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Marine litter within the European Marine Strategy Framework Directive

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Abstract:

There have been numerous anthropogenic-driven changes to our planet in the last half-century. One of the most evident changes is the ubiquity and abundance of litter in the marine environment. The EU Marine Strategy Framework Directive (MSFD, 2008/56/EC) establishes a framework within which EU Member States shall take action to achieve or maintain good environmental status (GES) of their marine waters by 2020. GES is based on 11 qualitative descriptors as listed in Annex I of the MSFD. Descriptor 10 (D 10) concerns marine litter. As a follow-up to the related Commission Decision on criteria and methodological standards (2010/477/EU) in which 56 indicators for the achievement of GES are proposed, the EC Directorate-General for the Environment, on the request of the European Marine Directors, established a Technical Subgroup on Marine Litter (TSG ML) under the Working Group on GES. The role of TSG ML is to support Member States through providing scientific and technical background for the implementation of MSFD requirements with regard to D 10. Started in 2011, TSG ML provides technical recommendations for the implementation of the MSFD requirements for marine litter. It summarizes the available information on monitoring approaches and considers how GES and environmental targets could be defined with the aim of preventing further inputs of litter to, and reducing its total amount in, the marine environment. It also identifies research needs, priorities and strategies in support of the implementation of D 10. The work of TSG ML also focuses on the specification of monitoring methods through the development of monitoring protocols for litter in the different marine compartments, and for microplastics and litter in biota. Further consideration is being given to monitoring strategies in general and associated costs. Other priorities include the identification of sources of marine litter and a better understanding of the harm caused by marine litter.

Keywords: Descriptor 10 ; Harm ; Litter ; marine debris ; marine litter ; Marine Strategy Framework Directive ; Monitoring ; MSFD ; Research ; Sources ; targets

INTRODUCTION

It is widely recognised that marine resources often undergo excessive pressures and demands and that action must be taken in order to minimise the associated negative impact on the marine environment (Barnes & Metcalf, 2010).

In this aim, the European Commission has developed the Marine Strategy Framework Directive (MSFD) for the protection and sustainable use of marine ecosystems. The MSFD builds on sector-based approaches such as the Common Fisheries Policy, Natura 2000 and the Nitrates Directive. It is the environmental pillar of the Integrated Maritime Policy for the European Union, which aims to achieve the sustainable development of maritime sectors (Markus et al., 2011).

The MSFD establishes a framework within which Member States are required to take action to achieve or maintain Good Environmental Status (GES) for the marine environment by 2020. It explicitly refers to the management of human activities, recognising that 'environmental status' also includes the impact of anthropic activities.

The EU Member States are required to take six steps between mid-2012 and 2016 to develop a marine strategy for their waters: (i) initial assessment of current environmental status (Article 8, 2012) (ii) definition of good environmental status (Article 9, 2012), (iii) drawing up of a comprehensive set of environmental targets and associated indicators (Article 10(1), 2012), (iv) drawing up and implementation of a monitoring programme for ongoing assessments, together with regular target updates (Article 11(1), 2014), (v) development of a measurement programme designed to achieve or maintain good environmental status (Article 13(1) to (3), 2015) and (vi) implementation of the measurement programme (Article 13(10), 2016).

After the initial assessment, the EU Member States will draw up a series of characteristics defining the GES of their relevant waters, taking in account the indicative 'pressures' and 'impacts' listed in Annex III of the Directive. These characteristics are to be determined on the basis of the 11 qualitative descriptors listed in Annex I and in reference to Commission Decision 2010/477/EU relating to 'Criteria and methodological standards on good environmental status of marine waters', which proposes 56 indicators for the 11 descriptors.

This approach aims to establish consistent criteria and methodologies across the European Union (EU), along with a meaningful harmonization of GES achievements across various regions.

The MSFD recognises that the conceptualisation of GES is not a one-off matter, but will continue to evolve and adapt due to dynamic factors such as ecosystem changes, new scientific knowledge and the development of new technological capabilities (Juda, 2010). Periodic assessments of the status of the marine environment, together with monitoring efforts and the formulation of environmental targets, are perceived as part of the continuous management process. Provisions have therefore been made for the modification of adopted marine strategies and measures.

Human pressures on the oceans have increased substantially in recent decades. The expansion of coastal and marine activities has adversely impacted the marine environment and affected ecosystem goods and services. In addition, coastal and marine human activities generate considerable quantities of waste that potentially contaminate the marine environment.

Much of this litter will persist in the sea for years, decades or even centuries. On average, three-quarters of all marine litter consists of plastics known to be particularly persistent. The occurrence of litter has been demonstrated worldwide: in oceanic gyres, on coastlines, in sediments and in the deep sea. Litter is accumulating in both densely-populated areas and remote regions such as the Antarctic (Barnes et al., 2009).

Of the 11 descriptors listed in Annex I of the MSFD for determining GES, descriptor 10 has been defined as 'Marine litter does not cause harm to the coastal and marine environment'.

Commission Decision 2010/477/EU identifies the following criteria and four associated indicators for Descriptor 10:

Criteria 10.1. Characteristics of litter in the marine and coastal environment

— Trends in amount of litter washed ashore and/or deposited on coastlines, including analysis of its composition, spatial distribution and, where possible, source (10.1.1)

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

— Trends in amount, distribution and where possible, composition of micro-particles (in particular microplastics) (10.1.3)

Criteria 10.2. Impacts of litter on marine life

— Trends in amount and composition of litter ingested by marine animals (e.g. stomach analysis) (10.2.1).

In 2010, as a follow-up to Commission Decision 2010/477/EU, the European Marine Directors requested the Directorate-General for the Environment (DG ENV) of the European Commission to establish a technical subgroup under the Working Group on GES (WG GES) for the implementation of MSFD Descriptor 10.

Based on the definition of UNEP (United Nations Environmental Programme) (Cheshire et al., 2009), the group defined marine litter as any persistent, manufactured or processed solid material discarded, disposed of, or abandoned in the marine and coastal environment. Litter consists of items that have been made or used by people and deliberately discarded or unintentionally lost in the sea or on beaches, including materials transported from land into the marine environment by rivers, run-offs, sewage systems or winds.

The initial mandate for the Technical Subgroup on Marine Litter (TSG ML) was drafted by DG ENV, discussed by WG GES and approved by the EU Marine Directors in 2011. IFREMER (France), UBA (Germany) and the Joint Research Centre (JRC) chair the work of this group. The group's mandate contained the following work items: (i) identify and review existing data and ongoing data collection on marine litter; (ii) describe data needs and methods for the future assessment of marine litter; (iii) consider standards for monitoring marine litter; (iv) develop proposals for the development of impact indicators for each of the regions; (v) address how to develop objectives (characteristics of GES), environmental targets and associated indicators in relation to marine litter; (vi) discuss the effectiveness of measures to reduce marine litter, and; (vii) recommend proposals for further research priorities.

The work undertaken by the group resulted in a report published in the JRC scientific and technical report series in 2011, entitled 'Marine Litter – Technical Recommendations for the Implementation of MSFD Requirements'. This report identifies and presents 15 options (a so-called toolbox) for monitoring litter in the various marine compartments, together with the biological impact of ingested litter or micro-litter. It also considers sources, GES, objectives, environmental targets and research needs, as well as a roadmap for further tasks in 2012 and 2013. This roadmap, along with a detailed work programme, was adopted by the EU Marine Directors to further support monitoring programmes conducted under the MSFD, including the development of monitoring protocols and additional recommendations on (i) general monitoring strategies and associated costs, (ii) sources and (iii) understanding harm. (See http://publications.jrc.ec.europa.eu/repository/handle/ 111111111/22826).

Despite today's litter-fighting efforts (Port reception facilities, Fishing for litter; International Coastal Cleanups, No-special-fee; Adopt-a-Beach; Blue Flag, etc.), current knowledge of the quantities of litter in European Seas, the degradation and fate of litter in the marine environment and its potentially harmful biological, physical and chemical impacts on marine life and habitats, remains inadequate. The methods used to monitor marine litter, together with our understanding of the sociological factors that underpin behavioural changes in relation to littering, are also insufficient. The evaluation and regulation of marine litter sources alone will not therefore suffice to achieve Good Environmental Status.

MARINE LITTER

What started as an aesthetic problem is now raising concern as to the various potentially-harmful implications of marine litter in the marine environment.

The majority of reported litter-related incidents affecting individual marine organisms involve plastic items. In terms of plastic litter or use, ropes and netting accounted for 57% of encounters in 2012, followed by fragments (11%), packaging (10%), other fishing-related litter (8%) and microplastics (6%) (CBD 2012). Encounters with marine litter were reported for 663 species (CBD 2012). Over half of the reported species (about 370) were associated with entanglement in and ingestion of marine debris, representing an increase of more than 40% since the last review in 1997, when 247 species were reported as being affected by the above two impact categories (Laist, 1997).

The entanglement of species in marine litter, which is often a result of normal behavioural patterns, has frequently been described as a serious mortality factor, leading to potential losses in biodiversity. The most problematic marine litter includes derelict or discarded fishing gear (nets, traps and pots), which may continue to 'fish' for years; this phenomenon has been termed 'ghost fishing'. It is estimated that 10% percent of all litter entering the oceans every year consists of so-called ghost nets (Macfadyen et al., 2009). However, many losses presumably remain unreported (UNEP, 2009). Entanglement in marine debris has been reported for pinniped species, cetaceans, all seven species of marine turtles and over 56 species of marine and coastal birds (Katsanevakis et al., 2007). The decline of deep-water sharks in the North Atlantic has been linked to ghost fishing in the region (Large et al., 2009).

At least 43 % of existing cetacean species, all species of marine turtles, approximately 44% of the world's seabird species and many fish species reportedly ingest marine litter, either because debris is misidentified as natural prey, or during the course of feeding and normal behaviour (Gregory, 2009, Katsanevakis 2008, CBD 2012). More recently, major commercial invertebrates were found to have ingested plastics (Murray & Cowie, 2011). In some species, a considerable proportion of the population is affected by interactions with litter that affect their body condition and ability to forage and reproduce, which may ultimately lead to mortality (Van Franeker et al., 2011).

An emerging area of concern is the accumulation of microplastic fragments in the water column and sediments (Thompson et al., 2004,). Pieces of common polymers (including polyester, nylon, polyethylene and polypropylene) of less than 20μm have been recorded worldwide (Barnes et al., 2009). Plastics are biologically inert. They degrade to tiny particles, which probably stay in the marine environment for long periods. Because of their size, they are available to a wide range of organisms, including bottom feeders, filter feeders and scavengers (Thompson et al., 2004). When ingested, plastics release chemicals (nonylphenols, polybrominated diphenyl ethers, phtalates and bisphenol A), together with sorbed hydrophobic pollutants such as PCBs and DDT that may be transferred to organisms, hence raising concern as to their subsequent adverse effects (Mato et al., 2001, Teuten et al., 2009). The ingestion of microplastic material could be a route for chemicals to pass from plastics to the food chain. More research is needed to establish the full environmental relevance and potential impact of these microparticles, in particular on distribution, transport, degradation/weathering processes and sorption/release mechanisms.

Ecologically-speaking, the 'level of litter that causes harm to the environment' depends on the type and quantity of litter measured and the affected environmental and ecosystem components. Conversely, the impact of microplastic particles resulting, for example, from the degradation of fishing nets, will persist for decades or centuries in the sea, possibly affecting a range of species through the mechanical and chemical consequences of ingestion.

Other known impacts of marine litter include the alteration, damage and degradation of benthic habitats such as coral reefs (Katsanevakis et al., 2007) and soft sediment abrasion caused by derelict fishing gear, or smothering by macro and microplastics in sandy sediment in intertidal zones (Katsanevakis et al., 2007, Richards, 2011). Litter can disrupt assemblages of organisms living on or in sediment (Chiappone et al., 2002). Microplastics and litter fragments on beaches reportedly alter the porosity and heat transfer capacity of sediment (Carson et al. 2011). Furthermore, marine litter items can facilitate the invasion of alien species, such as algae associated with red tides (Barnes, 2002; Barnes and Milner, 2005).

From a socioeconomic perspective, the harm caused by marine litter includes the cost of deterioration of ecosystem goods and services. Social harm includes the reduced recreational, aesthetic and educational value of areas such as beaches, together with human health hazards and risks such as floating objects, which may encounter boats.

The economic harm caused by marine litter includes significant direct costs and loss of income affecting a range of maritime sectors (including aquaculture, agriculture, fisheries, shipping and leisure boating), power plants and industry, local authorities and tourism.

Economic 'harm' may run into millions of euro per annum, even on a sub-regional scale (Mouat et al., 2010).

Marine litter is also a serious aesthetic problem for tourists and local beach-goers. In addition, sanitary, sewage-related and medical waste can cause injury and/or constitute a health hazard (Ivar do Sul and Costa, 2007). The environmental issues raised by marine debris can have an even wider social impact if the livelihood and health of local coastal communities are affected (Tinch et al. 2012). This aspect, i.e. what constitutes 'harm' in a socioeconomic sense, remains to be defined in relation to MSFD descriptor 10.

There is no solid, common understanding of what exactly constitutes 'harm' caused by marine litter, or how it can be assessed with respect to the implementation of the MSFD. Future studies will need to assess the available evidence base and attempt to develop a consensus on how to approach this issue. Research efforts aimed at developing a robust approach to harm assessment will have to be identified and facilitated where possible and the results taken into consideration by the TSG ML. Currently, a number of potential environmental issues caused by marine litter are not sufficiently taken into account. This may be due to inadequate monitoring or uncertainty as to how to approach the issue best, e.g. how to assess levels of entanglement in, or ingestion of litter by other target species such as fish.

It is paramount to identify potential gaps in our understanding and develop proposals for pilot monitoring schemes designed to address them in a coordinated manner before we consider whether robust monitoring tools and protocols can be realistically and cost-effectively implemented.

Litter can originate from numerous sources, which all need to be targeted by measures to reduce litter-induced pollution. Identifying the source of litter items is often a complex task, as marine litter enters the ocean from land, sea and widespread sources and can travel long distances before being deposited on shores or settling on the bottom of the ocean, sea or bay.

Litter from land-based activities, resulting from poor waste management, enters the marine environment via drainage or sewage systems, rivers, winds, road run-offs and storm water outflows. Land-based sources include tourism and recreational uses of the coast, the general public, fly tipping, local businesses, industry, harbours and unprotected waste disposal sites. Sea-based sources of marine litter include merchant shipping, ferries and cruise liners, commercial and recreational fishing vessels, military fleets and research vessels, pleasure craft, offshore installations such as oil and gas rigs, drilling rigs and aquaculture sites. Factors such as ocean currents, winds, tides and the proximity to urban centres, industrial and recreational areas, shipping lanes and fishing grounds also influence the types, nature and amount of litter found in the open sea or collected along beaches, waterways or underwater.

Marine litter sources can be characterised in several ways. A common method is to classify sources as either land-based or sea-based, depending on how the litter enters the marine environment. These broad categories can be further broken down into sources such as recreational litter, shipping litter and fishing litter. Some items can confidently be associated with their sources, such as various fishing items, sewage-related debris (SRD) and certain tourism-related litter. These so-called 'use categories' provide valuable information for setting targets and reduction measures, as they can easily be linked to measurements. The production or geographical source of litter can also be identified but, given the increasing globalisation of markets, this information is of less use for implementing effective measures and targets than use categories. Information on litter sources can be obtained by monitoring beaches, the sea surface or sea floor. A common approach to categorising litter in the different marine compartments is required.

PNUE/PAM/MEDPOL (2009) reported that most marine litter in the Mediterranean Sea comes from land rather than sea-based sources (e.g. ships). Litter mainly enters the sea from the coastline as a result of recreational activities. It comprises mainly plastics, aluminium and glass. Recordings of floating litter have confirmed the overwhelming presence of plastics in the Mediterranean Sea, accounting for about 83% of observed marine litter items. In some touristic areas, over 75% of annual waste production is generated in the summer season.

The situation is different in the North Sea. The wide diversity of items found along the North Sea coasts and the composition of litter recorded during the OSPAR Beach Litter monitoring programme indicate that maritime activities in the form of shipping, fishing and offshore installations are the predominant litter sources in the North-East Atlantic, together with coastal recreational and touristic activities (Fleet et. al., 2009; OSPAR, 2009; ARCADIS 2013(a)). A considerable proportion of litter enters the North Sea through transport by wind, currents and rivers and via the English Channel. Plastics account for around 75% of litter items found in the North-East Atlantic (JRC 2011).

The EC has commissioned pilot projects in the four regional seas (OSPAR, HELCOM, MEDPOL and Black Sea regions) in the aim of pinpointing missing information on the plastic cycle. The results will provide input for a further analysis of litter sources and fate by the TSG ML (see final reports by ARCADIS, BIPRO and RPA at http://ec.europa.eu/environment/marine/good-environmental-status/descriptor-10/index_en.htm).

Upcoming work will lead to a more precise understanding of waste pathways according to litter type. Source and quantity mapping remains a necessary step for planning effective countermeasures. Reducing litter inputs at source (domestic, industrial, tourism, rivers, shipping, fishing and aquaculture activities) as part of national marine strategies should contribute to reaching marine litter GES at a regional level. Although not all litter pathways to the sea have been identified to date, it seems likely that some litter sources will lie outside national jurisdiction; as a result, national measures will not suffice to achieve national GES.

MONITORING

Regular litter surveys, together with results analysis in relation to local weather conditions and coastal geomorphology, are necessary to obtain information on the geographical origins of coastal waste and form a basis for implementing actions to reduce litter pollution. Existing monitoring methods that are different but compatible need to be adapted and harmonised to take regional differences into account, e.g. coastline type or prevailing currents in offshore areas.

Methodologies for source assessment are mostly based on the identification and reporting of collected/observed marine litter. As a result of differences in monitoring approaches, the ability to identify litter types (categories) varies across the environmental compartments. For reporting purposes, the TSG ML recommends using categories that are compatible with various types of survey (beaches, sea surface and sea floor), in order to produce comparable results. Marine litter reporting for the purpose of source attribution still needs further development, as the efficiency of measures targeting specific litter sources depends on the identification of litter types / categories in the various environmental compartments.

The 2011 TSG ML report and other forums in the context of MSFD implementation provide guidelines for existing approaches, summarised in table 1 (after Galgani et al., 2010; Galgani et al, 2011):

Insert table 1

Litter will persist in the sea for years, decades and even centuries. Therefore, source assessment alone will not suffice and long-term monitoring in the marine environment will be necessary in order to understand trends. Monitoring scheme planning should also give proper consideration to spatial and temporal scales. Although beach litter surveys, sea floor monitoring on continental shelves and socioeconomic studies can readily be applied on a European scale, priority should be given to monitoring marine areas most affected by litter.

Methodological protocols in Europe are currently available for the assessment of certain types and occurrences of litter on coastlines (OSPAR, 2009). These standards should be adjusted to MSFD needs and harmonised for extension to other regions. Pilot projects have also indicated that litter on the sea floor could be measured in conjunction with routine biological trawling surveys (e.g. International Bottom Trawl Surveys in OSPAR area, Mediterranean International Trawl surveys, in the MEDPOL area), including source evaluation. Larger pieces of floating litter can be quantified by aerial observation and image recognition systems, whereas floating micro-litter can be monitored using tow nets or filtered water samples.

In the framework of the OSPAR Convention, the amounts of plastics found in Fulmar stomachs are used to assess temporal trends, local differences and compliance with set targets for acceptable pressures in the North Sea (van Franeker, 2011). This monitoring effort could be extended to other marine regions using region-specific indicator species, such as turtles in the Mediterranean Sea.

The future work of the TSG ML to support marine litter monitoring will need to focus on (i) developing common monitoring protocols, including advice on strategies that can be adopted to ensure the comparability of monitoring programs; (ii) facilitating the implementation of fit-for-purpose monitoring programmes, providing advice on potential common monitoring tools, identifying opportunities to improve comparability, ensuring continuous quality assurance and data control, etc. (iii) evaluating new monitoring tools and promising tools currently under development and providing advice on their suitability for meeting EU Member State monitoring and assessment needs; (iv) estimating the cost of implementing monitoring tools so that EU Member States can make informed choices and; (v) developing standardised litter categories in close conjunction with the Regional Seas Conventions, in order to harmonise currently-reported marine litter categories and improve comparability across Member States.

The evaluation of waste fluxes across the various marine compartments is a necessary step and goal for understanding transport and flux mechanisms and potential impacts. Figure 1 shows a diagram of litter fate, summarising the relationship between various habitats and biological entities, together with main interactions. Fluxes will still need to be assessed in terms of litter quantities and type/composition for each type of debris.

Insert Figure 1

Finally, understanding transport mechanisms will help explain the transformation of marine litter and provide a better description of its spatial distribution. The accumulation of litter on the sea bed, its degradation rate at sea, the associated chemical sorption/desorption kinetics and rate of ingestion by various marine organisms are all poorly-understood mechanisms. These knowledge gaps are a stumbling block for the identification of targeted and effective measures to reduce litter pollution.

The abundance of litter at sea can be estimated either by the direct observation of large items of debris (e.g. submersible remote observation vehicles (ROVs) for monitoring litter on the sea bed, or ship-based and aerial observations for debris floating on the sea surface), or by means of large-scale imagery (Hanke & Piha, 2011) and net trawls (for smaller items). Net-based surveys are the most widespread and efficient method found to date (Goldberg 1994; Galgani and Andral, 1998).

General protocols for investigating debris on the sea bed are similar to the methodologies used for monitoring benthic species. Greater emphasis should be placed on the number and type/category (e.g. bags, bottles and pieces of plastics) of litter items, rather than their weight.

Trend interpretation is problematic, as the fate of plastics at depth is not well-researched and the accumulation of plastics on the sea bed began long before specific scientific investigations were launched in the 1990s.

Among the areas investigated to date along the European coasts (Galgani et al., 2000), Mediterranean sites tend to show the greatest densities of litter accumulation. Debris - mainly plastics - that reaches the sea bed may have been transported a considerable distance from source, only sinking to the ground when weighed down by fouling. The result is an accumulation of plastic debris in bays and canyons, rather than in the open sea (Galgani et al., 1996; Katsanevakis et al., 2007). However, due to large-scale residual ocean circulation patterns, some accumulation zones in the Atlantic Ocean and Mediterranean Sea have very high debris densities, despite being located far from the coast (Galgani and Lecornu 2004).

We know little about the accumulation trends of debris at sea, but available data indicates considerable variability. Abundances decreased slightly in the Gulf of Lions (France) over a 15-year period (1994-2009). However, in some areas around Greece, the abundance of debris at depth increased over a period of 8 years (Koutsodendris et al., 2008). Debris is progressively broken down in the marine environment (Thompson et al., 2004) into micro-particles (< 5mm, Arthur et al., 2009). There is considerable concern about the accumulation of microscopic pieces of plastic ('microplastic'), in view of their prevalence at sea and slow chemical and biological degradation. This category includes spillages of pre-production plastics (resin pellets) (Ryan et al., 2009), granules, e.g. from cosmetic products and fibres from washing machines. These granules and fibres may be discharged from sewage treatment plants (Liebezeit & Dubaish 2012). The prevalence of small fragments and granules (<5mm in diameter) varies considerably according to area, although current quantities appear to be relatively low in most locations. Nonetheless, plastic micro-particles have been reported in quantities exceeding 100,000 items/km2 (Thompson et al. 2009) in the North Sea. Similar quantities of debris have been reported in the north-western area of the Mediterranean Sea (Collignon et al, 2012) with 115,000 items/km2 measured, giving a total extrapolated amount of 250 billion items throughout the Mediterranean basin.

The OSPAR Ecological Quality Objective (EcoQO) for litter in fulmar stomachs has provided various valuable information on temporal and spatial variations in marine litter abundance, trend variations in terms of industrial and user plastics and marine litter sources (Van Franeker et al., 2010). The EcoQO is currently applied in the North Sea, but can be adapted to most areas of the North-East Atlantic. Pilot studies for litter bio-monitoring should also cover other species, in particular marine turtles, which are regularly stranded in the Mediterranean region and often found to contain fatal quantities of ingested litter. Monitoring does exist in some Mediterranean countries and could provide a basis for evaluating litter ingestion, once monitoring methodologies have been harmonised. In the future, fish, zooplankton species, shellfish and seals may be considered as generally-applicable target species for most European seas, or as target species for one or more of the (sub-) regions listed in the MSFD.

DETERMINATION OF GOOD ENVIRONMENTAL STATUS

One of the key EU Member State challenges in implementing the MSFD is determining 'good environmental status'. Although this term is defined in the Directive (Art. 3(5) MSFD), GES takes on a variety of meanings in EU marine regions or sub-regions and is therefore open to interpretation (Barnes & Metcalf, 2010). The MSFD requires a holistic assessment of the impacts of anthropogenic pressures on marine ecosystem components. Regarding marine litter, more than one indicator will be required to assess GES in relation to the various marine compartments and various aspects of litter pollution. Metrics are not currently available for assessing the majority of biological impacts that litter may have. In their absence, thresholds could be replaced by trends in pressure-related indicators, such as the amount of litter on the sea floor or on beaches, in order to provide proxies for evaluating progress towards GES.

As we saw earlier, the 'harm' caused by marine litter can be divided into three general categories: social harm, i.e. impaired aesthetics and public health; economic harm, such as costs in terms of tourism, damage to vessels (nets and ropes in propellers), fishing gear and facility cleaning costs and; ecological harm, e.g. mortality of, or sublethal effects on animals through entanglement by ghost nets, derelict traps, pots or other fishing gear, or harm resulting from the ingestion of litter, including the uptake of micro-particles (mainly microplastics).

Insert figure 2

On the basis of the MSFD definition of GES for Descriptor 10 given above, GES could be considered as being achieved once litter and its degradation products present in, or entering EU marine waters (i) do not cause harm to marine life and habitats; (ii) (ii) do not cause direct or indirect risks to human health and (iii) do not have negative socioeconomic impacts.

At a national level, EU Member States may take additional priorities into account for evaluating GES. Alongside Descriptor 9 on the contamination of seafood, Descriptor 10 particularly focuses on human health (such as the risk of beach-goers and swimmers getting cut on sharp litter items and divers getting entangled in litter items), together with socioeconomic interests (such as the cost of cleaning beaches and fishing nets, or the risk of entanglement of ship propellers). The use of trend indicators as listed in the Commission Decision (10.1.1; 10.1.2; 10.1.3), aimed at observing and assessing trends in litter occurrence in the various marine compartments, will help predict both health-related and socioeconomic consequences.

Current assessments are not generally capable of providing information on the extent of harm at a population, community or ecosystem level and it is actually unlikely that we can develop an assessment procedure capable of showing effects at a population or ecosystem level. It is therefore essential to consider harm in relation to individual organisms. Assessing the numbers of affected individuals is likely to offer the most feasible and representative conclusions on biological impact. Following the example of the OSPAR EcoQ for plastic litter items in fulmar stomachs in the North Sea region, additional indicator species must be found for other EU marine regions (such as sea turtles for the Mediterranean Sea) and additional indicators on the ecological impacts of litter (e.g. on entanglements) may be required in reference to Commission Decision 2010/477/EU. Although litter potentially assists the transport and introduction of non-indigenous species, this impact has not been put forward for assessment using a specific indicator under Commission Decision 2010/477/EU.

DEFINING TARGETS

Achieving GES can be considered as a continuous reduction of inputs to reduce total amounts of marine litter by 2020 and reach levels that do not harm the coastal and marine environments.

Although initiatives to remove litter present in the marine environment will assist in reaching this goal, various major points need to be considered as follows:

- One of the stumbling blocks to target-setting in certain marine regions is the lack of available data for developing a baseline: rather than 'zero tolerance', the EU directive refers to an acceptable amount of litter that does not affect Good Environmental Status. In order to achieve this, classification must be performed according to the potentially harmful effects of various litter types (e.g. plastics, glass, metal, etc.) on various species and habitats, together with their use (e.g. nylon nets, plastics from households and industry and sanitary items). So-called 'use categories' provide the most useful information for setting targets and defining reduction measures.
- All marine litter assessments should take into account short-term variations caused by meteorological and/or hydrodynamic events and seasonal fluctuations, which influence our ability to detect underlying trends. Given the variability of litter data, which is greatly influenced by season, weather conditions and water currents, a 5-year running mean is considered as appropriate for providing a baseline in terms of average pollution. However, a reduction in litter inputs may not lead to a measurable reduction in total litter in the marine environment in the short term. This is due to the persistence of certain materials, together with the time scales and long degradation time of many litter categories (plastics, metal, glass and rubber). Observation timescales should therefore be adapted to ensure pluriannual monitoring frequencies.
- Finally, data aggregation for assessments at a sub-regional or even regional scale will differ according to the considered parameters. For example, beached litter surveys can be applied on the European spatial scale, whereas deep sea floor monitoring, which is limited to a few areas, is more relevant on smaller scales and over longer periods.

Even though it is reasonable to say that plastics, which are a major part of the marine litter problem, are completely unnatural, it would be unreasonable to argue that the ultimate goal of the MSFD should be zero plastic in the marine environment. Targets for the various marine compartments need to be set by EU Member States on the basis of their initial national assessments according to Article 8 MSFD and depending on the initial level of pollution in the considered area. An appropriate target for clean areas would be the maintenance of this status, along with the eventual achievement of clean area status in assessed areas with unacceptable litter levels.

The amount of litter present in the various marine compartments depends, among other factors, on regional topography, including sea bed topography and prevailing currents, winds and tidal cycles. Better knowledge of the amount and dynamics of litter in the marine environment will help determine whether targets need to be defined at a regional level, in addition to the targets set by individual EU member states.

Regarding litter on beaches, which is already well-monitored in some regions, it is suggested that the reduction goal recommended by the TSG ML be adopted as a first step. This goal aims to achieve a general, measurable and statistically-significant reduction in beach litter by 2020. Despite uncertainties relating to natural fluctuations in the quantities of litter washed ashore (annual variability, effects of storms, etc.), local applicability, technical feasibility (confidence, monitoring implications, spatial scale, etc.), trends and inflicted harm, trend-based targets may remain appropriate until a provenly viable alternative is produced. Discussions are currently revolving around the quantification of the following potential targets: (i) [XX%] overall reduction in the number of visible (> 2.5 cm) [new] litter items on coastlines by 2020 and, more specifically, (ii) [XX%] reduction in the number of plastic/fishing/sanitary litter items on coastlines by 2020.

Although yet to be harmonised, various protocols currently enable the assessment of litter floating on surface waters. However, specific areas will need to be selected for monitoring. Litter on the sea bed has been monitored at a few sites in the EU, but data is sparse and assessment is difficult. As a result, a trend target is now being considered, in which data would be derived from existing monitoring programmes, or programmes scheduled for extension, in order to improve temporal and spatial scales. The opportunistic sampling of litter on the sea bed would be conducted in conjunction with ongoing fish stock assessment and contaminant surveys (IBTS/ MEDITS programmes). Those monitoring programmes would support the application of the following potential targets for marine litter: (i) Overall reduction [XX %] in litter density in nationally-defined areas affected by litter floating on the sea surface (ii) Overall reduction [XX %] by 2020 in litter density on the sea bed as measured by trawl surveys, through diving in selected shallow waters and litter harvested through fishing operations.

Microplastics are not currently measured on a regular basis and no baseline is available, meaning we do not currently have enough information on most waters to set quantitative or qualitative targets. Adequate monitoring should therefore be performed and a baseline established before any targets are set.

Micro-particles on the sea surface and in the water column can be assessed by sampling with a manta trawl or filtration system. This data could be used to formulate a potential target for significantly reducing micro-particles by 2020. The occurrence of micro-particles in sediments should also be considered.

Recent studies on industrial plastics found in beached fulmars in the North Sea (Van Franeker et al., 2011) showed that reductions in the abundance of specific marine litter items, of around 50% per decade, are a feasible target if adequate measures are taken. In order to prevent items ending up as marine litter, it is important to tackle the problem at source. Operational targets relating to specific sources can be used to help draw up targeted measures aimed at reducing the amount of litter entering or present in the sea. However, although these targets can be used to assess the effectiveness of measures, they cannot act as substitutes for environmental targets.

OSPAR has defined its target for litter-induced ecological pressures in the North Sea as follows: less than 10% of Northern Fulmars should have over 0.1g plastic in their stomachs (undated target for the Greater North Sea). The OSPAR EcoQO cannot be directly transposed on other marine areas uninhabited by fulmars; in order to monitor the ingestion of litter in other EU marine regions, appropriate indicator species still need to be established (e.g. sea turtles in the Mediterranean Sea). Similarly to target setting for beach litter it may, for the time being, be more suitable to describe GES in relation to litter ingestion in terms of trend, e.g. x % annual reduction in the quantity of ingested litter. It is then important to establish a reference value, with which the reduction should rapidly be compared.

FURTHER SUPPORT TO MEMBER STATES

The MSFD definition of Good Environmental Status, the objectives for achieving or maintaining GES by 2020 and the related monitoring needs require a thorough understanding of the mechanisms and processes associated with litter at sea. In turn, this requires considerable research efforts in the aim, for example, of clarifying fundamental research gaps relating to litter quantities and associated harm in the context of GES, defining priorities, improving the scientific and technical basis of monitoring, harmonising and coordinating common and comparable monitoring approaches and, finally, supporting the development of guidelines for assessing GES.

An initial joint evaluation on the status of regional/sub-regional research by the EU Member States is currently under way in the aim of providing a scientific and technical basis for monitoring marine litter and defining knowledge gaps and priority research areas. Harmonisation, which is necessary to define common and comparable monitoring approaches and put forward recommendations and guidelines for assessing GES on a regional, national and European scale, will need to be coordinated by a group of experts from the EU Member States. Research will need to include improved knowledge on the impact of litter on marine life, litter degradation processes at sea, the study of litter-related micro-particles, the study of litter-associated chemicals, factors influencing the distribution and densities of litter at sea (human factors, hydrodynamics, geomorphology etc.), the comparability of monitoring methods and the determination of thresholds for GES. The assessment and monitoring of socioeconomic harm will also need to be addressed and research will be required to implement novel methods, automated monitoring devices and, finally, monitoring rationalisation.

MSFD implementation is a long-term and cyclic process, aimed at achieving good environmental status by 2020. Research must be undertaken rapidly, in particular to support the start of monitoring by 2014. A number of short-term priorities were identified by the GES TG group in 2010 (Galgani et al., 2010), including:

(1) Evaluate the behaviour (floatability, density, effects of wind, biofouling, degradation rates) and factors affecting the fate of litter (weather, sea state, temperature driven variations, slopes, canyons, bays, etc.) and affecting the transport of litter.

(2) Use comprehensive models to define source and destination regions of litter (especially accumulation areas, permanent gyres, deep sea zones), estimate residence times, consider the average drift times and Tran boundary transport from and to MSFD region/sub regions.

(3) Evaluate the rates of degradation of the different types of litter, quantify the degradation products (to nanoparticles) and evaluate the environmental impact of litter-related chemicals (Phthalates, bisphenol A, flames retardants, etc.) on marine organisms.

(4) Identify sources for direct inputs of micro-particles of litter.

(5) Establish the environmental impacts of micro-litter, in particular in relation to the potential physical and chemical impacts on wildlife, resources and the food chain.

(6) Evaluate biological impacts (on metabolism, physiology, survival, reproductive performance and ultimately on populations or communities).

(7) Evaluate the risk of the introduction of invasive non-indigenous species.

(8) Study dose/ response relationships in relation to the types and quantities of marine litter in order to enable science-based definitions of threshold levels for GES.

(9) Evaluate direct costs of marine litter to the maritime industry, fishing industry, local authorities and governments and in terms of impact on ecosystem goods and services.

(10) Develop automated monitoring systems (ship-based cameras, micro-litter quantification etc.) and impact indicators (aesthetic impact, effects on human health and harm to environment).

(11) Optimise monitoring (standards/baselines; data management/quality insurance; extend monitoring protocols to all MSFD (sub-) regions)

CONCLUSIONS

The EU Marine Strategy Framework Directive (MSFD) provides a framework for EU Member States to achieve or maintain Good Environmental Status for their marine waters by 2020. Annex I of the Directive lists marine litter as one of the qualitative descriptors for achieving GES and is therefore a key instrument for addressing this type of marine environment contamination, which must be tackled urgently. Plastics are a major part of the marine litter problem. As plastic is completely unnatural in the marine environment, the ultimate goal should be to produce plastics with no effects on it.

Policy makers, managers and scientists involved in implementing the MSFD on marine litter are faced with complex and diverse issues, including questions relating to the harmonisation of monitoring tools and strategies, the definition of 'harm' to the marine environment, the assessment of land and sea-based sources from which marine litter enters the sea and the development of a common understanding of the application of appropriate operational/environmental targets.

The TSG ML has been assigned to work on these various questions and draw up monitoring protocols, along with additional technical and procedural recommendations, in the aim of assisting EU Member States in taking the steps required to implement the MSFD. This supporting role will help combat marine litter, while providing a strong scientific and technical foundation for the implementation of Descriptor 10 of the MSFD.

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Table 1. Summary of approaches for assessing GES with regards to marine Litter (after Galgani *et al.*, 2010 and 2011).

Compartment	Approaches	Positive aspects	Poorly covered and negative aspects
Coastline	Counts of the amount of litter items on known stretches of coast.	Allows for assessment of composition, amounts, sources, trends, social harm (aesthetic, economic).	Very small items and microparticles in sediments are not quantified. Not all coasts are accessible or appropriate.
Sea surface	Ship observers.	Precise evaluation at local scale.	Depending on weather. Not at large scale, small debris not considered, strong temporal variation.
Sea surface and water column	Trawling and water filtration.	Precise evaluation at local scale, consider smaller debris.	Costs, strong temporal variation.
Sea surface	Aerial counts of the number of litter items floating on the sea surface along transects.	Assessment of densities of litter on water surface over large areas possible; correlation with shipping or fisheries activities.	Smaller items not covered. Only counts of items from TetraPak size upwards are possible.
Sea floor shallow	Visual survey with divers.	All substrate types, replicability, feasible to account for detectability.	Depth limitation (<40 m).
Sea floor, deep sea litter	Trawling.	Replicability, possible standardization.	Only where trawling is possible.
Sea floor, deep sea litter	Submersibles and remote operated vehicles.	All sites accessible.	Only small areas, costs.
Entanglement rates of marine organisms	Entanglement rates in birds found on the coastline.	Can be carried out as part of existing surveys.	Standard protocol would need to be developed and implemented.
OSPAR Fulmar Plastic Ecological Quality Objective (EcoQO)	Mass of plastic in stomachs of beached seabirds (Fulmars).	Operational and tested in North sea. Applicable everywhere in most of OSPAR area.	Focuses on surface litter in offshore habitats; not yet operational in all EU regions: need further developing.
Ingestion by other marine organisms	Abundance of plastic by mass.	Potentially similar to Fulmar EcoQO approach.	Need to be developed and tested.
Microplastic on shorelines	Extraction of fragments from sediment samples and subsequent identification using FT_IR spectroscopy.	Positive identification of specific polymers.	Analysis is time-consuming and is unlikely to detect all of the microparticles. This is especially true for very small fragments (<100 µm).
Microplastic at sea surface	Manta trawl (330 µm) and subsequent identification using FT_IR spectroscopy.	Positive identification of specific polymers.	Analysis is time-consuming and is unable to detect all of the microparticles.
Socio-economic	Assessment of direct costs through survey-based methods.	Provides indication of economic burden on marine and coastal sectors.	Does not capture full impact of degradation of ecosystem goods and services due to marine litter.

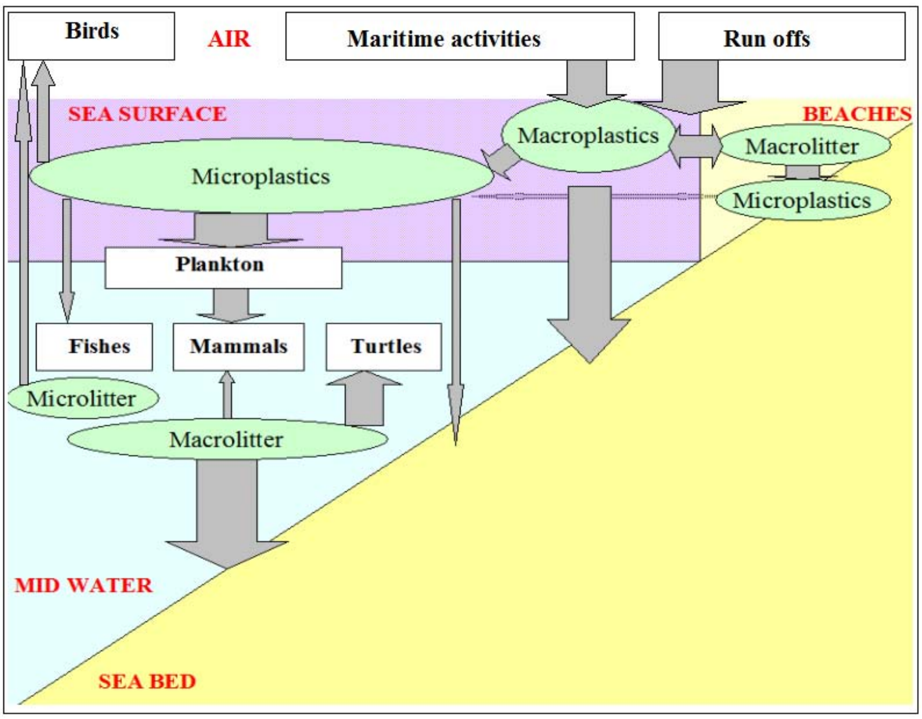

Figure 1: A schematic cycle of litter a Sea

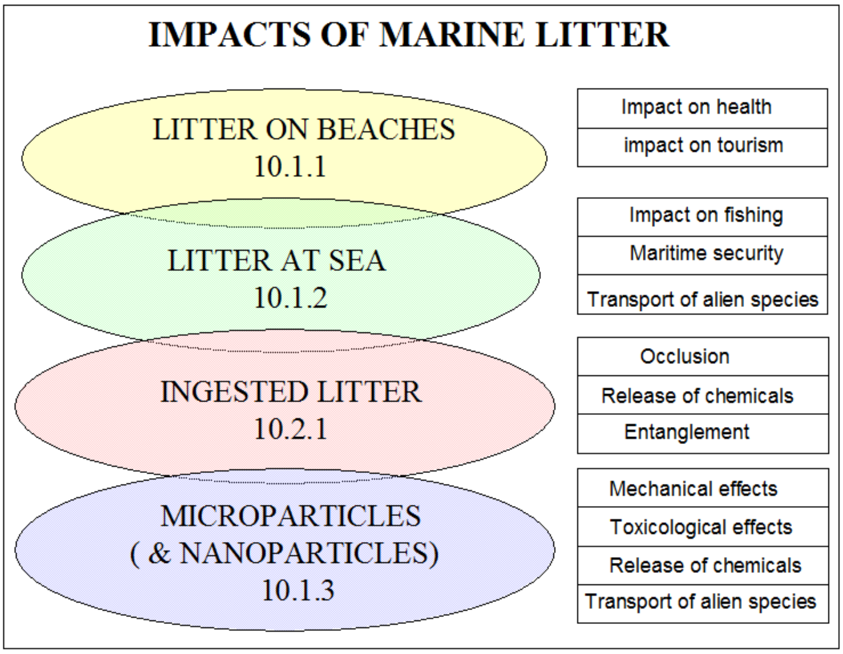

Figure 2: Major impacts of marine litter and related MSFD indicators. Minor impacts such as entanglement in pelagic species, transport of alien species to beaches etc. could be important in specific cases or areas.