Marine Strategy Framework Directive (MSFD)

Common Implementation Strategy

Setting of EU Threshold Values for impulsive underwater sound

Recommendations from the Technical Group on Underwater Noise (TG Noise)

MSFD Common Implementation Strategy
Technical Group on Underwater Noise
(TG NOISE)

Deliverable 2 of the work programme of TG Noise 2022

Foreword

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

This document has been agreed by the Marine Strategy Coordination Group (in accordance with Article 6 of its Rules of Procedures) on 14 November 2022. The Marine Directors of the European Union and associated countries to this process have also endorsed this Document during their informal meeting under the Czech Presidency on 29 November 2022.

Disclaimer:

This technical document has been developed through a collaborative framework (the Common Implementation Strategy) involving the European Commission, the Member States and other represented countries, and other stakeholders including Regional Sea Convention and non-governmental organisations. The document should be regarded as presenting an informal consensus position on best practice agreed by all partners. However, the document does not necessarily represent

the official, formal position of any of the partners. Hence, the views expressed in the document do not necessarily represent the views of the European Commission.

The technical document is intended to facilitate the implementation of Directive 2008/56/EC and is not legally binding. Any authoritative reading of the law should only be derived from Directive 2008/56/EC itself and other applicable legal texts or principles. Only the Court of Justice of the European Union is competent to authoritatively interpret Union legislation.

The concept of threshold values was introduced by Commission Decision (EU) 2017/848 of 17 May 2017 laying down criteria and methodological standards on good environmental status of marine waters and specifications and standardised methods for monitoring and assessment. In accordance with Article 2(5) of that Decision, '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.

Threshold values do not, by themselves, constitute Member States' determinations of good environmental status. Pursuant to Article 4 of Decision (EU) 2017/848, threshold values shall "be part of the set of characteristics used by Member States in their determination of good environmental status".

In three cases, for the descriptors on marine litter, underwater noise and seabed integrity, threshold values are to be established through cooperation at Union level. This has been done in the framework of the Common Implementation Strategy (CIS) set up by the Member States and the Commission for the purposes of Directive 2008/56/EC.

The adopted threshold values set out in this document are recommendations to the Member States by the informal Commission group of experts on the implementation of Directive 2008/56/EC (Marine Strategy Coordination Group).

Once established through Union, regional or subregional cooperation, these threshold values become part of Member States' sets of characteristics for good environmental status when they are sent to the Commission by Member States as part of their reporting under Article 17(3) of Directive 2008/56/EC.

1. GLOSSARY

ACCOBAMS	Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area
ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas
Art.	Article
CIS	Common Implementation Strategy
D11	Descriptor 11
D11C1	Descriptor 11, Criterion 1 as laid out in Commission Decision (EU) 2017/848
D11C2	Descriptor 11, Criterion 2 as laid out in Commission Decision (EU) 2017/848
DL1	Deliverable 1 of TG Noise: Common methodology for assessment of impulsive underwater (adopted MSCG/28/2021, May 2021)
DL2	Deliverable 2 of TG Noise: Setting of EU threshold values for impulsive noise
DL3	Deliverable 3 of TG Noise: Assessment Framework for EU Threshold Values for continuous underwater sound (adopted MSCG/29/2021, November 2021)
DL4	Deliverable 4 of TG Noise: Setting of T EU threshold values for continuous noise
EU	European Union
GES	Good Environmental Status
HARMONIZE	EU funded project harmonizing the assessment of impulsive noise
HELCOM	Baltic Marine Environment Protection Commission (Helsinki Commission)
LOBE	Level of Onset of Biological adverse Effects
MS	Member State(s)
MSCG	Marine Strategy Coordination Group
MSFD	Marine Strategy Framework Directive
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
TG-Noise	Technical Group on Underwater Noise
SAC	Special Areas of Conservation
QuietMed	EU funded project aiming to support Member States Competent Authorities in the Assessment of impulsive noise

For practical reasons the work of TG Noise was divided into the four deliverables covering assessment framework and settings of TVs.

- Deliverable 1 (DL1) Common methodology for assessment of impulsive underwater noise (adopted 2021)
- Deliverable 2 (DL2) Setting of Thresholds Values for impulsive noise (this report)
- Deliverable 3 (DL3) Assessment Framework for EU Threshold Values for continuous underwater sound (adopted 2021)
- Deliverable 4 (DL4) Setting of Thresholds Values for continuous noise

2. SUMMARY

The purpose of the present document is to give guidance on the setting of EU threshold values related to anthropogenic impulsive noise in water[1]. Such a guidance is meant to be used by regulators and managers of the EU Member States (MS) aiming to achieve Good Environmental Status of their marine waters, as requested by the Marine Strategy Framework Directive (MSFD)[2].

In this report a clarification of the assessment framework is done based on concepts of habitat, effect ranges and habitat degradation. The guidance is based on the earlier work done by TG Noise in deliverable 1 (DL 1) providing a common methodology for the setting of EU threshold values for impulsive sound and on results from the Harmonize project. An introduction is further given on the Level of Onset of Biological adverse Effects (LOBE), the noise level above which an adverse biological effect on an indicator species is expected to occur. It should be underlined that this document as well as the recommended threshold values are only dealing with displacement as results of anthropogenic impulsive noise. Other possible impacts of impulsive noise such as TTS, injury or death is not dealt with herein, since it is already covered by the Habitats Directive[3] and the Environmental Impact Assessment Directive[4].

A dual threshold approach is proposed recognising both temporal and spatial variability of potential disturbance effects related to exposure to underwater impulsive noise, where **short-term** is defined as 1 day, **long-term** is defined as 1 year and **long-run** is defined as the time it takes before a negative effect on the population occur, which often is longer than one year.

The general principle is that a threshold value for the size of an area that can be exposed to impulsive noise for shorter time period is higher than that for a longer period.

Two essential concepts are introduced in this document both necessary for assessing the status of a habitat, namely LOBE and TVs.

LOBE

The Level of Onset of adverse Biological Effects (LOBE) is a sound level above which an adverse biological effect on an indicator species is expected to occur, i.e., an effect that may affect the comfort, survival, and vital functions of individual animals.

If this happens too much of the time to many individual animals, it may affect their fitness. If this happens at too large a scale, in a large part of the habitat and affecting too many individual animals, it is assumed there will be negative effects on the population. To have tolerable status: LOBE is not exceeded, too often, and over too wide areas.

Settings of TVs

Based on this principle and a review of existing methods for identifying threshold values to reduce impacts to biodiversity (habitats and species), the following advice is provided:

- **For short-term exposure (1 day, i.e., daily exposure)**, the maximum proportion of an assessment/habitat area utilised by a species of interest that is accepted to be exposed to impulsive noise levels higher than LOBE, over 1 day, is 20% or lower (≤ 20%).

[1] in compliance with Descriptor 11 Criterion 1 of Commission Decision (EU) 2017/848

[2] Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008

[3] COUNCIL DIRECTIVE 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora

[4] Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011

- **For long-term exposure (1 year)**, the average exposure is calculated. The maximum proportion of an assessment/habitat area utilised by a species of interest that is accepted to be exposed to impulsive noise levels higher than LOBE, over 1 year on average, is 10% or lower (≤ 10%).

Finally, if the habitat is in non-tolerable status the MS can evaluate if the MRU(s) is in GES, taking the status of the habitat into account.

3. THE DIRECTIVE 2008/56/EC AND THE COMMISSION DECISION 2017/848

The Marine Strategy Framework Directive (MSFD) requires EU Member States to develop marine strategies to achieve or maintain good environmental status of EU MS marine waters by 2020. The Marine Strategy contains five main elements: the initial assessment (Art.8), the determination of good environmental status (Art.9), the establishment of environmental targets (Art.10), the monitoring programmes (Art.11, enabling the state of the marine waters concerned to be assessed on a regular basis), and the programme of measures (Art.13) to maintain and/or improve environmental status (see Fig. 3).

The MSFD identifies anthropogenic inputs of substances and energy into the marine environment including human-induced underwater noise, as pollution (MSFD Art. 3(7)). It also dedicates one of the specific qualitative descriptors (amongst 11) to define Good Environmental Status (GES) to this issue (Descriptor 11, D11).

The Commission Decision (EU) 2017/848 of 17 May 2017 provides criteria a for each of the MSFD Descriptors and methodological standards on Good Environmental Status of marine waters and specifications and standardised methods for their monitoring and assessment. As part of this, it sets out how to assess the extent to which Good Environmental Status is being achieved for impulsive and continuous noise. For D11, it defines two criteria (D11C1 for anthropogenic impulsive noise and D11C2 for anthropogenic continuous low-frequency noise) which consider the spatial distribution, temporal extent and the levels of anthropogenic noise.

For both criteria, EU Member States are to establish threshold values for the levels of underwater noise that should not be exceeded, through cooperation at EU level, considering regional and sub-regional specificities.

In order to guide and advise EU Member States on the operational implementation of this descriptor, a Commission expert group (the Technical Group on Underwater Noise, TG Noise) was established as a sub-group of the Marine Strategy Coordination Group (MSCG). Its main task is to address issues and questions related to the implementation of D11 and to provide Member States with guidance on its implementation. In the CIS Work Programme TG Noise was tasked to provide explicit advice on setting of threshold values.

4. THE STAFF WORKING DOCUMENT 2020/62

The Staff working Document 2020/62 (SWD, 2020) describes concepts and approaches intended to be generally applicable across all Member States. The SWD presents the state-of-the-art in approaches to implementation of the Directive and the GES Decision. The SWD explains the general concept of GES, habitat and some essential key elements such as reference condition and quality and proportion aspects of GES relevant for all Descriptors.

5. THRESHOLDS VALUES AND GOOD ENVIRONMENTAL STATUS

Threshold values for impulsive noise are outlined in the Commission Decision 2017/848 (Annex, p. 65). The following requirements are described:

> *The spatial distribution, temporal extent, and levels of anthropogenic impulsive sound sources do not exceed levels that adversely affect populations of marine animals. Member States shall establish threshold values for these levels through cooperation at Union level, taking into account regional or subregional specificities.*

Further, the extent to which good environmental status has been achieved shall be expressed for D11C1 for each area assessed as follows:

> *The duration per calendar year of impulsive sound sources, their distribution within the year and spatially within the assessment area, and whether the threshold values set have been achieved.*

and

> *The use of criteria D11C1 in the assessment of good environmental status for Descriptor 11 shall be agreed at Union level.*

In accordance with the last requirement, TG Noise developed an assessment methodology including additional concepts than what is required by the Decision (see chapter 7).

Clarification of expressions used in this document:

- A Grid Cell (unit area) can be acceptable or non-acceptable condition
- The assessment/habitat area can be in tolerable or non-tolerable status
- The MRU can be in GES or not in GES

6. UNION LEVEL COOPERATION, REGIONAL AND NATIONAL ASPECTS

In accordance with an effective and coherent implementation of the MSFD in all EU regions and sub-regions and with regard to the transboundary nature of the pollution of marine environments due to anthropogenic noise, common threshold values (TVs) for D11C1 are set through cooperation at union level taking into account regional specificities The threshold value for the assessment of the status of the assessment/habitat area is described in Chapter 10.

Biotic aspects of marine environments, including habitats, sound-sensitive species and protected species, are neither identical within the European Union seas, nor does a single sound-sensitive species occur throughout all EU waters. Similarly, a significant variability of abiotic aspects is found across the different regions and sub-regions. Acknowledging this, the Commission Directive 2017/848 require Member States (MS) to ensure cooperation at the Union level and envisaged that regional or sub-regional specificities must be taken into account when defining threshold values.

TG Noise, in consultation with the European Commission and the Working Group Good Environmental Status (WG GES), decided to work initially on a generic methodology for assessing the effects of anthropogenic noise on the marine environment. The intent was to enable use of common methods at Union level as the first step to establishing thresholds values. This resulted in the DL1 methodology report, which ensures that MS in all regions can work together, with similar terminology and conceptual

approaches. The regional particularities, which must be considered for the regional implementation of the EU thresholds include the special biotic and abiotic characteristics of the respective marine area, as well as the regional emphasis of impulsive noise pressure characteristics. For a target-oriented regional implementation of the thresholds, which best addresses the respective regional aspects, specifications on these aspects cannot be made at Union level. The MS therefore establish upper limit threshold values for the spatial distribution and temporal extent of anthropogenic impulsive noise using the methodology developed through cooperation at Union level as presented in this delivery. To take into account regional or subregional specificities, TG-Noise recommend that Member states establish LOBE values on a regional level guided by expert group advice.

7. SUMMARY OF EARLIER WORK BY TG NOISE

Background of TG Noise work

Tasker et al. 2010 provided the initial definition of indicators for impulsive and continuous noise, which was the basis for the MSFD commission decision in 2010. TG Noise started in 2011 and members were selected based on expertise, who were asked to provide an independent expert opinion. As TG Noise initially focussed on technical advice how to initiate monitoring in European waters. TG Noise produced advice on monitoring that was used by EU Member States. In the current CIS working programme, TG Noise was commissioned to provide advice on Threshold Values for D11, for both impulsive and continuous noise. When this work on TVs started, TG Noise realised that the work to be done by the group changed, as the choice for TV could have implications for policy choices in EU Member States. After raising this topic in the WG GES, the European Commission provided advice how to plan the work process of TG Noise and keep separate the technical advice on methodology and advice on TVs.

Sound or Noise?

For this report the term "noise" is used when discussing sound that has the potential to cause negative impacts on marine life.

The more neutral term "sound" is used to refer to the acoustic energy radiated from a vibrating object, with no particular reference for its function or potential effect.

"Sounds" include both meaningful signals and "noise" which may have either no particular impact or may have a range of adverse effects.

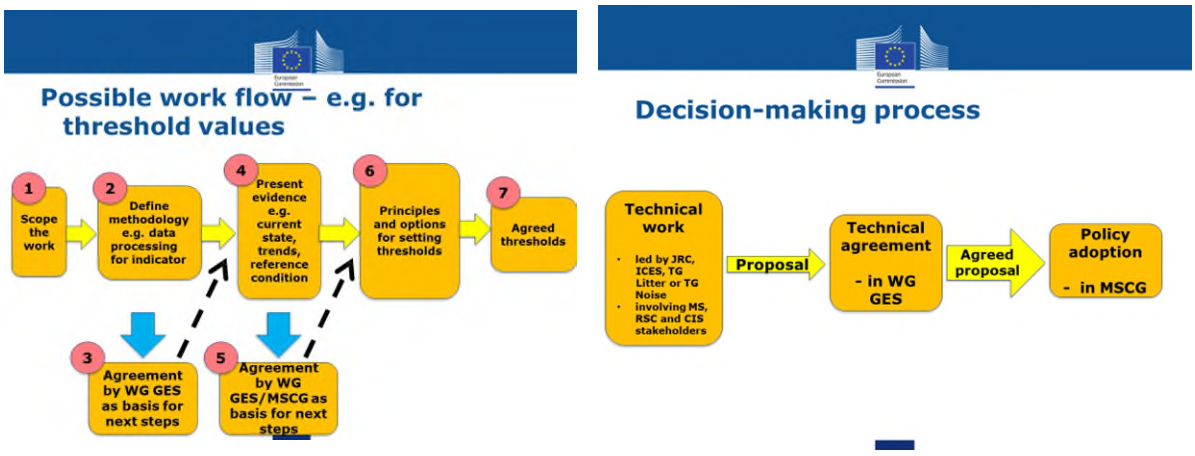

Figure 1. Guidance provided by the European Commission/DG Environment in 2017.

Therefore, TG Noise initially worked on two methodology reports, DL1 for impulsive noise, and DL3 for continuous noise. In a number of TG Noise meetings and workshops, different impulsive noise assessment methodologies were evaluated; consensus was obtained on a common framework (DL1) that was presented to and accepted by 22nd meeting WG GES in September 2019.

The impulsive noise framework

The assessment framework presented in DL1 was based on the following common principles:

- The framework would use information in the existing impulsive noise registries to determine affected area
- Information on the affected area can be combined with species distribution information to quantify potential exposure of marine species to underwater noise
- The approach should be similar to traditional risk assessment methodologies for hazardous substances

The structure of the impulsive noise framework was based on a step-by-step approach since information in the registries and scientific knowledge was not the same in all (sub)regions. This approach would ensure transparency as well as identification of regional needs. The framework consisted of the following steps:

0. Implementation of joint monitoring of impulsive sound sources
1. Define scope of assessment: specific purpose, area covered, time period or duration.
2. Decide on use of indicator/representative species or other method to define sound characteristics likely to affect populations of marine animals
3. Define sound characteristics to be used in the assessment
4. Produce pressure (activity) maps based on impulsive noise register data and the sound characteristics chosen
5. Specify estimated species densities or habitat area
6. Produce noise exposure risk maps combining sound pressure and species distribution or habitat area
7. Compute proportion of species population (if such data is available) or habitat area that may be exposed to noise, potentially using an exposure curve or index
8. Determine potential for negative effects at population level

The framework was thoroughly described in DL1.

From assessment framework to development of threshold values

TG Noise advised that MS working together in a region, should test the use of the assessment framework. The development of the assessment methodology was seen as first step towards development of TVs for D11C1; the assessment methodology could also be used as a basis for identifying options for setting thresholds at different stages of the assessment - where 4 different levels were identified where TVs could be established at a later stage.

Identifying options for TVs was not part of the DL1 report and discussion and rationale were taken up in the DL2 group. These options resulted in a table with alternative levels where TVs are set (see Annex I):

Different options were discussed and pros and cons of setting a TV at different levels were identified:

- A threshold value at the level of the pressure has the advantage that there is a clear link to target setting and measures. However, the link to effect on population level is less clear and is an area of ongoing research interest.
- A threshold value at the level of impact has the advantage that the end objective of the MSFD is addressed, although the link to management targets (i.e. how much noise can be allowed to be produced by anthropogenic activities) is less clear.

TVs at the level of impact (by quantifying either exposure with clearly stated assumptions regarding relationship between exposure and effect or population effects) are preferable to ensure requirements of the MSFD are met, but require more capabilities from MS, to collect data on sources, on sound propagation and not at least on the noise impact on e.g. fitness of sensitive species and population dynamics. This was also the advice given to TG Noise by WG GES in 2021. These capabilities were not available a decade ago. But by the establishment of the impulsive noise registers, national and European projects, combined with ongoing research efforts elsewhere, many of these capabilities have been built or may become available within the coming years.

Based on this discussion, TG Noise concluded that, setting of TVs could be based on exposure level and on related impacts and should be further elaborated on this basis (see chapter 9).

8. LEVEL OF ONSET OF BIOLOGICAL ADVERSE EFFECT (LOBE)

The Level of Onset of adverse Biological Effects (LOBE) is a sound level above which an adverse biological effect on an indicator species is expected to occur, i.e., an effect that may affect the comfort, survival, and vital functions of individual animals. LOBE should be specified in appropriate metrics, including sound pressure and duration of the acoustic event, e.g. it might be a sound pressure level delimiting the zones of no (or low) effect and adverse effect.

What is LOBE?

LOBE is defined as:

The sound level where individual animals start to have responses that are potentially adverse, e.g. disturbance leading to avoidance of an area.

If this happens too much of the time to many individual animals, it may affect their fitness. If this happens at too large a scale, in a large part of the habitat and affecting too many individual animals, it is assumed there will be negative effects on the population.

LOBE and tolerable status of the habitat:

- If LOBE is not exceeded at any time, we would have tolerable status.
- In practice there will always be areas where for some time LOBE is exceeded for parts of the time, i.e. at close ranges to anthropogenic activities some form of disturbance cannot be prevented. It is important to realize that if LOBE is exceeded in some part of the assessment/habitat area, for some part of the time this does not automatically mean that good environmental status is compromised.
- To have tolerable status:
    - LOBE is not exceeded, too often, and over too wide areas

Nevertheless, exceeding LOBE should not result in TTS, killing or injuring of the indicator species (Habitats Directive, Council Directive 92/43/EEC).

For impulsive noise, the biological effect that is considered to be relevant for evaluating GES is disturbance, that may lead to displacement or habitat degradation. It is essential to realize that exceeding

LOBE at one time in one location does not necessarily mean that there is a biologically significant effect on populations. A biologically significant effect requires that sound levels are higher than LOBE for too much time for too much of a population (or habitat area used by a population).

For impulsive noise:

- LOBE can be used to determine the size of the area affected by a specific sound source.
- LOBE similarities with dose/response levels or dose/response concentrations as they are typically used in environmental risk assessments of e.g. hazardous substances.
- For sonar it is likely a Sound Pressure Level (SPL), for pulse-like sounds like piling it might also be the peak sound pressure or the (single-pulse) Sound Exposure Level (SEL); for multiple pulses a lower threshold is assumed than for a single pulse event.
- The size of the area affected by a specific sound source can then be calculated through specific propagation modelling. This area is named effect range.
- Note that considering only received level to estimate the affected area may not always be appropriate. These limitations are addressed in DL1, paragraph 4.3 (step 4). If a modelling approach is not possible there is an alternative way by assigning fixed ranges. These can be based on observations of similar activities, but it is also possible to use a set of ranges that provide a default distance of effect for given circumstances (source, location, species), these can be based on a simplified modelling approach.

Once the LOBE values are defined, threshold values should be based on exposure to noise, in which case they might be a combination of (%) time and (%) population or habitat area that sound levels are above LOBE.

It is widely recognised that behavioural responses to noise (and so LOBE) are variable and context specific (Southall et al., 2007; Southall et al., 2019; Southall et al., 2021 and Gomez et al., 2016) between species and therefore habitat areas.

9. PRACTICAL IMPLEMENTATION OF THE COMMON EU FRAMEWORK FOR IMPULSIVE NOISE

This section describes the concrete implementation of the assessment framework for D11C1 impulsive noise, to assess the impact of impulsive underwater noise, across EU regions and sub-regions during the next MSFD cycle.

The assessment approach fulfils the following criteria:

1) The framework assesses whether marine regions or sub-regions represented by assessment/habitat area are in tolerable or non-tolerable status based on the TVs
2) The framework can be implemented by all regional sea conventions and by member states based on available data in the registries
3) The framework provides robust assessment of the status for the different regions based on a risk-based approach and therefore complies with the precautionary principle
4) The data components of noise exposure, based on the monitoring programme for D11C1, i.e., the noise registries, and the required biological data on habitats is in temporal and spatial coherence

5) The assessment method is widely accepted and well tested in case studies for several EU regions

6) Uncertainties are described and delimited, and monitoring may be used to validate and further improve assessment accuracy

Rationale of the assessment approach is based on principles as recommended by TG Noise (DL1), regional conventions and dedicated EU projects on impulsive noise, e.g., QuietMed (Maglio et al., 2018), QuietMed2 (Azzellino et al., 2021, Maglio et al, 2020), and HARMONIZE (Müller et al., 2022b).

The step wise assessment procedure is based on DL1, see description in Chapter 7, as indicated in DL1 and shown in Figure 2. The assessment follows the habitat approach. Although not specifically quantified, consideration of Step 8 - population level effects - is inferred by a relationship between populations and habitats in the sense of feeding or calving ground, migratory corridors etc.

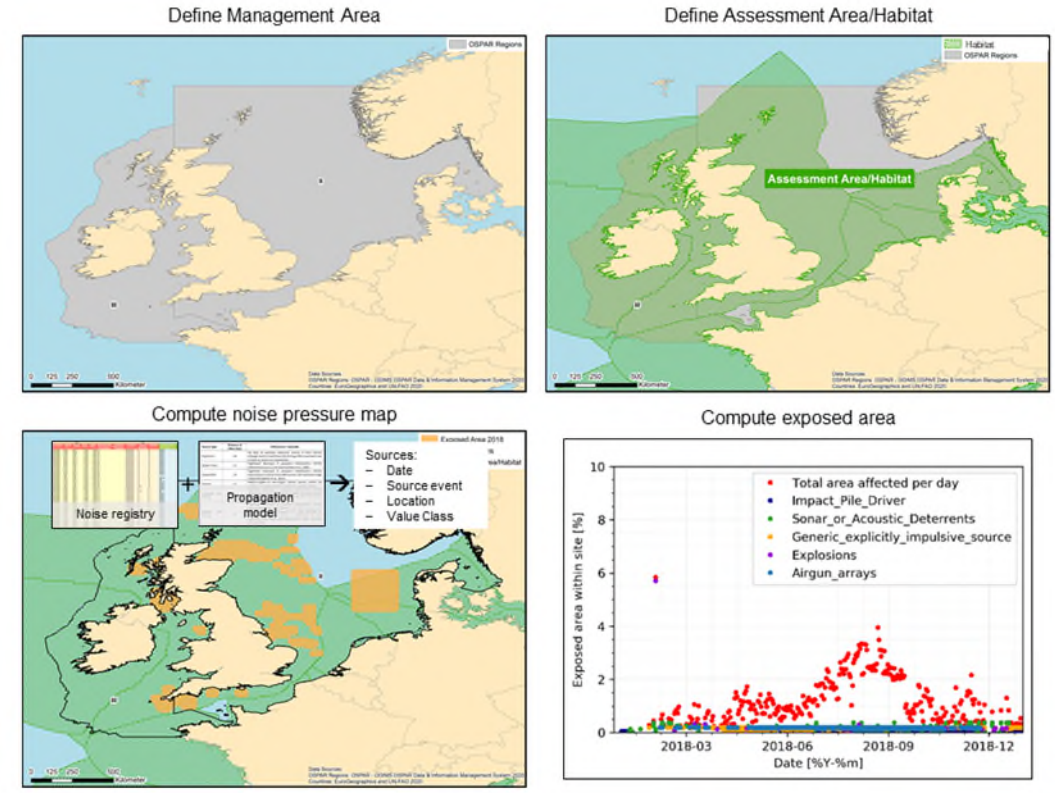

Figure 2: Illustration of the assessment procedure applied to the North Sea.

The practical implementation (see Figure 2) is as follows:

- Definition of the Management Area
- Determination of the assessment area/habitat of the indicator species
- Evaluation of completeness and quality of the data
- Consideration of Level of Onset of Biological adverse Effect (LOBE)

- Selection of a propagation model to estimate sound pressure fields, effect ranges or scientifically justified effect ranges
- Determination of the temporal and spatial noise pressure
- Calculation of exposure using assessment/habitat area and noise pressure and determining the exposed habitat (% area and time exposed)
- Assessment of the environmental status based on threshold values for tolerable temporal and spatial assessment/habitat area

Detailed description can be found in Part II and III in Müller et al. (2022).

Noise registries - D11C1 monitoring

As part of the implementation of the MSFD, regional noise registries have been established in cooperation between EU Member States and regional marine conventions since 2015, providing the data basis for the evaluation of GES with respect to underwater noise. The member states report impulsive noise events in the respective agreements, such as HELCOM, OSPAR, ACCOBAMS.

The classification of noise sources as proposed by TG Noise is summarised in **Fout! Ongeldige bladwijzerverwijzing.** (Dekeling et al., 2014a). Three noise type classes are distinguished: multiple impulsive sound events, such as those produced by pile driving and airguns, single events, such as explosions, and continuous sound/non-pulse events, such as sonars. Member States report impulsive sound events to regional noise registries according to these three noise activity classes, from which the list of specific noise generating activities, relevant to for the reporting to the regional noise registries, was derived. For each noise type class, one specific lower entry level determines the integration of impulsive sound events within each class into the regional noise registries (cf. lower limit of category "very low" in Table 1). These values represent three activity class specific choices for LOBE values for HF marine mammals, which are implemented in the operational noise registries.

As shown in Table 1, the lower limits and metrices of the registration are different for the different noise type classes. On one hand, this is due to the spectral distribution of the sound sources (airgun arrays and pile driving have a maximum at low frequency, non-pulse sounds at higher frequency). HF species were the basis for these studies. Individual events such as explosives were not weighted as disturbances but in relation to TTS (Dekeling et al., 2014b).

Specifically, the registration was based on studies up to 2013 (Dekeling et al., 2014b) on effect of impulsive noise on the marina environment: SEL for multiple impulsive sources of SEL 140 dB re 1 μPa^2s, for non-pulse sounds a SPL of 130 dB re 1 μPa^2 and for explosions a TTS-based SEL of 164 re 1 μPa^2s. These values can be considered as LOBEs for the impulsive noise assessment, if no better

information on the region and species is available. However, the advice from TG Noise is that LOBEs are set by member states on a regional level guided by expert advice.

Table 1: Registration of specific source level into classes proposed by TG Noise, in units of energy source level SL_E [dB] re 1 μPa^2m^2s and re 1 μPa^2m^2. Calculated from 1000 m levels (SEL, SPL) with propagation loss 46 dB.

	SL_E [dB] re 1 μPa^2m^2s multiple impulsive source	**SL_E re 1 μPa^2m^2s single impulsive source**	**SL dB re 1 μPa^2m^2 non-pulse sounds**
Very low	186 – 210	210 – 234	176 – 200
Low	211 – 220	235 – 244	201 – 210
Medium	221 – 230	245 – 254	211 – 220
High	230	255 – 264	221
Very high		265	

The noise registries are the main building blocks for the impulsive noise assessment related to the units of measurements for the criteria of Commission Decision 2017/848:

> *D11C1: Number of days per quarter (or per month if appropriate) with impulsive sound sources; proportion (percentage) of unit areas or extent in square kilometers (km^2) of assessment area with impulsive sound sources per year:*

The exposed area/habitat concept

General description

The basis for the description of the assessment/habitat area are the source strengths of the sound events taken from the noise register, as well as LOBE for the respective marine indicator species. With this database, a spatial view of the exposed area of respective sea region under consideration is obtained with the help of sound propagation calculations or scientifically justified effect ranges. Several simultaneous events, as reported in the noise register, can affect a maximum of 100% of the area under consideration. Since events are reported on a daily basis and not with the exact time and duration, the assessment is based on the assumption of simultaneity of the events.

Detailed Description

The methodology is based on three conceptual areas. The area, $A_{Register}$, covered by the registry, often synonym with the area of the region or the sub-region; and the assessment/habitat area, $A_{Habitat}$. The registers are based on Grid Cells (UK Blocks, ICES sub-rectangles, EA) wherein information on activities is stored. The time steps are counted in the unit of days, using the entries in the noise register. In total 365(366) evaluations are done corresponding to one assessment per day per calendar year. Notable, is that the evaluation can be restricted to months, years, seasons, or sensitive times, but always based on days.

- The first step is to determine what areas of the $A_{Register}$ are exposed to levels higher than LOBE. This is done for every day of the year. This will result in an exposure map for the whole area covered by the registry
- The next step is to determine the areas of $A_{Habitat}$ which are exposed to noise higher than LOBE. This area is denoted, A_{LOBE}
- Dividing the exposed area, A_{LOBE}, of the assessment/habitat area by the total area of the assessment/habitat area, $A_{Habitat}$, results in the fraction of habitat exposed, $F_{Habitat}$. The daily fraction can be expressed as

$$F_{Habitat}(t_i) = \frac{A_{LOBE}(t_i)}{A_{Habitat}} \cdot 100\%,$$

where t_i represents each individual day i within the assessment period. The daily fraction of the assessment/habitat area per day or assessment period can vary between 0% and 100%. If population density data or potentially usable habitat area are available, the assessment/habitat area can be spatially weighted using a weighting function that spans from zero to one (see Annex II). Notably, several events can take place in one Grid Cell on the same day, which is shown in Figure 3.

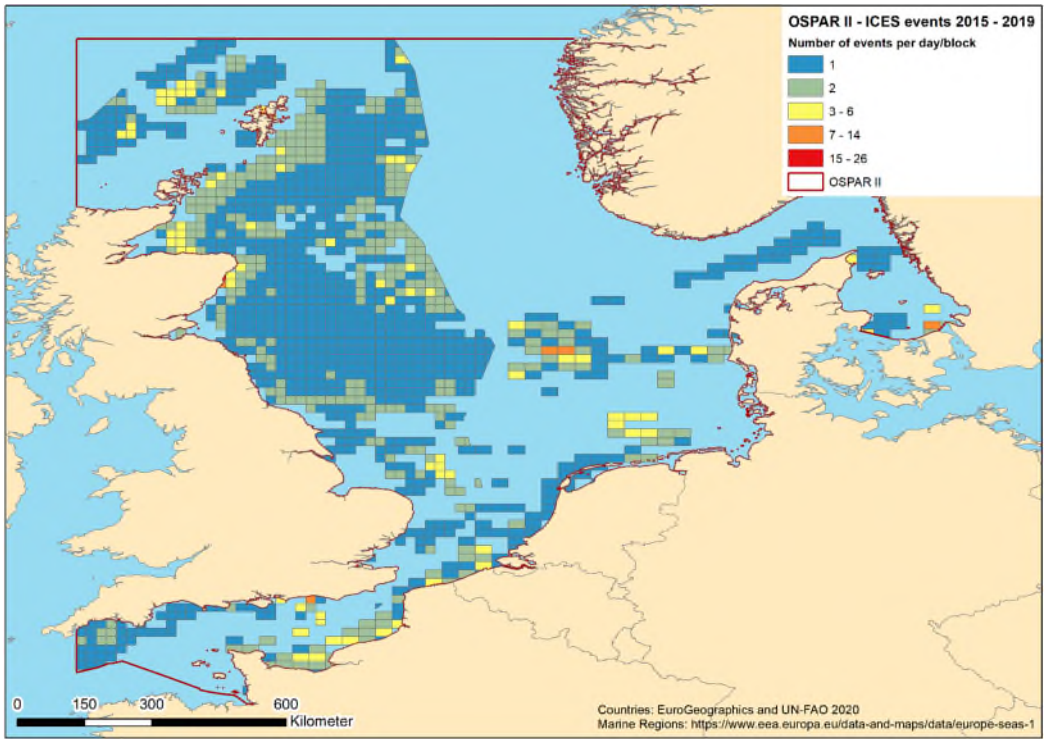

Figure 3: Distribution of registered sound events from 2015 to 2019, with the maximum number of events per day and block.

For these cases, the condition of the Grid Cell is only used once in the assessment of the daily assessment of $F_{Habitat}$. For estimation of affected areas (e.g. affected Grid Cells) the sound event with the largest impact (largest effect range) shall be considered, which leads to a worst-case estimation. The rationale for this choice is that the data in the noise register cannot resolve the events and taking the worst case will adhere to the precautionary principle.

Following the steps, result in 365 (366) estimates of $F_{Habitat}$., taking the assessment period into account (monthly, seasonal, yearly, or sensitive times). The average fraction of exposed area above LOBE during the assessment period can be determined. The assessment provides for an evaluation for acute and chronic exposure of the habitat where proposed TVs are set on the percentage of tolerable areas and tolerable duration of exposure, according to priority requirements of EU regions. The two TVs are:

- Less than X% of assessment/habitat area per day → limitation of acute exposed habitat
- Less than Y% assessment/habitat area within a month, quarter, sensitive time (season), year → limitation of long-term exposed habitat

An illustrative example of equal percentages (i.e., 10%) of area are depicted for the respective EEZs in the EU as examples of management area, see Figure 4.

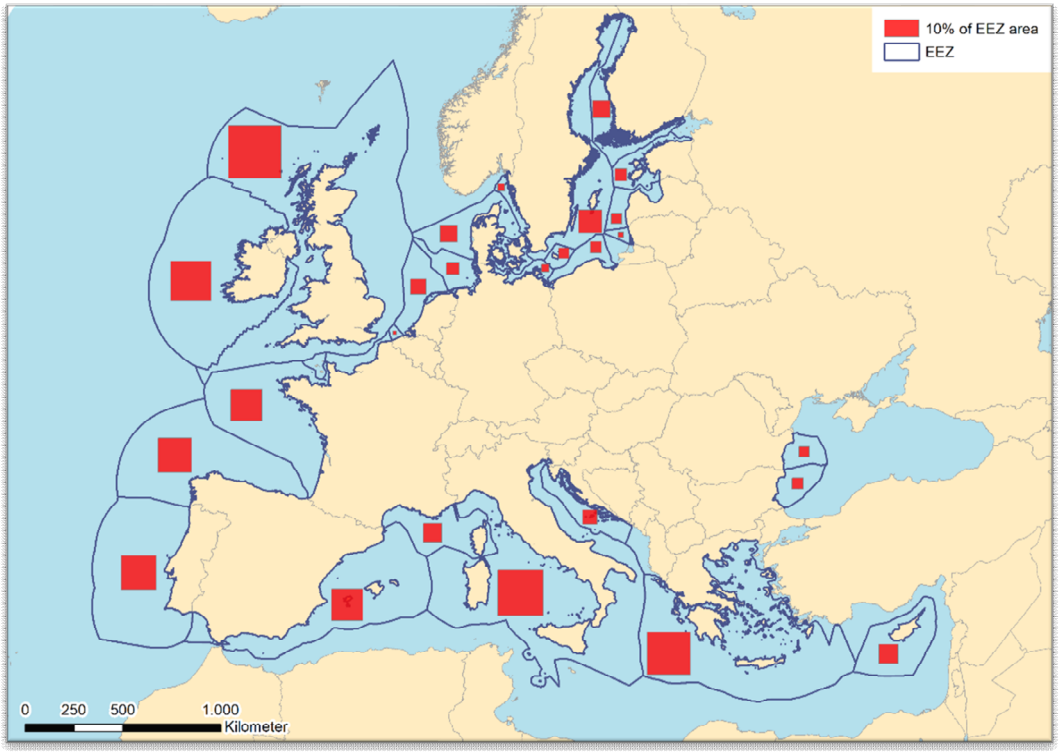

Figure 4: An illustrative map showing the same percentage area ratios in relation to the respective EEZ in the EU. The purpose is to exemplify the size of the MS area relative to their EEZ. [the map will be updated including and excluding countries.]

10. SETTINGS OF THRESHOLDS VALUES

Rationale and link with expected impact on populations of marine animals

The selection of TVs is based on three concepts: habitat degradation, the precautionary principle, and the potential consequences for populations of marine species living in habitats exposed to impulsive noise.

The presence of and exposure to impulsive noise reduces the quality of the habitat for sensitive species, inducing a range of negative effects including behavioural and physiological responses. The kind of effect depends on the intensity of sound signals and for DL2, the focus is on such levels that induce disturbance that may lead to displacement of individuals of a population of an indicator species population from a portion of their habitat or habitat degradation (cf. Level of Onset of Biological adverse Effects).

We assume that habitat degradation increases with the proportion of habitat exposed to sound and the duration of such exposure and is therefore associated with an increased likelihood of negative effects occurring at the population level for a species of interest.

When the exposure to sound is **temporary** the displacement is reversible, and the animals can return to a site after a sound producing activity has been completed. **Thus, short-term exposures of impulsive noise in the species' habitat are assumed to have low probability to cause negative effects in the long-run for the population. Negative effects on population in the long-run are species dependent but is often longer than one year.**

When the exposure to sound is **permanent**, the displacement of animals due to acoustic disturbance has been considered as a habitat loss, e.g.: (Brandt et al., 2018; Graham et al., 2019 and Thompson et al., 2013). **Thus, long-term exposures to impulsive noise over large areas of a species' habitat are assumed to have higher probability to cause negative effects in the long-run for the population.**

For these reasons, **a dual spatial threshold that address short- and long-term exposures to sound appears appropriate and also consistent with common risk assessment approaches.** Selecting spatial exposure limits above which the probability of negative effects for the population of a species is not tolerable and hence the status achieved for D11C1 is not tolerable, requires a discussion of the expected impacts on populations and management scenarios:

A relationship between noise-induced habitat loss and potential consequences on populations can be established using the ecological concept of Carrying Capacity, i.e., the maximum population size that an environment can sustain (see Annex III). If the carrying capacity is determined by the size of the environment where a species live (i.e., the habitat size), a reduction of the carrying capacity can be expected if the habitat size is reduced due to noise-induced habitat loss. Hence a threshold value for impulsive noise can be derived from the potential reduction of the carrying capacity of a habitat for the indicator species.

It is worth noting that the carrying capacity is a property of an environment and not of the population itself, hence the reduction of the population size is assumed to follow that of the carrying capacity after an amount of time which is influenced by the biological characteristics of the population (including the actual length of biological cycles, the birth and death rates, and more). For this reason, a reduction of the population size is expected especially for long-run exposures to impulsive noise. This reduction of carrying capacity has to be expressed relative to a baseline situation. This baseline situation is assumed to be the carrying capacity of the habitat without any pressure from impulsive noise. Effects of pressures from other sources than impulsive noise are not considered in this report.

In an expert report theoretical model based on a relationship of direct proportionality between the carrying capacity of an environment and the size of available habitat for harbour porpoise is proposed (Tougaard et al., 2013). In their report, the percentage of permanent habitat loss corresponds to the same percentage of decrease in the carrying capacity. The simplified model assumes a linear relationship for small reductions of the habitat (see Annex III).

Evidence from terrestrial ecology suggests that relationships between population and habitat size of many taxa have different shapes, including linear and non-linear regressions (Swift & Hannon, 2010), and that the shape can vary according to the ecological response studied (probability of presence, density, abundance, occurrence). Lacking information on the most relevant shape to describe the relation between habitat reduction and population reduction, for the purposes of DL2, the linear model proposed by Tougaard et al. (2013) for harbour porpoise is considered appropriate because it describes a generic relationship whereby the carrying capacity decreases due to a reduction of the habitat size. Therefore, this generic relationship can be applied to other highly mobile species such as marine mammals and fish living in waters surrounding Europe. This approach was adopted by the JNCC to advice about the management of acoustic disturbance in Special Areas of Conservation (SACs) for harbour porpoise in England, Wales and Northern Ireland (JNCC, 2020). Adopting this relationship is suggested by TG-Noise also for DL2.

Hence, based on above-mentioned assumptions, the calculation of how much habitat can be lost to maintain an agreed level of carrying capacity is straightforward following the linear relation, and it should follow possible management objectives which are reviewed in the next section.

We note here that the population decline due to noise-induced habitat loss is not the only type of population consequence that may reveal useful to set thresholds. Complementary methods, for example based on the models known as iPCoD and PCAD, may be tested by Member States to complement the methodology presented here and refine the threshold setting (e.g. Heinis et al., 2022 and Versteeg et al, 2020).

Possible management objectives and resulting options for threshold values

Possible management objectives have been sought in available scientific literature and existing management frameworks, including literature on terrestrial landscape ecology and management and the IUCN approach for assessment of the conservation status of species. Legal frameworks related to marine mammals were also considered, namely: the IWC approach for ensuring sustainable stock exploitation of whales, and the conservation objectives of international organizations such as ASCOBANS and ACCOBAMS. The range of possibilities reviewed includes minimum objectives, such as conserving minimum habitat areas to ensure the survival of the species (e.g., Rompré et al., 2010; McAfee and Malouin, 2008); quantitative objectives of population size to ensure sustainable whaling (Hammond and Donovan, 1997) or to avoid a species to be assessed as vulnerable (IUCN, 2012); and approaches in the frame of nature conservation such as restoring and/or maintaining stocks/populations to 80% or more of the carrying capacity in the long-run (Rejinders, 1997; ASCOBANS, 2000); and improving the conservation status of cetaceans and of their habitats by 2030 (ACCOBAMS, 2019). Lower values are found in terrestrial nature conservation management, where often a permanent habitat loss of only 1% is deemed significant and seems therefore not acceptable (RAMSAR Convention). A summary of the objectives is presented in Figure 5.

Since MSFD aims at GES, the target should be more ambitious than just ensuring survival or avoiding vulnerable status. Therefore, TG-Noise recommend to maintain a population size of 80% (i.e. 80% carrying capacity) in the long term as a minimum target, thereby leaning up against the 80% objective

of other regional and national marine management agreements. This objective has also been accepted (as a minimum standard) by a number of EU countries that are Party to the ASCOBANS Agreement.

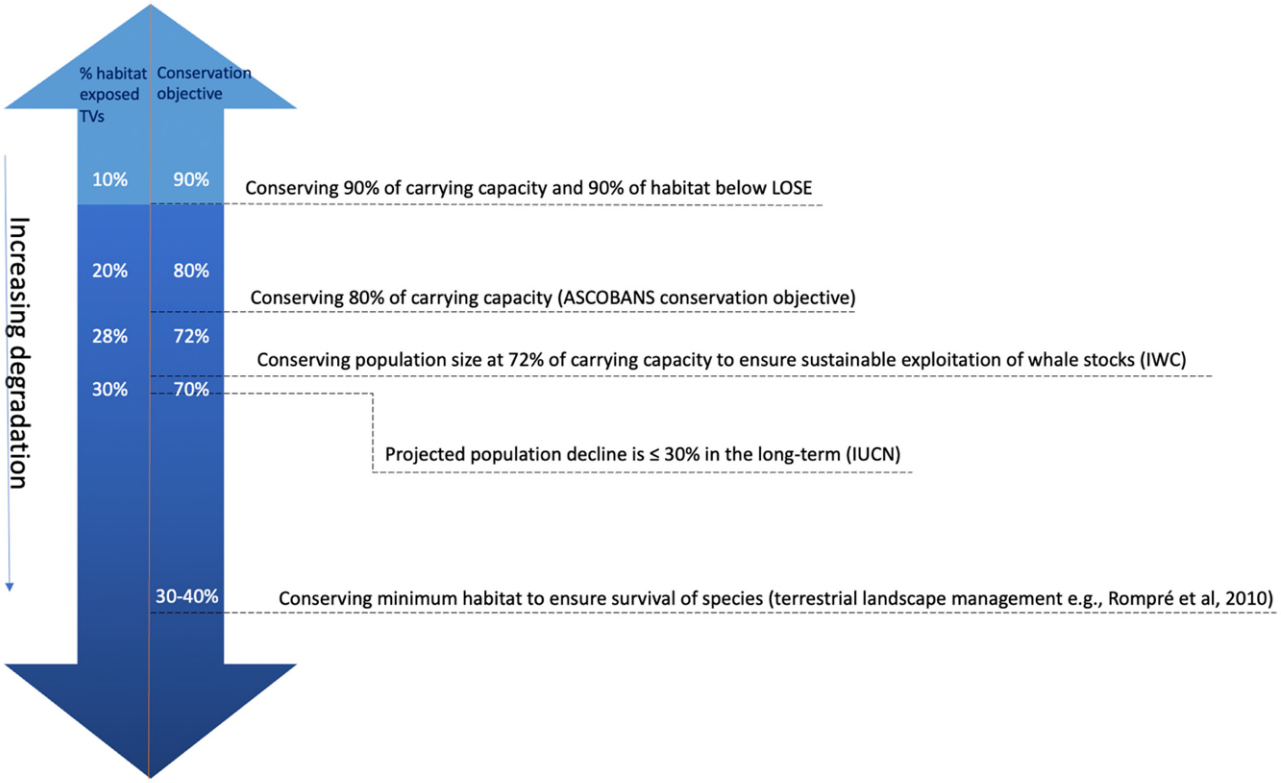

Figure 5. Summary of management objectives and TVs.

If we consider a management scenario of a habitat loss resulting in a reduced carrying capacity and we use the linear model proposed by Tougaard et al. (2013), and further assume that a population is not limited by other pressures a conservation objective of maintaining 80 % of the carrying capacity can be translated into a 20% reduction of the habitat of an indicator species due to long-term acoustic disturbance and hence a decline of 20% of the population size in the long run.

However, since several other stressors put pressure on marine biodiversity and habitat availability, a projected habitat decline of 20% due to impulsive noise alone may in concert with other stressors induce larger actual declines and therefore not be acceptable. To take cumulative effects with other stressors into account, a maximum of 10% of the habitat of an indicator species is considered as an appropriate choice of threshold level for exposure to impulsive noise in the long-term. This reasoning appears consistent with the approach advised by the JNCC for management of acoustic disturbance in marine Special Areas of Conservation (SACs) in England, Wales and Northern Ireland (JNCC, 2020).

Further risk factors may be included in the assessment that justify setting a threshold value lower than 10%. We consider that the TV for the tolerated fraction of habitat area exceeding LOBE should be set to values lower than 10%, in for example the following situations:

- during ecologically and biologically relevant periods such as mating, breeding, etc.,
- in critical habitat such as spawning areas
- in case the assessment addressed threatened species or depleted population.

Further, when it appears convenient to convergence with the objectives set by regional organisations (such as Regional Seas Conventions), the tolerable exposed area for short- and long-term exposure may

also be set to lower percentages of the habitat of an indicator species. For this reason, the threshold values are given as a maximum level or lower.

Long-term exposure duration is set to 1 year, based on the duration of the annual biological cycle of most marine mammals and fish living in waters surrounding Europe and taking the risk of a low breeding success caused by disturbance during one annual cycle into account. This also matches the period indicated in the Commission Decision 2017/848 for assessment of D11C1. To address long-term exposure, the calculation of the exposed area is proposed to be the arithmetic mean of the daily exposed areas, over 1 year. This way allows for some flexibility with a certain number of days in a year above 10% as long as the annual average meets the 10% limit.

With regards to short term exposures, it is assumed that these will have lower probability to impact the population size because intermittent short-term exposures are considered to induce reversible displacement and hence no habitat loss. Hence, short-term exposure duration is set to 1 day because this is short enough to be confident that this assumption applies. Also, this is the time unit of the noise registries, and it is therefore the shortest possible time frame. It is considered as well that a threshold for short-term exposure may allow for a larger area exposed to impulsive noise compared to long-term exposures, without this inducing a decline in the population size in the long-run. However, the threshold should be low enough to avoid large exposures for intermediate periods (e.g., periods or seasons that may be biologically or ecologically relevant for the species used in the assessment). For example, 90% of the habitat of an indicator species exposed to impulsive noise for 40 days will still result in less than 10% of habitat exposed on average over 1 year, but this scenario is not considered acceptable. Therefore, a threshold value for short-term exposure (1 day) of 20% of the habitat of indicator species will have low probability to induce a population decline for the reasons described above, will avoid unwanted large exposures for intermediate durations (months), and allows for some flexibility with regards to the long-term exposure limit. Finally, the threshold value for the tolerable exposed area related to short-term exposures might be set to lower than 20% for the same reasons discussed for long-term exposures.

Tolerable exposed area

As a result from the discussion above, the conservation objectives reviewed in combination with the linear model linking carrying capacity and habitat size (Tougaard et al, 2013) are the basis for the proposal of TVs. A dual threshold is proposed to address short-term and long-term exposure to impulsive noise, where short-term exposure is set to 1 day and long-term exposure is set to 1 year. TG Noise advice is that:

- **For short-term exposure (1 day, i.e., daily exposure)**, the maximum fraction of the habitat of an indicator species that is accepted to be exposed to impulsive noise levels higher than LOBE over 1 day, is 20% or lower (≤ 20%).
- **For long-term exposure (1 year, i.e., yearly exposure)**, the average exposed[5] area is calculated. The maximum fraction of the habitat of an indicator species that is accepted to be exposed to impulsive noise levels higher than LOBE, over 1 year on average, is a 10% or lower (≤ 10%).

Regional or local specificities and indicator species will be taken into account when determining the exact threshold value by Regional Sea Conventions (RSCs).

As noted in DL1, there is an increasing prevalence of alternative methods for quantitatively assessing population effects being develop and applied to specific and/or representative species. As further

[5] Arithmetic mean of daily exposures over 1 year.

information becomes available, for example through future or parallel adoption of these methods, the above threshold values and supporting assumptions should be tested and refined.

Use of the threshold levels

Tolerable status relative to D11C1 is achieved if for all single days over a year the exposed area is 20% or lower (≤ 20%), and if the average exposure over 1 year is 10% or lower (≤ 10%). This mechanism implies that a certain number of days over a year are allowed between the short-term and the long-term threshold.

These values for the extent of exposure are considered based on available information (see rationale above). Considering this possibility, the TVs for Tolerable Exposed Area that appear as acceptable proposals are summarised as follows in Table 2.

Table 2. Suggested TVs and rationale.

PERIOD	TOLERABLE EXPOSED AREA	SHORT DESCRIPTION OF RATIONALE
Short-term exposure (1 day)	20% or lower	20% is set as the maximum amount of habitat that can be disturbed by noise higher than LOBE, on a daily basis. It is higher than for long-term exposure because short-term exposure is deemed unlikely to induce a decline in the population size in the long-run. It is low enough to avoid unwanted large exposures for intermediate durations (months), still allowing for some days with more than 10% of the habitat exposed to impulsive noise. Threshold Levels lower than 20% can be set according to local or regional specificities such as during critical times and in critical habitat area or if a species conservation status requires a stricter limit.
Long-term exposure (average over 1 year)	10% or lower	As LOBE is set to address the displacement of animals due to acoustic disturbance, long-term exposure to impulsive noise higher than LOBE will displace animals almost permanently from portions of their habitat and this has been considered as habitat loss. The reduction of habitat translates into a reduction of the carrying capacity and hence a decline in population size in the long run. Setting 10% as the maximum amount of a habitat disturbed by underwater impulsive noise, on average over 1 year, allows maintaining 90% of the habitat of a target species not degraded by noise as well as the population size of the species used in the assessment at least at 90% of the carrying capacity in the long run. Threshold Levels lower than 10% can be set according to local or regional specificities.

Summary of TVs

TG Noise advice is to set the threshold values to:

- **For short-term exposure (1 day, i.e., daily exposure)**, the maximum proportion of a habitat area utilized by a species of interest that is accepted to be exposed to impulsive noise levels higher than LOBE, over 1 day, is 20% or lower (≤20%).
- **For long-term exposure (1 year)**, the average exposure is calculated. The maximum proportion of a habitat area (calculated as the mean of the daily proportions over one year) utilized by a species of interest that is accepted to be exposed to impulsive noise levels higher than LOBE, over 1 year on average, is 10% or lower (≤10%).

The TVs are given as a range (X% or lower) in order to take regional and sub-regional specificities into account. This is an advice based on available information (see above) considering the request of the Commission for a cooperation at EU level between Member States. In accordance with the Commission Decision of 2017, Member States have and can set lower TVs when improved information is available.

The TG Noise expert group was established to guide and advice Member States. The TVs are based on available information but with new knowledge these TVs could be changed.

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ANNEX I

Levels where thresholds can be set presented in tabl1 A1.

Table A1. Principle thresholds values.

Level where TV is set	Explanation, information used	Example	Further information needed
Pressure (sources/activities)	Information from noise registries, including #, scale, duration of activities generating impulsive noise, Source strength, categories	TV could be: xx times (or days) per year, yy activities, maximum source levels of zz dB	Information on relation between pressure and effect on populations (over the whole above mentioned assessment chain)
Pressure (noise levels)	Noise maps, made with information from the noise registries, calculating amount of area, amount of time that a predefined response level is exceeded.	TV could be: xx % of the assessment area, yy % time above the predefined response level	D/r level for a predefined effect (e.g. received level of 140 dB SEL leading to area avoidance by porpoises); distribution of sensitive animals; + relation between disturbance and population effects.
Impact (exposure)	Using the noise maps, calculated amount of population or habitat that is exposed to sound levels above the predefined response level	TV could be: xx % of the population/habitat, yy % time above the predefined response level	Relationship between exposure to sound and impact population effects.
Impact (population)	Determination of effects on population	TV could be: xx % mortality of population per year (or over yy years)	Relationship between responses (such as disturbance) and population effects. Acceptable mortality of population (similar to acceptable bycatch)

ANNEX II

Taking habitat modelling and population density into account

For indicator species used in the assessment, habitat and/or population density data should be available. Either measured or modelled data can be used. With regards to habitat data, common habitat modelling implies estimating the probability *W* (spanning between 0, low, and 1, high) of an animal being in a Grid Cell, e.g Potential Usable Habitat Area (PUHA). With regards to population density data, the use of common abundance modelling usually produces estimations of animal density per Grid Cell. Therefore, population density data need to be normalized, i.e., to bring all values into the range [0,1]. The fraction of area exposed is then evaluated by weighting all areas of the Grid Cells with either habitat data or rescaled population density data. E_{LOBE} is defined as

$$A_{LOBE}(t_i) = \sum_{1}^{n} W_n \cdot A_{GC}$$

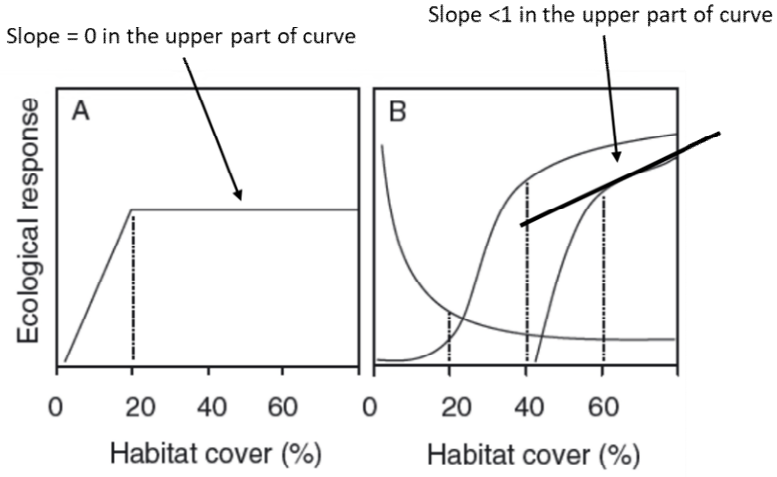
where *n* is the index for Grid Cells in the assessment /habitat area, A_{GC} is the area of the Grid Cell. Irrespectively of methods, the assessment shall comply with the metric specified in the Decision 2017/848:

> *"Number of days per quarter (or per month if appropriate) with impulsive sound sources; proportion (percentage) of unit areas or extent in square kilometres (km2) of assessment area with impulsive sound sources per year"*

ANNEX III

On the topic of habitat loss and carrying capacity.

Two points are important. First, the reduction in carrying capacity with reduction in habitat can only be assumed if the population is food limited or limited by some other resource restricted to the habitat (e.g. haul-out sites for seals). If a species is limited by factors not related to the habitat, such as fishery, by-catch or contaminants, then this/these factors will determine the carrying capacity, not the habitat size. Thus, assuming a link between habitat size and carrying capacity is precautionary. Second, the relationship between habitat size and carrying capacity is likely to be close to linear for not too large changes in habitat size. If the indicator species is not already severely limited by habitat size, the slope of this line is likely to be less than 1 for small reductions in habitat size. See figure (adapted from Swift and Hannon, 2010). The consequence is that assuming a linear relationship (slope = 1) is precautionary.



Computation of the long-term exposure. The use of a one-year average of the daily exposed averages effectively means a perfect trade-off between time and area that can be exemplified with two extremes, the assessed impact of one assessment block that is above LOBE 365 days of the year is equivalent to 365 different blocks, each being above LOBE for a single day (on the same day, or on consecutive days).