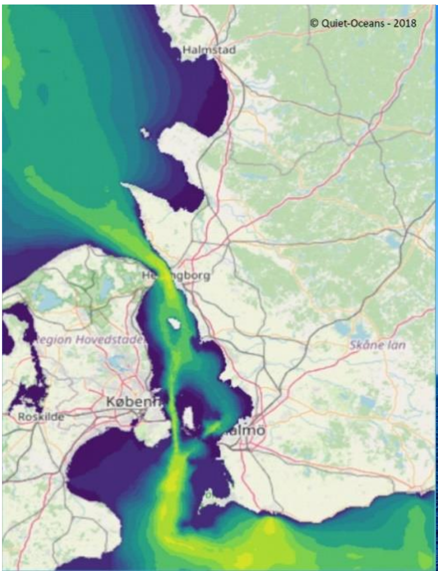
Setting EU Threshold Values for continuous underwater sound

Technical Group on Underwater Noise (TG NOISE)

MSFD Common Implementation Strategy

Edited by Druon, J.N., Hanke, G. and Casier, M.

2023



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JRC133476

PDF ISBN 978-92-68-03349-4 doi:10.2760/690123 KJ-04-23-492-EN-N

Luxembourg: Publications Office of the European Union, 2023

How to cite this report:
Borsani, J.F., Andersson M., André M., Azzellino A., Bou M., Castellote M., Ceyrac L., Dellong D., Folegot T., Hedgeland D., Juretzek C., Klauson A., Leaper R., Le Courtois F., Liebschner A., Maglio A., Mueller A. , Norro A., Novellino A., Outinen O., Popit A., Prospathopoulos A., Sigray P., Thomsen F., Tougaard J., Vukadin P., and Weilgart L., Setting EU Threshold Values for continuous underwater sound, Technical Group on Underwater Noise (TG NOISE), MSFD Common Implementation Strategy, Edited by Jean-Noël Druon, Georg Hanke and Maud Casier, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/690123, JRC133476

Contents

Abstract

The purpose of the present document is to give guidance on the setting of EU threshold values related to anthropogenic continuous noise in water[1]. Such 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].

This document is intended to inform managers and other stakeholders of practical options for setting threshold values for continuous sound. The rationale for setting regional conditions to evaluate the status of habitat is explained. Practical examples that illustrate regional approaches are demonstrated in detail. Finally, and most important to managers, options for setting threshold values for continuous sound are illustrated.

[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

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.

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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
- 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 (this report)

1. Introduction

Criterion D11C2 originated as a pressure indicator, designed to track trends in continuous underwater sound in marine waters. This origin and purpose of the criterion is reflected in previous advice from TG-Noise on how to quantify and evaluate such trends in sound levels. However, with the Commission Decision of 2017, criterion D11C2 changed and should now express: "*The spatial distribution, temporal extent and levels of anthropogenic continuous low-frequency sound do not exceed levels that adversely affect populations of marine animals*" (Comm.Dec.2017). The change is effectively a switch from a pressure indicator, simply quantifying the amount of noise in the marine waters, to an impact indicator, intended to quantify the impact of the noise on marine organisms.

The Commission Decision of 2017 further require that "*Member States shall establish threshold values for these levels through cooperation at Union level, taking into account regional or subregional specificities*" (CD2017). Such thresholds for underwater noise are not about source levels from individual sound sources or sound pressure levels received by individual animals but relate to the spatial and temporal extent of permissible deviation of the current condition from the reference condition which leads to habitat degradation. Based on the assessment framework for EU threshold values (deliverable 3, DL3) elaborated by the technical group on underwater noise (TG Noise), thresholds for D11C2 are proposed to be a number, which describe the maximum tolerable deviation from the reference condition while still remaining in Good environmental status (GES). Previous guidance on assessment of continuous noise (TG-Noise 2014) was given under the condition that descriptor 11 should characterize the pressure on the environment, i.e. quantify the amount of anthropogenic noise in the environment and in particular address possible trends (positive or negative) in the pressure. This interpretation is no longer valid after the Commission Decision of 2017, which explicitly establish D11C2 as an indicator of the *impact* of continuous noise on the marine habitats. This change has considerable implications for the assessment procedure, as it means that the metric(s) used to characterize the deviation of the current condition from the reference condition should relate to impact on indicator species or ecosystems, rather than simply being measures of the amount of anthropogenic sound in the ocean.

The threshold provided in this document is the maximum percentage of habitat where the Level of Onset of Biologically adverse Effects (LOBE) can be exceeded within the assessment period. GES is to be assessed in areas such as Marine Reporting Units, MRU's which are set by member states over defined assessment periods.

The value of LOBE is closely coupled to the choice of indicator species and thereby it should be set together with indicator species. As indicator species are likely to differ between regions and subregions this means that selection of LOBE values should be at this level too. Thresholds for determining whether habitats are in acceptable status, however, should be established in accordance with the Commission Decision 2017, stating that this should be done in close cooperation at EU and regional level. On this basis, the present report intends to provide managers with options and recommendations for setting EU wide threshold values for continuous sound, based on worked examples.

The assessment procedure and application of LOBE and threshold values to monitoring data has been described in DL3, but can be summarized in nine steps (see DL3 for details):

Step 1. Define indicator species and their habitats,

Step 2. Define the level of onset of biologically adverse effects (LOBE),

Step 3. Determine time periods for assessment:

Three time periods mentioned in DL3: observation period, analysis period, and assessment period. Threshold values are applied at the level of assessment period.

Step 4. Assess the acoustic status by monitoring,

Step 5. Establish the reference condition,

Step 6. Establish the current condition,

Step 7. Evaluate the condition of the grid cells:

From DL3: "The condition of a grid cell is determined by assessing the proportion of the time where the current condition is higher than LOBE". The result is a proportion of time for each grid cell. If this proportion is not higher than the temporal threshold value, the condition in the grid cell is considered acceptable.

Step 8. Determine the status of the habitats:

The status of habitats is assessed by evaluating the proportion of grid cells of the habitat where conditions are not acceptable. This number is compared to the spatial threshold value, which sets an upper limit to how large a fraction of the habitat can be in not acceptable condition.

Step 9. Assess the status of the MRU as being GES or not GES:

If MRUs equal habitats, then an MRU is considered in GES if the fraction of the habitat in not acceptable condition does not exceed the spatial threshold value. If MRUs are not identical to habitats, GES in an MRU is evaluated by combining the status of the habitats which together constitutes the MRU. There can be more than one habitat within an MRU.

2. Level of Onset of Biological adverse Effect (LOBE)

LOBE is an essential part of Descriptor 11 Criterion 2 (D11C2). The LOBE for continuous noise is conceptually identical with LOBE as defined for impulsive noise (see DL2). In DL3, the term LOSE (Level for Onset of Biologically Significant Adverse Effects) was used, but it has been changed in this report into LOBE since the term 'Significant' could be misleading.

Definition of LOBE

The noise level at which individual animals start to have adverse effects that could affect their fitness.

Clarifications

Examples of adverse effect include behavioural disturbance, stress, reduced communication space, and temporary or permanent habitat loss.

Fitness is the ability of an individual to successfully reproduce relative to other individuals in the population. If an animal experiences a loss in fitness, it means that its reproductive output is affected negatively, even if only slightly.

For continuous noise D11C2, noise level that can be spatially averaged sound pressure level or excess level.

2.1. Choose effect

Underwater sound can affect marine organisms in different ways and through different mechanisms, which has implications for the choice of appropriate metric to quantify the deviation of the current condition from the reference condition. Broadly, the effects can be grouped into three categories:

- Masking of acoustic communication and other sounds of importance for the indicator species. Masking can lead to impact on reproduction by affecting mating communication and mother-offspring communication, increased mortality through decreased predator detection and decreased food intake through interference with orientation and prey detection.
- Disturbance of natural behaviour of the indicator species, leading to negative impacts on the time budget of the individuals, and possible extra energy expenditure. Disturbances means that less time is available for foraging and nursing offspring, which, when cumulated over many smaller disturbances, lead to reduced survival and reproductive success.
- Effects on physiology, such as increased stress hormone levels and cardio-vascular effects by long-term exposure to elevated noise levels.

Loud sound can also lead to hearing impairment and in extreme cases (explosions) to tissue damage outside the inner ear. These effects are considered outside the scope of D11C2, as they are unwanted and must be regulated by member states already, as part of implementation of the protection through the Habitats Directive.

2.2. Select appropriate metric

A metric must be selected to quantify the deviation of the current condition from the reference condition in order to assess the status of a habitat. As D11C2 relates to the impact of continuous noise on animals/ecosystems, this metric must correlate with the effect and the type of metric therefore depends on the choice of effect on which the assessment is based.

Masking is closely related to degradation in signal to noise ratio. Under conditions where acoustic communication between two animals can take place, the signal intensity is sufficiently above ambient noise for the signal to be heard and understood by the receiver. At a given ambient noise level this means that there is some maximum distance over which communication can reliably take place. If the ambient noise is raised by the presence of ship noise, the maximum communication distance decreases. In other words, the maximum communication range changes with the ambient noise level[3]. This link between increases in ambient noise and decreases in communication distances means that a suitable metric to address the potential for masking is the elevation of ambient noise caused by ship noise and other anthropogenic sources. This metric has been termed the excess (see DL3) and is estimated by subtracting from the current condition noise level (with natural + anthropogenic sources) the level corresponding to the reference condition (with natural noise sources only). As masking changes rapidly with changing noise levels (time scale below 1 second), there is a case for considering changes in excess a fine time scale, comparable with the time scale of masking, i.e. seconds to minutes.

The link between sound levels and disturbance of behaviours has been extensively studied but no overarching framework for describing the relationship has emerged (see for example Southall et al 2021). Substantial evidence, however, supports that there is a strong link between the perceived loudness of a sound and the likelihood that an animal will respond. This fundamental relationship is then modulated by a range of factors, such as motivation and state of the individual, prior experience with the sound, and inter-individual differences. However, the perceived loudness of sounds is known to be affected primarily by the frequency of the sound in relation to the frequency of best hearing of the animal, and the duration of the sound. Short sounds, below the integration time of the auditory system (on the order of some hundred milliseconds) have a lower loudness than longer sounds, which means that sound pressure levels must be averaged over a period between some hundred milliseconds or more in order to correlate with loudness. For continuous signals the averaging time can be longer than the auditory integration time. For sounds with relatively stable frequency spectra, such as noise from larger ships, a suitable proxy for loudness may be the sound pressure level within a specified frequency band (one decidecade or wider). However, loudness is also affected by masking, meaning that if ambient noise is very high, a higher sound pressure level may be required before animals react to the sound. Thus, excess level may also under some conditions serve as a useful proxy for loudness. There is currently too limited empirical evidence regarding physiological effects to provide advice on suitable metrics to address these types of impact.

The choice of metric involves a choice of temporal observation window (TOW). The above considerations suggest a TOW of 1-60 s for masking, or 1-2 hours up to several days for behavioural effects. In addition, there are practical arguments for selecting TOW of at least 60 s (IQOE 2019), and it could be as large as 1 day or 1 month. For assessing the environmental quality for human health due to airborne noise, the international standard requires use of a daily Leq (ISO 1996-2), which would strengthen the case for choosing TOW longer than 24 h.

[3] Strictly, this is only true if the hearing of the species in question is limited by the ambient noise in the surroundings and not the absolute sensitivity of their hearing.

DL3 recommends using an assessment period (also known as temporal analysis window) of one month. The following advice assumes that MS follow this DL3 recommendation.

The arithmetic mean (AM) for a given month is independent of TOW if the average is taken over the entire month. By contrast, the median and all other percentiles for a given month are sensitive to TOW when the average is taken over the entire month.

In 2014, TG Noise recommended use of AM for Indicator 2 of Descriptor 11 (per CD 2010, a pressure indicator). The main reason for this recommendation was the robustness of AM to choice of TOW, and this remains an important consideration in 2022. In 2014, TG Noise recommended retaining the full time series of SPL vs time; the main reason for this recommendation was the uncertainty about what was needed to determine impact. CD 2017 supersedes CD 2010 and introduces D11C2, which TG Noise interprets as an impact indicator.

TG Noise recognises that the criteria (and associated metrics) for an impact indicator are different than those for a pressure indicator. TG Noise has discussed the implications of CD 2017 but is not yet able to provide recommendations on the choice of metric for an impact indicator.

Different projects (JOMOPANS, JONAS, QUIETSEAS) have selected different metrics. The value of LOBE should be tailored to the selected metric. Because the median (and other percentiles) is sensitive to TOW, assessments using the median (or other percentile) need to select a value of LOBE corresponding to the selected TOW.

In addition to TOW, the choice of metric involves a choice of spatial observation window (SOW). TG Noise is not yet in position to advise on the choice of SOW.

2.3. Establish LOBE

The values of LOBE for a certain indicator species, are set by regions/MS and should be chosen based on results from evidence-based studies, if available. If such studies are missing, the precautionary principle should be indicative. In Annex 3, a list of scientific studies has been compiled to show some examples. LOBE can be either an SPL or excess level, depending on the effect studied. The indicator species conservations status should be considered when setting LOBE. The choice of the temporal observations windows (TOW) will have an effect on the assessment where LOBE is used.

In order to establish LOBE one must have some knowledge about the relationship between the chosen noise metric and the magnitude of the negative effect addressed in assessment. Provided that this knowledge is available, one may define LOBE as the value of the metric that corresponds to the absence of adverse effects for the target species individuals or populations. Another possibility, when the cut-off between the no effect and the lowest effect condition is not easily determinable, is to define LOBE as the maximum tolerable impact, (E_{max} in the figure scheme).

Once LOBE is defined, this value can be used to determine whether the habitat condition is in tolerable status or not, depending on the noise level for the time-period chosen being above or below LOBE.

The next chapter shows examples of the assessment methodology where different LOBE values are used to demonstrate the effect of LOBE on the habitat status assessment.

3. Working example summary

Five working examples of application of the continuous noise assessment framework are describe and presented in this document. The detailed examples can be found in Annex 1. Three different areas were investigated using the results from three European funded projects (JOMOPANS, JONAS and QUIETSEAS). A fourth approach, involving averaging in time and space, is described in Annex 1. These working examples were crucial in the production of this document as they have brought to light fundamental and technical complexities.

All of the presented examples heavily rely on the use of numerical models to produce sound maps. A variety of sound mapping methodologies exist and are commonly used by member states. Two of them were used in the production of the five examples (e.g. instantaneous for JOMOPANS or statistical methods for JONAS and QUIETSEAS). Member States should keep the potentiality to perform sound mapping by following different approaches and methods of their choice with guidance from recommendations, for example, de Jong *et al.* 2021 and QUIETSEAS D4.2 2022, until an international standard is published. This ensures adaptability of the presented framework to future methodological improvements in order to follow potential innovations in this field. While the methods employed can be different, it is expected that the results should be comparable and all associated with an estimate of their uncertainties. The assessment framework should be applicable to *in-situ* measurements as well but was not tested in these examples.

The five examples were conducted in biogeographically diverse areas which are impacted by different noise pollution pressures. This diversity of environment is impacting the assessment results which emphasise the need to include such variability in the presented assessment framework.

The noise level thresholds (LOBE) used in all the examples were defined arbitrarily in order to detail the framework methodology. The presented example LOBE values do not follow the definition given in the LOBE section of this document. These example values are not meaningful to any given species and do not rely on any biological evidence, so they should not be used directly for any assessments by member states.

The following Table 1 summarises the approaches and inputs values of the working examples.

Summary of findings from the three examples:

The examples above have used similar modelling approaches to identify the implications of different spatial and temporal thresholds for continuous underwater noise in three areas corresponding to three different sub-regions in Europe's Seas. Each example used several noise level thresholds values and several spatial and temporal thresholds. The LOBE is expressed both as a SPL and an excess level: values in the range 90-110 dB re 1µPa in one side and values either 6 dB or 20 dB in the other side. The spatial threshold (Tolerable area) in the range of 10 to 25% and the temporal threshold (Tolerable Impacted area) up to 50%, are set. These analyses illustrate how the choice of different temporal, spatial and noise level thresholds result in different areas considered impacted or achieved a tolerable habitat status.

In the French Atlantic example, marine mammal species are the indicator organisms. The selected tolerable duration of 50% results in the proportion of the time corresponding to the percentile P50 over the month. And the Tolerable Impacted Area is set at 20% which results in a non-tolerable status of habitat where the major shipping routes is.

Table 1. Summary of metrics used by JOMOPANS, JONAS and QuietSeas projects, and by Annex C examples.

	JOMOPANS (excess level)	JOMOPANS (SPL)	JONAS	QuietSeas	Annex C (110 dB)
Temporal					
Temporal Observation Window (TOW)	30 s[4]	30 s	24 h	1 mo	7 d
Temporal Resolution	2 h	2 h	24 h	1 mo	7 d
Temporal Assessment Window (TAW)	1 mo	1 mo	1 mo	1 mo	7 d
Spatial					
Spatial observation window (SOW)	Vertical line (surface to seabed)	Vertical line (surface to seabed)	Point	Point	5 km x 5 km x water depth
Spatial Resolution	50 m x 50 m	50 m x 50 m	15 km x 15 km	15 km x 15 km	5 km x 5 km
Spatial Assessment Window (SAW)	n/a	n/a	n/a	n/a	
Metric					
Metric	Excess level	SPL[5] re 1 µPa Monthly median of depth-averaged SPL samples	SPL re 1 µPa (Maximum in water column) Monthly median of largest 24-h SPL sample	AM[6] re 1 µPa Monthly AM of mean-square sound pressure at 50 m and 1000 m depth	AM re 1 µPa Weekly AM of spatially averaged mean-square sound pressure
Frequency	125 Hz	125 Hz	63 Hz	63 Hz	125 Hz
LOBE	6-20 dB	90-110 dB	90-110 dB	90-110 dB	110-120 dB
Tolerable area	25%	25%	10% - 20%	10%	

[4] The precise TOW duration used by JOMOPANS is not clearly defined, but is considered to be between 10 s (the estimated minimum averaging duration for the source level of a fast ship) and 60 s (the estimated time for a ship distribution to change sufficiently to affect the sound map).

[5]SPL = sound pressure level (see Annex 4)

[6]AM = arithmetic mean of squared sound pressure (see Annex 4)

In the Western Mediterranean example, the selected thresholds of 10% for Tolerable Impacted Area that should not be exceeded in any month of the assessment year results in a tolerable habitat status for the bottlenose dolphin across the area considered.

The North Sea example used two different values of LOBE. Example A uses LOBE as an excess noise level (above reference conditions) whereas example B uses the specific sound pressure levels of 100dB re 1µPa. Example B is therefore more readily compared with the North Atlantic and Mediterranean examples. As in the French Atlantic example the 50% tolerable duration, and 100 dB LOBE level, result in the busiest shipping areas falling outside habitat tolerable status. This example also illustrates that, maintain the LOBE at 100 dB but changing the tolerable duration to 10% in the North Sea would result in a large fraction of the area falling outside the range of tolerable habitat status.

Overall, the examples illustrate that the temporal thresholds (tolerable durations) selected have considerable effects on the size of the areas considered to be in tolerable habitat status and therefore considerable policy consequences for achieving it, but the effects of establishing these pressure thresholds on the state of the indicator populations remains uncertain.

4. Standards

Until the choice of metric and corresponding value of LOBE are harmonized, different assessments selecting different metrics may result in different outcomes for the same grid cell and time assessment period (see LOBE). In other words, assessments choosing different metrics are not directly comparable. *It does not follow from the examples provided that conditions in any one region or sea are better than in any other region or sea (see EXAMPLES).*

A pre-requisite for assessments to become consistent across regions is the development and adoption of relevant international standards. International standards have been published for underwater acoustical terminology (ISO 18405), for measuring underwater sound from pile driving (ISO 18406) and for measuring underwater sound from surface vessels (ISO 17208)).

Of these, only ISO 18405 (terminology) is relevant to D11C2. Use of ISO 18405 is imperative to effective communication on matters related to underwater sound, including D11. TG Noise strongly advises regional projects and MS to follow ISO 18405.

While use of the ISO 18405 ensures the same terminology is used, TG Noise has observed that sound levels for D11C2 status assessments are not monitored in a coherent way by Member States. Monitoring underwater sound involves a combination of measurements and modelling. In 2022, no international standard exists for measuring or modelling ambient sound pressure in water.

A standard for *measuring* ambient sound is under development. This work is driven mainly by Canada, Netherlands and United Kingdom, and the resulting ambient sound measurement standard (ISO 7605) is scheduled for publication in 2024. Without more input from EU MS, this standard is unlikely to reflect MSFD priorities. No comparable work is being done on modelling.

TG Noise encourages support in the short term for developing ISO 7605. In the longer term, standards are also needed for modelling and monitoring of underwater sound.

5. Settings of Thresholds values for continuous noise

5.1. Rationale and link with expected impact on populations of marine animals

The presence of and exposure to continuous 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 it may lead to habitat degradation.

Degradation can come in two forms: decreased habitat size through habitat loss or fragmentation, and decreased habitat quality through loss of resources, pollution or other forms of habitat alteration.

Habitat size and quality are assumed to influence extinction risk through different causal mechanisms. Poor habitat quality is expected to influence extinction risk in two ways: poor quality habitats can only support small populations that are prone to extinction from demographic stochasticity, or poor habitat quality diminishes a population's growth rate thereby diminishing the buffer that exists between the long-run average population size and extinction.

These implications of carrying capacity and reproductive potential for population extinction are theoretically well established (MacArthur 1972; Tier & Hanson 1981; Pimm et al.1988; Hakoyama et al.2000), while it is still not fully understood whether it is habitat size or habitat quality that better correlate with carrying capacity - i.e. the maximum population size that an environment can sustain - and extinction risk.

Results of empirical studies show that extinction risk can be influenced most by habitat size (e.g. Johansson & Ehrlen 2003), habitat quality (e.g. Franken & Hik 2004) or a combination of the two (e.g. Dennis & Eales 1997; Fleishman et al. 2002).

So, following this rationale, it is assumed that habitat degradation induced by continuous underwater noise increases with the proportion of habitat exposed to noise and the duration of such exposure, being therefore associated with an increased likelihood of negative effects occurring at the population level for a species of interest.

D11C2 requires to define the spatial exposure limits above which the probability of negative effects for the population of a species is not tolerable. To define such spatial exposure limits, some assumptions are required:

(i) Larger habitats support populations with higher carrying capacities;

(ii) Higher quality habitats support populations with higher carrying capacities;

(iii) There is no difference in population growth rate between large and small habitats.

(iv) Population growth rates are higher in high-quality habitats than low-quality habitats.

These assumptions have been also experimentally verified by Griffen and Drake study (2008) that provides additional evidence that improving habitat size and quality can both reduce extinction risk by increasing population growth rates and thus allowing populations to more effectively increase when rare.

Based on these concepts, a relationship between noise-induced habitat degradation and carrying capacity/population growth rate can be assumed, and a reduction of the population size can be expected for chronic (i.e., long-term) exposures to noise.

Ecological studies concerning many taxa in terrestrial habitats show that the relationship between population and habitat size may have different shapes, including linear and non-linear regressions (Swift & Hannon, 2010).

So, following the same rationale described in DL2, we assume here the model proposed by Tougaard et al. (2013) for harbour porpoise describing a generic linear relationship between carrying capacity/population size and habitat size that is precautionary for species that are not primarily habitat limited, but also limited by other stressors, including fishery and bycatch. Additional caution would be required in case of species that are already severely habitat limited.

Following the linear hypothesis, **1% of permanent habitat loss may correspond to 1% of decrease in the carrying capacity and so forth.**

This assumption was also 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 (Clare et al. 2020).

5.2. Possible management objectives and resulting options for threshold values

Available scientific literature and existing conservation management frameworks (IWC, ASCOBANS and ACCOBAMS) and the IUCN approach for assessment of the conservation status of species have been reviewed.

The general goal of these management framework 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, 2003) or to avoid a species to be assessed as vulnerable (IUCN, 2012), and conservative approaches such as conserving at least 80% of the carrying capacity for small cetaceans in the long term (Rejinders, 1997; ASCOBANS, 2000).

Following the same reasoning of DL2 concerning impulsive noise, the 80% objective of ASCOBANS was taken as a lower bound tolerable threshold in reason of the consideration that it is more precautionary compared to other quantitative options considered (namely the IWC approach to sustainable whaling and the IUCN Criteria that classify a species as vulnerable). The 80% objective has also been accepted (as a minimum standard) by a number of EU countries that are Party to the ASCOBANS Agreement.

Assuming the linear model proposed by Tougaard et al. (2013) which links the carrying capacity and the habitat size, the conservation objective can be translated into a 20% reduction of the habitat of a target species due to long-term acoustic disturbance, potentially leading to a decline of 20% of the population size in the long run.

Continuous noise is a chronical pressure in most of the marine environments since it is almost permanent. So, it was not considered useful to set a short-term threshold as for impulsive noise which on the other hand is in many cases a transitory stressor.

In continuous noise assessment, the long-term exposure duration is set to 1 year, consistently with the period indicated in the Commission Decision 2017/848 for assessment of D11C2, while the temporal resolution of assessment is monthly (the chosen metric should reflect the central tendency of the monthly scenario).

5.3. Tolerable exposed area

In the framework previously explained and, grounding also on the experience of the project case studies which showed that the maximum threshold of 20% of impacted habitat can be also considered a sort of current baseline for the investigated areas, **20% of the habitat was assumed as the upper bound of *Tolerable exposed area* not to be exceeded in any month of the assessment year,** in agreement with the conservation objective of the 80% of the carrying capacity/habitat size.

5.4. Use of the threshold levels

Tolerable status relative to D11C2 is achieved if for all single months over a year the tolerable exposed area is equal to or below 20%. This value for the extent of exposure (20% of habitat) is considered as having scientific foundation (see rationale above), however, lower TVs might be set according to regional to local specificities. Some regions are faced by constant high levels of shipping. For these regions it may be (almost) impossible to reach a tolerable status in the foreseeable future.

Table 2. Suggested TVs and rationale.

Period	Tolerable exposed area	Short description of rationale
Long-term exposure (1 year assessment, monthly basis)	20% or lower	As LOBE is set to address the onset of effects for target species due to acoustic disturbance, long-term exposure to continuous noise higher than LOBE will impact almost permanently species habitat and this has been considered as habitat loss. The reduction of habitat may potentially lead into a reduction of the carrying capacity/population size in the long term. Setting 20% as the maximum amount of a habitat disturbed by underwater continuous noise, on average over 1 month, allows maintaining 80% 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 80% of the carrying capacity in the long term. Threshold Levels lower than 20% can be set according to local or regional specificities.

Summary of TVs:

TG Noise advice is to set the continuous noise threshold values to:

20% of the target species habitat having noise levels above LOBE not to be exceeded in any month of the assessment year, in agreement with the conservation objective of the 80% of the carrying capacity/habitat size.

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 considering regional and sub-regional specificities. Beside this advice, Member States have the task to establish the threshold values nationally.

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.

This threshold has been set at the best of the current knowledge. Future studies are strongly encouraged to quantitatively assess population effects of specific and/or representative species enabling to provide further support to our basic assumptions or even refine the chosen threshold value.

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QUIETSEAS D4.2 2022

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List of abbreviations and definitions

ACCOBAMS Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic area

ADEON Atlantic Deep water Ecosystem Observatory Network (adeon.unh.edu)

AIS Automatic Identification System

AM Arithmetic Mean

ASCOBANS Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas

BIAS Baltic Sea Information on the Acoustic Soundscape (biasproject.wordpress.com)

COMDEC2017 Commission Decision (EU) 2017/848

D11C2 Descriptor 11, Criterion 2 (regarding anthropogenic continuous low-frequency sound in water), as laid out in the Commission Decision (EU) 2017/848

ddec decidecade (a logarithmic unit of frequency ratio equal to one tenth of a decade)

DL2 Options for EU threshold values for impulsive noise, TG-Noise Deliverable 2

DL3 Assessment Framework for EU Threshold Values for continuous underwater sound, TG-Noise Recommendations - Deliverable 3 of the work programme of TG Noise 2020-2022 TG- Noise guidance, adopted on 12 November 2021

EEA European Environmental Agency

EEZ Exclusive Economic Zone

EU European Union

GFCM General Fisheries Commission for the Mediterranean

GES Good Environmental Status

ICES International Council for the Exploration of the Sea

IQOE International Quiet Ocean Experiment

ISO International Organization for Standardization

IUCN International Union for Conservation of Nature

IWC International Whaling Commission

JNCC Joint Nature Conservation Committee

JOMOPANS Joint Monitoring Programme for Ambient Noise North Sea (northsearegion.eu/jomopans/)

JONAS Joint Framework for Ocean Noise in the Atlantic Seas (jonasproject.eu)

LOBE Level of Onset of Biologically adverse Effects

MRU Marine Reporting Unit

MS Member State(s)

MSFD Marine Strategy Framework Directive

NGO Non-Governmental Organization

NOAA National Oceanic and Atmospheric Administration

NFMS National Marine Fisheries Service (NOAA Fisheries)

OSPAR (Oslo-Paris) Convention for the Protection of the Marine Environment of the North-East Atlantic

PUHA Potentially Usable Habitat Area

RC Reference Condition

SAC Special Area of Conservation

SATURN Developing Solutions for Underwater Radiated Noise (saturnh2020.eu)

SAW Spatial Analysis Window (see SATURN terminology standard)

SOW Spatial Observation Window (see SATURN terminology standard)

SPL Sound Pressure Level

TAW Temporal Analysis Window (see SATURN terminology standard)

TG-Noise Technical Group on Underwater Noise

TOW Temporal Observation Window (see SATURN terminology standard)

TV Threshold Value

QUIETMED Joint programme on underwater noise (D11) for the implementation of the Second Cycle of the MSFD in the Mediterranean Sea (http://www.quietmed-project.eu)

QUIETMED2 Joint programme for GES assessment on D11- noise in the Mediterranean Marine Region (https://quietmed2.eu)

QUIETSEAS Assisting (sub) regional cooperation for the practical implementation of the MSFD second cycle by providing methods and tools for D11 (underwater noise) (https://quietseas.eu)

List of tables

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Annex 1. Three examples of application of DL3 framework to monitoring data for underwater continuous sound in European waters.

1. French Atlantic Economic Exclusive Zone

Total shipping noise is modelled in computational cells, based on information about presence, size and speed of ships (from AIS information). The modelling methodology used in this example is based on statistical shipping noise mapping method (detailed in Le Courtois et al., 2016). The shipping noise maps generated are based on 31 mean daily maps, aggregate to a monthly median map of shipping noise for January 2019. The shipping noise level returned is the maximum noise level over the water column for each computation cell. The status of the habitat is assessed by evaluating the fraction of time LOBE is exceeded in each assessment grid cell, followed by evaluating the fraction of grid cells in each area that are significantly affected. In this example, the definition of LOBE is represented as the Sound Pressure Level from shipping noise, which can lead to a disturbance effect. It can be related to behavioural disturbance and addressing effects on time budgets/energetics of marine species.

Step by step framework example

Step 1. Define indicator species and its habitat

Three different marine sub-regions designated by the MSFD are assumed as habitats relative to several marine mammal species.

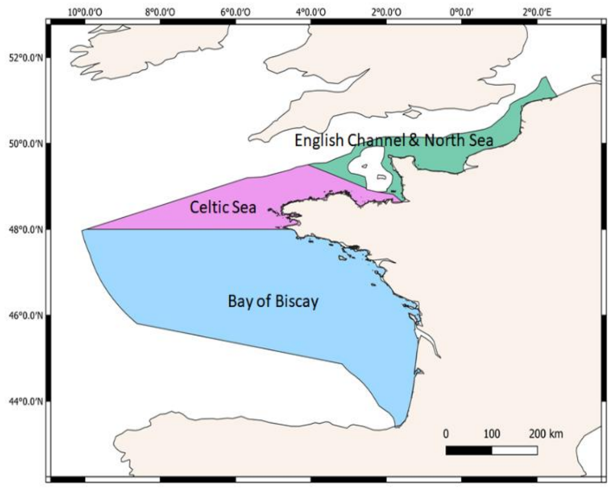


Figure A.1.1.1

Three sub-regions in the French Economic Exclusive Zone, defined by MSFD used as habitats in the example: English Channel and North Sea, Celtic Sea and Bay of Biscay.

Step 2. Define LOBE

LOBE in the example is set at 100 dB re 1μPa in the one third band centred on 63 Hz, corresponding to a possible level of behavioural disturbance for marine mammal species.

Step 3. Determine time periods for the assessment

The temporal observation window (TOW) is the temporal resolution of the marine traffic statistical model. It is set to 1 day. The temporal assessment window (TAW), over which status of the habitats is evaluated, is set to one month.

Step 4. Assess the acoustic state by monitoring

The current conditions in the French EEZ are modelled based on the shipping noise generated by the model. In the example, results from the one third octave band centred on 63 Hz are used. The spatial resolution (spatial observation window, SOW) is 10 arc-minutes longitude by 10 arc-minutes latitude (approx. 15 x 15 km).

Step 5. Establish the Reference Condition

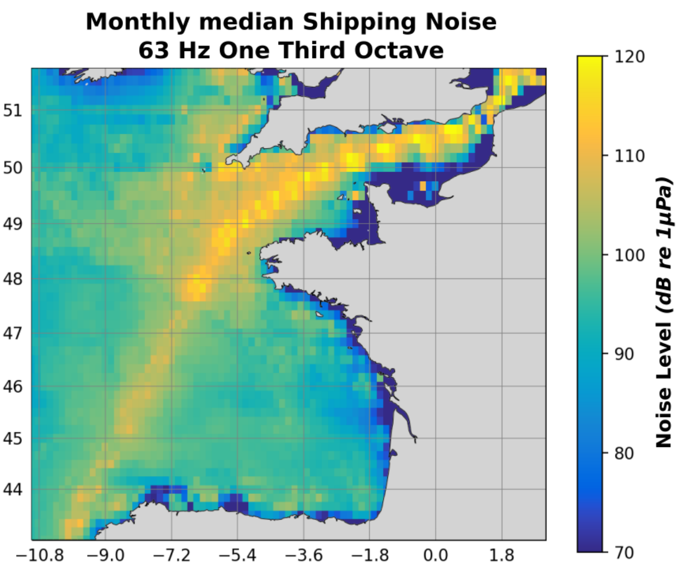
In this example the model outputs return the shipping noise levels only. The Reference Condition is not established nor used.

Step 6. Establish the Current Condition

The current condition is modelled by noise from all ships in the French EEZ (obtained from AIS). Source characteristics for each ship were modelled from size, speed and ship categories (using Randi 3.1 source model, Breeding et al., 1996). Distribution of the Sound Pressure Levels of the shipping noise were quantified for each temporal observation window over a month.

Figure A.1.1.2

Current condition for the **monthly Median of shipping noise in one third octave band centred on 63 Hz.** Colour scale represent the shipping noise level (SPL in dB re 1μPa) over the French Economic Exclusive Zone.



Step 7. Evaluate grid cells

The **condition of each grid cell** is determined by assessing the proportion of the time where the noise level is higher than LOBE. In this example, the proportion of the time is set at 50%, corresponding to the percentile P50 over the month. Grid cells over LOBE are considered as **significantly affected**.

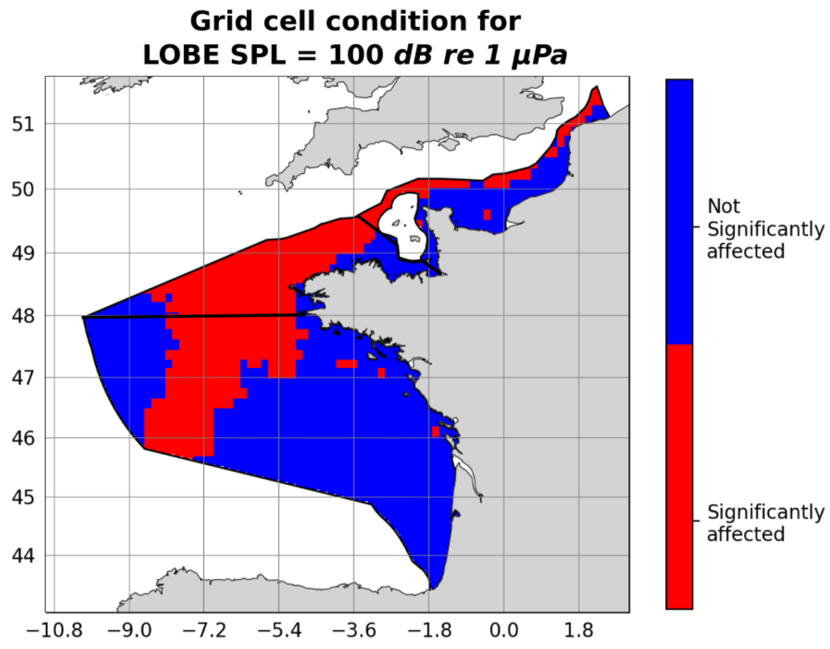
Figure A.1.1.3

Assessment of conditions of individual grid cells.

Blue cells represent grid cells which are not significantly affected by noise for the set LOBE.

Red cells represent grid cells which are significantly affected by noise for the set LOBE.

The Temporal Observation Window (TOW) is set for **24h.** The Spatial Observation Window (SOW) is represented by a point for each grid cell. The Temporal Assessment Window (TAW) is set over **a month** (January 2019).

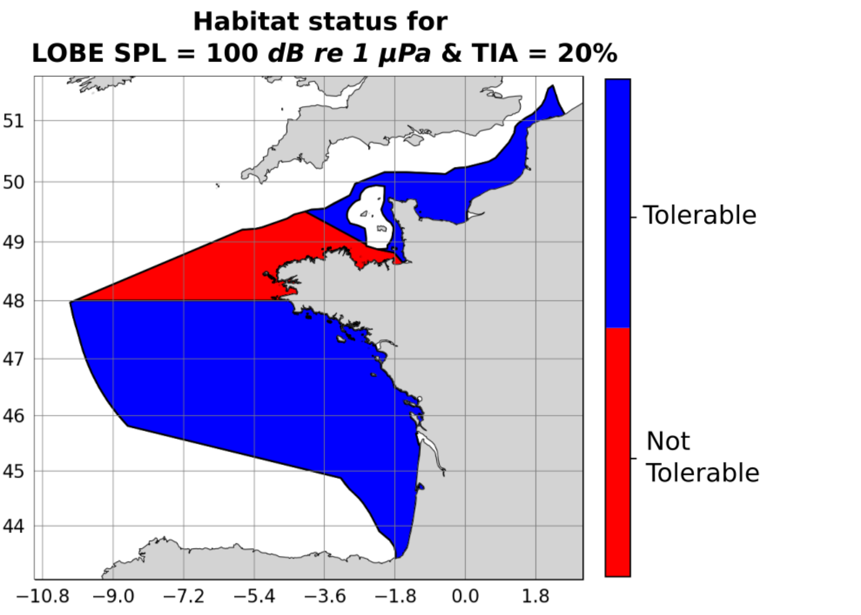


Step 8. Determine the status of the habitat

Figure A.1.1.4

The status of habitats is assessed by comparing the fraction of grid cells in a habitat that are significantly affected against the **Tolerable Impacted Area (TIA).** The tolerable impacted area in this example is set to **20% for a month.**

Two sub-regions are in **tolerable status:** North Sea & English Channel and Bay of Biscay. One sub-region, Celtic Seas, is **not in tolerable status.**



Changing the values of LOBE and tolerable duration

The outcome of the assessment is very sensitive to the choice of LOBE, tolerable duration, and tolerable impacted area. This is illustrated in Figure A.1.1.6 where the condition of grid cells was evaluated with different combinations of LOBE. LOBE is applied on shipping noise maps at percentile 50 over a month.

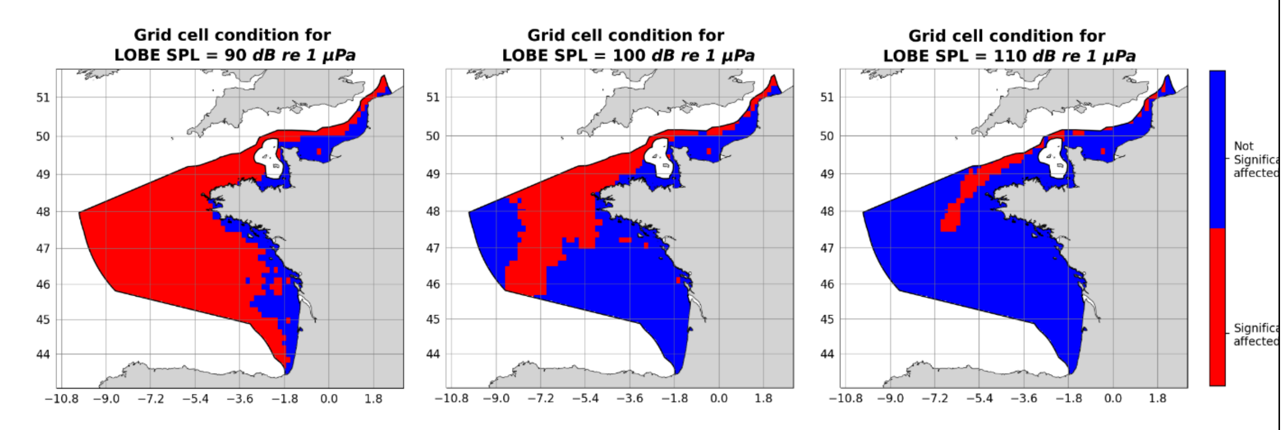


Figure A.1.1.5 Influence of choice of parameters LOBE on the evaluated condition of grid cells. Three different values of LOBE (90 dB, 100 dB and 110 dB) were used. The maps are very different, but persistent features such as the consistently high impact along the shipping rail of Ouessant, especially the north part crossing the Celtic seas are retained across maps.

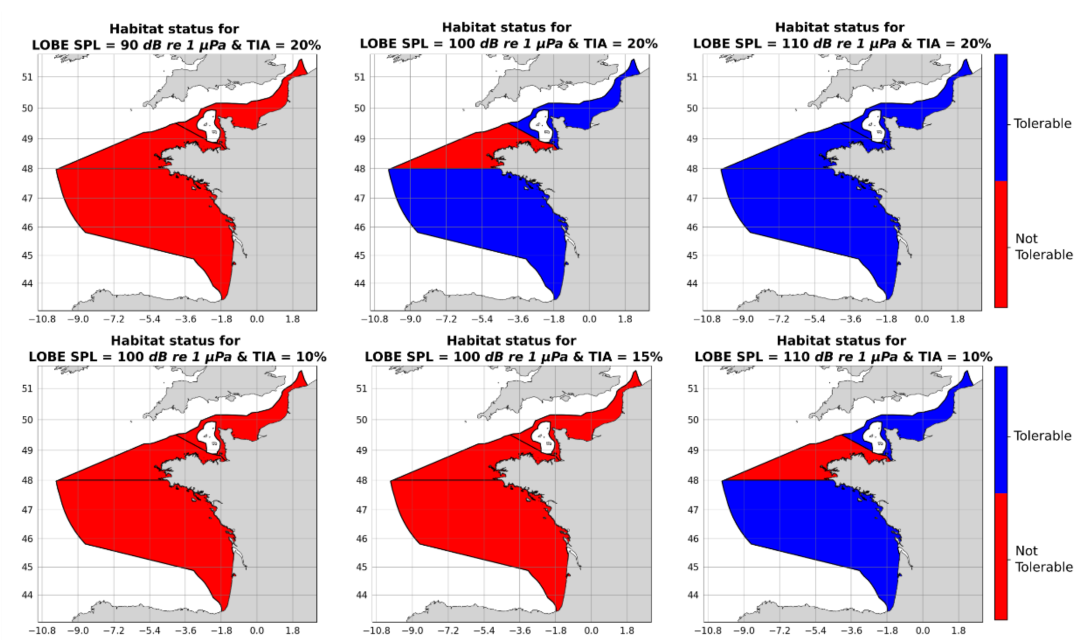


Figure A.1.1.6 Influence of choice of parameters LOBE and Tolerable Impacted Area (TIA) on the evaluated status of the Habitat. Three different values of LOBE (90 dB, 100 dB and 110 dB) and three different values of Tolerable Impacted Area (10%, 15% and 20%) were used.

2. Western Mediterranean Sea

Total shipping noise is modelled in computational cells, based on information about presence, size and speed of ships (from AIS information). The modelling methodology used in this example is based on statistical shipping noise (more detailed in Le Courtois et al., 2016). The shipping noise maps generated are based on a mean monthly map. The status of the sub-region is assessed by evaluating the fraction of area LOBE is exceeded on the monthly average scenario. In this example, LOBE is defined as a Sound Pressure Level and for the example is assumed as 100 dB re 1μPa.

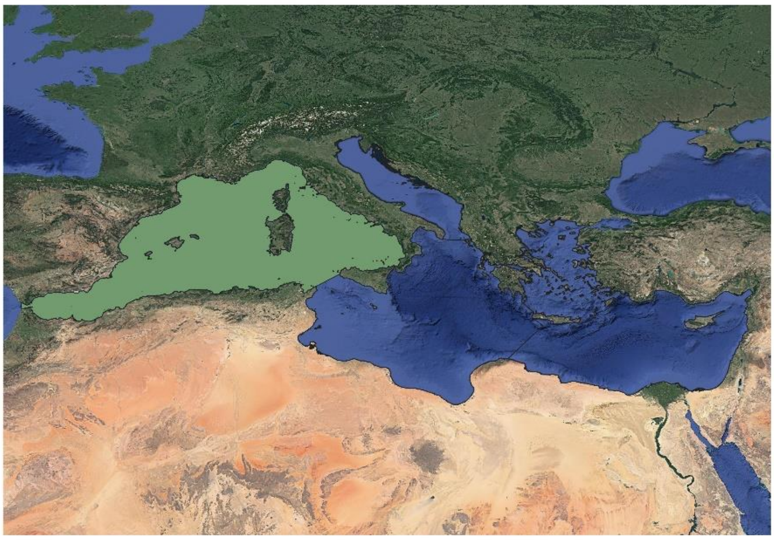
Step by step framework example

Step 1. Define indicator species and its habitat

The Western Mediterranean area is characterised by the presence of 6 regular species of marine mammals, each having their own specific habitat preferences. In this example bottlenose dolphin is assumed as target being the habitat of this species mostly coastal and therefore largely exposed to shipping noise.

Figure A.1.2.1

The **Western Mediterranean Sea** MSFD reporting unit.



Step 2. Define LOBE

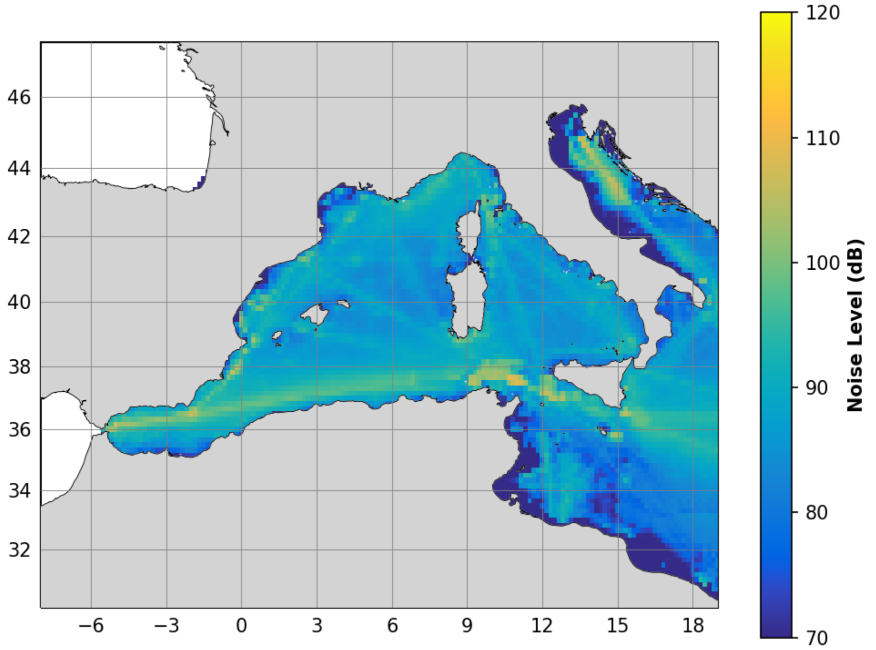
LOBE in the example is set at 100 dB re 1µPa in the one third band centred on 63 Hz, corresponding to a possible level of behavioural disturbance for marine mammal species.

Step 3. Determine time periods for the assessment

The temporal observation window (TOW) is the temporal resolution of the marine traffic statistical model. It is set to 1 month. The temporal assessment window (TAW), over which status of habitat is evaluated, is set to one month.

Figure A.1.2.2

Current condition for **one third octave band centred on 63 Hz** in the Mediterranean Sea region. Colour scale represents grid cell monthly average SPL.



Shipping noise for one third octave band centred on 63 Hz over a month in the Mediterranean Sea.

Step 4 Assess the acoustic state by monitoring

The current conditions in the Western Mediterranean Sea are modelled based on the noise generated by the average monthly shipping density. In the example, results from the one third octave band centred on 63 Hz are shown. The spatial resolution (spatial observation window, SOW) is 10 arc-minutes longitude by 10 arc-minutes latitude (approx. 15 x 15 km).

Step 5. Establish the Reference Condition

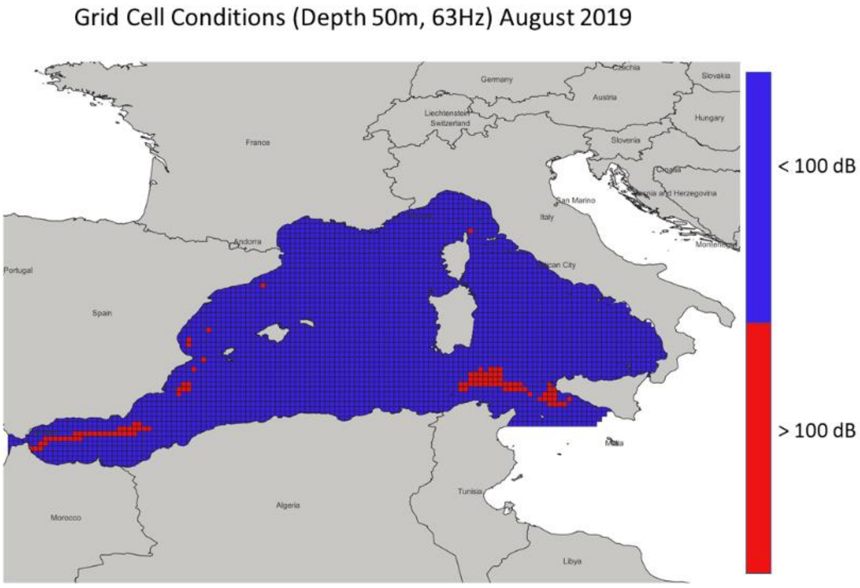
The Reference Condition is 100% of the habitat exposed to sound level lower than LOBE.

Step 6. Establish the Current Condition

The current condition is modelled by noise from all ships in the Western Mediterranean unit (obtained from AIS monthly average shipping density data). Source characteristics for each ship were modelled from size, speed and ship categories (using Randi 3.1 source model, cf. Breeding *et al.*, 1996).

Step 7. Evaluate grid cells

The **condition in each grid cell** based on a monthly central tendency over the month and comparing the predicted SPL with the assumed LOBE (this implies that LOBE compliance is based on a mean or a median). If the grid cell SPL average is above the LOBE, the cell is said to be **significantly affected**.

Figure A.1.2.3 Assessment of conditions of individual grid cells. **Blue** cells represent grid cells which are **not significantly affected** by noise for the set LOBE. **Red** cells represent grid cells which are **significantly affected** by noise for the set LOBE. The Temporal Observation Window (TOW) is set for **1 month.** The Spatial Observation Window (SOW) is represented by a point for each grid cell. The Temporal Assessment Window (TAW) is set over **a month.**	LOBE: 100 dB re 1 μPa 

Step 8. Determine the status of the habitat

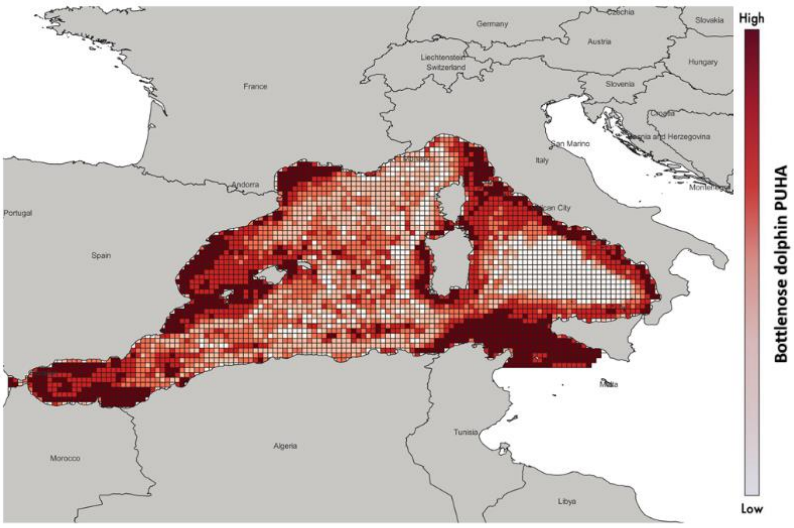
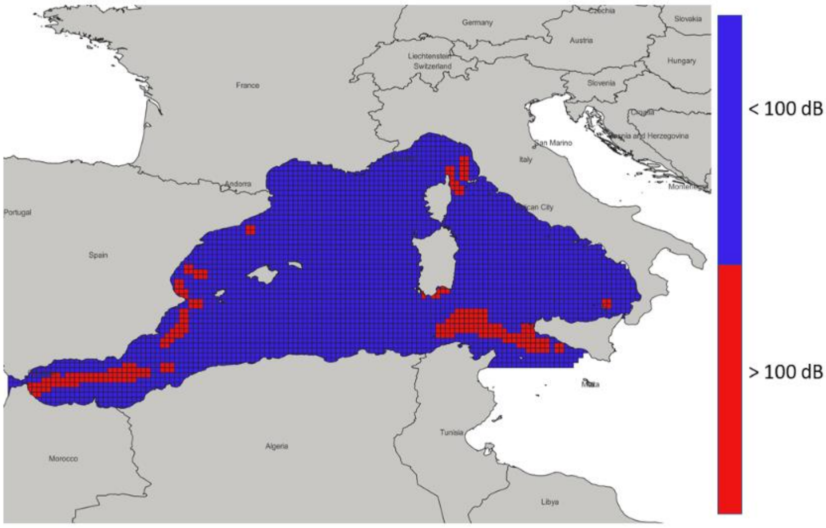
Figure A.1.2.4 The status of habitats is assessed for the target species in terms of PUHA, **Potentially Usable Habitat** Area (cf. QuietMed2 DL5.2). In this example the PUHA of **bottlenose dolphin** is considered and overlapped to predicted noise levels.	Bottlenose dolphin PUHA 

Figure A.1.2.5	Noise Level overlapped to bottlenose dolphin PUHA
The status of habitats is assessed by comparing the portion of target species habitat in the assessment area that is significantly affected by noise against the **tolerable impacted area.** The tolerable impacted area in this example is set to **20% of the habitat being exposed to average noise levels higher than LOBE.** It can be assumed that if a portion of the species habitat equal to 10% or lower, is exposed in average every month over a year to continuous noise at levels higher than LOBE, this can be considered an acceptable deviation from the reference conditions (i.e. 100% of the Potentially Usable Habitat Area exposed to sound level lower than LOBE). In this example, **only a fraction of about 7% of the bottlenose dolphin PUHA is exposed to noise levels higher than LOBE** (100dB re 1uPa). In the example, the status of the habitat is considered as tolerable.	LOBE: 100 dB re 1 µPa Bottlenose dolphin habitat status 

Changing the values of LOBE and tolerable duration

The outcome of the assessment is very sensitive to the choice of LOBE. This is illustrated in Figure A.1.2.6 where the condition of grid cells was evaluated with different combinations of LOBE. LOBE is evaluated here on noise maps generated from a monthly average of shipping noise.

LOBE = 90 dB re 1µPa | LOBE = 100 dB re | LOBE = 110 dB re 1 µPa

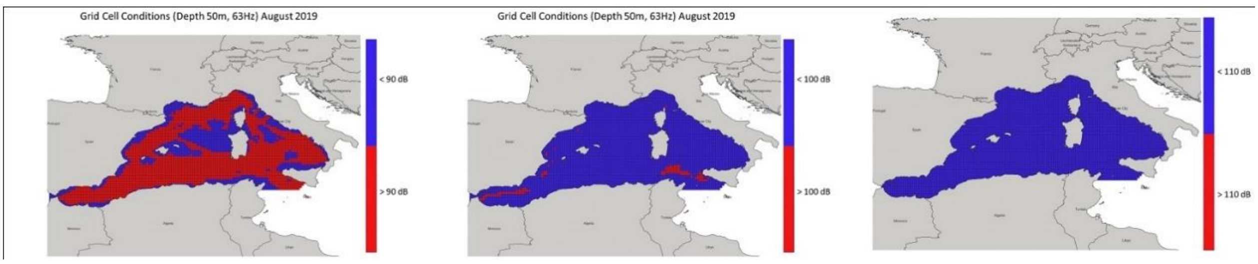


Figure A.1.2.6 Influence of LOBE selection on the assessment. Three different values of LOBE (90 dB, 100 dB and 110 dB) are considered.

3. North Sea

Two examples, based on the same dataset, are given. In the first example LOBE is interpreted from DL3 as an excess noise level above the reference condition, thereby addressing impact in the form of masking. The second example interprets LOBE as a fixed level of the current condition, above which behavioural reactions to the noise is considered likely.

Example A: LOBE as an excess noise level

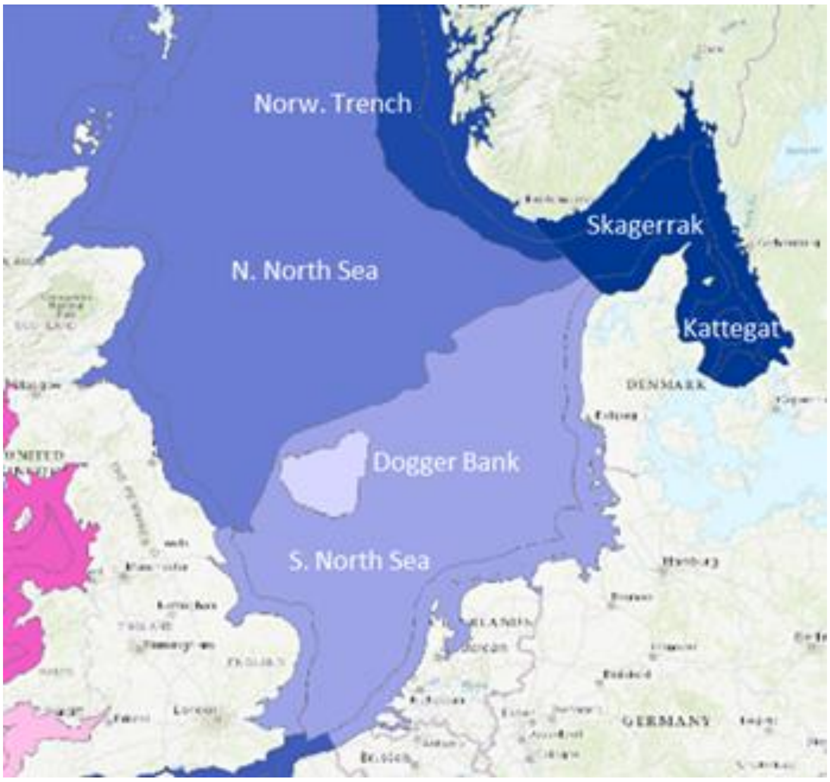
In this example, the definition of LOBE in DL3 is interpreted as an instantaneous deviation of the current condition from the reference condition.

Step 1. Define indicator species and its habitat

Six habitats were selected, based on areas previously designated by OSPAR as biogeographical subdivisions of the North Sea (Figure 3.1).

Figure A.1.3.1

Six habitats in the North Sea, defined by OSPAR: Southern North Sea, Northern North Sea, Dogger Bank, Norwegian Trench, Skagerrak and Kattegat.



Step 2. Define LOBE

LOBE in the example is set at 20 dB excess in the 125 Hz decidecade band, corresponding to current state being 20 dB higher than the reference state. This value has been selected to represent a condition where the maximum communication range of an animal communicating in the 125 Hz decidecade band is severely limited by ship noise.

Step 3. Determine time periods for the assessment

The temporal observation window (TOW) is the temporal resolution of the underlying soundscape model. It is set to 30 s. The temporal assessment window (TAW), over which status of grid cells is evaluated, is set to one month.

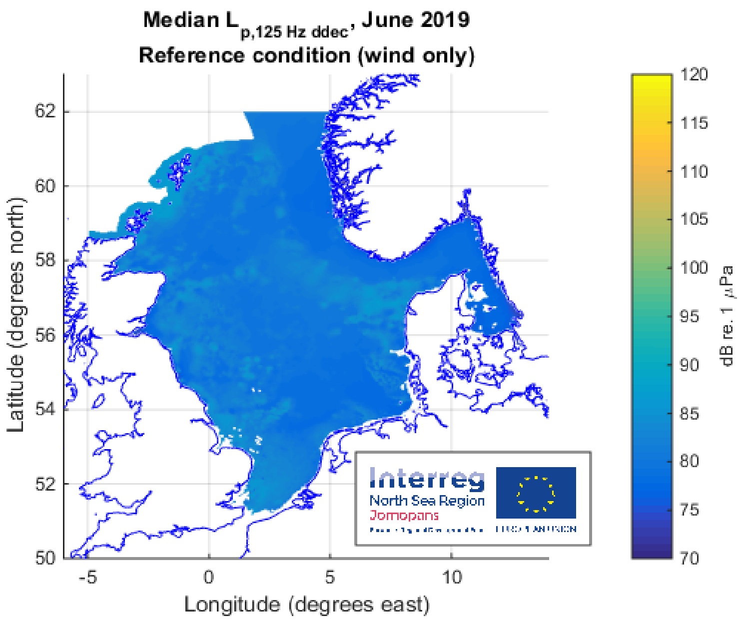
Step 4. Assess the acoustic state by monitoring

The reference and current conditions in the North Sea were modelled in two steps: the reference condition and the current condition. In the example, results from the 125 Hz decidecade band are used. The spatial resolution is 3 arc-seconds longitude by 1.5 arc-seconds latitude (approx. 50 m x 50 m) and the spatial observation window, SOW is a vertical line (from surface to seabed).

Step 5. Establish the Reference Condition

Figure A.1.3.2

Monthly median of the reference condition (ambient sound without anthropogenic input) calculated from TOW, time observation windows (see table 1).

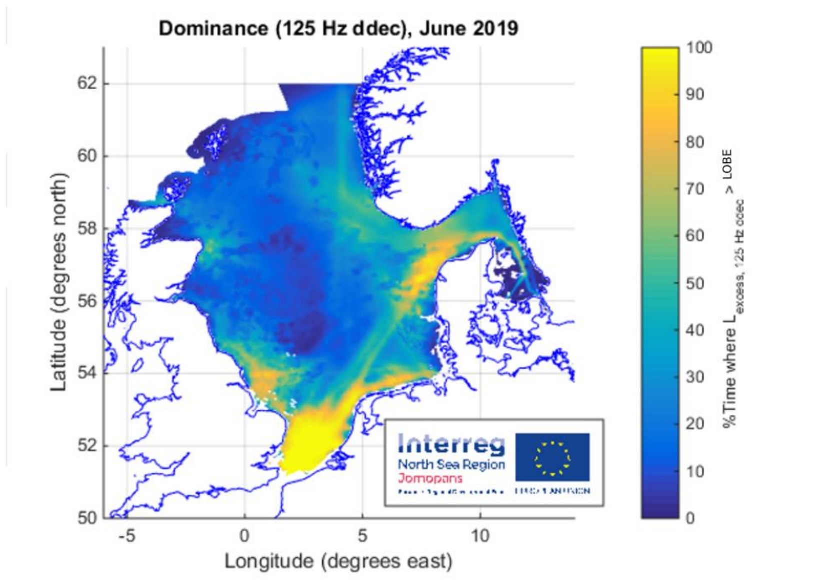


Step 6. Establish the Current Condition

The current condition is modelled by adding noise from all ships in the North Sea (obtained from AIS) to the reference condition. Source characteristics for each ship was modelled from size, speed and ship class (MacGillivray & de Jong, 2021). Deviation of current condition from reference condition was quantified for each temporal observation window by the **excess level**, defined as current condition reference condition.

Figure A.1.3.3

Current condition for June 2019 in the 125 Hz decidecade band. Colour scale represents grid cell by grid cell the fraction of the temporal assessment window (TAW = 1 month) L_{excess} is above LOBE. The spatial resolution is 50m x 50m. And the spatial observation window (SOW) represented a vertical line (from surface to seabed).



Step 7. Evaluate grid cells

The condition in each grid cell is evaluated against the **tolerable duration**, in this example set to 50%. If the dominance of the grid cell is above the tolerable duration, the cell is said to be **significantly affected**.

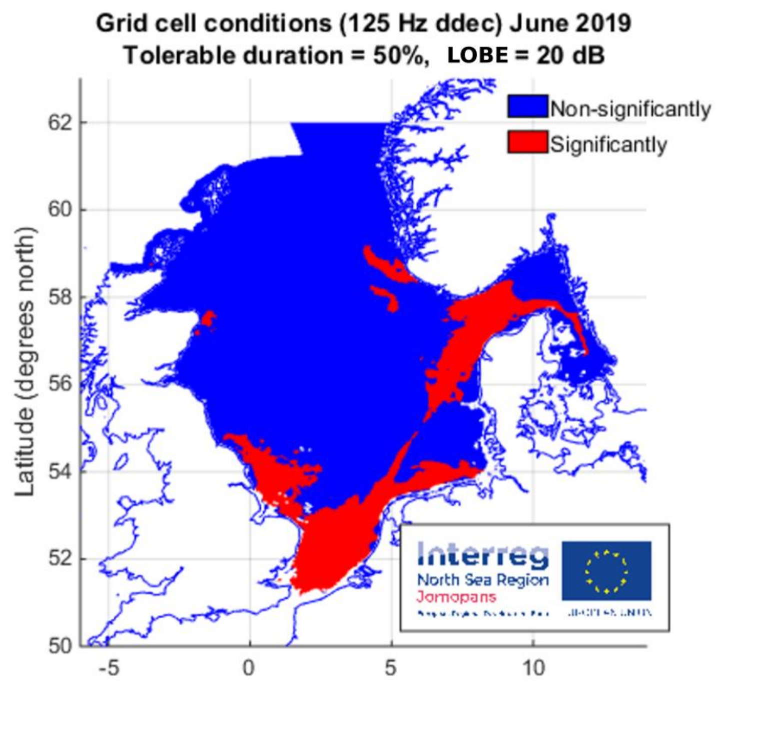
Figure A.1.3.4

Assessment of conditions of individual grid cells.

Blue cells represent grid cells which are not significantly affected by noise for the set LOBE.

Red cells represent grid cells which are significantly affected by noise for the set LOBE.

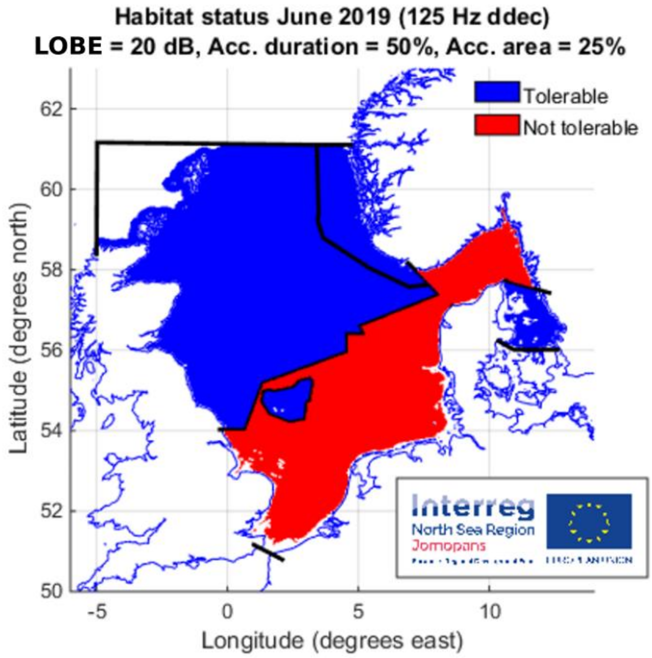
The Temporal Observation Window (TOW) is set for 30s. The Spatial Observation Window (SOW) is represented by a vertical line (surface to seabed). The Temporal Assessment Window (TAW) is set over **a** month.



Step 8. Determine the status of the habitat

Figure A.1.3.5

The status of habitats is assessed by comparing the fraction of grid cells in a habitat that are significantly affected against the **tolerable impacted area.** The tolerable impacted area in this example is set to 25%. Two are not in tolerable status: Southern North Sea and Skagerrak, whereas the remaining areas are in tolerable status.



Example A -> Changing the values of LOBE and tolerable duration

The outcome of the assessment is very sensitive to the choice of LOBE, tolerable duration, and tolerable impacted area. This is illustrated in Figure A.1.3.6 where the condition of grid cells is evaluated with different combinations of LOBE and tolerable duration.

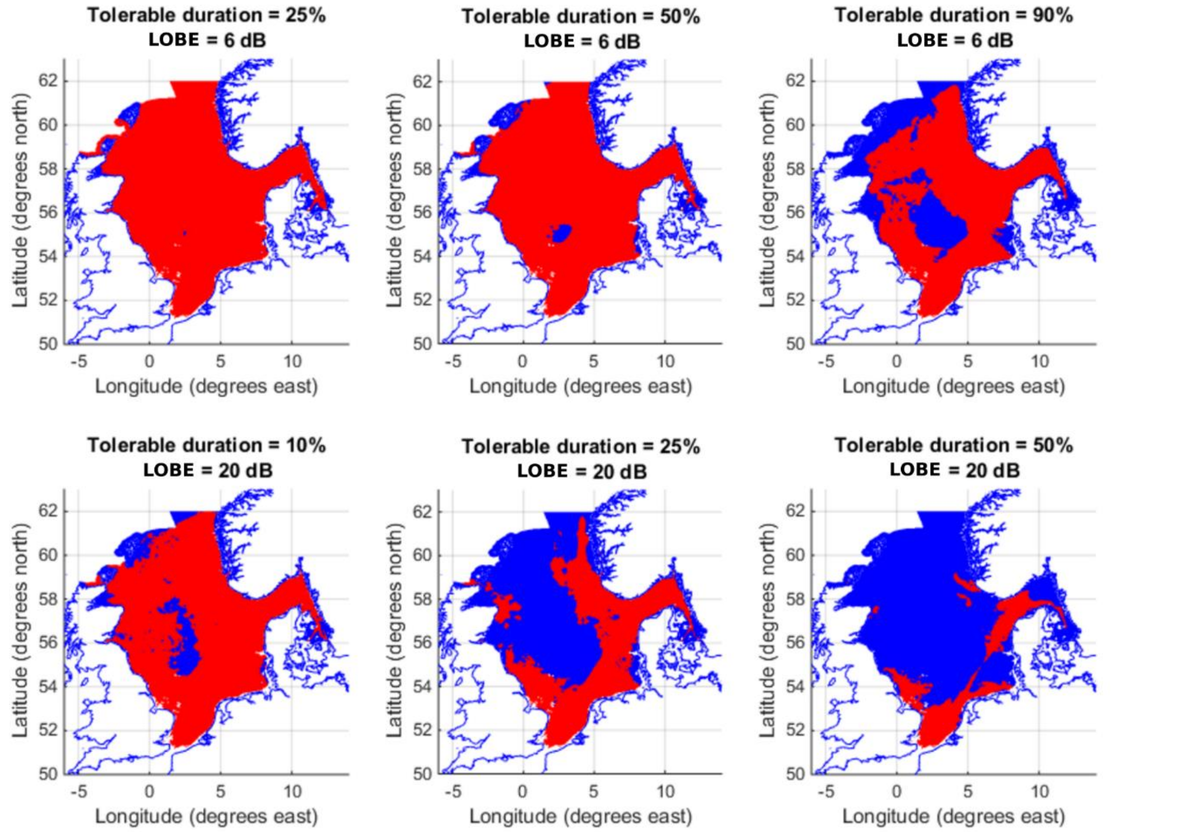


Figure A.1.3.6 Influence of choice of parameters LOBE and tolerable duration on the evaluated condition of grid cells. Three different tolerable durations (25%, 50% and 90%) and two values of LOBE (6 dB and 20 dB) were used. The maps are very different, but persistent features such as the consistently high impact in the English Channel and along the English, Dutch, German and Danish coasts, are retained across maps.

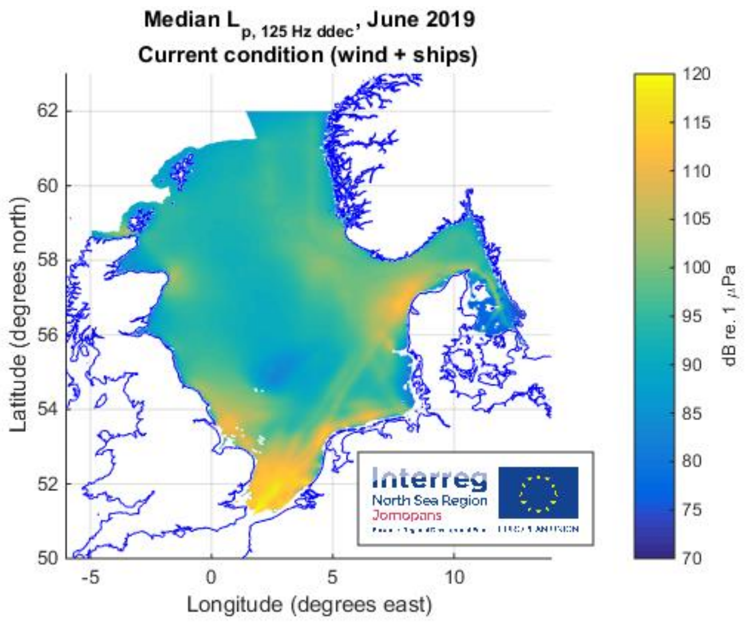
Example B: LOBE as a fixed sound pressure level

In this example, LOBE is interpreted from the DL3 definitions as a fixed sound pressure level of the current condition. Otherwise, procedures are identical to example A.

Step 2. Define the Level for Onset of Biologically Adverse Effects (LOBE)

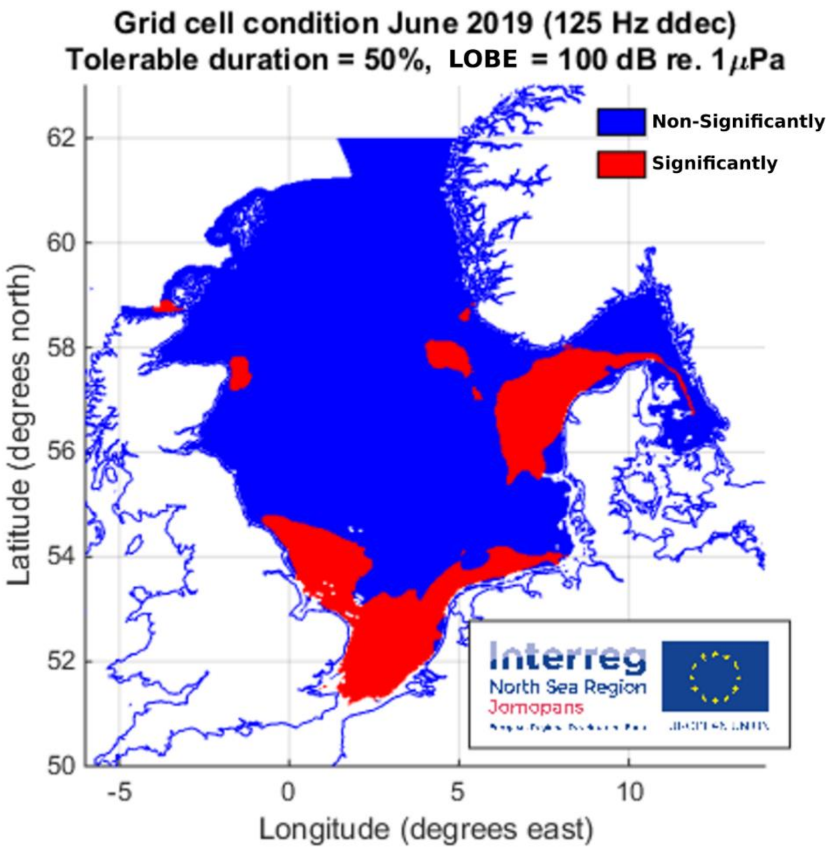
LOBE in this example is set at 100 dB re 1 μPa in the 125 Hz decidecade band. LOBE in this case is interpreted as a level, above which there is an increased likelihood of behavioural reactions to the noise.

Step 6. Establish current condition

Figure A.1.3.7 Current condition for the month of June 2019, expressed at the median sound pressure level (L_{50}) in the 125 Hz decidecade band. The spatial resolution is 50m x 50m. And the spatial observation window (SOW) represented by a vertical line (from surface to seabed).	

Step 7. Evaluate the condition of the grid cells

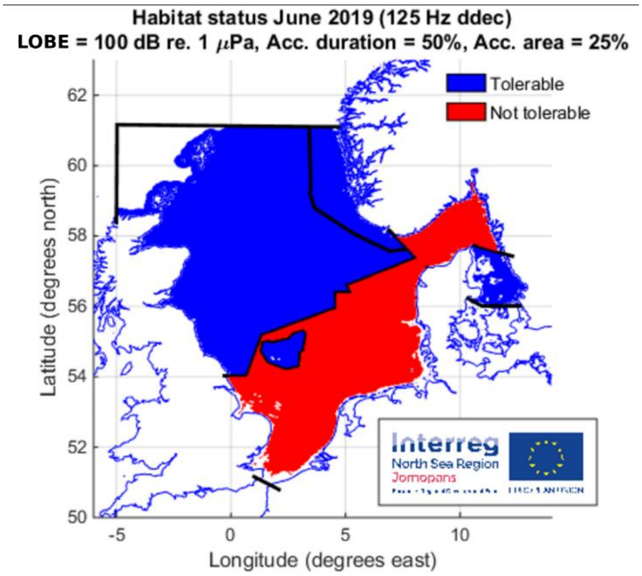
As in the first example, the fraction of the temporal assessment window (TAW) where LOBE is exceeded is calculated for each grid cell and compared to the tolerable duration.

Figure A.1.3.8 Conditions of individual grid cells indicated by colours. **Blue** cells represent grid cells which are not significantly affected by noise for the set LOBE. **Red** cells represent grid cells which are significantly affected by noise for the set LOBE. The Temporal Observation Window (TOW) is set for 30s. The Spatial Observation Window (SOW) is represented by a vertical line (surface to seabed). The Temporal Assessment Window (TAW) is set over **a month**.	

Step 8. Determine the status of the habitats

Figure A.1.3.9

The status of habitats is assessed by comparing the fraction of grid cells in a habitat that are significantly affected against the **tolerable impacted area.** The tolerable impacted area in this example is set to 25%. Two are not in tolerable status: Southern North Sea and Skagerrak, whereas the remaining areas are in tolerable status.



Example B-> Changing values of LOBE and tolerable duration

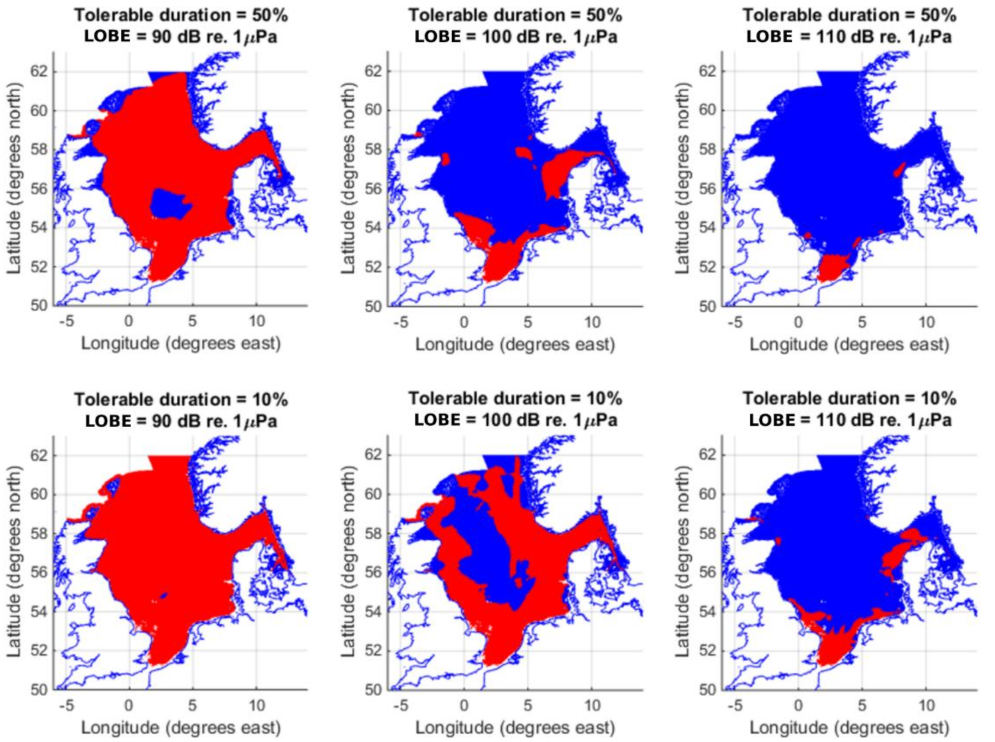


Figure A.1.3.10

As in example A, the choice of parameters LOBE and tolerable duration has a large impact on the evaluated condition of grid cells. Two different tolerable durations (10% and 50%) and three values of LOBE (90, 100 and 110 dB re. 1μPa) were used in the examples.

Annex 2. The choice of Grid cell

The Grid Cell as elementary unit assessment

The Grid cell is the **elementary unit for the assessment** of the habitat. The **Computation cell** is the **data unit of noise maps** obtained from modelling or measurements.

To ensure adaptability of the presented framework to future methodological improvements, computation power and efficiency as well as comparison between assessments, some recommendations may be followed:

- The size of the Computation cell should have the finest possible spatial resolution in accordance with the modelling methodologies, computation capacities and should be adapted to the size of the modelled area.
- The Grid cell should have the same size or bigger than Computation cell.
- Grid cell should be chosen among existing grid cell (cf. DL3): ICES statistical grid for the Atlantic region and Baltic Sea; General Fisheries Commission for the Mediterranean (GFCM) grid for Mediterranean and Black Sea; EEA marine assessment grid for all European marine areas; C-squares - Concise spatial query and representation system.
- The size of the Grid cell may be a proportion of the habitat of interest, and common to all habitats in order to facilitate the comparison between large and small habitats:

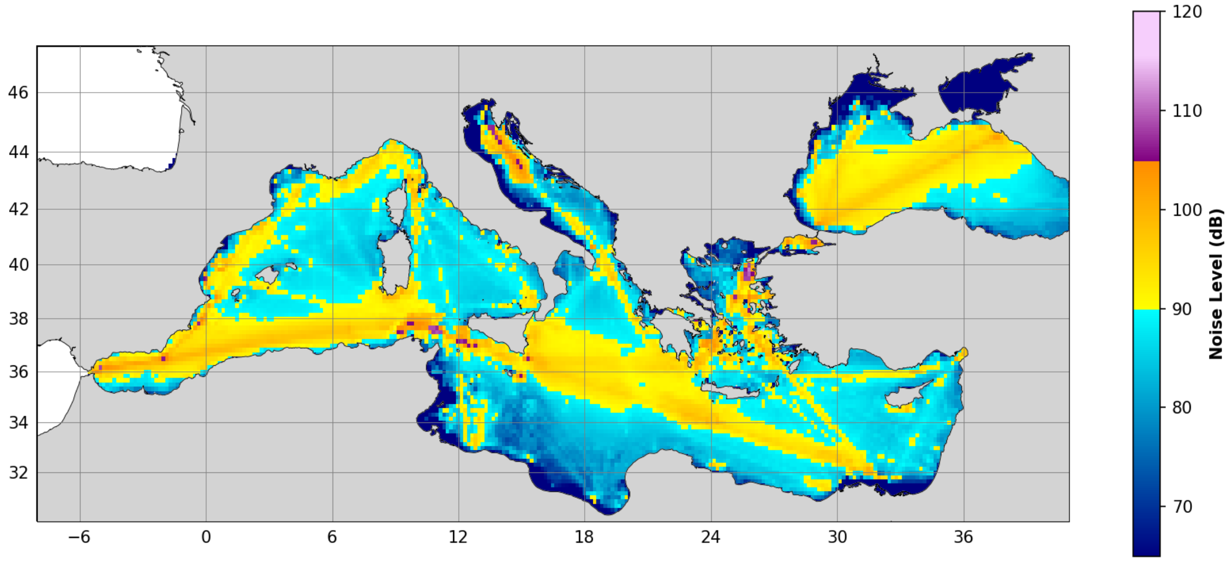
Example: The size of the grid cell represents X % (have to be determined) of the habitat. Habitat *1 is 1000 km², habitat 2 is 500 km²; If the grid cell is 5% of habitats: 5% of habitat 1 is 50km² so each grid cell is 7 km x 7km. 5% of habitat is 25km² so each grid cell is 5km x 5km.*

The Grid cell is considered as an assessment unit, it simplified the information contained in one or multiple computation cells. The grid cell contains the information related to:

- **Noise level**: which is expressed as a Sound Pressure Level in dB re 1 µPa or as an Excess Level in dB.
- **Time:** following the modelling or measurement methods, aggregating the noise level temporal variations of the computation cells into a grid cell needs to be performed at this step (averaging or percentiles over assessment period).
- **Space:** similarly, spatial aggregation needs to be performed at this step. The grid cell then represents a **unit of volume** of the habitat. Depending on the chosen depth, an averaging method can be selected to account for depth variations (average, maximum…). Changes in resolution between computation and grid cells might be complex to undertake.

Example of noise map following grid cell recommendation

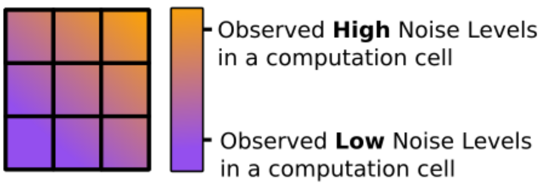
Figure A2.1 Example of a computed shipping noise map in the Mediterranean and Black Seas. From QuietSeas project. The map is Arithmetic Mean of noise level over the month of May 2019, for One Third Octave band centered on 63 Hz (dB re. 1µPa) at 5 meters depth. The Computation cell resolution is 10 arc minutes x 10 arc-minutes.



Assessment steps from computation grid cell to habitat

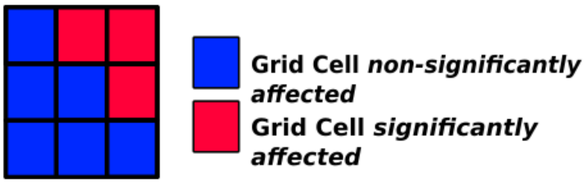
Steps 1 to 6:

- Define LOBE based on biological knowledge on key species.
- Model or measurements used to map with Temporal Observation Window (TOW) and Spatial Observation Window (SOW). The reference and current condition correspond the Arithmetic Mean over time (TOW) and space (SOW).
- Results are a collection of maps or measurements for each SOW and TOW establishing the reference and current conditions.



Step 7: Evaluate the condition of the grid cells

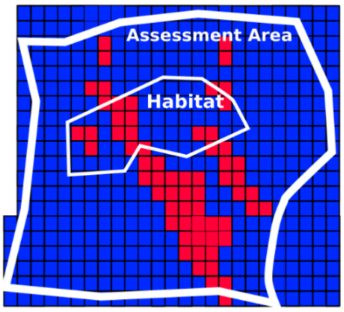
- Condition of the grid cell aim to find where and when this collection of maps or measurements are above the LOBE threshold value or not.
- Condition of the grid cell is defined in aggregated TOW-data over the TAW (1 month), and compare the Arithmetic Mean or median above LOBE. Then, the Grid cell is significantly affected or not.



- Results from this step are expressed in proportion of to the TAW (e.g. % of the Time and % of the Area above LOBE or not).

Step 8: Determined the status of the habitats

- Determined the grid cells significantly affected in the habitats of the key species.
- The goal is to determine if the significantly affected grid cells in the habitats of the key species exceeds the thresholds Tolerable Duration and Tolerable Impacted Area. Status of habitat is defined as tolerable or not.



Annex 3.

Examples of evidence-based studies

There are several studies on mammals that present SPL in dB re 1Pa where it has been observed that the animal has been affected. Notable is that these levels are determined on single animals or smaller groups. While the SPLs that show a detectable response may be highly variable and dependent on many other factors such as context, the SPL at which any serious response *may begin to occur* may provide some guidance. It should be noted that the LOBE has to be larger than the Reference Condition (RC), i.e., allow for an acceptable deviation from the RC. If this is not the case, then the LOBE cannot be used, since it will overestimate the affected area of the habitat. Stocktaking on LOBE shows the following results, irrespectively of temporal or spatial observation window, metric, frequency weighting, hearing range, species, severity or even the quality of the study.

Di Franco, E., Pierson, P., Di Iorio, L., Calò, A., Cottalorda, J.M., Derijard, B., Di Franco, A., Galvé, A., Guibbolini, M., Lebrun, J. and Micheli, F., 2020. Effects of marine noise pollution on Mediterranean fishes and invertebrates: A review. Marine Pollution Bulletin, 159, p.111450.

Gomez, C., Lawson, J. W., Wright, A. J., Buren, A. D., Tollit, D., & Lesage, V. (2016). A systematic review on the behavioural responses of wild marine mammals to noise: the disparity between science and policy. Canadian Journal of Zoology, 94(12), 801-819.

Southall, B.L., Nowacek, D.P., Bowles, A.E., Senigaglia, V., Bejder, L. and Tyack, P.L., 2021. Marine Mammal Noise Exposure Criteria: Assessing the Severity of Marine Mammal Behavioral Responses to Human Noise. Aquatic Mammals, 47(5), pp.421-464.

Southall, B. L., Finneran, J. J., Reichmuth, C., Nachtigall, P. E., Ketten, D. R., Bowles, A. E., ... & Tyack, P. L. (2019). Marine mammal noise exposure criteria: Updated scientific recommendations for residual hearing effects. Aquatic Mammals, 45(2), 125-232.

Southall, B.L., Bowles, A.E, Ellison, W.T., Finneran, J.J. Gentry, R.L., Greene, C.R. Jr., Kastak, D., Ketten, D.R., Miller, J.H., Nachtigall, P.E., Richardson, W.J., Thomas, J.A., and Tyack, P.L., 2007. Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations. Aquatic Mammals, 33(4), pp. 411-522.

Weilgart, L. 2018. The impact of ocean noise pollution on fish and invertebrates. Report for OceanCare, Switzerland. 34 pp. Available at: https://www.oceancare.org/wp-content/uploads/2017/10/OceanNoise_FishInvertebrates_May2018.pdf

National or regional regulations

National Oceanic and Atmospheric Administration (NOAA) criteria for auditory injury (NMFS, 2018) and its earlier versions (NOAA 2013 and 2015, NMFS 2016) were extensively reviewed by the public, industry, NGOs, and academic scientists. NMFS (National Marine Fisheries Service) currently uses all-or-none SPL thresholds of 120 dB re 1 µPa for non-impulsive sounds for noise-induced behavioral impacts for marine mammals (NOAA 2019). This threshold has also been used in the ACCOBAMS guidelines (ACCOBAMS, 2013). The 120 dB re 1 µPa threshold is associated with continuous sources and was based on studies of behavioural responses of gray whales (*Eschrichtius robustus*) to oil drilling (NOAA, 2019), referring to Malme *et al.* (1983, 1984, 1986). Malme *et al.* (1986) found that drillship noise did not produce clear evidence of disturbance or avoidance for SPLs below 110 dB re 1 µPa, but possible avoidance occurred for SPLs approaching 119 dB re 1 µPa. The 120 dB threshold is also suggested in the Biological Assessment Preparation Manual for Construction Underwater Noise Impact Assessment of the Washington State Department of Transport (WSDOT, 2020) regarding vibratory pile driving disturbance for Cetaceans and Pinnipeds.

For fish (salmon and bull trout), an alternative criterion is presented in the WSDOT (2020). The manual suggests an unweighted sound pressure level of 150 dB re 1 µPa as the threshold for onset of behavioural effects for fish, based on work by Hastings (2008).

ACCOBAMS. 2013. Anthropogenic Noise and Marine Mammals: Review of the Effort in Addressing the Impact of Anthropogenic Underwater Noise in the ACCOBAMS and ASCOBANS Areas.

Malme, C.I., Miles, P.R., Clark, C.W., Tyack, P. and Bird, J.E., 1984. *Investigations of the potential effects of underwater noise from petroleum-industry activities on migrating gray-whale behavior. Phase 2: January 1984 migration* (No. PB-86-218377/XAB; BBN-5586). Bolt, Beranek and Newman, Inc., Cambridge, MA (USA).

Malme, C.I. and Miles, P.R., 1983. Acoustic testing procedures for determining the potential impact of underwater industrial noise on migrating gray whales. *The Journal of the Acoustical Society of America*, *74*(S1), pp.S54-S54.

Malme, C.I., Würsig, B., Bird, J.E. and Tyack, P., 1986. Behavioral responses of gray whales to industrial noise: Feeding observations and predictive modelling.

NMFS. 2016. Technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing: underwater acoustic thresholds for onset of permanent and temporary threshold shifts. Silver Spring, US Department of Commerce, NOAA.

NMFS. 2018. Revision to technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (version 2.0): underwater thresholds for onset of permanent and temporary threshold shifts. Silver Spring,US Department of Commerce, NOAA.

NOAA. 2013. Draft guidance for assessing the effects of anthropogenic sound on marine mammals: acoustic threshold levels for onset of permanent and temporary threshold shifts. Document prepared by the National Marine Fisheries Service and the National Oceanic and Atmospheric Administration, 23 December 2013, Silver Spring, NOAA.

NOAA. 2015. Draft guidance for assessing the effects of anthropogenic sound on marine mammal hearing: acoustic threshold levels for onset of permanent and temporary threshold shifts. Document prepared by the National Marine Fisheries Service and the National Oceanic and Atmospheric Administration, 31 July 2015, Silver Spring, NOAA.

NOAA. 2019. ESA section 7 consultation tools for marine mammals on the West coast. In: NOAA [online]. Silver Springs. [Cited 10 March 2020]. https://www.fisheries.noaa.gov/west-coast/endangered-species-conservation/esa-section-7-consultation-tools-marine-mammals-west

WSDOT, 2020. Biological Assessment Preparation Manual, 7.0 Construction Noise Impact Assessment, 7.2 Underwater noise, Washington State Department of Transport, 95 p.

Species-specific studies

Aguilar Soto N., Johnson M., Madsen P.T., Tyack P.L., Bocconcelli A., Borsani J.F., 2006. Does intense ship noise disrupt foraging in deep-diving Cuvier's beaked whales (Ziphius Cavirostris)? Marine Mammals Science, 22(3): 690–699. https://doi.org/10.1111/j.1748-7692.2006.00044.x

Amorim, M.C.P., Vieira, M. Meireles, G. et al., 2022. Boat noise impacts Lusitanian toadfish breeding males and reproductive outcome, Science of the Total Environment. https://doi.org/10.1016/j.scitotenv.2022.154735

Blom, E.L., Kvarnemo, C., Dekhla, I., Schöld, S., Andersson, M.H., Svensson, O. and Amorim, M., 2019. Continuous but not intermittent noise has a negative impact on mating success in a marine fish with paternal care. Scientific reports, 9(1), pp.1-9.

Buscaino, G., Filiciotto, F., Buffa, G., Bellante, A., Di Stefano, V., Assenza, A., Fazio, F., Caola, G. and Mazzola, S., 2010. Impact of an acoustic stimulus on the motility and blood parameters of European sea bass (Dicentrarchus labrax L.) and gilthead sea bream (Sparus aurata L.). Marine environmental research, 69(3), pp.136-142.

Celi, M., Filiciotto, F., Maricchiolo, G., Genovese, L., Quinci, E.M., Maccarrone, V., Mazzola, S., Vazzana, M. and Buscaino, G., 2016. Vessel noise pollution as a human threat to fish: assessment of the stress response in gilthead sea bream (Sparus aurata, Linnaeus 1758). Fish Physiology and biochemistry, 42(2), pp.631-641.

de Jong, K., Amorim, M.C.P., Fonseca, P.J., Fox, C.J., and Heubel, K.U. 2018. Noise can affect acoustic communication and subsequent spawning success in fish. Environ. Poll. 237: 814-823.**de Jong, K., Forland, T.N., Amorim, M.C.P., Rieucau, G., Slabbekoorn, H. and Sivle, L.D**., 2020. Predicting the effects of anthropogenic noise on fish reproduction. Reviews in Fish Biology and Fisheries, 30(2), pp.245-268.

Gendron G., Tremblay R., Jolivet A., Olivier F., Chauvaud L., Winkler G., and Audet C., 2020. Anthropogenic boat noise reduces feeding success in winter flounder larvae (Pseudopleuronectes americanus). Environ Biol Fish (2020) 103:1079–1090. https://doi.org/10.1007/s10641-020-01005-3

Jolivet, A., Tremblay, R., Olivier, F., Gervaise, C., Sonier, R., Genard, B. and Chauvaud, L., 2016. Validation of trophic and anthropic underwater noise as settlement trigger in blue mussels. Scientific reports, 6(1), pp.1-8.

Kastelein, R. A., Jennings, N., Verboom, W. C., De Haan, D., & Schooneman, N. M. (2006). Differences in the response of a striped dolphin (Stenella coeruleoalba) and a harbour porpoise (Phocoena phocoena) to an acoustic alarm. Marine Environmental Research, 61(3), 363-378.

Purser, J., Bruintjes, R., Simpson, S.D. and Radford, A.N., 2016. Condition-dependent physiological and behavioural responses to anthropogenic noise. Physiology & behavior, 155, pp.157-161

Sierra-Flores, R., Atack, T., Migaud, H., and Davie, A. 2015. Stress response to anthropogenic noise in Atlantic cod *Gadus morhua* L. Aquacultural Eng. 67: 67-76.

Simpson, S.D., Purser, J. and Radford, A.N., 2015. Anthropogenic noise compromises antipredator behaviour in European eels. Global change biology, 21(2), pp.586-593.

Solan, M., Hauton, C., Godbold, J.A., Wood, C.L., Leighton, T.G. & White, P. 2016. Anthropogenic sources of underwater sound can modify how sediment-dwelling invertebrates mediate ecosystem properties. *Scientific reports*, 6(1): 1–9.

Southall, B. L., Finneran, J. J., Reichmuth, C., Nachtigall, P. E., Ketten, D. R., Bowles, A. E., ... & Tyack, P. L. (2019). Marine mammal noise exposure criteria: Updated scientific recommendations for residual hearing effects. Aquatic Mammals, 45(2), 125-232.

Vasconcelos, R.O., Amorim, M.C.P. and Ladich, F., 2007. Effects of ship noise on the detectability of communication signals in the Lusitanian toadfish. Journal of Experimental Biology, 210(12), pp.2104-2112.

Wale, M.A., Simpson, S.D. and Radford, A.N., 2013. Noise negatively affects foraging and antipredator behaviour in shore crabs. Animal Behaviour, 86(1), pp.111-118.

Wysocki, L.E., Dittami, J.P. and Ladich, F., 2006. Ship noise and cortisol secretion in European freshwater fishes. Biological conservation, 128(4), pp.501-508.

Annex 4. Terms and definitions

A common understanding of terms and their definitions is a pre-requisite for effective communication. TG Noise follows ISO 18405 for basic acoustical terminology. More advanced terminology needed for monitoring is under development by SATURN. TG Noise has decided to follow the SATURN terminology standard, which is based on and fully compatible with ISO 18405.

DL3 requires a choice to be made between the arithmetic mean (AM) and the median (Annex 3). TG Noise 2012 pointed out that the median is sensitive to the choice of averaging time, whereas AM is robust to this choice. TG Noise 2014 recommended use of AM for this reason. The TG Noise 2014 (Part 2) advice was

"The advantages and disadvantages of different averaging methods (arithmetic mean, geometric mean, median and mode) are reviewed, and TSG Noise recommends that Member States adopt the arithmetic mean.

In order to establish the statistical significance of the trend, additional statistical information about the distribution is necessary. TSG Noise recommends that complete distribution be retained in the form of sound pressure levels as a function of time, along with a specified averaging time. TSG Noise advises the retention of the amplitude distribution for this purpose in bins of 1 dB, and the associated snapshot duration. TSG Noise advises MS that the snapshot duration should not exceed one minute."

The caveat about additional statistical information is important if one wishes to avoid the simplification of characterising the environmental status of a complete habitat in terms of a single number. We further note that the AM (and not the median) is used for airborne noise (ISO 1996-2) – see Annex 3 for details – thus providing further motivation to justify TG Noise's previous advice to adopt the arithmetic mean.

Metrics and their implications for LOBE

This annex addresses terminology, choice of metric, and implications of that choice on LOBE.

Terminology for D11C2

Introduction

A common understanding of terms and their definitions is a pre-requisite for effective communication. TG Noise follows ISO 18405 for basic acoustical terminology. More advanced terminology needed for monitoring is under development by SATURN. TG Noise has decided to follow the SATURN terminology standard, which is based on and fully compatible with ISO 18405.

An ambient sound measurement standard[7] is under development by ISO, using terminology from ADEON (Ainslie et al., 2020) and JOMOPANS (Robinson & Wang 2021). The ISO standard is scheduled for publication in 2024. TG Noise recommends use of the terminology of ISO 7605 for future ambient sound measurement projects.

[7] ISO 7605 'Measurement of ambient ocean sound'

Mean-square sound pressure and sound pressure level

Sound pressure level (SPL), denoted L_p, is the level of the mean-square sound pressure, denoted $\overline{p^2}$. In other words

$$L_{p,i} = 10 \log_{10} \frac{\left(\overline{p^2}\right)_i}{p_0^2} \text{ dB},$$

where i indicates the sample number, and p_0 is the reference sound pressure, equal to 1 μPa.

Arithmetic mean of the squared sound pressure

The arithmetic mean, denoted $L_{p,\mathrm{AM}}$, is

$$L_{p,\mathrm{AM}} = 10 \log_{10} \frac{\overline{p^2}}{p_0^2} \text{ dB},$$

where $\overline{p^2}$ is the arithmetic mean of the squared sound pressure samples. If samples are equally spaced:

$$\left(\overline{p^2}\right)_{\mathrm{AM}} = \frac{1}{N}\sum_{i=1}^{N}\left(\overline{p^2}\right)_i,$$

where i indicates the ith sample out of N,

$$\overline{p^2} \equiv \frac{1}{T}\int_0^T p^2 \, \mathrm{d}t.$$

and T is the duration of the temporal analysis window (TAW[8]).

The term "AM" is used here and throughout to indicate an average over squared sound pressure.

The corresponding spatial AM is:

$$\langle p^2 \rangle \equiv \frac{1}{V}\oint_V \overline{p^2} \, \mathrm{d}V.$$

where the integral is over the volume V of the spatial analysis window (SAW[9]).

Median level

The median, denoted $L_{p,\mathrm{median}}$, is the value of L_p that is exceeded by half the N samples and not by the other half. The median can be calculated in time, in space, or in time and space combined.

Dose-response curves

The concept of a dose-response curve for a population is introduced here. The concept is needed for correct interpretation of LOBE.

Traditional dose-response curve (Figure A4.1, left graph) shows the probability of a specified effect on an individual animal (the response) as a function of the value of a specified stimulus (the dose). The graph shows curves for a hypothetical sensitive individual (green), a robust individual (red) and an individual of intermediate sensitivity (blue). The three vertical lines show thresholds of the dose above which the probability of the specified effect on an individual exceeds 50 %.

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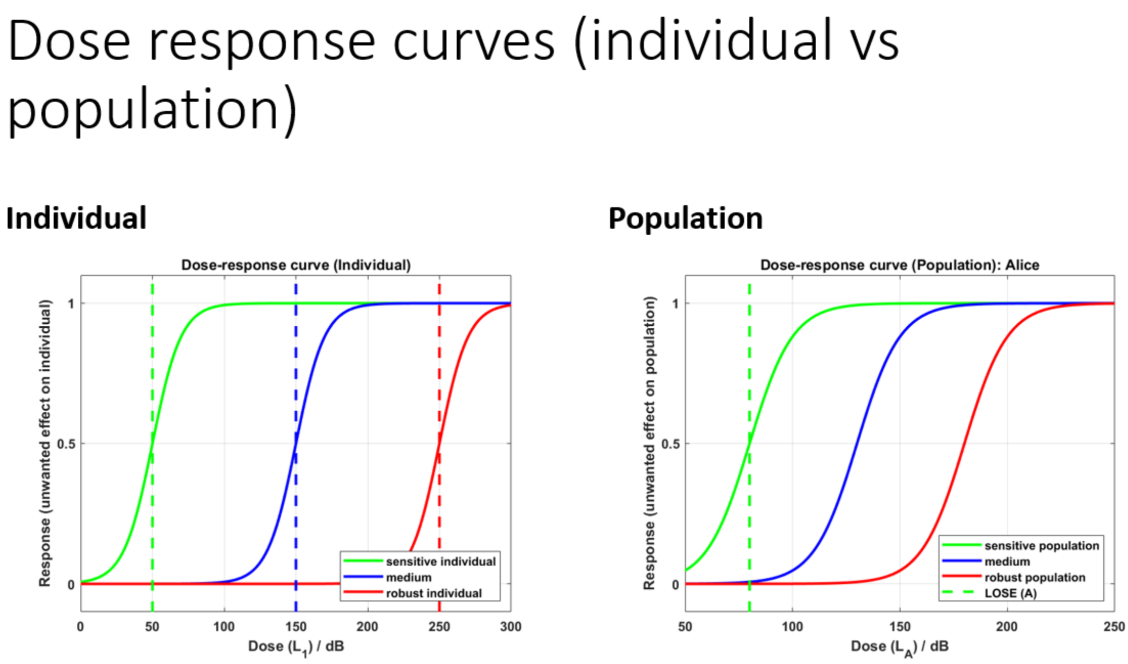
[8] TAW is the assessment period (typically one month)

[9] SAW is the region of space (volume, including the depth dimension) encompassed by the assessment area

GES is about populations rather than individuals. To establish a dose threshold relevant to GES one needs a dose-response curve for a population (Figure A4.1, right graph), showing the probability of a specified effect on a population as a function of the value of a specified dose. The graph shows curves for a hypothetical sensitive population (green), a robust population (red) and a population of intermediate sensitivity (blue). The vertical green line shows the threshold of the dose above which the probability of the specified effect on the sensitive population exceeds 50 %. This is LOBE.

Figure A4.1. Hypothetical dose-response curves (probability of effect vs dose) for an individual (left) and population (right). The dose for an individual could be SPL. The dose for a population would be a statistic of SPL to be determined.



Metrics (mean and median)

DL3 requires a choice to be made between the mean (AM) and the median.

TG Noise 2012 pointed out that the median is sensitive to the choice of temporal observation window (TOW), whereas AM is robust to this choice. TG Noise 2014 recommended use of AM for this reason.

The projects BIAS, JOMOPANS and JONAS made the choice for median and other percentiles of the distribution of sound pressure levels. In adopting the median, JOMOPANS (Merchant et al, 2018) refers on page 17 to Hatch et al, 2012 and Putland et al, 2018 to justify the ecological relevance as the basis of this choice.

Hatch 2012 makes a compelling case for using the median with the sonar equation but does not motivate the choice of TOW (1 s). For this approach to work one would need to match the TOW value to the integration time used by the sonar.

Putland 2018 applies a simplified sonar equation (neglecting processing gain as well as important departures of propagation loss from spherical spreading) and does not state the value of TOW explicitly.

TG Noise is not in a position to provide firm advice on the choice of TOW and SOW, but points out the need to select and motivate appropriate values of TOW and SOW before any choice of LOBE is made for a median quantity. For example, a door slamming once every ten seconds would disrupt a conversation between two human beings, who would either seek a quieter location or abandon their attempts at communication. But the slamming door has no effect on a median with TOW= 1 s (which is perhaps why the AM is preferred in air), suggesting that a larger value of TOW should be considered when assessing environmental status.

Arithmetic mean

The AM is independent of the spatial observation window (SOW) and of the order in which the averaging is done.

The metrics used in airborne acoustics for assessing environmental noise, such as road and rail traffic noise, aircraft noise and industrial noise are Leq and Lmax (ISO 1996-2):

- Leq is the level of the mean-square weighted sound pressure (arithmetic mean of the squared frequency-weighted sound pressure), thus setting a terrestrial precedent for AM. The frequency weighting means that it is adjusted according to the sensitivity of human hearing in air by emphasising those frequencies to which the human ear is most sensitive, and de-emphasising other frequencies.
- Lmax is the maximum sound level during a 24 hour period.

Median level

The median is sensitive to the choice of TOW and SOW, and to the order in which the averaging is done.

Temporal and spatial averaging

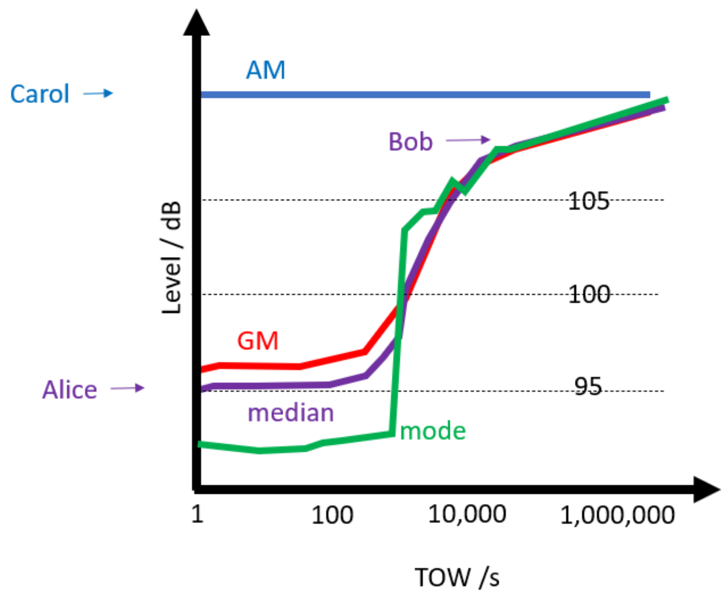
To quantify LOBE, it is first necessary to clarify the meaning of the quantity “Dose (L_A)” (see right-hand graph of Figure A4.1). A choice is necessary between multiple options and the value of LOBE depends on this choice. Two important aspects to consider before making the choice are the amount of temporal and spatial averaging.

Temporal averaging

During an assessment period (say one month) the SPL at any given location (latitude, longitude, and depth) changes with time. If a single average value of SPL is used to represent the assessment period, the selected value will depend on how the individual SPL values are averaged. The median varies with TOW, while the AM is independent of TOW.

Alice, Bob and Carol are three scientists working independently on characterising the sound field at location X. They use measurements of the sound field at X at the same time and under identical conditions, and thus work with identical sequence of SPL values. Alice and Bob characterise the time series using the median (with TOW equal to 1 s and 24 h, respectively), while Carol uses the AM. For an identical reference value equal to the international standard (1 μPa), the dose they each measure (for the identical sound field at location X) is 95 dB (Alice), 108 dB (Bob), 110 dB (Carol) – see Figure A4.2.

Figure A4.2. Dependence of SPL (125 Hz decidecade band) on TOW (adapted from Merchant et al 2012).

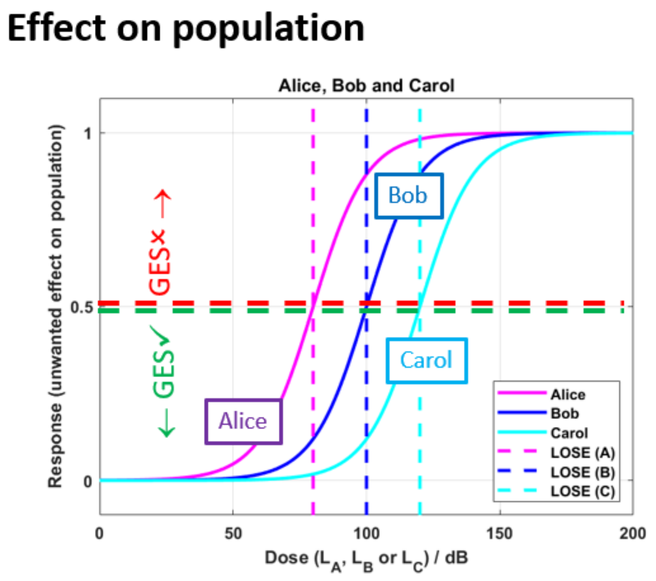


Thus, the reported SPL differs by 15 dB for identical conditions, the difference being caused by the different averaging methods *alone*. If LOBE were chosen to be (say) 100 dB, Alice reports a value 5 dB below this (achieving the criterion for GES), while Bob and Carol report values 8 and 10 dB above it, apparently failing the GES criterion, for identical conditions. To avoid a bias, it would be necessary to either prescribe a single averaging method (such that Alice, Bob and Carol obtain the same value) or to apply different LOBE values, according to the averaging method (Figure A4.3). To avoid a bias for this example, LOBE (C) would need to be 15 dB higher than LOBE (A).

Table A1. Effect of TOW on AM, GM, median and mode. The temporal analysis window (TAW) is 1 year. The arithmetic mean (AM) is calculated as the mean of the squared sound pressure samples. The sound pressure reference value is 1 μPa.

modeller	method	dose
Alice	Median (1 s)	95 dB
Bob	Median (24 h)	108 dB
Carol	Arithmetic mean	110 dB

Figure A4.3. Hypothetical dose-response curves (probability of effect vs dose) for a population calculated using three different methods for identical sound field. The calculated dose depends on the method used.



Spatial averaging

Within a grid cell (of area, say, 100 km^2) the SPL at any given time changes with position (latitude, longitude, and depth). If a single average value of SPL is used to represent the area, the selected value will depend on how the individual SPL values are averaged. Possibilities include the median and arithmetic mean. The median varies with SOW, while the AM is independent of SOW.

Sound map (SPL in 125 Hz decidecade band) dB

Figure A4.4. Map of AM. Netherlands EEZ. SOW=5x5 km^2 x water depth (Sertlek et al 2019). The sound pressure reference value is 1 μPa.

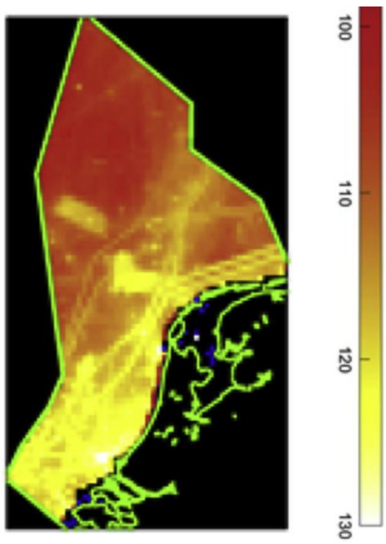
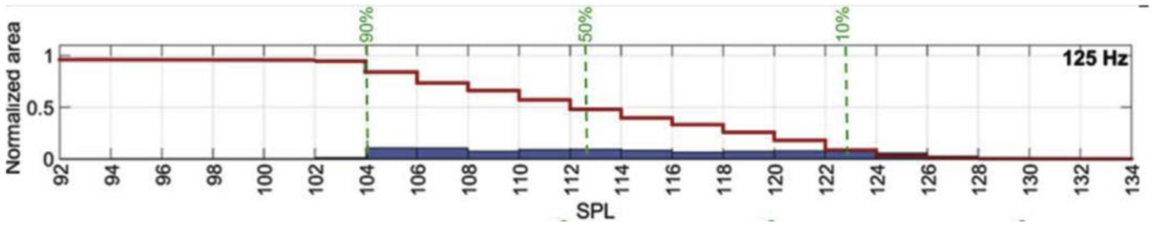


Figure A4.5. Histogram of spatial distribution. The spatial median is 113 dB. SOW=5x5 km^2 x water depth. SAW=Dutch EEZ. (Sertlek et al 2019). The sound pressure reference value is 1 μPa.



The difference between AM and median will increase with decreasing SOW, but has not been quantified for spatial averaging.

According to DL3 (Annex 4) "The Grid Cells should be the smallest unit over which it is practicable to evaluate the condition of the area covered by the Grid Cell. Within a Grid Cell the acoustical parameters are described by a single quantity, which will vary in time." In this sentence the term "Grid Cell" is used to refer to the assessment grid cell, not the computational grid cell, which would be smaller.

While in principle the single quantity representing the assessment grid cell can be a mean or a median, in practice there is too much uncertainty in the median. TG Noise therefore recommends the mean (AM) in space as well as in time.

Examples: Effect of TV on LOBE

Consider the southern North Sea and northern Adriatic Sea (Figure A4.6). With LOBE=110 dB, large parts of the sea exceed the LOBE threshold (Figure A4.7). With this choice of LOBE, a high TV is appropriate because effect severity is relatively low. With LOBE=120 dB, large parts of the sea are within the LOBE threshold (Figure A4.8). With this choice of LOBE, a low TV is appropriate because effect severity is relatively high.

Figure A4.6. Case study areas in southern North Sea (left) and northern Adriatic Sea (right) (Sertlek 2021).

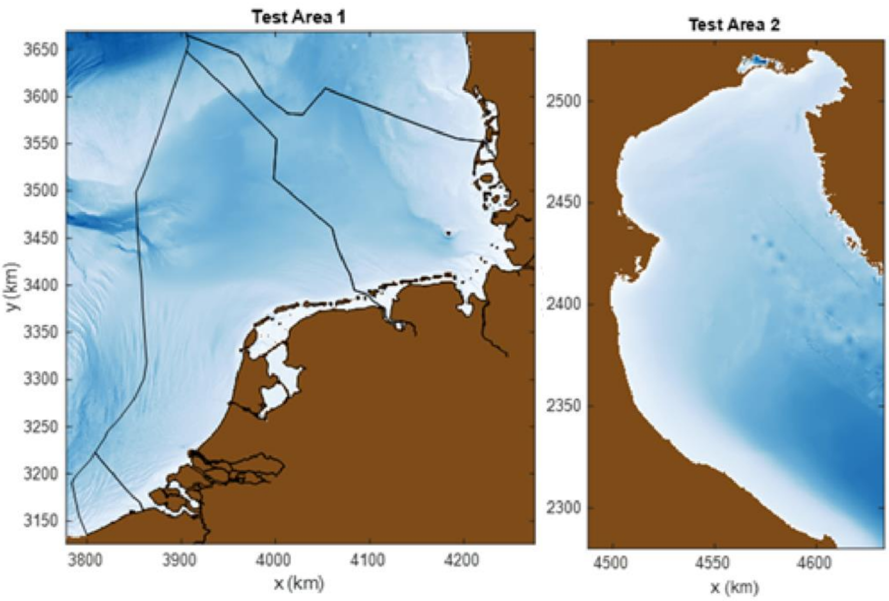


Figure A4.7. GES maps for AM with LOBE = 110 dB. Red: SPL > LOBE; blue: SPL < LOBE. (data from Sertlek 2021). The sound pressure reference value is 1 μPa.

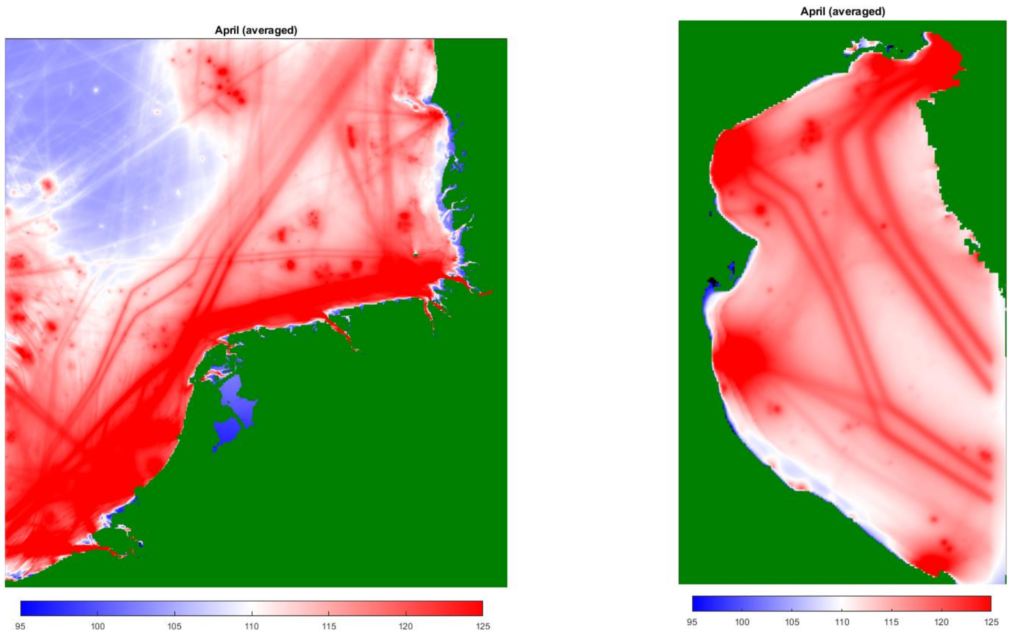
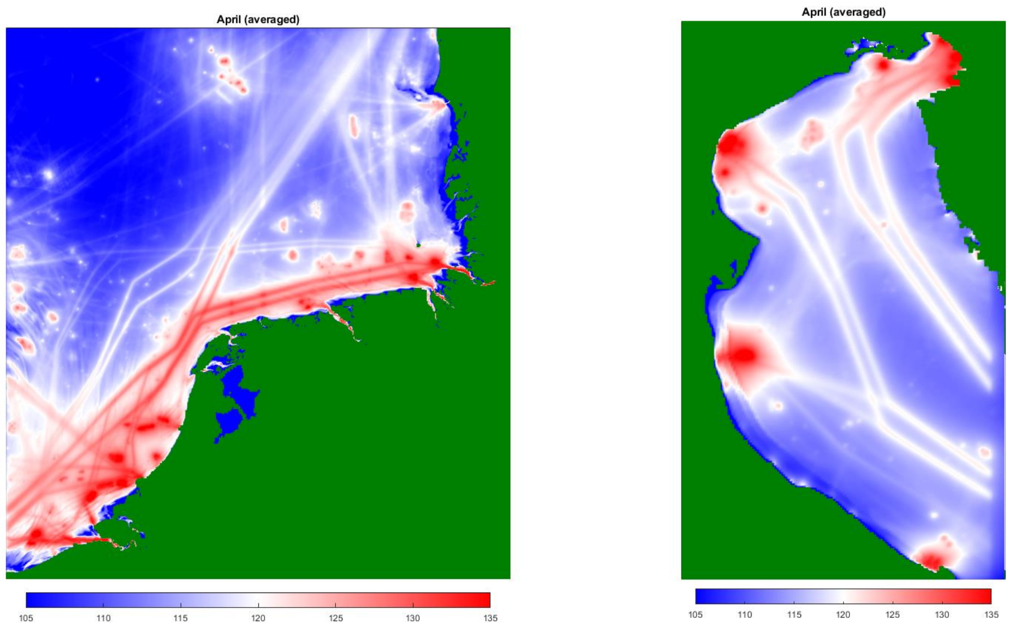


Figure A4.8. GES maps for AM with LOBE = 120 dB Red: SPL > LOBE; blue: SPL < LOBE. The sound field is identical to that from Figure A4.7. The sound pressure reference value is 1 μPa.



Acknowledgement

Dr H. Özkan Sertlek kindly provided sound maps from his 2021 publication.

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