HARMONIZE

A Harmonized and Applicable Assessment Framework for Impulsive Noise – Interim Report

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Summary of Content:

The project „Harmonize“ develops a harmonized assessment framework for impulsive underwater noise for immediate implementation by all Member States, based on current knowledge, data and resources. Thus, the project supports and enables threshold setting and evaluation of GES to fulfil requirements in upcoming reporting for MSFD. This interim report presents the results obtained during the first half of the project.

For the purpose of harmonizing assessment approaches for impulsive noise, four criteria to evaluate various approaches for impulsive underwater noise were identified: suitability, applicability, feasibility and reproducibility.

These principle criteria have been used to elaborate on a methodology with respect to the purpose of immediate implementation. Based on current knowledge and resources, habitat approaches as described in DL1, are practicable methodologies for all Member States, which can be implemented immediately.

Furthermore, an assessment framework is proposed in this report including the following steps:(1) definition of the assessment area, (2) proof of data completeness and quality, (3) choice of thresholds regarding indicator species, (4) choice of propagation model, (5) determination of effect ranges and (6) evaluation of the status of the defined area. We used data, which are available in the noise registries from the International Council for the Exploration of the Sea (ICES) and the European Marine Observation and Data Network (EMODNet) for analyses. In this report, we also discuss the completeness and quality of data.

The project “Harmonize” is funded by the Directorate-General for Environment (DG ENV) of the European Commission. The German Federal Maritime and Hydrographic Agency (BSH) is coordinating the project, while the Swedish Royal Institute of Technology (KTH) and the Italian Institute for Environmental Protection and Research (ISPRA) are cooperating partners. For this report, the German consultancy Müller-BBM GmbH has been commissioned with research and analyses required to establish the above-mentioned framework.

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1 Introduction

This project aims to facilitate the harmonization of assessment approaches regarding impulsive underwater noise and standardization of procedures. The primary project objective is to recommend a harmonized methodology for regional assessments. The latter must fulfil the requirements of the MSFD regarding D11.1, as well as being feasible, applicable and affordable for all regions and Member States.

A common methodology with examples of possible implementations was described in report DL 1 [1]. However, methodologies described in DL 1 need to be evaluated with respect to requirements of the MSFD and regarding their applicability across all regions and Member States. All Member States are now called upon to define appropriate thresholds describing the level up to which the effects of anthropogenic sound no longer adversely affect the marine environment.

In this report, the feasibility of implementing the assessment is examined on the basis of currently available data supplied from the member states to the respective national registries. Common features of strategies are elaborated and discussed. This interim report is focused on the practical implementation of an assessment, with particular focus on uncertainties and consequences of an assessment of Good Environmental Status.

The interim results were presented at a TG Noise workshop in September 2021. A summary of the workshop is included in the appendix.

This project was founded by DG ENV/MSFD 2020.

2 Status quo

2.1 Commission decisions (EU) 2017/848

The Marine Strategy Framework Directive 2008/56/EC (MSFD) seeks to achieve sustainable use of the marine environment by requiring member states to achieve and maintain Good Environmental Status (GES). Thus, GES is a common European goal. Hence, GES needs to be defined and a methodology must be elaborated with the aid of which it can be assessed. Directive 2008/56/EC provides a list of qualitative descriptors for GES in Annex I, with Descriptor 11 comprising “the level of introduced energy/underwater noise into the marine environment“.

In order to establish a clear link between the determination of a set of characteristics (Descriptors) for good environmental status and the assessment of progress towards its achievement, it is necessary to establish criteria and methodological standards on the basis of the qualitative descriptors laid down in Annex I to Directive 2008/56/EC.

Commission Decision 2010/477/EU [2] specifies criteria for GES and methodological standards relevant for the Descriptors. With regard to impulsive noise, primary criteria are defined, including a spatial component as well as a temporal component. The use of these criteria is meant to provide a description of the spatial and temporal distribution of impulsive noise events within an assessment area throughout a calendar year.

Within the Commission Decision (EU) 2017/848 [9], detailed criteria were given for descriptor 11. These specify the requirements on the anthropogenic input of underwater sound. Additionally, they give guidance for the assessment.

The level of sound input into the marine environment should not cause adverse effects on populations of marine animals. Member states should define threshold values through cooperation at Union level that enable the requirement to be fulfilled. An excerpt from the requirement is shown in Figure 1. Notable specifications are given on the assessment. However, there is room for adaption and interpretation. For example, acoustic metrics of sound sources are specified and a rough assessment scheme is given.

Descriptor 11

Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment

Relevant pressures: Input of anthropogenic sound; Input of other forms of energy

Criteria, including criteria elements, and methodological standards

Criteria elements	Criteria	Methodological standards
Anthropogenic impulsive sound in water.	D11C1 — Primary: 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.	*Scale of assessment:* Region, subregion or subdivisions. *Use of criteria:* The extent to which good environmental status has been achieved shall be expressed for each area assessed as follows: (a) for D11C1, 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; (b) for D11C2, the annual average of the sound level, or other suitable temporal metric agreed at regional or subregional level, per unit area and its spatial distribution within the assessment area, and the extent (%, km^2) of the assessment area over which the threshold values set have been achieved. The use of criteria D11C1 and D11C2 in the assessment of good environmental status for Descriptor 11 shall be agreed at Union level. The outcomes of these criteria shall also contribute to assessments under Descriptor 1.
Anthropogenic continuous low-frequency sound in water.	D11C2 — Primary: The spatial distribution, temporal extent and levels of anthropogenic continuous low-frequency sound 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.	

Specifications and standardised methods for monitoring and assessment

1. For D11C1 monitoring:

   (a) Spatial resolution: geographical locations whose shape and areas are to be determined at regional or subregional level, on the basis of, for instance, activities listed in Annex III to Directive 2008/56/EC.

   (b) Impulsive sound described as monopole energy source level in units of dB re 1 μPa^2 s or zero to peak monopole source level in units of dB re 1µPa m, both over the frequency band 10 Hz to 10 kHz. Member States may consider other specific sources with higher frequency bands if longer-range effects are considered relevant.

Units of measurement for the criteria:

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

— D11C2: Annual average (or other temporal metric) of continuous sound level per unit area; proportion (percentage) or extent in square kilometres (km^2) of assessment area with sound levels exceeding threshold values.

Figure 1: Extract from Commission Decision (EU) 2017/848 [9], Descriptor 11 [1].

2.2 Guidance from TG-Noise and EU-definitions

For the implementation of the Commission's requirements, TG Noise currently provided technical reports such as, a) the TG Noise guidance (3 parts): [3], [4], [5] and b) the assessment method for impulsive noise DL1 [1].

The document "Good environmental status and its links to assessments and the setting of environmental targets" published by the Commission in 2020, gives a detailed guideline [10] for terminology and definitions, which are often referred to in this report.

According to the guideline published by the Commission and TG Noise advice in preparation included in DL3 [10] it is important to distinguish among definitions of area such as: grid cell, habitat and management reporting unit (MRU).

Habitat is defined as a particular area that is characterized by specific communities of species (i.e. a multi-species concept of habitat); in this case the habitat comprises particular biotic and abiotic characteristics (often referred to as a biotope and termed 'natural habitats' under Directive 92/43/EEC)). This makes it distinguishable from surrounding habitat types. In contrast to the habitat of a single species, this use of the term habitat refers to something that is more uniform in its character, leading to the definition and classification of habitat types and the ability to produce maps of habitats. The European Environment Agency's EUNIS habitat classification provides a Europe-wide classification of marine (and terrestrial) habitats in a 6-level hierarchical system. The Habitats Directive and several international conventions (e.g. HELCOM, OSPAR) have developed lists of habitat types which require protection. Within a habitat the status can be determined. As a result a habitat can be at tolerable or not tolerable status.

According to the Assessment Framework, condition of grid cells but also habitats and indicator species can primarily be considered at Member state level (SWD (2020) 62 final) [10].

Finally, a MRU is defined as an area where the environmental status is assessed. A MRU may or may not be in good environmental status (GES). Based on the available guidance detailed above, the appropriate scale of a GES assessment for D11C1 MRUs may be regions, subregions or a suitable (and preferable low) number of subdivisions (of regions or subregions), the latter being potentially delineated using national borders of marine waters (SWD (2020) 62 final, Section 5.4). This recommendation is in line with the Commission Decision (EU) 2017/848 under “Methodological standards” for D11 and also included in DL3 (Assessment Framework for D11C2) [6].

2.3 DL 1: Towards threshold values for underwater noise – Common methodology for assessment of impulsive noise, Comparison of assessment methods

TG Noise advices to implement a step-by-step approach, which enables Member States to start the process of implementation. Methodologies to assess effects of impulsive underwater noise were described and a step-by-step approach was proposed for further implementation in DL1 [1]. A detailed explanation of each step can be found in [1].

To date, a main achievement driven by Guidance from TG-Noise regarding D11C1 is the development and establishment of noise registries operated by the sea conventions such as HELCOM, OSPAR and ACCOBAMS, which was pointed out by TG Noise as a fundamental tool for a joint monitoring on regional or sub-regional level. Based on information from noise registries, DL 1 includes examples of methodological options, which aim at assessing GES. Table 1 summarizes the approaches described in DL 1. However, DL 1 does not provide guidance for setting thresholds to assess Good Environmental Status (GES).

Table 1. Tabular comparison of currently used methodologies. (MA) is the management area and could be a region, subregion, (MPA) are Marine Protection Areas, e.g. Natura 2000 sites, (PUHA) Potentially Usable Habitat Area).

Main aspects	**A: Approach described in Merchant et al. (2017) [1], [14]**	**B: Population based approach as applied in the Netherlands [1], [15], [19]**	**C: Habitat based approach as applied in Germany [1], [15]**	**D: Habitat based approach as proposed by QuietMed2 [1]**
Baseline	Disturbance	Disturbance	TTS/Disturbance	Disturbance
Source data	Noise registry	Noise registry	Noise registry	Noise registry
Effect ranges	Observations for species (based on specific adverse effect e. g. disturbance related to a specific activity)	Propagation model	Empirical propagation model/ measurements	Propagation algorithms / predefined buffers
Assessment areal focus	MA, e.g. OSPAR II, MPAs	MA	MA (EEZ) and MPA	MA and PUHA,
Adverse effect	Population (density)	Population (decline in density)	Habitat affected (quality loss)	Habitat affected (quality loss)
Assessment metric/parameter to evaluate/interpret	Exposure curve (index)	Population dynamics (Model-based)	(Adaptable percentage of area over time (based on sensitive periods)	Percentage of area and time exposed
Options for Threshold for GES	Change in the form of the Exposure curve (or change in index)	Change of population based on a model result, Perhaps x % reduction in population	Percentage of area (x % EEZ or MPA) exposed over time	e.g. x % area exposed (MA and MPA) and y % time exposed

The methodologies included in Table 1 are investigated in this report. The aim of these investigations is the elaboration of a harmonized assessment process. It should be stressed that methodology B (TNO) stands out in the respect that it requires a deeper analysis of data as well as it predicts consequences for the population.

As shown in Table 1 approaches described under C and D are almost identical, with both being based on habitat as defined in SWD (2020) 62 final, Section 5.4. For defining effect ranges, approach C relies merely on empirical modelling and measurements; approach D makes also use of propagation algorithms and predefined buffers. Both approaches C and D quantify adverse effects with habitat loss for the population/s addressed. Results of these two approaches are expressed in the same metrics (% area exposed for % time exposed). On the other hand approach A is also aiming at describing adverse effects as revealed by population decline (% of population) based on assumptions regarding biological variables to predict effect ranges. The final metric of the results is an exposure curve. Finally, approach B implies modelling to describe adverse effects directly on population/s decline (% of population) on the basis of models using biological variables which must be assumed.

3 Harmonization criteria for assessment framework

3.1 Description of harmonization criteria

Crucial requirements for the suitability of approaches for D11C1 are 1) that they are able to assess whether a defined area does or does not achieve GES, 2) that they can be handled by regulators, and 3) that they can be implemented based on available data, with the constraint to provide for robust statements about GES in the different regions. A central objective of HARMONIZE is to answer the following question:

Which approaches can currently be used with respect to the presently available data (noise registries and biological data) in the different regions, when aiming at robust statements about GES?

The four assessment approaches considered for harmonization in this project can be classified by a number of characteristic aspects. These aspects were summarized in table 1. In recent years, there have been numerous discussions within the TG-Noise on options to implement an assessment and on related constraints.

Considering the discussions held during several workshops and meetings of TG-Noise, important criteria have been identified by HARMONIZE. These consider technical-scientific and practical-financial feasibility for the assessment process in particular.

For the purpose of harmonizing available assessment approaches, HARMONIZE extracted a set of four most relevant *Harmonization Criteria* for the evaluation of the suitability of specific aspects of a harmonized approach, which are outlined in the following. Furthermore, these criteria have been structured into minimum requirements and further aspects of consideration with respect to an aspired implementation for assessment purposes based on resources available to all Member States (MS).

<u>1. Suitability</u>: data and information available allow for an evaluation of status, uncertainties are well delimited and results can be practically translated into regulation if needed.

Minimum requirements

Data availability concerning habitat (abiotic parameters like water depth, slope, currents, fronts and biotic parameters like Chlorophyll a concentration, species spectrum, mammal occurrence) or population dynamics (abundance and distribution of target species).

Further aspects of consideration

For habitat-based approaches: 1) good knowledge on fundamental abiotic parameters and general information on mammal and other relevant species occurrence within either defined areas of interest or administrative areas (such as EEZ’s), and 2) availability of impulsive noise event data, 3) a **temporal and spatial coherence between data in 1) and 2)**.

For population-based approaches: In addition to 1) abundance and distribution, 2) good knowledge on vital rates such as reproduction / growth / mortality rate, food resources, diseases, effects of climate change, other anthropogenic impacts than noise, and 3) clear links between sound exposure and resulting impact are relevant.

2. Applicability: assessment methods are well defined, uncertainties can be estimated reliably enough for each Member State to apply them for its own assessment purposes, e.g. setting regulatory measures or evaluating the sufficiency of measures.

Minimum requirements

1) Methods available are widely accepted and well tested in case studies for as many EU regions as possible and transferable between regions, 2) uncertainties are well defined and delimited, and 3) monitoring may be used to evaluate the sufficiency of measures

Further aspects of consideration

National agencies or institutes are 1) capable of performing such an assessment and 2) are not entirely dependent on multinational actions for information needed to plan, implement and monitor national measures.

3. Reproducibility: methods applied are transferable to subregions and regions, results are non-ambiguous and allow for comparison of GES at Union level.

Minimum requirements

Assessment method and monitoring actions allow to compare results and efficiency of measures among regions and member states

Further aspects of consideration

Each member state is able to compare results on national level with regional and cross-regional results

4. Feasibility: assessment effort is such that each MS is able to implement common requirements with own resources and capabilities.

Minimum requirements

Each member state should be able to participate with the financial capacity and with resources currently available, without depending on expertise that exists only in some Member States or specialized institutes

Further aspects of consideration

At least one responsible agency or institute per Member State should have the necessary capacities to perform an assessment, including personnel and equipment.

3.2 Assessment using habitats, populations and PUHA approaches

For the assessment of noise impact on the marine environment four different approaches are according to DL1 under consideration, (summary in Table 2). They can be sorted with respect on using habitats or species population for the assessment:

The two approaches by Germany and QuietMed2 are similar, both use area for assessment purposes and, therefore, are considered habitat-based approaches. TNO and Merchant use instead population as for assessment purposes and, therefore, are considered population-based approaches. The habitat-based approach estimates how large of the habitat area is affected by noise, whereas a population-based approach estimates, how large a fraction of the population is affected by noise. The definition of habitat in the habitat-based approach refers to a biological context defining areas as suitable for a species or species community according to abiotic and biotic parameters. Thus, the term “habitat” can include MRUs, MPAs, Natura 2000 sites, marine sanctuaries or others.

The habitat-based approach as applied in the German approach is based on knowledge on habitat characteristics, such as hydrographic and geological conditions and occurrence of species of concern, like cetaceans. Further, the preferred food sources of species of concern, such as the harbour porpoise, are taken into account. Information on presence and food can be obtained from survey data (sightings) and measurements of environmental parameters such as water depth, currents, salinity or sea surface temperature, tides, fronts, and surface sediments. Modelling is not necessary in the simplest way of dealing with the habitat. The QuietMed2 habitat-based approach makes use of the concept of Potential Usable Habitat Area (PUHA), which is based on environmental parameters correlated to species and their occurrence. Such parameters are e.g. bathymetry or slope of the sea floor. The potential use of habitat area is scaled from 0 % indicating, that an area is not suitable as habitat for a given species up to 100 % indicating that an area is most suitable as habitat for a given species. The latter case implies a high probability this species to occur in the respective area. However, it does not indicate that the species is currently in this area. It is assumed that within these areas species are present with higher probability than in the surrounding areas.

The seasonal variation of a species’ occurrence can also be taken into account by considering all habitats used by a species throughout its life cycle. Studies on the variability of species’ occurrence and habitat use already exist [23]. Models correlating species occurrence with environmental parameters can even predict specie’s occurrence in new areas of the same environmental characteristics to some extent [24].

The aim of the habitat-based approach is to minimize impact on habitats by setting spatial and temporal thresholds for noise in certain areas or parts of areas (e.g. National reporting units, subregional units, MPAs). The habitat-based approach clearly follows the precautionary principle as required by EU-legislation. For preventing impacts on marine life due to impulsive but also continuous noise it is essential to protect habitats regularly or potentially used by species of concern in a way that at any time sufficient area will be available for animals of relevant populations to use for vital functions and avoid adverse effects due to significant noise disturbance.

The population-based approach aims at assessing noise impacts at population level by either using population density (Merchant et al., [15]) or by predicting model frameworks (TNO, [20], [21]). The population-based approach by Merchant et al.[15] calculates “exposure indices”, which represent the integrated exposure based on an area spanned by percentage of a population exposed to noise and percentage of time during the assessment period. Whether a small proportion of a population is exposed for a longer period of time (chronic exposure) or vice versa (exposure prevalence) is indicated by “chronic exposure rates” as well as “exposure prevalence rates”. The approach by Merchant et al. also provides the use of habitats instead of population density. Since population density is a constantly changing value and highly mobile species like harbour porpoises cannot be allocated to certain spots over time, the use of habitats as whole areas seems to be favourable.

In context of the population-based approach predictive model frameworks like PCoD (Population Consequences of Disturbance) or DEPONS (Disturbance Effects on the Harbour Porpoise Population in the North Sea) need physiological and demographic variables [25]. Values for those variables are derived from little empirical data on specific species or based on expert assumptions. This is due to a lack of empirical data describing the relation between noise exposure and physiological or behavioural reactions and their consequences on population level.

In comparison the habitat-based approach relies on sighting data and measurements of environmental parameters instead of assumptions or approximations. Since, overall amount of uncertainty in assessment should be kept at a minimum, habitat approach is less uncertain than population-based approach. Moreover, as stated before, defining suitable habitats (based on knowledge of where species occur with high probability) in combination with thresholds to minimize the impact on this habitat follows the precautionary principle.

Data for a habitat-based approach are mostly available, since most European Member states are part of transnational long-term surveys and also have environmental data of their national waters such as bathymetry, currents, temperature profiles. Data used for predictive models in context of the population-based approach are currently still scarce. This might be due to the fact that physiological, demographic or telemetry data are obtained with higher efforts and probably higher costs resulting in low sample sizes. A feasible and robust assessment approach seems to be one with a comparatively large, empirical data basis (instead of approximations or assumptions), which is already available to member states. Another aspect is the applicability of measures: thresholds as used in habitat-based approaches can provide effective and easy handling of measures for regulators across Member States.

3.3 Interim analysis of the four assessment approaches

The four assessment approaches considered in DL 1 are to be analysed against the four *Harmonization Criteria* established for the purpose of harmonization. The emphasis is on the application by each Member State at national level with capacities available and on the unambiguity of the results. For reducing uncertainty, only minimum requirements have been considered so far, since most Member State do not have the specific data or expertise required. The results of the interim analysis are summarized in Table 1.

Table 2. Interim analysis of approaches included in DL1 [1] including relevant practical aspects for Member States based on the criteria suitability, applicability, feasibility and reproducibility.

Criteria	Practical aspects for Member States	**A: Approach described in Merchant et al. (2018)**	**B: Population based approach as applied in the Netherlands**	**C: Habitat based approach as applied in Germany**	**D: Habitat based approach as proposed by QuietMed2**
Suitability	Data availability	Likely partially fulfilled by few MS	Likely partially fulfilled by few MS	Likely fulfilled by most MS	Likely fulfilled by most MS
	Direct assignment to MRU or other spatial entities	Likely partially fulfilled by few MS	Likely partially fulfilled by few MS	Likely fulfilled by most MS	Likely fulfilled by most MS
	Temporal coherence between noise and biology	Difficulty to achieve temporal coherence between noise data and population density data	Method based on numerical modelling, most steps regarding biological parameters are not standardized	Empirical calculation with a limited number of variables, can be standardized	Numerical calculation with a limited number of variables, can be standardized
Applica-bility	Estimation of uncertainties	Uncertainties due to temporal incoherence of noise maps and population density maps	Uncertainties in population variables cannot be reliably estimated	Uncertain-ties are related to a limited number of input variables	Uncertainties are related to a limited number of input variables

	Validation of assessment results with data	Difficulty for populations of mobile species	Only partially, since many biological variables are missing	Possible for habitat related variables is possible	Possible for habitat related variables is possible
Feasibility	Personnel capacities / infrastructure	Likely high complexity for effective use on a regulatory level	Likely high complexity for effective use on a regulatory level	Likely feasible complexity for the majority of MS with current capacities	Likely feasible complexity for the majority of MS with current capacities.
	Financial capacities	Implemen-tation likely possible with capacities in several MS	Modelling partly possible for some MS; gain of empirical data likely very cost-intensive	Implemen-tation likely possible with capacities in most MS	Implemen-tation likely possible with capacities in most MS
Reproducibility	Comparability within and across regions	Risk maps contain weighting, not comparable between large and small populations	Conse-quences on populations not validated by empirical data so far, no interregional comparison possible	Habitat related variables may be validated with data, possibility for comparison with other regions	Habitat related variables may be validated with data, possibility for comparison with other regions

The analysis of implementation aspects of the four approaches considered indicates advantages of an assessment framework based on habitat / area considerations, in particular, when considering the state of knowledge and the applicability with present resources for each Member State.

The approaches followed in the Netherlands mostly require complex modelling and are based on assumptions on population status. The approach by Merchant et al. 2018 requires population density maps and noise maps as basis for calculating exposure curves. The habitat-based approaches on the other hand makes use of environmental data, that are widely available by all Member States, seems easier to apply with available capacity and expertise and is practical for regulatory purposes considering the precautionary principle.

Important issues to address in the future include: a) the evaluation of the current situation in terms of GES and, b) options to practically incorporate measures to reduce impact on marine life in case GES has not been achieved.

It is also clear that with advances in knowledge on population dynamics and major population variables the assessment framework may be broadened in the future.

Priority targets for harmonization of the assessment framework could be identified at the present time. These include:

- data completeness and quality, which allows for robust results, with acceptable uncertainties
- consideration of biological issues, such as relevant species per region
- knowledge on occurrence of mammal species and the corresponding spatial and temporal context
- review of noise data characteristics, such as spatial and temporal variation and source differences
- consideration of additional information on noise data, such as measured values or mitigation procedures (e.g. technical noise abatement, spatial/temporal restrictions, deterrence).

Conclusion:

In this report the four approaches described in DL1 have been considered for implementation. For this purpose, criteria have been set to evaluate the practical implementation of the four approaches for all MS, with a focus on suitability, applicability, feasibility and reproducibility (3.1). Advantages and disadvantages regarding the implementation of each approach have been thoroughly described. (3.2). Finally, practical aspects have been comprehensively analysed to identify best practice for all MS, under current conditions (3.3).

The analysis shows that the habitat-based approach as proposed and applied in Germany and in QuietMed2 is most appropriate for an application by all MS under the current status of knowledge and resources.

4 Analysis of available data

4.1 Main objective

As already described, an essential prerequisite for the implementation of an assessment are the underlying data. In this chapter we focus on physical data, i.e. the description of sound sources and their consequences for modelling.

In Sections 4.2 4.3 the data in the respective sound registries are considered from the point of view of completeness and data depth. In Section 4.3 the basis of the sound registry and the comparability of different sound sources are briefly discussed. In Section 4.4 the influence of the classification of sound sources on the evaluation results is discussed. The effect of source event classes on the exposed area are described in Section 4.5. Section 4.6 briefly outlines the need for threshold values. Section 4.7 deals with the selection of a suitable propagation model. In Section 4.8 sound propagation calculations are discussed on and test cases are given. Section 4.9 briefly describes an example of analysing data from noise registries.

4.2 Data availability

A starting point in the assessment of GES is the completeness of the available data. Currently the EU member states report noise events into the EU noise registries (e.g. ICES, EMODnet, QuietMED). These data are then used to derive the GES status using various approaches. However, some events, for whatever reason (e.g. military operations), are not reported into the noise registries. Thus, the noise registries are neither complete, nor is it possible to quantify how much data are missing.

In order to assess GES, it will be necessary to set a limit (in percentage) on how much data have to be in the registry for a meaningful assessment.

At present, where only single events (respectively a limited number of events) are evaluated, the lack of data completeness may be tolerable; looking into the future, however, a high degree of data completeness will be necessary for a useful assessment.

4.3 Noise registries

In report [10] the publicly available datasets have been analysed and an overview of the available data and the information contained therein have been given. There are three publicly available regional databases (ICES, QuietMed and EMODnet), which hold datasets that contain information about impulsive underwater noise:

- ICES noise registry for OSPAR and HELCOM regions,
- QuietMed noise registry for the Mediterranean,
- EMODnet with subsets of data from different regions.

The data contained within the noise registries are summarized in Table 3, and Figure 2 shows the locations of data reported within the publicly available datasets.

Table 3. Comparison of publicly available datasets.

Geometry	Region	Years	No. of events	Grid size	Event date	Source event
ICES noise registry						
Point	OSPAR / HELCOM	2011 – 2019	5600	-	yes	yes
Polygon	OSPAR / HELCOM	2008 / 2010 / 2011 / 2015 – 2019	23987	varied	yes	yes
QuietMED noise registry						
Point	ACCOBAMS	2016 – 2019	114	-	yes	yes
Polygon	ACCOBAMS	2016 – 2020	15	55 x 55 km	yes	yes
EMODnet noise registry*						
Polygon	HELCOM / OSPAR / ACCOBAMS	2014 – 2017	3433	30 x 30 km	no (no. of events per cell)	no

**Overlapping events with ICES registry should be checked*

There are three major differences between the datasets. First, some events are reported using a specific point position, while others are reported by means of a polygon-shaped sea area. The size of the polygon depends on the definitions used by each noise registry and can also be variable, e.g. the ICES noise registry contains polygons such as ICES sub-rectangles and UK-blocks but also partial sections of them. This option allows to mask the exact location of events, which increases the willingness to report certain activities. However, it leads to inaccuracies in GES assessment. For a conservative assessment of GES, it is necessary to assume that the event occurred at each position within the polygon, or alternatively at the position within the polygon closest to the receiving position. Second, the description of noise events varies between noise registries. In most cases an individual noise event is described with at least the type of source (e.g. airgun-array, explosion, pile-driving, etc.) and a value code (e.g. low, medium, high). Often, additional information such as applied noise mitigation measures or similar is also provided. However, for some of the reported data, only a value code is reported without source event. This makes an accurate estimate of the sound propagation difficult. Third, the description of the time span of an event is done in different ways depending on the noise registry. The most accurate method is to specify a start date and time in combination with an exact duration.

In some cases, e.g. military operations, only a very rough temporal and spatial scale is available. A less accurate option is to report only the number of days within a given time period. If the occurrence of indicator species or multiple species sensitive to noise, and their vulnerability to sound varies strongly in time, an annual time period is not appropriate.

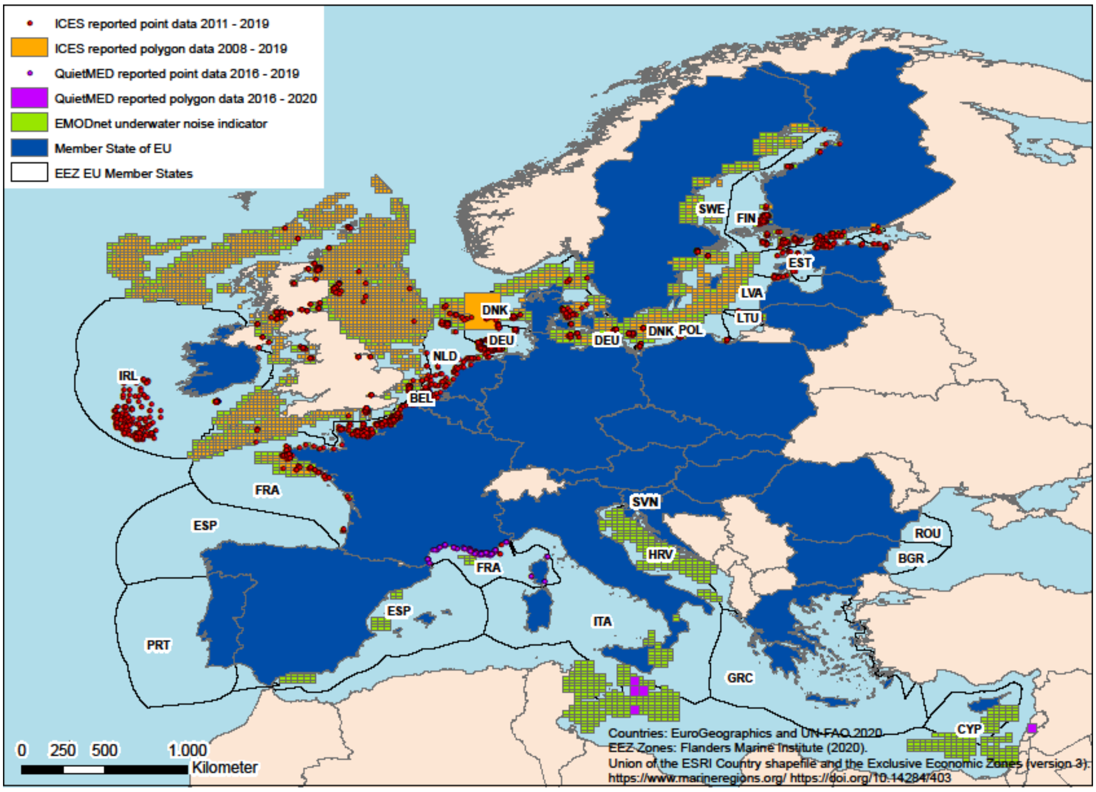


Figure 2: Data reported within the publicly available datasets.

4.4 Classification of source events, input data for the assessment

TG noise advised the option of not reporting the specific level, but instead using classes that allow sensitive and detailed information not to be disclosed [4]. Unfortunately, this option has been adopted by member states as a mandatory format to report sound events into the noise registries. Therefore, all levels are reported using the classes.

The classification of noise sources proposed by TG Noise is summarised in Table 3 and Table 4. Three noise classes are distinguished: multiple impulsive noise events, such as those produced by pile driving and airguns, single events, such as explosions, and continuous sound events, such as sonars. The threshold value above which noise sources are included in the noise registry was derived from studies on marine mammals, using disturbance as the assessment basis for multiple impulsive noise events and continuous noise. For explosions, TTS was considered as the basis for assessment. A distance to the source of 1000 m was defined for which the named threshold values apply and then converted to a monopole energy source level[1] with a propagation loss (shallow water) of 46 dB. In relation to the 1000 m level

[1] The monopole energy source level, also called energy source level or the sound exposure source level re 1 μPa^{2}m^{2}s in a specified direction is equal to sound exposure level re

the classification described in [5] where a SEL (single event level) of 140 dB re 1 μPa^{2}s to 164 dB re 1 μPa^{2}s for multiple pulses and for single pulses, such as explosions, a SEL of 164 dB re 1 μPa^{2}s to 188 dB re 1 μPa^{2}s, are both categorized as very low. It is not obvious that a direct comparison between the classes is possible.

Comparing different source events with each other, metrics and thresholds vary. Thus, already at this stage, a weighting (depending on the duration and intensity of the source event) is imposed without considering regional and species-related criteria.

One aspect that should be pointed out is that the basis of the classification of the sound sources according to the Commission decision of 2017 [9] should correspond to a monopole sound source level. It is important to know that there are no national or international standards that describe how to determine a monopole sound source level from measurements underwater. Therefore, it must also be assumed that the classification (Table 4) is additionally subject to uncertainty, the extent of which cannot be estimated. In the case of pile driving noise, TG Noise has made an initial revision that allows measurement data for the classification of noise, [22]. Due to the available database and the possibility of using measurement data, the application of sound mitigation measures is considered in the categorisation. An international standard for this measurement is available in ISO 18406 [32].

Table 4. Registration of specific source level (energy source level SL_E [dB] re 1 μPa^{2}m^{2}s (single events) and source level re 1 μPa^{2}m^2) into classes proposed by TG Noise in [5]. Calculated from 1000 m levels (SEL, SPL) with propagation loss 46 dB (shallow water).

	SL_E [dB] re 1 μPa^{2}m^{2}s multiple impulsive source	**SL_E re 1 μPa^{2}m^{2}s single impulsive source**	**SL dB re 1 μPa^{2}m^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	

1 μPa^{2}s at a distance of 1 m from a hypothetical point source, placed in the (hypothetical) infinite uniform lossless medium. Definitions are described in ISO 18405, [26].

Table 5. Registration of specific source level (which may be classified) and related physical quantities into classes proposed by TG Noise in [5].

	SL_E [dB] re 1 µPa^{2}m^{2}s generic explicitly impulsive source	SL [dB] re 1 µPa^{2}m^2 sonar or acoustic deterrents	SLzp [dB] re 1 µPa^{2}m^2 Airgun arrays	Explosions [eq. TNT charge mass kg]	Pile driving [hammer energy MJ]
Very low	186 – 210	176 – 200	209 – 233	0.008 – 0.210	- 0.28
Low	211 – 220	201 – 210	234 – 243	0.220 – 2.1	0.29 – 2.80
Medium	221 – 230	211 – 220	244 – 253	2.11 – 21	2.81 – 28
High	230	220	253	22 –210	28
Very high				210	

Conclusions:

1. It is clear that the present classification of sound leads to initial uncertainty in the assessment of the data. The different approaches from DL1 currently have to deal with these uncertainties, and it should be investigated to what extent the assessment can still be regarded robust. Merchant [15] circumvented this problem by introducing effect ranges (12 km and 20 km) for specific source types from the outset on the basis of observations of harbour porpoise disturbance. By using effect ranges based on the source event, the different source level or value class was not considered. The simplified approach can lead to uncertainties as the actual impact of noise depends on the strength of the source, which is indicated by the value code (very low to very high).
2. In addition to the source level (single-number value), which the sound registry offers with a certain accuracy, also the frequency distribution, e. g. in third octaves, is required for an accurate propagation estimate. However, this information is generally not available. Sources close to the surface, such as airgun arrays, also have a distinctive directional characteristic that is not represented by monopole sound sources. The "correct" description depends on the choice of propagation models. In 2020, it was decided to revise the TG Noise Guidance. The topic of directional characteristics is suggested to be addressed.
3. Based on the classes of sound sources, it can be concluded whether a sound source has the potential of eliciting PTS or TTS. This information can and should also be used in the assessment, in line with the commission (SWD) [10] for an assessment: Highest priority on activities with risk for most severe adverse effects, followed by lower priorities for less severe adverse effects.

4.5 Effect of source event classes on exposed area

To clarify effects of using source event classes, a generic test case was used, which evaluates a pile-driving event in the central North Sea (based on similar events reported to the ICES noise registry), see report [12].

The range of each value class differs per source event, ranging between 10 and 24 dB, Table 3. This leads to uncertainties when determining the noise propagation due to the lower- and upper-class limits. For visualizing the uncertainties caused by the class range the test case was created under following assumptions and approaches:

- The event was reported in a polygon (not as point data). In order to make a conservative estimate of the sound propagation, the propagation was computed with fictive events along the polygon perimeter (a less conservative approach would be to use the polygon centre as single origin).
- Based on the comprehensive knowledge of BSH and Müller-BBM regarding sound propagation (empirical, numerical and experimental) in the region, the propagation was computed using the semi-empirical Thiele & Schellstede formula [17] in consideration of the bathymetry by means of a cut-off frequency. In order to fulfil the requirements for the use of the cut-off frequency method, a standardized frequency distribution for pile-driving was used.
- Within the vicinity of the event, the marine protection areas Southern North Sea and Dogger Bank are located. The major noise sensitive species considered is the harbour porpoise, considering a commonly applied threshold (disturbance) of SEL = 140 dB re 1 $\mu Pa^2 s$.
- The exposed area is defined as area with a sound level higher than the threshold value.

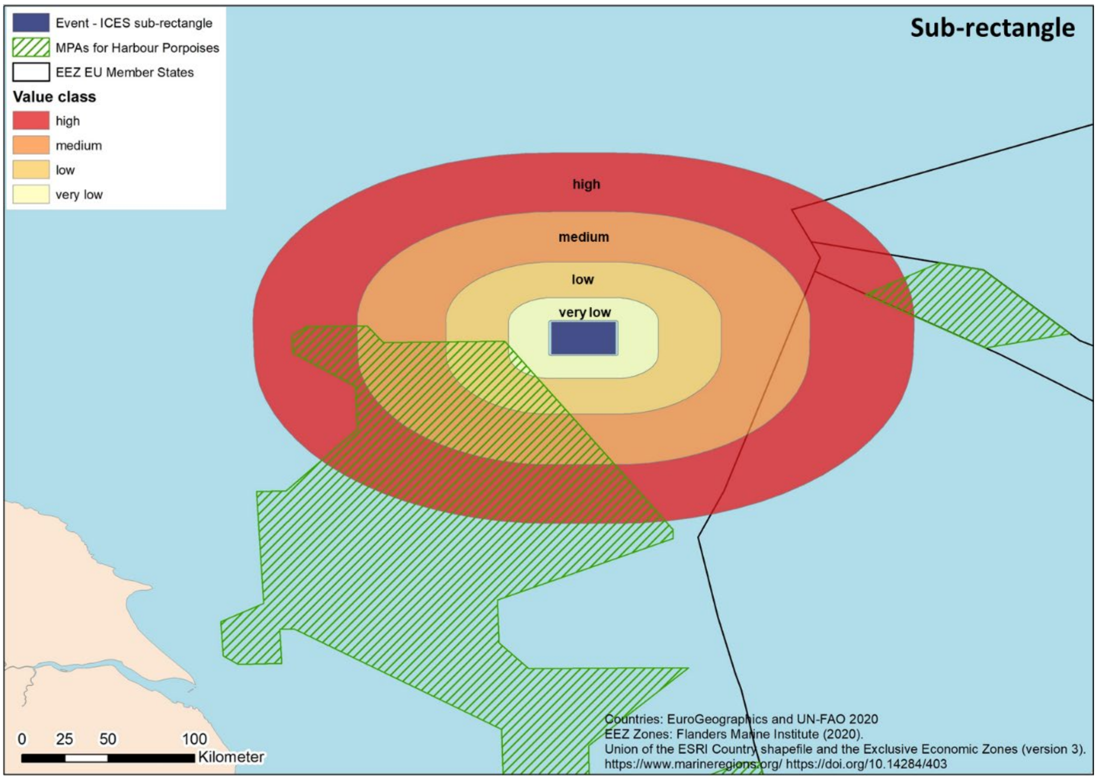


Figure 3: Exposed area for the different classes (here pile-driving in North Sea).

Figure 3 shows the position of the event and the MPAs as well as the computed exposed area by classes. The areas of the respective value class are determined on their class boundaries. Due to the fact that a class range differs in between 10-24 dB, the affected area varies in between the classes. While events in class *very low* only have a negligible overlap, events of class *high* have a substantial overlap with MPA Southern North Sea and even interfere with MPA Dogger Bank. To determine the effect on the MPA, the percentage impaired area was calculated. In value class *high*, an SL_E re 1 μPa^2 m^{2}s of 182-191 dB for pile-driving is assumed, which leads to an overlap of the MPA area of 6 to 19 % based on the class range. The massive difference in the calculation of the affected area of the MPA leads to uncertainties in the assessment of the results.

According to the current German regulation an exposure of maximum 10 % of the area of the MPA area is allowed, thus, the use of class instead of specific values would result in exceeding the regulation for the MPA. The spatial uncertainties of the propagation range shown are related to the value classes and their class range in SEL. This fact can also occur when evaluating other spatial dimensions such as Marine Reporting Units (MRU) or EEZs.

This example showed that the use of value classes for the noise propagation can lead to uncertainties on the affected area and thus also effects the evaluation on compiled spatial thresholds.

More details on this test case with additional evaluation are given in [12].

4.6 Defining threshold values in the assessment framework

There is no doubt that assessment of noise impact requires setting of thresholds, because the assessment process itself should provide clear measures to decide whether a sound (noise) event is to be classified as “adverse” or not and therefore requires regulatory action by decision makers or not. However, assessment of noise impact includes different types of thresholds:

Thresholds which are currently in use within different assessment approaches (see section 3.2) define maximum proportions of populations or habitats to be exposed to noise, e.g. in a habitat-based approach the maximum area of habitats which are allowed to be exposed could be at 10% of the total area. This threshold alone would be meaningless without a definition of how much noise may be allowed within our area of 10%. Therefore, threshold referring to population or habitat can be considered as technical threshold, while the second type of threshold defining the maximum level of noise should be a biological threshold. The term biological threshold has been chosen, since noise thresholds should be based on biological considerations, e.g. sound sensitivity of species. One example of a biological threshold is a SEL of 140 dB re 1µPa^{2}s for a maximum area of 10% within the German EEZ. This biological threshold is based on a study by Lucke et al. (2009), [27], who describes aversive behavioural reactions for a harbour porpoise at SEL of 145 dB re 1µPa^{2}s. This value indicates a first biological approximation to establish a threshold, which can be used as a measure to take regulatory decisions. Of course, it does not include all biologically relevant aspects of sound perception in a marine mammal:

First of all, the result of the study is based on experiments with a single animal. Intraspecific variations due to sex or age are not considered. Other aspects like naivety of the individual with respect to the noise source or behavioural context prior to the sound event are known as influencing factors in the behavioural response to noise (Gomez et al., 2016) [27]. Severity of a behavioural response is not always linked to a higher received level of sound. Difficulties in determining a biologically relevant threshold arise due to the low sample size in experimental studies, especially for studies with comparable methods.

Furthermore, sound sensitivity in a marine mammal species differs for different frequencies, i.e. the type of sound source characterized by a certain frequency composition needs to be considered when defining a biological threshold. In other words, different sound sources might require different biological thresholds.

Similarly, different biological thresholds can also be considered for different species of marine mammals. According to their hearing capabilities Southall et al. (2019), [29], divides marine mammal species into different hearing groups.

The basis of setting biological thresholds must be knowledge of hearing capabilities in different marine mammal species. Audiograms are one fundamental component characterizing hearing capabilities. However, they can be derived from psychophysical experiments or auditory evoked potentials (AEPs) or even models based on skull morphology. Especially when comparing psychophysical results with results from AEPs reveals discrepancies in the lower frequency range (Erbe et al., 2016) [30].

In conclusion, there is a strong necessity for integrating biological thresholds in the assessment. However, it is crucial to define standards on how to set biological thresholds and to define the degree of achievable accuracy and complexity.

A detailed elaboration on biological thresholds should be included in deliverable DL2 of TG Noise.

The objective of each assessment is to determine the area to which an adverse effect on the marine environment can be attributed to specific sound events. We refer to these areas as exposed areas. Commonly, a threshold is used to define an exposed area depending on the region and/or the prevailing species. For example, a commonly applied threshold value for disturbance of harbour porpoises in the North Sea is a SEL value of 140 dB re 1µPa^{2}s.

Unfortunately, information on threshold values for relevant species in EU waters is not available in a transparent way. Therefore, further efforts are needed to establish these specific values for all typical species in EU waters, especially since most of the approaches currently used are based on these values.

4.7 Decision scheme to select appropriate propagation models

In the current section a decision scheme for the selection of appropriate propagation models is discussed. The decision (Figure 4) follows four interlinked steps:

1. Range of interest:
   Depending on the species and the region, the range of propagation modelling needs to consider that:
   - Each habitat or MRU has different physical and biological characteristics, that should be examined carefully;
   - A single indicator species or groups of species (LF, MF, HF) react differently depending on auditory capabilities, frequency and sound levels.
   - Sound propagation in shallow waters e. g. in the North Sea differs from propagation in deep waters e. g. Mediterranean Sea
2. Quality of noise data in registries:
   Ideally, a complete dataset of the source event should be available for determining the sound levels using propagation modelling (source type, source level, location, duration). Beside mandatory data in noise registries, additional data, e.g. frequency distributions, specified source level, and measured levels would significantly improve the quality of the modelling. However, the quantity and quality of available noise data should be evaluated carefully.
3. Selection of Habitat / Area of Assessment:

Habitat or area-relevant for assessment should be defined considering environmental (bathymetry, topography, currents) and biological (species spectrum, occurrence) characteristics. For regulatory purposes, the consideration of an EEZ could be a suitable choice, which allows Member States to regulate and monitor activities and to define measures to achieve GES, if required.

4. Information on geographical, geological and hydrographic data for habitats or MRUs:
Hydrographic and geological information is important for the quality of the modelling. Propagation conditions depend on several parameters such as soil properties, stratification of the water column and sound velocity profiles, which may change seasonally. There may be situations where these data may or may not be available for area certain habitat or MRU. This must also be considered when selecting the appropriate modelling approach.

5. Decision on propagation modelling:
The previous four points shall be considered for the selection of the propagation modelling approach, which may correspond to an advanced numerical simulation or empirical model, an analytical model, or even an effect range.

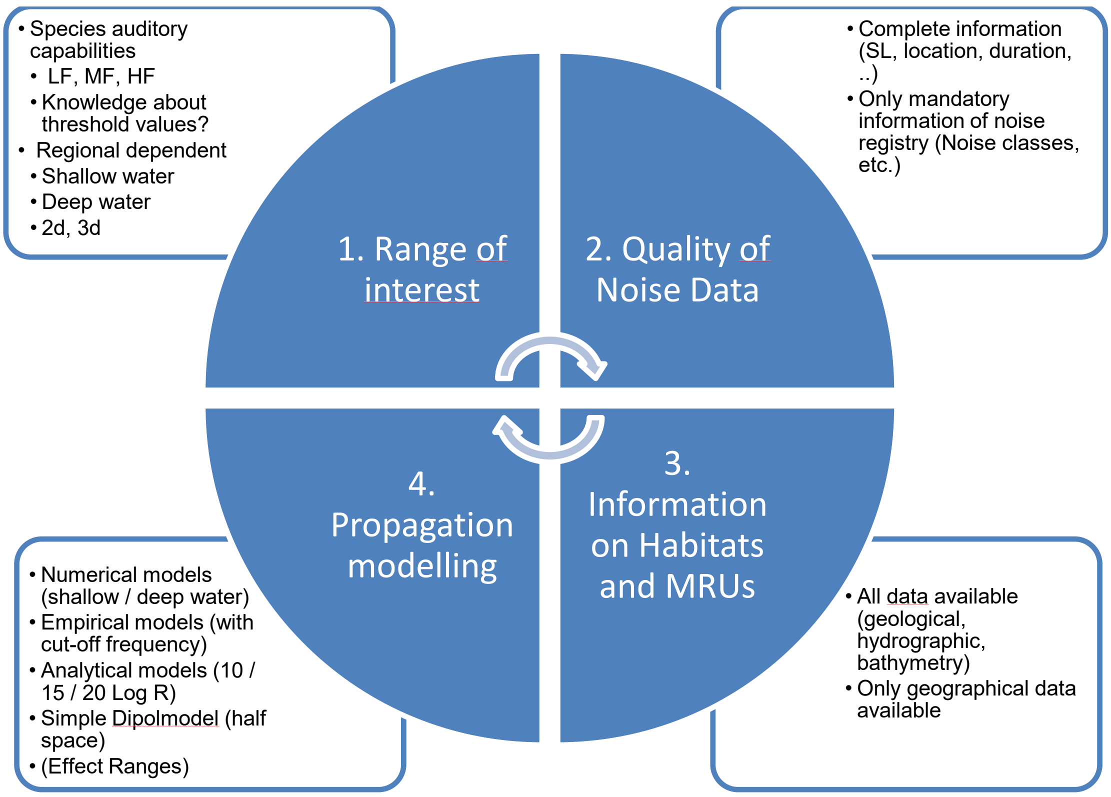


Figure 4 : Consideration scheme to select an appropriate propagation model.

The decision process is based on a cycle scheme, since input data and selected procedures at all four levels will influence the evaluation of the environmental status and therefore, the assessment of GES. Additionally, uncertainties within each step will influence the quality of the final assessment. On one hand, this can be regarded as a drawback, on the other hand it will allow to optimize the process.

Conclusions:
In conclusion, current evaluations considering the number of events, the precision of the reported data within the noise registries, the current knowledge on habitats, population and species, point towards the recommendation that a simple and effective propagation model is sufficient. However, if more detailed information is available, it does not preclude the use of a more complex propagation model.

4.8 Propagation modelling

In the project HARMONIZE, an aim is to investigate to what extent the data available in the sound registry are suitable for an assessment in the region. For this purpose, we have investigated three test cases that consider three source types (pile driving, explosion and airgun array) with different aspects. One aspect is the modelling of the propagation. In this chapter, we first present two test cases that were initially investigated using empirical and analytical computational methods, respectively. A numerical analysis to evaluate the advantages and limitations will follow later in the project.

In the following section, two additional test cases are discussed, outlining some of the challenges related to propagation modelling. The first test case refers to explosions in the Baltic Sea originating from a measurement campaign, followed by an extensive numerical simulation study. The second case refers to the absence of cetaceans in the Mediterranean Sea (no sightings during a two-month period), which was subsequently linked to airgun array activities near the Îles d'Hyères.

4.8.1 Propagation modelling – Explosion in the Baltic Sea

In the archipelago of Stockholm, a measurement campaign with explosions was performed (eq. TNT mass of 105 kg at variable water depth, water depth at the source ~-80 m, water depth at measurements ~-30 m). The events were reported into the ICES noise registry. In addition to the noise registry, the publicly open bathymetry from EMODnet and the TG Noise guidance were used to compute the test case. In Figure 5 is the results summarized. The x-axis describes the distance from the source event towards the position of measurements. The measurements were performed close to the coast at the outlines of MPA Huvudskär (Nature2000 area with grey seal). The green curve shows the change of water depth. The blue curves are the results using the publicly available data using a generic frequency distribution and considering the bathymetry via a cut-off frequency. The solid curve refers to a computation using Thiele & Schellstede formula [17] with consideration of the bathymetry by means of a cut-off frequency and the source level according to [5] at 1 m from the source. The dashed curve refers to a computation using a measurement-based empirical formulae source level at 1000 m. The grey curve, which fits well with the experiments, is the result of an extensive study of the propagation using a PE-model considering bathymetry and velocity profiles [18]. Note that the near and far field propagation of the explosion are handled in different ways.

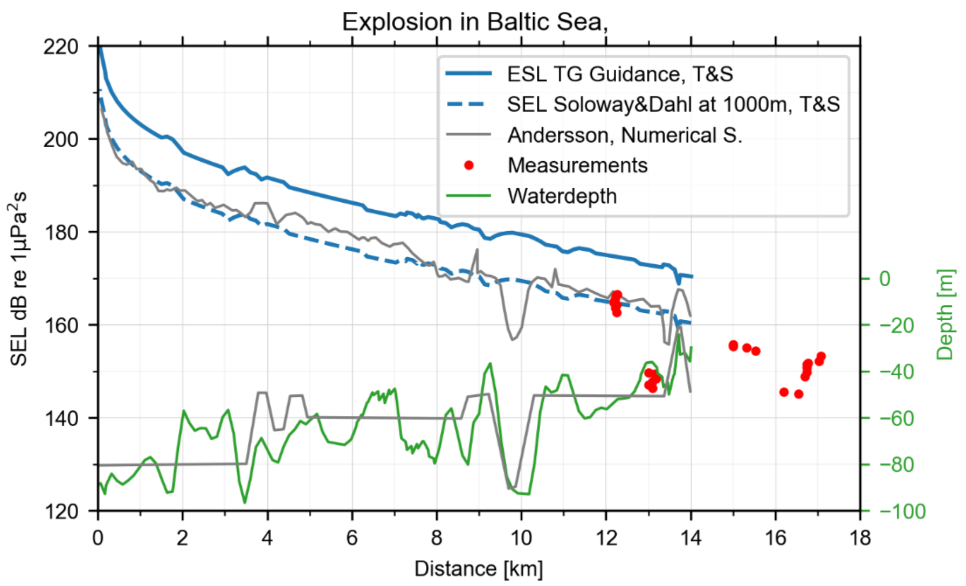


Figure 5: Propagation loss computed with different approaches [13].

There is an offset of about 10 dB between the measured data and the approach using the 1 m source level. The difference is probably due to the physics of explosions which describes near field and far field effects with in different ways. An alternative would be to use the measurable 1000 m sound exposure level, SEL, which would lead to less error in the far field. More details on this test case with additional evaluation are given in [13].

Conclusion:

The approach using a 1 m energy source level (see Chap. 4.4) is comprehensible, but it has two major drawbacks. A 1 m source level is not a measurable quantity in most cases and, with the focus on far-field sound propagation, a description of the source outside the near field leads to more accurate results.

In this test case, it has been shown that simple propagation models with a suitable description of the source can be used to describe sound propagation into the far field. If areas in the near field of an explosion are to be considered for the protection of marine life, a different descriptive metric may have to be applied.

To describe the source, we have used empirical formulas that scientists have determined from measurements. Since in principle one uses measurements at a certain distance, one can also use this possibility to collect measured data in a sound register. This would have the advantage, for example, that explosions with sound measures such as bubble curtains could also be classified. It is recommended that this consideration will be discussed in the revision of the TG Noise Guidance of 2014.

4.8.2 Propagation modelling – Airgun array in Mediterranean Sea

The third test case deals with airgun array activities in class *very low* near by the French Îles d'Hyères. In retrospect the reported absence of cetaceans in the Mediterranean Sea (no sighting at all during a period of 2 month in 2002 by multiple whale watching companies) was correlated with typical airgun array noise events observed in the Ligurian Sea. The measurements were used to derive the position of the sound source which was determined to be outside Toulon. Similar events are unfortunately not reported in the noise registries (events took place before the implementation of the registries), nevertheless the case is relevant, since compared to North Sea and Baltic Sea, the distance range (more than 250 km), the bathymetry range (from -80 m up to -3500 m) as well the species (here cetaceans) are different.

Despite the different boundary conditions, the same methodology was used to evaluate the test case as in the previous example. However, the input parameters and thresholds were adapted to the new circumstances:

- Source event as point source in front of Îles d'Hyères.
- Source level in class *low* with values according to TG Noise Guidance Part II [4].
- Generic frequency distribution of an airgun array.
- Bathymetry from publicly available dataset from EMODnet.
- Propagation modelling using four standard approaches (10 log with surface duct, 15 log, Thiele & Schellstede and 20 log).
- In lack of prescribed thresholds (frequency distribution and level values) in relation with cetaceans the threshold was chosen in line with typical sound levels of ocean background noises at different frequencies, e.g. in [19].

Figure 6 shows results of the evaluation: The left part of the Figure is the evaluated sound propagation using a 15 log attenuation, while the lower part shows the sound levels using a 10 log law with surface duct. Using 15 log leads to quick decrease of the initial levels, while using 10 log results in is different, within a duct (or layering) the pressure loss is slower and thus extends over large distances. At the location of the observational site the estimate levels differ by more than 60 dB, whereby the level using 15 log is close to typical background noise levels.

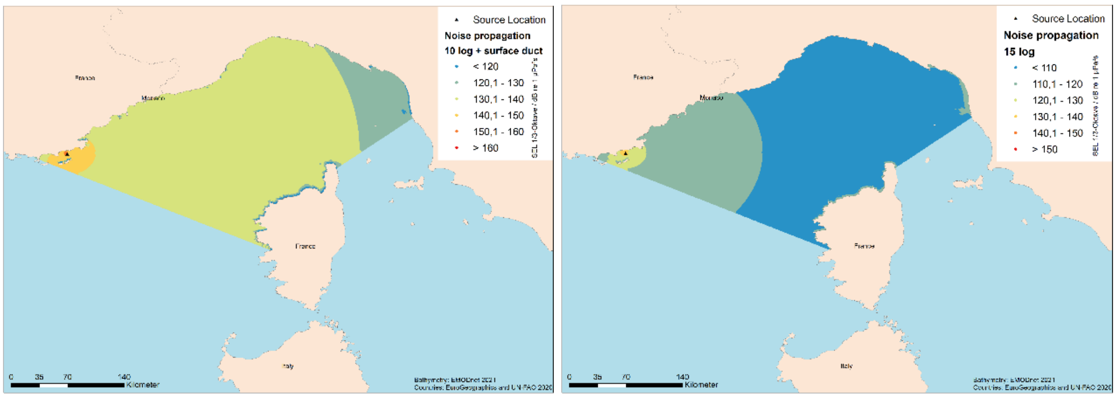


Figure 6: Examples of propagation of an airgun array estimate in Mediterrean Sea, right panel using 15-log law, left panel 10-log with surface duct.

This test case shows that to make a reasonable estimate of the sound propagation in the affected sea area in addition to the source description, a good knowledge of the region and its acoustic properties is necessary. In this case, the knowledge of the depth of the source and the layering in the Mediterranean Sea is essential.

More details on this test case are given in [14].

Conclusions:

1. To estimate the sound levels accurately information on layering is necessary
2. The test case raises the question that an event taking place in one sea territory is having an influence on the territories of other Member States.

4.9 Example for habitat-based approach, evaluation of OSPAR II region data

In this section, it is pertinent to give an example on how a possible assessment can be realised. A habitat-based approach is taken as an example. A first analysis of this approach was presented according to German regulations in report [16], in which individual aspects of the accuracy of predictions and the presentation of results were discussed.

In this example, we follow the effect ranges of individual noise sources according to Merchant et al. [15] to determine the exposed area. The entire OSPAR II region is considered as habitat for the key species harbour porpoise, which implies a certain overestimation of the area. In order to represent the main concentrations of harbour porpoises, the harbour porpoise habitats (MPAs) are also considered, as shown in Figure 7.

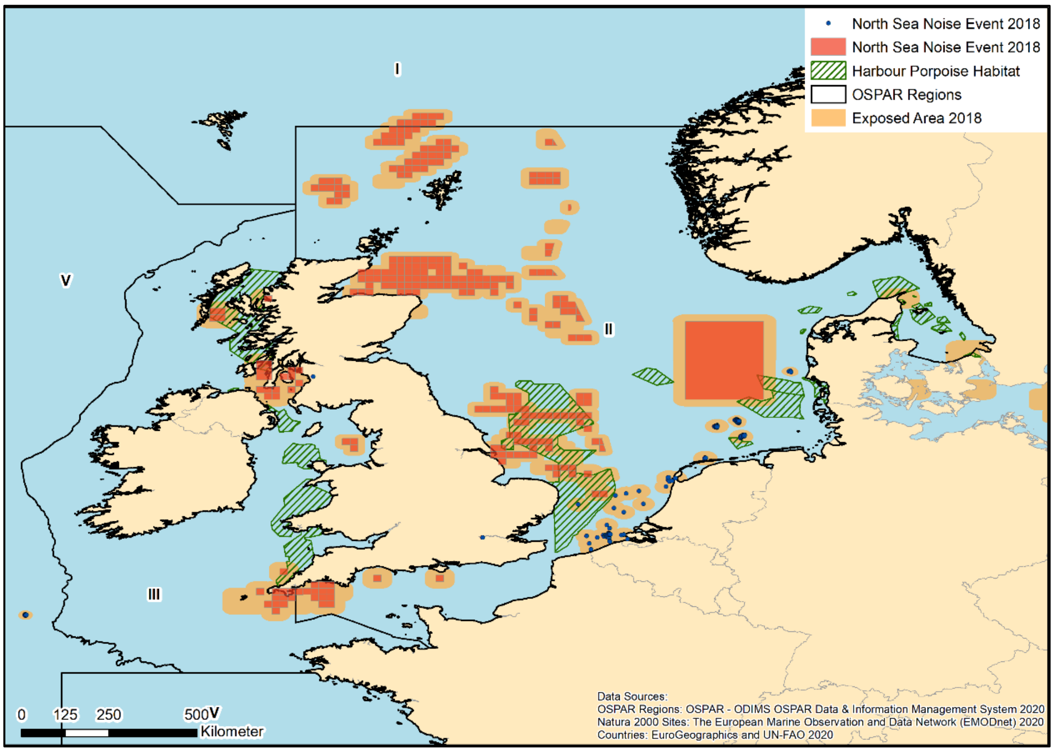


Figure 7: Events and exposed area within OSPAR II region.

Figure 8 shows a possible representation of the results. The diagram shows the percentage of the area exposed by human activities over the time period.

The representation can also be presented for each or all MPAs in the OSPAR II region and thus be considered individually, offering the possibility of assessment and, if necessary regulation.

For each MPA, the exposure curve can be determined on monthly, quarterly, or yearly base. Any time scale can be used but the assessment has to be based on same time length and on the same area (or at least with the same area) to be comparable to each other.

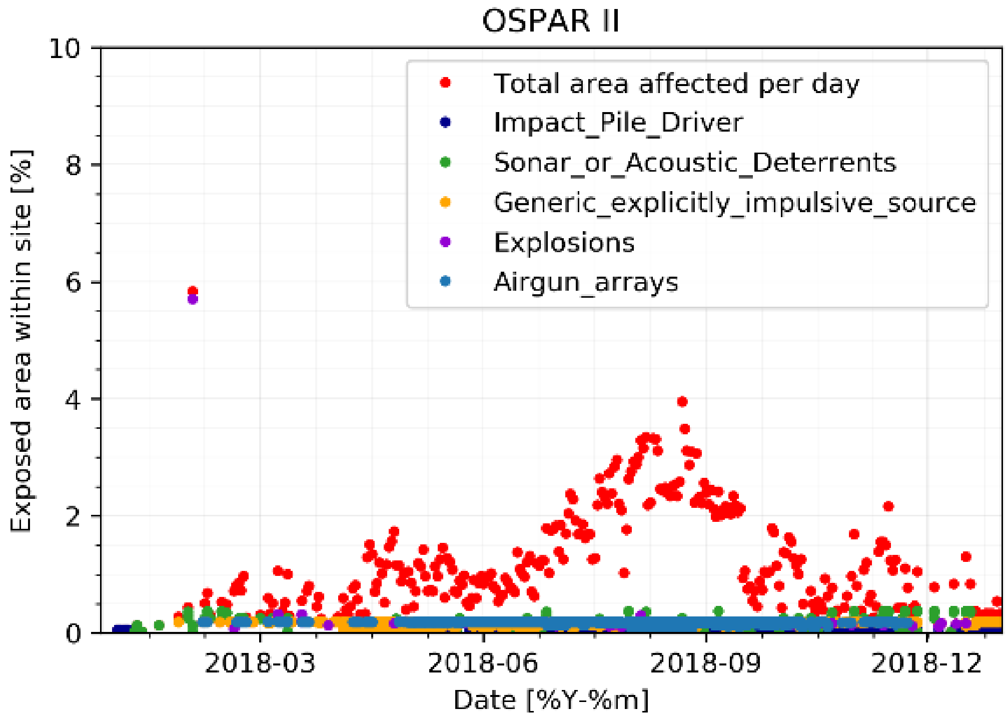


Figure 8: Exemplary presentation of evaluations. Exposed area over time (daily resolution) within OSPAR II.

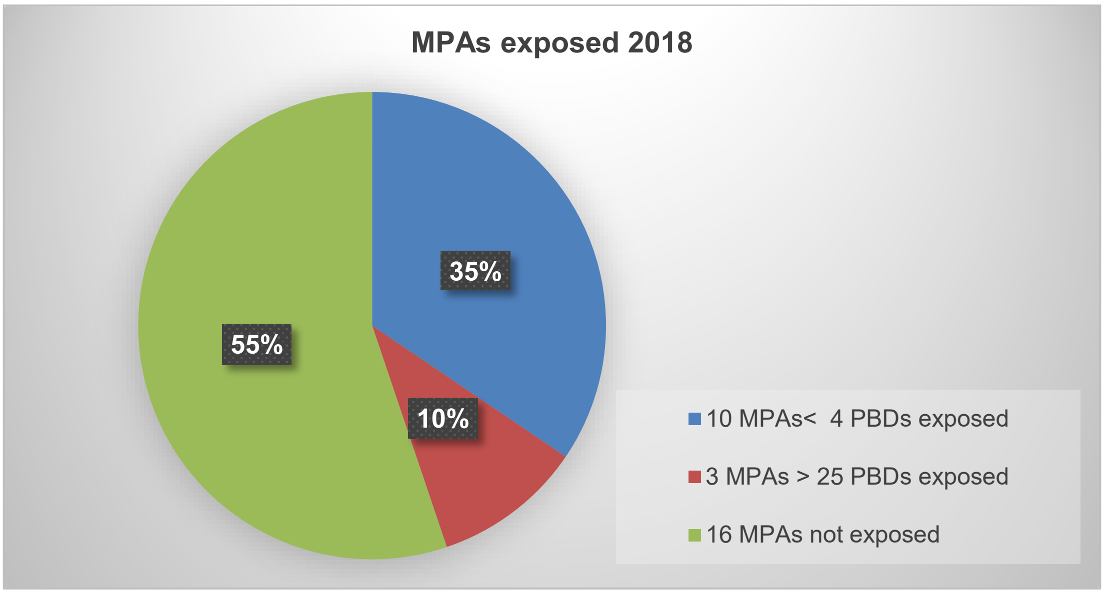


Figure 9: MPAs exposed in 2018 within OSPAR II region.

An interesting aspect is to look at the MPAs for Harbour Porpoises in the OSPAR II region. The percentage distribution of impacted MPAs can be seen in Figure 9. Within the OSPAR II region 55 % of the areas were not exposed at all in 2018, 35 % with more than 4 Pulse Block Days (PBD), i.e. for 4 days within the year and only 10 % (3 MPAs) with more than 25 PBDs per year.

These results will be published by end of 2021 [23].

5 Draft proposal for a harmonized assessment procedure

5.1 General assessment procedure

The starting point for the assessment procedure is document DL1 [1]. In this section, a stepwise procedure is described, which will lead to a general assessment using currently available data.

The general procedure (see Figure 10) is described by the following steps, based on [15] and [16]:

- Define the Management Area (MA) for indicator species.
- Specify the habitats or assessment area of the indicator species.
- Determine the noise pressure map for the assessment period.
- Calculate a risk map using habitat/assessment area and noise pressure map.
- Determine the exposed area (% area and time exposed).
- Decide on a maximal proportion of area that may not be exceeded over a certain period of time to keep the area in GES.

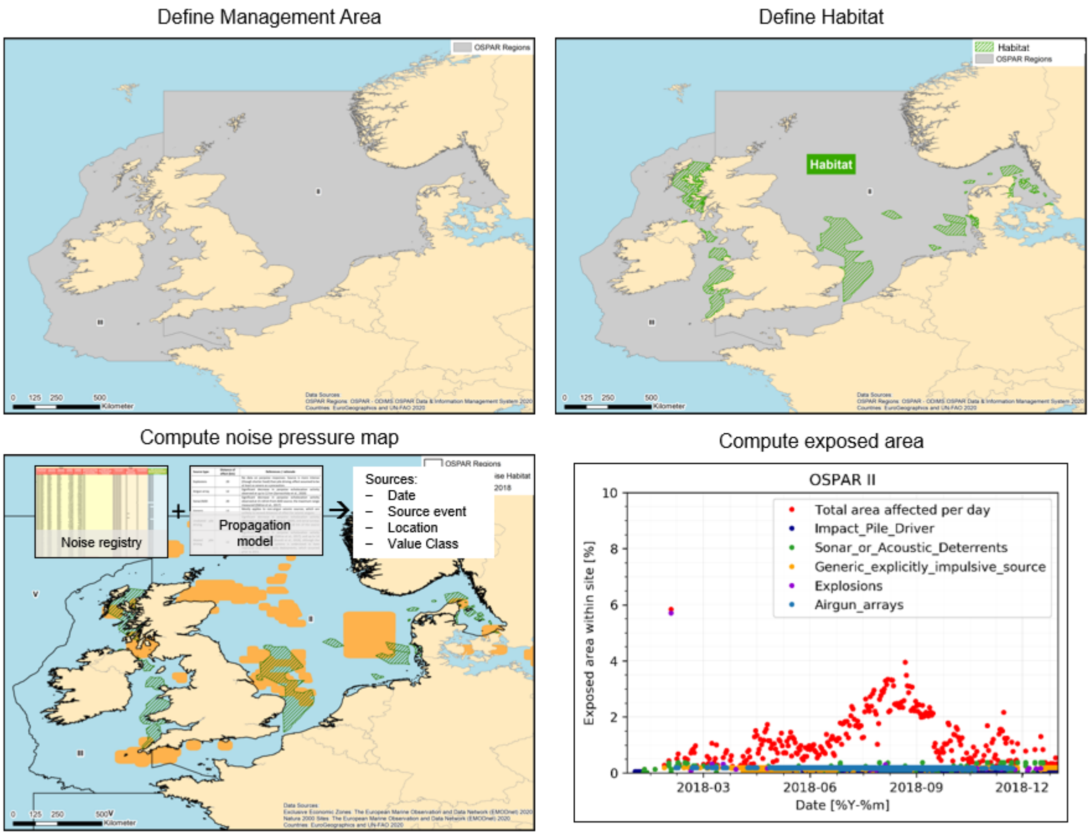


Figure 10 : The test case in the Baltic Sea with underwater explosions using the gnereal assessment procedure.

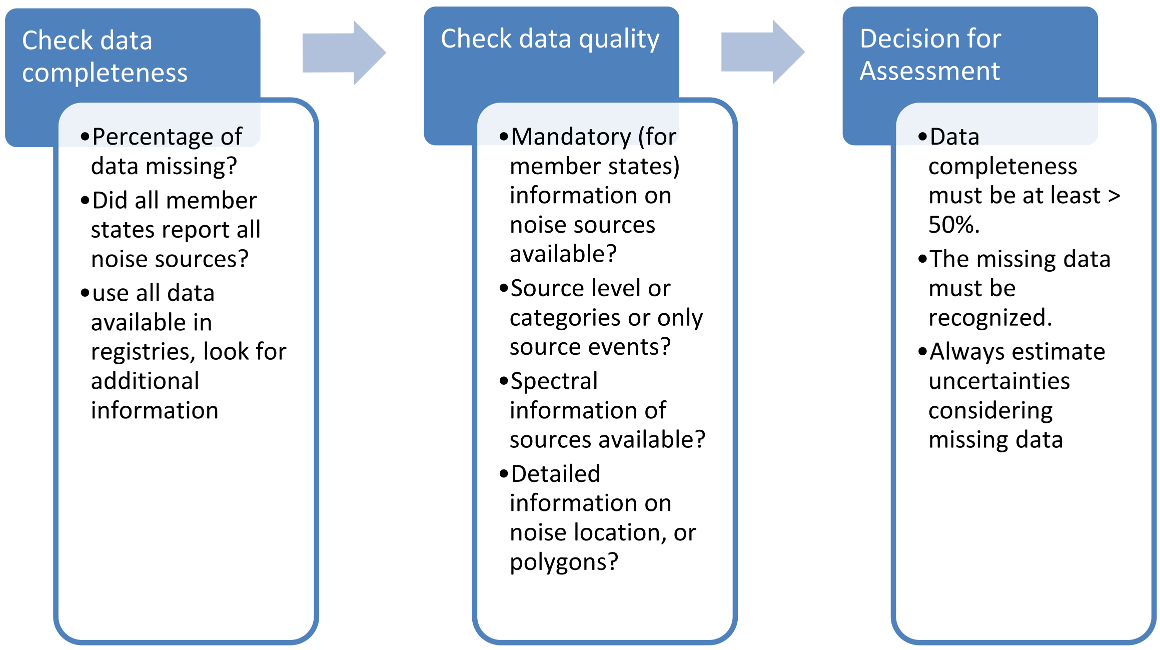
Remark on thresholds for GES:
Depending on seasonal specificities, e. g. mating season, the proportion of area for special protection areas may be zero to keep the area in GES.

5.2 First step: Define the Management area

The management area (MA) is defined according to the needs of the respective agreements (HELCOM, OSPAR, ACCOBAMS) and requirements of the EU. For example, for OSPAR individual OSPAR regions have to be considered for the assessment. Due to the fact that the present data situation only allows a classification of the sources rather than providing information necessary for an accurate assessment, it is necessary to compromise on the depth of the analysis. Thus, detailed population dynamics calculations with current information from the respective noise registries are, if at all feasible, subjected to high uncertainties, see also conclusion in DL1 [1].

It is an important question on how populations can be taken into the analysis, different concepts exist like the direct application of population densities or MPAs (e.g. Natura 2000 site), Important Marine Mammal Areas (IMMAs) and Specially Protected Areas of Mediterranean Importance (SPAMIs). The Exclusive Economic Zones (EEZs) of Member States might be also of interest for regulators.

5.3 Second step: Check data completeness and quality

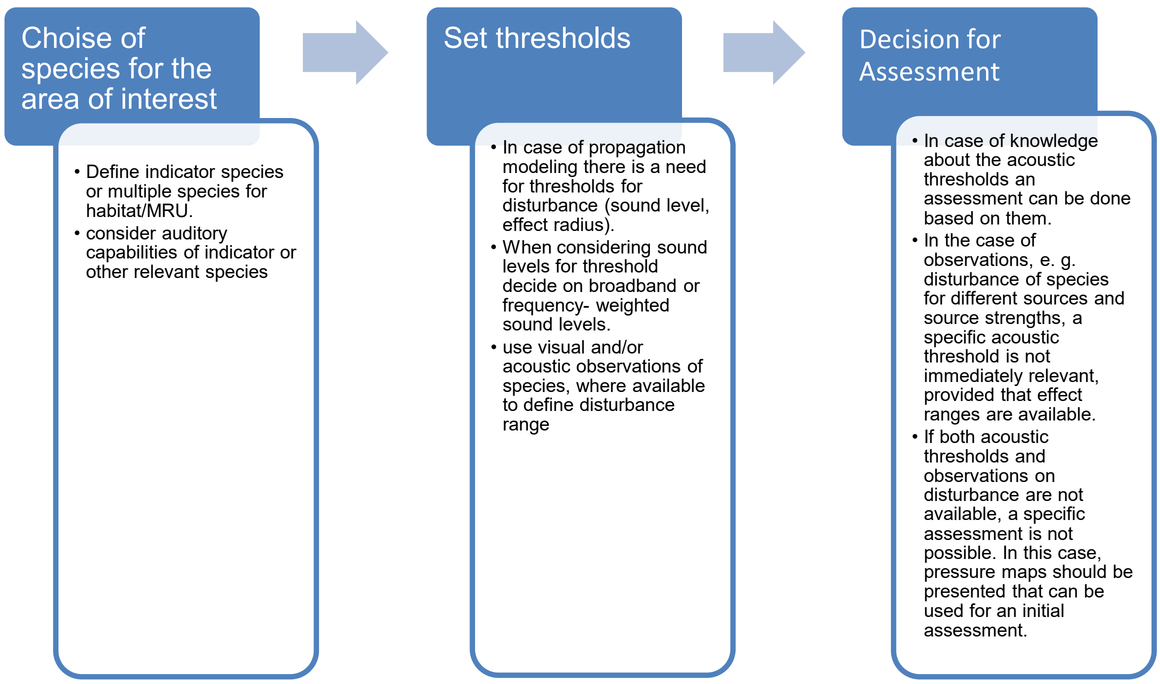


The data completeness and data quality are major keys for the subsequent assessment. As already addressed in Chapter 4.2, the following improvements have to be implemented:

- Define/estimate data completeness and if necessary and possible increase data completeness
- Increase data quality: favourable accurate data, specific values (point, levels)
- Extend the data base: add frequency distributions, used mitigation, measurement data

5.4 Third step: Choice of Thresholds for the relevant indicator species

In any case of an assessment the evaluation basis (indicator species, one or more) must be chosen.



5.5 Fourth step: Choice of the propagation model

According to the current status of the noise registries, a detailed propagation calculation does not match the uncertainties of the registry data and thus is superfluos This is due to the fact that the position of the sound source, the intensity of the sound source and the sound characteristics (frequency distribution, directivity) are not available from the registries. Some of the data are available as classes, allowing a wide range, which leads to a relatively large inaccuracy. However, a high-quality data base is an essential prerequisite for an accurate calculation. See also discussion in section 4.5.

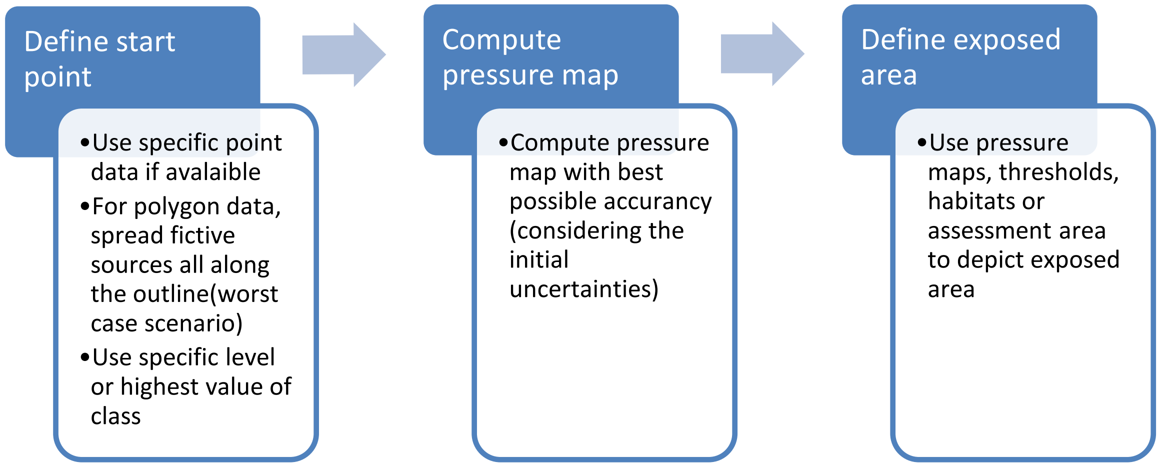
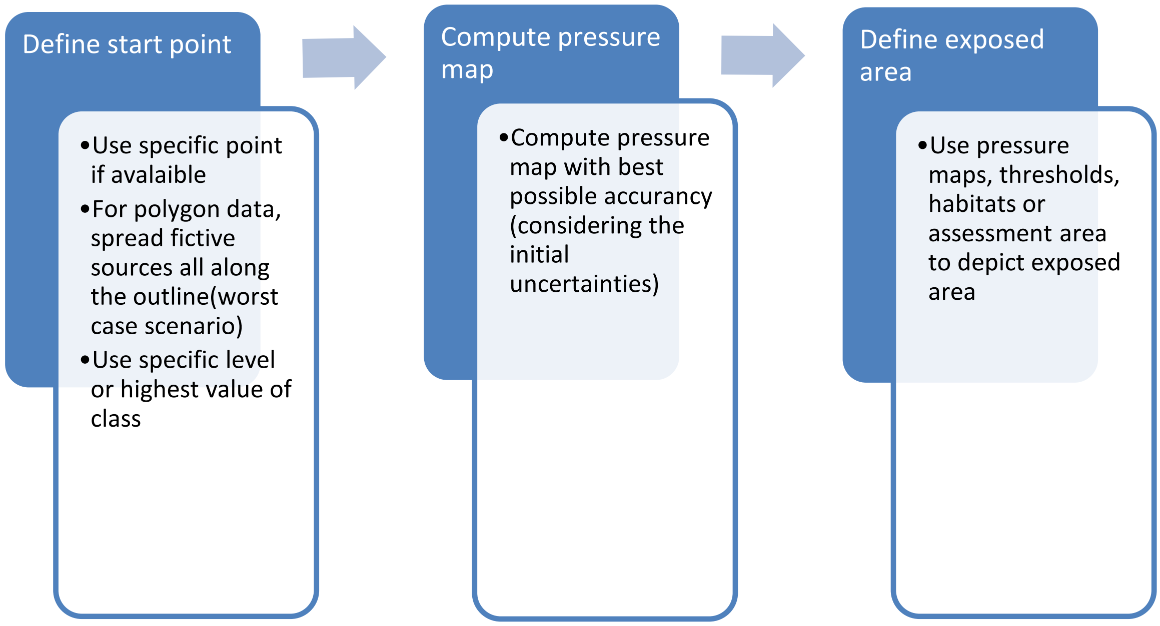


Figure 11 : Consideration scheme to select propagation model.

Remark:
The examples presented in Chapter 4.8 outline the issues when dealing with the current available data base. Especially the Mediterranean Sea test case with wide effect ranges up to 250 – 300 km is can hardly be assessed without further information or profound knowledge of the area. On the other hand, the test case with short effect ranges smaller than x km (x to be defined, e.g. 20 – 30 km) was in fair agreement with available experimental data.
Thus, in case of short effect ranges, simple calculation models can be used, unless better information is available for the sea region. In accordance with the TG Noise guidance [5], for shallow water a 15 log R law could be appropriate. Remark: A numerical analysis to evaluate the advantages and constraints will follow later in the project HARMONIZE.

5.6 Fifth step: Calculate or apply effect ranges



If classes are used, the assessment needs to consider the worst-case scenario (precautionary principle). This implies that the upper range of the level classes and for polygons all locations are starting conditions.

Remark:
From a statistical point of view the use of a worst-case approach will lead to an over-estimate of exposed area. The only way to prevent this is to perform the assessment with accurate input data and efforts.

5.7 Sixth step: Evaluation of the status of the assessment area

The presentation of all events based on the sound registry, in a map over a defined period of time, e.g. year, and the examination, if possible, whether adverse effects could potentially occur for individual sound classes for the animal species under consideration are the first steps of the assessment. These results generate an estimate of the area affected by anthropogenic sound contributions over time for MA /MRU, Subregions, and sensitive areas (e.g. MPA). The analysis can be carried out for individually defined protected areas such as MPAs. For the MPAs temporal and spatial considerations and specifications can be set separately and with higher requirements. For example, during the mating season the area effected may be set to zero for GES to prevail.

An alternative or complement is to consider known habitats of protected species, such as Marine Protected Areas. Analyses can then be carried out as described in Chapter 4.9.

In order to achieve the above-mentioned aims, the use and the relation between the evaluation methodology, the pressure map, area of interest, habitats ad thresholds have to be sorted out.

When using an area-based approach, the threshold could be defined as the maximum proportion of a habitat affected. Additionally, a combined threshold could define the maximum area of a habitat exposed to a stressor along with a maximum proportion of time for this exposure., i.e. a combined threshold of x % area exposed and y % of time exposed. The threshold can count for the whole region and additionally for areas of interest such as MPAs or special known sensitive areas.

6 Summary

The present report started with a description of status quo, followed by the definition of *Harmonization Criteria*, by the documentation of analyses performed and open questions addressed so far in the Harmonize project. The final chapter describes a draft harmonized assessment approach based on the prior work. The scheme is built up as common framework with thresholds still to be defined and with the possibility (if more efforts are possible) to increase the depth of the analysis.

Further, open questions and recommendations to improve the assessment are covered in the different chapters of this report. Three major points of improvements are identified:

- Improve and complete input data quality of the registries.
- Define thresholds for species, groups of species or areas of interest for the assessment to determine the affected area.
- Apply simple and robust area-based assessment methodologies since the quality of information in the registries, are afflicted with uncertainties.

On the basis of the investigations carried out so far, it has also become apparent that an adjustment of the noise register will be useful for an assessment. This applies in particular to the source types explosions, for which it should also be possible to include sound mitigation measures, and for the source type seismic surveys.

7 Glossary

ACCOBAMS	The Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic area
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
DEPONS	Disturbance Effects on the Harbour Porpoise Population in the North Sea
Directive 92/43/EEC	Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (art 1 k)
EEZ	Exclusive Economic Zone
EMODnet	European Marine Observation and Data Network
EU	European Union
GES	Good Environmental Status
HELCOM	Helsinki Convention for the Protection of the Baltic Sea Environment
ICES	International Council for the Exploration of the Sea
ISO	International Organization for Standardization
MPA	Marine Protection Area
MRU	Marine Reporting Unit
MS	Member States
MSFD	Marine Strategy Framework Directive
Natura 2000	EU-wide network of protected areas for the conservation of endangered habitats and species
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
PCoD	Population Consequences of Disturbance
PUHA	Potentially Usable Habitat Area
TG-Noise	Technical Group on Underwater Noise
TNO	Netherlands Organisation for applied scientific research
QUIETMED	A joint programme on underwater noise (D11) for the implementation of the Second Cycle of the MSFD in the Mediterranean Sea
QUIETMED2	A Joint programme for GES assessment on D11- noise in the Mediterranean Marine Region

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EU Commission documents:

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Appendix 1

TG Noise Workshop 14.9. /Presentation and discussion Project HARMONIZE - Agenda

Schedule

Tuesday 14 September

Session 3: TG Noise Deliverable 1: Assessment framework for EU threshold values for impulsive noise

10:00 – 11:00: Presentation of interim results from project HARMONIZE [2] – Plenary session

10:00- 10:10: Opening Chairs, Main Objectives Project HARMONIZE -> Carina Juretzek (BSH)

10:10-10:40: Presentation of interim results, Project HARMONIZE, Andreas Müller, Müller-BBM

10:40-10:55: Habitat approach, -> Benedikt Niesterok BSH

10:55-11:00: Main discussion points wrap up -> Carina Juretzek (BSH)

11:00-12:00: Discussion on project results – Breakout rooms

11:00-11:35: Discussion in three Breakout groups

11:35-11:40: Result Breakout group 1

11:40-11:45: Result Breakout group 2

11:45-11:50: Result Breakout group 3

11:50-12:00: Conclusion

[2] *Toward the regional cross-operational unification and harmonisation of applicable assessment approaches for descriptor 11 on impulsive noise, in regard of special requirements from EU regions and sub regions*

Appendix 2

The purpose of the break out groups is to and to motivate feedback and to assess the acceptance of the interim conclusions, which were derived in Harmonize, and the acceptance for the underlying harmonization criteria to be used in the project.

Discussion time in each group in the break out room:

11:00 – 11:30 with presence of group members ;

11:30 – 11:35 with group chair and support for summarizing the discussion results

From 11:35 each chair will present her or his impression of the discussion and summarize some aspects that were discussed. (Extensive summary is not necessary here, discussion notes will be considered in the further project work).

For the determination of the harmonized ambition level for the assessment on impulsive noise, the following questions should be raised during the group discussion time and notes should be taken. The focus is to get the big picture on the question:

Group: Habitats for Harmonization (Chair Arianna Azzellino, support Benedikt Niesterok, Ramona Eigenmann)

The focus of the group on Habitats for Harmonization is to assess acceptance for the use of habitat information or proxies for habitats across the EU regions.

1. Which of the available methods (PUHA, MPA, Sanctuary,..collect) are widely accepted and well tested (in case studies or in practise)?
2. Are methods applicable and reproducible on a regional level? Can approaches be transferred and reproduced between region and within regions?
3. For which of the methodological aspects, monitoring may be used to evaluate the sufficiency of potential measures (at regional and national level)?

Group: Ambition level for harmonization (Chair Alexander Liebschner, support Maria Boethling)

The focus of the group on achievable ambition level for harmonization is to assess, which of the aspects of the different assessment examples known to TG Noise is achievable and suitable, based on the available data, but also based on regulatory purposes, and based on principles (precautionary principle) established in international conventions, included in EU directives (MSFD, Habitat Directive, Bird Directive) and in UNCLOS.

1. For which of the methodological aspects can uncertainties be well defined and delimited?

2. Which of them may be characterized as robust, which of them would not be reliable enough for regulatory purposes (at regional and national level)?

3. For which of the methodological aspects, monitoring may be used to validate the assessment results? How could sound pressure levels for the onset of biological adverse effects be used?

Group: Criteria for harmonization (Chair Carina Juretzek, support Andreas Müller)

Test for consensus on the following proposed criteria for harmonization:

Criteria Suitability

Description: Availability of data concerning noise and habitat (abiotic parameters like water depth, slope, currents, fronts and biotic parameters like mammal occurrence, species abundance, biomass, biological variables of indicator species), understanding of means of biological relevance and possibility to consider most sever adverse effects with priority.

Minimum Requirement: Good knowledge on fundamental abiotic parameters and some information on mammal and other species occurrence at defined areas alternatively administrative areas like EEZs and also availability of impulsive event data in a temporal and spatial context

Criteria Applicability

Description: Methods available are widely accepted and well tested in case studies or practise, for as much EU regions as possible and transferrable between regions, uncertainties are well defined and delimited. Moreover, monitoring provides the possibility to evaluate the sufficiency of measures

Minimum Requirement: National agencies or institutes are able to perform such an assessment and do not completely depend on multinational actions for gaining information necessary to plan, implement and monitor national measures.

Criteria Reproducibility and Validation

Description: Assessment method and monitoring actions allow to validate and compare assessment results and to evaluate the efficiency of potential measures at the level of regions and member states.

Minimum Requirement: Each member state is able to compare results on national level with regional and cross-regional results

Criteria Feasibility

Description: Each member state should be able to implement the method with financial capacities available at present time and with resources available without depending on expertise only available in some member states or specialized institutes

Minimum Requirement: At least one responsible agency or institute per member state has the capacity to implement the assessment, with standard hardware and software equipment.

Appendix 3

Minutes and summary of discussion within the break out groups

The purpose of the break out groups was to motivate feedback and to assess the acceptance of the interim conclusions and the acceptance for the underlying harmonization criteria for harmonization.

Group 1: Habitats for Harmonization (Chair Arianna Azzellino)

The focus of the group on Habitats for Harmonization was to assess acceptance for the use of habitat information or proxies for habitats across the EU regions.

1. Which of the available methods (PUHA, MPA, Sanctuary) are widely accepted and well tested (in case studies or in practise)?

Feedback:

- Key question is whether the habitat definition should be the same than the scale of the GES assessment (MRU)
- MRUs matters for legislation. MSFD does not consider MPAs. Natura2000 sites political tools
- MPAs are politically designed and they may include many habitats
- Decision case to case. MPAs are not necessarily political designations. They can include suitable habitats.
- TG Noise may recommend starting the assessment from MRU which may not encompass the whole habitat of the target species

2. Are methods applicable and reproducible on a regional level? Can approaches be transferred and reproduced between region and within regions?

Feedback:

- The open question is whether the available methods can be applied to MRU assessment
- Data available are accurate enough to support the assessment (natural, seasonal variability)?
- We should extent habitat assesment to cover seasonal variability since data are not always available. Data lacks are even worse for population approaches at the current state
- Different reliability of models for different species
- Target species different for different regions
- Uncertainty can be handled

Summary of main challenges identified during the discussion by group chair:

There is a common misunderstanding about the habitat interpretation. Habitat is very often seen as an area, which is already defined as critical for one or more species (e.g. MPA, Pelagic Sanctuary) at the scale that is comparable with the scale of the MRU. TG Noise is also struggling with this in DL3.
That leads to the question about the identification of habitat with MRU, when the concept of MPA is also involved, the confusion turns even to a higher level! The main discussed point is that MPA are designed based on both ecological and political reasons and they do not properly fit in the concept of GES assessment. MSFD does not specifically address management MPAs. The key node to be sorted out is still about MRU and the relationship with potentially present MPAs within the MRU.
Most of the people in the breakout sessions agree with the fact that MPAs/Natura2000 sites should be left aside from the habitat assessment, if they are not explicitly considered as representative also of the MRU.

Starting the GES assessment from MRU there would be the caveat that MRU might not necessarily encompass the whole habitat of the target species.
Concerning the habitat approach applicability it was discussed that data availability which might be extremely heterogeneous among regions would be the bottleneck for the habitat approach, although we might expect the problem being even worse for the population-based method. Even with the caveat of data availability, there was some confidence that data gaps might be handled following the precautionary principle as the existence of data uncertainties. There was no time to discuss the question about the possibility of monitoring the efficacy of potential measures.

Group 2: Ambition level for harmonization (Chair Alexander Liebschner)

The focus of the group on achievable ambition level for harmonization was to assess, which of the aspects of the different assessment examples known to TG Noise is achievable and suitable, based on the available data, on regulatory purposes, and based on principles (precautionary principle) established in international conventions, included in EU directives (MSFD, Habitat Directive, Bird Directive) and in UNCLOS.
Due to time constraint, only the first question was discussed.

1. For which of the methodological aspects can uncertainties be well defined and delimited?

Feedback:

- The group was reminded on the 4 methods from the Framework DL3 - dependence on data availability – question what is available at the moment;
- The availability of data is the main key; an assessment of the uncertainties (for the different approaches) is important
- Habitat approach looks for exposure and does not reflect uncertainties; population approach takes uncertainties into account
- Proposal to elaborate on a concept which explicitly mentions an 'expectation value' and in addition outlines uncertainties
- There is a difference between lack of knowledge (biological – need for more science) and lack of information/data (e.g. available in the registers)
- A distinction in the two approaches is not useful - both have positive and negative aspects;

Group 3: Criteria for harmonization (Chair Carina Juretzek)

Assess consensus on the following proposed criteria for harmonization:

Criteria Suitability

Description: Including aspects of availability of data concerning noise and habitat (abiotic parameters like water depth, slope, currents, fronts and biotic parameters like mammal occurrence, species abundance, biomass, biological variables of indicator species), understanding of means of biological relevance and possibility to consider most sever adverse effects with priority.

Minimum Requirement: Knowledge on fundamental abiotic parameters and information on mammal and other species occurrence at defined areas alternatively administrative areas like EEZs and availability of impulsive event data and their temporal and spatial context.

Feedback:
- maintain ecosystem approach - requirement of MSFD
- minimum list of parameter, which need to be available -> include sound propagation conditions (for sake of comparability regarding methodology and region)
- each MS should draft a list of important areas of specific interest or specific ecosystems importance
- add information on the kind of important habitats (e.g. migration corridors, etc.)
- consider available biological studies on effects on biota, in order to consider the appropriate criteria/biological relevance; include knowledge on severe impacts on biota; review available scientific knowledge
- development of noise assessment ambition level from simple model on imp. noise data (distribution in time and space) to broad spectrum of complex methodologies; consider aspects of uncertainty related to this development of approaches and input; increase of assessment complexity also increases the uncertainty -> ambition level needs to be linked to available knowledge basis; higher complexity of methods require better coverage of data and input

Criteria Reproducibility and Validation

Description: Assessment method and monitoring actions allow to validate and compare assessment results and to evaluate the efficiency of potential measures at the level of regions and member states.
Minimum Requirement: Each member state is able to compare results on national level with regional and cross-regional results

Feedback:
- propose minimum standards for MS, which allow all responsible institutes to follow for their own calculation of the assessment, in order to compare results with other regions and among e.g. projects
- possibility for member states to choose most suitable approach for their region/conditions; freedom for member states to choose appropriate solutions is important

Criteria Feasibility

Description: Each member state should be able to implement the method with financial capacities available at present time and with resources available without depending on expertise only available in some member states or specialized institutes
Minimum Requirement: At least one responsible agency or institute per member state has the capacity to implement the assessment (with feasible effort on hardware and software equipment).

Feedback:
- also solutions for increasing capacity needs for implementation (find solutions for all MS in communication with EU)

Criteria Applicability

Description: Methods available are widely accepted and well tested in case studies or practise, for as much EU regions as possible and transferrable between regions, uncertainties are well defined and delimited.
Moreover, monitoring provides the possibility to evaluate the sufficiency of measures

Minimum Requirement: National agencies or institutes are able to perform such an assessment and do not completely depend on multinational actions for gaining information necessary to plan, implement and monitor national measures.

Feedback: Could not be discussed during the break out discussion.