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Title: **A European Threshold Value and Assessment Method for Macro Litter on Coastlines**

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Contents

Abstract

The Marine Strategy Framework Directive (MSFD, 2008/56/EC) requires that European threshold values (TVs) for marine litter (descriptor 10) be defined. The MSFD Technical Group on Marine Litter (TG ML) decided to focus on coastline litter (Criterion 1), often referred to as beach litter, in a first step, since for this criterion a monitoring framework is in place and a substantial amount of fit-for-purpose beach litter monitoring data is available at the European scale (see Hanke et al., 2019).

This report describes the rationale and method to obtain a European TV for beach litter, as developed by Member States and other experts within the TG ML.

It was concluded by TG ML that a TV cannot be based on quantitative ecological and socio-economic harm due to a lack of scientific data on harm caused by marine litter on beaches. Of the remaining options, the use of the 10th percentile value of the total litter abundance dataset from all European beaches in the baseline period 2015-2016 was selected and applied, as it was considered to be sufficiently precautionary while being based on already available beach litter abundances in the EU. The underlying baseline dataset was developed within the TG ML.

Calculation of the 10th percentile of the EU baseline dataset resulted in a value of 13 litter items per 100 m of coastline length. Further consideration of the 95% confidence intervals of the TV and assessment value, respectively, led to a final TV of 20 litter items/100 m beach length, which corresponds to the 15th percentile value of the EU baseline dataset. This TV is estimated by experts from TG ML to reduce harm from beach litter to a sufficiently precautionary level. The methodology acknowledges uncertainties in the underlying data which is considered in the proposal. The median assessment value is compared with this TV for compliance checking.

It is acknowledged that achieving this TV will require substantial and sustained measures over a longer period. Intermediate targets over time towards the proposed TV are proposed to support the achievement of the TV.

Foreword

The Marine Directors of the European Union (EU), Acceding Countries, Candidate Countries and EFTA Countries have jointly developed a common strategy for supporting the implementation of the Directive 2008/56/EC, "the Marine Strategy Framework Directive" (MSFD). The main aim of this strategy is to allow a coherent and harmonious implementation of the Directive. Focus is on methodological questions related to a common understanding of the technical and scientific implications of the 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 (TG ML) led by DG ENV and chaired by IFREMER, the EC Joint Research Centre (JRC) and the German Environment Agency (UBA), is delivering thematic technical reports such as Guidance for Monitoring of Marine Litter, Harm caused by Marine Litter, Identifying Sources of Marine Litter, Riverine Litter Monitoring – Options and Recommendations, Top Marine Beach Litter Items in Europe and EU Marine Beach Litter Baselines. These thematic reports are targeted to those experts who are directly or indirectly implementing the MSFD in the marine regions.

This Technical Report should further support EU Member States (MS) in the implementation of monitoring programmes and plans of measures to act upon marine litter. The members of the Marine Strategy Coordination Group will assess and decide upon the necessity for reviewing this document in the light of scientific and technical progress and experience gained in implementing the MSFD. The proposed fixed threshold value (TV) and assessment method should only be reconsidered if clear and extensive data on harm caused by beach/marine litter on the marine environment becomes available. This is not expected to happen in the near future.

This document was agreed to by the Marine Strategy Framework Coordination Group through its adoption on 31 August 2020 by written procedure.

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1 Background and rationale

The TG ML has been mandated, through the MSFD 2016-2019 work programme of the Common Implementation Strategy, to develop approaches for setting TVs and to work towards agreed TVs for the criteria of Descriptor 10 on marine litter, as requested by the MSFD Commission Decision 2017/848/EU. TG ML presented a discussion document (GES_20-2018-04) on general approaches for setting TVs for marine litter criteria first to WG GES, which was later adopted by MSCG (MSCG_23-2018-10).

In a first step towards agreed TVs, TG ML recommended to focus on litter on the coastline (in particular on beaches, as areas with sand and pebbles are predominately monitored) because for this criterion essential prerequisites in form of an existing consolidated monitoring framework and the availability of a large and for some regions long-term dataset, allowing for a baseline for setting TVs, are available (further detail to be found in chapter 2). This recommendation was confirmed by WG GES. As a follow-up, concepts for beach litter TV setting have been developed. This document provides a proposal for setting a TV for beach litter prepared by a beach litter expert group affiliated to the TG ML. As specified in the Commission Decision 2017/848/EU, this TV is intended to contribute to MS` determination of a set of characteristics for good environmental status and to inform on their assessment of the extent to which good environmental status is being achieved.

This Commission Decision 2017/848/EU provides the following requirements for a TV for beach 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.

The TG ML provided a platform for cooperation at Union level, which enabled the active participation of all MS in the TV development. This document proposes to apply a single TV for beach litter at the EU level based on the assumption that the potential harm of a specific concentration of beach litter across different types of harm is the same for all regions or subregions within the EU. While conditions in different regions, countries and also at beach level, regarding the shapes and types of beaches, the presence of marine species and human beach uses may be different, the analysis of the potential harm has shown that a quantitative precise differentiation between regions and areas is not possible and may even compromise protection against harm to specific ecosystem elements and activities. The use of a single TV for beach litter then provides an equal level of precautionary protection across Europe.

Under natural conditions there would be no litter on coastlines/beaches and this could be the ultimate goal. However, it was concluded that small residual amounts of litter on beaches can be acceptable in relation to the MSFD implementation, given the amounts already present in the marine environment.

In the TG ML confirmed by the beach litter expert sub-group, consensus was reached that, although litter evidently causes harm to biota and habitats, it is currently not possible to derive quantitative dose-effect relationships for ecological harm caused by beach litter (Werner *et al.,* 2016). It was also considered unfeasible to develop harm-based TVs for beach litter based on field and laboratory studies. In addition to ecological harm, the expert group considered socio-economic harm, such as high costs for municipalities incurred by beach clean-up activities, the potential loss of income due to beach litter in relation to tourism and other costs to industry, local authorities and governments, but also socially acceptable levels of marine litter (including aesthetic impact/disamenity) to the society. The public regards litter on beaches as a direct annoyance or hindrance to beach activities and has a desire for clean beaches.

However, a short review of literature on socio-economic harm showed that there is almost no quantitative information on the disamenity of beach litter for the public (see Annex 4). Consequently, the precautionary principle was applied, as specified in the MSFD (EU 2008, EU 2017), and the threshold value development was based on all available baseline beach litter survey results from within the EU (Hanke *et al*., 2019). The use of data-based TV's is common practice for EU Water Framework Directive (WFD) and MSFD indicators. The application of the precautionary principle will necessitate measures effecting change on a wide array of economic consumption behaviours, waste management and human behaviour.

Since it is not considered possible to derive a TV based on harm data, two alternative approaches were considered. These are (a) the use of median beach litter abundances in nearly-pristine areas (e.g. Greenland, 1.8 items/100 m) and (b) the use of a low percentile value (e.g. the 1^{st}, 5^{th}, 10^{th} or 15^{th} percentile value) calculated with the EU beach litter baseline dataset (see Chapter 2).

Option (a) however would rely on the availability of reliable data from nearly pristine beaches, which is currently not always the case. In addition, this method would produce very low TVs (see example of Greenland above). Option (b) has been used in environmental assessments, e.g. chemical assessments, where reference background values and toxicological cut-off values are estimated as low percentile values of baseline chemical datasets (EC 2018, Oste *et al.,* 2012). While pollution through chemical substances typically can be based on laboratory based toxicological studies, the basic concept of dose-effect relationships can also be applied to beach litter, as both regard the input of chemicals or materials having adverse effects. Therefore, option (b), the use of low percentile values of beach litter on all EU beaches, was selected for development of a TV for beach litter, because it is a data-based, transparent and practical statistical method. See Annex 1 for more information about the application of percentile values.

2 Requirements for a Coastline Litter Threshold Value

Building upon the rationale for a TV, presented in Chapter 1, additional specifications were developed for the threshold setting and assessment methods, which are explained in the following text.

2.1 Based on comparable beach litter monitoring data

Compliance checking against a TV requires fit-for-purpose data. In order to achieve comparable national assessments across the EU, the monitoring data should be acquired through harmonized methodologies. Data acquisition should follow TG ML litter monitoring guidance (TG ML, 2013) and the principles used for litter baseline setting (Hanke *et al.*, 2019). For example, the monitoring data should preferably be collected at a coastline/beach length of 100 m, and each monitoring beach should preferably be surveyed four times per year, with one survey in every season. Note, however, the accessibility of specific monitoring beaches may be limited due to winter conditions, and consequently data from fewer surveys per year may be available. It is recommended that all official national monitoring beaches, which are used for national, MSFD and regional assessments, are registered in the proposed EMODNET beach catalogue, and are consistently monitored and assessed. In addition, the application of agreed guidance and protocols, as developed by the TG ML, including the use of the Joint List of Litter Categories is essential, to achieve and maintain the comparability of beach litter data on a European scale. Meso- (<2.5 cm) and micro-litter (<5 mm) should be considered separately as they require different methodologies for monitoring. In addition the litter abundances of these size classes are not comparable due to differences in monitoring between countries. See Chapter 3.2 for a description of the beach litter data clean-up.

2.2 Robust through data basis and statistical methodology

A pan-European beach litter baseline dataset for 2015-2016, which was developed within TG ML, has been used (Hanke *et al.*, 2019). To ensure a robust TV, the 10th percentile value of this large EU dataset was calculated. The 5th and 10th percentile value of a large dataset are commonly used practical methods to calculate threshold or reference values, e.g. in case real ecotoxicological TVs cannot be derived such as for beach litter (EU, 2018). Two applications of the 10th percentile value are described in this EU technical guidance for deriving environmental quality standards, one of them as a lower effect value (ERL, Effect Range Low) for concentrations of chemicals in sediment causing benthic effects. In addition, a Dutch study from Oste *et al.* (2012) has recommended the 10th percentile value as the most robust percentile value for deriving background values for metals in European waters. For more details on the percentile method see Annex 1. For the beach litter TV, the 10th percentile value was selected over the lower 5th percentile value because it is practically more feasible to reach. In addition, the 10th percentile value is statistically more robust than the 5th percentile value.

2.3 Equal protection across Europe

The TV should provide enough precautionary protection from potential harm to species which live on, or visit, the beach and also address socio-economic issues. Furthermore, beach litter can be used as a proxy for litter in the marine environment in general. It is important to recognize that the lower the TV is set, the lower the residual risk of ecological harm will be. In addition, a low TV will lead to low socio-economic harm when the TV has been reached, although there will also be substantial costs to reach this TV. Note that it will probably take several MSFD cycles to reach this TV (depending on the subregion), and that intermediate targets will be used by TG ML and Regional Sea Conventions (RSCs) to make a manageable pathway towards reaching the TV.

The complete absence of beach litter (pristine situation), while being the ideal situation, is not proposed as a TV because it is unlikely that it will ever be reached and a residual litter background, e.g. due to involuntarily lost items and to amounts of litter already present in the environment, can be

expected and could be acceptable. Persistent plastic items/fragments will occur, to some extent, on beaches for a long time to come.

One European TV for coastline/beach litter is needed, because the potential ecological and socio-economic harm caused by litter at a certain pollution level is expected to be comparable on all EU beaches. It would be difficult to explain, from the viewpoint of ecological and socio-economic harm, why different EU regions should have different beach litter TVs, related to a different level of protection. An equal level of protection across the EU is therefore required.

It was decided by TG ML in 2019 that the TV should be based on the total abundance of beach litter. It was also agreed that an additional TV for individual litter categories or litter category groups is not necessary, since about 90% of the litter items recorded on beaches are made of plastics. While the Directive 2019/904/EU on the reduction of the impact of certain plastic products on the environment is expected to have considerable impact on marine litter prevention and reduction, additional measures and their implementation will be necessary to address other sources, items and materials of litter. The EU beach litter baseline report (Hanke *et al.*, 2019, Chapter 8.1, Figure 22) shows that the single use plastic (SUP) and fishing related items groups (FISH) are in general responsible for more than 50% of the total abundance of beach litter.

As current litter abundances are often much higher than the proposed TV, it was proposed by TG ML that intermediate targets can be set on the way towards reaching the final TV.

2.4 The assessment value must be robust

It was agreed in TG ML that the median assessment value is suitable for beach litter assessment, because it is robust against extreme values, which frequently occur in beach litter monitoring, and because median beach litter abundances show a good correlation with mean beach litter abundances (Annex 2). Furthermore, it is necessary to define a minimum number of assessment surveys to obtain sufficiently robust median assessment values. This minimum number was optimized using the 95% confidence interval of the median and appeared to be 40 surveys per country-subregion (Annex 3). This is the number of surveys (N) at which a further increase of N has less added value for the robustness of the assessment value.

3 Calculation and assessment of a Coastline Litter Threshold Value

3.1 Dataset

The EU baseline dataset 2012-2016 (Output_Baseline_2018-12-05-wide-20190716) was used for the TV calculations (Hanke *et al.*, 2019). The data for deriving EU beach litter baselines were collected under the lead of JRC from EU Member States, compiled in collaboration with EMODNET, and then harmonized and analysed by the University of Wageningen (Dennis Walvoort) in collaboration with the NL Rijkswaterstaat (Willem van Loon). The dataset contains the results of 3044 surveys for the period 2012-2016. As agreed in TG ML, the data from 2015-2016 were selected from this dataset and stored in the file: Output_Baseline_2018-12-05-wide-20190716-2015-2016. This 2015/2016 file contains the results from 1470 surveys: 695 surveys for 2015 and 775 for 2016. Data from these years (2015 and 2016) were used because most EU countries have beach litter data available for this period.

3.2 Data clean-up and total abundance calculation

The aim of data clean-up performed to provide an EU baseline dataset was to obtain a comparable beach litter dataset across the EU, containing monitoring data of all anthropogenic and macro-sized materials (>2.5 cm, mostly artificial polymers) which can be monitored.

The underlying data used to derive the EU beach litter threshold here is identical with the EU Marine Beach Litter Baseline dataset (Hanke *et al*. 2019).

Note that this cleaned dataset is used to calculate the TV, as well as to calculate the assessment values per country-subregion. Some litter types were removed from the dataset, and other types retained, for specific reasons:

Fragments <2.5 cm were removed (because of probably incomparable monitoring results).

Paraffin, wax, oil and other pollutants were removed (because these are solid or liquid chemicals; and require other dedicated monitoring methods).

Cigarette butts were retained in the data (because they are mostly larger than 2.5 cm, fairly persistent and toxic and among the most frequently found items on beaches and therefore targeted by Directive (EU) 2019/904)), Surveys of 10 m were excluded because they were considered not to be representative for 100 m of beach.

Glass, metal, wood, cloth, rubber and paper/cardboard were retained in the data as anthropogenic materials because they can also be harmful.

After data clean-up, the following actions were performed to obtain the total abundance of beach litter per 100 m beach length (Hanke *et al*., 2019):

- The remaining litter types and abundances per survey were summed to obtain the total abundance per survey
- All litter type abundances were normalized to 100 m. Survey length in the baseline dataset ranged between 30 m and 2511 m. 76% of surveys were performed on 100 m of beach.

3.3 Threshold value calculation method

In order to obtain a robust TV, it was calculated using the complete cleaned EU baseline dataset (2015-2016) of 1470 records. This is the earliest period in which most EU countries have beach litter data available. The availability of many surveys (1470) is expected to compensate for using a minimum period of two years in obtaining a robust TV. Possible EU TVs for beach litter have been calculated as 1^{th}, 5^{th}, 10^{st}, 15^{th} and 20^{th} percentile values of the final EU baseline dataset 2015-2016. The calculations were performed in Excel using the PERCENTILE function, after which the percentile results were validated using R, which showed that the results were identical.

3.4 Assessment method and metric

The assessment method deals with the data analysis of the set of surveys which are compared with the TV. In the assessment method the following aspects must be defined: the assessment metric, the spatial level, the temporal level, the selection of locations and the number of surveys. The assessment metric is based here on the agreed data treatment for the calculation of marine beach litter baselines.

Two commonly used assessment metrics, the arithmetic mean and median, were compared with respect to the criteria: (a) quantitative comparability, (b) robustness against extreme values and (c) transparency and practicality. Based on this comparison (Annex 2), TG ML agreed to use the median as assessment metric.

3.5 Spatial and temporal assessment scales

It was agreed in TG ML in 2019 that a combination of the country and the MSFD region (Baltic Sea and Black Sea) or subregion (Mediterranean Sea and NE Atlantic Ocean regions) (country-subregion) is a logical coherent geographical unit for the assessment and reporting of beach litter status and trends, both nationally and for the EU. Using this assessment level, each country can assess the current national beach litter status, and the combined effects of national and (sub)regional measures. The following ten MSFD regions and (sub)regions have been defined (in alphabetical order): Adriatic Sea, Baltic Sea, Bay of Biscay and the Iberian Coast Sea, Black Sea, Celtic Seas, Eastern Mediterranean (Aegean-Levantine Sea), Greater North Sea, Ionian Sea and the Central Mediterranean Sea, Macaronesia, Western Mediterranean Sea (Figure 1. The UK Exclusive Economic Zone marine waters will be removed in future analyses).

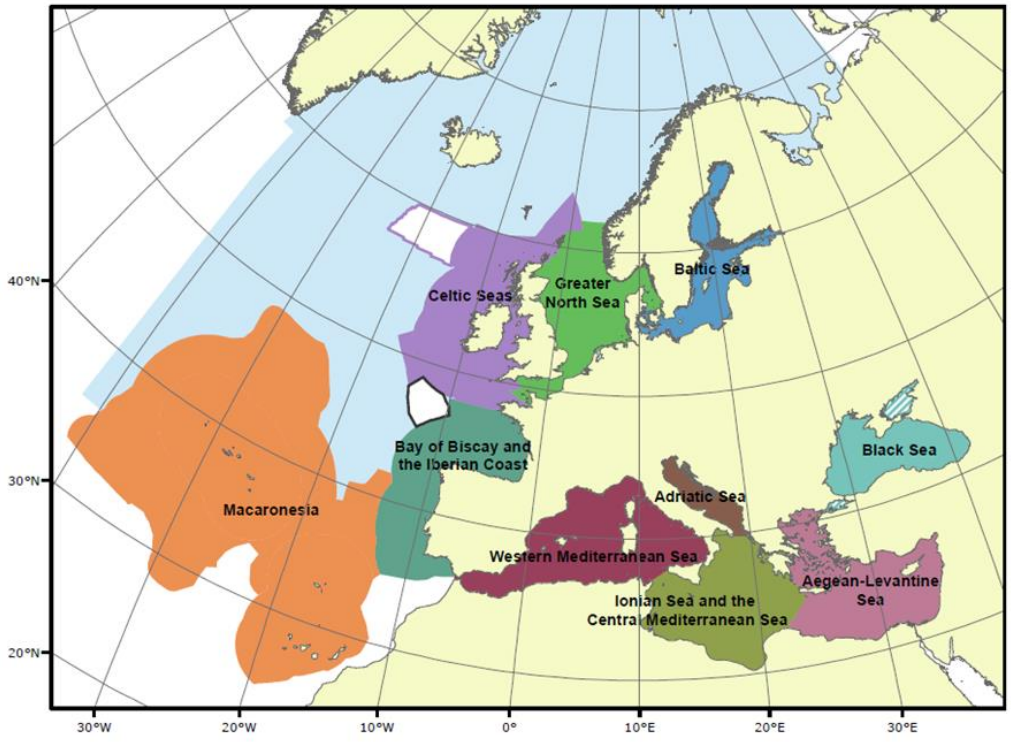

Figure 1: Map of European MSFD regions and subregions. The combination of country + subregion is proposed as spatial assessment scale for beach litter (EEA 2019).

It is quite common to use an assessment period of several years, in order to even out the relatively large variations in beach litter concentrations due to variations in hydrodynamic conditions (e.g. storm events) and human activities (including accidental litter spills). It is proposed to use a standard MSFD

assessment period of six years for EU assessment and reporting. If a country would like to perform an intermediate assessment, e.g. after three years, this is always possible on a voluntary basis.

Beach litter is often a mixture of litter from sea-based sources (such as shipping, fishing, aquaculture and maritime industry) and land-based sources (such as sewage and stormwater, urban waste, harbours and beach tourism/recreational activities). Therefore, the selected beaches should be a representative mixture (for the specific country-subregion) of rural/non-touristic beaches, which are generally expected to better reflect sea-based sources, and intermediate and touristic beaches, which are generally estimated to better reflect land-based sources. It is assumed that this is the case for the current set of EU monitoring beaches, and this should be ensured through agreed guidance for monitoring when additional monitoring beaches are selected in the future.

Annex 3 includes a statistical analysis of the required minimum number of surveys. This resulted in a minimum number of 40 surveys for the assessment of a given country-subregion. These 40 or more surveys should be available within one MSFD cycle period of six years.

The progress of national litter reduction should be assessed for each country-subregion, e.g. FR_Mediterranean, using a six years MSFD cycle using all official beach litter monitoring data, with a minimum of 40 surveys. If desired, countries can make intermediate beach litter assessments more frequently, as long as a minimum number of 40 surveys is available per country-subregion.

4 EU wide Coastline Litter Threshold

The requirements for an EU wide beach litter TV have been considered when developing this approach. Table 1 below shows the results of beach litter percentile calculations at the EU level.

Table 1: Beach litter percentile values at EU level/litter counts per 100 m coastline using the EU baseline dataset 2015-2016

N surveys	Mean	Median	1 perc.	5 perc.	10 perc.	15 perc.	20 perc.
1470	504	133	2	7	13	20	27

The 10th percentile value (13) falls within the range of 10-20 items/100 m, for which the TG ML jointly estimated that the potential ecological and socio-economic harm at beaches is low. In addition, the 10th percentile value has been recommended as being a pragmatic and robust indicator for setting reference levels, e.g. in the EU Guidance document for deriving Environmental Quality Standards (EC 2018, Oste *et al.,* 2012; Annex 1). Therefore, this 10th percentile value of 13 items/100 m of beach was selected for further testing in this study as the European TV for beach litter.

Note that this fixed TV is fundamentally different from the concepts of baseline reductions and decreasing trends, which were formerly used for MSFD purposes (Werner *et al.*, 2019). The use of a fixed TV is intended to fully replace these older concepts for improving the status of marine litter.

This fixed TV should only be reconsidered if clear and extensive data on harm caused by beach/marine litter becomes available. This is not expected to happen in the near future.

While this value has already been achieved in 2015/2016 on 10 percent of the EU surveys, respectively, it remains a substantial final MSFD goal, and in some areas, it cannot be reached in a short time period. Like with other pollution issues (e.g. Mercury in biota) it will take considerable efforts and time to reach the needed large reductions. This should not influence the selection of the TV itself, but rather lead to the intensified development and implementation of strategies, measures and actions to reduce marine litter.

4.1 Application of confidence intervals

The uncertainty of litter monitoring data used for deriving the percentile value of beach litter abundances is approximated through the calculation of confidence intervals. Considering the 95% confidence interval of the baseline data 10th percentile value expands its range to an upper confidence limit of 15 litter items/100 m coastline. The confidence interval is small for this beach litter dataset, because of the large number (1470) of surveys involved. A minimum number of 40 surveys for a beach litter TV assessment is recommended, because the addition of more surveys beyond this number provides only a limited gain in the improvement of the confidence interval.

Considering uncertainties of data and the resulting confidence intervals, the resulting threshold value can be considered as reached statistically, if the lower 95% confidence limit of the aggregated monitoring values touches the upper 95% confidence limit of the 10th percentile of the baseline data. At this point, the assessment value and threshold value are not significantly different any more (Cummings et al., 2006).

This corresponds to a median assessment value of approx. 20, for a range of 40 to 100 assessment surveys. A similar statistical method is used in the TV proposal for plastics in fulmar stomachs (Van Franeker et al., 2019). See Annex 3 for more details on the calculation of the confidence intervals.

In order to facilitate the compliance checking it is proposed to base compliance checking on the comparison of the threshold value, considering uncertainties, directly against the

assessment value. This is in line with other threshold compliance processes, such as the WFD EQS for chemical pollutants.

It is therefore proposed to select the 15th percentile as the threshold value, which corresponds to 20 items/100 m, and to directly compare this threshold value with the median value of the assessment surveys from the selected assessment area and period.

4.2 Application of the beach litter threshold value and assessment method

The 15th percentile of the 2015/2016 EU beach litter dataset, at 20 litter items/100m of coastline, is selected in order to include the confidence intervals of the underlying data, and the resulting threshold value is still judged by TGML to be sufficiently precautionary to protect beaches from ecological and socio-economic harm.

In summary, the application of the 15th percentile method leads to an EU Beach Litter Threshold Value of **20 litter items/100 m** of coastline.

Table 2 allows for a comparison of the proposed TV of 20 litter items/100 m with the EU baseline values from 2015-2016.

Table 2: Median and mean total beach litter abundance per 100 m of beach (Hanke *et al.*, 2019) for all country-MSFD subregions in Europe for the period 2015-2016. Note that the median values are used for the TV assessment.

Country_subregion	Number of surveys	Median [TA/100 m]	Mean [TA/100 m]
BE_NorthSea	17	93	118
BG_BlackSea	32	174	222
DE_BalticSea	160	26	46
DE_NorthSea	31	79	98
DK_BalticSea	12	66	82
DK_NorthSea	19	221	1077
EE_BalticSea	40	43	45
ES_Biscay/Iberian	87	244	328
ES_Macaronesia	14	134	151
ES_Mediterranean	95	120	242
FI_BalticSea	56	49	114

Country_subregion	Number of surveys	Median [TA/100 m]	Mean [TA/100 m]
FR_Biscay/Iberian	8	2134	2690
FR_CelticSeas	43	273	390
FR_Mediterranean	32	294	394
FR_NorthSea	11	671	2002
UK_CelticSeas*	102	222	585
UK_NorthSea*	75	423	877
GR_Ionic/CentralMed	15	165	178
HR_AdriaticSea	12	155	1686
IE_CelticSeas	32	61	73
IT_AdriaticSea	56	590	1087
IT_Ionic/CentralMed	33	376	438
IT_WesternMed	88	623	1244
LV_BalticSea	71	133	170
NL_NorthSea	32	205	232
PL_BalticSea	111	13	31
PT_Biscay/Iberian	70	335	473
RO_BlackSea	9	15	20
SE_Baltic	48	19	40
SE_NorthSea	44	191	2610
SI_AdriaticSea	15	586	581
Medians EU	33	174	242

(* total litter abundance values dataset from all European beaches from the baseline period 2015-2016 when UK was full EU member)

It appears from Table 2 that the majority of the country-subregions do not yet reach the redefined threshold value of 20 items/100 m. The number of surveys per country-subregion is already in many cases matching the recommended minimum number of 40.

It is acknowledged by TG ML that this TV will probably require substantial and sustained measures to prevent and reduce litter and an extensive period of time to achieve (see e.g. an estimation of the time period for the Dutch situation below). The fact that beaches in several countries within the Baltic, and probably the Black Sea are already close to the proposed TV supports our view that this TV is feasible in practice. The possibility to compare the status of different country-subregions and their beaches can be a viable tool to communicate achievements and therefore mark milestones/intermediate targets towards reaching the TV.

The three European country-subregions with relatively high mean values (Sweden North Sea, Denmark North Sea and Croatia Adriatic Sea) will not be disadvantaged by using the median assessment method, because the median assessment value is (much) lower than the mean value, and lies within the range of median values of the 25 country-regions with a comparable ratio between the mean and median value.

An example of the time period needed to reach the TV in the more polluted Atlantic subregion is given here for the assessment area NL North Sea. The Dutch combined trend of 4 beaches for the period 2013-2018 is -21 items/100 m*year. The median assessment value for this period in January 2016 (centre of the trend period) for total abundance is 308. This indicates that it would take around (308-13)/21 = 14 years to reach the TV for beach litter, assuming a linear trend in the North Sea region with its relatively high litter abundances. However, since it is likely that the trend will level off in the future leading to a more asymptotic trend, an arbitrary safety factor of 30% is applied and a period of 18 years is estimated. This indicates that in the year 2016 + 18 = 2034 the TV could be reached in the Netherlands. This corresponds roughly to 2 to 3 MSFD periods/assessment cycles (2031 to 2037). It is possible to use non-linear (e.g. logarithmic) regression to obtain more accurate non-linear curves to estimate when the TV within a country-subregion could be reached (van Franeker *et al.*, 2019).

This is obviously a fairly long period which is not so easy to oversee. It is therefore necessary to define one or more intermediate measurable targets (IMTs) over time towards the TV. For example, for every MSFD period of six years, an intermediate target could be developed, coordinated by TG ML and WG GES. For the more polluted Atlantic and Mediterranean country-subregions, three to five MSFD periods/assessment cycles may be necessary to reach TV starting from the current baseline value 2015-2016. It is proposed that TG ML will develop a method for the setting of intermediate targets, in cooperation with the Regional Sea Conventions. Via these intermediate targets, country-subregions will eventually reach the final beach litter TV, as a part of Good Environmental Status (GES) for marine litter.

While the proposed beach litter TV is based on the ultimate aim of achieving Good Environmental Status in European Seas, its implementation will require a stringent implementation of existing and introduction of additional measures at different levels and a set of additional marine litter TVs for concentrations and impacts in the different marine environmental compartments.

5 Achievement of the EU Coastline Litter Threshold Value

The reduction of coastline/beach litter in Europe will require a combination of efforts on different levels. These include legislative actions at EU level in the framework of Water and Waste policies, the Circular Economy approach, activities in the context of the Regional Action Plans against marine litter, national initiatives ranging from country-level to municipalities including awareness raising, targeting different parts of the society. While some of the provisions will target a wide range of litter types, such as through waste management, others may tackle individual litter items, guided e.g. through operational targets.

As the litter quantities at the 2015/2016 baseline are often much higher than the proposed TV, it is proposed to follow a strategic approach, guided by intermediate targets, set in order to achieve stepwise quantitative measurable progress. This will allow the consideration of regional and country specificities. It also will enable Member States to ensure that the multitude of litter reduction activities will lead towards the final goal of reducing marine litter and thus avoid harm to the marine environment. The main short-term objective in terms of the implementation of the MSFD for Descriptor 10 in this context must be the prevention of further input of marine litter into the marine environment.

5.1 Intermediate Measurable Targets

The TG ML recognises that the proposed TV for beach litter may take several MSFD implementation cycles to reach, after the implementation of extensive and sustained measures to reduce and eliminate litter inputs in the marine environment. The application of IMTs for beach litter will support the path to achieving the TV. The MSFD (EU, 2008) specifies those (national) targets, according to Article 10 of the MSFD, related to monitoring and assessment in its Annex IV point 2, as well as the setting of targets and a timescale for their achievement in Annex IV point 6:

Box 1. Annex IV – Indicative list of characteristics to be taken into account for setting environmental targets

(2) Need to set (a) targets establishing desired conditions based on the definition of good environmental status; (b) measurable targets and associated indicators that allow for monitoring and assessment and (c) operational targets relating to concrete implementation measures to support their achievement.

(6) Formulation of targets, including possible interim targets, with a timescale for their achievement).

Each EU MS has its own set of national measurable targets to guide progress to reach GES (and the supporting TVs). According to the MSFD article 10 sub 1 (EU, 2008), relevant transboundary impacts and features, such as international shipping and sea currents, are to be taken into account as well when defining national measurable targets, to the extent possible.

Regarding possible timelines for the achievement of the TV, there appear to be large differences within European MSFD regions and subregions. Whereas in the Baltic, the TV for beach litter may be reached on some beaches already and for others within a single MSFD cycle, for the Dutch beaches in the North Sea subregion it is estimated that the TV may only be reached within 2 to 3 MSFD cycles. For more heavily polluted subregions, such as part of the Mediterranean and Skagerrak coasts (Strand *et al.,* 2015), including for example the Swedish west coast (which is a sink region for the North Sea), 4 or 5 MSFD cycles may be necessary to reach the TV.

It is proposed that TG ML, based on a mandate and in close collaborations with the Regional Sea Conventions will develop a method for the setting of intermediate targets in the near future. This method should take subregional specificities, such as e.g. fishing and aquaculture, and possibly population density, and other parameters into consideration. This method can then be applied by individual countries and RSCs to design their national or RSC intermediate targets and associated time line.

5.2 Transboundary litter pollution

It is recognized that in certain countries, prevailing currents may deposit relatively high amounts of litter on the coastline, which does not originate from the country itself. For example, it is known that dominant currents transport litter from the Greater North Sea and from a large Atlantic current to the west Swedish coastline (Turrell, 1992).

In the Mediterranean Sea, there is concern whether marine litter originating from the African coast could reach for instance the Italian, French and Spanish coastlines, and vice versa. The availability and application of modelling methods to describe this transboundary litter pollution aspect, and to estimate the contribution of foreign sources to the national levels of beach litter, is currently increasing. A relevant paper of Liubartseva *et al.* (2018) describes the high spatial and temporal variability of the accumulation areas of floating debris in the Mediterranean Sea. This paper provides modelling evidence that most of the beach litter originates from national sources (called the "boomerang effect"), and that shipping lanes are the second most important (international) marine source of macro-litter. Although the "boomerang effect" needs more study, it emphasises the key role of coastal areas in the adequate reduction of their litter. Relatively small amounts of litter come from terrestrial sources from other countries. The amount of litter coming from other European countries should reduce significantly when a European TV for beach litter is applied.

Additional macro-litter modelling studies and in-situ measurements are necessary to validate and further improve the conclusions of the results from Liubartseva *et al.* (2018). A JRC modelling exercise (Macias *et al.,* 2019) could support the identification and indicative quantification of the origin of litter transported by sea currents. Actions and measures taken by Member States, Regional Sea Conventions and international organizations (e.g. IMO) are expected to reduce (transboundary) litter pollution.

Furthermore, e.g. in the Clean Atlantic project and national research and development projects litter transport and distribution modelling have been and are applied. It is intended by JRC to deliver a suitable model to estimate transboundary pollution in the mid-term future.

The JRC modelling tool used in Macias *et al.* (2019) is being expanded to cover the different regional seas around Europe (a recent application to the Black Sea could be found in Miladinova *et al*., 2020). This approach, even if not fully capable to resolve litter arrival to individual beaches, could help to identify areas that are more prone to receive litter inputs from open-sea sources and distant origins (i.e., transboundary pollution). This tool, hence, could help MS to understand when the litter on their beaches is of local origin or is more likely originating from somewhere else. Results of JRC model simulations should be made available for use to the different EU countries in the near future.

The new modelling information of transboundary pollution could lead in the future to a method, developed by TG ML, for how transboundary pollution may be accounted for in the reporting of beach litter pollution nationally, to the RSC and to the EU.

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List of abbreviations and definitions

EU	European Union
IMT	Intermediate Measurable Targets
MS	Member States
MSFD	Marine Strategy Framework Directive
RSC	Regional Sea Conventions
TG ML	MSFD Technical Group on Marine Litter
TV	Threshold Value
WFD	Water Framework Directive
WG GES	Working Group on Good Environmental Status

Annex 1: Percentile method

The percentile method has frequently been used in environmental assessment methods, in case real reference values from pristine reference areas are missing, and feasible threshold values must be set using a pragmatic statistical method. Some of these applications are described below.

The 5th and 10th percentile value of a large dataset are commonly used practical methods to calculate threshold or reference values, e.g. in case real ecotoxicological threshold values cannot be derived such as for beach litter (EU, 2018). For the 10th percentile two applications are described in the EU Technical guidance for deriving environmental quality standards, one of them using 10th percentile of a set of concentrations of chemicals in sediment which cause benthic effects, as a lower effect value (ERL, Effect Range Low).

In addition, a Dutch study (Oste *et al*., 2012) has recommended the use of 10th percentile values as the most robust percentile value for setting reference background levels for metals in European waters if data are not accessible from "pristine areas", but only from more or less locally impacted areas. However, median values were found to be the most robust estimator for reference values if the dataset only included data from known "pristine" areas.

In European intercalibration studies for marine benthic assessments, the 95th or 99th percentile value of large benthic datasets (data from impacted and less disturbed areas combined) have been used to estimate benthic reference values (Van Hoey *et al.,* 2019). For beach litter data, this can be translated into the use of the 5th or 1st percentile value for setting a threshold value.

In this proposal, the 10th percentile value was originally used. The confidence intervals of the threshold value and assessment values were then added to the assessment method, and this resulted in an "effective threshold value" of 20 items/100 m. Since this value corresponds to the 15th percentile value of the EU baseline dataset, the TV was set at 20 litter items/ 100 m (corresponding to the 15th percentile value) and the median assessment value is simply applied. This method is easier to apply by specialists in the beach litter assessment, and is easier to communicate to policy makers and the public.

Annex 2: Selection of assessment metric

The relation between the mean and median assessment values for each country-subregion for the period 2015-2016 is shown in Figure 3. In this figure, four outlying datapoints from Sweden (North Sea), Denmark (North Sea), France (North Sea) and Croatia (Adriatic Sea) (see also Chapter 4.3 Table 2), which have much higher mean values compared to their median values, have been removed. The plot shows a clear relation between the mean and median assessment values, with a slope of 0.72 and a correlation coefficient (R^2) of 0.94. If the four outlying datapoints would be included, R^2 would have been 0.48. The median value is on average 0.72 of the associated mean value, which demonstrates the skewed data distributions of beach litter. The clear and good relation of the median and mean shows that the robustness criterion (see Chapter 1.2.4) can be used to select the median as the assessment metric for beach litter.

The median has the following advantages for the assessment of beach litter compared to the arithmetic mean:

- It is less sensitive to extreme values. For example, the median beach litter abundance values of Sweden, Denmark and Croatia (Table 2) are within the normal range of median abundance values of other OSPAR regions, but their mean abundances are much more extreme compared to other mean values. Also for European countries with beach litter distributions with a commonly observed skewness, extreme values may sometimes occur, e.g. due to a storm event or an accidental loss of litter at sea. For all countries, the use of the median will make the assessment insensitive to these occasional extreme values.
- Both the threshold value (the 10th percentile value) and the assessment value (the median, 50th percentile value) are calculated using a percentile method (comparability).
- In trend analysis of beach litter, the robust Theil-Sen trend analysis method is often used (Schulz *et al.,* 2017; Schulz *et al.,* 2019; Walvoort *et al.,* 2019). This trend analysis method is based on a median-type method. Therefore, the use of the median as assessment metric is consistent with the use of the Theil-Sen trend analysis method.

Based on these three considerations the median has been selected as the assessment metric for beach litter.

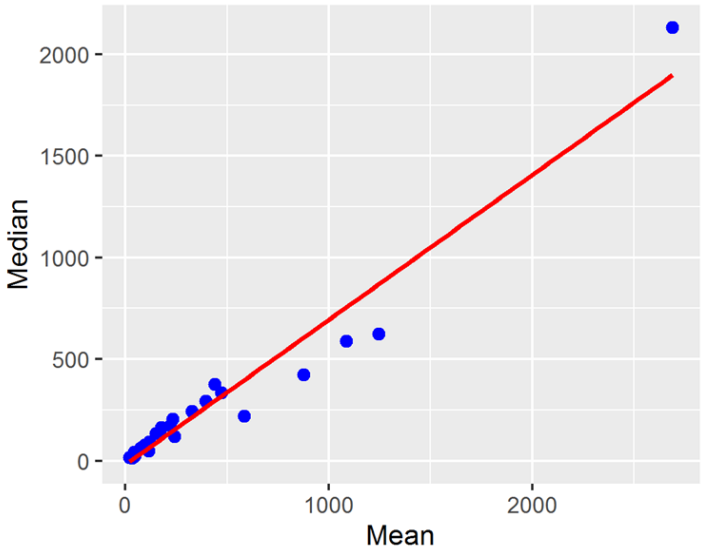

Figure 3: Relation between the median and mean total abundance for the baseline datasets 2015-2016 of most (31) European country subregions, but without outlying data points of Sweden (North Sea), Denmark (North Sea), France (North Sea) and Croatia (Adriatic Sea). The relation is: median = 0.72*mean - 13, R^2 = 0.94.

Annex 3: Calculation of confidence intervals and minimum number of surveys

For the assessment value, it is well known that an increase in the number of surveys (samples) gives an improved (narrower) confidence interval, and therefore a more precise and reliable assessment value (van Franeker and Meijboom, 2002). It is therefore important to statistically establish a minimum number of surveys which are to be used for the beach litter threshold assessment.

The minimum number of assessment surveys was calculated using the 95% confidence interval. This interval was calculated using the software:

http://epitools.ausvet.com.au/content.php?page=CIProportion

using a 95% confidence interval (two-sided) and the default Wilson method. The choice of method has very little effect on the results. This tool is based on the binomial model from Brown *et al.* (2011) and was validated using a bootstrapping program in R kindly provided by Jon Barry (2019), based on a bootstrap method from Bryan and Manly (1998). The validation showed an excellent linear relation ($Y = 0.99*X + 2$, $R^2 = 0.9999$) between the epitool and bootstrap results. Therefore, the epitool was used for the optimization of the confidence interval of the median assessment value.

The relation between the number of surveys and the lower 95% confidence limit is shown in Figure 4. This figure shows a breakpoint in the curve at around 40-45 surveys. A higher number of surveys leads to a limited gain in the confidence interval width. Therefore, 40 surveys are proposed as a minimum requirement for a MSFD threshold assessment of beach litter, because it constitutes an optimum point in achieving a reasonable confidence interval width with a feasible number of surveys within an MSFD period of 6 years. The application of a minimum number of surveys, which is possible in beach litter monitoring via the monitoring design, provides a very useful method to obtain median assessment values with comparable precision across Europe.

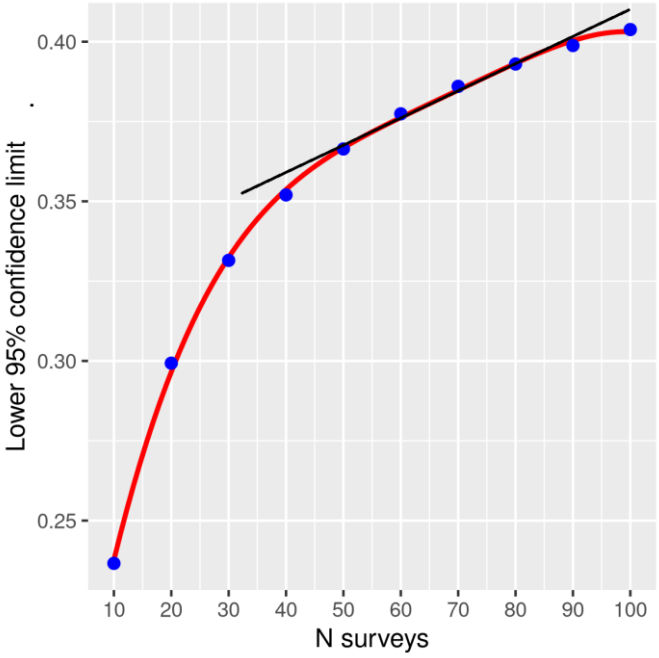

Figure 4: Relation between the number of surveys and the lower 90% confidence limit of the median. Note that the median corresponds to 0.5. At around 40-45 surveys, a breakpoint can be observed. Above this breakpoint, additional surveys add less to the gain in confidence of the median assessment value.

Annex 4: Disamenity considerations

Some additional literature research has revealed a significant amount of scientific publications on socio-economic harm of beach litter, including some results on disamenity for beach litter. The results of this literature research are summarized below.

In conclusion, the presented socio-economic papers provide a significant amount of research of beach perception in a broad sense (including scenery, facilities etc.), but very limited information on possible threshold values for total abundances of beach litter. The only useful classification method is the Litter Grading protocol of EA/NALG (2000), which proposed a class A with a **class border** of **approx. 50 litter items/100 m** (in fact 49 general litter items and 9 cotton butt sticks). This class border could be translated into a **class middle of 25 items/100 m**. This classification method has been used several times in the literature (e.g. Somerville *et al*., 2003), indicating that it is appreciated by several experts. Note however that this classification schema is still only based on expert judgement, and not on monitoring data or socio-economic harm data, and therefore has limited scientific value.

In conclusion, disamenity of beach is currently not yet a scientifically valid method to use or assist in the setting of a beach litter threshold value. More detailed information from the reviewed references is given below.

In Rangel *et al*. (2018) three methods have been applied to measure the beach scenic quality, namely the methods of Ergin *et al*. (2004) for scenic quality, the Litter Grading of EA/NALG (2000; see **Table 3** in Rangel 2018), and Typology (Micallef and Williams, 2003). The Litter Grading classification method is composed of a litter classification table for several types of litter items, and border line values for the quality classes A to D. All litter items from the high water strand line to the back shore are counted, which resembles at least the OSPAR monitoring protocol. For **general litter**, the range for **class A is 0-49** items/100 m, and for cotton buds (separate class, related to sewage) the class A range is 0-9 items/100 m.

Krelling *et al*. (2017) have investigated beach litter disamenity in Brazil, and found that 20.4 % of the beach users would be deterred at a maximum amount of 500 litter items per 100 m. It is not clear how this high number can be extrapolated to the public perception of a really clean beach, as experienced by e.g. 95% of the users.

Ergin *et al*. (2004, 2006) developed a beach litter evaluation index (D), using a fuzzy logic method, which generated weight factors for a range of physical and human beach litter parameters. The human weight factors Litter and Sewage appeared to have the highest weight in the analysis.

Human health impacts by beach litter have been investigated in New Zealand (Campbell, 2019) and Tasmania (Campbell, 2016).

Brouwer *et al*. (2017) performed social research in Bulgaria, Greece and The Netherlands, respectively. They reported that cigarette butts are the most frequently recorded litter type, and are a good indicator for pollution by beach visitors. Plastic bottles and bags rank second and third in the reported litter types.

The report of Leggett *et al*. (2014) presents models and results for the costs of beach litter. In the monitoring method used in this report, also only macro-litter >2.5 cm is used for data analysis, which confirms the choice made in the EU beach litter baseline report (Hanke *et al*., 2019).

According to Ballance *et al.* (2000), beach cleanliness was stated in interviews as the most important factor in influencing choice of beach, especially by foreign tourists.

The paper of Rodella and Corbau (2020) reports that beach users report the beach cleanliness, good sea water and high quality services as the most important aspects of a beach in Italy. In the classification system in this paper, the highest beach litter quality **score 5** is defined as **"litter virtually absent", score 4** is defined as **"a few scattered items".** These descriptions suggest a relatively low threshold value, which is however not specified.

Exploratory results of David Fleet (presentation, 2019) show that 13 artificial tetrapaks per 100 m, within a simulated floodline of 2 m width, are still visible and disturbing for a beach visitor. However, many beach litter items are smaller than tetrapaks, and this would allow for a higher TV based on visibility/disamenity.

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