach (the *gizzard*) where harder prey remains can be processed through mechanical grinding. For the purpose of most cost-effective monitoring, the contents of proventriculus and gizzard are combined, but optional separate recordings should be considered where possible.

Stomach, contents are carefully rinsed in a sieve with a 1mm mesh and then transferred to a petri dish for sorting under a binocular microscope. The 1 mm mesh is used because smaller meshes become easily clogged with mucus from the stomach wall and with food-remains. Analyses using smaller meshes were found to be extremely time consuming and particles smaller than 1 mm seemed rare in the stomachs, contributing little to plastic mass.

If oil or chemical types of pollutants are present, these may be sub-sampled and weighed before rinsing the remainder of stomach content. If sticky substances hamper further processing of the litter objects, hot water and detergents are used to rinse the material clean as needed for further sorting and counting under a binocular microscope.

Litter Categories – source related information

In the Fulmar EcoCO, stomach contents are sorted into the following categories (Table 7), and this categorisation is followed for marine biota monitoring ingestion in seabirds, marine turtles and fish.

BIOTA categories for contents of digestive tract *(oesophagus, stomach(s), intestine)*			
PLA	**PLASTIC**	**acronym**	all plastic or synthetic items: note number of particles and dry mass for each category
IND	**pellets**	**ind**	industrial plastic granules (usually cylindrical but also oval spherical or cubical shapes exist
	probab ind?	**pind**	suspected industrial, used for the tiny spheres (glassy, milky, ...) occasionally encountered
USE	**sheet**	**she**	remains of sheet, eg from bag, cling-foil, agricultural sheets, rubbish bags etc
	thread	**thr**	threadlike materials, eg pieces of nylon wire, net-fragments, woven clothing; includes 'balls' of compacted such material
	foam	**foam**	all foamed plastics so polystyrene foam, foamed soft rubber (as in matras filling), PUR used in construction etc
	fragments	**frag**	fragments, broken pieces of thicker type plastics, can be bit flexible, but not like sheetlike materials
	other	**Poth**	any other, incl elastics, dense rubber, sigarette-filters, balloon-pieces, softairgun bullets; objects etc. DESCRIBE!!
RUB	**OTHER RUBBISH**	**acronym**	any other non synthetic consumer wastess: note number of particles and (in principle) dry mass for each category
RUB	**paper**	**pap**	newspaper, packaging, cardboard, includes multilayerd material (eg Tetrapack pieces) and aluminium foil
	kitchenfood	**kit**	human food remains (galley wastes) like oinion, beans, chickenbones, bacon, seeds of tomatoes,grapes, peppers, melon etc
	other user	**rva**	other consumber waste, like processed wood, pieces of metal, metal air-gun bulletes; leadshot, painchips. DESCRIBE
	FISHHOOK	**hoo**	fishing hook remains (NOT FOR HOOKS ON WHICH LONGLINE VICTIMS WERE CAUGHT - THOSE UNDER NOTES)
POL	**POLLUTANTS (INDUS/CHEM WASTE)**	**acronym**	other non synthetic indusrial or shipping wastes (number of items and mass per category (wet for paraffin)
POL	**slag/coal**	**sla**	industrial oven slags ('looks like non-natural pumice) or coal remains
	oil/tar	**tar**	lumps of oil or tar (also not n=1 and g=0.0001g if other particles smeared with tar but cannot be sampled separately)
	paraf/chem	**che**	lumps or mash of unclear paraffin, wax like substances (NOT stomach oil!) if needed subsample and estimate mass
	featherlump	**rva**	lump of feathers from excessive preening of fouled feathers (n=1 with drymass) (NOT for few normal own feathers)
FOO	**NATURAL FOOD**	**foo**	various categories, depends on the species studied, and aims of study
NFO	**NATURAL NON FOOD**	**nfo**	anything natural, but which can not be considered as normal nutritious FOOD for the individual

Table 7: Categories for classification of items for Biota

The fulmar categorisation of stomach contents is based on the general 'morphs' of plastics (sheet-like, filament, foamed, fragment, other) or other general rubbish or litter characteristics. This is because in most cases, particles cannot be unambiguously linked to particular objects. But where such is possible, under notes in datasheets, the items should be described and assigned a litter category number using the "Master List" developed by the TSG ML group (Chapter 8 – Annex 8.1).

For each litter category/subcategory an assessment is made of:

1) **incidence** (percentage of investigated stomachs containing litter);
2) **abundance by number** (average number of items per individual), and
3) **abundance by mass** (weight in grams, accurate to 4^{th} decimal)

Because of potential variations in annual data, it is recommended to describe '**current levels'** as the average for all data from the most recent 5-year period, in which the average is the 'population average' which includes individuals that were found to have zero litter in the stomach.

As indicated, EcoQO data presentation for Northern Fulmars is for the combined contents of glandular (proventriculus) and muscular (gizzard) stomachs. Results of age groups are combined except for chicks or fledglings which should be dealt with separately. Potential bias from age structure in samples should be checked regularly.

Size range

In the fulmar monitoring scheme, stomach contents are rinsed over a sieve with mesh 1 mm prior to further categorisation, counting and weighing. The size range of plastics monitored is thus ≥ 1 mm. Unpublished data on particle size details in stomachs of fulmars show that a smaller mesh size would not be of use because smaller items have passed into the gut.

In the OSPAR Fulmar EcoQO approach, the focus is on mass of categories of litter, rather than on the size of individual particles. However, the litter descriptor of the MSFD makes a distinction between macro- and micro-particles of litter, defined as objects with largest measurement over or below a limit of 5 mm. Both size groups are common in seabird stomachs. For comparative purposes it is then useful to know proportions of micro- and macro litter found in seabird stomachs. Whether such assessment of particle size is incorporated into standard monitoring methods, or is evaluated on a more incidental basis, will depend on practical and financial considerations. In the current Fulmar project, particle size assessment is not standard procedure (particle number and combined mass per litter category only give 'average' size information), but a dedicated study is currently assessing exact sizes of all particles in a large number of samples from different locations and time periods. Such dedicated detailed work can be repeated at appropriate moments.

In the seabird studies it is standard to filter stomach contents over a 1 mm sieve, and these thus largely ignore potential presence of micro-plastics below the 1 mm size. In the stomachs such sizes seem extremely rare, but potentially they could be present in gut material in the intestines resulting from break up of larger items in the stomach of from secondary ingestion with zooplankton or fish. For study of particles in such size range in bird intestines, methods as described in Chapter 7 on microplastics in biota should be followed.

Spatial coverage

Dead birds are collected from beaches or from accidental mortalities such as long-line victims, fledgling road kills etc. (for methodology see Van Franeker, 2004).

Survey frequency

Continuous sampling is required. A sample size of 40 birds or more is recommended for a reliable annual average for a particular area. However, also years of low sample size can be used in the analysis of trends as these are based on individual birds and not on annual averages. For reliable conclusions on change or stability in ingested litter quantities, data over periods of 4 to 8 years (depending on the category of litter) is needed (Van Franeker & Meijboom, 2002).

Maturity of the tool

The method is mature and in use.

Regional applicability of the tool

The tool is applicable to the MSFD marine regions where fulmars occur; the Greater North Sea, the English Channel, and the Celtic Seas For similar seabird species such as any of the family of the tubenoses, the methodology can follow this protocol. This could for example be applied to shearwater species occurring further south in the Atlantic or in the Mediterranean Sea.

6.2.2. Estimation of costs

A cost estimate for the fulmar biota monitoring can be based on current level of funding available for the monitoring project in the Netherlands. This currently amounts to approximately € 50k annually, almost completely for scientist staff costs (covering roughly 300 man-hour or 7.5 work-week, costs based on contract rates by Wageningen UR, The Netherlands). This concerns the time invested in coordinating the collection program by volunteer and other groups (c. €10k), lab dissections, stomach analyses and data-analyses of approximately 40-50 birds annually (€20k), formal report writing and production (€15k) and associated post reporting activity (€5k). Material costs for transports and lab disposables are minor in the Netherlands, c. €1k/year, but occasionally more if providing volunteer groups with materials like freezers. The actual field work in this approach is conducted without cost by volunteer beach bird surveyors or other persons/organisations regularly surveying beaches. Their 'reward' is provided by the coordinator, spending considerable part of his effort on a good back-reporting to the participants about the programs outcomes (reports, webpage, individual contacts).

In the Dutch programme, some limited account is taken of assisting other countries and integrating report writing for OSPAR (to allow this international component, data analyses and reporting were reduced from annual effort to once in two years). Costs for separate national programs may be reduced significantly if such integration of analyses and reporting by a single lead partner is more structurally arranged and financially supported.

6.2.3. Quality Assessment /Quality Control

The methodology referred to in this tool is based on an agreed OSPAR methodology which has been developed over a number of years with ICES and OSPAR and which has received full quality assurance by publication in peer reviewed scientific literature (Van Franeker *et al.,* 2011a). The EcoQO methodology has been fully tested an implemented on Northern Fulmars *Fulmarus glacialis*, including those from Canadian Arctic (Provencher *et al.,* 2009) and northern Pacific areas (Avery-Gomm *et al.,* 2012). All methodological details can be applied to other tubenosed seabirds (Procellariiformes) with no or very minor modifications. Trial studies are being conducted using shearwaters from the more southern parts of the north Atlantic and Mediterranean. In other seabird families, methods may have to be adapted as stomach morphology, foraging ecology, and regurgitation of indigestible stomach contents differ and can affect methodological approaches.

Trend assessment

In the Fulmar EcoQO, statistical significance of trends in ingested litter, *i.e.* plastics, is based on linear regression of ln-transformed data for the mass of litter (of a chosen category) in individual stomachs against their year of collection. 'Recent' trends are defined as derived from all data over the most recent 10-year period. The Fulmar EcoQO focuses on trend analyses for industrial plastics, user plastics, and their combined total.

Target definitions

In OSPAR the target for the Ecological Quality Objective is defined by the proportion of birds which exceeds a particular limit of plastic mass in the stomach. For the North Sea, the current, undated target is defined as

> *"There should be less than 10% of Northern fulmars having 0.1 gram or more plastic in the stomach in samples of 50-100 beached fulmars from each of 5 different regions of the North Sea over a period of at least 5 years".*

Other ways of target definitions are of course possible, *e.g.* in terms of average mass of plastic to be achieved by a specific date, or significance levels of rates of change that can be assessed on the basis of the data collected.

6.3. Sea turtles

Protocol name

MSFD Protocol for the monitoring of litter ingested by sea turtles *(Caretta caretta*) and MSFD Protocol for sampling litter excreted by live sea-turtles (faecal pellet analysis) (optional) are based on tool 10.2.1_T3 – Sea Turtle.

Protocol description

The stomach contents of stranded Loggerhead sea turtles *Caretta caretta* (Linnaeus, 1758) are used to measure trends and regional differences in marine litter. A pilot study evaluating methods and potential sources of bias was conducted during 2012 by ISPRA, CNR-IAMC Oristano, Stazione Zoologica Napoli; University of Siena, University of Padova, ArpaToscana. Dissection procedure, measurement, and litter analysis are shown below.

Related marine compartments

Caretta caretta feeds in the water column and at the seafloor. Therefore these two marine compartments are addressed when quantifying litter in the stomachs of stranded Loggerhead sea turtles.

6.3.1. Technical requirements

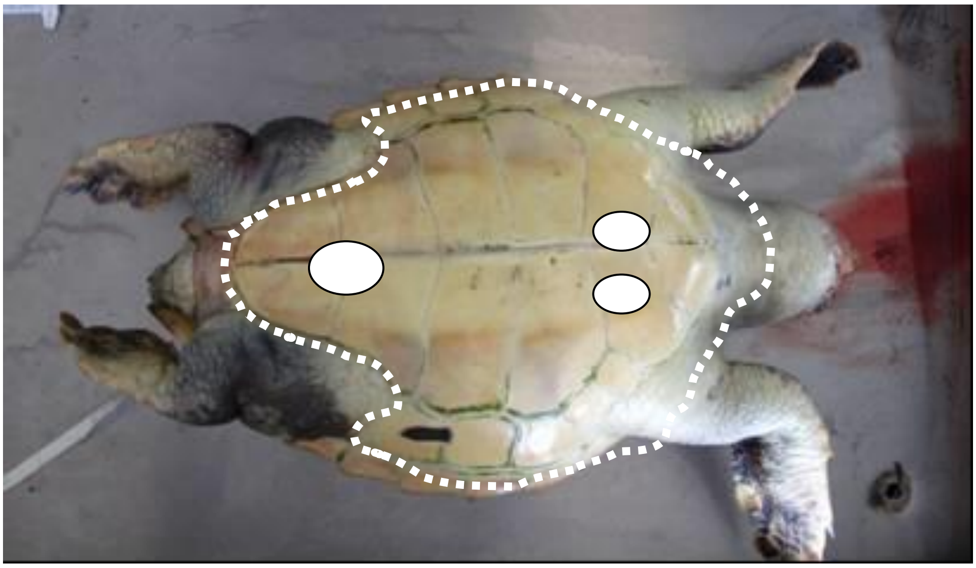
The Loggerhead sea turtle *Caretta caretta* is a protected species (CITES Appendix I), therefore only authorized people can handle them.

i) Protocol for application in case of finding of a dead sea turtle

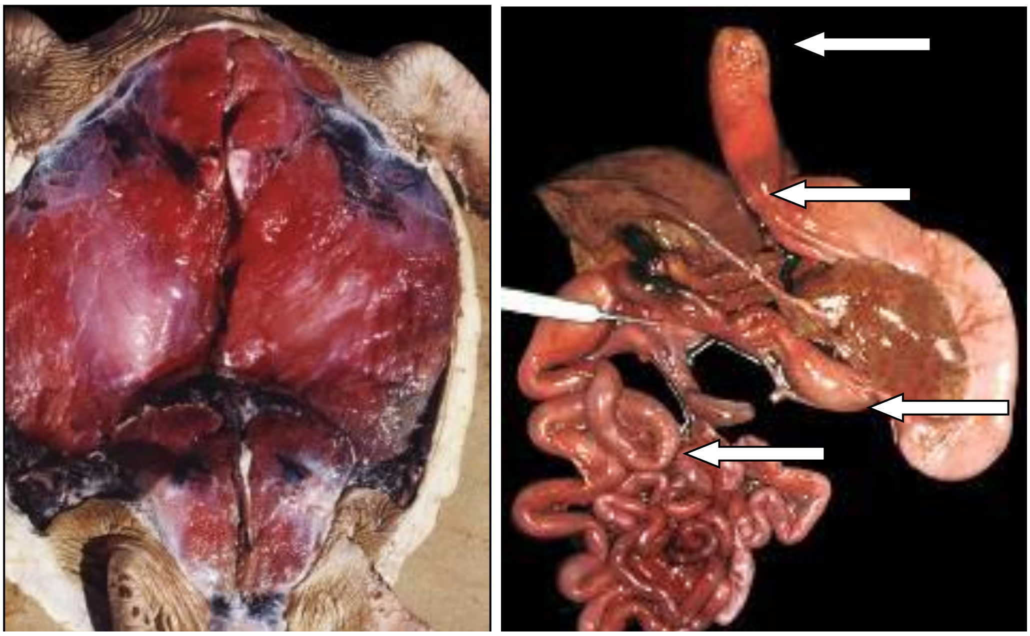
Upon finding the animal, its discovery should be reported to the main authorities and the operation of coordinated with the local authorities (depending on national law). Based on initial observations and if possible still at the place of discovery, some data should be recorded (See "Identification Data" Sheet in Annex 6.1). The animal should be transported to an authorized service centre for necropsy. In case the body is too decomposed, the integrity of the digestive tract should be assessed before disposal at the licensed contractor. If the necropsy cannot be carried out immediately after recovery, the carcass should be frozen at -16 ° C, in the rehabilitation facility.

Before the necropsy operation, morphometric measurements should be collected (see Annex 6.1). External examination of the animal should be conducted, including inspecting the oral cavity for possible presence of foreign material. To remove and separate the plastron from the carapace, an incision should be made on the outside edge, as shown as a dashed line in Picture 2. Once the inside of the plastron is accessed, the ligament attachment of the pectoral and pelvic girdle should be cut, as indicated in white circles in Picture 2. Qualitative evaluation of the trophic status of the animal should be made, including the atrophy of pectoral muscles (none, moderate, severe), fat thickness in the articular cavities and on the coelomic membrane (abundant, normal, low, none).

Removal of pectoral muscles and the heart should expose the gastrointestinal system (GI) (Picture 3, Left). The different portions of the GI should be isolated by means of plastic clamps, fixed on esophagus proximal to the mouth, on the esophageal valve, on the peg and on the cloaca, as close as possible to the orifice anal, as indicated by arrows in Picture 3 (Right). The entire GI should be removed and placed on the examination surface. This is easier if done by at least 2 operators: one person keeps the animal lying on its side, while the other separates the ligaments of the different organs and the membranes of the carapace by extracting the GI from the animal. The sex of the animal should be recorded. The 3 parts of the GI (esophagus, stomach, intestines) should be separated, affixing a second clamp at the cut edge to prevent spillage of the contents.



Picture 2: Cutting line and location of main plastron ligament in a turtle (Wyneken, 2001)



Picture 3(Left): The ventral pectoral and pelvic musculature covers most of internal organs, which must be removed to expose the peritoneal cavity; **(Right):** Sea turtle gastrointestinal different portion (Wyneken, 2001)

The following sampling procedure of GI contents can be applied to any section of the GI: the section of the GI should be placed in a graduated beaker of adequate size, pre-weighed on electronic balance (accuracy of ± 1g). The section of GI should be open and the contents emptied into the beaker with the help of a spatula, followed by the record of the net weight and volume of the content. The section of the GI should be observed and any ulcers or any lesions caused by hard plastic items should be recorded.

The contents should be inspected for the presence of any tar, oil, or particularly fragile material that must be removed and treated separately. The liquid portion, mucus and the digested unidentifiable matter should be removed, by washing the contents with freshwater through a filter mesh 1 mm, followed by a rinse of all the material collected by the filter 1mm in 70% alcohol and finally again in freshwater. The retained content should be enclosed in plastic bags or pots, labelled and frozen, not forgetting the sample code and corresponding section of the GI. Finally, the contents can then be sent for analysis.

NOTE: If the contents are stored in liquid fixative, remember to take note of the compound and the percentage of dilution and communicate them to the staff in charge for the further analysis.

For the analysis of the contents of the GI, the organic component should be separated from any other items or material (marine litter). The fraction of marine litter should be analysed and categorised with the help of a stereo-microscope, following the approach used in the protocol for ingestion in birds (see section 6.2 above) (Van Franeker *et al.*, 2005; 2011b; Matiddi *et al.*, 2011) and using a data-sheet as the one provided in Annex 6.2.

The fraction of marine litter should be dried at room temperature and the organic fraction at 30°C. Both fractions should be weighted, including the different categories of items identified within the marine litter fraction. The volume of the litter found should also me measured, through the variation of water level in a graduated beaker, when the items are immersed without air. If possible, different categories of "food" should also be identified. Otherwise, the dry contents should be kept in labelled bags and sent to an expert taxonomist.

ii) Optional protocol for application for sampling litter excreted by live sea-turtles (faecal pellet analysis) in case of finding a specimen alive:

Upon finding the animal, its discovery should be reported to the main authorities and the operation of coordinated with the local authorities (depending on national law). Based on initial observations and if possible still at the place of discovery, some data should be recorded (See "Identification Data" Sheet in Annex 6.1). The animal should be transported to an authorized rehabilitation facility

At the rehabilitation facility, the remaining morphologic parameters should be recorded (annex 6.1) and the animal placed in the rehabilitation tanks. As soon as the animal begins to feed, a coloured plastic ball should be added to the food in order to assess the rate of gastrointestinal transit (size of plastic ball must be related to animal size). In most cases, the observed standard time for gastrointestinal transit is approximately 1.5 months after the first evacuation. The faeces should be sampled from the tank for the entire period between the arrival of the animal and the expulsion of the first coloured ball. The digested part should be removed by washing the sample with freshwater through a filter mesh 1mm and drying the retained fraction at room temperature. To analyse the content and identify the different categories of possible litter, the same approach as for the bird stomach content should be followed, as indicated above (Van Franeker *et al.*, 2005; 2011b; Matiddi *et al.*, 2011) and using a similar template as in Annex 6.2.

Extraction of data

Following the protocol for seabirds, abundance by mass (weight in grams, accurate to 3^{th} decimal) is the main information useful for monitoring program.

Other information as colour of items, volume of litter, different type of litter, different incidence of litter in oesophagus, intestine and stomach, incidence and abundance by number per litter category, are useful for research and impact analysis.

Data entry as described in Annex 6.2.

Litter Categories - source related information

For turtle analyses, stomach contents are sorted into the categories as given above for birds (Table 7). Following the protocol for seabirds, abundance by mass (weight in grams, accurate to 3^{th} decimal) is the main information useful for monitoring program. Other information as colour of items, volume of litter, different type of litter, different incidence of litter in oesophagus, intestine and stomach, incidence and abundance by number per litter category, are useful for research and impact analysis.

The proposed form for data recording is given in Annex 6.2.

Size range

≥1 mm (stomach contents are rinsed over 1 mm mesh sieve)

Spatial coverage

Dead sea turtles are collected from beaches or at sea from accidental mortalities such as victims of long-line fishing (by catch) or of boat collisions.

Survey frequency

Continuous sampling is required. Minimum sample population size for year and period of sampling must be established for reliable conclusions on change or stability in ingested litter quantities.

Maturity of the tool

Not mature at this stage. Specific monitoring programs are required.

Regional applicability of the tool

The tool is applicable to the MSFD marine regions where sea turtles *Caretta caretta* occur; in particular Mediterranean Sea country and a part of Atlantic East coast, not in Black sea.

6.3.2. Estimation of costs

A cost estimate for the sea turtle litter monitoring is difficult to estimate due to the lack of dedicating monitoring programs at national level. Cost to be intended per single sea turtles rescue centre in an assessment area and monitoring programs can be integrated with stranding monitoring programs or collaboration with other research programs on the chemical pollution and diseases in this species.

The costs presented below are calculated on the base of the activity at the Stazione Zoologica of Naples, where main equipment and facilities are already present.

Cruise cost	€2 k	Fuel and vehicle for the collection of the carcasses
Staff costs	€4.5 k	Coordinator (1 researcher x 1 month/year)
	€9 k	Dissection (1 researcher x 2 months /year)
	€7 k	Dissection and field collection (1 technician x 2 months/year)
Capital Equipment cost	€1 k	Consumable
	€2 k	Deep Freezer
	€1 k	Dissection table
	€3 k	Stereomicroscope
Cost Processing/analysing samples	€12 k	300 €/Turtle (including carcass disposal costs). Estimated 40 turtles/year

Table 8: Estimation of costs for analysis of litter ingestion in marine turtles

6.3.3. Quality assurance/quality control

There is a lack of quality assurance/quality control (QA/QC) due to lack of long monitoring programs. Data available are poor and based on few years (Matiddi *et al.,* 2011; Bentivegna *et al.*, 2013; Camedda *et al.,* 2013; Travaglini *et al.,* 2013). More publications in peer reviewed scientific literature are required.

Trend assessment

Specific long monitoring programs are required.

Target definitions

Specific long monitoring programs are required.

6.4. Protocol for litter ingestion by fish

Protocol name

MSFD Protocol for the monitoring of litter ingested by fish.

Protocol description

The methodology of this tool follows methods described in the literature for monitoring macro-, meso- and microlitter items > 1mm in stomachs of fish. It can be complemented by analysis of microlitter fraction of smaller scales but that requires a different method for analysing (see Chapter 7). The stomach contents can be employed to measure trends and regional differences in marine litter.

Related marine compartments

The tool is proposed for application for pelagic and benthic feeding fish species. Therefore the water column as well as the seafloor of the marine compartment is addressed when quantifying litter in the stomachs of different fish species.

6.4.1. Technical requirements

As a number of regular fish monitoring programmes is in existence, fish samples can be easily obtained from these. For the North Sea a list of surveys is available at http://www.cefas.defra.gov.uk/publications-and-data/fishdac.aspx. Similarly data may be found at www.ices.dk, including Baltic surveys. The Mediterranean is covered by http://www.sibm.it/SITO%20MEDITS/.

A list of suggested species will not be provided here. However, the most common ones both from an ecosystem perspective as well as from commercial importance should be investigated. These may include *e.g.* herring (*Harengus harengus*), cod (*Gadus morhua*), tuna species and anchovy (*Engraulis encrasiccous*).

The following parameters should be recorded immediately after sampling:

- location
- trawl/fishery type
- species
- length and standard length
- age
- sex
- visible deformations and skin condition (*e.g.* ulcers)

Note that no standard procedure for litter ingested by fish has been developed so far. For large fish *e.g.* adult cod, procedures similar to those followed for seabirds and turtles might be adequate but for smaller fish or juvenile life stages methods may need to be more in line with details for microlitter studies, as described in the Chapter 7. Procedures for size ranges of herring and smaller, as given below but might be subject to amendments as knowledge advances.

A sample size of at least 50 specimens per species and age group is recommended although data on variability are still missing. As more data become available this number may be reduced or increased depending on the relative loads found, *i.e.* a statistically relevant number of samples is required. Furthermore, when procedures become routine, pooling of samples to reduce workload may also be considered. When examination directly after sampling is not possible fish should be stored deep frozen.

Stomach should be removed and exterior rinsed with deionised water to avoid secondary contamination of the contents. Small stomachs are treated with 10 % KOH or 30 % H_2O_2[25] at ambient temperature to degrade natural organic matter. Depending on the amount this treatment has to be repeated several times as necessary, *i.e.* until the reaction has visibly stopped.

Chemical treatment of stomach contents has to be carried out carefully as the action of hydrogen peroxide on organic matter may lead to strong reactions such as intense foaming. Hence gloves and goggles have to be used. Note that this treatment does not degrade chitin completely but weakens it only structurally. So far no appropriate solvent has been found that will degrade marine chitin under mild conditions. The potential occurrence of chitin remains from *e.g.* zooplankton or crab remnants interferes with the quantification of fragments.

Larger stomachs are opened and contents removed. Again a peroxide treatment may be necessary to remove natural organic matter such as food-derived fat adhering to plastic items. After oxidation the remaining material may be washed through a series of sieves to obtain defined size fractions. In order to differentiate between macro- and microlitter smaller than 1 mm, at least a 1 mm sieve separation is to be carried out.

The retained material is visually inspected and counted under a dissecting microscope where necessary. In cases where the identification of plastic by visual inspection is ambiguous, *i.e.* for smaller items, confirmation might be sought by spectroscopy, *e.g.* FT-IR or Raman, or the "hot needle" technique may be employed. The fraction passing a 1 mm sieve may then be used for an analysis of microliter smaller than 1 mm (see Chapter 7 for details).

For carnivorous species fish bones may be removed by extended treatment with c-HCl. Most polymer types are not degraded by up to 5 % hydrochloric acid while polyamide, polycarbonate and some of the less regularly occurring ones such as polyoxymethylene are affected at higher concentrations (see *e.g.* http://www.kuhnke.de/fileadmin/templates/content/Automation/Branchen/Medizintechnik/764343chemische_bestaendigkeit.pdf).

As an additional method to separate smaller plastic litter from natural inorganic matter in stomach samples, density separation may be applied (see Chapter 7). Nevertheless, this method will require removal of natural organic matter as described above. With density separation, also surface-tension phenomena should be taken into account. For example, considerable numbers of sand grains may remain at the liquid-surface of a jar in which stomach contents are shaken for separation. Only when surface tension is broken by *e.g.* lightly stirring the surface with a tweezer, such sand grains drop, and true density separation is reached.

The categorisation of stomach contents is based on the general morphology of plastic items found, *i.e.* sheet like, filament, foamed, fragment or other (see list given under a- birds). In most cases, smaller fragments will not be unambiguously related to a particular defined item. Where this is, however, possible items should be described and assigned a litter category number using the master list developed by the TSML group (Chapter 8).

For each litter category/subcategory an assessment is made of:

- **incidence** (percentage of investigated stomachs containing litter);
- **abundance by number** (average number of items per individual), and
- **abundance by mass** (weight in grams, accurate to 4th decimal)

Because of potential variations in annual data, it is recommended to describe '**current levels'** as the average for all data from the most recent 5-year period, in which the average is the 'population average' which also includes individuals that were found to have zero litter in the stomach.

Litter categories - source related information

For fish analyses, stomach contents are sorted into the categories as given above for seabirds (Table 7).

Size range

[25] Note that the effectiveness of the oxidative treatment still has to be fully investigated

Both juveniles and adults and, wherever possible, also intermediate stages have to be considered. However, depending of the type of litter to be determined, *i.e.* macro- *vs*. microlitter, different size ranges may be preferred. In general it depends on fish size and choice of litter particle size considered. For micro-sized plastics below mm range, methods using KOH etc., density separation, acids etc. are given in the microlitter report detailed explanation and precautionary recommendations.

Spatial coverage

As mentioned above sampling for analysis of litter in fish should be part of already established surveys.

Survey frequency

Continuous sampling is required.

Maturity of the protocol

Not mature at this stage. Specific monitoring programs are required. Methods for the analysis of fish stomach contents, although restricted to natural food items, have been reviewed by Hynes (1950), Pillay (1952), Natarajan and Jhingran (1961), Hyslop (1980) and Cortes (1997) while statistical techniques, *i.e.* cluster analysis, have been addressed by Rice (1988) and Tirasin and Jørgensen (1999).

Regional applicability of the protocol

The tool is applicable anywhere. Species/size selection should be optimized for regional comparison and, wherever possible, overlapping species must be chosen in adjacent areas.

6.4.2. Estimation of costs

The most significant costs arise from sampling, *i.e.* when dedicated cruises become necessary. This can be overcome by obtaining samples from established monitoring programmes.

The overall estimated effort for the analysis of one stomach is approximately one to two man-hours.

Quality assurance / quality control

The methodology needs to be further developed. There is presently a lack of quality assurance/quality control (QA/QC) due to non-existence of long-term monitoring programmes. Only few data are available which usually are based on single surveys (*e.g.* Anonymous, 1975; Davison and Asch, 2011; Foekema *et al.,* 2011, 2013; Possatto *et al.,* 2011; Anastasopoulou *et al.,* 2013;).

Trend assessment

Due to the lack of maturity of the tool specific long-term programmes have to be developed.

Target definitions

Specific targets have to be developed, *e.g.* based on the OSPAR recommendation for seabirds (see above).

6.5. Plastic as nest material & entanglement in Bird colonies

Name of protocol

MSFD Protocol for the monitoring of plastic litter as nesting material in seabird breeding colonies and associated entanglement mortality.

Protocol description

Seabirds are apex predators in marine systems and are particularly vulnerable to entanglement with plastics and other marine litter (Votier *et al.,* 2011). Seabirds such as northern gannets (*Morus bassanus*), shags (*Phalacrocorax aristotelis*) or kittiwakes (*Rissa tridactyla*) tend to incorporate marine litter, much of it originating in fisheries, into their nests, at times resulting in entanglement. Depending on the regional occurrence and distribution of breeding colonies the nesting material of different species can be assessed for marine litter. In addition, the associated entanglement mortality can be studied as well. Ideally both components should be assessed in combination. The share of plastic items in nests of certain species of birds can be used as an indicator of the amount of litter in the natural environment in the vicinity of their breeding site and to assess entanglement risk of animals. The associated entanglement mortality can serve as an indicator for the direct harm caused by the incorporation of marine litter in nests of breeding colonies.

In terms of European findings to develop a protocol for the use of plastic litter as nesting material and associated entanglement in birds, surveys of breeding colonies might be a powerful indicator regarding inflicted mortality for seabirds due to marine litter. Negative effects can be documented rather easily and clearly compared with the often more indirect and sub lethal effects of *e.g.* plastic ingestion.

An advantage is that many seabird colonies are already regularly surveyed in many European countries to document the number of breeding pairs and/or breeding success. Thus, a protocol on entanglement in marine litter might potentially be filled out alongside with other existing investigations without too much extra effort.

Related marine compartments

The litter is collected by seabirds for nest construction in the surroundings of the colonies on beaches and at the sea surface.

6.5.1. Technical requirements

Select a (part of) a colony which is easily viewed from fixed viewpoint(s) and for which the borders of the study section(s) can be easily described. If only a part is monitored this should be representative of the whole colony and at least comprise 5 to 10% of all nests (at least several tens of nests). Subsampling of a representative plot can allow for calculating pollution/entanglement for an entire colony, but this is also a function of frequency. If frequency of occurrence of marine litter is low, a large number of nests need to be monitored to be able to accurately monitor trends.

Using GPS and ground-marks, fix the point(s) from which observations will be made, and ensure that such spot(s) can be easily found again in later years for continued monitoring.

Using photography, document exactly which are the borders of the study plot. In principle select an area fully defined by 'natural' borders, so that it is easily reproduced.

Decide on standard dates at which surveys should be conducted: as a minimum a first count should be made prior to the nesting season, to establish potential remainders of entangled corpses still present from the previous year. The second count should be conducted during the peak of the breeding season to receive the maximum number of 'apparently occupied nets' (AON) and respective total number of breeding birds for all species in the colony/monitoring plot. The third survey should be planned shortly after fledging of the chicks, to establish litter rates in the nests, and presence of (new) corpses of birds that died from entanglement. Intermediate or later counts may refine the picture, and may be combined with surveys of breeding effort and success.

For the surveys, use a prescribed observation tool, *e.g.* binoculars or a telescope of fixed type and magnification ('standardizing the likelihood of observing details in nest structures). When the location and accessibility to the colonies allow, *in situ* observations can be made.

Make a detailed count of the number of nests in the study plot and document number of nests with (digital) photographs whenever possible. This helps to ensure consistent monitoring of plots regarding the number of breeding birds, categorization of litter types and entanglement rates.

Make a detailed count of the structures in above count that contain visible marine synthetic litter, document pollution with digital photographs whenever possible. The \`nest litter rate\` is assessed as the number of nests containing visible litter divided by the overall number of nests in the study plot

Depending on situation, try to specify details of relative abundance of different types of litter, *e.g.* roughly as threadlike, sheets, foams, fragments or other, or in more detail using standard MSFD categorization of litter items, try to identify source of litter as *e.g.* fishing, shipping, recreational. Make a count of birds visibly entangled, recording separately species (other species than the breeders may become entangled), and age (adults, immature or chick) and if alive or dead. Document entanglement with (digital) photographs whenever possible. Ideally this count is done at a standard date, which needs to be defined, shortly AFTER fledging of main number of chicks from the colony.

Impact level from litter in nests is then assessed as the number of dead or dying animals (specified for species and age classes) divided by the overall number of breeding birds in the study plot *('entanglement mortality rate').* The number of live birds that are cut loose and released should be specifically recorded as such but included in the totals for individuals mortally entangled, because without human intervention they would have died; in situations where colonies are intensively surveyed for population monitoring, entanglement rates can be compared also to number of breeders, numbers of chicks etc.).

If possible conduct this type of survey in a number of different plots to provide a measure for local variability (known to be high *e.g.* in neighbouring shag colonies in France (Cadiou *et al.,* 2011).

Above observation survey types can be conducted easily without entering study plots and without or with little interfering with the breeding of birds. As a general rule for repeated monitoring, it is NOT recommended to collect nest structures after the breeding season to quantify proportions of litter included. In many cases, nests are multi-year structures, and removal may negatively affect breeding of site-owners and their neighbours in the next season, either by extra efforts to construct a new nest, disputes with neighbours over remaining nests and materials, or quality of the nest affecting nesting success. This type of work is recommended only as incidental effort by specialized researchers in dedicated research projects. Selected details from some earlier studies are specified in Annex 6.3.

Litter categories – source related information

There are issues to be aware of in interpreting results from this type of monitoring.

Different seabird species have different ranges from colonies when looking for nesting material and may use different types of litter into their nests depending on species and location.

The litter in nests of Northern Gannets (*e.g.* Montevecchi 1991, Votier *et al.,* 2011, Bond *et al.,* 2012) originates exclusively from the sea, whereas Kittiwakes also pick up litter as nesting material from land (*e.g.* Clemens & Hartwig 1993, Hartwig *et al.,* 2007). The latter may also apply to cormorants and possibly also shags.

Votier *et al.*, (2011), described that gannets seemed to prefer certain type of plastics such as synthetic rope for building nests compared with its proportion found on adjacent beaches. This apparent selectivity needs to be considered if seabirds are used as indicators for measuring trends in certain types of litter. More background info on above mentioned species can be found in Annex 6.3.

Size range

Detection of all visible litter particles from macro- to microlitter is possible.

Spatial coverage

This protocol is designed for application in breeding colonies of seabirds.

Survey frequency

In general, well-built nest are found during incubation and during the rearing period the nest is frequently more or less destroyed by the young; to investigate entanglement rate the best period is after fledging but to investigate the occurrence rate of marine litter the best period is during incubation.

Maturity of the tool

Not mature at this stage. So far no standard protocols to document entanglement in seabird colonies could be identified to be in use although several studies seem to have used a consistent methodology and a number of studies have been conducted on Northern Gannets, European Shags and Black-legged Kittiwakes.

Regional applicability of the protocol

This protocol can be applied in all regions wherever breeding colonies exist. A partial overview of breeding colonies for especially suitable species can be found in Annex 6.3. It could also be used in waters such as the Baltic or Black Sea where species as Cormorants and Shags breed that build litter into their nests but where other suitable biomonitors such as Northern Fulmars or Sea Turtles are absent.

6.5.2. Estimation of costs

In general no special cruise costs are required in case this protocol can be applied within other monitoring or studies in existing study colonies (on breeding pairs/success, or any study involving capture/banding of adults and/or chicks). In case dedicated monitoring is carried out just for this reason one cruise day to the colony with one day of fieldwork (driver of the boat is required). In addition staff-costs for two observers incurred to survey around 100 nests in 20-30 minutes each (and then take the mean) in addition to the costs for the boat is needed. At regularly-worked colonies, multiple surveys each year are possible.

The equipment costs are low consisting of binoculars/scopes which in most cases will be part of already existing field equipment. Data entry requires additional 1-2 hours of work. The costs for reporting depend on the venue and come down to around 10 hours for untrained technical to summarize data and prepare the report.

In the special case of the monitoring in the *Iroise Marine Natural Park* on shags, about 5 days of fieldwork for the different colonies (1 boat + 1 pilot + 2-4 observers according the colonies) and 2 days for data processing, analyses and annual short report are required.

6.5.3. Quality assurance / quality control

Having 2 observers (or even >2) count independently can produce error estimates. The methodology needs to be further developed.

Trend assessment

Data analysis and trend assessments can be carried out by time series analyses (found in most statistic packages).

A problem is the longevity of plastic litter in nests as in many locations these materials may persist for many years if they are not blown or washed away by storms, rain and flooding or taken away by humans.

Thus, nests may contain the plastic litter of several breeding seasons, and trends in the indicator values may show delays and may thus have functionality for assessing long term rather than short term trends. Finally, as indicated variability scales in the indicator need to be assessed (*e.g.* Cadiou *et al.,* 2011)

Target definitions

At this stage it seems premature to identify targets reflecting good environmental status or to specify requirements for trend calculations to assess speed of change towards achievement of GES.

6.6. Considerations on further options for monitoring impacts of marine litter on biota

6.6.1. Entanglement rates among beached animals

Direct harm or death is more easily observed and thus more frequently reported for entanglement than for ingestion of litter (CBD 2012). This applies to all sorts of organisms, marine mammals, birds, turtles, fishes, crustaceans etc.

It is, however, difficult from simply looking at the outside appearance of an animal to identify whether a particular individual has died because of entanglement in litter rather than from other causes, mainly entanglement in active fishery gear (bycatch). Nevertheless it is possible to differentiate between animals that have died quickly due entanglement and sudden death in active fishing gear and those suffering a long drawn out death after entanglement in pieces of nets, string or other litter items, because entangled birds, which have been entangled for a time before death are emaciated.

Proportions of sea birds found dead with actual remains of litter attached as evidence for the cause of mortality are extremely low. For beached birds, entanglement rates in the Netherlands are far below 1%, and only for Gannets may reach up to a few percent (Camphuysen, 2008). The possible use of entangled beached birds as an indication of mortality due to litter will be further investigated.

In marine mammals, numbers of beached animals and especially cetaceans are often high (*e.g.* of harbour porpoises at shores of the North Sea (and even at the Baltic Sea compared to predicted population numbers) or of common dolphins at beaches of the Eastern North Atlantic) and many have body marks suggesting entanglement, although remains of ropes or nets on the corpses are mostly rare. Given that in a lot of places well working stranding networks are already in place, dead marine mammals should, whenever possible, become subject to pathologic investigations which need to include an assessment for the cause of disease and death and the relevance of marine litter in this connection.

This issue will be further investigated and the development of a dedicated monitoring protocol for the entanglement of marine mammals in marine litter will be considered in the next report of the TSG ML.

6.6.2. Entanglement rates among live animals (other than in relation to seabird nests)

Sightings records and a photo identification catalogue from a haul out site in southwest England were used to establish entanglement records for grey seals. Between 2004 and 2008 the annual mean entanglement rates varied from 3.6 % to 5%. Of the 58 entanglement cases, 64% had injuries, which were deemed serious. Of the 15 cases where the entangling litter was visible, 14 were entangled in fisheries materials (Allen *et al.,* 2012). This sort of study is extremely valuable to estimate impacts from marine litter, but requires high levels of specialist research effort. Rare opportunities for this type of study and high costs prevent a recommendation as standard monitoring tool, but dedicated research efforts are highly recommended where possible.

6.6.3. Ingestion of litter by marine mammals

Samples of 107 stomachs, 100 intestines and 125 scats of harbour seals from the Netherlands were analysed for the presence of plastics. Incidence of plastic was 11% for stomachs, 1% for intestines, and 0% for scats. Younger animals, up to 3 years of age, were most affected (Rebolledo *et al.,* 2011). In this paper, ingestion rates, although of serious concern, were considered too low, and in combination with low sample availability and high cost led to the conclusion that they would not provide a useful MSFD monitoring tool. However, further studies are recommended, as in each of 19 analysed samples of faces from harbour and grey seals in the German Lower Saxony Wadden Sea, microplastics mainly from granular origin and fibers were found ranging from some milligram to a few grams per sample (personal comment by G. Liebezeit), but that needs to be confirmed by peer-reviewed literature. Determination for microplastics should be implemented in the systematic analyses before final conclusions can be taken.

A recent study described a case of mortality of a sperm whale related to the ingestion of large amounts of marine litter in the Mediterranean Sea. The results show how these animals feed in waters near an area completely flooded by the greenhouse industry, making them vulnerable to its waste products if adequate treatment if this industries waste is not in place (Stephanis *et al.*, 2013).

Ingestion of litter by a wide range of whales and dolphins is known. Although known rates of incidences of ingested litter are generally low to justify a standard MSFD monitoring recommendation at this point, it can also be argued that the number of pathologically studied animals is low as well. Dead marine mammals should, whenever possible, become subject to pathologic investigations which need to include an assessment for the cause of disease and death and the relevance of ingested marine macro- and microlitter in this connection.

Therefore the development of a monitoring protocol for the ingestion of marine litter in the different size categories by marine mammals will be considered in the next report of the TSG ML.

6.6.4. Ingestion of litter by marine invertebrates

As concluded in the chapter on microplastics, it would be premature to recommend monitoring programs for specific organisms such as zooplankton species, shellfish like mussels and others as there is insufficient view on frequency of occurrence of ingested litter and species specific requirements in fairly complicated research methods. General methods for dedicated microplastics research in invertebrate biota have been described in chapter 7. Further research into litter ingestion and impacts is highly recommended.

6.6.5. Research on food chain transfer

More and more studies are available, which indicate the affiliation of toxic substances by marine organisms when ingesting plastic litter. *E.g.* in three of 12 analyses in abdominal adipose of oceanic seabird (short-tailed shearwaters) higher-brominated congeners (polybrominated diphenyl ethers 10 (PBDEs)) were detected, which are not present in the natural prey (pelagic fish). The same compounds were present in plastic–derived chemicals from ingested plastics to the tissue of marine based organisms (Tanaka *et al.*, 2013).

In a study by Fossi *et al.,* 56 % of surface neustonic/planktonic samples in the Mediterranean contained microplastic particles. The highest abundance (9.63 items/m^3) was found in the Portofino MPA (Ligurian Sea). High concentrations of phthalates (DEHP and MEHP) were detected in the neustonic/planktonic samples. The concentrations of MEHP found in the blubber of stranded fin whales suggested that phthalates could serve as a tracer of the intake of micro-particles.

Although highly relevant, impacts of trophic transfer of microplastics through marine food chains with relevance also on human consumption, are beyond the scope of MSFD monitoring, but are highly important in future research.

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Annex 6.1 - Sea Turtle Necropsy Data Sheet

Identification Data	
Species, Tag/chip number	
Date of finding	
Circumstances (stranded, interaction with human activity (precise, and precise gear when interaction with fishing activity, death at rescue center)	
Date of necropsy (after or before freezing, if freezed indicate at which temperature)	
Trophic status atrophy of the pectoral muscles (None, Moderate, Severe) fat thickness in the articular cavities and on the coelomic membrane (Abundant, Normal, Low, None)	
Fresh/Decomposition status (categories to be explained)	
Date of turtle death	
Cause of death, if determined	
Location	
Coordinates	
Identification number (code) (International CITES code)	
Finder personal details (name, telephone, mel)	

Measurements	**Unit (cm)**
Carapace length (CCL)	
Overcurve width (CCW)	
Plastron length (CPL)	
Plastron width (CPW)	

External observation	**Comments**	**Photo (if relevant)**
Head		
Flipper		
Carapace		
Plastron		
Tail		
Sex-maturity		
Skeletal-damage		
Foreign bodies		
Cause of death		
Other		

Gastrointestinal tract	**Observation/Comments**	**Photo (if relevant)**
Oesophagus		
Stomach		
Intestine		

Annex 6.2 – Data sheet for recording of ingested items in sea-turtles

To do for each part of the gastrointestinal tract (oesophagus, stomach, intestine)

Oesophagus, Stomach or Intestine	

Type of Litter	**Presence yes/no**	**Abundance (items number)**	**Volume ($ml\ H_2O$)**	**Color (number)**	**Dry Weight (g)**	**Microlitter abundance (number items <5mm)**
IND ind						
IND Pind						
USE she						
USE thr						
USE foa						
USE fra						
USE Poth						
RUB pap						
RUB kit						
RUB rva						
RUB hoo						
POL sla						
POL tar						
POL che						
FOO						
NFO						

For litter categories see Table 7 inserted in the birds protocol.

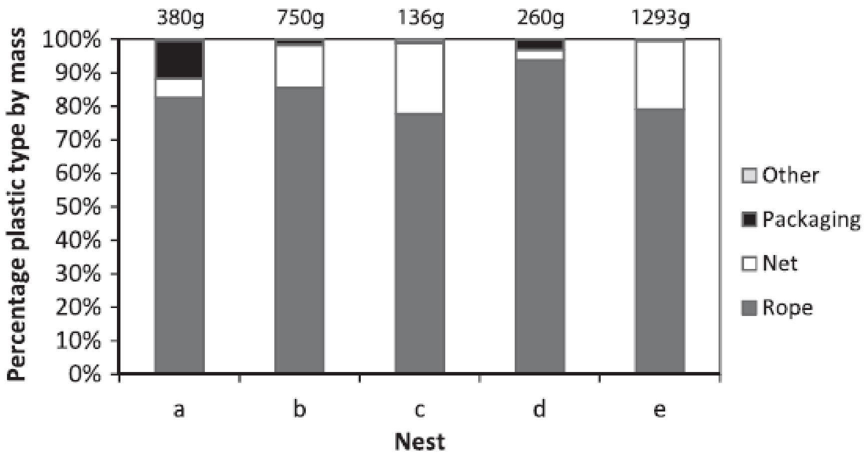
Annex 6.3 – Litter in nests of 3 species of European Sea-birds

Northern gannet (*Morus bassanus*)

The northern gannet is endemic to the North Atlantic and most breed in Canada, Britain and Ireland. There are 21 gannetries around the British Isles (JNCC 2009), with most being on remote offshore islands and stacks, and two on mainland cliffs. Between March and September Britain is in fact home to nearly 70% of the world's breeding gannet population, making their habitat internationally important.

A study by Votier *et al.,* (2011) investigated the use of plastics as nesting material by northern gannets for the years 1996-1997 and 2005-2010 in the third largest gannet colony in the world (Grassholm, Whales) where approximately 40.000 pairs of gannet breed. On average gannet nests contained 469.91 g (range 0–1293 g) of plastic, equating to an estimated colony total of 18.46 tons (range 4.47–42.34 tonnes). Litter in nests were categorized into four categories: rope made from synthetic fibers, fishing nets, packaging (plastic bags and strapping) and any other plastic which did not fit into the former three categories. The majority of nesting material was synthetic rope, which appears to be used preferentially. The relative contribution of the main types of macro-plastics were calculated and compared with shipping- and fisheries-derived plastics collected from nine nearby-beaches. Within these two categories the plastics were assigned to the same four categories as those used for gannets nests and presented in frequency of occurrence. Overall the plastic component was dominated by rope made from synthetic fibers (83%), followed by netting (15%), packaging (2%) and a very small proportion of other plastics (<1%) (Figure below).

The associated levels of mortality were assessed as well. Based on data from eight years of surveys to release entangled birds at the end of the breeding season, the number of entangled birds by year and age class was reported. On average 62.85 ± 26.84 (range minima 33–109) birds were entangled each year, totalling 525 individuals over eight years, the majority of which were nestlings. The number of entangled gannets showed no consistent linear trend over time. The percentage mortality also varied markedly among years and there was a tendency for higher mortality during later visits. The vast majority of entangled birds were fully-grown nestlings, ranging from 75% to <100% of the total numbers.



Percentage of four main plastic types found in five northern gannet nests. Values above bars indicate total dry weight (g) of plastic for each nest. We included a sixth nest in our analysis that contained no plastic. Values above bars are total plastic mass for each nest.

Already in the mid 1980ties 2.6 % of all (non-breeding) northern gannets observed at the island of Helgoland (south-eastern North Sea) were entangled in fishing gear (Schrey & Vauk, 1987). Today, virtually all nests of the breeding colony on Helgoland contain plastic litter (632 pairs in 2013, O. Hüppop, pers. comm.). Dierschke *et al.,* (2011) estimated that at least 20 to 30 gannets are annually killed in this colony by entanglement. The vast majority of nests here is not accessible by humans. Visual observations are possible, but not done yet at a routinely basis.

A study by Bond *et al.* (2012) assessed the prevalence and composition of fishing gear litter in the nests of northern gannets and found a relation to fishing effort. This long-term study was done in the Northwest

Atlantic Ocean, almost all gannet nests examined at two colonies situated in Newfoundland contained marine litter in the late 1980s, much of it being fishing gear litter. The proportion of nests with marine litter decreased following the fishery closure (investigated in 2007) and the proportion of nests with marine litter was related exponentially to the number of gillnets set around the breeding colonies.

Kittiwake (*Rissa tridactyla*)

The Kittiwake is a colonial breeding seabird and occurs discontinuously along the shores of north-west Europe, from the coasts of Portugal and Galicia (north-west Spain) in the south, through Brittany (France), Ireland and Britain, the German Island of Helgoland, Iceland and along Scandinavian coasts to the Kola Peninsula. In the UK, Kittiwakes occur on most coasts, although there are few colonies on the south and east coasts of England. A high percentage of the British Kittiwake population nests in northern Scotland and along the North Sea coast south to East Yorkshire.

The recording of the share of marine litter used as nest construction material by the Kittiwake colony at the Bulbjerg at the Jammerbugt in Northwest Denmark in 1992 has been taken up in 2005. Whereas in the year 1992 plastic litter items were included in 39.3% of 466 Kittiwake nests in the Bulbjerg colony, in 2005 57.2 % of 311 nests contained plastic litter (Hartwig *et al.,* 2007). Litter items detected in 1992 consisted of white, black, green, red, and blue synthetic strings, plastic foil and fishing net remnants, the ones identified on 2005 could be assigned to tight meshed netting and strings in various colours (red, blue and black).

The share of litter seems to correspond to the amount of litter of these categories on the beach and in the surroundings of the colony. This is supported by findings reported in Clemens and Hartwig 1993 for the Kittiwakes at the colony on Helgoland, where during the 1992 breeding season, of the 152 nets counted, spread over the entire colony, in 17 (=11,1%) nests visible litter particles such as net fragments, plastic strings, plastic foil and rubber band were found. Anyway, in both publications (Clemens & Hartwig, 1993, Hartwig *et al.,* 2007) there is no exact quantification of litter types given, neither in Kittiwake nests nor for litter in the surrounding environment of the colonies. Moreover, the size of this surrounding area which is assumed to act as source of the litter in nests is not defined either. Thus, the initial conclusion that the share of litter in Kittiwakes nest reflects the amount of litter of these categories on the beach and surroundings would need further specification and testing.

Shag (*Phalacrocorax aristotelis*)

The European Shag can be found along the entire Atlantic coast of Europe as far north as Finland and including Iceland, as far south as the coast of Morocco, and ranges in the entire Mediterranean nesting on parts of the coastline of most European (*e.g.* Italy, Turkey) and north African countries (*e.g.* Algeria, Libya), as well as parts of the Black Sea coast (*e.g.* Ukraine).

In Western Brittany marine litter in shag´s nests is used as indicator of marine pollution. This monitoring is carried in the Marine Natural Park (Cadiou *et al.,* 2011). A simple assessment method was developed to assess occurrence and abundance of marine litter in nests during annual census of breeding pairs, tested in 2010-2012.

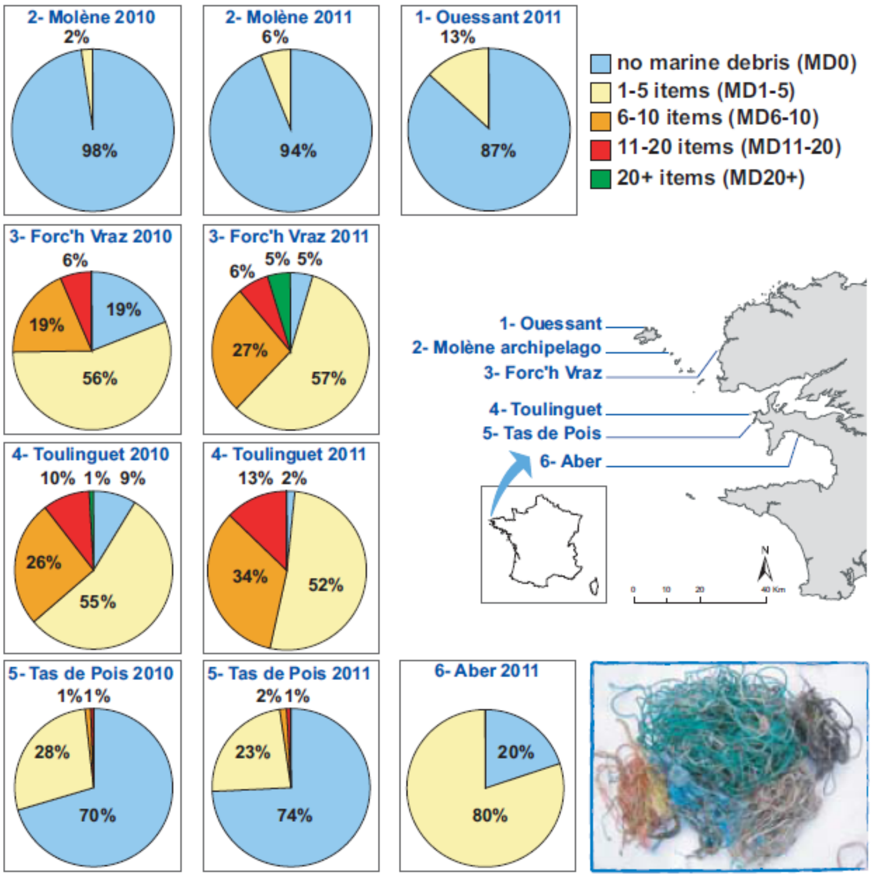
Five abundance classes were distinguished, from MD 1-5 (1-5 items identified) to MD20+ (see Table below. Hereby an example how the data collection on one day but in different colonies is taken:

Date	Colony	Observers	Nest-content	marine-debris remarks
18.05.2012	Ar Gest	B. Cadiou	0	MD0
18.05.2012	Ar Gest	B. Cadiou	1E1D	MD0
18.05.2012	Ar Gest	B. Cadiou	2D	MD01-05
18.05.2012	Ar Gest	B. Cadiou	2B1W	MD01-05
18.05.2012	Ar Gest	B. Cadiou	0	MD01-05
18.05.2012	Ar Gest	B. Cadiou	3A	MD06-10

18.05.2012	Ar Gest	B. Cadiou	1D1W	MD06-10
18.05.2012	Ar Gest	B. Cadiou	0	MD11-20
18.05.2012	Ar Gest	B. Cadiou	2C	MD11-20
18.05.2012	Ar Gest	B. Cadiou	0	MD21+
				MD0 = no marine litter
				MD01-05 = 1-5 items of marine litter
				MD06-10 = 6-10 items
				MD11-20 = 11-20 items
				MD21+ = >20 items
			0 = empty nest	
			W = egg	
			A-G = age classes of chicks	
			e.g. 2B1W = 2 chicks (age class B) + 1 egg	
Bernard Cadiou - Bretagne Vivante-SEPNB, Brittany, France				

Example of table for data collection in different colonies

Samples of litter were randomly collected in different nets after fledging. Items were classified into different categories according to the OSPAR classification of marine litter, in order to identify their origin (fishery activities, domestic use etc.). Results pointed out high variability of occurrence and abundance of marine litter between colonies (table below). The abundance class MD50+ was not met so far. A few cases of entangled birds have been reported with breeding adults or young found dead in their nests. It is planned to further investigate in marine currents in the study area to investigate on possible explanations about higher densities of floating litter in the vicinity of some breeding colonies.



Number of litter items in nests in different breeding colonies (Cadiou *et al.*, 2012)

7. Microlitter

7.1. Introduction to Microlitter

Microlitter is considered in Section 4.4 of the MSFD descriptor 10 ''*Amount, distribution and composition of microparticles*. *The attribute will establish baseline quantities, properties and potential impacts of microparticles. Microplastic is likely to be the most significant part of this*.''

In effect microparticles consist of similar materials to other types of litter; they are merely pieces of litter at the very small end of the size spectrum. Microparticles of a range of common material types including glass, metal, plastic and paper litter are undoubtedly present in the environment. The protocols outlined here focus on microplastics as descriptor 10 considers these to be the most significant component of the microliter in the environment. This statement is partly based on the frequency of reports of microplastics (Hidalgo-Ruz *et al.* 2012), but relative proportions of material types will be influenced by the physical conditions of the habitat sampled, for example metal and glass microlitter is not likely to be found at the sea surface. The approaches described here are likely to capture other man-made particles. Where materials other than plastics contribute a major proportion of the microliter in a particular location it is important that this is recorded and if necessary protocols are modified to ensure this litter is as completely sampled as possible.

When first described the term microplastic was used to refer to truly microscopic particles in the region of 20 µm diameter (Thompson *et al.* 2004). The definition has since been broadened to include all particles < 5 mm (Arthur *et al.* 2009). Microplastics are widely dispersed in the environment and are present in the water column, on beaches and on the seabed (Barnes *et al.* 2009; Browne *et al.* 2011; Claessens *et al.* 2011; Collignon *et al.* 2012; Colton *et al.* 1974; Goldstein *et al.* 2012; Law *et al.* 2010). Hence microplastics are relevant to other protocols in descriptor 10, relating to the monitoring of larger items of litter; however they are treated separately here because their size necessitates specific methodology.

MSFD considers that in order to achieve GES that the quantities of microplastics in the environment should not result in harm. When defining methodological criteria it is essential to recognise that our understanding of the potential impacts of microplastic on organisms and the environment (i.e. the 'harm' that they might pose from the perspective of MSFD) is still not fully understood. A range of concerns have been outlined including: physical obstructions impairing feeding and digestion, particulates-type toxicity (analogous to airborne particulates) and the transfer of toxic substances to biota upon ingestion and physical damage to organs and tissues as a consequence of the physical presence particulates (Browne *et al.* 2008; Mato *et al.* 2001; Secretariat of the Convention on Biological Diversity and Scientific and Technical Advisory Panel GEF 2012; Teuten *et al.* 2007; Wright *et al.* 2013). The relative importance of these issues is likely to vary across the size spectrum of the plastic in relation to the size of the organism concerned. For example, items at the large end of the microplastic size distribution (1-5 mm) have been reported in the stomach of seabirds where they may compromise feeding and digestion *(*van Franeker *et al.* 2011). While in small invertebrates much smaller particles of plastic in the 10 µm size range have been shown to translocate from the intestine into the circulatory system (Browne *et al.* 2008) and there is considerable evidence for the translocation of even smaller nanoparticles. Work using sub-millimetre sized particles (200-250 µm) has indicated the potential for the transport of persistent organic pollutants (Teuten *et al.* 2007).

An upper size bound of 5mm has been widely (but not exclusively) adopted and for the purpose of MSFD we suggest the upper bound to be taken to as items <5mm in their largest dimension. Current definitions do not explicitly state a lower size limit and lower size limits have seldom been reported for microplastic concentrations in the environment. The lower size limit is perhaps assumed to be the mesh size of the net or sieve through which the sample passed during the sampling, sample preparation or extraction. The size limits of microplastic particles that can be reported are also dependent on the method of detection, in many cases microscope-aided visual inspection. When identifying microparticles there are also size limits imposed by the analytical techniques employed (*e.g.* minimum sample intake requirements for detection and analysis). Hence an important part of establishing standard methods and protocols within MSFD will first be to define the appropriate size range, and this aspect is considered in the present report.

Most studies have focused on sampling intertidal sediments and the sea surface / water column (Hidalgo-Ruz *et al.* 2012). However, despite the numerous studies one of the main limitations to our ability to make spatial and temporal comparisons, especially at broad scales, is that a variety of approaches have been used to identify, quantify and report measured concentrations of microplastics (Hidalgo-Ruz *et al.* 2012). Work to date represents the critical pioneering steps towards understanding the distribution and fate of microplastics in the environment. After this initial period of discovery, microplastics research now finds itself at a stage of development where there is a lack of quality assurance/quality control (QA/QC) instruments available: *e.g.* no organisations yet offer proficiency training or testing, there have been no inter-laboratory studies, no certified reference materials are available, no standardized sampling and analysis protocols have been published, no accreditation certificates have been issued and some procedures in use have not yet been validated. Approaches for QA/QC will therefore be very useful for evaluating sources of variability and error and increasing confidence in the data collected.

Microplastics comprise a very heterogeneous assemblage of pieces that vary in size, shape, colour, specific density, polymer type, and other characteristics. For meaningful comparisons and to answer the specific questions and to test hypotheses through monitoring, it is important to define methodological criteria to quantify such metrics as for *e.g.* the abundance, distribution and composition of microplastics and to ensure sampling effort is sufficient to detect the effects of interest. Protocols to monitor microplastic in four compartments of the marine environment: 1) intertidal sediments, 2) Sea surface, 3) subtidal sediment and 4) biota are presented here at present our understanding of the sources, distribution and fate of microplastics in the environment are very limited, as is our understanding of any associated effects on wildlife. As a consequence it is not possible to present fully validated standard operating procedures. Instead we present recommendations for monitoring supported by a discussion of considerations and limitations according to the knowledge base at the time of writing. Most work to date has focused on intertidal sediments and sea surface sampling and so our recommendations for these compartments are more detailed than those for subtidal sediment and biota. The aim of this text is to maximise consistency and comparability of future data collection by recommending approaches.

Collection of data is costly and it will be critical to identify monitoring approaches (and associated meta data such as QA/QC) that directly support the aims of Descriptor 10, item 4.4 'microparticles (especially microplastics)'. In this respect it is important to note, as a general point, that mismatches in *how monitoring data are collected and the hypothesis or question(s) being addressed by the data* customarily limit the power of monitoring data and may weaken the conclusions that can be drawn from them. As we move forward toward GES the strategy of designing microplastic monitoring should therefore be to prevent the 'data-rich but information-poor' ailment that has affected various environmental monitoring data sets in the past. However, because of the relative infancy of microplastics research it is essential that the approaches outlined should be re-evaluated and refined as new information emerges.

It is hoped that these recommendations will help in the collection of new data to inform our understanding on trends in the abundance and distribution of microplastics; however in some instances the data collected may at this stage be more important for *hypothesis generation* rather than *hypothesis testing*. We strongly advocate the need for workshops to inter-calibrate methods and review data collected in order to refine specific monitoring and achieve the greatest level of efficiency.

7.2. Scope and key questions to be addressed

Technical Recommendations for the Implementation of MSFD Requirements were outlined in 2011 (MSFD GES Technical Subgroup on Marine Litter, 2011) and concluded that:

''There is a need to standardize sampling approaches in order to monitor the abundance of microplastic for MSFD. For samples from sea surface, water column, sediment and biota, this needs to consider both the sampling design in terms of number and size of replicates, spatial area and frequency of coverage as well as the methodological approach; type of net or core and method of identification used. Given this is an emerging area with numerous recent studies it is not reasonable to prescribe set methodologies at this time and the development of standard approaches and protocols should be seen as a goal over the next 4 years''

'' By 2012 there should be identification and recommendation of protocols to provide consistent, reliable and relatively easily obtainable data on spatial and temporal trends in microplastic. Since patterns of distribution and the movement of particles between compartments, for example sea surface to seabed, is far from clear; it will be important to evaluate methods to sample shorelines, sea surface.''

This document presents a review of existing approaches considering sampling design, methods of sample collection and identification of microparticles and the extent of current usage which is important for comparative purposes. **The main objective of the present document is to give guidance to MS for monitoring of microplastics in marine habitats; it considers monitoring design, sampling, analysis, reporting. Where possible, basic criteria and approaches are advocated so as to maximise the comparability of future sampling. However, microparticles represent an emerging area of scientific research and as yet there are few robustly tested and validated approaches. Hence, in addition to providing recommendations that will be feasible and effective for MS at the present time, this chapter identifies areas where methods need developing. It is essential that approaches are reviewed as our understanding of this topic evolves.**

Sampling of microplastics will be considered for each of the following compartments: Beach, Water column and Sea surface, Subtidal sediment and Biota. Section 7.4 discusses the current status of sampling approaches for each of the four compartments considering the difficulties associated with applying these methods and any limitations. Section 7.5 then presents our recommendations for monitoring in each of the compartments. It also addresses aspects of quality assurance and quality control. However detailed power analyses to indicate the levels of spatial and temporal replication required in order to detect given levels of change (effect size) from back ground variability are yet to be undertaken. Such analyses are therefore an important priority in order to refine more efficient protocols in future. This chapter makes recommendations on sampling (Section 7.5) based primarily on approaches that have been used to date. **It considers monitoring approaches that address the full size spectrum of microparticles that can feasibly be sampled with recognised approaches i.e. millimetres, 100s of µm and 10s of µm. It seems inevitable that even smaller anthropogenic debris including nanoparticles are also present in the environment, however at present there is little that can be done to monitor particles of this size and they are considered beyond the scope of this review**.

The key questions addressed here are:

How to determine the abundance of microplastic in intertidal sediment?

How to determine the abundance of microplastic in subtidal sediment?

How to determine the abundance of microplastic at the sea surface?

How to determine the abundance of microplastic in biota?

How to introduce and maintain appropriate QA/QC measures in the field and the laboratory?

All of the above must be considered within the framework monitoring programs that are appropriate to the questions or hypotheses being tested. **At the present time it is not possible to advocate a single universal protocol or compartment to provide a reliable index of microplastics in the marine environment. We discuss methods for each compartment and make recommendations on sampling approaches based on current understanding. The document does not therefore advocate that Member States monitor microplastics in a particular compartment and choice of compartment for monitoring rests with Member States. However, for efficiency of sampling it is advocated that microplastic sampling be conducted in parallel with existing monitoring and so the document gives advice on how to sample in each of the four compartments.**

7.3. General Sampling Methods

Sampling of microplastics in different main marine environments (sea surface, water column, sediment and biota) has been approached using a variety of methods: samples can be selective, bulk, or pre-treated to reduce their volume (Hidalgo-Ruz *et al.,* 2012).

Selective sampling in the field consists of direct extraction from the environment of items that are recognizable by the naked eye, usually on the surface of sediments. For example particles in the size range

1–5 mm diameter are easily recognizable. However, when smaller microplastics are mixed with other debris or lack distinctive shapes there is a great risk of overlooking them. This form of sampling is therefore only valuable if the aim of the monitoring is to determine the abundance of specific items that are readily recognisable to the naked eye, such as resin pellets or if the aim is to quantify items of specific sizes (*e.g.* those > 3mm). It cannot be used to quantitatively sample a variety of microplastic shapes and sizes.

Bulk samples refer to collection of the entire volume of the sample (water or sediment) without reducing it during the sampling process. This enables the reporting of concentration units, (*e.g.* based on sample mass) and can facilitate more rapid sampling especially when microplastics cannot be easily identified visually in the field because for example because they are covered by sediment particles. Sediments and seawater can also be pre-treated to reduce the bulk of the sample. Here a known and recorded volume of the sample is processed preserving the portion of the sample that is of interest. For example, sediment can be sieved directly on the beach or particles can be separated according to density; while on board a vessel seawater samples can filtered or sieved.

Most studies use a combination of these steps after which a purification step is required to sort the micro litter from natural particulates. Visual characterisation is the most commonly used method for the identification of microplastics (using type, shape, degradation stage, and colour as criteria). Chemical and physical characteristics (*e.g.*, specific density) can also be used. However, the most reliable method is to identify the chemical composition of microplastics is by infrared spectroscopy (Hidalgo-Ruz *et al.,*, 2012), This approach requires equipment that may be considered relatively costly compared to sampling of large items of debris (€ 20 -100k) however FT-IR is widely available in laboratories throughout Europe and can be used to identify particles down to around 20μm in size.

In all four compartments (sea surface, water column, sediment and biota) we recommend quantifying microplastics in the size range 20μm to 5mm. Microplastics should be categorised according to their physical characteristics including size, shape and colour (see Table 9). It is also important to obtain information on polymer type, since this can help identify potential sources and pathways, which is potential monitoring goal. Microplastics should be categorised according to size with a minimum level of resolution being to allocate the material found in to size bins of approximately 100 μm (20-100 μm, 101-200 μm, 201- 300μm etc). Ability to visually distinguish synthetic fragments from other natural and man-made particulates becomes increasingly difficult as the size of the piece under examination decreases, unless IR techniques are used (which is feasible >20μm). We advocate that all particles in the range 20-100 μm be subjected to further analysis to confirm identity (*e.g.* using FT-IR). For particles in the size range 0.1 -5mm we recommend that a proportion (for example 10%) of the material in each size class, up to a maximum of 50 items per year or sampling occasion whichever is the least frequent) of the items considered to be microplastics be subjected to further analysis to confirm identity (*e.g.* using FT-IR). This step is important in order to 1) ensure quality control of visual identification and 2) gain information on the relative abundance of different polymer types which can be used to help identify potential sources and pathways leading to the accumulation of microplastics.

Sampling Frequency - Detailed power analyses to indicate the levels of spatial and temporal replication required in order to detect given levels of change (effect size) form back ground variability are yet to be undertaken for any habitat. This is an important priority in order to develop more efficient protocols in future. This document therefore makes recommendations on sampling based primarily on approaches that have been used to date. To achieve the greatest efficiency microparticles should be sampled alongside other routine sampling programmes. For example microparticles in beaches can be sampled at the same time as macro debris on beaches, or in parallel with any other routine intertidal monitoring (*e.g.* for chemical contaminants, biota). Similarly sampling of subtidal habitats or the sea surface could also be incorporated into routine monitoring programmes. For biota it is not possible at this time to recommend specific organisms as indicator species of micro particles. Methods are provided indicating how biota such as birds, turtles, fish, and invertebrates can be sampled. For greatest efficiency we suggest microparticles be quantified as part of any routine sampling of macro litter within biota; for example in Birds, as outlined in Chapter 6 on Biota.

7.3.1. Sampling intertidal sediments

A recent review identified over forty studies examining the abundance of microplastics in sedimentary environments, mostly on sandy beaches (Hidalgo-Ruz *et al.,* 2012. The number of sites sampled in each study ranged from one to 300 beaches. Most studies examined between 5 and 18 beaches. The specific tidal zone sampled on a beach varied considerably among studies; some covered the entire extent of the beach, from the intertidal to the supralittoral zone, some distinguished several littoral zones, while others pooled samples across different zones. The majority of studies, however, focused on the most recent flotsam deposited at the high tide line. As with other types of debris the accumulation of microplastics on shorelines is likely to vary according the depositional regime. This will most probably occur in a similar manner to the deposition of natural particulates, however attempts to relate microplastic abundance to differences in sediment type among shores have not shown significant correlations (Browne *et al.,* 2011). To date most sampling in the intertidal has been on sandy shorelines. This is easier since separation of small pieces of microplastics (< 500 µm) from bulk sediment by density and filtration is more efficient in relatively coarse sediments since fine material such as silt and clay remains in suspension and can clog filters. More work is needed in order to understand factors influencing the distribution of microplastics along gradients of sheer stress (wave exposure, tidal flow). However, since most work to date has been from relatively coarse sandy sediments **our recommendation is that microplastics should be monitored on the top of the shore (strand line) and where available on sandy shores (0.1 – 0.0125 mm diameter). We suggest that separate samples be collected to monitor each of two sizes of debris (1-5mm and 20 µm – 1mm).**

Sampling depths reported in previous studies ranged from 0 to 32 cm; most studies sampled a single depth layer within the top 5 cm of sediment. Given that beaches and subtidal coastal habitats are dynamic systems with continuous and seasonal erosion and deposition of sediment microplastics may become buried in during periods of accretion; however more research is needed to establish the extent of this. Since most work to date has been from the surface of sediments **our recommendation is that samples should be collected from the surface 5cm of the sediment.**

Most studies have sampled at the strand line, either: (i) sampling a linear extension along the strandline with a spoon and/or a trowel or (ii) sampling an areal extension using quadrats. Sampling units were directly related to the sampling instrument used. Studies that sampled a specific areal extension (from 0.0079 to 5 m^2) employed quadrats and corers. Other sampling units were weight (from 0.15 to 10 kg) and volume of sediment (from 0.1 to 8 L). **Our suggestion (based on previous studies) is that a minimum of five replicate samples be collected from the strandline. Each replicate should be separated by at least 5m. Replicates can be distributed in a stratified random manner so as to be representative of an entire beach or a specific section of beach.** This ultimately depends on the specific locations and questions of interest at a local scale. We suggest that power analyses be conducted to further guide the most appropriate level of replication.

Microplastics 1 – 5mm - This should be collected as an additional entirely independent sample at each location and, in order to minimise the risk of contamination form persons undertaking the sampling itself, should be obtained AFTER the sampling the smaller size fraction (<1 mm, see below) The sediment can be sampled by collecting with a metal spoon or trowel the top 5cm of sand from the area contained within a metal 50 cm x 50 cm quadrat and passing through a 1 mm metal sieve and then be stored in metal (*e.g.* foil) or glass containers (*i.e.* not stored in plastic containers). Record the volume of sediment examined. **Our recommendation ins that these be sampled using an extension of the protocol for meso debris (5-25mm) which uses a 5mm sieve to separate debris from beach sediment (see protocol for sampling beaches Section 3). This approach can be extended by including a further metal sieve of 1mm mesh to achieve volume reduction in the field. Preferably the sieves could be stacked together.**

Microplastics 20 µm – 1mm - should be collected from the top 5cm of sand using a metal spoon (suggest 15ml). Because the weight of sediment can vary considerably according to water content we suggest standardising sampling by volume and collecting approximately 250ml of sediment Microplastics can subsequently be extracted in the laboratory by density separation (see later). Sediment should be stored in metal (*e.g.* foil) or glass containers (*i.e.* not stored in plastic containers). The sample can be collected by kneeling on the strand line and collecting a series of scoops at arms-length at intervals within an arc shaped area to the front.

7.3.2. Sampling seawater

Seawater samples have mostly taken by nets, the main advantage being that large volumes of water can be sampled quickly, retaining the material of interest. Most studies from surface waters have used Neuston nets and from the water column, zooplankton nets. Another instrument, that is deployed on a global scale and that has also been used for microplastic sampling is the continuous plankton recorder (CPR). The most relevant characteristics of the sampling nets are mesh size and the opening area of the net. Mesh sizes used for microplastic sampling range from 0.053 to 3 mm, with a majority of the studies (rather than individuals samples collected) ranging from 0.30 to 0.39 mm. The net aperture for rectangular openings of neuston nets (sea surface) ranged from 0.03 to 2.0 m2. For circular-bongo nets (water column) the net aperture ranged from 0.79 to 1.58 m2. The length of the net for sea surface samples has varied from 1.0 to 8.5 m, with most nets being 3.0 to 4.5 m long. Techniques using apparatus to collect Seawater and pass it through a filter on-board ship are being developed for example by CEFAS, UK they use the ships water inlet, collecting seawater from the side at specified depths, mostly ranging between 4m and 1m depth. The seawater is passed through sieves or nets in closed containers after which these can be removed and analysed for microplastics.

A key consideration in collecting seawater samples is the cost of ship time. Hence the potential to sample during existing cruises or from existing monitoring programmes such as the CPR is well worth considering. Manta and bongo nets have been used at the sea surface. With netsit is important to deploy the trawl out of the wake zone as turbulence inside the wake zone does not allow for a representative sample to be collected. Use a spinnaker boom or 'A' frame to deploy the trawl away from the side of the vessel. Keep a close-eye on the net while trawling to observe its performance and adjust speed and cable length if necessary. Avoid sampling at the peak of plankton blooms as this may clog the net.

Since most plastics are buoyant they are likely to accumulate at the sea surface. Surface sampling techniques can be used close inshore, but are restricted to calmer weather conditions, whereas CPR and other sub surface approaches can be used in rougher weather. High speed Manta trawls can be deployed in a range of sea states, but CPR is the least sensitive to sea state and samples at an average depth of around 6m. Manta trawls can be used to sample large volumes of surface water, but are relatively insensitive to smaller size fractions (< 1mm) which can be difficult to separate or sort form the large surface area of the net. CPR has a very much smaller aperture (around 1.6cm2) and hence samples smaller quantities of water per km but can be deployed for much longer periods (distances) than the Manta without clogging as it has a continuous net spool which collects the sample. With the CPR the entire filter is sealed automatically and then transferred to the laboratory for examination under the microscope. Preliminary data indicate CPR and Manta nets collect similar quantities of debris per unit volume of water sampled; however because of the larger aperture of nets such as Manta the quantity of debris collected per distance towed is substantially greater than CPR. During trawls it is important to maintain a steady linear course at a constant speed. A hi-speed manta trawl can be deployed up to 8 knots, build up the speed slowly towards maximum speed. Higher speeds reduce the ability to sieve seawater, creating a bow wake in front of the trawl.

At present it is not appropriate to recommend one approach over all others. Each approach has advantages and disadvantages and may be preferable according to local availability / sampling opportunities, the characteristics of the area to be sampled. Our recommendation is to obtain samples from sea water and to ensure the following details are recorded to accompany each sample: type of net, aperture, mesh size (**preferably 333 µm mesh, 6m length for greatest inter-comparability among sampling programmes**). It is not possible to specify standard haul duration as at some times of year, for example during a plankton bloom, nets may readily become clogged with natural material rendering them inefficient – **a duration of 30 min is suggested and the duration of the trawl and the estimated water volume must be recorded**. Samples from nets should be stored in glass jars taking care to rinse material as thoroughly as possible from the sides of the net using filtered sea water. Microparticles are recorded as the total quantity of such captured by the net during the period it is deployed. Note this may well include some items that are smaller than the mesh of the net itself since with fine nets of this type approximately half the surface area of the net is the mesh material itself (the remainder being the gaps between the mesh) and this mesh will directly trap small particles.

7.3.3. Sampling Subtidal Sediment

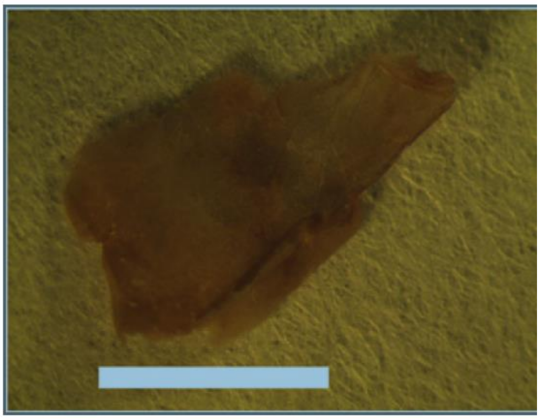
Material can be collected using any approach that recovers a sample of relatively undisturbed surface sediment from the sea bed (*e.g.* Van veen grab, multi corer, box core etc.). Once recovered onto the vessel a small sample of sediment ideally around 250 ml is recovered to best represent the location of the original 5 cm surface to sub surface of the seabed. Because the weight of sediment can vary considerably to water content we suggest standardising sampling by volume. Avoid sampling next to the edge of the apparatus to minimise risk of contamination form the equipment (*e.g.* paint flakes other contamination on the grab / core). The sample is transferred to a metal or glass container for subsequent density separation / FT-IR spectroscopy.

7.3.4. Sampling Biota for microplastics

A range of organisms including filter feeders, deposit feeders and detritivores have been shown to ingest microplastic in the laboratory (Browne *et al.,* 2008; Thompson *et al.,* 2004). There are a growing number of studies showing that organisms form natural habitats also contain microplastic in their gut. This has been shown for seals (from scats) (Eriksson & Burton 2003), birds (van Franeker *et al.,* 2011), fish (Lusher *et al.,* 2012), crustaceans and echinoderms (Graham & Thompson 2009). For some organisms a substantial proportion of the population is affected. For example data collected on the Northern Fulmar show that over 95% of individuals washed ashore dead contained plastic in their guts and much of this material was microplastic. While a study in the Clyde Sea, UK showed that contamination in the commercially important crustacean *Nephrops norvegicus,* was wide spread with 83 % individuals containing plastic. A recent study in the English Channel showed that 10 species of fish and over all around one third of individuals (sample size n = 500) contained small quantities of microplastic (Lusher *et al.,* 2012).

For biota it is not possible at this time to recommend specific organisms as indicator species of micro plastics. Protocols are provided indicating how biota such as birds, fish, and invertebrates can be sampled. For greatest efficiency we suggest microparticles be quantified as part of routine sampling of macro litter within biota; for example in Birds and Fish, as outlined in Section 6 on Biota.

If individuals are live then they must be humanely killed adhering to any prevailing ethical legislation. Small individuals can be stored whole. For larger individuals the gut can be dissected but otherwise left stored intact. Examination of the gut is facilitated with a dissecting microscope. The digestive tract is slit open using scissors and examined immediately. Depending on the size of the organism the gut can be examined in its entirety or samples of gut wall (*e.g.* 10cm x 10cm (or similar standard area) can be removed and viewed under a dissecting microscope. Any fragments of an unusual appearance are removed with forceps and placed on clean filter papers in petri dishes which are then sealed prior to further examination for example via spectroscopy (Picture 4).



Picture 4: Figure 1- Microplastics from the gut of a fish collected in the English Channel. Scale bar represents 2mm (Lusher *et al.,* 2012).

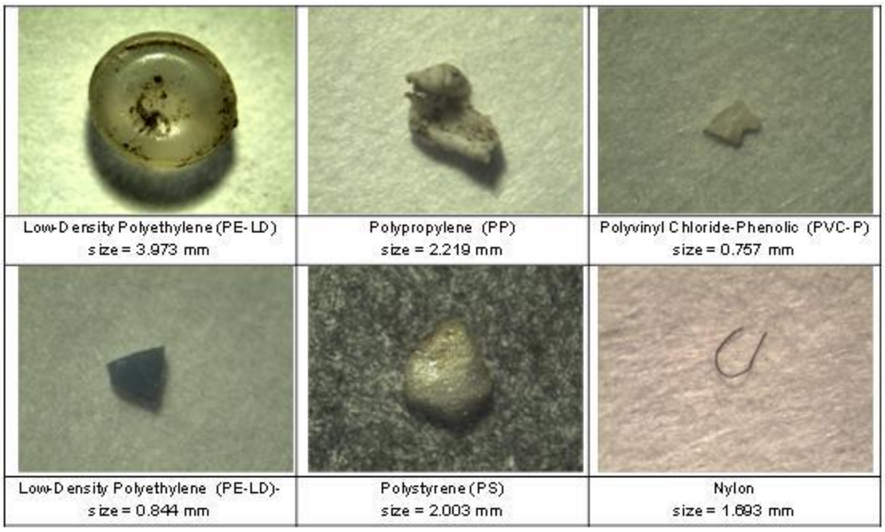
7.3.5. Laboratory analyses of samples collected in the field

Density Separation for extracting plastics from sediment - The specific density of plastic particles can vary considerably depending on the type of polymer and the manufacturing process. Density values for plastics range from 0.8 to 1.4 g cm−3. These values refer to virgin resins, without taking into account the effect on density of various additives that might be included during product manufacturing or the effects of biofouling on the surface of the plastic. Typical densities for sand or other sediments are 2.65 g cm^{-3}. This difference is exploited to separate the lighter plastic particles from the heavier sediment grains by mixing a sediment sample with a saturated solution of Sodium Chloride and shaking. After mixing, coarse sediment will rapidly settle to the bottom, while low density particles remain in suspension or float to the surface of the solution. Subsequently, the supernatant with the plastic particles can be extracted onto filter paper for further processing. Fine sediments such as silt and organic particulates such as fragments of algae and plants are likely to remain in suspension and will be separated together with any plastic present.

Of the 13 sediment studies examined by Hidalgo-Ruz *et al.* in 2012 ten included density separation using a saturate saline Sodium Chloride (NaCl) solution (1.2 g cm^{-3}). One limitation with this approach is that the density of some plastics (*e.g.* PVC) is greater than that of saturated NaCl and therefore separation of these denser polymers will be relatively poor. Other solutions of greater density have been applied for example, sodium polytungstate solution with a density of 1.4 g cm−3 tap water, Sodium Iodide solution (NaI) (Claessens *et al.* 2013) and Zinc Chloride ($ZnCl_2$). Plastics that float in fresh and seawater are polystyrene in foamed form, high and low density polyethylene, and polypropylene. Polystyrene in solid form also floats in a hypersaturated saline solution. The plastics that float in sodium polytungstate solution also include flexible and rigid polyvinyl chloride (PVCs), polyethylene terephthalate (PETs), and nylon. A range of separation devices have also been developed such as the Munich Plastic Sediment Separator (Imhof *et al.,* 2012). There are merits to all of these approaches; however detailed cross calibration of extraction, efficiency, equipment cost, sampling time and health and safety are yet to be undertaken among methods. We therefore recommend extraction with Sodium Chloride as it has been most widely used, extraction apparatus is simple and widely available Sodium chloride is inexpensive and not hazardous. However in making this recommendation we acknowledge that extraction of denser polymers will be more efficient using some of the other solutions described above. With any of these approaches it should be recognised that extraction will not be complete and that the methods provides an index of the abundance of microplastic.

With the Sodium Chloride separation a known volume (normally 50 ml) of sediment is added to a separating funnel using a metal spoon and 200 ml of saturated NaCl added. A stopper is added and the mixture agitated by hand for 2 minutes, and then allowed settling for 2 minutes. The supernatant is then transferred to suction filtration via a buckner funnel and passed through 10 µm retention glass fibre filter paper. Filter papers are removed and stored in sealed petri dishes prior to examination under a microscope. The NaCl separation procedure is repeated three times with each sediment sample to ensure a high proportion of buoyant debris is removed data form the three filter papers are added together**.** Subtidal sediments are typically finer than those from sandy beaches and so may be likely to clog filter papers and produce a relatively thick layer of fine natural particulates. This problem can be reduced by repeatedly filtering smaller volumes of sediment on and then pooling data form each separation. **We recommend using a concentrated saline NaCl solution (1.2 g cm^{-3}) to achieve bulk separation according to density. This is inexpensive, readily available, non-toxic has been most widely used to date and will achieve good separation for most polymers.**

Filter papers can then be examined sealed within the petri dishes under a binocular microscope. The abundance of any pieces of unnatural appearance (due to colour, shape, dimensions) is recorded. Positions can be marked on the top of the petri dish lid to facilitate relocation / removal. It is advantageous for analysts to be familiar with the appearance of microplastics items (Picture 5 below) and also familiar with natural particulates such as sand / plankton. Trained plankton analysts can achieve around 70% accuracy for fragments down to 50-100 µm. For smaller (<100 µm) fragments FT-IR or Raman spectroscopy is essential. Even within the range 500 – 100 µm it is important to have a proportion of the items that are visually identified as plastic to be formally checked by FT-IR or Raman spectroscopy.



Picture 5: Examples of microplastic pieces collected from waters around Plymouth, UK (Courtesy of S. Sadri, Plymouth University).

Separation from seawater (e.g. suspended material and seawater retained form plankton nets) - Samples in seawater can be passed through a 500 µm sieve, and liquid passing through the sieve then filtered through 10 µm retention glass fibre filter paper using a Buckner funnel. Filter papers can then be examined under a dissecting microscope as for intertidal sediment. Sample on CPR silk filter screens can be examined directly under the dissection microscope.

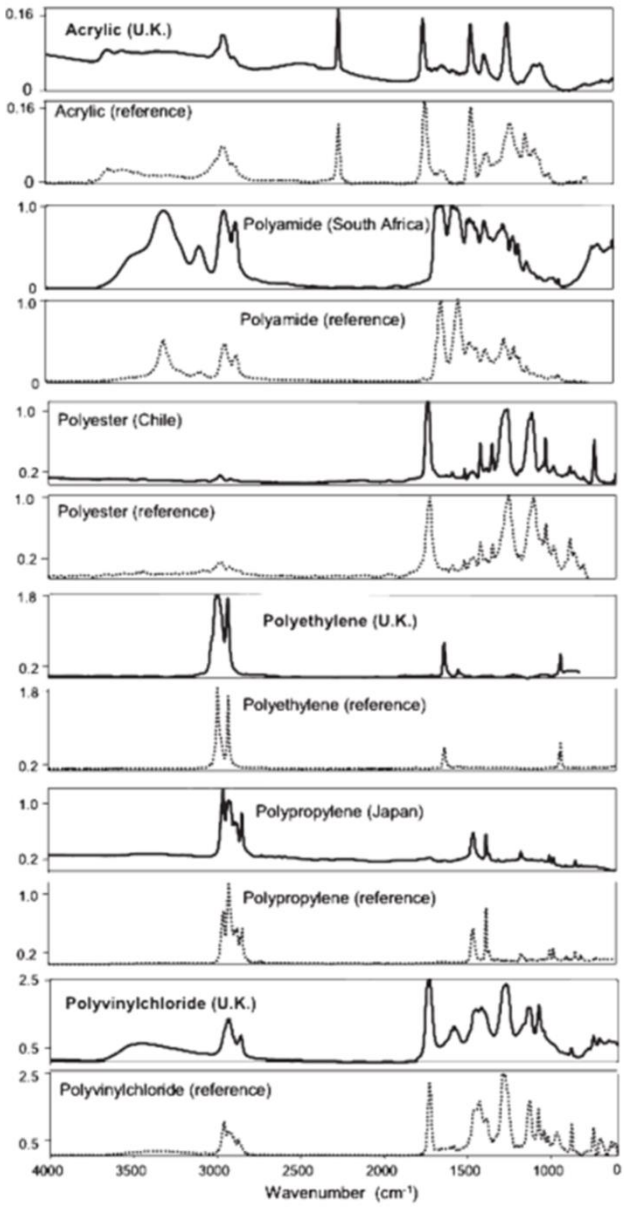
Size	Record size of each item. Minimum resolution is to allocate in to bin sizes of 100 µm
Type	Plastic fragments, pellets, filaments, plastic films, foamed plastic, granules, and styrofoam
Shape	For pellets: cylindrical, disks, flat, ovoid, spheruloids; For fragments: rounded, subrounded, subangular, angular; For general- irregular, elongated, degraded, rough, and broken edges
Colour	Transparent, crystalline, white, clear-white-cream, red, orange, blue, opaque, black, grey, brown, green, pink, tan, yellow

CATEGORIES FOR MICROPARTICLES	
Material	**Description**
Plastic	Plastic fragments rounded
	Plastic fragments subrounded
	Plastic fragments subangular
	Plastic fragments angular
	cylindrical pellets
	disks pellets
	flat pellets
	ovoid pellets
	spheruloids pellets
	filaments
	plastic films
	foamed plastic
	granules
	styrofoam
Other	Other (glass, metal, tar)

Table 9: Categories used to describe microplastics appearance

Polymer type	Density (g cm-3)	No. of studies
polyethylene	0.917–0.965	33
polypropylene	0.9–0.91	27
polystyrene	1.04–1.1	17
polyamide (nylon)	1.02–1.05	7
polyester	1.24–2.3	4
acrylic	1.09–1.20	4
polyoximethylene	1.41–1.61	4
polyvinyl alcohol	1.19–1.31	3
polyvinylchloride	1.16–1.58	2
poly methylacrylate	1.17–1.20	2
polyethylene terephthalate	1.37–1.45	1
alkyd	1.24–2.10	1
polyurethane	1.2	1

Table 10: Number of Studies That Identified Polymer Type among the Sorted Microplastic Debris and Specific Densities of Different Polymer Types (n = 42 studies). From Hidalgo-Ruz *et al.* (2012).



Formal identification of particles using FT-IR or Raman Spectroscopy – this apparatus is relatively expensive and requires a trained operator. It is less critical for routine monitoring of larger fragments >500 µm. However it should be considered essential for fragments <100 µm and a proportion (5 – 10%) of all samples should be routinely checked to confirm the relative accuracy of any visual examination. This is achieved by comparing the spectra from the unknown sample collected form the environment against that of a known standard polymer in a database (Figure 1). It should be noted that this method is only definitive where a good match is obtained and this is not always possible. A suitable approach (used by one of us - RCT) would be to automatically accept any match >70% similarity, to individually examine matches between 60-70% similarity rejecting any samples whish do not show clear evidence of peaks corresponding to known synthetic materials and to routinely reject (as being synthetic) any samples which produce spectra with a match < 60%).

Figure 1: - Examples of Fourier transform infrared spectra of microplastic and corresponding reference material from ATR spectral database, vertical axis represents transmission in standard optical density units. (Bruker Optics ATR-Polymer Library - a Collection of Synthetic Fibres, Copyright 2004 Bruker Optic GmbH). From Browne *et al.,* 2011.

7.4. Recommended methods for sampling microplastics

7.4.1. Guidelines for sampling intertidal beach sediments

<u>Goal:</u> to determine number of microplastics per cm³ of strandline

<u>How data users can use this data:</u> to compare the abundance between locations or times

Our recommendation is that microplastics should be monitored on the top of the shore (strand line) and where available on sandy shores (0.1 – 0.0125 mm sediment diameter). Samples should be collected from the surface 5cm of the sediment surface. This will maximise the potential for comparison between regions. Our recommendation is that five replicate samples be collected from the strandline at each site. Each replicate should be separated by at least 5m. Replicates can be distributed in a stratified random manner so as to be representative of an entire beach or a specific section of beach. This ultimately depends on the specific locations and questions of interest at a local scale. Sampling should be conducted separately for each of two size categories.

Microplastics 1 – 5mm - These should be collected as an additional entirely independent sample at each location sand should be obtained AFTER the sampling the smaller size fraction (<1 mm see below) in order to minimise the risk of contamination form persons undertaking the sampling itself. The sediment can be sampled by collecting with a metal spoon or trowel the top 5cm of sand from the area contained within a metal 50 cm x 50 cm quadrat and passing through a 1 mm metal sieve and then be stored in metal (*e.g.* foil) or glass containers (*i.e.* not plastic). Record the volume of sediment examined. Our recommendation ins that these be sampled using an extension of the protocol for meso debris (5-25mm) which uses a 5mm sieve to separate debris from sediment. This protocol can easily be extended by including a second metal sieve of 1mm mesh to achieve volume reduction of the sediment sample in the field. Preferably these sieves could be stacked together.

Microplastics 20 µm – 1mm - need to be collected as a bulk sample of sediment and subsequently extracted in the laboratory by density separation (see later). Sediment should be collected from the top 5 cm of sand using a metal spoon (suggest 15 ml) and then be stored in metal (*e.g.* foil) or glass containers (*i.e.* not plastic). Because the weight of sediment can vary considerably according to water content and type of sediment we suggest standardising sampling by volume. Approximately 250 ml of sediment should be collected of 50 ml will normally be sufficient for density separation. The weight used for the density separation should also be recorded so that the quantity of debris per gram can be determined approximately if required. The sample can be collected by kneeling on the strand line and collecting a series of scoops at arms-length at intervals within an arc shaped area to the front.

Precautions to minimise contamination (field) – Since the majority of microparticles is plastic care should be taken to avoid use of plastic. Metal scoops, trowels and quadrates should be used. These should be cleaned prior to sampling and wrapped in tinfoil or stout paper (not tissue as this may fray and introduce fibres). Samples should be collected and stored in stout paper bags / envelopes, metal or glass containers. People undertaking the sampling should minimise any synthetic clothing and avoid wearing garments that readily shed synthetic fibres (such as fleece). Position of the person sampling should be down-wind of the sampling area.

Meta data – To accompany each sample or set of replicates as appropriate It is worth noting any obvious local point sources of microparticles such as the proximity of relevant manufacturing industry or bulk handling facilities (*e.g.* for plastic pellets or powders) or local sources of small items of debris (*e.g.* sewage outfalls). Date of sampling, co-ordinates of location, sediment particle size. Also record relevant information form AQ/QC procedures such as the quantity of contamination recorded in blanks.

Required reporting units – items / ml of sediment, size of microparticles, in addition because our understanding of the sources, pathways and sinks for microplastics are currently limited, and because the main costs are in collection and processing it is considered very worthwhile to record additional observations including: relative abundance of main colours and shapes. If FT-IR or Raman is used then polymer type should also be recorded (Tables 9 and 10). Microplastics should be categorised according to size with a minimum level of resolution being to allocate the material found in to size bins of 100 µm (20-100 µm, 101-200 µm, 201- 300µm, etc.).

7.4.2. Recommendations for sampling surface waters

<u>Goal</u>: to determine number of microplastics per m^3 of seawater?

<u>How data users can use this data</u>: to compare the abundance between locations or times

Deploy the net from the vessel out of the wake zone. The turbulence inside the wake zone does not allow for a representative surface sample to be collected. Use a spinnaker boom or A frame to deploy the trawl away from the side of the vessel. Keep close eyes on the net while trawling to observe its performance and adjust speed and cable lengths if necessary. Avoid periods of plankton blooms as this may clog the net and complicate further analysis.

Maintain a steady linear course at a constant speed. The hi-speed trawl can be deployed up to 8 knots, build up the speed slowly towards maximum speed. Higher speeds reduce the ability to sieve seawater, creating a bow wake in front of the trawl. The net can jerk forcefully as it surfs and ploughs through the waves, so watch the net while you trawl to observe its performance and adjust speed accordingly. Begin with a half hour trawl. Use your judgment on duration based on your field observations and allowed trawling time *e.g.*: deploy the trawl when leaving a station and trawl up to the next station. Recover and secure trawl on the deck. Record STOP immediately and note down the values on the flow meter.

In order to process the sample for storage - rinse the net from the outside with a hose or bucket to concentrate the sample in the cod end. Never rinse the sample through the opening of the net.

a) You will need a large bowl, squirt bottles, sample container, spoon, tweezers, and a preservative (isopropyl alcohol or formalin).
b) Remove the cod end over a bucket, as a precaution to catch any spillage
c) Transfer sample into a large bowl.
d) Invert the cod end and wash it out from the outside using very little water, scrape left over sample into the large bowl using the spoon. Rinse the spoon into the bowl.
e) Pour entire sample into the sample container and add preservative. A sample may consist out of several containers.

Label the lid and outside of the sample container with the trawl number, date and time. Use waterproof marker for labels. Include a waterproof label in the sample. This label contains the same information as the external labels.

Sample Preparation:

a) Drain sample through 5 mm sieve into one large bowl.
b) Use fresh water wash bottle to rinse off plastic particles adhering to the inside of the sample jar.
c) Rinse sample inside sieve in order to separate plastics thoroughly.
d) Transfer each size class to a different large Petri dish.
e) Rinse equipment gently with the wash bottle so that no plastic particles are left behind.
f) If the process above does not result in adequate liquid in the Petri dishes for sorting, then add sufficient water to float all plastic bits – do not overfill

NOTE: If the sample is too large to perform the procedure above for the entire sample, then split carefully, sort separately, and combine the data later.

Separating sample into size classes >5mm and <5mm:

a) Place each Petri dish under a microscope.
b) Using forceps, remove all recognizable pieces of floating plastic.
c) Rinse off plastic bits with fresh water wash bottle to make sure smaller particles or plankton are not sticking to them.
d) Place rinsed bits of plastic in a separate labelled empty vial and set aside for later drying, typing, counting and weighing.

For size class <5mm, use a spoon to remove all remaining plastic. There may be more there, so start looking at centre of Petri dish and move out to the sides. Use a dissecting microscope to conduct a more thorough check of the sample. Once the plastic, plankton and organic debris are separated, the plastic is size classed and dried. The wet weight of the plankton and organic debris are measured and then dried.

Drying of separated plastic:

a) Set your drying oven at 20°C.
b) Sieve sample and spread onto Petri dishes or leave in sieves.
c) Place sample in oven or a secure dry location.
d) Dry samples at 20° for about 30 minutes. If the samples are still wet after 30 minutes, leave them in the oven and check regularly. If they are left in a dry location, then check every few hours.

When the sample comes out of the oven it is placed in a dissector to cool, then weighed.

Sorting plastic to determine type, count and weight:

a) With each size class dried in its own Petri dish or sieve, use forceps to sort sample into different types of plastic as categorized on the data sheet (see below).
b) Count number of plastics for each type for each size category.

c) Tare the scale with Petri dish and weigh sample on a gram scale.
d) Record weight and count on the data sheet
e) Transfer sorted and weighed plastic to labelled vials.

The plastic is removed from the sieves and each of the six size classes is sorted into shape type (fragment, pellet, line, film, and foam). The colour of each piece of plastic is also recorded (by size class) on a separate sheet. During this process each container is labelled and all data sheets are updated.

Precautions to minimise contamination (field) - Since the majority of microparticles is plastic care should be taken to avoid use of plastic during the protocol. Metal equipment should be used and should be cleaned prior to sampling and wrapped. Samples should be collected and stored in metal or glass containers. People undertaking the sampling should minimise any synthetic clothing and avoid wearing garments that are likely to shed synthetic fibres (such as fleece). Position for those undertaking sampling down-wind of the sampling apparatus during deployment and recovery. Prior to use equipment can be swabbed with damp filter papers which are sealed in petri dishes and checked for contamination.

Meta data –record: date, mesh size, aperture size, type of net, depth (preferably either at the sea surface or within surface 10m for greatest inter-comparability among sampling programmes) distance towed, location of tow (in / out of water) volume of water filtered (this is best obtained from a current meter as this will allow for tidal movement as well as ship speed). Also prevailing weather conditions and sea state, together with any relevant information on the volume of plankton or other particulates sampled, for example if there is concern that the net may have become clogged due to high concentration of plankton, this must be recorded.

Required reporting units – items/ m^3 of water, size, colour and shape, etc. If FT-IR or Raman is used then polymer type should also be recorded (see descriptions in Tables 9 and 10). Microplastics should be categorised according to size with a minimum level of resolution being to allocate the material found in to size bins of 100 µm (20-100 µm, 101-200 µm, 201- 300µm etc.). See Figure 2 for example of recording sheet.

SAMPLE SORTING DATA SHEET

SURVEY NAME: ________________ LOCATION:________________ DATES: ____________

CONTACT INFORMATION: Name ______________ Phone ______________ Email________________

			Fragment		Pellet		Line		Thin Film		Foam		Other (glass, metal, tar)		Total count	Total Weight
Sample #	Latitude and Longitude	Size Class	count	weight	count	weight	count	weight	count	weight	count	weight	count	weight		
	Lat.	<5mm														
	Long.	>5mm														
	Lat.	<5mm														
	Long.	>5mm														
	Lat.	<5mm														
	Long.	>5mm														
	Lat.	<5mm														
	Long.	>5mm														

This Standard Operating Procedure (SOP) is based on existing protocols from the Algalita Marine Research Foundation (AMRF).

Figure 2: Example of standard recording sheet

7.5. Recommendations for sampling Subtidal Sediments

<u>Goal</u>: to determine number of microplastics per cm^3 of sediment from the seabed

<u>How data users can use this data:</u> to compare the abundance between locations or times

Material can be collected using any approach that recovers a sample of relatively undisturbed surface sediment from the sea bed (*e.g.* van veen grab, multi corer, box core etc.). Once recovered onto the vessel a small sample of sediment ideally around 250ml is recovered to best represent the location of the original 5cm surface to sub surface of the seabed. Because the weight of sediment can vary considerably to water content we suggest standardising sampling by volume. Avoid sampling next to the edge of the apparatus to minimise risk of contamination form the equipment (*e.g.* pain flakes other contamination on the grab / core). The sample is transferred to a metal or glass container for subsequent density separation / spectroscopy.

Meta data – Date, location, depth, sea state, type of equipment used, volume of sample collected, any relevant information *e.g.* complete quantitative sample, or some material lost during recovery etc. nature of sea bed sediment including particle size, organic matter, any available data on biota present.

Precautions to minimise contamination (field) - Since the majority of microlitter is plastic care should be taken to avoid use of plastic during the protocol. Metal equipment should be used and should be cleaned prior to sampling and wrapped. Samples should be collected and stored in metal or glass containers. People undertaking the sampling should minimise any synthetic clothing and avoid wearing garments that are likely to shed synthetic fibres (such as fleece). Position for those undertaking sampling down-wind of the sampling apparatus during deployment and recovery. Prior to use equipment can be swabbed with damp filter papers which are sealed in petri dishes and checked for contamination.

Required reporting units – items / ml sediment, size, colour and shape etc. If FT-IR or Raman is used then polymer type should also be recorded (see descriptions in Tables 9 and 10).

7.6. Suggestions for sampling microplastics in biota

<u>Goal</u>: to determine number of microplastics per individual or part thereof (e.g. gut)

<u>How data users can use this data</u>: to compare abundance in individuals between locations or times

Sampling – At present it is not possible to recommend particular species or times of year that would be most appropriate to specifically monitor microplastics. For efficiency we suggest routine examination for microplastics in any organisms that are already being considered for macrolitter (*e.g.* Fulmars in northern Europe, see Biota Section 6). If individuals are live immediately prior to sampling then they must be humanely killed adhering to any prevailing ethical legislation. In many cases it may be possible to examine organisms that are dead at the time of collection for example fish or invertebrates from trawls or other sampling programmes, seabirds or turtles that have been washed ashore dead. Small individuals can be stored whole. For larger individuals the digestive tract can be dissected but otherwise left intact and stored intact.

Examination of the gut is facilitated with a dissecting microscope. The gut is slit open using scissors and examined immediately. Depending on the size of the organism the digestive tract can be examined in its entirety or samples of gut wall (*e.g.* 10cm x 10cm (or similar standard area) can be removed and viewed under a dissecting microscope. Any fragments of an unusual appearance are removed with forceps and placed on clean filter papers in petri dishes which are then sealed prior to further examination for example via spectroscopy

Meta data – Please record: species and standard dimensions of length and weight (*e.g.* carapace length for crustaceans) together with gender, physical condition, alive, injured or dead at time of collection, reproductive state, quantity of food present in digestive tract, presence of parasites etc. Location collected, circumstances of capture, part of routine monitoring, from fisheries landings, individual brought to recovery facility (*e.g.* birds, seals).

Precautions to minimise contamination (field)- If organisms are collected alive in nets the possibility of plastic ingestion in the sampling net must be eliminated. Hence collecting fish from plankton nets where microplastic has been shown to accumulate is not a reliable approach. Where fish are caught in standard mesh nets the issue of contamination from the net is considerably reduced. However a confirmatory step should be included using FT-IR to confirm that fragments form the organisms do not match those of the polymer used in the nets.

Required reporting units – Items / g of intestine, size, colour and shape etc. If FT-IR or Raman is used then polymer type should also be recorded (see descriptions in Tables 9 and 10). Species of organisms and standard dimensions *e.g.* carapace length for crustaceans should be recorded and weight. Microplastics should be categorised according to size with a minimum level of resolution being to allocate the material found in to size bins of 100 µm (20-100 µm, 101-200 µm, 201- 300µm etc).

7.7. Recommendations for laboratory separation of microplastics from bulk samples

Laboratory separation from intertidal sediment **-** we recommend using a concentrated saline NaCl solution (1.2 g cm^{-3}) to achieve bulk separation according to density. This is inexpensive, readily available, non-toxic has been most widely used to date and will achieve good separation for most polymers. After preparation, the solution should be passed through al glass ware and filtered as below until no microparticle residues are apparent when filters are examined under a low power binocular microscope (x 50). A known volume (normally 50 ml) of sediment is added to a separating funnel using a metal spoon and 200 ml of saturated NaCl added. A stopper is added and the mixture agitated by hand for 2 minutes, then allowed to settle for 2 minutes. The supernatant is then transferred to suction filtration via a Buckner funnel and passed through a 10µm retention filter paper. Filter papers are removed and stored in sealed petri dishes prior to examination under a microscope. The NaCl separation procedure is repeated three times with each sediment sample to ensure a high recovery (RCT unpublished data) of buoyant debris. Data from the three filter papers are added together.

Laboratory separation from subtidal sediment – This is conducted according to the protocol for intertidal sediment and using the same precautions to minimise / quantify procedural contamination*.* However subtidal sediments are typically finer than those from sandy beaches and so may be likely to clog filter papers and produce a relatively thick layer of fine natural particulates. This problem can be reduced by repeatedly filtering smaller volumes of sediment on and then pooling data form each separation.

Formal identification of particles using FT-IR or Raman Spectroscopy - This is not critical for identification of larger fragments >500 µm. However it should be considered essential for fragments < 100 µm and a proportion (10%) of all samples should be routinely checked to confirm the relative accuracy of any visual examination. This is achieved by comparing the spectra from the unknown sample collected form the environment against that of a known standard polymer in a database. It should be noted that this method is only definitive where a good match is obtained and this is not always possible. A suitable approach would be to automatically accept any match >70% similarity, to individually examine matches between 60-70% similarity rejecting any samples whish do not show clear evidence of peaks corresponding to known synthetic materials and to routinely reject (as being synthetic) any samples which produce spectra with a match < 60%). Microplastics should be categorised according to size with a minimum level of resolution being to allocate the material found in to size bins of 100 µm (20-100 µm, 101-200 µm, 201-300µm etc.).

Precautions to minimise contamination (laboratory) - Extreme care must be taken to ensure the processing area is meticulously clean and in particular free from dust or particles. Cotton laboratory coat should be worn, minimise any synthetic clothing (*e.g.* synthetic fleece), do not process samples near to carpeted areas, minimise air circulation in the processing area (windows, doors, etc. that may carry air-borne particulates). Ensure samples are exposed to the air for the absolute minimum period required to transfer them between containers. At all other times containers remain covered. Ensure all containers and sampling equipment is scrupulously clean prior to use. Controls of clean NaCl should be run through apparatus and collected over filter papers as described above as a procedural control (blank) to check for contamination. Repeat cleaning until contamination in blanks is zero or negligible. As procedural controls to check ambient cleanliness place unused clean filter papers in petri dishes. Remove the lid and wrap it in clean foil, leave the petri-dish open for a fixed time period relevant to the time period for which samples might be exposed to the air during examination. Seal the petri-dish with the lid and count any fragments which have settled on the filter paper. Procedural contamination should < 10% of the average values determined form the samples themselves.

When examining biota in the laboratory it is important to record the time between the digestive tract first being cut open and the end of the examination. This can then be compared to levels of contamination collected on clean filter papers left exposed to the air for similar periods adjacent to the working area. Hence it is beneficial to work carefully and quickly once the digestive tract is opened. For larger specimens and in particular where there is a substantial quantity of food in the gut it may be necessary to wash the contents from the digestive tract using clean saline and collect in a petri dish and sealed from the air. Any fragments of unusual appearance should be removed and archived in sealed petri dishes prior to formal identification with FT-IR.

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8. Litter Categories

8.1. Introduction to Litter Categories

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.

The use of standard lists and definitions of items will enable the comparison of results between regions and environmental compartments. If the list is detailed enough it will be possible, to a certain degree, to infer about potential or/and most likely sources (*e.g.* fisheries, shipping), type of item (*e.g.* packaging, user item) or even related potential harm that items can cause (*e.g.* risk of entanglement, ingestion, etc.).

This is a crucial step in helping to identify key priorities to tackle, design a programme of measures and support the monitoring of their effectiveness.

8.2. Scope and key questions to be addressed

This chapter compares litter items used in a number of on-going European monitoring programmes - those included in general lists of items compiled by various organisations such as UNEP and the Ocean Conservancy and lists produced as part of other sections in this report.

A Master List of all litter items for use in litter monitoring programmes in the European marine environment is being produced on the basis of this comparison (see the draft version in Annex 8). The structure and on-going process of elaboration of such list is described in this chapter.

This Master List is also being prepared for use in the development of the new mobile-phone application *Marine LitterWatch*, developed by the EEA.

8.3. Comparison of lists

The Master List was developed based on the categories of items used in a series of other programmes:

- For beach litter: UNEP, OSPAR, MCS, Slovenia, ICC.
- For floating litter: HELMEPA, NOAA, ECOOCEAN and Hinojosa/Thiel (2009).
- For seabed litter: OSPAR/ICES list (IBTS) and HELMEPA.
- For micro-litter: CEFAS.

For ingested litter: Monitoring programme of Fulmars (ingestion), used in the North Sea.

The OSPAR beach litter list was used as the basis for the Master List as it is one of the most detailed and represents the most mature protocols in the EU, which has been proved and tested over a ten year period.

The other lists were compared with the OSPAR list and similarities and differences were noted. Generally in order to produce the Master List items have been added to the OSPAR list and the list has been rearranged.

The list was also modified on the basis of proposals made by the “4 Seas” pilot project (ARCADIS, 2012). In this process some OSPAR categories were sub-divided in more detailed sub-categories, *e.g.* the OSPAR item “cosmetic bottles and containers” was divided into two master-list items - those items that are beach related (*e.g.* sun-block bottles) and those that are related to hygiene and not normally used on beaches (*e.g.* aftershave containers). This was done where individual OSPAR items could have very different sources, *i.e.* coastal recreation or shipping/fishing, respectively.

8.4. Proposed Master List

The Master List (Annex 8.1) includes a detailed list of items with a series of parameters:

- "General Code" is a unique alphanumeric code attributed by the TSG-ML ,
- "General Name" is a short description of the item,
- "Materials" is (main) material the items are made of. Each material has more items, but each item is associated with only one material,

Further levels of information can be added, which could improve the value of the data especially with regard to the identification of sources or the assessment of harm for example:

- "Source" if identifiable.
- "Pathway - General use of the item" provides information on the activities in which items are most probably used and possible pathways of entry into the marine environment.,
- "Source groupings" - sensible groupings of items, which will give the sum of items from a given source etc. (*e.g.* smoking related).
- "Potential threat" of the item to the marine environment *e.g.* entanglement, ingestion, smothering of marine habitat.

The addition of further levels will require some careful deliberation and the allocation of the litter items to different categories within these levels will differ from region to region.

The Master List includes also corresponding codes of OSPAR and UNEP, when applicable. This should allow comparisons with data from these programmes. Regarding materials in the Master list there have been made some changes, when compared with the OSPAR list. A key change, when compared with the OSPAR list, is that the category "sanitary" or "sewage-related" items have been allocated to different material classes.

The Master List includes recommendations for item lists which can be used in the different compartments of the marine environment, as defined by the COM DEC 2010/477/EU.

A photographic guide based on the guidelines published by OSPAR for the OSPAR beach litter monitoring programme should be developed and the lists should be translated into all the main European languages to aid identification of the litter items in the field.

8.5. Procedure for addition of new items

Most of the main types and forms of marine litter, which are to be found in the marine environment in the EU region, are included in the Master List. In the event of a new item becoming common enough for it to be considered being added to the list we suggest the following procedure:

a) An item not yet included in the list is regularly seen and described in protocols as one of the 'other' categories for a given material class.
b) A proposal for this item to become a listed item together with a photo to be added to the photo guide should be sent to the organisation or steering group responsible for the maintenance of the Master List within the MSFD implementation process.
c) The item is given a unique identifier and all monitoring groups and Member States are informed.

8.6. The assessment of sources and pathways

As mentioned above, the identification of the source (usually a sector/actor, *e.g.* fishing industry, improper disposal in the toilet) and the pathway that led the item to enter the marine environment (*e.g.* direct release in the sea/coast, riverine transport, sewage) is a crucial step in determining the appropriate and pragmatic actions and measures to address the issue in a given area or region.

For some items a source can be identified easily *e.g.* fishing gear originates from commercial or recreational fishing, while items such as cotton bud sticks, tampons and wet wipes are mainly entering the marine environment through sewerage systems. However, for other (often the majority) items it is much more difficult to assign a source with a robust level of accuracy, *e.g.* a plastic bottle may enter the marine environment directly from a beach user or from the crew of a ship or indirectly via riverine input. It is therefore expected that for a relatively large number of items the source will not be identified with certainty. In addition, the identification of litter sources is influenced by several methodological and environmental factors and even within a given source the pathway of input into the marine environment can be vary considerably. For example, the source for both nets and small pieces of net is fishing, however, whereas nets can be lost during fishing activities small pieces of net are often the result of net repair activities, which are often carried out in ports and harbours on land. Measures to directly combat the two pathways of input will differ considerably.

Nevertheless, a number of techniques have been developed to assist in the identification of sources on the basis of litter items recorded in the marine environment *e.g.* the Matrix Scoring Technique to Determine Litter Sources at a Bristol Channel Beach (Tudor & Williams 2004), The use of multivariate statistical techniques to establish debris pollution sources (Tudor *et al.* 2002) and Beach litter sourcing in the Bristol Channel and Wales (Williams *et al.* 2003).

ARCADIS *et al.* (2012) further developed the Matrix Score Technique (Tudor & Williams, 2004) for use with the OSPAR Beach Litter data. This method allocates the level of likelihood each litter item has of originating from all potential sources. This requires a very good knowledge of the activities in the area and potential deficiencies in the system that can generate marine litter. Therefore, in this project, the allocation of sources and pathways to occurring items in 4 sites in Europe have been done through a bottom-up approach, consulting and finding consensus with local key stakeholders. The likelihoods are then given a score and the relative contribution of the different sources is calculated. This method allows for the possibility of specific item types originating from more than one source; this flexibility and transparency means that it is less prescriptive than some other methods.

Furthermore, along the allocation of sources and pathways, this Pilot Project developed a series of parameters that can be directly linked to each item and which provides an insight into the nature, use and potential harm (*e.g.* if the item is for single-use/multi-dose use or long-lasting us; if it is packaging or a primary use item; if item is packaging, what type of packaging). This can further support the elaboration of strategies to target better production, use, disposal and possible alternatives of items that are commonly found as marine litter.

These strategic parameters and the procedure to allocate likelihoods of sources to the different items will be further elaborated throughout the next period of work of the TSG-ML and will be made available in the next report.

8.7. Indicator items

It can be useful to identify indicator items which represent a specific source and/or a given pathway of input of litter into the marine environment. The OSPAR beach litter monitoring programme has identified a number of indicator items for different sources. The identification of indicator items is easier for some sources *e.g.* fishing but can be quite difficult for others *e.g.* tourism, because in some cases the same items can come from beach users, ships crews or from inland sources. This is therefore a broad category that includes items that can originate from multiple sources. However, this can be of use to have a rough idea of the key sources in the area, until a more detailed methodology is made available.

Some care needs to be taken to ensure that a decrease in the occurrence of the indicator item is a result of the measure implemented to combat it rather than the result of a general reduction in the use of the item or because the item has been replaced with a similar item which is not being monitored *e.g.* glass bottles being replaced by plastic bottles.

8.8. How to use the list

The final Master List consists of a set of over 200 items. It will not always be practical to use such a long list of items, many of which may not occur regularly in a particular region. However, a considerable number of items will be common to all regions.

To best create a usable list relevant for the region:

1. Create a basic list using those core items for the particular compartment to be surveyed *e.g.* beach, floating, biota.
2. Use those items relevant for the region to create a full list.
3. If new items are found, use the relevant category from the master list.
4. If an item is not found in the master list, use the procedure below to add new items.

It is important, however, that not just the abundances of only a selection of items are registered. It is vital to assess all items occurring in the given monitoring unit if the total amount of litter present is to be assessed and if the methodology in place allows for such level of detail. Non-identified items should be recorded in the categories for "other items" under their respective material class and specified/described as much as possible.

The size of litter items is currently not recorded. The Master list includes some information on size scales of items but the overall limitations for size according to compartment should be taken into account. For this please consult appropriate chapter (beach litter – Chapter 3, etc.).

With the question of interpreting small pieces of litter and/or entangled litter we follow OSPAR guidelines. Here are some detailed guidelines for individual items:

- All pieces of litter that are recognisable as an item should be counted as one item.
- Pieces of plastic which are not recognisable as an item should be counted as a "plastic piece 2.5-50 cm" which is item "G77" in the current Master List.
- Pieces of plastic that are recognisable as a (shopping) bag (G3 - Shopping Bags incl. pieces) should be registered as such.
- Pieces of plastic that are recognisable as a small plastic bag (G4 - Small plastic bags, *e.g.* freezer bags incl. pieces) should be registered as such.
- All pieces that are recognisably part of a balloon (including the plastic valves, the plastic ribbons or string tied to the balloon) should be registered as "Balloons incl. plastic valves, ribbons, strings, etc." (G121).
- Pieces of glass that are recognisable as for example bottles (G197 – "Bottles incl. parts") should be registered as such.
- Pieces of glass that are not recognisable as an item are counted as G205 "Glass or ceramic fragments (>2.5 cm)".
- All pieces of string and cord (G51 – "String and cord (diameter less than 1cm)") should be counted as single items.

8.9. Key messages to MSFD implementation process

For monitoring the effectiveness of marine litter measures on both a local and regional scale we need to be able to compare among similar variables. Therefore a standard list of items which are recorded in the marine environment should be used throughout the entire EU area and within all compartments of the marine environment (beach, sea-floor, floating). The Master List includes a list of core items – which occur in all regions (*e.g.* cigarette ends, plastic bottles) and regionally specific items (*e.g.* octopus pots), which only occur in some sub-regions. The list also notes, where possible, the source and use of an item. This will further aid in devising appropriate measures to combat litter pollution of the marine environment.

8.10. References

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Annex 8.1 - Master List of Categories of Litter Items

Master List of Categories of Litter Items

TSG_ML General- Code	OSPAR- Code	UNEP- Code	General Name	Level 1 - Materials	Core	Beach	Seafloor	Floating	Biota	Micro
G1	1	PL05	4/6-pack yokes, six-pack rings	Artificial polymer materials	x	x				
G2		PL07	Bags	Artificial polymer materials	x		x	x		
G3	2	PL07	Shopping Bags incl. pieces	Artificial polymer materials		x				
G4	3	PL07	Small plastic bags, *e.g.* freezer bags incl. pieces	Artificial polymer materials		x				
G5	112		Plastic bag collective role; what remains from rip-off plastic bags	Artificial polymer materials		x				
G6	4	PL02	Bottles	Artificial polymer materials	x		x	x		
G7	4	PL02	Drink bottles <=0.5l	Artificial polymer materials		x				
G8	4	PL02	Drink bottles >0.5l	Artificial polymer materials		x				
G9	5	PL02	Cleaner bottles & containers	Artificial polymer materials	x	x				
G10	6	PL06	Food containers incl. fast food containers	Artificial polymer materials	x	x	x			
G11	7	PL02	Beach use related cosmetic bottles and containers, *e.g.* Sunblocks	Artificial polymer materials		x				
G12	7	PL02	Other cosmetics bottles & containers	Artificial polymer materials	x	x				
G13	12	PL02	Other bottles & containers (drums)	Artificial polymer materials	x	x				
G14	8		Engine oil bottles & containers <50 cm	Artificial polymer materials		x				
G15	9	PL03	Engine oil bottles & containers >50 cm	Artificial polymer materials		x				
G16	10	PL03	Jerry cans (square plastic containers with handle)	Artificial polymer materials		x				
G17	11		Injection gun containers	Artificial polymer materials		x				
G18	13	PL13	Crates and containers / baskets	Artificial polymer materials		x	x	x		
G19	14		Car parts	Artificial polymer materials		x				
G20		PL01	Plastic caps and lids	Artificial polymer materials			x			
G21	15	PL01	Plastic caps/lids drinks	Artificial polymer materials		x				
G22	15	PL01	Plastic caps/lids chemicals, detergents (non-food)	Artificial polymer materials	x	x				
G23	15	PL01	Plastic caps/lids unidentified	Artificial polymer materials		x				
G24	15	PL01	Plastic rings from bottle caps/lids	Artificial polymer materials		x				
G25			Tobacco pouches / plastic cigarette box packaging	Artificial polymer materials		x				
G26	16	PL10	Cigarette lighters	Artificial polymer materials	x	x				
G27	64	PL11	Cigarette butts and filters	Artificial polymer materials		x	x			
G28	17		Pens and pen lids	Artificial polymer materials		x				
G29	18		Combs/hair brushes/sunglasses	Artificial polymer materials		x				
G30	19		Crisps packets/sweets wrappers	Artificial polymer materials		x				

Master List of Categories of Litter Items

TSG_ML General- Code	OSPAR- Code	UNEP- Code	General Name	Level 1 - Materials	Core	Beach	Seafloor	Floating	Biota	Micro
G31	19		Lolly sticks	Artificial polymer materials		x				
G32	20	PL08	Toys and party poppers	Artificial polymer materials	x	x				
G33	21	PL06	Cups and cup lids	Artificial polymer materials	x	x				
G34	22	PL04	Cutlery and trays	Artificial polymer materials		x				
G35	22	PL04	Straws and stirrers	Artificial polymer materials		x				
G36	23		Fertiliser/animal feed bags	Artificial polymer materials		x				
G37	24	PL15	Mesh vegetable bags	Artificial polymer materials		x				
G38			Cover / packaging	Artificial polymer materials				x		
G39		PL09	Gloves	Artificial polymer materials			x	x		
G40	25	PL09	Gloves (washing up)	Artificial polymer materials	x	x				
G41	113	RB03	Gloves (industrial/professional rubber gloves)	Artificial polymer materials	x	x				
G42	26	PL17	Crab/lobster pots and tops	Artificial polymer materials		x				
G43	114		Tags (fishing and industry)	Artificial polymer materials		x				
G44	27	PL17	Octopus pots	Artificial polymer materials		x				
G45	28	PL15	Mussels nets, Oyster nets	Artificial polymer materials		x				
G46	29		Oyster trays (round from oyster cultures)	Artificial polymer materials		x				
G47	30		Plastic sheeting from mussel culture (Tahitians)	Artificial polymer materials		x				
G48			Synthetic rope	Artificial polymer materials			x	x		
G49	31	PL19	Rope (diameter more than 1cm)	Artificial polymer materials	x	x				
G50	32	PL19	String and cord (diameter less than 1cm)	Artificial polymer materials	x	x				
G51		PL20	Fishing net	Artificial polymer materials			x	x		
G52		PL20	Nets and pieces of net	Artificial polymer materials	x	x				
G53	115	PL20	Nets and pieces of net < 50 cm	Artificial polymer materials		x				
G54	116	PL20	Nets and pieces of net > 50 cm	Artificial polymer materials		x				
G55		PL18	Fishing line (entangled)	Artificial polymer materials			x			
G56	33	PL20	Tangled nets/cord	Artificial polymer materials		x				
G57	34	PL17	Fish boxes - plastic	Artificial polymer materials		x		x		
G58	34	PL17	Fish boxes - expanded polystyrene	Artificial polymer materials		x		x		
G59	35	PL18	Fishing line/monofilament (angling)	Artificial polymer materials	x	x	x			
G60	36	PL17	Light sticks (tubes with fluid) incl. packaging	Artificial polymer materials		x				
G61			Other fishing related	Artificial polymer materials			x			
G62	37	PL14	Floats for fishing nets	Artificial polymer materials	x	x				
G63	37	PL14	Buoys	Artificial polymer materials		x		x		

Master List of Categories of Litter Items

TSG_ML General- Code	OSPAR- Code	UNEP- Code	General Name	Level 1 - Materials	Core	Beach	Seafloor	Floating	Biota	Micro
G64			Fenders	Artificial polymer materials		x				
G65	38	PL03	Buckets	Artificial polymer materials		x				
G66	39	PL21	Strapping bands	Artificial polymer materials	x	x	x			
G67	40	PL16	Sheets, industrial packaging, plastic sheeting	Artificial polymer materials		x	x	x		
G68	41	PL22	Fibre glass/fragments	Artificial polymer materials		x				
G69	42		Hard hats/Helmets	Artificial polymer materials		x				
G70	43		Shotgun cartridges	Artificial polymer materials		x				
G71	44	CL01	Shoes/sandals	Artificial polymer materials		x				
G72			Traffic cones	Artificial polymer materials		x				
G73	45	FP01	Foam sponge	Artificial polymer materials		x				
G74			Foam packaging/insulation/polyurethane	Artificial polymer materials				x		
G75	117		Plastic/polystyrene pieces 0 - 2.5 cm	Artificial polymer materials		x				
G76	46		Plastic/polystyrene pieces 2.5 cm > < 50cm	Artificial polymer materials		x				
G77	47		Plastic/polystyrene pieces > 50 cm	Artificial polymer materials		x				
G78			Plastic pieces 0 - 2.5 cm	Artificial polymer materials		x				
G79			Plastic pieces 2.5 cm > < 50cm	Artificial polymer materials		x		x		
G80			Plastic pieces > 50 cm	Artificial polymer materials		x		x		
G81			Polystyrene pieces 0 - 2.5 cm	Artificial polymer materials		x				
G82			Polystyrene pieces 2.5 cm > < 50cm	Artificial polymer materials		x		x		
G83			Polystyrene pieces > 50 cm	Artificial polymer materials		x		x		
G84			CD, CD-box	Artificial polymer materials		x				
G85			Salt packaging	Artificial polymer materials		x				
G86			Fin trees (from fins for scuba diving)	Artificial polymer materials		x				
G87			Masking tape	Artificial polymer materials		x				
G88			Telephone (incl. parts)	Artificial polymer materials		x				
G89			Plastic construction waste	Artificial polymer materials		x				
G90			Plastic flower pots	Artificial polymer materials		x				
G91			Biomass holder from sewage treatment plants	Artificial polymer materials		x				
G92			Bait containers/packaging	Artificial polymer materials		x				
G93			Cable ties	Artificial polymer materials		x	x			
G94			Table cloth	Artificial polymer materials				x		
G95	98	OT02	Cotton bud sticks	Artificial polymer materials	x	x	x			
G96	99	OT02	Sanitary towels/panty liners/backing strips	Artificial polymer materials		x	x			

Master List of Categories of Litter Items

TSG_ML General- Code	OSPAR- Code	UNEP- Code	General Name	Level 1 - Materials	Core	Beach	Seafloor	Floating	Biota	Micro
G97	101	OT02	Toilet fresheners	Artificial polymer materials		x				
G98		OT02	Diapers/nappies	Artificial polymer materials		x	x			
G99	104	PL12	Syringes/needles	Artificial polymer materials		x	x			
G100	103		Medical/Pharmaceuticals containers/tubes	Artificial polymer materials		x				
G101	121		Dog faeces bag	Artificial polymer materials	x	x				
G102		RB02	Flip-flops	Artificial polymer materials		x				
G103			Plastic fragments rounded <5mm	Artificial polymer materials						x
G104			Plastic fragments subrounded <5mm	Artificial polymer materials						x
G105			Plastic fragments subangular <5mm	Artificial polymer materials						x
G106			Plastic fragments angular <5mm	Artificial polymer materials						x
G107			cylindrical pellets <5mm	Artificial polymer materials						x
G108			disks pellets <5mm	Artificial polymer materials						x
G109			flat pellets <5mm	Artificial polymer materials						x
G110			ovoid pellets <5mm	Artificial polymer materials						x
G111			spheruloids pellets <5mm	Artificial polymer materials						x
G112		PL23	Industrial pellets	Artificial polymer materials	x				x	
G113			Filament <5mm	Artificial polymer materials						x
G114			Films <5mm	Artificial polymer materials						x
G115			Foamed plastic <5mm	Artificial polymer materials						x
G116			Granules <5mm	Artificial polymer materials						x
G117			Styrofoam <5mm	Artificial polymer materials						x
G118			Small industrial spheres (<5mm)	Artificial polymer materials					x	
G119			Sheet like user plastic (>1mm)	Artificial polymer materials					x	
G120			Threadlike user plastic (>1mm)	Artificial polymer materials					x	
G121			Foamed user plastic (>1mm)	Artificial polymer materials					x	
G122			Plastic fragments (>1mm)	Artificial polymer materials					x	
G123			Polyurethane granules <5mm	Artificial polymer materials				x		
G124	48	PL24	Other plastic/polystyrene items (identifiable)	Artificial polymer materials		x	x	x		
G125	49	RB01	Balloons and balloon sticks	Rubber	x	x	x	x		
G126		RB01	Balls	Rubber		x		x		
G127	50		Rubber boots	Rubber		x	x	x		
G128	52	RB04	Tyres and belts	Rubber	x	x	x	x		
G129		RB05	Inner-tubes and rubber sheet	Rubber		x				
G130			Wheels	Rubber	x	x				
G131		RB06	Rubber bands (small, for	Rubber		x				

Master List of Categories of Litter Items

TSG_ML General- Code	OSPAR- Code	UNEP- Code	General Name	Level 1 - Materials	Core	Beach	Seafloor	Floating	Biota	Micro
			kitchen/household/post use)							
G132			Bobbins (fishing)	Rubber		x	x			
G133	97	RB07	Condoms (incl. packaging)	Rubber		x	x			
G134	53	RB08	Other rubber pieces	Rubber		x	x	x		
G135		CL01	Clothing (clothes, shoes)	Cloth/textile				x		
G136		CL01	Shoes	Cloth/textile			x			
G137	54	CL01	Clothing / rags (clothing, hats, towels)	Cloth/textile	x	x	x			
G138	57	CL01	Shoes and sandals (*e.g.* Leather, cloth)	Cloth/textile		x				
G139		CL02	Backpacks & bags	Cloth/textile		x				
G140	56	CL03	Sacking (hessian)	Cloth/textile		x				
G141	55	CL05	Carpet & Furnishing	Cloth/textile		x	x	x		
G142		CL04	Rope, string and nets	Cloth/textile		x	x	x		
G143		CL03	Sails, canvas	Cloth/textile		x		x		
G144	100	OT02	Tampons and tampon applicators	Cloth/textile	x	x				
G145	59	CL06	Other textiles (incl. rags)	Cloth/textile		x	x	x		
G146			Paper/Cardboard	Paper/Cardboard			x			
G147	60		Paper bags	Paper/Cardboard		x				
G148	61	PC02	Cardboard (boxes & fragments)	Paper/Cardboard	x	x	x	x		
G149		PC03	Paper packaging	Paper/Cardboard				x		
G150	118	PC03	Cartons/Tetrapack Milk	Paper/Cardboard	x	x				
G151	62	PC03	Cartons/Tetrapack (others)	Paper/Cardboard	x	x				
G152	63	PC03	Cigarette packets	Paper/Cardboard		x				
G153	65	PC03	Cups, food trays, food wrappers, drink containers	Paper/Cardboard	x	x				
G154	66	PC01	Newspapers & magazines	Paper/Cardboard		x		x		
G155		PC04	Tubes for fireworks	Paper/Cardboard		x				
G156			Paper fragments	Paper/Cardboard		x				
G157			Paper	Paper/Cardboard					x	
G158	67	PC05	Other paper items	Paper/Cardboard		x	x	x		
G159	68	WD01	Corks	Processed/worked wood		x				
G160	69	WD04	Pallets	Processed/worked wood	x	x	x	x		
G161	69	WD04	Processed timber	Processed/worked wood		x				
G162	70	WD04	Crates	Processed/worked wood	x	x		x		
G163	71	WD02	Crab/lobster pots	Processed/worked wood		x				
G164	119		Fish boxes	Processed/worked wood	x	x				
G165	72	WD03	Ice-cream sticks, chip forks, chopsticks, toothpicks	Processed/worked wood	x	x				

Master List of Categories of Litter Items

TSG_ML General- Code	OSPAR- Code	UNEP- Code	General Name	Level 1 - Materials	Core	Beach	Seafloor	Floating	Biota	Micro
G166	73		Paint brushes	Processed/worked wood		x				
G167		WD05	Matches & fireworks	Processed/worked wood		x				
G168			Wood boards	Processed/worked wood				x		
G169			Beams / Dunnage	Processed/worked wood				x		
G170			Wood (processed)	Processed/worked wood			x			
G171	74	WD06	Other wood < 50 cm	Processed/worked wood		x				
G172	75	WD06	Other wood > 50 cm	Processed/worked wood		x				
G173		WD06	Other (specify)	Processed/worked wood	x		x	x		
G174	76		Aerosol/Spray cans industry	Metal	x	x				
G175	78	ME03	Cans (beverage)	Metal	x	x	x	x		
G176	82	ME04	Cans (food)	Metal	x	x	x			
G177	81	ME06	Foil wrappers, aluminium foil	Metal		x				
G178	77	ME02	Bottle caps, lids & pull tabs	Metal	x	x				
G179	120		Disposable BBQ's	Metal		x				
G180	79	ME10	Appliances (refrigerators, washers, etc.)	Metal		x	x			
G181		ME01	Tableware (plates, cups & cutlery)	Metal		x				
G182	80	ME07	Fishing related (weights, sinkers, lures, hooks)	Metal		x	x	x		
G183		ME07	Fish hook remains	Metal					x	
G184	87	ME07	Lobster/crab pots	Metal	x	x				
G185			Middle size containers	Metal			x			
G186	83	ME10	Industrial scrap	Metal		x				
G187	84	ME05	Drums, *e.g.* oil	Metal		x	x			
G188		ME04	Other cans (< 4 L)	Metal		x				
G189		ME05	Gas bottles, drums & buckets (> 4 L)	Metal		x				
G190	86	ME05	Paint tins	Metal		x				
G191	88	ME09	Wire, wire mesh, barbed wire	Metal		x		x		
G192		ME05	Barrels	Metal				x		
G193			Car parts / batteries	Metal		x	x			
G194			Cables	Metal		x	x			
G195		OT04	Household Batteries	Metal		x				
G196			Large metallic objects	Metal			x			
G197			Other (metal)	Metal			x	x		
G198	89	ME10	Other metal pieces < 50 cm	Metal		x				
G199	90	ME10	Other metal pieces > 50 cm	Metal		x				
G200	91	GC02	Bottles incl. pieces	Glass/ceramics	x	x	x			
G201		GC02	Jars incl. pieces	Glass/ceramics		x	x			

Master List of Categories of Litter Items

TSG_ML General- Code	OSPAR- Code	UNEP- Code	General Name	Level 1 - Materials	Core	Beach	Seafloor	Floating	Biota	Micro
G202	92	GC04	Light bulbs	Glass/ceramics	x	x				
G203		GC03	Tableware (plates & cups)	Glass/ceramics		x				
G204	94	GC01	Construction material (brick, cement, pipes)	Glass/ceramics		x				
G205	92	GC05	Fluorescent light tubes	Glass/ceramics	x	x				
G206		GC06	Glass buoys	Glass/ceramics		x				
G207	95		Octopus pots	Glass/ceramics		x				
G208		GC07	Glass or ceramic fragments >2.5cm	Glass/ceramics		x	x			
G209			Large glass objects (specify)	Glass/ceramics			x			
G210	96	GC08	Other glass items	Glass/ceramics	x	x	x			
G211	105	OT05	Other medical items (swabs, bandaging, adhesive plaster etc.)	unidentified		x				
G212			Slack / Coal						x	
G213	181, 109, 110	OT01	Paraffin/Wax	Chemicals		x			x	
G214			Oil/Tar	Chemicals					x	
G215			Food waste (galley waste)	Food waste					x	
G216			various rubbish (worked wood, metal parts)	undefined					x	
G217			Other (glass, metal, tar) <5mm	unidentified						x

European Commission
EUR 26113 EN – Joint Research Centre – Institute for Environment and Sustainability

Title: **Guidance on Monitoring of Marine Litter in European Seas**

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TSG-ML acknowledges the valuable contributions and comments received from: Leo De Vrees (EC), Ijubomir Jeftic (MED POL), Nils Guse (Forschungs- und Technologiezentrum Westküste FTZ), Alexander Bond (University of Saskatchewan), Bernard Cadiou (Seabird Monitoring Programme in Brittany), Ommo Hüppop (Institut für Vogelforschung «Vogelwarte Helgoland»), Ursula Siebert (Institute for Terrestrial and Aquatic Wildlife Research ITAW), Constança Belchior (EEA), Tom Doyle (UCC-CMRC, Ireland), Lars Gutow (Alfred-Wegener Institute for Polar and Marine Research, Germany), Martin Tiel (Facultad Ciencias del Mar, Universidad Catolica del Norte, Chile), Dennis Gräwe (Landesamt für Umwelt, Naturschutz und Geologie, Mecklenburg-Vorpommern, Germany), Léa David (EcoOcéan Institute, France), Nathalie Di-Méglio (EcoOcéan Institute, France), Ioannis Pesmatzoglou (HELMEPA, Greece), Richard Cronin (DECLG Ireland), Marcus Schulz (University of Osnabrück) and UNEP.

The cover page image has been kindly provided by Joana Mira Veiga, EUCC, the Netherlands.

TSG–ML was supported by the Coastal & Marine Union (EUCC) and Arcadis, under framework contract ENV.D.2/FRA/2012/0025.

Final edition was done by Georg Hanke (co-chair, EC JRC), Stefanie Werner (co-chair, UBA), François Galgani (chair, IFREMER), Joana Mira Veiga and Maria Ferreira (EUCC).

Luxembourg: Publications Office of the European Union

2013 – 128 pp. – 21.0 x 29.7 cm

EUR – Scientific and Technical Research series – ISSN 1831-9424 (online), ISSN 1018-5593 (print)

ISBN 978-92-79-32709-4 (pdf)
ISBN 978-92-79-32710-0 (print)

doi:10.2788/99475 (pdf)

Abstract:
The MSFD Technical Subgroup on Marine Litter was tasked to deliver guidance so that European Member States could initiate programmes for monitoring of Descriptor 10 of the MSFD. The present document provides the recommendations and information needed to commence the monitoring required for marine litter, including methodological protocols and categories of items to be used for the assessment of litter on the Beach, Water Column, Seafloor and Biota, including a special section on Microparticles.

LB-NA-26113-EN-N

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ISBN 978-92-79-32709-4