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Threshold Values for Marine Litter

General discussion paper on defining threshold values for marine litter

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MSFD Technical Group on Marine Litter

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Contents

Abstract

The revised Commission Decision 2017/848/EU requires EU Member States to establish threshold values for criteria of Descriptor 10 on marine litter. Threshold values, which are now mandatory through the new provisions, are intended to contribute to Member States' determination of a set of characteristics for Good Environmental Status and enable their assessment of the extent to which Good Environmental Status is being achieved under the Marine Strategy Framework Directive (MSFD).

The MSFD Technical Group on Marine Litter has been mandated, through the MSFD 2016-2019 work program of the Common Implementation Strategy, to develop approaches for setting threshold values and to work towards agreed threshold values. This document sets out the scope of setting threshold values for marine litter criteria, explores general concepts of threshold setting and how those concepts can be translated to address the various hazardous effects of marine litter. It evaluates potential options for setting threshold values and their suitability for use with marine litter.

While thresholds for marine litter criteria in different environmental compartments may follow the same basic concepts, they may each require specific approaches and need to be discussed separately. Therefore, basic thoughts are presented and questions are raised, which should be addressed when defining threshold values for litter in the different marine compartments and for marine litter impacts. In conclusion, recommendations for marine litter threshold setting are made.

Foreword

The Marine Directors of the European Union, Acceding Countries, Candidate Countries and European Free Trade Association (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 MSFD. In particular, one of the objectives of the strategy is the development of non-legally binding and practical documents, such as this report, on various technical issues of the Directive.

The MSFD Technical Group on Marine Litter led by the Directorate-General for Environment and chaired by the European Commission Joint Research Centre, the German Environment Agency and IFREMER, is delivering thematic technical reports such as Guidance for Monitoring of Marine Litter, Harm caused by Marine Litter, Identifying Sources of Marine Litter, and Riverine Litter Monitoring – Options and Recommendations. These thematic reports are targeted at experts, who are directly or indirectly implementing the MSFD in the marine regions.

This Technical Report should further support European Member States in the implementation of monitoring programmes and programmes of measures to act upon marine litter.

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1 Background

Descriptor 10 of the Marine Strategy Framework Directive (MSFD, 2008/56/EC) requires EU Member States (MS) to ensure that "Properties and quantities of Marine Litter (ML) do not cause harm to the coastal and marine environment." The process toward reaching this state includes the definition of Good Environmental Status (GES), target setting, monitoring, assessment and the implementation of measures. Assessing the current environmental status requires a comparison between a reference (expected/usual/normal) state and an impacted one. Thus, it is necessary to define the reference values for indicators against which the actual or potentially changed situation can be compared. Therefore, by definition, the determination of GES as required by the MSFD, implies a condition, which has been or can be compared against an anthropogenically altered state, where effects can be demonstrated (Borja et al., 2013).

The MSFD Commission Decision (EU) 2017/848 (COM DEC), which lays down criteria and methodological standards on GES of marine waters, specifies that Threshold Values (TVs) for the criteria of Descriptor 10 (D10) on ML, should be agreed through cooperation at EU-level. This should be done within the framework of the Common Implementation Strategy (CIS) set up by the MS and the European Commission (EC) for the purposes of the MSFD.

The MSFD Technical Group on Marine Litter (TG ML) has been mandated, through the MSFD 2016-2019 CIS work program, to develop approaches for setting TVs and to work towards agreed TVs for Descriptor 10. This document compiles available information and identifies topics for further discussion in order to derive an agreed strategic approach and to facilitate progress towards the setting of TVs for ML Criteria.

2 Scope of setting threshold values

The revised MSFD COM DEC (EU) 2017/848 follows to some extent a different concept in comparison to the requirements of the previous Commission Decision (2010/477/EU). The revised decision requires the use of quantified threshold values for ML criteria instead of trends for assessing the achievement of MSFD aims.

Box 1. MSFD Commission Decision 2017/848/EU

Article 2

Definitions

(5) `threshold value' means a value or range of values that allows for an assessment of the quality level achieved for a particular criterion, thereby contributing to the assessment of the extent to which good environmental status is being achieved.

Article 4

Setting of threshold values through Union, regional or subregional cooperation

1. Where Member States are required under this Decision to establish threshold values through Union, regional or subregional cooperation, those values shall:

(a) be part of the set of characteristics used by Member States in their determination of good environmental status;

(b) be consistent with Union legislation; 18.5.2017 L 125/47 Official Journal of the European Union EN (1) Regulation (EU) No 1143/2014 of the European Parliament and of the Council of 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species (OJ L 317, 4.11.2014, p. 35);

(c) where appropriate, distinguish the quality level that reflects the significance of an adverse effect for a criterion and be set in relation to a reference condition;

(d) be set at appropriate geographic scales of assessment to reflect the different biotic and abiotic characteristics of the regions, subregions and subdivisions;

(e) be set on the basis of the precautionary principle, reflecting the potential risks to the marine environment;

(f) be consistent across different criteria when they relate to the same ecosystem element;

(g) make use of best available science;

(h) be based on long time-series data, where available, to help determine the most appropriate value;

(i) reflect natural ecosystem dynamics, including predator-prey relationships, and hydrological and climatic variation, also acknowledging that the ecosystem or parts thereof may recover, if deteriorated, to a state that reflects prevailing physiographic, geographic, climatic and biological conditions, rather than return to a specific state of the past;

(j) be consistent, where practical and appropriate, with relevant values set under regional institutional cooperation structures, including those agreed in the Regional Sea Conventions.

The calculation of reduction-rates, as requested in the previous COM DEC 2010/477/EU, can still be used as a basis for achieving a given operational TV. Reduction targets, used in this sense, can be especially suitable if they are set for the most frequent litter items/types found in the marine environment in order to validate the effectiveness of reduction and removal measures taken.

TVs, which are now mandatory through the new provisions of the revised COM DEC (2017/848/EU), are intended to contribute to MS' determination of a set of characteristics for GES and enable their assessment of the extent to which GES is being achieved. TVs are used to distinguish between GES being achieved and GES not being achieved, the latter triggering a need for targets and measures. ML, as considered through MSFD Descriptor 10, represents a pressure to the marine environment. Borja et al. (2013), proposed that it might be easier and cheaper to determine GES as the `absence of pressures` (or a reference condition allowing a certain amount of litter as long as it does not cause harm) in a region rather than the `presence of good environment`.

Resource management and efficiency, with associated reduction targets, which have been proposed and set by MS and other international agreements, aim to reduce the input of ML into the marine environment as well as the amount already in the sea within a reasonable and achievable time frame. However, even a significant reduction of e.g. 50 % could leave high litter concentrations in the marine environment in some areas, where litter pollution is elevated well above acceptable levels. Therefore, absolute numeric thresholds are not only required by the COM DEC (2017) but are also beneficial to the well-being of the marine environment. Given that zero litter levels are no-longer achievable, especially due to the high persistence of plastic litter already present in the sea, the central challenge is to define "sustainable" levels, which ensure that the amounts and types of litter, which occur, do not cause significant impacts on or risks to marine biodiversity, marine ecosystems, human health or legitimate uses of the sea as specified in Art. 1(2)(b) of the MSFD.

The setting of TVs commits to a level of litter pollution above which it is agreed that GES has not been achieved. This is related to its potential for causing harm, as discussed in the TG ML report on "Harm caused by marine litter" (Werner et al., 2016). The risk caused by ML is a function of its spatial distribution and quantity within the potential impact area as well as its potential to cause harm. Harm can be to marine organisms and habitats, e.g. through entanglement, ingestion and other forms of biological impact, as well as to humans, e.g. socio-economic harm, human perception of litter and potential consequences to human health. According to Descriptor 10 of the MSFD, GES is achieved, when "marine litter does not cause harm to the coastal and marine environment." This objective prescribes a low threshold of harm requiring the application of the precautionary principle in line with Art. 4, 1. (e) of the COM DEC (EU) 2017/848, which reflects the potential risks of litter to the marine environment. The precautionary principle means setting TVs at a level, where it is certain that litter pollution will not cause harm to the marine environment. This might need to be adjusted at a later stage, if research shows that, at that particular level, harm does not occur. However, it could also infer that combating the highest levels of litter should be first priority and the levels, which cause harm, should be defined, once there is enough evidence available.

While the MSFD provides a legal commitment for MS to address the problem of ML, including micro-litter, as one of the qualitative descriptors for GES of marine waters, the investigation of litter sources and increased awareness of this type of pollution has also led to the consideration of litter as a topic relevant to other EU policies. These policies include the European Strategy for Plastics in a Circular Economy (COM(2018) 28 final), with its related Directive (EU) 2019/904 on the reduction of the impact of certain plastic products on the environment as well as the Water Framework Directive (2000/60/EC), the Waste Framework Directive (2018/851/EC amending Directive 2008/98/EC on waste), the Landfill Directive (1999/31/EC), the Urban Waste Water Treatment Directive (91/271/EEC), the Port Reception Facility Directive (2000/59/EC), the Eco-design Directive (2005/32/EC), the Drinking Water Directive (98/83/EC) and the EU´s Water reuse and Food Protection/Safety policies. Because litter pollution is a cross-cutting issue, the establishment of thresholds for D10 MSFD criteria will need to refer to these policies in order to strive for compatible approaches and resource efficient working processes. An efficient working arrangement could e.g. mean to have agreed TV in the marine environment, where the litter ends up and targets for measures implemented under various policies to work towards the reductions of marine litter pollution. Although these policies should be referred to under the MS Programmes of Measures (PoMs), the setting of TVs should primarily relate to scientific data and risks ("harm") within the marine environment. Therefore, ecologically relevant targets leading to the reduction in litter levels required to achieve a GES, which is based on ecologically relevant values for "harm", should only be developed within the context of the MSFD.

Consultation processes and scientific research are ongoing. Therefore, this discussion paper cannot be conclusive on some aspects, but aims to consolidate the discussion towards the setting of TVs for ML criteria. Before developing actual TVs for the different criteria, the next steps are to determine how litter is measured in the different marine compartments and biota, which types of metrics are involved and which statistical instruments are available for providing baselines and TVs.

A explained above, the TVs to be defined, should be set at a level that does not cause harm to the coastal and marine environment by setting concentration levels (D10C1 and D10C2), levels corresponding to impact levels (D10C3) or to impacts directly (D10C4) that should not be exceeded. D10C1 and D10C2 are to be established at Union level, D10C3 and D10C4 at a regional or subregional level (see Box 2 & 3). However, as already highlighted, a concerted approach is to be developed within TG-ML for all D10 criteria.

Box 2. MSFD Commission Decision 2017/848/EU

Preamble (8)

"For each of the qualitative descriptors listed in Annex I to Directive 2008/56/EC, and on the basis of the indicative lists in Annex III to that Directive, it is necessary to define the criteria, including the criteria elements and, where appropriate, the threshold values, to be used. Threshold values are intended to contribute to Member States' determination of a set of characteristics for good environmental status and inform their assessment of the extent to which good environmental status is being achieved. It is also necessary to set out methodological standards, including the geographic scales for assessment and how the criteria should be used. Those criteria and methodological standards are to ensure consistency and allow for comparison, between marine regions or subregions, of assessments of the extent to which good environmental status is being achieved."

Annex: Criteria for D10 on Marine Litter

D10C1 — Primary: The composition, amount and spatial distribution of litter on the coastline, in the surface layer of the water column, and on the seabed, are at levels that do not cause harm to the coastal and marine environment. Member States shall establish threshold values for these levels through cooperation at Union level, taking into account regional or subregional specificities.

D10C2 — Primary: The composition, amount and spatial distribution of micro-litter on the coastline, in the surface layer of the water column, and in seabed sediment, are at levels that do not cause harm to the coastal and marine environment. Member States shall establish threshold values for these levels through cooperation at Union level, taking into account regional or subregional specificities.

D10C3 — Secondary: The amount of litter and micro-litter ingested by marine animals is at a level that does not adversely affect the health of the species concerned. Member States shall establish threshold values for these levels through regional or subregional cooperation.

D10C4 — Secondary: The number of individuals of each species which are adversely affected due to litter, such as by entanglement, other types of injury or mortality, or health effects. Member States shall establish threshold values for the adverse effects of litter, through regional or subregional cooperation.

Box 3. MSFD Commission Decision 2017/848/EU

Preamble (13)

"Threshold values should reflect, where appropriate, the quality level that reflects the significance of an adverse effect for a criterion and should be set in relation to a reference condition. Threshold values should be consistent with Union legislation and set at appropriate geographic scales to reflect the different biotic and abiotic characteristics of the regions, subregions and subdivisions. This means that even if the process to establish threshold values takes place at Union level, this may result in the setting of different threshold values, which are specific to a region, subregion or subdivision. Threshold values should also be set on the basis of the precautionary principle, reflecting the potential risks to the marine environment. The setting of threshold values should accommodate the dynamic nature of marine ecosystems and their elements, which can change in space and time through hydrological and climatic variation, predator-prey relationships and other environmental factors. Threshold values should also reflect the fact that marine ecosystems may recover, if deteriorated, to a state that reflects prevailing physiographic, geographic, climatic and biological conditions, rather than return to a specific state of the past."

Preamble (15)

"It is necessary to lay down TVs which will be part of the set of characteristics used by MS in their determination of GES in accordance with Article 9(1) of the Directive 2008/56/EC, and the extent to which TVs are to be achieved. TVs therefore do not, by themselves, constitute MS` determination of GES."

While the setting of qualitative or quantitative reduction targets provides an overall ambition to move towards GES, the efforts needed in different geographical areas will vary. The effort is also dependent on the decision to set consistent thresholds for all regions at EU level or not. However, TVs should be set on a scientific basis without considering the measures required to reach them, which is a task for managing at a later stage.

The definition of scientifically derived TVs enables the identification of a desirable situation across Europe considering regional and subregional specificities, which is approved by MS at the Marine Strategy Coordination

Group (MSCG) based on TG-ML proposals and which provides an equal level of protection from harm throughout Europe. In the framework of the MSFD the ecological threshold concept is closely linked to adaptive management as a tool for addressing environmental pressures. In adaptive management, measures, as solutions to problems, are proposed and implemented. However, specifications are constantly re-evaluated based on actual ecosystem response to management. As requested by the MSFD, monitoring/measurements in the marine and coastal environment are used as a tool for supporting iterative management decisions concerning the implementation of PoMs. Monitoring is the means of assessing the current status, which then drives the need (or not) for measures.

Although the thresholds for D10C3 and D10C4 will vary between subregions due to the spatial distribution of appropriate species, it is proposed to discuss the approach of setting thresholds for both criteria at the EU level, in order to provide coherence, a common base for further work and to avoid duplicating work. It is therefore of prime importance to involve experts from MS, the scientific community, environmental NGOs and Regional Sea Conventions (RSCs) in the discussion.

While thresholds will need to be adopted at the national level, ML is a transboundary problem and litter crosses national borders. Achieving TVs will require close collaboration between neighbouring countries, especially in the framework of RSCs, including those outside the EU. Therefore, although ideally TVs are to be set at European level, there is also need for cooperation within a global framework. International agreements are needed e.g. with United Nations (UN) agencies, like the International Maritime Organization (IMO), to tackle sources like shipping. If thresholds and targets to reduce litter in the marine environment have already been adopted in other fora, targets and thresholds defined under the MSFD should ideally be compatible and comparable.

The COM DEC (EU) 2017/848 states explicitly that, in cases where TVs have not been defined, MS should establish TVs through Union, regional or subregional cooperation. Furthermore, the decision stresses that TVs should be set at appropriate geographic scales to reflect the different biotic and abiotic characteristics of the regions and subregions, which may result in the setting of TVs, which are specific to a region or subregion. If the TVs for each of the D10 criteria do vary between regions or subregions, the ongoing work will primarily focus on discussing and proposing a common approach on how to set these values. The equal level of protection across Europe should be ensured by the definition of a common/harmonized approach to setting TVs while considering the physical and biological specificities of regions and subregions.

3 General concepts of threshold setting

Box 4. General definitions of the meaning of thresholds for discussion

Oxford dictionary (*https://en.oxforddictionaries.com/definition/threshold*)

"The magnitude or intensity that must be exceeded for a certain reaction, phenomenon, result, or condition to occur or be manifested."

Groffmann et al., 2006

"The point at which there is an abrupt change in an ecosystem quality, property or phenomenon, or where small changes in an environmental driver produce large responses in the ecosystem."

Rosenthal, 1997

"The dose of the toxicant below which no adverse effects will occur."

The setting of TVs assumes that specific values of a parameter can be derived in a quantitative way in order to provide protection against adverse effects. This is not always possible, due to lack of knowledge, inaccuracy of quantification or the nature of adverse effects and cumulative unknown effects of several pressures acting together. Furthermore, analysis of thresholds is complicated by nonlinear dynamics and multiple factor controls that operate at diverse spatial and temporal scales (Groffmann et al., 2006).

3.1 Harmful effects of marine and beach/coastal litter

The effect of a toxic substance is typically described by the endpoints, i.e. the biochemical pathways and the mode-of-action through which the substance acts on the metabolism. A toxicity endpoint is the result of a study conducted to determine how dangerous a substance is. However, the toxic component is just part of the range of impacts caused by ML. Therefore, in the following, an attempt is made to translate the concept of toxic endpoints to address the various hazardous effects of ML, namely:

- Toxicological action mode (lethal and sublethal)
- Physical damage such as entanglement, intestinal obstruction (lethal and sublethal)
- Disturbance of human activities (sublethal)
- Human health implications (sublethal and lethal)

An overview of "Harm caused by marine litter" is provided in a report published by the TG ML (Werner et al., 2016). The general conclusions of this report are:

- The numbers of animals affected by negative interactions with ML and the associated suffering that affects animal welfare, in combination with the extent of encounters which in some represent a substantial proportion of a population, clearly show that reductions in further input and of existing amounts of ML are urgently needed.
- The relative importance of plastic as a solid environmental contaminant is likely to increase over time. Even if the introduction of large items of litter into the marine environment ceases, the abundance of micro-plastics will continue to increase because of the fragmentation of larger plastic items (legacy items). What we do today will strongly influence future quantities of micro- and potentially nano-particles.
- About the quality of evidence, it can be concluded that monitoring of impacts on biota is challenging, but there is clear evidence of harm to individuals and, to a lesser extent, assemblages of organisms and populations of some species. There is evidence that increasing numbers of species are experiencing encounters with ML with manifold consequences.

The report provides available evidence of relevant impacts of ML and some specific conclusions, which includes information on entanglement, ingestion, chemical transfer, ML as a vector for biota, marine litter altering/modifying assemblages of species, levels of biological organization affected, animal welfare, socio-economic harm and risk assessment for ML.

3.2 Marine and coastal litter as a pollutant

Article 1(2)(b) of the MSFD requires prevention and reduction of inputs into the marine environment, in order to phase out pollution as defined in Article 3(8), so as to ensure that there are no significant impacts on or risks to marine biodiversity (also in microbial communities), marine ecosystems, as well as socio-economic implications.

Thresholds are used to protect the environment and humans against detrimental disturbances/pollution levels of substances of concern. The setting of thresholds for ML and its effects appears similar to this type of application. Therefore, concepts from chemical pollution could be relevant for setting TVs for ML and are being discussed regarding their applicability. In this context and referring to the scope of Article 3(8), litter should be considered as a pollutant causing physical and chemical harm to biodiversity, human health, uses of the sea, etc.

One should also keep in mind that plastic pollution in the marine environment is being considered as a planetary boundary threat. From a stratigraphic perspective, there is a clear Anthropocene threshold between pre-plastic and post-plastic systems, but for a chemical pollutant to pose a planetary boundary threat, its environmental exposure and/or its disruptive effects must be poorly reversible. Plastic pollution in the marine environment will always fulfil this condition, as the ultimate end-fate of most mismanaged plastics is that they end up deposited and compartmentalised in the ocean (Villarrubia-Gomez et al., 2017). Given the long timeframes for the degradation of plastics, we do not know if the disruptive effects (e.g. smothering of seafloor, ecotoxicological effects from nano-plastics) are, in the end, reversible or not.

The pollution of the environment by chemical substances has been addressed by setting TVs based on scientific knowledge and experimental data. For example, the Water Framework Directive (WFD) provides a scheme for the setting of environmental quality standards for chemical pollutants in the freshwater and marine environment: WFD TGD EQS setting[1]. Litter (including macro, meso and micro-litter) could be regarded in this way too. As already highlighted, the introduction of litter into the marine environment causes chemical vector effects. However, ML is causing additional impacts such as physical harm/damage of marine species and habitats and disturbance of human activities as well as socio-economic harm, which need to be addressed, too.

Threshold concepts of toxicological concern are based on the possibility of establishing an exposure TV below which no significant risk is to be expected. By determining the “no observable adverse effect level” and the “lowest observable adverse effect level”, the (absolute) threshold must lie between these two doses (Rosenthal, 1997). However, in case of uncertainty about the caused effects, the concept of “thresholds of no concern” (which is a conservative approach using levels where effects were not observed or expected to be observed) has been applied in the food safety area[2].

The outputs of relevant projects, such as JPI Oceans (Intergovernmental platform Joint Programming Initiative Healthy and Productive Seas), will be considered once they become available.

3.3 Requirements and uncertainties related to TVs

While thresholds are expressed as numerical values, it should be kept in mind that they have been derived from underlying data, with uncertainties. These uncertainties must be considered in TV developments. In practical applications, this is often taken into consideration by applying ample safety factors to the TVs in order to take gaps in knowledge and uncertainties in the data into account. However, uncertainty becomes more of an issue, when measured levels are very close to a GES threshold, where it is then unclear if GES is achieved or not. If GES is clearly out of reach, there is a need to act (take measures) and the degree of uncertainty is less of an issue.

A basic pre-requirement for the setting and compliance checking with TVs is the availability of a monitoring framework for data collection that supports representative quantitative assessments of litter in appropriate environmental compartments and that delivers data with a known uncertainty allowing for comparison against TVs. The potential costs in case of non-compliance with agreed TVs are supposed to create a joint incentive to comply with them.

The concept of thresholds assumes that there are levels of pollutant concentrations that, according to scientific studies, do not cause significant impacts on or risks to marine biodiversity, marine ecosystems, human health or legitimate uses of the sea as specified in Art. 1(2) b of the MSFD. This implies the ability to identify amounts

(1) https://circabc.europa.eu/sd/a/0cc3581b-5f65-4b6f-91c6-433a1e947838/TGD-EQS%20CIS-WFD%2027%20EC%202011.pdf
(2) https://www.efsa.europa.eu/en/topics/topic/threshold-toxicological-concern

or concentrations of litter in areas with an affected environmental status, but where litter does not significantly impact the marine or coastal environment. This will not work for all types of ML, e.g. those especially prone to cause entanglement. The setting of quantitative thresholds requires monitoring data of sufficient quality and in agreed matrices, in order to allow compliance checking against TVs. This applies to the unit of measurement, as well as to the environmental compartment or species, and the harmonization of micro-litter quantification. Properties that ML thresholds should have, are listed below:

- Ideally, they should be based on scientific evidence and long-time series of data.
- They should be set so that they are achievable, but always in relation to a harm level. If the scientific evidence clearly demonstrates the need to set very low thresholds, this should be done, regardless of the achievability. There will be litter reductions that are more easily achieved than others (cost, practicality, societal willingness), but to prevent harm to the marine environment has priority in defining TVs, whereas achievability comes secondary.
- They should enable compliance checking through existing and implemented monitoring protocols.
- They should be numerical values and be based on a comparable expression of litter quantities and effects for the different marine reporting units.
- They should be based on the precautionary principle, reflecting the potential risks to the marine and coastal environment.
- They should be set in relation to reference conditions, a probable effect situation or a no-effect situation.
- They should be based on reference conditions, which will be very dependent on the chosen geographic scale; EU, regional, subregional or local.
- They should be consistent with thresholds set under other criteria for the same element (species, habitat).
- They should be set at appropriate geographical scales of assessment and be consistent, where practical and appropriate, with relevant TVs set under regional institutional cooperation structures within an EU framework as well as with those agreed in the RSCs.

3.4 Risk assessment

TVs should represent a pressure level, which ensures that there are no significant impacts on, or risks to marine biodiversity, marine ecosystems, ecosystem functioning, species, habitats, individuals/populations, human health, societies or economics or legitimate uses of the sea. These provisions require the identification, quantification and prioritization of harmful effects. This also includes the identification of significant versus non-significant risks of harm, the societal agreement on acceptable risk levels, and thus the introduction of quantitative evaluation criteria. While there is longstanding experience of environmental and human risk assessment, e.g. for chemical contaminants, such approaches for ML are still under development. The risks related to ML and the concept of using a risk assessment approach for ML have been described in a TG ML report on harm (Werner et al., 2016). A quantitative risk assessment approach for ML, in the sense that risk of harm is used to set TVs, should be discussed (analogous to contaminants).

The assessment of risk is also relevant to the prioritization of measures against specific litter types, because some litter types pose a greater threat to the marine environment than others do. This implies that thresholds should be set for individual litter types, groups of litter types or sub-criteria elements, which could be used to set operational reduction targets and hence measures and actions.

3.5 Existing threshold values for marine litter

There are currently few established TVs for ML. One exception is the objective of the OSPAR indicator on plastic particles in the stomachs of the Northern Fulmar *Fulmarus glacialis*. The monitoring program uses corpses of beached birds or individuals accidentally killed. OSPAR has a long-term objective of less than 10 % of fulmars exceeding a level of 0.1 gram of plastic in their stomach contents. This is regarded as a pressure TV correlated with impacts. Other potential TVs correlated to impacts or directly representing impacts are presently under discussion e.g. (i) the number of plastic pieces in turtle stomachs occur below levels that might affect the body condition and cause mortal effects, and (ii) plastic litter used as nesting material in seabirds' breeding colonies is below amounts observed in least polluted areas in order to reduce mortality rates due to entanglement.

Thresholds should also take population level effects into account by considering the state of the population as a whole. If the population of a species is already threatened by other factors, then an even lower litter impact should be aimed for. For instance, some harbour porpoise *Phocoena phocoena* populations are already threatened and a threshold for by-catch of zero individuals in active fishing gear is proposed. This has to be taken into account when assessing entanglement/mortalities in Derelict Fishing Gear.

In addition, litter reduction targets (Art 10 MSFD) have been defined by some countries/regions in the framework of Regional Action Plans on ML and the MSFD PoMs. These are based on a percentage reduction over time in the amount of litter entering the marine environment and/or the amount of litter already present in the marine environment as well as microplastics applied in products and industrial processes.

4 Options for setting threshold values

As already expressed, harm caused by marine litter is manifold. Depending on the type of harm (e.g. ingestion, entanglement, habitat alteration, socio-economic etc.), different levels of litter pollution must be considered for threshold setting and possibly also different thresholds for different types of litter.

Different options and concepts for setting of thresholds are presented below. These are provided as a non-exhaustive list with the aim of stimulating discussion (the order does not represent a prioritization).

4.1 The zero option

ML items are mainly made up of artificial polymers, which, by definition, do not exist in nature. Some litter items are made from other materials, though their origin is still anthropogenic. The ultimate goal for avoiding harm caused by litter could be a waste free environment. However, plastics are widely used and are currently very abundant in the marine environment. The ubiquity of marine plastic litter and the unfeasibility of its total removal from the marine environment, especially in the case of micro-particles, means that exposure is essentially irreversible (Villarrubia-Gomez et al., 2017). On the short-term or even the intermediate to long-term, it will be impossible to prevent all input of litter to, or remove all litter from, the marine environment. Thus, the setting of a TV of zero litter, even on the long-term, may not be a realistic/operational option, because it would not be achievable. However, it can still be treated as a reference condition considered as the ultimate goal to achieve.

4.2 Points-of-no-return and tipping points

Points-of-no-return are system condition parameter values that indicate a level, which, when surpassed, will lead to irreversible alterations in system conditions (playground slide effect). A point-of-no-return might be reached if, due to ML, a population declines beyond recovery. This could also include declines as a result of cumulative effects with other detrimental factors. However, population-level effects have been difficult to quantify for ML. All factors affecting a population need to be studied to determine how much additional mortality or reduced fitness the population can tolerate, before a threshold for litter-based effects can be set.

Tipping points are system condition parameter values that indicate a level, which, when surpassed, will alter system conditions drastically (see-saw effect). These effects may occur in cases of extremely high litter concentrations.

Both approaches, point-of-no-return and tipping points, are only applicable to population-level effects. Since they both refer to a status that is opposite to GES, being points of no return in terms of values, above which harm is already occurring, they are not options for setting ML thresholds. In addition, there is currently not enough data available to support such an approach. Once this data becomes available, it would be necessary to use safety factors/uncertainty factors to prevent irreversible alterations.

4.3 Precautionary approach

There is clear evidence of harm to many marine species caused by ML, largely on individuals and to a lesser extent on assemblages of organisms and populations (Werner et al., 2016). There is evidence that increasing numbers of species are experiencing encounters with ML with multiple/numerous consequences. However, conclusive scientific knowledge on the quantitative relationship between the amount and the exact rate of harm caused by ML is currently only partially available, especially regarding sub-lethal effects. As research is currently unable to provide clear TVs, an initial approach to setting TVs should make use of the precautionary principle, thus providing the maximum protection against adverse effects by introducing large safety margins. This could be based on an expert judgement approach (a subjective opinion based on scientific evidence), by eliciting the expertise of a wide range of qualified contributors to make sure that such judgement is demonstrably robust and explicitly stated. Currently models for using expert judgement are under development, especially in quantitative risk assessment. This approach should be used especially for micro-plastics, tackling their input from various sources

A threshold based on the precautionary principle may e.g. allow the setting of thresholds if the quantitative concentration/risk relation is not known, but there are indications of risk. Another way is the concept of using litter pollution levels from pristine or near-pristine areas as TV, as was done for the OSPAR litter in fulmar stomachs indicator. This means accepting a slight deviation from the reference (pristine) condition by using the situation of least pollution found elsewhere in the environment of concern.

4.4 Cut-off values

There is societal agreement on the need to reduce the amount of litter, especially plastic litter, in marine ecosystems. The presently high litter pollution levels are not considered tolerable. The tolerance of certain levels of pollution by the public is the key element to be considered here. Disturbance of human wellbeing is a component of socio-economic harm. It might be possible to define levels of pollution linked to targets, which are acceptable to society. People envisage the environment as degraded, when they see litter or hear that marine animals have litter in their digestive systems. While scientific research is still investigating the physical and chemical effects as well as toxicological properties and impacts of litter, areas of potentially high impact can already be predicted based on concentration/abundance mapping. In addition to available information on highly polluted regions, increased surveillance is providing comparable and representative data for areas of lower impact. Assessing litter abundance of specific litter types or groups of litter types (e.g. single-use plastics) should allow the identification of heavily polluted versus near-pristine areas, taking also cross-border processes and transport into account. This information will then enable the prediction of litter concentration thresholds that, while not yet based on quantitative harm/impact data, can minimize litter impact, and can be conceived as tolerable to society.

Such cut-off values could be defined as a proportion or a percentile in relation to reference conditions, averages or maximum concentrations. The rationale for this approach is that the lower concentrations, which already exist in certain areas, should be the goal for other areas. This concept would be supported by the requirement of an equal level of protection in all areas and seas.

4.5 Lowest endpoint

In this case the threshold is set to the lowest concentration causing an adverse effect on one of the specific types of harm. For ML this denotes that, while it might be difficult or impossible to decide on the relative importance of different adverse effects such as toxicological, entanglement or socio-economic, the lowest TV will be most relevant. Thus, if a TV, based on a perceived disturbance by beach visitors, is occurring at a lower litter abundance level than other impacts, it would determine the threshold level. However, this option requires substantial knowledge of the different adverse effects before it can be applied in practice.

4.6 Non-deterioration

While the application of reduction percentages does not foresee an increase of litter concentrations and impacts, the MSFD goal to prevent deterioration of the marine waters and coastal environment should be addressed. According to MSFD Article 1(2) EU MS shall protect and preserve the marine environment, prevent its deterioration or, where practicable, restore marine ecosystems in areas where they have been adversely affected. Similar to the WFD, the non-deterioration approach could usefully be combined with other options of setting TVs. The setting of absolute TVs at an EU-level should not allow increases in litter pollution in countries where litter pollution levels are already below the TV. This will be especially important as we struggle to determine thresholds for micro-plastics. There is no consensus yet on how risk assessment for micro-plastics should be conducted, and attempts are currently hampered by a lack of data. It is therefore important to stress that, especially for micro-plastics, there should be no allowances for increases.

A combined approach of non-deterioration, based on existing data, alongside a precautionary approach, with proposed TVs, which are reviewed, when new scientific and monitoring data are available, could be a possibility.

5 Towards thresholds for marine litter

The discussions on thresholds for ML in TG-ML will not be straightforward due to the current limited state of knowledge. It will certainly require initial exchange of information between MS. The COM DEC (EU) 2017/848 provides options for bridging the time until jointly set TVs are set:

Box 5. MSFD Commission Decision 2017/848/EU

Preamble (12)

"In cases where no threshold values are laid down, Member States should establish threshold values through Union, regional or subregional cooperation, for instance by referring to existing values or developing new ones in the framework of the Regional Sea Conventions. In cases where threshold values should be established through cooperation at Union level (for the descriptors on marine litter, underwater noise and seabed integrity), this will be done in the framework of the Common Implementation Strategy set up by the Member States and the Commission for the purposes of Directive 2008/56/EC. Once established through Union, regional or subregional cooperation, these threshold values will only become part of Member States' sets of characteristics for good environmental status when they are sent to the Commission as part of Member States' reporting under Article 17(3) of Directive 2008/56/EC. Until such threshold values are established through Union, regional or subregional cooperation, Member States should be able to use national threshold values, directional trends or pressure-based threshold values as proxies."

It might be advisable to attempt to reach agreement on provisional thresholds at EU-level, rather than moving towards a situation with many different national approaches across Europe. This might include setting values for levels, which would be clearly unacceptable considering the precautionary principle. These TVs could be adjusted in the future, as evidence on harm improves.

The derivation of provisional thresholds could be done by compiling information on the current state of marine and coastal litter pollution, including patterns across regions and their change over time and, where sufficient data is available, by considering the baselines and, in a final step, by defining the methods used for data processing. It could be helpful to use intermediate/provisional TVs/directional trends for criteria that do not yet allow for the setting of ultimate TVs. Proposals for possible intermediate thresholds should also include the option of non-deterioration

Furthermore, the COM DEC only refers to two types of indicators: the absolute level type and the type stating a required percentage reduction. However, in other descriptors, where knowledge is currently insufficient to define levels for one of the two types, the requirement is simply that a significant trend over a specified period should occur. This option, which lies somewhere between a percentage decrease and non- deterioration, should be considered for use with ML. However, in order to detect a trend, long time series of data are usually a prerequisite and such data is not yet available for ML in all areas, since many countries only started monitoring around 2015.

The contribution of stakeholders from different backgrounds will be beneficial to the further process of defining TVs. For instance, the involvement of behavioural scientists could add significant value to this discussion.

6 Thresholds for individual MSFD COM DEC (EU) 2017/848 Descriptor 10 criteria

While thresholds for ML in the different marine compartments (coastline, surface layer of the water column, seabed) may follow the same basic concepts, they might each require specific approaches and need to be discussed separately.

In the following, basic thoughts and questions are raised, which should be discussed further taking into consideration the approaches set out above, when working on the definition of TVs for the different ML criteria.

6.1 Litter on the coastline (beach litter)

- TVs should be based on data on the abundance of litter recorded during beach surveys. TVs should be cut-off values (absolute/percentiles) determined through expert judgement. TVs for groups of litter types (i.e. all plastic items, all packaging items) as well as individual litter types should be defined in order to be able to assess the efficiency of measures and instruments aimed at reducing ML. TVs developed for litter types or groups of litter types, should be based on the identification of a "near-to-pristine" condition (Schulz et al., 2013), which, would strive towards a status where less harm is caused.
- There is a potential conflict between 'based on expert judgement' and 'near-to-pristine', as the latter may intrinsically involve expert judgement. The term 'near-to-pristine' needs to be defined more clearly, but may be linked to litter occurrence in remote areas, as e.g. the Arctic.
- Interim targets toward achieving the TV could be based on reduction trends for the six-year MSFD assessment cycle. The calculation of an interim target could be performed by defining a baseline and setting a reduction target of a given percentage or a downward trend from that baseline for a set period. The baseline can be calculated from existing data from beach litter surveys. A 30 % reduction from a baseline of e.g. 60 items/100 m would give a target value of 42 items/100 m. An annual reduction of 10 % over a six-year period from a baseline of 60 items/100 m would give a target value of 31.89 items/100 m (i.e. for a six-year period, an annual 10 % reduction is about the same as a total 50 % reduction). Interim reduction targets need to be ambitious in order to achieve a prescribed TV within a couple of MSFD cycles e.g. a 10% reduction per year from 60 items would take about 14 years to reach a TV of 13 items/100m.
- It is important to determine cut-off values using a sound analysis of reliable data.
- A focus should be on plastic litter, which is dominated by single-use and fishery-related items and linked to the Plastics Strategy and the associated directive on the reduction of the impact of certain plastic products in the environment.

6.2 Surface layer of the water column

- For litter on the surface layer of the water column far less data is available than for beach litter. Nevertheless, the same approach as for beach litter could be used by analysing existing data sets, where available, and determining a close-to-pristine state using percentile values of those data sets. The analysis of data and definition of TVs could be done at a sea-basin level.
- If litter in the stomachs of seabirds, such as the Northern Fulmar, are used as an indicator of litter on the water surface, a draft TV is already available for the North Sea (OSPAR indicator). However, birds do not ingest all litter types and ingestion is generally limited to smaller litter items (meso & micro) and thus the type of litter assessed is not representative of litter on the sea surface overall. Additionally, for some areas (e.g. the Baltic Sea), indicator species have yet been identified. Although it is accepted that the birds, which are used as samples, are representative of the marine waters, where they are collected, information on where the individual birds, live, feed, breed and die is limited.
- Abandoned, lost and otherwise discarded fishing gear (ALDFG), which also can occur in the surface layer of the water column, also needs to be considered, when defining TVs.

6.3 Seafloor litter

- Seafloor litter data is mostly available from bottom-trawl-net fishing.
- The availability of information on the dynamics of litter on the seafloor is limited.

- Monitoring methods are lacking for large areas of the seafloor, where bottom trawling is not possible. For such areas, innovative methods need to be developed and implemented. Since bottom trawling is destructive to the seabed, data must only be collected as a by-product of other scientific surveys e.g. fish-stock assessments (platforms of opportunity).
- Certain areas of the seafloor are final sinks for litter. Under the assumption that most ML is highly persistent material, in some areas litter quantities on the seafloor are unlikely to diminish over time. In this respect, the removal of ML by Fishing-for-Litter (FFL) activities is probably relatively negligible in most areas and the proportion of seafloor litter, which is washed up on the coastline, is unknown.
- Hotspots, accumulation zones and sinks need to be considered, when collecting data on seafloor litter. For monitoring chemicals, specific accumulation zones are used, which are believed to be representative of a larger area such as a sea basin. This idea could be applied to seafloor litter.
- Thresholds could be derived for certain litter types, prioritising litter types, which are especially harmful (e.g. lost and discarded fishing gear such as nets and remains of nets). That implies the need for improvement in monitoring especially in areas where trawl surveys are not possible. The use of innovative methods for monitoring seafloor litter, such as side-scan-sonar or ROVs, could support the development of TVs for this marine compartment.

6.4 Micro-litter (beach/coastal, sea surface, seafloor)

Box 6. Shortlist of prerequisites needed for threshold setting for micro-litter

— Set-up and/or extension of a reliable database providing comparable data including:

— Determination of environmental compartment(s) to be investigated (beach sediment, seabed sediment, surface water, water column, biota)

— Definition of reference sampling sites based on regional or subregional level

— Definition on temporal resolution of surveys

— Agreement on harmonized methods for sampling, sampling design, sample preparation and identification

— Identification of further basic parameters (such as meteorology, morphology, sediment parameters, etc.)

— Agreement on reference units and reporting values (size, weight, shape, colour, etc.)

— Central documentation and statistical evaluation

- It is currently difficult to derive TVs based on the toxicological and other properties of marine micro-litter. There is a need for a combined approach considering societal concerns and especially the inability, in many cases, to exclude impacts, as no conclusive information on potential harm is available.
- However, information is available for mechanical/physical impacts; ongoing literature reviews (e.g. by the ECHA/JPI Oceans) should be consulted.
- Monitoring frameworks and QA/QC schemes are under development, as well as monitoring schemes and strategies.
- The latest scientific findings should be considered (development is ongoing).
- It may not be possible to derive toxicology-based thresholds for marine micro-litter at present.
- It is assumed that the major part of micro-litter is resulting from degradation of macro litter. It is extremely challenging to set TVs for such secondary micro-plastics.
- According to the COM DEC (EU) 2017/848, micro-litter shall be monitored in a way that can be related to point-sources for inputs (such as harbours, marinas, waste-water treatment plants, storm-water effluents), where feasible.
- Focus should be on input from sewage, rivers and estuaries. Atmospheric and sea-based sources as well as fragmentation processes should be second priority. Whether the focus should be on wastewater treatment and/or on microplastics out at sea, needs clarification.

- Fluxes between sources, pathways and sinks (even temporary sinks) need to be considered. Since seabed sediments are final sinks for microplastics, TVs for their concentration in sediments could be the most relevant approach. However, it could be better to wait until effects of microplastics on benthic organisms are better known.
- Sediment sampling also allows for the assessment of different size fractions and could potentially also be used to assess the litter flux from the water column.
- Reference sites need to be identified for monitoring trends.
- A precautionary approach needs to be applied to pathogens, which might severely impact on the marine environment. However, although some initial evidence is available, it is too early to draw conclusions.
- In some countries, the proposal for (large) micro-litter is to set thresholds similar to the OSPAR indicator on plastic particles in the stomachs of the Northern Fulmar i.e. that a certain percentage of the area of a compartment of the marine environment, e.g. beach, water surface, seafloor, should not contain more than a certain amount of micro-litter.

6.5 Ingested litter

- The amount of litter ingested and potentially causing entanglement must be reduced drastically; D10 criteria 1 and 2 support this.
- The approach for quantification of ingestion if ML by different target species is still under development.
- The approach for Northern Fulmar in the North Sea (OSPAR common indicator) is available and has been used for many years. The TV could aim at the same goal as the OSPAR indicator, which relates to close-to-pristine conditions.
- Thresholds for ingestion of litter by turtles, based on the work of Matiddi et al. (2017), were developed during the INDICIT project and are available.
- In some areas (see also Werner et al., 2016) it could be feasible to set thresholds for individual species because around 40 % of the individuals of some populations ingest ML.
- Numerous results are now available for benthic and pelagic fish species, for example from the ICES fish disease surveys. Although these surveys include a bias since they are only possible in areas with a certain sediment, which will need to be corrected for, they have potential as good indicators, if the right species are chosen.
- Effects of micro-plastic exposure on predator-prey interactions have not yet been established in the marine environment. However, there is abundant evidence that animals do consume plastics, possibly mistaking litter and plastic particles for prey (De Sa et al., 2018).
- Micro-plastics have been shown to alter feeding behaviour as well, and feeding preferences can affect propensity to ingest plastics (Mizraji et al., 2017).
- Upcoming monitoring of micro-plastics should include sentinel species such as filter feeders, which are known to ingest plastic particles (e.g. blue mussels).
- The achievement of GES with regard to Criterion D10C3 has the potential to fail when populations are simultaneously in- or decreasing, e.g. through successful measures taken or measures not taken to combat other pressures. Therefore, the work on this criterion should initially aim to monitor the proportion (%) of individuals impacted by ingestion of ML relative to the total number of individuals in the studied population, while taking into account information available for other anthropogenic pressures.

6.6 Entanglement or other forms of injury/sub-lethal effects or death

- The approach for quantification of entanglement events is still under development. Entanglement was included as a secondary criterion in the revised COM DEC in 2017. Only a few monitoring approaches have been tested so far.
- The protocol to assess entanglement in seabird colonies, which is recommended by TG Litter, has been applied in the Gannet colonies on the islands of Helgoland in the North Sea and Grassholm off the

coast of Wales. Options for thresholds could be the number of entangled birds/unit of colony and calculated mortality rates from entanglement.

- The link between seafloor litter and entanglement requires further discussion (e.g. with regards to rates of interaction between animals and ML).

6.7 Thresholds for individual litter items/types

As reduction measures will target specific litter types, or groups of litter types, as well as sources and pathways, thresholds could also be set for these different levels (e.g. plastic drink bottles, plastic bags, packaging, pre-production pellets, fishing nets, sewage-related litter or single use plastics). These litter type or litter group-related TVs should be derived in relation to measures, e.g. for specific litter types or groups of litter items. However, they should still be based on risk for harm to the marine environment, and the assessment should then inform on the need for measures under relevant legislation. This must consider EU-level legislation, related to the EU Plastics Strategy, as well as RSCs in order to be aligned with the operational reduction targets, which exist within the framework of the Regional Action Plans on ML.

7 Conclusions and recommendations

Based on the discussions within the TG ML, the following recommendations for ML threshold setting are proposed:

- Threshold values define agreed borderlines which contribute to the definition of GES.
- The COM DEC (EU) 2017/demands the development of thresholds for ML criteria to protect the marine environment and human activities against all types of harm caused by litter, which include physical damage, toxicological responses, disturbance of human activities as well as socio-economic harm.
- Before discussing individual TVs, agreement on the concept and approach should be reached.
- Thresholds for ML should ideally be set at EU-level in order to provide equal protection across the EU. However, there may be sound reasons for setting (sub-)regional values, e.g. where different species are involved.
- ML is a global problem. Nevertheless, TVs need to be set at a specific geographic scale and assessed at that scale or possibly finer spatial scales. For instance, TVs could be set at a regional scale (if it is not appropriate to have them set at EU-level) and then assessed at finer spatial scales e.g. to assess whether the threshold has only been achieved by some MS or even in part of a MS marine waters.
- Thresholds for ML can only be set if it is possible to check compliance against quantitative values from monitoring.
- Thresholds for ML are to be set for the individual criteria as defined by the COM DEC (EU) 2017/848 and specifically for defined litter size-fractions and possibly also for litter types/categories.
- The derivation of thresholds for ML requires the distinction between significant and non-significant risks of harm as well as a societal agreement on acceptable risk levels and, thus, the introduction of quantitative evaluation criteria.
- TVs for ML should be set at the appropriate spatial scale which should be compatible with other litter-relevant spatial scales, such as those used for the calculation of baselines.
- Although monitoring of impacts on biota is challenging, there is clear evidence of harm to individuals. To a lesser extent, there is evidence of harm on assemblages of organisms as well as on populations of some species. It is, therefore, in some cases, possible to set TVs for ML based on biological dose-response relationships.
- It is currently not possible to set agreed TVs for ML based on quantitative toxicological dose-effect relationships.
- Due to the transboundary nature of ML pollution, the compliance with thresholds may require multilateral measures and international as well as regional cooperation.
- The natural state of the seas, which is the ultimately desired state, is a litter-free environment.
- The present level of litter pollution in the marine environment of the EU is considered unacceptable, because it reduces wellbeing, generates high costs to local communities, can cause harm to human health and hinders the use of the sea for recreational use.
- The setting of TVs at litter pollution levels in least contaminated areas appears reasonable.
- For criteria that do not yet allow the setting of quantitative TVs, which are based on established baselines, intermediate targets could be established, based on the precautionary principle aiming at a downward trend or non-deterioration.

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List of abbreviations and definitions

ALDFG	Abandoned, lost and otherwise discarded fishing gear
CIS	Common Implementation Strategy
COM DEC	Commission Decision
D10	Descriptor 10
DG ENV	Directorate-General for Environment
EC	European Commission
EFTA	European Free Trade Association
EU	European Union
FFL	Fishing-For-Litter
GES	Good Environmental Status
IMO	International Maritime Organization
JPI	Joint Programming Initiative
JRC	Joint Research Centre
ML	Marine Litter
MS	Member State
MSCG	Marine Strategy Coordination Group
MSFD	Marine Strategy Framework Directive
OSPAR	Oslo Paris Convention for the Protection of the North Atlantic and North Sea
PoM	Programme of Measures
RSC	Regional Sea Convention
TG ML	MSFD Technical Group on Marine Litter
TV	Threshold Value
UN	United Nations
WFD	Water Framework Directive

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