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Thresholds for MSFD Criteria: state of play and next steps

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Abstract

The Marine Strategy Framework Directive (MSFD) requires that Good Environmental Status (GES) should be achieved in EU marine waters as described by eleven environmental Descriptors, each of them assessed by several GES Criteria. At the core of the GES assessment lies the need for threshold values (TVs) which enable a quantitative assessment of environmental status for the indicators and elements used for each GES Criterion. In this report, we review the availability of agreed threshold-setting approaches/methods and TVs for all Criteria of the eleven MSFD Descriptors. We showcase the progress made with regards to the establishment of thresholds, discuss the relevant ongoing developments, and highlight the remaining gaps in both threshold-setting methods and TVs. We also suggest ways forward to improve the availability of thresholds for the MSFD Criteria.

1 Introduction

The Marine Strategy Framework Directive (MSFD) requires that EU Member States (MS) should achieve a good environmental status (GES) of their marine waters (EU, 2008). At the core of the assessment of the extent to which GES has been achieved lies the threshold values that need to be set for individual Criteria. The Commission Decision (EU) 2017/848 (EU, 2017) - hereafter 'GES Decision' - specifies that: "*Threshold values* [TVs] *are intended to contribute to MS' determination of a set of characteristics for GES and inform their assessment of the extent to which GES is being achieved*" and that "[TVs] *should be set in relation to a reference condition*". Article 4 of the GES Decision goes on to provide specific principles and guidelines on how to set TVs for the MSFD Criteria in order to facilitate the definition of GES (EU, 2017; Box 1).

Box 1. Article 4 (1) of the GES Decision (EU, 2017)

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;

(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.

TVs, in the context of the MSFD implementation, are generally defined as environmental objectives in relation to a desirable condition (EU, 2020). The GES Decision defines threshold values as follows: *"'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."*

TVs are typically set at levels considered a 'safe' or 'acceptable' deviation (i.e. no adverse effects expected) from background/natural levels in the environment (Box 1 (1c); Palialexis et al. 2021), while in some cases (e.g. D6, D7) they may refer to the maximum spatial extent of the acceptable loss/damage. However, to pinpoint such 'acceptable' deviations can be quite challenging, as it depends on such aspects as the exact state-pressure relationship, data availability, knowledge gaps and shifting baselines. Within an environmental monitoring framework, such as the MSFD, TVs should enable a comparable and scientifically sound environmental protection, where compliance checking of the current quantitatively monitored situation against the TV results in an undisputed assessment that triggers policy action, resulting finally in mitigation actions through measures. Additionally, the implementation of a quantitative TV requires the availability of a monitoring framework providing data of fit-for-purpose quality that are comparable over the envisaged spatial scale (i.e. EU scale or regional scale, where applicable) and over time in order to enable assessments against the threshold.

While good progress has been made lately in the establishment of TVs for several MSFD Criteria (e.g. Tornero et al. 2019; Van Loon et al. 2020; Palialexis et al. 2021), the complexity of the European marine ecosystems

and of human interactions with them has challenged the determination of a complete set of GES definitions and of relevant TVs.

In the Art. 8 reporting, the TVs are applied to indicators at parameter level. Several indicators may be used per Criterion, several Criteria may be integrated per element, and several elements may be integrated per feature. Accordingly, there are 'GES extent thresholds' at feature level (e.g. % of bird species in pelagic feeding bird group that should be in good status for the group (feature) to be in GES), while most TVs are expressing the quality to be achieved at parameter/indicator level. All these are reported under the Art. 8 schema, but are in reality expressions of Art. 9. This report focuses on the availability of threshold-setting approaches/methods and TVs applied to indicators at the parameter level for each of the MSFD Criteria, i.e. the values reported under the Art. 8 reporting field 'Threshold value [upper/lower]'.

The aim of this report is to capture the current state of play on the second half of the second MSFD cycle (2022) with regards to threshold availability across the different Criteria of the 11 MSFD Descriptors and to identify discussion needs and next steps in further TV development. In this report, we approach thresholds by Criterion, and by indicator/parameter of each Criterion where relevant, without going into detail on thresholds for GES, which depend on the Descriptor-specific integration rules outlined in the GES Decision, reporting guidance and Art. 8 assessment guidance (European Commission, 2019). We examine separately the development of agreed approaches/methods to establish thresholds, and the presence/absence of TVs themselves. This 'snapshot' serves to highlight both the progress made with regards to the establishment of thresholds for the different MSFD Criteria and the remaining gaps in threshold-setting methods and TVs.

2 Thresholds for Descriptors of predominant pressures and impacts

Following the structure of the GES Decision (EU, 2017), here we consider the thresholds of those Descriptors linked to anthropogenic pressures: biological pressures (Descriptors 2 and 3), physical pressures (Descriptors 6 ([1]) and 7) and substances, litter and energy (Descriptors 5, 8, 9, 10 and 11).

2.1 D2: Non-indigenous species

MSFD Descriptor 2 (D2) addresses non-indigenous species (NIS) which are introduced by human activities and should be at levels that do not adversely alter the ecosystem (EU, 2017). Introduction of new NIS, their abundance and distribution are assessed by one primary Criterion related to the state of the marine environment (D2C1) and two secondary Criteria informing on its pressure and impact (D2C2 and D2C3) (EU, 2017):

D2C1: "The number of non-indigenous species which are newly introduced via human activity into the wild, per assessment period (6 years), measured from the reference year as reported for the initial assessment under Article 8(1) of Directive 2008/56/EC, is minimised and where possible reduced to zero".

D2C2: "Abundance and spatial distribution of established non-indigenous species, particularly of invasive species, contributing significantly to adverse effects on particular species groups or broad habitat types".

D2C3: "Proportion of the species group or spatial extent of the broad habitat type which is adversely altered due to non-indigenous species, particularly invasive non-indigenous species".

For D2C1 and D2C3 Criteria, the EU (2017) definition includes that MS shall establish the threshold values for, respectively, the number of new NIS introductions and adverse alteration to species groups and habitat types by regional and subregional cooperation. Conversely, for D2C2 MS shall refer to the list of Union concern of the Regulation (EU) No 1143/2014 and cooperate regionally and sub-regionally to expand the NIS inventory.

Currently the work of D2 is carried out by nationally appointed experts under the coordination of the JRC.

2.1.1 D2C1: Number of NIS which are newly introduced via human activity into the wild per assessment period

For D2C1, there is a recommendation for GES at regional and subregional scale for the EU consisting in the percentage of NIS reduction over the 6-year MSFD cycle. The approach is not yet operational and based on the number of new NIS introduced in the region or subregion in the short- (e.g., one MSFD cycle of 6 years) or long-term (e.g., multiple MSFD cycles). For example, assuming a percentage of reduction of 50% for a subregion, and a number of new NIS introduction of 30 taxa during the last three 6-year periods (i.e., 18 years in total), and an average number of NIS per period equal to 10, the TV corresponding to the 50% reduction is 5 new NIS.

The percentage reduction is to be decided at regional and subregional scale considering: i) the pressure of pathways of introduction, ii) the monitoring coverage in each region and subregion, and iii) the number of NIS of previous MSFD assessment cycles (Tsiamis et al. 2021). Finally, about specific species groups to exclude in setting TVs (i.e., phytoplankton, parasitic partly-native NIS in the same MSFD subregion), there are specific recommendations in Tsiamis et al. (2021).

Given the monitoring bias in space, time and taxonomic group, baseline data of NIS in Europe by the end of 2011, and new NIS introductions by the end of 2017, refined datasets were developed as a result of coordinated evaluations between scientific and policy communities at national, regional and interregional levels (Tsiamis et al. 2019; Tsiamis et al. 2021). Currently, this data is hosted by the JRC EASIN web services.

At Regional Sea Convention (RSC) scale, HELCOM (2018a) has established the TV of zero new NIS introductions and used it in the latest MSFD 6-year assessment period. OSPAR (2018) has not yet established a TV value but is considering the possibility of accounting for the relative change in the number of new NIS introductions over successive assessment periods (e.g. 6 years). UNEP-MAP and the Black Sea Commission have not yet agreed on a TV value.

([1]) Only D6C1, D6C2 and D6C3

RSCs representatives, chairs of regional working groups on NIS, and the JRC have grouped to coordinate the application and discussion of the agreed threshold methods at national and regional level to ensure harmonised TVs across EU marine areas.

2.1.2 D2C2: Abundance and spatial distribution of established non-indigenous species particularly of invasive species, contributing significantly to adverse effects on particular species groups or broad habitat types

The Criterion does not require a TV. To facilitate the Criterion assessment and quantify the scale of the pressure for use in D2C3, it has been suggested by Tsiamis et al. (2021) to consider the Union concern species included in the Regulation (EU) No 1143/2014 as starting point for the assessment of the Criterion. While this approach would allow relying on well-developed species spatial distribution data, more work is needed to collect records on their abundances.

2.1.3 D2C3: Proportion of the species group or spatial extent of the broad habitat type which is adversely altered due to non-indigenous species, particularly invasive non-indigenous species

At regional, subregional or European level, there is no agreed TV for GES for D2C3. It has been suggested by Tsiamis et al. (2021) that for coherence with targets of the EU Biodiversity Strategy 2030, the species of the IUCN Red List threatened by invasive NIS should be taken into consideration for the application of D2C3. Also, in support of D2C3 assessment, MS could rely on the application of the Biopollution Index (Olenin et al. 2007) and the CIMPAL Index (Katsanevakis et al. 2016). The importance of D2C3 (together with D2C2) was highlighted in Tsiamis et al. (2021), which considers that D2 assessment should take into consideration D2C3, making a recommendation for gathering more data on invasive NIS and development of guidelines for the efficient assessment of the Criterion.

2.1.4 D2 thresholds overview

With regards to agreed threshold methods and TVs for D2 Criteria, the situation is rather good for D2C1 and poor for D2C3 (Table 1).

Table 1. Availability of agreed threshold-setting methods and Threshold Values (TVs) for each of the three D2 Criteria. Red: methods/TVs mostly or fully absent (relevant to less than 3 MS and/or inconsistent); orange: methods/TVs partly present (consistent but relevant to 3-10 MS or to limited regions); green: methods/TVs mostly present (consistent and relevant to more than 10 MS and to most regions). Secondary Criteria have been italicised.

D2 Criterion	Agreed threshold methods	TVs available	Comments	Related regulations
D2C1	Yes (Tsiamis et al. 2021)	Only for the Baltic	Ongoing work among RSCs; the establishment of a D2 core group will ensure steering and coordination encompassing all RSCs	
D2C2	-	-	No thresholds needed	
D2C3	No	No	Need to gather more data. Importance of the Criteria flagged by experts (Tsiamis et al. 2021)	EU 1143/2014

2.2 D3: Commercial species

MSFD Descriptor 3 (D3) covers populations of commercial fish and shellfish species. Specifically, the MSFD (EU, 2008) notes under D3 that: "*Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock*". Descriptor D3

includes one primary Criterion related to impact (D3C1), and two primary Criteria related to state (D3C2 and D3C3), as following (EU, 2017):

D3C1: "The Fishing mortality rate of populations of commercially-exploited species is at or below levels which can produce the maximum sustainable yield (MSY)".

D3C2: "The Spawning Stock Biomass of populations of commercially-exploited species are above biomass levels capable of producing maximum sustainable yield".

D3C3: "The age and size distribution of individuals in the populations of commercially-exploited species is indicative of a healthy population. This shall include a high proportion of old/large individuals and limited adverse effects of exploitation on genetic diversity".

For the definition of D3C1 and D3C2 it is noted (EU, 2017) that "*Appropriate scientific bodies shall be consulted in accordance with Article 26 of Regulation (EU) No 1380/2013* [i.e. the Common Fisheries Policy - CFP]". For D3C3, it is noted that "*Member States shall establish threshold values through regional or subregional cooperation for each population of species in accordance with scientific advice obtained pursuant to Article 26 of Regulation (EU) No 1380/2013*". In other words, D3 Criteria and their TVs are largely based on the CFP regulation (EU, 2013).

2.2.1 D3C1: Fishing mortality rate is at or below levels which can produce MSY

The stock-specific fishing mortality rate producing MSY (F_{MSY}) is the threshold for D3C1; exceeding F_{MSY} indicates overfishing. F_{MSY} comes from analytical stock assessments carried out by dedicated Expert Working Groups (EWGs) of different scientific bodies: the International Council for the Exploration of the Sea (ICES) in the NE Atlantic, the General Fisheries Commission for the Mediterranean (GFCM) and the Scientific, Technical and Economic Committee for Fisheries (STECF) in the Mediterranean Sea, and the International Commission for the Conservation of Atlantic Tunas (ICCAT) for large pelagic species (e.g. tunas, swordfish, marlins). While there are some technical differences in the estimation of F_{MSY} in different stocks/marine regions (e.g., in the Mediterranean, $F_{0.1}$ is typically used as a proxy of F_{MSY}), F_{MSY} is a quantitative threshold that serves the purpose of characterising GES, as it allows the identification of sustainable exploitation rates.

F_{MSY} has a stock-specific value, hence in many cases it cannot be mapped directly to the marine waters of a specific MS; rather, its spatial scale depends on the population structure of each stock. Nevertheless, MS should still report the TVs for populations that occur in their marine waters and these TVs may be applicable across several MS. Also, F_{MSY} is prone to be revised when a new stock assessment or benchmark is approved, due to changes in the available information feeding into the stock assessments (e.g. better data becoming available and/or biological changes occurring in the stock), changes in fisheries selectivity and/or the specific type of stock assessment model used.

F_{MSY} can only be estimated in analytically assessed stocks ('data-rich' stocks). For data-poor stocks, according to the GES Decision (EU, 2017): "*if quantitative assessments yielding values for Fishing mortality are not available* (…), *other variables such as the ratio between catch and biomass index ('catch/biomass ratio') may be used as an alternative method*". Naturally, in those cases F_{MSY} cannot be used as a threshold; rather, the GES decision suggests that: "*an appropriate method for trend analysis shall be adopted (e.g. the current value can be compared against the long-term historical average)*".

2.2.2 D3C2: Spawning stock biomass is above levels capable of producing MSY

The stock-specific spawning stock biomass (SSB) producing MSY (B_{MSY}) is the threshold for D3C2; SSB levels above B_{MSY} indicate a sustainable stock size. Just like F_{MSY}, B_{MSY} comes from analytical stock assessments carried out by dedicated EWGs of ICES, GFCM, STECF and ICCAT. B_{MSY} is a quantitative threshold that serves the purpose of characterising GES, as it allows the identification of sustainable stock sizes. The GES Decision allows for B_{MSY} to be alternatively expressed as the number of individuals instead of biomass if this is in accordance with the official stock assessments. It should be noted that B_{MSY} is often not explicitly estimated in stock assessments, but rather it is set as equal to the precautionary biomass levels (B_{pa}); nevertheless, the MS often use and report B_{pa} or B_{MSY} interchangeably as a threshold for D3C2 (Vasilakopoulos et al. 2021).

There is a marked regional difference in the availability of D3C2 TVs: while these are available for most NE Atlantic stocks (assessed by ICES) and stocks of large pelagic species (assessed by ICCAT), they are largely absent for Mediterranean (assessed by STECF and GFCM) and Black Sea stocks (assessed by GFCM). Also, just like F_{MSY}, B_{MSY} is stock-specific and may be updated following the most recent stock assessment or benchmark,

due to changes in the available information feeding into the stock assessments and/or the specific type of stock assessment model used.

B_{MSY} can only be estimated in analytically assessed stocks ('data-rich' stocks). For data-poor stocks, according to the GES Decision (EU, 2017): "*If quantitative assessments yielding values for Spawning Stock Biomass are not available* (…)*, biomass-related indices such as catch per unit effort or survey abundance indices may be used as an alternative method.*". Naturally, in those cases B_{MSY} cannot be used as a threshold; rather, the GES Decision suggests, like for F_{MSY}, that: "*an appropriate method for trend analysis shall be adopted (e.g. the current value can be compared against the long-term historical average)*".

2.2.3 D3C3: The age and size distribution of individuals is indicative of a healthy population

According to the GES Decision: "D3C3 shall reflect that healthy populations of species are characterised by a high proportion of old, large individuals. The relevant properties are the following: (i) size distribution of individuals in the population, expressed as: the proportion of fish larger than mean size of first sexual maturation, or the 95th percentile of the fish-length distribution of each population, as observed in research vessel or other surveys; (ii) genetic effects of exploitation of the species, such as size at first sexual maturation, where appropriate and feasible. Other expressions of the relevant properties may be used following further scientific and technical development of this Criterion." Therefore, unlike D3C1 and D3C2, neither is there a single indicator for D3C3, nor are the suggested indicators readily available from stock assessment reports. Operational TVs are also largely absent for the different indicators for D3C3.

During the first MSFD cycle (2012-2017), the European Commission (EC) made a special request to ICES in order to advance D3C3 indicators and relevant TVs through dedicated meetings and workshops (ICES, 2016; 2017). However, this process did not yield concrete recommendations on D3C3 indicators due to unresolved conceptual issues. Since then, not a lot of movement has occurred in identifying TVs or even agreeing on the optimal D3C3 indicators, other than some sporadic regional/exploratory attempts (e.g. Borja et al. 2021; Probst et al. 2021); a state which has not gone unnoticed by fisheries scientists (e.g. Raicevich et al. 2017). In the latest (2018) MS reports for Art. 8 of the MSFD, only two MS (EE, RO) reported some quantitative thresholds for D3C3 and another four MS (FI, LT, MT, CY) reported some qualitative thresholds (Vasilakopoulos et al. 2021). These corresponded to just 1% and 11% of the total D3C3 entries, respectively. Recently, within the Art.8 assessment guidance (*in press*), ICES proposed the use of a mixture of D3C3 indicators coming from the GES Decision and of some new ones, without explicitly addressing TVs. It is clear that more research is needed to link D3C3 indicators with the notion of a healthy population, and ultimately estimate TVs for these indicators.

In conclusion, there needs to be a focused effort to set relevant TVs for the different D3C3 indicators mentioned within the GES Decision and/or elsewhere. These TVs would probably need to be stock-specific, and should be compatible with the TVs of D3C1 and D3C2. Narrowing down the D3C3 indicators mentioned within the GES Decision, or even restructuring this criterion (ICES, 2016), could also facilitate a more focused exploration of threshold-setting approaches and relevant TVs.

2.2.4 D3 thresholds overview

With regards to agreed threshold methods and TVs for D3 criteria, the situation is rather good for D3C1 and D3C2 and poor for D3C3 (Table 2.) Nevertheless, the analysis of the latest (2018) MS reports for Art. 8 of the MSFD (Vasilakopoulos et al. 2021) suggested that even for D3C1 and D3C2 there was still scope for further improvement and harmonisation in TVs. It should be also noted that while the types of thresholds for D3C1 and D3C2 are quite robust (F_{MSY} and B_{MSY} respectively), the actual TVs may change with newer stock assessments/benchmarks in a more frequent fashion than most TVs within other MSFD Descriptors. Such changes are typically less frequent and of lesser magnitude in the NE Atlantic, where the assessments are more stable, than the Mediterranean. Nevertheless, these changing TVs are not considered a big issue for the assessment of GES in the MSFD, as they have not been an issue for the assessment of overfishing in the CFP. In practice, it is the latest F/ F_{MSY} and B/B_{MSY} ratios (with F and B also subject to updates) that really matter to establish GES.

Table 2. Availability of agreed threshold-setting methods and Threshold Values (TVs) for each of the three D3 Criteria. Red: methods/TVs mostly or fully absent (relevant to less than 3 MS and/or inconsistent); orange: methods/TVs partly present (consistent but relevant to 3-10 MS or to limited regions); green: methods/TVs mostly present (consistent and relevant to more than 10 MS and to most regions).

D3 Criterion	Agreed threshold methods	TVs available	Comments	Related regulations
D3C1	Yes; F_{MSY}	Yes; good availability in all regions	Some technical differences in the estimation of F_{MSY} in different stocks/marine regions	CFP
D3C2	Yes; B_{MSY}	Partly; TVs largely absent in the Mediterranean and Black Sea	Other relevant thresholds (B_{pa}, B_{lim}) often reported in the absence of B_{MSY}	CFP
D3C3	No	No; only two MS declared some nationally-defined TVs in their in their latest Art. 8 reports	A range of different candidate indicators is mentioned in the GES Decision; consolidation of D3C3 indicators is ongoing	

2.3 D5: Eutrophication

Descriptor 5 is specified as "*Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters*" (EU, 2017). There are eight Criteria for D5, three primary (D5C1, D5C2 and D5C5) and six secondary (D5C3, D5C4, D5C6, D5C7 and D5C8, except when D5C8 is used as a substitute for D5C5) as follows:

D5C1: "Nutrient concentrations are not at levels that indicate adverse eutrophication effects".

D5C2: "Chlorophyll-a concentrations are not at levels that indicate adverse effects of nutrient enrichment".

D5C3: "The number, spatial extent and duration of harmful algal bloom events are not at levels that indicate adverse effects of nutrient enrichment".

D5C4: "The photic limit (transparency) of the water column is not reduced, due to increases in suspended algae, to a level that indicates adverse effects of nutrient enrichment".

D5C5: "The concentration of dissolved oxygen is not reduced, due to nutrient enrichment, to levels that indicate adverse effects on benthic habitats (including on associated biota and mobile species) or other eutrophication effects".

D5C6: "The abundance of opportunistic macroalgae is not at levels that indicate adverse effects of nutrient enrichment".

D5C7: "The species composition and relative abundance or depth distribution of macrophyte communities achieve values that indicate there is no adverse effect due to nutrient enrichment including via a decrease in water transparency".

D5C8: "The species composition and relative abundance of macrofaunal communities, achieve values that indicate that there is no adverse effect due to nutrient and organic enrichment".

The main actors in setting thresholds for D5 Criteria are the EU-MS through the WFD and the Regional Sea Conventions (RSCs) for consistency in the offshore waters.

2.3.1 D5C1: Nutrient concentrations are not at levels that indicate adverse eutrophication effects

Nutrients in the water column relevant to D5C1 are: Dissolved Inorganic Nitrogen (DIN), Dissolved Inorganic Phosphorus (DIP), Total Phosphorus (TP) and Total Nitrogen (TN). However, the GES Decision states that these parameters should be reported "*within coastal waters, as used under Directive 2000/60 EC*"; therefore, MS can report other parameters (i.e., Ammonia, Nitrite, etc.) as used under the WFD for coastal waters and not report

the above mentioned parameters. TVs are specified under the WFD in coastal waters and should be consistent and established through regional (OSPAR, HELCOM, Black Sea) or subregional cooperation in the open sea.

The numbers of MS reporting TVs for the MSFD for coastal waters by nutrient category are: TN (10), TP (12), DIN (13), DIP (12). The numbers of MS reporting TV for MSFD for the open sea by nutrient category are: TN (7), TP (9), DIN (15), DIP (14). Nutrient concentration is measured in surface water or in the water column (µmol/l). Nutrient concentrations are compared against reference levels. For some regions TVs are based on results from modelling, expert evaluation and work conducted under WFD.

Main challenges include the varying availability of TVs across regions (some regions have almost no established TVs), and the harmonisation of WFD-MSFD for coastal waters.

2.3.2 D5C2: Chlorophyll-a concentrations are not at levels that indicate adverse effects of nutrient enrichment

This Criterion refers to Chlorophyll-a concentration in the water column. TVs are specified under the WFD in coastal waters and should be consistent and established through regional (OSPAR, HELCOM, Black Sea, Barcelona convention) or subregional cooperation in the open sea. The values for coastal waters have been harmonized at common surface water body type level.

All countries have established TVs for coastal waters (WFD) and the relevant values are published in the EU Decision 2018/229 (EU, 2018). The number of MS reporting TVs for the MSFD for coastal waters and open sea is 15 and 17, respectively. Chlorophyll-a concentration is measured in µg/l and Chlorophyll-a concentrations are compared against reference levels. For some regions, the TVs are based on results from long-term monitoring, expert evaluation and work conducted under WFD.

Although the GES Decision states that TVs are "*in coastal waters, the values set in accordance with Directive 2000/60/EC*", there is still some harmonization needed between WFD and MSFD for coastal waters.

2.3.3 D5C3: The number, spatial extent and duration of harmful algal bloom events are not at levels that indicate adverse effects of nutrient enrichment

This Criterion refers to harmful algal blooms (e.g., cyanobacteria) in the water column. TVs are specified under the WFD in coastal waters and should be consistent and established through regional (HELCOM) or subregional cooperation in the open sea.

Most of Baltic MS reported relevant TVs. No D5C3 index (e.g., red tides) has been used in other regions than the Baltic. HELCOM uses a cyanobacteria bloom index, whereby the occurrence of algal blooms (number, biomass, surface accumulation, etc.) is compared against a reference level. For some regions there is statistical analysis of long-term data (*in situ* and satellite-based measurements) and the analysis is combined with expert judgment.

There is varying availability of TVs across regions, with some regions having almost no established TVs.

2.3.4 D5C4: The photic limit (transparency) of the water column is not reduced, due to increases in suspended algae, to a level that indicates adverse effects of nutrient enrichment

This Criterion refers to the photic limit (transparency) of the water column. TVs are specified under the WFD in coastal waters and should be consistent and established through regional (OSPAR, HELCOM, Black Sea) or subregional cooperation in the open sea.

The number of MS reporting a TV for the MSFD for coastal waters and open sea is 11. The metric for D5C4 is secchi depth (m). Water transparency is compared against a reference value. Note that France is using turbidity instead of transparency (with no direct relationship). For some regions, TVs are based on short-term monitoring, expert evaluation and work conducted under the WFD.

Main challenges include the varying availability of TVs across regions (some regions have almost no established TVs), and the harmonisation of WFD-MSFD for coastal waters.

2.3.5 D5C5: The concentration of dissolved oxygen is not reduced, due to nutrient enrichment, to levels that indicate adverse effects on benthic habitats (including on associated biota and mobile species) or other eutrophication effects

This Criterion refers to dissolved oxygen (D.O.) concentration at the bottom of the water column. TVs are specified under the WFD in coastal waters and should be consistent and established through regional (OSPAR, HELCOM, Black Sea) or subregional cooperation in the open sea.

The number of MS reporting D.O. for coastal waters and open sea is 12 and 14, respectively. TVs refer to bottom oxygen concentration or oxygen saturation (mg/l) and depth of measurement is likely indicative. Oxygen levels are compared against values derived from reference conditions. For some regions, TVs are based on project results and work under WFD, combined with expert evaluation. In the Baltic, the TVs for oxygen debt were defined from the 95th percentiles during the pre-eutrophicated period (before 1940), detected through change-point analysis for all assessment units (HELCOM, 2018).

Main challenges include the varying availability of TVs across regions (some regions have almost no established TVs), and the harmonisation of WFD-MSFD for coastal waters.

2.3.6 D5C6: The abundance of opportunistic macroalgae is not at levels that indicate adverse effects of nutrient enrichment

This Criterion refers to opportunistic macroalgae in benthic habitats. TVs are specified under the WFD in coastal waters and should be consistent and established through regional (OSPAR, HELCOM) or subregional cooperation in the open sea. Although light often limits macroalgae development at seabed in the open sea due to water depth, such a requirement is mentioned in the MSFD Decision to account for these light-restricted areas.

Only six MS have reported TVs for this Criterion in coastal waters in the MSFD reporting, while none have been reported for the open sea. TVs for coastal waters have been harmonized at EU level. All the MS considering opportunistic macroalgae have established TVs for coastal waters (WFD) with published values in the EU Decision 2018/229 and in the technical reports available at CIRCABC (when opportunistic macroalgae is considered one of the metrics of an index).

There is varying availability of TVs across regions, with some regions having almost no established TVs.

2.3.7 D5C7: The species composition and relative abundance of macrophyte communities, achieve values that indicate that there is no adverse effect due to nutrient and organic enrichment

This Criterion refers to macrophyte communities in benthic habitats. The GES Decision stipulates that in coastal waters TVs are set in accordance with Directive 2000/60/EC and in the open sea TVs should be consistent with WFD and established through regional or subregional cooperation.

Only five MS have reported TVs for this Criterion in coastal waters for the MSFD, while all MS have published TVs for coastal waters under the WFD in the EU Decision 2018/229. No TVs are reported for the open sea. These TVs for coastal waters have been harmonized at common type level. Should this Criterion be relevant for waters beyond coastal waters, values should be consistent with those for coastal waters under the GES Decision.

There is varying availability of TVs across regions, with some regions having almost no established TVs.

2.3.8 D5C8: The species composition and relative abundance of macrofaunal communities achieve values that indicate that there is no adverse effect due to nutrient and organic enrichment

This Criterion refers to macrofaunal communities of benthic habitats. The GES Decision stipulates that in coastal waters TVs are set in accordance with Directive 2000/60/EC and in the open sea TVs should be consistent with WFD and established through regional (OSPAR) or subregional cooperation. TVs are established at national level for coastal waters (as under WFD). These values for coastal waters have been harmonized at common type level.

All the countries have established TVs for coastal waters (WFD), which are published in the EU Decision 2018/229 (EU, 2018). Nine MS have reported TVs for this Criterion in coastal waters in the MSFD reporting and

none has reported for the open sea. For some regions, statistical tests and expert judgment were used to set the TVs, while for others monitoring data were combined with statistical analysis and intercalibration processes.

There is varying availability of TVs across regions, with some regions having almost no established TVs.

2.3.9 D5 thresholds overview

With regards to agreed threshold methods for D5 Criteria, the situation is good for all of them (Table 3). With regards to TVs, there is not any Criterion for which all 22 MS have reported TVs, while there are four Criteria (among which three primary) for which more than half of MS have reported TVs (including nearly more than half for D5C1 in the open sea) and another four (all secondary) for which less than half of MS have reported TVs (Table 3).

Table 3. Availability of agreed threshold-setting methods and Threshold Values (TVs) for each of the eight D5 Criteria. Red: methods/TVs mostly or fully absent (relevant to less than 3 MS and/or inconsistent); orange: methods/TVs partly present (consistent but relevant to about 3-10 MS or to limited regions); green: methods/TVs mostly present (consistent and relevant to more than 10 out of 22 MS and to most regions). Secondary Criteria have been italicised.

D5 Criterion	Compartment	Agreed threshold methods	TVs available	Comments	Related regulations
D5C1	Coastal waters	Nutrient concentration in surface water or in the water column	From 10 to 13 MS reported TVs for the different nutrient categories	Strong input of WFD in coastal waters, some MS TVs still missing, especially in the open sea.	WFD
	Open sea		From 7 to 14 MS reported TVs for the different nutrient categories		
D5C2	Coastal waters	Chlorophyll-a in the water column	15 MS reported TVs	Strong input of WFD in coastal waters.	WFD
	Open sea		17 MS reported TVs		
D5C3	Coastal waters	Harmful algal blooms in the water column	Only Baltic MS reporting a cyanobacteria bloom index	No index (e.g. red tides) in other marine regions	
	Open sea				
D5C4	Coastal waters	Photic limit (transparency) of the water column	11 MS reported TVs		WFD
	Open sea		11 MS reported TVs		
D5C5	Coastal waters	Dissolved oxygen at the bottom of the water column	12 MS reported TVs	For some regions, TVs from project results and WFD are combined with expert evaluation. D5C5 may be substituted by D5C8.	WFD
	Open sea		14 MS reported TVs		
D5C6	Coastal waters	Opportunistic macroalgae of benthic habitats	3 MS reported TVs		WFD
	Open sea		None		

D5 Criterion	Compartment	Agreed threshold methods	TVs available	Comments	Related regulations
D5C7	Coastal waters	Macrophyte communities of benthic habitats	5 MS reported TVs	Availability of TVs across regions is challenging	WFD
	Open sea		None		
D5C8	Coastal waters	Macrofaunal communities of benthic habitats	9 MS reported TVs	Availability of TVs across regions is challenging	WFD
	Open sea		None		

2.4 D6: Sea floor (pressures and impacts)

The D6 Criteria allow for assessing two pressures: the extent of the overall permanent physical loss (D6C1) and of temporary or reversible physical disturbance (D6C2) to the seabed. Other pressures on seabed habitats are addressed under other Descriptors. Assessment of physical disturbance pressures across the entire sea-floor (D6C2) is then used to examine, for each broad habitat type (BHT) and other types of habitat, the extent of adverse effects (impacts) (D6C3) based on changes in their biotic and abiotic structure and functions (e.g., changes in species composition, presence or absence of species, size structure of species).

MSFD Descriptor 6 (D6) (EU, 2017) includes five Criteria; three relate only to the pressures 'physical loss' and 'physical disturbance' and their impacts on the sea-floor ecosystem (D6C1, D6C2, D6C3), specifically, that "sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected". The other two Criteria (D6C4, D6C5) assess the "overall assessment of Descriptor 6, together with that for benthic habitats under Descriptor 1" and in this report are listed under D1/D6.

The pressure Criteria of Descriptor 6 include three primary Criteria (EU, 2017):

D6C1: "Spatial extent and distribution of physical loss (permanent change) of the natural seabed."

D6C2: "Spatial extent and distribution of physical disturbance pressures on the seabed."

D6C3: "Spatial extent of each habitat type which is adversely affected, through change in its biotic and abiotic structure and its functions (e.g., through changes in species composition and their relative abundance, absence of particularly sensitive or fragile species or species providing a key function, size structure of species), by physical disturbance."

The Criteria D6C1 and D6C2 assess the extent of loss and disturbance pressures and their outcome is used to assess the extent of loss and adverse effect per habitat type under D6C4 and D6C3, respectively.

Criteria D6C1 and D6C2 do not have elements as the assessment is conducted for 'physical loss' and 'physical disturbance' ('features' in the reporting) on the overall assessment area. In the MSFD, assessment of Criterion D6C3 is conducted for the broad habitat types (BHT) specified in Table 2 of the GES Decision, which also equates to one habitat type, or more aggregated, at the level of the European Nature Information System (EUNIS) habitat classification (Evans et al. 2016).

2.4.1 D6C1: Spatial extent and distribution of physical loss of the natural seabed

No threshold is required for Criterion D6C1 as it assesses the extent of the pressures intended as "permanent changes to the seabed from different human activities (including permanent changes to natural seabed substrate or morphology via physical restructuring, infrastructure developments and loss of substrate via extraction of the seabed materials) which last for a "period of two reporting cycles (12 years) or more."

2.4.2 D6C2: Spatial extent and distribution of physical disturbance pressures on the seabed

No threshold is required for Criterion D6C2 as it assesses the extent of "physical disturbances from different human activities (such as bottom-trawling fishing)."

2.4.3 D6C3: Spatial extent of each habitat type which is adversely affected, through change in its biotic and abiotic structure and its functions by physical disturbance

TVs for D6C3 need to be established at regional and subregional level. The state of play of the discussion on thresholds for D6C3 done by TG Seabed is reported in the document 'Setting threshold values for seabed habitats' (SEABED_10-2022-02_Thresholds) presented at the 8th TG Seabed meeting on 1-2 December 2021 and currently under review.

2.4.4 D6 (pressures and impacts) thresholds overview

No thresholds are needed for D6C1 and D6C2. There are currently no agreed threshold methods/TVs for D6C3 (Table 4).

Table 4. Availability of agreed threshold-setting methods and Threshold Values (TVs) for each of the three D6 impact Criteria. Red: methods/TVs mostly or fully absent (relevant to less than 3 MS and/or inconsistent).

D6 Criterion (impact)	Agreed threshold methods	TVs available	Comments	Related regulations
D6C1	-	-	No thresholds needed	
D6C2	-	-	No thresholds needed	
D6C3	No	No	Ongoing work at TG Seabed for TVs to OSPAR and HELCOM RSCs	

2.5 D7: Hydrographical conditions

MSFD Descriptor 7 (D7) refers to the permanent alteration of hydrographical conditions that should not adversely affect marine ecosystems (EU, 2017). Descriptor D7 includes two secondary Criteria, as follows (EU, 2017):

D7C1: "Spatial extent and distribution of permanent alteration of hydrographical conditions (e.g. changes in wave action, currents, salinity, temperature) to the seabed and water column, associated in particular with physical loss of the natural seabed."

D7C2: "Spatial extent of each benthic habitat type adversely affected (physical and hydrographical characteristics and associated biological communities) due to permanent alteration of hydrographical conditions."

2.5.1 D7C1: Spatial extent and distribution of permanent alteration of hydrographical conditions to the seabed and water column, associated in particular with physical loss of the natural seabed

No threshold is required for D7C1, as the Criterion's purpose is to assess the spatial extent of alterations to hydrographical conditions and use this as a basis to assess the extent of impacts under D7C2.

2.5.2 D7C2: Spatial extent of each benthic habitat type adversely affected (physical and hydrographical characteristics and associated biological communities) due to permanent alteration of hydrographical conditions

The GES Decision suggests that "*Member States shall establish threshold values for the adverse effects of permanent alterations of hydrographical conditions, through regional or subregional cooperation*".

Analysis of the latest (2018) MS reports for Art. 8 of the MSFD (Friedland et al. 2021) indicated that only four MS (EE, NL, PL, IT) had provided some TVs, which were based on decisions taken at national level. The HD mentions that 90% of a habitat should be in good status, but it has not been settled whether this is an appropriate TV for the MSFD purpose. Environmental Impact Assessments as done for new constructions could be helpful to determine impact and consequently TVs.

2.5.3 D7 thresholds overview

No threshold is needed for D7C1. There are currently no agreed threshold methods for D7C2 and only some sporadic TVs reported (Table 5).

Table 5. Availability of agreed threshold-setting methods and Threshold Values (TVs) for each of the two D7 criteria. Red: methods/TVs mostly or fully absent (relevant to less than 3 MS and/or inconsistent). Secondary Criteria have been italicised.

D7 Criterion	Agreed threshold methods	TVs available	Comments	Related regulations
D7C1	-	-	No threshold needed	
D7C2	No	No; Only four MS declared some TVs in their latest Art. 8 reports, which differ from each other and their scientific basis is unclear.	There needs to be regional cooperation for the establishment of both threshold methods and TVs	HD

2.6 D8: Contaminants in the environment

The GES Decision (EU, 2017) notes under MSFD Descriptor 8 (D8) that "*Contaminants are at a level not giving rise to pollution effects*". D8 includes two primary Criteria related to the concentration of contaminants (D8C1) and the occurrence of significant acute pollution events (D8C3) and two secondary Criteria related to the adverse effects of those contaminants (D8C2) and pollution events (D8C4).

2.6.1 D8C1: Concentrations of chemical contaminants in water, biota or sediments

The toxicity of chemical substances is established in laboratory experiments involving different species, in-vitro assays, as well as Quantitative Structure Activity Relationship modelling. The resulting No Effect Concentrations NOECs (or Predicted No Effect Concentrations PNECs) are then, adding a safety factor, established as TVs.

Under D8C1, MS shall consider the Priority Substances (PS) and River Basin Specific Pollutants (RBSP) identified under the Water Framework Directive (WFD, 2000/60/EC) as well as additional contaminants which may give rise to pollution effects in the region or subregion. For each contaminant under D8C1, MS shall express its concentration, the matrix used for monitoring (water, sediment, and biota), whether the TVs set have been achieved, and the proportion of contaminants assessed which have achieved the TVs.

Environmental Quality Standards (EQS) have been derived at EU level for assessing the chemical status of water bodies under the WFD. The EQS Directive (EQSD, 2008/105/EC) established the maximum acceptable concentration and/or annual average concentration for 33 PS (and 8 other pollutants) which, if met, allow(s) the chemical status of the water body to be described as 'good'. This Directive was updated in 2013 (2013/39/EU), extending the number of PS to 45 substances or groups of substances. Currently, EQS in water have been set for 44 PS and EQS in biota for 11 of those very hydrophobic PS; the WFD does not set legally binding EQS in sediments.

The methodology to derive EQS under the WFD is described in the technical guidance documents developed under the WFD (WFD TGD, 2011, updated in 2018). In addition, the WFD establishes the principles to be applied by MS to develop EQS for RBSP that "are discharged in significant quantities" as part of the assessment of the ecological status.

According to the GES Decision, for the contaminants identified under the WFD, MS must apply the WFD EQS thresholds. When no EQS has been set under the WFD for a specified matrix, as well as for additional contaminants, the TVs should be established through regional or subregional cooperation.

However, the review of last MSFD reporting cycle (Tornero et al. 2021) has shown that, while the WFD 'EQSwater' values are commonly used by MS for D8C1 assessments of PS, the WFD 'EQSbiota' values are not always applied, and MS sometimes use instead other TVs or assessment Criteria agreed at national or regional level (e.g., the maximum levels in foodstuff (EC 1881/2006) are used in OSPAR as an alternative to EQSbiota to

assess mercury). This discrepancy with the GES Decision requirements can lead to conflicting assessment goals for some parameters across the EU.

Biota and sediments are the matrices commonly used by MS for assessing some contaminants under the MSFD, but, as mentioned above, the WFD sets EQS mainly in water and few in biota, so additional biota and sediment TVs need to be established through regional or subregional cooperation.

Within the OSPAR region, measured biota and sediment concentrations are compared with assessment concentrations describing cut-offs for categories of environmental quality. If the mean concentration of a given data set is significantly below the Background Assessment Concentration (BAC), the concentration is considered "near background" or "close to zero" in case of man-made substances. There are also agreed Environmental Assessment Criteria (EAC), which represent the concentration below which no chronic effects are expected to occur in the marine environment, for some contaminants. However, no EAC are available for all contaminants/matrix combinations required and some alternatives have instead been used. For instance, for heavy metals, the EC maximum levels in foodstuffs have been adopted as a proxy means for assessing the ecological significance of biota concentrations. However, although the WFD starting toxicological endpoint can be similar to the EC Food Regulation, a full equivalence between foodstuff standards and the EQSbiota set to protect human health cannot be expected. Therefore, EU Food standards are used in OSPAR only as an interim solution to address the need for Criteria until a more appropriate approach can be agreed. Moreover, in sediments, OSPAR has adopted the Effects Range-Low (ERL) levels (indicative of concentrations below which adverse effects rarely occur), developed by the US National Oceanic and Atmospheric Administration (NOAA), to assess polyaromatic hydrocarbons (PAHs) and metals. The procedure by which ERL are derived is very different from the general approach used to derive EU thresholds in sediment, so precise equivalence should not be expected. There are ongoing discussions to develop new assessment Criteria based on the EAC principles or on the WFD in order to replace the ERL Criteria.

In HELCOM, the specific benthic Quality Standards (QS) derived under the WFD for some PS have been adopted as sediment thresholds. There are, moreover, ongoing discussions regarding the need for a review of the EQS for polybrominated diphenyl ethers (PBDE) in biota, the establishment of threshold values for diclofenac and the development of a Copper indicator. A compilation of available marine contaminant thresholds or assessment Criteria at EU and regional level as well as in other relevant frameworks beyond the EU, have been compiled by Tornero et al. (2022, *in preparation*). All those TVs or assessment Criteria (derived under the different frameworks: WFD, RSCs, etc.) are based on the direct toxic effects of individual (or group of) toxicants and the identification of the non-significant adverse effect on the exposed organisms. However, each framework follows its own derivation principles, which are described in the corresponding guidelines. The requirements regarding the type and quality of data (i.e., data relevance and reliability) are quite similar among frameworks, but the minimum data requirements for the derivation of thresholds as well as the protection goals are quite different (Tornero et al. 2022).

2.6.2 D8C2: Adverse effects of chemical contaminants

While D8C1 regards concentrations of chemical substances in different marine matrices, D8C2 includes provisions for the assessment of the effects of contaminants on the health of species and the condition of habitats. According to the GES Decision, EU MS shall establish those adverse effects and their TVs through regional or subregional cooperation.

D8C2 has been reported by 13 MS in the last MSFD reporting cycle, showing there are still hindrances in the application of methods for the assessment of the status of the marine environment. There is a high variability in the biological-effect methods considered by MS and, although there are some regional or national thresholds available for some of them, those are not at all consistently used by MS (Tornero et al. 2021). For biomarkers, some BAC and EAC have been developed, generally based on the deviation from reference conditions, but the actual methodology may vary between different biomarkers. Under the MSFD, EAC are used as threshold for GES. Consistency in D8C2 assessments is only high for the methods agreed at regional level, e.g., imposed in marine gastropods within the OSPAR area, and white-tailed sea eagle reproduction ('productivity' and the two supporting variables 'brood size' and 'breeding success') in HELCOM.

2.6.3 D8C3: Significant acute pollution events

"Significant acute pollution events" involving polluting substances, crude oil and similar compounds should be included when MS assess the (good) status of the marine environment. While the provisions of the GES Decision are intended in general for spills of chemicals at sea, most experience is with oil pollution.

D8C3, i.e. "the spatial extent and duration of significant acute pollution events are minimized", is a primary Criterion. 18 out of 21 MS have reported on D8C3 in the latest MSFD reporting cycle, but the parameters used for reporting vary highly among MS. The levels at which an "acute pollution event" is considered as "significant" is not defined under the MSFD and there is still need for a comparable approach. According to the GES Decision, no TVs are required for significant acute pollution events and the determination of GES needs to express an ambition to prevent/reduce significant pollution events.

In the Baltic region, there is a TV for oil spills from ships, which refers to the oil spill volume in each sub-area defined on the basis of a reference period (2008-2013), where the estimated amount of oil spill was considered to be at a historically low level.

2.6.4 D8C4: Adverse effects of significant acute pollution events

Only three of the 18 MS that reported on D8C3 in the 2018 MSFD reporting did so also report on D8C4. D8C3 shall be used to trigger the assessment of Criterion D8C4 "the adverse effects of significant acute pollution events on the health of species and on the condition of habitats are minimised and, where possible, eliminated". The use of this Criterion in the overall D8 assessment shall be agreed at regional or subregional level. In the event that there is an acute pollution event, ad hoc monitoring activities are required and detailed information on the concentration of the pollutant in the exposed environment as well as possible effects on biota/habitat is gathered. The way in which D8C4 results are to be incorporated into other Descriptors' assessments (e.g. D1, D6C5) for the overall purpose of GES assessment should be clarified.

2.6.5 D8 thresholds overview

With regards to agreed threshold methods and TVs for D8 Criteria, the situation is rather good for D8C1 (with the exception of TVs in sediments) and rather poor for D8C2 (Table 6). No thresholds are needed for D8C3 and D8C4.

Table 6. Availability of agreed threshold-setting methods and Threshold Values (TVs) for each of the four D8 Criteria. Red: methods/TVs mostly or fully absent (relevant to less than 3 MS and/or inconsistent); orange: methods/TVs partly present (consistent but relevant to 3-10 MS or to limited regions); green: methods/TVs mostly present (consistent and relevant to more than 10 MS and to most regions). Secondary Criteria have been italicised.

D8 Criterion	Compartment	Agreed threshold methods	TVs available	Comments	Related regulations
D8C1	water	From WFD TGD, 2011, 2018	WFD EQS_{water}	WFD EQS_{water} are frequently used for D8C1 assessments. However, there is limited availability of thresholds for contaminants other than priority substances (PS) as well as high variability among those few additional thresholds.	WFD
	biota	From WFD TGD, 2011, 2018	EQS_{biota} set for 11 PS 19 EAC or EAC proxies applied in OSPAR	Some WFD EQS_{biota} are available, but they are not always applied for MSFD. In OSPAR, some EAC have been adopted as an interim solution, but a more appropriate approach is needed.	WFD; RSC
	sediment	From WFD TGD, 2011, 2018	Few assessment Criteria and TVs are	No legally binding $EQS_{sediment}$ have been set under the WFD. There are current discussions to replace ERL	WFD; RSC

D8 Criterion	Compartment	Agreed threshold methods	TVs available	Comments	Related regulations
			available at regional level	as sediment thresholds for OSPAR assessments.	
D8C2	-	No guidance available	Very few thresholds available and not consistently applied	There is need for harmonized and agreed methodologies for threshold setting. A particular challenge is to use D8C2 in integrated assessments (chemical data + biological effects data) for a complete assessment of risks from chemicals.	WFD; RSC
D8C3	-	No threshold needed		The methodological standards for D8C3 assessment and the definition of "significant" acute pollution event should be agreed at EU level. As the number of significant oil spills should be minimised, there could be the question on the level that should be reached.	
D8C4	-	No threshold needed		D8C4 is only triggered if a significant, acute spill has occurred. The use of this Criterion in overall D8 assessment or in contributing to D1 and D6C5 assessments is not yet agreed.	

2.7 D9: Contaminants in seafood

According to the GES Decision, MSFD Descriptor 9 (D9) comprises one primary Criterion (D9C1), which considers the concentration of contaminants (contaminants listed in Regulation (EC) No 1881/200613 as well as additional contaminants established through regional or subregional cooperation) in edible tissues of seafood caught or harvested in the wild (i.e., excluding finfish from mariculture). For each contaminant, MS shall provide its concentration in seafood, the matrix used (species and tissue), whether the TVs set have been achieved, and the proportion of contaminants assessed which have achieved their TVs.

2.7.1 D9C1: Contaminants in fish and other seafood for human consumption

D9C1 assessments are essentially based on food safety monitoring data and focus on the few contaminants and standards set under Food Regulation 1881/2006 (as amended). Maximum Levels as laid down in the Food Regulation are set in accordance with the ALARA ("as low as reasonably achievable") principle. These are the lowest concentrations that are considered reasonably achievable using good agricultural, fisheries or manufacturing practices and taking into account the risk related to the consumption of food. As said above, a full equivalence between foodstuff standards and the EQSbiota set to protect human health cannot be expected.

Despite the limited number of contaminants listed in the Food Regulation (although there are ongoing discussions on setting limits for other substances like fluorinated compounds), many MS do not provide assessments for all of them.

2.7.2 D9 thresholds overview

D9C1 has well specified threshold-deriving methods and TVs (Table 7), even if still many MS do not provide assessments for all contaminants.

Table 7. Availability of agreed threshold-setting methods and Threshold Values (TVs) for the D9 Criterion. Green: methods/TVs mostly present (consistent and relevant to more than 10 MS and to most regions).

D9 Criterion	Agreed threshold methods	TVs available	Comments	Related regulations
D9C1	ALARA ("as low as reasonably achievable") principle	Food standards are set for a number of contaminants in different marine seafood and fish species and tissues, but there are some reporting issues	Food standards are generally used as thresholds for MSFD D9 assessments. There are ongoing discussions under the Food Regulation to extend the number of regulated contaminants.	Food Regulation 1881/2006

2.8 D10: Marine litter

Marine litter is defined under the MSFD as *"any persistent, manufactured or processed solid material that is discarded, disposed of, or abandoned in the marine and coastal environment"*. The provisions of MSFD Descriptor 10 (D10) aim to protect the marine environment against harm caused by litter, considering the *"Properties and quantities of marine litter do not cause harm to the coastal and marine environment"* (EU, 2008). The GES Decision requires Member States (MS) to assess D10 using the following Criteria (EU, 2017):

D10C1 (primary Criterion): "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".

D10C2 (primary Criterion): "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".

D10C3 (secondary Criterion): "The amount of litter and micro-litter ingested by marine animals is at a level that does not affect the health of the species concerned".

D10C4 (secondary Criterion): "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".

According to the GES Decision, for the definition of D10C1 and D10C2 *"Member States shall establish threshold values for these levels through cooperation at Union level, taking into account regional or subregional specificities"*. For the secondary Criterion D10C3, it is noted that "*Member States shall establish threshold values for these levels through regional or subregional cooperation*", while for D10C4 *"Member States shall establish threshold values for the adverse effects of litter, through regional or subregional cooperation"*. In this sense, the MSFD Technical Group on Marine Litter (TG ML) has been mandated to compile information and develop approaches for setting TVs for Descriptor 10 (Werner et al. 2020).

2.8.1 D10C1: 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.

Criterion D10C1 comprises three environmental compartments (coastline, surface layer of the water column, seabed), where the TVs are at different stages of development. Overall, the TVs for D10C1 are or have been quantitatively based on data on the abundance of litter (Werner et al. 2020).

The total abundance of litter on EU coastlines has been analysed and, based on the precautionary principle, taking into account also disturbance to human activities, the 15th percentile level of the 2015/2016 baseline was selected as the TV.

For litter on the coastline, a TV has been developed, based on the abundance of all litter items per 100 m of this environmental compartment (Van Loon et al. 2020). The EU beach litter baseline dataset (2012 - 2016) was used to derive this TV at 20 litter items/100 m coastline, which was agreed by the Marine Strategy Coordination Group and adopted at EU level in 2020 (Hanke et al. 2019; Van Loon et al. 2020). However, the proposed TV is ambitious and it may take several MSFD implementation cycles to reach; therefore, TG ML and RSCs are developing intermediate measurable targets that take into consideration the different (sub-) regional aspects. Transboundary impacts should also be considered during the formulation of targets and intermediate measurable targets where in-situ measurements supported by modelling studies could facilitate the identification of the origin of litter transported by sea currents (Macias et al. 2019; 2022).

During the 2018 MSFD reporting cycle, only 10 MS out of 22 reported some quantitative TVs for D10C1, mostly based on baseline values at regional or national level (Ruiz-Orejón et al. 2021), due to the absence of EU-agreed TVs at the time of reporting in 2018. While at regional level, UNEP/MAP proposed the TV-2021 (130 litter items/100 m coastline) based on the updated Baseline Value for the Mediterranean Sea (UNEP/MAP, 2021).

Regarding litter in the surface layer of the water column and seabed environmental compartments, some MS reported quantitative TVs during the 2018 MSFD reporting cycle(Ruiz-Orejón et al. 2021), based on the upper values of baselines calculated by UNEP/MAP, while other MS used trends at national level. Discussions are currently taking place to define TVs for water surface and seabed, based on the methodology used for the coastline compartment, while the collection of data of surface and seabed litter from the MS through the EMODnet platform is also in progress.

Discussions on the development of TVs for environmental compartments other than coastlines are ongoing. They depend to a large extent on the availability of monitoring programmes and data. Given the practical difficulties in deriving data on litter inputs to the marine environment (from both land and sea-based sources), current thinking supports the application of a similar cut-off values approach, previously used for the definition of TVs for macro litter on Coastlines, for the surface layer of the water column from available data sets. For seafloor litter, TVs may be derived for certain types of potentially harmful litter (e.g. fishing nets) given the limited information available (Werner et al. 2020).

2.8.2 D10C2: 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.

Criterion D10C2 is subdivided into the same environmental compartments cited for D10C1 but focuses on litter smaller than 5 mm in maximum length, termed micro-litter. According to the Commission Decision (EU) 2017/848: *"micro-litter shall be monitored in a manner that can be related to point-sources for inputs (such as harbours, marinas, waste-water treatment plants, storm-water effluents), where feasible"*. Nevertheless, during the 2018 MSFD reporting cycle, only two MS reported TVs based on baseline values proposed by UNEP/MAP (Ruiz-Orejón et al. 2021; UNEP/MAP, 2015). Therefore, operational TVs agreed at European or regional level for Criterion D10C2 are currently absent and deriving TVs from micro-litter properties linked to impacts (e.g. toxicological effects) is currently challenging (Werner et al. 2020).

Discussions in TG ML, in close collaboration with the RSCs, on the approach towards the assessment methods to derive TVs at EU level have started, along with the collection of micro-litter data through the EMODnet platform. In this regard, there have been several calls for the contribution of data sets by MS through the EMODnet platform; however, current participation is limited. Additionally, a list of prerequisites needed for threshold setting for micro-litter (e.g. definition of reference sampling sites and temporal resolution surveys, agreement on harmonized methods, reference and reporting values) has been compiled based on the discussions within TG ML (Werner et al. 2020).

2.8.3 D10C3: The amount of litter and microlitter ingested by marine animals is at a level that does not affect the health of the species concerned

Under D10C3, MS shall assess the amount of litter and micro-litter ingested by any species of the following groups: birds, mammals, reptiles, fish or invertebrates. The Commission Decision (EU) 2017/848 also indicates that the *"MS shall establish threshold values for these levels through regional or subregional cooperation"*.

Initial discussion were based on the amount of litter in the stomach and intestines of selected species commonly found stranded in the environment compared against a TV based on the percentual occurrence of litter in these animals. Currently, one TV has been defined at regional level, based on litter ingested by the Northern Fulmar seabird in the North Sea (OSPAR RSC common indicator 'EcoQO') and related to close-to-pristine conditions. Some MS used it during the 2018 MSFD reporting cycle (Ruiz-Orejón et al. 2021; Werner et al. 2020). Recently, TVs for litter ingestion in turtles have also been developed and proposed for the Mediterranean Sea region based on INDICIT project approaches in relation to the percentage of turtles with more plastics ingested than total ingested material (Matiddi et al. 2017; 2019); however, regional differences in the selection of species for the determination of TVs at regional or subregional level are still under discussion.

2.8.4 D10C4: 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.

MS shall assess species of birds, mammals, reptiles, fish or invertebrates which are at risk from litter under D10C4. The Commission Decision (EU) 2017/848 also indicates that the *"MS shall establish threshold values for the adverse effects of litter, through regional or subregional cooperation"*. During the last decades, the harm caused by litter (which mainly derive from land-based sources) to marine species has become scientifically evident (*e.g.* Werner et al. 2016).

TVs were not reported by MS during the 2018 MSFD reporting cycle (Ruiz-Orejón et al. 2021), and no TVs are currently available for this Criterion. Different approaches for quantification of entanglement events are under development but monitoring of adverse effects on biota is still a challenge. In the Mediterranean Sea, INDICIT consortiums has proposed protocols, collected data and harmonised with other working groups to support the implementation of the indicator entanglement of sea turtles and biota in marine litter (Matiddi et al. 2019; Rodríguez et al. 2022).

2.8.5 D10 thresholds overview

With regards to agreed threshold methods and TVs for D10 Criteria, the situation is rather good for D10C1 on the coastline and moderate to poor for the other compartments of D10C1 and D10C2, and for D10C3 and D10C4 (Table 8).

Table 8. Availability of agreed threshold-setting methods and Threshold Values (TVs) for each of the four D10 Criteria. Red: methods/TVs mostly or fully absent (relevant to less than 3 MS and/or inconsistent); orange: methods/TVs partly present (consistent but relevant to 3-10 MS or to limited regions); green: methods/TVs mostly present (consistent and relevant to more than 10 MS and to most regions). Secondary Criteria have been italicised.

D10 Criterion	Compartment	Agreed threshold methods	TVs available	Comments	Related regulations
D10C1	Coastline	Yes (EU Beach Litter)	Yes	EU Beach Litter TV agreed in 2020 at EU level	
	Surface layer of the water column	Baselines under development	No	Baseline development has started at EU level	
	Seabed	Baselines under development	No	Baseline development has started at EU level	
D10C2	Coastline	No	No	Discussed in TG ML	
	Surface layer of the water column	No	No	Discussed in TG ML. Collection of microlitter data has started.	

D10 Criterion	Compartment	Agreed threshold methods	TVs available	Comments	Related regulations
	Seabed	No	No	Discussed in TG ML	
D10C3	Biota	At regional level (OSPAR indicator)	Only OSPAR	Availability of TVs across regions is challenging	
D10C4	Biota	No	No	Availability of TVs across regions is challenging	

2.9 D11: Introduction of energy

MSFD Descriptor 11 (D11) refers to the introduction of energy, including underwater noise, which should be at levels that do not adversely affect the marine environment. Descriptor D11 includes two primary Criteria, one referring to impulsive sound and one to continuous low-frequency sound, respectively, as following (EU, 2017):

D11C1: "The spatial distribution, temporal extent, and levels of anthropogenic impulsive sound sources do not exceed levels that adversely affect populations of marine animals".

D11C2: "The spatial distribution, temporal extent and levels of anthropogenic continuous low-frequency sound do not exceed levels that adversely affect populations of marine animals".

Work on the establishment of thresholds for D11 is led by the Technical Group on underwater noise (TG Noise).

2.9.1 D11C1: The spatial distribution, temporal extent, and levels of anthropogenic impulsive sound sources do not exceed levels that adversely affect populations of marine animals

The GES Decision requires that "*Member States shall establish threshold values for these levels through cooperation at Union level, taking into account regional or subregional specificities*".

An EU assessment framework has been developed and adopted by the Marine Strategy Coordination Group in May 2021 including definition of metrics (Dekeling et al. 2020). At present, the framework entails four different methodologies developed in different regions:

Method 1: Loss of habitat area (TV1a and TV1b, two numbers depending on the status of the area) and an allowed duration (TV2).

Method 2: Impact on species distribution (TV1) assessed on a monthly basis (TV2) using exposure curves and index.

Method 3: Impact on population using species distribution combined with population model, using exposure curves and index.

Method 4: Loss of habitat area (TV1) and allowed duration (TV2).

The four methodologies have overlaps. The project 'Harmonize' aims to further develop the framework and converge the four methods; the outcome will be taken into account for the definition of options for EU threshold values for impulsive noise, planned for 2022 in line with the objectives set by the Zero Pollution action plan. TG Noise also agreed that such a general EU framework should then be implemented at regional level, taking into account regional and sub-regional specificities (as for D11C2, see below).

2.9.2 D11C2: The spatial distribution, temporal extent and levels of anthropogenic continuous low-frequency sound do not exceed levels that adversely affect populations of marine animals

The GES Decision requires that "Member States shall establish threshold values for these levels through cooperation at Union level, taking into account regional or subregional specificities" (EU, 2017).

An EU assessment framework for continuous underwater noise has been developed by TG Noise and adopted by MSCG in November 2021 (Sigray et al. 2021) and includes the definition on two TVs (Dekeling et al. 2020). The starting point of the assessment is to determine the condition of a grid cell, which usually is a sub-area of the habitat or portion of the species distribution. The condition of the grid cell can be either acceptable (blue) or non-acceptable (red). The habitat (distribution) consists of many grid cells and will thus consist of a number of blue and red grid cells. In the next step the number of red grid cells (equivalent to percentage of habitat or in km^2) during a period (month) will determine if the habitat is in tolerable or non-tolerable status for that specific month. The TVs for GES are set in terms of Tolerable Impacted Area (percentage of the Habitat) and Tolerable Duration (in percent) depending on the Level of Onset of Biologically Significant Adverse Effects in line with the Criteria defined for Descriptor 11 in Commission Decision (EU) 2017/848. GES is maintained or achieved if the tolerable impacted area and tolerable duration are not exceeded. The last step is to transpose the status of the habitat to the Marine Reporting Units (MRUs). In the MRU the status of the Environment (GES) will finally be assessed. This last step is not dealt with in the current framework but will be handled in the next assessment of DL4.

2.9.3 D11 thresholds overview

With regards to agreed threshold methods and TVs for D11 Criteria, the process is ongoing, while TVs are largely missing (Table 9). The analysis of the latest (2018) MS reports for Art. 8 of the MSFD indicates that most MS did not report any thresholds in their assessments of D11 (Vighi et al. 2021).

Table 9. Availability of agreed threshold-setting methods and Threshold Values (TVs) for each of the two D11 Criteria. Red: methods/TVs mostly or fully absent (relevant to less than 3 MS and/or inconsistent); orange: methods/TVs partly present (consistent but relevant to 3-10 MS or to limited regions).

D11 Criterion	Agreed threshold methods	TVs available	Comments	Related regulations
D11C1	Partly; the process is ongoing	No; meaningful TVs are still largely missing	TG Noise is working on this	
D11C2	Partly; the process is ongoing	No; the metrics of the TVs are determined but not the mechanism of settings	TG Noise is working on this	

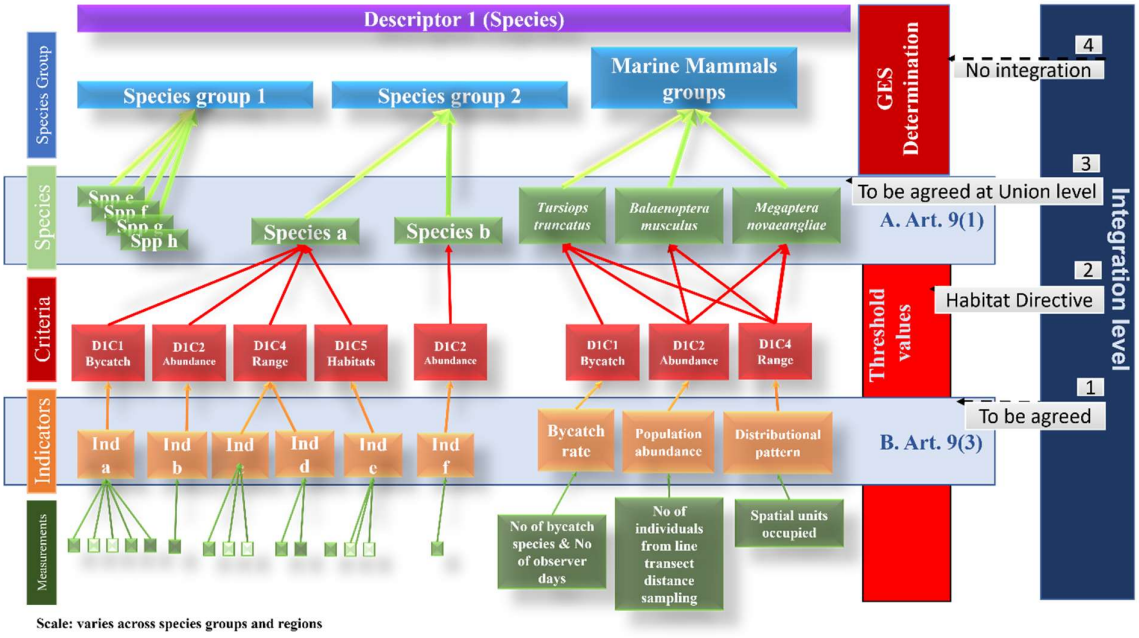
3 Threshold values for Descriptors of essential features and characteristics and current environmental status

Following the structure of the GES Decision, here we consider the TVs of those Descriptors linked to the relevant ecosystem elements: species groups of birds, mammals, reptiles, fish and cephalopods (Descriptor 1), pelagic habitats (Descriptor 1), benthic habitats (Descriptors 1 and 6 ([2])) and ecosystems, including food webs (Descriptors 1 and 4).

3.1 Theme: Species groups of birds, mammals, reptiles, fish and cephalopods (relating to Descriptor 1)

The MSFD Descriptor 1 (D1) includes five Criteria for the five Criteria elements of birds, mammals, reptiles and non-commercially exploited species of fish and cephalopods (D1C1 to D1C5). Each Criterion element includes one to many species groups according to Table 1 of the GES Decision (EU, 2017). Fig. 1 presents the assessment of species, starting from the parameters to the species group level, which entails three integration levels. These levels are positioned in the dark blue column on the right-hand site of the figure. The parallel red column indicates the level where TVs or GES determination is required. This chapter is focused on the methods to set thresholds at Criterion level.

Figure 1. D1C1-D1C5 assessment of species, from parameters to species groups, indicating the integration levels and the levels where agreed threshold values and GES determination (as an agreed value) are required (modified from Palialexis et al. 2016).



Species group (= 'Feature' in the reporting) is the level for which GES should be determined and assessed following the levels and integration steps presented in Fig. 1. At this level a TV to determine GES corresponds to an agreed proportion of species to be in good status out of the total number of species assessed in the group (e.g. 80% of the wading bird species need to be in good status for the species group 'wading birds' to be in GES). This percentage reflects the number of species that can simultaneously present a stable or increasing population against the remaining proportion which might decrease because of the inter-species competition, rather than from anthropogenic activities. Failure to achieve GES threshold indicates that more species than the environmentally targeted/accepted are in bad status and as such (more) measures are required. In this case, the individual species assessments should be further studied to determine the kind of measures to be taken. The determination of the TV that corresponds to the species group level (GES level for species groups – feature

([2]) Only D6C4 and D6C5

level) is not within the scope of this report, which is focused on the TVs at Criterion level. The five Criteria for the individual species assessments are below (EU, 2017):

D1C1: "The mortality rate per species from incidental by-catch is below levels which threaten the species, such that its long-term viability is ensured". Primary Criterion.

D1C2: "The population abundance of the species is not adversely affected due to anthropogenic pressures, such that its long-term viability is ensured". Primary Criterion.

D1C3: "The population demographic characteristics (e.g. body size or age class structure, sex ratio, fecundity, and survival rates) of the species are indicative of a healthy population which is not adversely affected due to anthropogenic pressures". Primary Criterion for commercially exploited fish and cephalopods and secondary for other species.

D1C4: "The species distributional range and, where relevant, pattern is in line with prevailing physiographic, geographic and climatic conditions". Member States shall establish threshold values for each species through regional or subregional cooperation. Primary Criterion for species covered by Annexes II, IV or V to Directive 92/43/EEC and secondary for other species.

D1C5: "The habitat for the species has the necessary extent and condition to support the different stages in the life history of the species". Primary Criterion for species covered by Annexes II, IV and V to Directive 92/43/EEC and secondary for other species.

At the level of Criteria, the MSFD Biodiversity theme for species includes some highly mobile species that require regional coordination for the assessment of their Criteria. To achieve comparable and consistent assessments for these Criteria it is imperative to harmonise the methods to set TVs for the GES Criteria within and if possible, across the four EU regions and the five species groups (birds, mammals, reptiles, fish and cephalopods) (Palialexis et al. 2021).

The Regional Sea Conventions and European policies, such as the BD and the HD, provide thresholds or operational methods to set thresholds for the species classification status (Palialexis et al. 2019). In marine EU Directives and in marine regional assessment methodologies (HELCOM 2018c, OSPAR 2017, UNEP/MAP 2017) TVs are generally defined as 'the desired condition' and in relation to a reference condition. These values should be considered and reused for the MSFD assessments in line with the "use of Criteria" in the GES Decision. However, depending on the region, the species group, and the GES Criterion, several gaps were identified in operational methods and TVs for species covered by those policies and international agreements (Palialexis et al. 2021).

The five species Criteria differ in terms of a) the parameters and/or indicators needed to be assessed, b) whether being primary or secondary which depends on the species group and c) the ecological relevance to the life-cycle of each species or group. These differences should be considered for the formulation of the thresholds' narrative at the Criteria level for each species group. Generally, failure to achieve a threshold at the Criterion level does not automatically trigger a response, as it depends on the integration rules to inform the overall status of the species (Dierschke et al. 2021) and then on the number of species being in subGES in the species group assessment. In the case of failure to achieve GES at the species group level, then the GES Criteria contain the needed information for particular species to trigger possible measures to improve subGES towards GES. In the Criteria section below several measures are linked with pressures, impact or state of the species to indicate the nature of actions that failing to achieve a threshold can trigger.

3.1.1 D1C1: The mortality rate per species from incidental by-catch is below levels which threaten the species, such that its long-term viability is ensured.

This is a primary Criterion; however, it is not relevant to all species, as not all species and species groups are subjected to incidental by-catch. As such, the developed and agreed TVs are species-specific (e.g. for harbour porpoise in the Baltic and North Seas). For most of the relevant species or species groups there are no TVs available, since this Criterion was introduced in the GES Decision and EU MS had insufficient or no monitoring programmes in place. However, the CFP requires data collection for incidental by-catches. For the time being there is no centralised repository for such data, or obligation to the MS to immediately make them available. MS have to make DCF data available when requested, and have to report them under MSFD Art 19(3), a process that needs to be further developed.

Regarding the methods to set TVs for D1C1, they vary from simple methods such as the number of animals caught and the fishing effort to more sophisticated, such as population models that include more sources of mortality, like the Catch Limit Algorithm which requires a number of parameters to be estimated ([3]) (Table 10).

A failure of the TV for this Criterion could trigger measures related to fishing activities (gear selectivity, reduction of fishing effort, protected areas).

Table 10. Availability of agreed threshold-setting methods and Threshold Values (TVs) for D1 Criteria elements of D1C1. Red: methods/TVs mostly or fully absent (relevant to less than 3 MS and/or inconsistent); orange: methods/TVs partly present (consistent but relevant to 3-10 MS or to limited regions); green: methods/TVs mostly present (consistent and relevant to more than 10 MS and to most regions).

D1 Criterion	Criteria elements	Agreed threshold methods	TVs available	Comments	Related regulations
D1C1	Birds	Reference point as a fixed % of the best population estimate	No		CFP
	Mammals	BAL: Catch Limit Algorithm CLA (harbour porpoise); Population Viability Analysis PVA/CLA (seals) NEA: CLA (harbour porpoise, North Sea) MED: Reference point as a fixed percentage of the best population estimate	Only for harbour porpoise in BAL and NEA	A streamlining of methods is needed. A possible common method would be Catch Limit Algorithm (CLA) or Population Viability Analysis (PVA)	HD; CFP
	Reptiles	Potential Biological Removal	No		HD; CFP
	Fish & cephalopods	BAL/NEA: Reference point F_{MSY} (CMSY method) MED/BLK: Empirical estimates of F_{MSY} from survey data	No	Methods to set thresholds have been proposed for testing	CFP

3.1.2 D1C2: The population abundance of the species is not adversely affected due to anthropogenic pressures, such that its long-term viability is ensured.

This is a primary Criterion for all species. The species which are covered by the HD (92/43/EEC) should have TVs consistent with the Favourable Reference Values (FRPs) established by the relevant MS (Table 11). The species relevant for the MSFD that are covered by the HD are listed in Palialexis et al. (2018). A comparative analysis of the MSFD and HD reporting (Palialexis et al. 2020) showed that the HD partially provides TVs for species and

([3]) Required parameters and data to calculate the Catch Limit Algorithm: Species population; anthropogenic mortality [by-catch estimate; hunting bag; estimate of other anthropogenic removal (e.g., collision with vessels)]; CLA calculation: a x Rmax (Dt-β) x Nt [Population model fit to current population size Nt (time-series of population estimates available-and trends to set the recovery factor in PBR), Current status Dt; Maximum population growth rate Rmax]

Criteria. A general recommendation for the sake of consistency and comparability of the assessments is to align the MSFD and HD and apply the same methods to set thresholds and integration rules for all species under D1C2 and D1C4.

The GES Decision presumes that the threshold setting for D1C2 should consider the natural variation in population size and the mortality rates derived from D1C1, D8C4 and D10C4 and other relevant pressures. A failure of a species to be in good condition caused by this Criterion should drive to explore the assessments of the relevant pressure and impact Criteria. For the endangered species from the IUCN Red-listed more drastic measures could be applied such as strict protection to the essential habitats coincide with the natural distribution of the species.

Table 11. Availability of agreed threshold-setting methods and Threshold Values (TVs) for D1 Criteria elements of D1C2. Red: methods/TVs mostly or fully absent (relevant to less than 3 MS and/or inconsistent); orange: methods/TVs partly present (consistent but relevant to 3-10 MS or to limited regions); green: methods/TVs mostly present (consistent and relevant to more than 10 MS and to most regions).

D1 Criterion	Criteria elements	Agreed threshold methods	TVs available	Comments	Related regulations
D1C2	Birds	NEA & BAL: Reference based using modern baseline	No	A promising method to be tested: improved reference based using modern baseline, i.e. HELCOM GAM approach instead of TRIM	BD but no assessments are required
	Mammals	NEA: Reference based using a rolling baseline (6-year cycle) & HD baseline year MED: HD FRPs BAL: Minimum Viable Population MVP / Growth rate (seals). HD FRP; Reference based founded on an indicative healthy historical baseline (harbour porpoise)	For some HD species	A streamlining of methods is needed. A possible common method would be Catch Limit Algorithm (CLA) or Population Viability Analysis (PVA)	HD
	Reptiles	The population abundance at sea over 6 years AND nesting sites over the longest time series	No		HD
	Fish & cephalopods	BAL/NEA: Reference point F_{MSY} (CMSY method) MED/BLK: relative index of abundance OR Deviation from baseline - trend based threshold (e.g. through Breakpoint analysis on CPUE or Biomass estimates)	No	The methods to set thresholds were proposed for testing. Potential but data hungry methods for testing include analytical stock assessments. Reference point B_{MSY} (or Bthreshold)	CFP; HD (some fish species)

3.1.3 D1C3: The population demographic characteristics (e.g. body size or age class structure, sex ratio, fecundity, and survival rates) of the species are indicative of a healthy population which is not adversely affected due to anthropogenic pressures.

This is a primary Criterion for commercially-exploited fish and cephalopods and secondary for other species. However, it is widely acknowledged that D1C3 can be more informative for some species groups compared to other primary Criteria for the status assessment of the population, as is the case for birds and turtles. The major challenge to harmonise methods for setting thresholds for D1C3 is that the GES Decision anticipates use of a number of different population characteristics (e.g., body size or age class structure, sex ratio, fecundity, and survival rates) each one being a different indicator based on different datasets (Table 12). As such, the first step is to identify a common indicator (or more) for each species or species group and then to harmonise the method to set thresholds.

Indeed, D1C3 can provide more direct links with anthropogenic activities and pressures affecting species populations, compared to D1C2 and D1C4, which are primary Criteria. For instance, class structure is sensitive to increased mortality at certain age classes because of fishing for fish, or hunting for birds and seals. Failure of a species to be in good condition caused by this Criterion can lead to more specific measures or actions compared to D1C2 or D1C4, but given the number of species, different life-cycles and possible indicators under D1C3, such actions should be sought case by case.

Table 12. Availability of agreed threshold-setting methods and Threshold Values (TVs) for D1 Criteria elements of D1C3. Red: methods/TVs mostly or fully absent (relevant to less than 3 MS and/or inconsistent); orange: methods/TVs partly present (consistent but relevant to 3-10 MS or to limited regions); green: methods/TVs mostly present (consistent and relevant to more than 10 MS and to most regions).

D1 Criterion	Criteria elements	Agreed threshold methods	TVs available	Comments	Related regulations
D1C3	Birds	Assessment of widespread and frequent breeding failure	No	A promising method to be tested: breeding success levels and their impact on population growth rate	
	Mammals	NEA: Percentage deviation from the baseline value (two types of baseline, modern and beginning of the 6-year reporting cycle)	For some seals		
	Reptiles	No	No		
	Fish & cephalopods	BAL/NEA: Reference point optimal conservation length (LFI - Large Fish Index) MED: Reference point r (population growth rate); L95 proportion of large fish; Gonadosomatic Index (GSI); Optimal Conservation Lengths as Lmax5% or L25%	No	The methods need to be tested	CFP

3.1.4 D1C4: The species distributional range and, where relevant, pattern is in line with prevailing physiographic, geographic and climatic conditions.

Primary Criterion for species covered by Annexes II, IV or V of the HD (92/43/EEC) (i.e. mammals, reptiles and certain fish species) and secondary for other species. The GES Decision requires that MS shall establish TVs for each species through regional or subregional cooperation. For species covered by the HD, these shall be consistent with the Favourable Reference Range values established by the relevant MS under HD (Table 13). Assessments of the adverse effects from pressures under Criteria D1C1, D2C3, D3C1, D8C2, D8C4 and D10C4, as well as the assessments of pressures under Criteria D9C1, D10C3, D11C1 and D11C2, shall be taken into account in the assessments of species under Descriptor 1 (EU, 2017). D1C4 presents conceptually many similarities with D1C2, and both were expected to be assessed by adopting the methods to set thresholds from the HD. The response to failure to achieve the TV for this Criterion is analogous to D1C2. However, the discussions on harmonising the methods to set thresholds are not as advanced as is D1C2.

Table 13. Availability of agreed threshold-setting methods and Threshold Values (TVs) for D1 Criteria elements of D1C4. Red: methods/TVs mostly or fully absent (relevant to less than 3 MS and/or inconsistent); orange: methods/TVs partly present (consistent but relevant to 3-10 MS or to limited regions); green: methods/TVs mostly present (consistent and relevant to more than 10 MS and to most regions).

D1 Criterion	Criteria elements	Agreed threshold methods	TVs available	Comments	Related regulations
D1C4	Birds	Deviation from baseline: change in occupancy rate and shift in the distribution	No		BD but no assessments are required
	Mammals	FRR; Favourable Reference Range and FRA; Favourable Reference Area	For some HD species	Very few species in each species group have TVs	HD
	Reptiles	The population abundance at sea over 6 years AND nesting sites over the longest time series	No		HD
	Fish & cephalopods	BAL/NEA: Species Distribution Models. MED/BLK: Survey-based methods e.g. through Breakpoint analysis on spatial expansion/occurrence. BLK: IUCN Categories and Criteria to estimate trends of "extent of occurrence" and/or "area of occupancy"	No	The methods to set thresholds were proposed for testing, no agreement	CFP

3.1.5 D1C5: The habitat for the species has the necessary extent and condition to support the different stages in the life history of the species.

D1C5 is a primary Criterion for species covered by Annexes II, IV and V to Directive 92/43/EEC (i.e. mammals, reptiles and certain fish species) and secondary for other species. However, it remains the less reported and assessed Criterion for both the HD and MSFD (Table 14). Indeed, for the highly mobile species links with particular habitats at each stage of their life-cycle might not be easy to establish, especially in a generalised manner covering several species. Nevertheless, this Criterion can be very informative for species with critical links with particular habitats, such as marine turtles and nesting sites, seals and occupied caves, green turtle and foraging extent of *Posidonia* seagrass meadows. In these cases, failure to reach the TV can lead to specific anthropogenic pressures and actions, such as forbidding any activity close to turtles' nesting sites. Another

challenging aspect to set TVs for this Criterion is the difficulty to set a baseline or a reference point of an acceptable status of anthropogenic pressure, because of gaps in data and knowledge.

Table 14. Availability of agreed threshold-setting methods and Threshold Values (TVs) for D1 Criteria elements of D1C5. Red: methods/TVs mostly or fully absent (relevant to less than 3 MS and/or inconsistent); orange: methods/TVs partly present (consistent but relevant to 3-10 MS or to limited regions); green: methods/TVs mostly present (consistent and relevant to more than 10 MS and to most regions).

D1 Criterion	Criteria elements	Agreed threshold methods	TVs available	Comments	Related regulations
D1C5	Birds	Deviation from a baseline distribution (in response to pressure from human activities)	No		
	Mammals	HD FRR (Favourable Reference Range) and FRA (Favourable Reference Area): habitat needed to maintain species in viable populations -depending on D1C2	No	Thresholds should come from HD	HD
	Reptiles	The extent of suitable habitats	No		HD
	Fish & cephalopods	No agreement on methods to be tested	No		

3.2 Theme: Pelagic habitats (relating to Descriptor 1)

This theme includes Criterion D1C6 (EU, 2017):

D1C6: "The condition of the habitat type, including its biotic and abiotic structure and its functions (e.g. its typical species composition and their relative abundance, absence of particularly sensitive or fragile species or species providing a key function, size structure of species), is not adversely affected due to anthropogenic pressures".

3.2.1 D1C6: The condition of the habitat type, including its biotic and abiotic structure and its functions, is not adversely affected due to anthropogenic pressures

The broad habitat types defined under the D1C6 correspond to the elements: variable salinity pelagic habitat, coastal pelagic habitat, shelf pelagic habitat and oceanic/beyond shelf pelagic habitat. Methods for estimating TVs have not yet been agreed at habitat, regional and European levels to a large extent, resulting in a generally missing quantitative definition of GES for pelagic habitats. Few regional indicators with agreed methods and TVs are available (Table 15).

For example, in the Baltic Sea region, two indicators exist for assessing the GES of pelagic habitat using the deviation from baseline method. The "Zooplankton Mean Size and Total Stock (MSTS)" achieves good status when both mean size and total stock meet specific TVs at the scale of the assessment unit (HELCOM, 2018c). Baselines are set by two approaches depending on the length of zooplankton time series (Gorokhova et al. 2016). The "Seasonal Succession of Dominating Phytoplankton Groups" considers deviation from the seasonal succession pattern (growth curve) of Diatoms, *Mesodinium rubrum*, Cyanobacteria and Dinoflagellates, that may affect trophic cascades and have wider implications for the sedimentation and the biogeochemical processes. The indicator is currently applied to 12 assessment units in the Baltic Sea (HELCOM, 2018d). In the Mediterranean Sea, Chlorophyll-a (Chl-a) concentration is the operational indicator for D1C6. Reference conditions and TVs have been identified in coastal waters for six of eight MSs, as a result of the Water Framework Directive Mediterranean Geographical Intercalibration Group (Commission Decision EU 2018/229). In the Black Sea, five indicators (phytoplankton biomass, phytoplankton abundance, mesozooplankton biomass, mesozooplankton abundance and Copepoda biomass) are used for the D1C6 assessment. These indicators were developed for the WFD assessment of coastal and transitional water bodies and rely on long-time data series for the calculation of reference values and TVs (Moncheva and Boicenco, 2011). Time periods and TV methods

are species group-specific. Finally, in the NE Atlantic region, no agreed method exists for GES estimate for pelagic habitats.

In conclusion, there is a need to discuss methods and integration among indicators for TVs. A first proposal was made during the JRC workshop (9-10 March 2021) on the use of indicators that have an EU-wide scale of applicability and on methods for their integration for the final GES assessment (Magliozzi et al. 2021). Also, the new EU-funded projects NEA PANACEA, HELCOM BLUES and ABIOMMED will work in this direction.

Table 15. Availability of agreed threshold-setting methods and Threshold Values (TVs) for the D1C6 Criterion. Orange: methods/TVs partly present (consistent but relevant to 3-10 MS or to limited regions).

D1 Criterion	Agreed threshold methods	TVs available	Comments	Related regulations
D1C6	Some regional attempts	Only for some indicators/regions	There are some indicators with TVs in BAL, MED and BLK	WFD

3.3 Theme: Benthic habitats (relating to Descriptors 1 and 6)

MSFD Descriptor D6 focuses on the sea-floor and its benthic habitats and includes two primary Criteria in part II of the GES Decision, which also address benthic habitats under Descriptor 1 (EU, 2017):

D6C4: "The extent of loss of the habitat type, resulting from anthropogenic pressures, does not exceed a specified proportion of the natural extent of the habitat type in the assessment area."

D6C5: "The extent of adverse effects from anthropogenic pressures on the condition of the habitat type, including alteration to its biotic and abiotic structure and its functions does not exceed a specified proportion of the natural extent of the habitat type in the assessment area."

In the MSFD, as for D6C3, the Criteria D6C4 and D6C5 are applied to the broad habitat types (BHT) specified in Table 2 of the GES Decision, which correspond to one or more habitat types at level 2 of the European Nature Information System (EUNIS) habitat classification (Evans et al. 2016). Other habitat types (OHT), derived from other Directives (e.g., HD) and red lists (e.g. RSC, IUCN), can additionally be assessed under the MSFD. Criterion D6C5 takes into account also the assessments of impact to seabed habitats under Descriptors 2, 5, 7 and 8; consequently the TVs need to be set at equivalent levels across these Descriptors (GES Decision Art. 4(2)(d)).

The state of the broad habitat types (BHT) and their associated biological communities is assessed by estimating the proportion and extent of loss of the total natural extent of habitat type (D6C4) and assessing if the extent of the adverse effects (e.g., changes in typical species composition per habitat type) exceeds a specified proportion of each habitat (D6C5). These two 'extent' thresholds, together with a 'quality' threshold under D6C5 are to be agreed at EU level. The habitats to be assessed are listed in Table 2 of Commission Decision (EU) 2017/848 and correspond to one or more habitat types of the EUNIS habitat classification.

3.3.1 D6C4: The extent of loss of the habitat type, resulting from anthropogenic pressures, does not exceed a specified proportion of the natural extent of the habitat type in the assessment area.

Results from the D6C1 are needed to assess the extent per habitat type of D6C4.

For D6C4, the maximum allowable extent loss of the habitat type, resulting from anthropogenic pressures is not already agreed at EU level. The threshold values should not exceed a specified proportion of the natural extent of the habitat type in the assessment area TG Seabed is working on the 'extent' threshold and the updates on the discussion are reported in the document 'Approach to setting threshold values for seabed habitats' (SEABED 10-2022-02) presented at the 10th TG Seabed meeting on 15 March 2022.

The use of HD and WFD assessments in the MSFD was reviewed by TG Seabed and reported in the document 'Review of relevant methods for assessing habitat status under other policies', adopted by MSCG on 12 November 2021 (MSCG 29-2021-04).

3.3.2 D6C5: The extent of adverse effects from anthropogenic pressures on the condition of the habitat type, including alteration to its biotic and abiotic structure and its functions, does not exceed a specified proportion of the natural extent of the habitat type in the assessment area.

Results from the D6C4 (i.e. the extent of loss per habitat) are used to assess the extent of the adverse effects on the habitat for D6C5. For the latter, the loss of habitat extent is to be considered the worst form of adverse effect.

Similarly to D6C4, quality and extent TVs have not yet been agreed at EU level for D6C5 but TG Seabed is working on the issue (see chapter 3.3.1).

3.3.3 D6 (state) thresholds overview

No agreed threshold methods or TVs are available for D6C4-D6C5, but relevant work is ongoing by TG Seabed (Table 16).

Table 16. Availability of agreed threshold-setting methods and Threshold Values (TVs) for each of the two D6 state Criteria. Red: methods/TVs mostly or fully absent (relevant to less than 3 MS and/or inconsistent).

D6 Criterion (state)	Agreed threshold methods	TVs available in MSFD	Comments	Related regulations
D6C4	No	No	Work ongoing by TG Seabed	HD
D6C5	No	No	Work ongoing by TG Seabed	WFD; HD

3.4 Theme: Ecosystems, including food webs (relating to Descriptors 1 and 4)

3.4.1 D4: Food webs

MSFD Descriptor 4 (D4) covers food webs, through assessment of trophic guilds of an ecosystem. Descriptor D4 includes two primary Criteria (D4C1 and D4C2) and two secondary Criteria (D4C3 and D4cC4), as following (EU, 2017):

D4C1: "The diversity (species composition and their relative abundance) of the trophic guild is not adversely affected due to anthropogenic pressures".

D4C2: "The balance of total abundance between the trophic guilds is not adversely affected due to anthropogenic pressures".

D4C3: "The size distribution of individuals across the trophic guild is not adversely affected due to anthropogenic pressures".

D4C4: "Productivity of the trophic guild is not adversely affected due to anthropogenic pressures".

For the definition of the four Criteria mentioned above it is noted (EU, 2017) that "Member States shall establish threshold values through regional or subregional cooperation".

No regional/subregional TVs or methods are in place for D4 Criteria as they have not been agreed or discussed (Table 17).

For D4, in the MSFD Art. 8 reports, just a few TVs were reported by MS, covering all the trophic levels: planktivores, primary and secondary producers, fish community, apex predators, and sub-apex demersal predators (Boschetti et al. 2021). The main source of the TVs was HELCOM, with 13 TVs, while six were (sub)regional, two from the WFD, one from the BD and one national. The work developed by HELCOM and the close collaboration between the Baltic Sea MS is a good practice to drive regional coordination. In NEA, only NL reported to use a TV, from OSPAR, although the value was not reported. In MED, no TV nor any source was reported by any MS. Finally, four MS (DK, FI, PL, PT) reported 16 qualitative thresholds.

Table 17. Availability of agreed threshold-setting methods and Threshold Values (TVs) for each of the four D4 Criteria. Red: methods/TVs mostly or fully absent (relevant to less than 3 MS and/or inconsistent). Secondary Criteria have been italicised.

D4 Criterion	**Agreed threshold methods**	**TVs available**	**Comments**	**Related regulations**
D4C1	No	No	TV/methods not agreed or discussed	
D4C2	No	No	TV/methods not agreed or discussed	
D4C3	No	No	TV/methods not agreed or discussed	
D4C4	No	No	TV/methods not agreed or discussed	

4 Conclusions

4.1 General overview

The information on the current availability (second half of the second MSFD cycle) of agreed threshold-setting approaches/methods and TVs for all MSFD Criteria has been summarised in Table 18 and Table 19 for Descriptors of predominant pressures and impacts, and Descriptors of essential features and characteristics and current environmental status, respectively.

Table 18. Availability of agreed threshold-setting methods and Threshold Values (TVs) for the Criteria of Descriptors of predominant pressures and impacts (January 2022). Red: methods/TVs mostly or fully absent (relevant to less than 3 MS and/or inconsistent); orange: methods/TVs partly present (consistent but relevant to 3-10 MS or to limited regions); green: methods/TVs mostly present (consistent and relevant to more than 10 MS and to most regions); grey: no thresholds needed. The colour scale refers to the availability of thresholds and not to the environmental status (GES or subGES) of each Criterion. Secondary Criteria have been italicised.

Descriptor	Criterion	Agreed threshold methods	TVs available	Chapter
D2: Non-indigenous species	D2C1			2.1
	D2C2			
	D2C3			
D3: Commercial species	D3C1			2.2
	D3C2			
	D3C3			
D5: Eutrophication	D5C1		coastal	2.3
			open sea	
	D5C2		coastal	
			open sea	
	D5C3			
	D5C4		coastal	
			open sea	
	D5C5		coastal	
			open sea	
	D5C6		coastal	
			open sea	
	D5C7		coastal	
			open sea	
	D5C8		coastal	

Descriptor	Criterion	Agreed threshold methods	TVs available	Chapter
			open sea	
D6: Sea floor (impact)	D6C1			2.4
	D6C2			
	D6C3			
D7: Hydrographical conditions	*D7C1*			2.5
	D7C2			
D8: Contaminants in the environment	D8C1	water	water	2.6
		biota	biota	
		sediment	sediment	
	D8C2			
	D8C3			
	D8C4			
D9: Contaminants in seafood	D9C1			2.7
D10: Marine litter	D10C1	coastline	coastline	2.8
		surface	surface	
		seabed	seabed	
	D10C2	coastline	coastline	
		surface	surface	
		seabed	seabed	
	D10C3			
	D10C4			
D11: Introduction of energy	D11C1			2.9
	D11C2			

Table 19. Availability of agreed threshold-setting methods and Threshold Values (TVs) for the Criteria of Descriptors of essential features and characteristics and current environmental status (January 2022). Red: methods/TVs mostly or fully absent (relevant to less than 3 MS and/or inconsistent); orange: methods/TVs partly present (consistent but relevant to 3-10 MS or to limited regions); green: methods/TVs mostly present (consistent and relevant to more than 10 MS and to most regions). The colour scale refers to the availability of thresholds and not to the environmental status (GES or subGES) of each Criterion. Secondary Criteria have been italicised.

Descriptor	Criterion	Agreed threshold methods	TVs available	Chapter
D1: Biodiversity	D1C1	Birds	Birds	3.1.1
		Mammals	Mammals	
		Reptiles	Reptiles	
		Fish & cephalopods	Fish & cephalopods	
	D1C2	Birds	Birds	3.1.2
		Mammals	Mammals	
		Reptiles	Reptiles	
		Fish & cephalopods	Fish & cephalopods	
	D1C3	Birds	Birds	3.1.3
		Mammals	Mammals	
		Reptiles	Reptiles	
		Fish & cephalopods	Fish & cephalopods	
	D1C4	Birds	Birds	3.1.4
		Mammals	Mammals	
		Reptiles	Reptiles	
		Fish & cephalopods	Fish & cephalopods	
	D1C5	Birds	Birds	3.1.5
		Mammals	Mammals	
		Reptiles	Reptiles	
		Fish & cephalopods	Fish & cephalopods	
D1: Pelagic habitats	D1C6			3.2
D6: Benthic habitats (state)	D6C4			3.3
	D6C5			
D4: Food webs	D4C1			3.4.1

Descriptor	Criterion	Agreed threshold methods	TVs available	Chapter
	D4C2			
	D4C3			
	D4C4			

As also mentioned in the Introduction, the current analysis has focused on the availability of 'first-level' thresholds (values/conditions that if exceeded, would indicate good/bad status), i.e. it is an overview of thresholds of Criteria/indicators reported in the 'ThresholdValue' field of the Art. 8 reporting schema. We have not dealt with thresholds for GES ('GESextentThreshold' field in the reporting schema), which would be based on specific integration rules across Criteria and/or Criteria elements (e.g. the 'one out, all out' rule for contaminants). In any case, the limited availability of 'first-level' thresholds highlighted by this study implies a limited capability to define GES thresholds as well.

Unsurprisingly, there is better availability of agreed threshold-setting approaches/methods than of actual TVs (Table 18; Table 19), due to the latter depending on the former. Nevertheless, our review indicates that there is still quite some way to go before we achieve both agreed threshold-setting methods and TVs for all MSFD Criteria. Additionally, there is a great imbalance between Descriptors, with some of them having rather good availability of thresholds, at least for the primary Criteria (e.g. D3; D5; D8, D9), while others exhibit an almost entire absence of thresholds (e.g. D4, D6, D7). This is largely a reflection of the longevity of dealing with these topics in other EU policies (e.g. WFD, CFP) and in the RSCs, with the MSFD introducing new topics for assessment when adopted in 2008, thereby initiated a new phase in development of assessment methods, indicators and TVs. It has also been challenging to define TVs at national level for those Descriptors where new TVs have been set at EU level (e.g. D10 and D11). Additionally, primary Criteria usually result in higher reporting rates by MS, as opposed to secondary Criteria where rates are usually (very) low, which generally also has an effect on TV availability (better for primary than secondary Criteria).

While we tried to harmonise as much as possible the use of the traffic colour palette when characterising threshold availability across the MSFD Criteria, it should be noted that there are both Descriptor-specific and Criteria-specific particularities that make the interpretation of the colouring somewhat different between Descriptors. For example, the absence of thresholds in some of the MSFD Criteria is due to the absence of relevant indicators (e.g. D4), which is a prerequisite for defining relevant thresholds. In other 'red' cases, there have been multiple specific indicators on the table, some even mentioned within the GES Decision, but there are still conceptual challenges in shortlisting the 'optimal' ones and identifying relevant TVs (e.g. D3C3). There are also cases where a 'red' assessment is the direct product of poor data availability, rather than of the need for more conceptual work (e.g. D10C2). Finally, we need to reiterate the issue of the two different general TV concepts within the MSFD: first, there are TVs expressing the quality to be achieved for an element, either from a pure state perspective (e.g. D1), or from an acceptable deviation from reference state in relation to a specific pressure (e.g. D3, D6), or set through lab-based risk (e.g. D8, D9); second, other TVs express the maximum extent of acceptable loss or damage (e.g. D6C3-C5, D7). Consequently, the reader is encouraged to look into the Criteria-specific chapters in order to better comprehend the exact meaning of 'green', 'orange' and 'red' of each entry in Table 18 and Table 19.

4.2 Closing remarks and suggestions

- It is notable that there are still many parts of the MSFD with limited threshold availability. The heterogeneity of the MSFD and its thresholds depicted in this report suggests that to improve threshold availability we would need to focus at a Descriptor- or Criterion-specific level. The lack of thresholds is associated with a wide range of different challenges, such as conceptual complexities, limited data availability, monitoring shortcomings etc. While there appears to be much potential in collaborative joint interpretation through guidance, some very basic principles in TV setting for MSFD appear to require discussion and common understanding. Importantly, we need to clarify the relationship between monitoring methods, data aggregation, TVs, integration rules and GES.
- Specific recommendations based on the results of the current analysis can be made for the different levels of action within the MSFD review process, ranging from incentivising monitoring in order to gather missing data, further technical collaborative work to agree on specific issues in the MSFD CIS (TGs and ENV), providing joint interpretations through guidance, adjustment of Criteria and adjustment of Descriptors.

- There are different types of thresholds being developed. While pressure related TV aim at the identification of parameter specific trigger values, others are based on the spatial application of Criteria. This should be clarified and explained well.in order to facilitate the MSFD implementation process.
- Thresholds for secondary Criteria, which were found to be largely 'red', may be developed using an EU regional approach, but they should still follow common principles/approaches to ensure comparable assessments.
- Setting TVs should not be seen as a theoretical exercise. To be operational as a management tool, all MSFD Criteria need to come with TVs that will trigger some action. It is still unclear what kind of action is/should be triggered by the current TVs of several Descriptors (e.g. D1, D4, D6).
- TVs are anthropocentric management tools (nature does not have 'preferred states') that are intended to promote desirable outcomes. While we do not address compliance and enforcement here, it should be clear that a TV is only useful if there is a long-term sustainable monitoring system that supports compliance checking.

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List of abbreviations and definitions

ALARA	As Low As Reasonably Achievable
BAC	Background Assessment Concentration
BAL	Baltic Sea
BD	Birds Directive
BHT	Broad Habitat Types
BLK	Black Sea
CFP	Common Fisheries Policy
CIMPAL	Cumulative IMPacts of invasive ALien species
CIP	Common Implementation Strategy
CIRCABC	Communication and Information Resource Centre Administrator
CIS	Common Implementation Strategy
CLA	Catch Limit Algorithm CLA
CPUE	Catch Per Unit of Effort
D.O.	Dissolved Oxygen
DIN	Dissolved Inorganic Nitrogen
DIP	Dissolved Inorganic Phosphorus
EAC	Environmental Assessment Criteria
EMODnet	European Marine Observation and Data Network
EQS	Environmental Quality Standards
ERL	Effects Range-Low
EUNIS	European Nature Information System
FRP	Favourable Reference Value
GFCM	General Fisheries Commission for the Mediterranean
HD	Habitats Directive
HELCOM	The Baltic Marine Environment Protection Commission
ICCAT	International Commission for the Conservation of Atlantic Tunas
ICES	International Council for the Exploration of the Sea
IUCN	International Union for Conservation of Nature
JRC	Joint Research Centre
MED	Mediterranean Sea
ML	Marine Litter
MRU	Marine Reporting Unit
MSCG	Marine Strategy Coordination Group
MSFD	Marine Strategy Framework Directive
MSTS	Zooplankton Mean Size and Total Stock
MSY	Maximum Sustainable Yield
NEA	Northeast Atlantic Ocean
NIS	Non Indigenous Species

NOEC	No Effect Concentration
OHT	Other Habitat Types
OSPAR	The Convention for the Protection of the Marine Environment of the North-East Atlantic
PAHs	Polyaromatic Hydrocarbons
PBDE	Polybrominated Diphenyl Ethers
PNEC	Predicted No Effect Concentrations
PS	Priority Substances
PVA	Population Viability Analysis
RBSP	River Basin Specific Pollutants
RSC	Regional Sea Conventions
STECF	Scientific, Technical and Economic Committee for Fisheries
TG	Technical Group
TN	Total Nitrogen
TP	Total Phosphorus
TV	Threshold Value
UNEP/MAP	Mediterranean Action Plan of the United Nations Environment
WFD	Water Framework Directive

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