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DELIVERABLE 4.1

Proposed methodological framework for regional and sub-regional risk-based assessment for impulsive noise in the Mediterranean region

Deliverable: D4.1. Proposed methodological framework for regional and sub-regional risk-based assessment for impulsive noise in the Mediterranean region
Document Number: QUIETMED2 – D4.1
Delivery date: 20th May 2020
Call: DG ENV/MSFD 2018
Grant Agreement: No. 110661/2018/794481/SUB/ENV.C2
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10	Specially Protected Areas Regional Activity Centre	SPA/RAC	Tunisia
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Abstract

This document is the Deliverable “D4.1.Proposed methodological framework for regional and sub-regional risk-based assessment for impulsive noise in the Mediterranean region” of the QUIETMED2 project funded by the DG Environment of the European Commission within the call “DG ENV/MSFD 2018 call”. This call funds projects to support the implementation of the second cycle of the Marine Strategy Framework Directive (2008/56/EC) (hereinafter referred to as MSFD), in particular to implement the new GES Decision (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, and repealing Decision 2010/477/EU) and Programmes of Measures according to Article 13 of the MSFD. The QUIETMED2 project aims to support Member States Competent Authorities in the Assessment of the extent to which GES on Descriptor 11-Underwater noise has been achieved in the Mediterranean Region by providing practical outcomes to implement the new GES Decision through: i) a joint proposal for an assessment framework for impulsive noise in the Mediterranean Region ii) a common methodology for Competent Authorities to establish thresholds values, together with associated lists of elements and integration rules, iii) a data and information tool to support the implementation of the monitoring programmes on impulsive noise based on the current ACCOBAMS joint register which will be demonstrated on iv) an operational pilot of the tool and v) several activities to boost current regional cooperation efforts of Barcelona Convention developing new Mediterranean Region cooperation measures. This document addresses item i) of the previous list.

Table of Contents

1. Introduction and objectives 6
2. Background 7
2.1. Background on risk assessment 7
2.2. Relevant regional processes 10
2.3. Availability of data and tools 10
2.4. Practical feasibility of monitoring 11
2.5. Readiness and feasibility of the assessment methodology 12
3. Technical specifications 13
3.1. Metrics 13
3.2. Ecological endpoint: Habitat rather than population densities 13
3.3. Applicability to sub-regions 13
3.4. Assessment scales 14
4. Links to other EU legislation or international agreements 15
5. Assessment 16
5.1. General framework 16
6. Implementation 19
6.1. Some examples from recent efforts 19
6.2. Metrics involved in the assessment methodology 20
6.3. Reference and baseline levels 21
6.4. Assessment criteria and targets 21
6.5. Spatial scope and aggregation 22
6.6. Monitoring requirements 22
6.7. Reporting 22
6.8. Visualisation 23
6.9. Further development 23
7. Convergence and divergence of North-East Atlantic and Mediterranean approaches 24
8. Conclusions and next steps 25
9. References 27

List of figures

Figure 1. Principles of an exposure assessment 9
Figure 2 Extent of exposure calculated as overlap (in %) between the Noise Event footprint and the habitat of a species (or populatin density if available) 17
Figure 3; Example workflow for mapping risk 19
Figure 4. Example of pressure map based on the use of acoustic modelling to calculate the distance of effect 20
Figure 5. Example of the implementation in the Adriatic Sea of the sound propagation modelling step on noise event data contained in the ACCOBAMS noise register 20

List of tables

Table 1. Risk-assessment framework, taken form examples in toxicology, and its possible parallels for D11C1 assessment. 9
Table 2. Fixed vs. Adjusted buffer: strenghts and weaknesses 17
Table 3. Atlantic and Mediterranean approaches on D11C1 assessment. 24

List of Abbreviations

CTN	Centro Tecnológico Naval y del Mar
ACCOBAMS	Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area
DFMR	Department of Fisheries and Marine Research
IZVRS	Inštitut za vode Republike Slovenije/Institute for water of the Republic of Slovenia
HCMR	Hellenic Centre for Marine Research
IOF	Institute of Oceanography and Fisheries
UM	University of Malta -The Conservation Biology Research Group
POLIMI-DICA	Politecnico di Milano-Department of Civil and Environmental Engineering
SSW	Special Secretariat for Water-Hellenic Ministry of Environment and Energy
SPA/RAC	Specially Protected Areas Regional Activity Centre
ICES	International Council for the Exploration of the Sea
MSFD	Marine Strategy Framework Directive
GES	Good Environmental Status
MS	Member States
INR-MED	Impulsive Noise Register for the Mediterranean Sea
GFCM	General Fishery Commission for the Mediterranean
TVs	Threshold values
RSC	Regional Sea Convention
SEL	Sound Exposure Level
BSIMAP	Black Sea Integrated Monitoring and Assessment Programme
MPA	Marine Protected Area
CCH	Cetacean Critical Habitats
IMAP	Integrated Monitoring and Assessment Programme of the Barcelona Convention

1. Introduction and objectives

The QUIETMED2 Project is funded by DG Environment of the European Commission within the call "DG ENV/MSFD Second Cycle/2018". This call funds the next phase of MSFD implementation, in particular, to implement the new GES Decision (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, and repealing Decision 2010/477/EU) and Programmes of Measures according to Article 13 of the MSFD.

This activity was designed to bring forward the process to enable the assessment of impulsive noise within the scope of Criterion 1 of Descriptor 11 (D11C1) of the MSFD, according to GES Decision 2017/848/EU.

Activity 4 of QUIETMED2 Project has one main objective:

- Developing an assessment framework for impulsive noise (D11C1).

In addition, activity 4 will establish effective links to Member States' competent authorities to ensure the outcomes are MSFD oriented and to the Barcelona Convention to ensure coordination across regions or subregions:

- Ensuring that this methodology is consistent with both TG-Noise and ACCOBAMS objectives concerning the management of threats to cetaceans and their habitats.
- Ensuring that this methodology falls within the scope of Common Indicator 26 of the Ecosystem Approach process of the UN-Environment/MAP-Barcelona Convention (EcAp).

2. Background

The assessment of the Good Environmental Status' achievement or not, regarding the anthropogenic underwater noise, is still far to be defined. Nevertheless, many successful efforts have been done to develop definitions, methodologies and tools for the monitoring of impulsive noise, including the International Noise Register for the Mediterranean Sea region (INR-MED), developed under the EU-funded project QUIETMED (QUIETMED-Deliverable 4.1). This document presents a proposal of a framework to use the INR-MED and the impulsive noise monitoring data for the different provisions of the MSFD, including the following:

- Assessing the environmental status of marine waters.
- Defining environmental targets and management measures to achieve these targets.
- Assessing whether the targets were achieved and whether the measures were appropriate.

This proposed methodological framework for the assessment of underwater impulsive noise (D11C1) is based on the use of the INR-MED and takes advantage of the work done by TG-Noise, OSPAR ICG-Noise and ACCOBAMS on the same topic. Several works which constitute the reference basis for this activity, are here reported:

- TG-Noise Monitoring Guidance issued in 2014;
- The workshops on the development of impact indicators and threshold values (TVs) held by TG-Noise in 2016 (Hamburg), 2017 (Torrelodones), 2018 (Bucharest) and during 2019 (Brussels);
- The results of QUIETMED, including the development of the INR-MED region steered by ACCOBAMS;
- The initiatives for a new impact indicator undertaken under OSPAR.

The main outcomes of Activity 4 and its related two workshops (June 2019 in Monaco and January 2020 in Cartagena, Spain), led to the conclusion that the development of this assessment framework for impulsive noise should be based on a conventional risk-based approach which can be adapted to the specific framework of the MSFD. Based on this, the impulsive noise can be considered as a hazard that may cause negative effects on populations of marine species. Therefore, it is possible to estimate the ecological risk by quantifying the extent of the exposure to impulsive noise by selected marine species.

2.1. Background on risk assessment

Risk assessment is an exercise performed to evaluate the likelihood of adverse effects occurring as a result of exposure to stressors/hazards. In ecological terms and at the ecosystem scale, this may be translated as the probability that there will be a significant impact on a particular ecosystem as a whole, for example in an assessment area that is not too large and thus manageable. To turn this definition practical, we may consider cetacean populations as the ecological endpoint indicating the status of ecosystem health. Also, the impact can be described as the displacement of cetacean populations

induced by impulsive noise, where displacement is “severe and/or sustained and/or long-term avoidance of an area” (Dekeling et al. 2014, Van der Graaf et al, 2012). In synthesis, the definition of Risk Assessment used in this document is the following:

- **Evaluating the probability that there will be a displacement of cetacean populations as a result of exposure to impulsive noise events during the assessment period**.

The INR-MED is designed to address only noise events which are known to exceed source levels entailing negative effects, which means that it includes noise events which cause negative effects individually. Hence, the main question could regards the probability’s estimate that cumulated noise events over a relevant time window produce negative effects on the ecosystem. Here we assume that this probability increases along with increasing spatial and temporal overlap between noise events and populations of marine species. This overlap (exposure) can be quantified and therefore it can be used as an indicator or a proxy of this probability (risk).

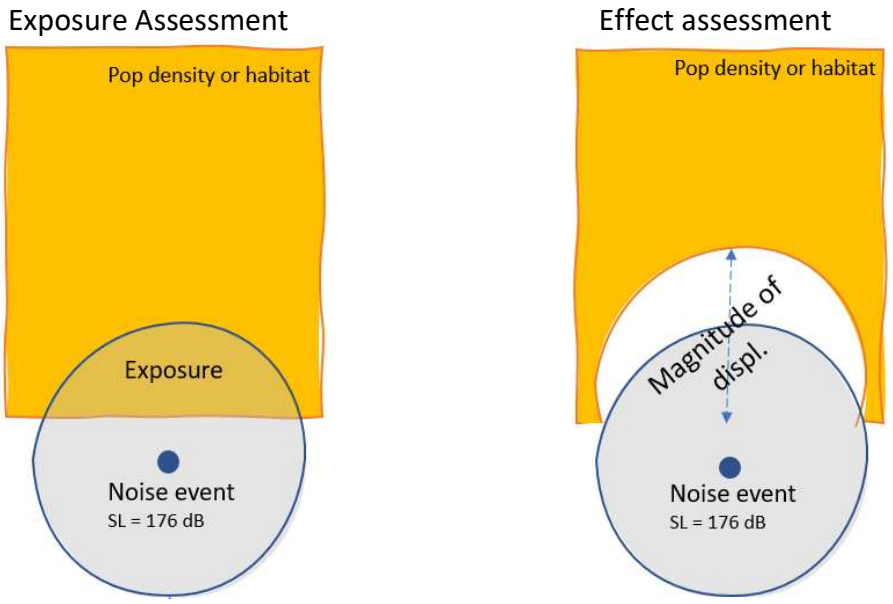
For the purposes of this document, we use this background concepts to develop the assessment framework for impulsive noise. The likelihood of adverse effect to occur is treated as a function of the exposure: the more the extent and duration of exposure, so much greater is the odds of adverse effect on ecological endpoints (e.g. populations or habitats). Therefore, this is the main step forward proposed in this document. The stepwise process described below in Table 1, present the elements of a generic risk assessment with examples in eco-toxicology (a discipline which extensively uses ecological risk assessment related to toxic substances and pollutants) and its possible parallels for D11C1 assessment.

N	Steps	Examples in Ecological Risk Assessment (Eco-Toxicology)	Possible parallel with a risk-based assessment of D11C1
1	Definition of the hazard i.e. the description of the hazard and the ecological endpoint of the related danger, the source of this danger and the environment where it exists	Agriculture pesticides drifts causing river fish kills	Noise events causing displacement of marine species in MSFD assessment areas (regions, subregions, subdivisions)
2	Assessment of the exposure an estimate of contact with or dose to ecological endpoint	Pesticide concentrations in river fish habitats and duration of exposure to such concentrations	Extent and duration of exposure to noise events
3	Assessment of the magnitude of the effects	Expressed in terms of dose-response curve, predicts the mortality of fish as function of the received doses (e.g. median lethal concentration - LC50)	No such dose-response curves are sufficiently known for wild cetaceans (apart from some species such as harbour porpoises, which is not common in the Mediterranean Sea) a magnitude of displacement cannot be predicted accurately; instead, the occurrence of displacement can be assumed in response to single noise events in the INR-MED

4	Characterisation of the risk/result of assessment	The likelihood that hazard concentrations in rivers are above thresholds of effects (e.g. 96h-LC50) **Example of risk formulation**: it is expected (= high probability, may be quantified) that there will be X% of fish mortality in rivers close to farms	The likelihood that exposure to cumulative noise events will cause displacement of cetaceans from their habitats. The likelihood may be expressed as a function of the spatial and temporal overlap between noise events and populations of marine species (extent of the exposure).
5	Management of the risk	Measures for reducing risks, not addressed in this document	

Table 1. Risk-assessment framework, taken form examples in toxicology, and its possible parallels for D11C1 assessment.

The principles described in the previous table are depicted in the following figure (Fig. 1). Also, the picture presents the conceptual difference between exposure assessment and effect assessment.



Assessing the **extent of the exposure** in a risk-based approach: exposure can be assessed in terms of space and time coverage of habitats by noise levels causing impacts (noise events). If population density data are available, exposure can also be estimated in terms of number of animals potentially affected.

The magnitude of the displacement could be **predicted** if dose-response curves were available, but this is probably not the case for wild cetaceans and other marine species sensitive to noise.

Also, the availability of dose-response curves may allow **measuring** the magnitude of displacement with dedicated monitoring programmes. In this case, it would be possible to build an indicator of the impact of impulsive noise; but again this is not envisaged since dose-response curves are not available.

Figure 1. Principles of an exposure assessment as described in this section (left); and difference from the effect assessment (right). The SL of 176 dB re 1µPa is just an example corresponding to SLs proposed by TG-Noise for generic low-frequency impulsive sound sources.

2.2. Relevant regional processes

This document involves three main regional processes, here listed:

- The Marine Strategy Framework Directive and the implementation of D11C1 in the Mediterranean Sea Region.
- The ACCOBAMS Agreement, which includes among its objectives the reduction of threats (i.e. underwater noise) to cetaceans and their habitats.
- The EcAp process and the implementation of Ecological Objective 11 (Energy, including underwater noise), undertaken since 2008 by the UN-Environment/MAP-Barcelona Convention.

This Deliverable is meant to be brought to the attention of relevant bodies of ACCOBAMS and the Barcelona Convention, following the procedures of these international fora, with the aim of promoting the adoption of effective common monitoring methods and tools for regulating underwater impulsive noise at regional level.

2.3. Availability of data and tools

The assessment methodology is based on noise event data that should be reported to the INR-MED, as required by the MSFD. The same requirement exists concerning Common Indicator 26 in the EcAp process (although this is still a candidate common indicator and therefore not mandatory for Contracting Parties which are not EU-Member States).

As a first step, during QUIETMED2 project, a Data Call has been planned to be issued to ACCOBAMS Parties which is requested to provide data in a voluntary way. Currently, political process is ongoing in ACCOBAMS and in the Barcelona Convention to better understand how to make this effort more effective. However, it is worth considering here that neither ACCOBAMS nor UNEP/MAP are binding legal frameworks and that their provisions cannot be enforced through mandatory processes. Nevertheless, there are successful examples, such as for the OSPAR and HELCOM Convention, for which data request and voluntary submission may work well. However, there is little chance that this will work for naval related data (sonar). One further option is the cooperation with the General Fishery Commission for the Mediterranean (GFCM), established under the FAO. The GFCM adopts binding recommendations for member countries and thereby provisions contained in such recommendations may potentially be implemented more effectively. However, there is a need for people involved in MSFD and EcAp implementation to better understand GFCM processes, if these can address human-made impacts (e.g. noise) and how these could help and/or contribute. Moreover, the GFCM focusses on fish and only marginally on cetaceans (in particularly to address the issue of by-catch). Such questions are not addressed here but it is worth exploring it in the future to improve data gathering efforts.

An important point is that, among the contributors to this activity of QUIETMED2 (i.e. Project Partners, TG-Noise members in the advisory board, members of the CMS/ACCOBAMS/ASCOBANS JNWG), there is general consensus that, despite the amount of effort that can be put on noise event data gathering, such data will remain incomplete as far as known barriers to data availability will exist (e.g. confidentiality of military exercises including sonars). Therefore, it is desirable that the implementation of INR-MED, as well as any output built on this tool (e.g. assessment reports), will ensure this issue will be correctly explained.

Available data on species distributions and/or the identification of defined suitable habitat are also required. During the 1st JNWG-QUIETMED2 meeting, it was stressed that data are available for the most common Mediterranean species (e.g. delphinids, fin whales) and for many areas of the Mediterranean Sea, likely allowing the use of the methodology presented here. Nonetheless, strong synergies will be necessary to improve the knowledge about species distribution (especially in un-surveyed or less monitored areas) within ACCOBAMS and other regional bodies that coordinate dedicated initiatives on the monitoring of cetacean populations.

To date, the INR-MED provides information on the spatial and temporal distribution of underwater impulsive noise sources (http://80.73.144.60/CTN_Geoportal/home/). It is expected that the INR-MED will support in foreseeable future the implementation of the assessment methodology presented here by the end of QUIETMED2 project or soon after.

2.4. Practical feasibility of monitoring

The assessment methodology for impulsive noise does not require additional monitoring than the existing programmes on the pressure indicator for impulsive noise. Reporting of noise events for the INR-MED is still at the early stage, where only data from France are available for 2016 and 2017. For this reason, as just reported in the previous section (2.3), during QUIETMED2 project, a Data Call has been issued to attempt gathering a first round of data.

Regarding species data availability, the approach proposed in this document is that monitoring programmes for relevant species distribution and habitat should be used or adapted to the scope of the present proposal (e.g. MSFD-Descriptor 1 and NATURA 2000 monitoring programmes, ACCOBAMS Survey Initiative, etc.).

Although it is well known that long term databases (based on more than 30 years data) on cetacean monitoring exist for some areas of the Mediterranean Sea. Results from these long term data series could be used as a valuable tool for the implementation of this proposed methodological framework. However, it is important to remark that long time series of data are available only for some areas of the Mediterranean sea (e.g. Pelagos Sanctuary area) the discussion on the goodness and suitability of available data on Mediterranean cetacean populations at Regional scale is still ongoing at this stage. This discussion could be more effectively addressed by working groups and experts on

Descriptor 1 at EU, Regional Sea Conventions and national levels. Alternatively, a dedicated study should be undertaken to come up with an agreed evaluation concerning the availability of good quality cetacean data and their adequacy for the risk-based assessment of D11C1.

2.5. Readiness and feasibility of the assessment methodology

All the steps in Table 1 (section 2.1), reported here below, can be executed:

1. hazard definition;
2. exposure assessment;
3. effect assessment;
4. characterisation of the risk.

However, we can identify a weak point in the effect assessment step (3): the assessment of the magnitude may be done accurately through dose-response curves allowing to predict such effects; however for many cetaceans species and other marine wildlife such dose-response curves may be largely unavailable. Nevertheless, scientific references do exist concerning ranges of impacts for different species (not addressed in detail in this Deliverable, but see section 6.3 for some references), thereby supporting the feasibility of this approach. Also, the lack of accurate dose-response curves can be overcome by assuming that the probability of occurrence of negative effects increases along with increasing extent and duration of exposure to noise events by populations of marine species. Therefore, this weakness does not appear to prevent the execution of the whole process and the only drawback is that the characterisation of the risk in terms of likelihood (4) will be less accurate in the first phase of implementation. More research efforts in deriving dose-response curves shall certainly allow improving the prediction of effects and thereby the overall assessment accuracy.

Hence, the assessment methodology for the regional and sub-regional scales may be already operational, provided two conditions are met:

- the available data on cetacean's populations and/or habitat are deemed suitable
- Impulsive noise events are submitted to the INR-MED

The proposal is to develop and proceed with a test for this assessment methodology, especially based on QUIETMED2 activities (Activity 9). This test may focus, on a first level, on the species/habitats with the highest quality data and the highest management priority (e.g. including IUCN status as a factor for prioritization). This will greatly help calibrating the methodology. Once priority management areas are identified where data is deficient, a second level assessment will focus on how to afford these areas.

3. Technical specifications

3.1. Metrics

Indices of the extent and duration of exposure are proposed (Exposure Indices, EIs). As a reminder, the term exposure is referred to the meaning that is commonly used in Risk Assessment, and does not necessarily refers to acoustic indicators such as SEL (Sound Exposure Level).

The extent of exposure is calculated as the proportion of a habitat overlapped by noise events from the Noise Register (% of habitat exposed) during a time window (assessment period). The duration of exposure is the duration in days of that exposure over the assessment time window (% of time that habitat is exposed).

In case enough reliable data become available for both noise events and ecological parameters (i.e. population distribution and density), modified versions of EIs may be used in the future.

3.2. Ecological endpoint: Habitat rather than population densities

The habitat definition for this indicator, as resulted from the two JNWG-QUIETMED2 meetings (June 2019 in Monaco and January 2020 in Cartagena, Spain), should be the predicted suitable habitat (potential habitat) of selected species, modelled by using physiographical characteristics as covariates (e.g. bathymetry and slope see Azzellino et al. 2012). However, it is important to consider other biological characteristics can contribute to the species habitat selection. As an example, the continental shelf might become an important habitat for a species only when upwellings are occurring, which are known to be seasonal. One way to address seasonality and other biological aspects may be selecting relevant assessment areas (i.e. upwelling areas) and periods (i.e. summer period).

3.3. Applicability to sub-regions

The INR-MED is intended to be applied in the Mediterranean Sea basin region, subregions and subdivisions. These latter units are not defined yet.

Marine subregions (https://www.eea.europa.eu/data-and-maps/data/europe-seas) are:

- Western Mediterranean Sea;
- Ionian Sea and Central Mediterranean Sea;
- Adriatic Sea;
- Aegean-Levantine Sea.

Further, the Black Sea region is already covered, on an interim basis, by the INR-MED since the ACCOBAMS Agreement area covers also the Black Sea.

3.4. Assessment scales

Assessment scales will be determined, considering the noise register availability, by the distribution of indicator habitats. The Noise Register grid (30 min in latitude and longitude) could be considered as the maximum computational unit of measurements. A finer scale may be considered for the habitat approach, for example a 20x20 km grid.

4. Links to other EU legislation or international agreements

The MSFD is the main driver through the guidance developed by the TG-Noise for D11C1 which QUIETMED2 adheres too. Moreover, this methodology is fully pertinent with the Ecological Approach process (Ecological Objective 11 – EcAp/EO11, Barcelona Convention), and obviously with the ACCOBAMS objectives concerning the implementation of measures against threats to cetaceans.

To date, the INR-MED is conceived to support ACCOBAMS in producing information that will feed regional assessments on underwater noise pollution, and its Contracting Parties to report on anthropogenic impulsive sounds either for the process relative to the Marine Strategy Framework Directive (MSFD) or the Ecosystem Approach (EcAp) led by Barcelona Convention.

As stated above (section 3.5), the Black Sea region is already covered, on an interim basis, by the existing INR-MED since the ACCOBAMS Agreement area covers also the Black Sea. Ongoing initiatives on the implementation of the Ecosystem Approach in the Black Sea (Black Sea Integrated Monitoring and Assessment Programme, BSIMAP) may well benefit from the adoption of this existing tool and the proposed methodology developed through this document.

Finally, it is worth considering the possible complementary scopes of national and international registers. Today the ACCOBAMS impulsive noise register is primarily meant to assess past activities, while national registers may well be conceived as planning tools, and therefore include data about future or requested activities for such purposes as the planning and management of national maritime space.

5. Assessment

5.1. General framework

The proposed assessment framework for impulsive noise is presented hereafter:

1. Select indicators species or habitats:
   - The calculation of the EIs using habitats appears adequate for species with lacking reliable and relatively accurate abundance estimates; until agreement is not reached about reliability and quality of existing population data for the selected species and/or for the related monitoring programs (e.g. on D1), it is preferable to use habitat instead of population density (see section 3.2);
   - The selection of indicator species and related habitats should be done according to a list of relevant factors. A dedicated deliverable addresses the process and factors to consider for selecting relevant species and habitats (QUIETMED2-D5.1 https://quietmed2.eu/outputs/).

2. Define assessment area:
   - Define assessment area and temporal resolution based on management (i.e., MPAs), important habitat/ecological relevance (i.e., mating, corridor, feeding, resting), and suitability (i.e., physical features).

3. Specify important habitats based on a score:
   - The habitat can be represented as a spatial grid where each grid cell corresponds to a suitability score (usually spanning from 0 - unsuitable, to 1 - highly suitable);
   - As stated above, the suitability score should be defined primarily on physical features (e.g. bathymetry, slope; see section 3.2). Other features such as biological or ecological characteristics (e.g. seasonality) can be addressed as well.

4. Produce pressure maps:
   - According to a defined impact (e.g. displacement, disturbance, PTS/TTS) and to source properties. If we consider TG Noise guidance (Dekeling et al. 2014), the reference impact is displacement. We consider two ways of deriving pressure maps:
     a) using a fixed distance of effect around each class of noise source, based on the scientific literature on effects of noise on cetaceans (fixed buffer);
     b) using acoustic modelling, with assumed thresholds for response, which results in using an adjusted buffer around the noise source based on source properties and propagation medium;
   - At this stage, the two options are considered valid and not clear preference appears for one rather than the other. The Table 2, hereafter, displays the advantages and disadvantages of each type of buffer.

Type of buffer	Advantages	Disadvantages
FIXED	Simplify the implementation	Too many knowledge and hypotheses, cannot be very accurate
	Stable results	Species specific
	-	Uncertainties in the position of the noise source for noise events represented as polygons
ADJUSTED	Better adaptation to biological characteristics	More complexity-programming, Deep understanding
	More accurate results	More complex to interpret
	Open doors for improvement of this framework through research	Uncertainties in the position of the noise source for noise events represented as polygons

Table 2. Fixed vs. Adjusted buffer: strenghts and weaknesses.

5. Compute exposure maps and indices by combining points 3 and 4:

- This step can be resumed here as the calculation of the following quantities:
  - the extent of exposure as the spatial coverage of noise events over the selected habitat, e.g.: X% of the habitat of some cetacean habitat is covered by Noise Event (see figure 3) over 1 year;
  - the duration of exposure as the number of days with noise events over the assessment period and assessment area, e.g.: the X% of time over 1 year (days/365*100) of some cetacean habitat is covered by Noise Events

The specific methodology for this step is defined in Deliverable 6.2 of QUIETMED2, which addresses the proposed methodological framework for the setting of thresholds for GES assessment.

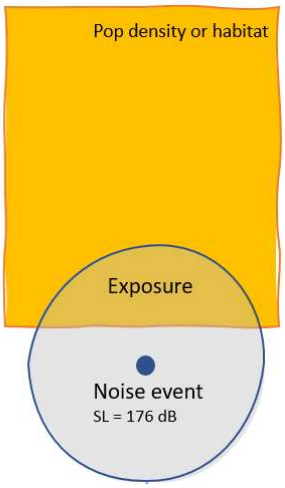


Figure 2 Extent of exposure calculated as overlap (in %) between the Noise Event footprint and the hábitat of a species (or populatin density if available)

6. Assess confidence in exposure indices values:
   - Including sources of uncertainty. This point is the last crucial aspect to be addressed in order to deliver meaningful D11C1 assessments. However, it was not addressed in depth during this Activity of QUIETMED2. It obviously deserves better consideration in future efforts to improve the methodology.

6. Implementation

6.1. Some examples from recent efforts

Two examples are described hereafter:

- *Marine Noise Budgets in Practice* (Merchant et al., 2018), proposing a framework of noise exposure indicators based on fixed distance of effect (fixed buffer) related to biological risk.
- *Modelling sound and disturbance maps using the impulsive noise register for assessing cumulative impact of impulsive sound* (von Benda-Beckmann et al., 2017), proposing a framework based on modelled sound field from impulsive noise sources (adjusted buffer) related to biological risk.

The approach presented by Merchant et al. (2018, Fig.2) uses fixed distance of effect based on observational studies of species reactions to noise. The distance is set at 20 km based on studies on Harbour porpoise (*Phocoena phocoena*) response to noise (Tougaard, 2012). Therefore, the grid cells falling in this fixed buffer are considered to compute the pressure map. The second method included in this approach is the use of acoustic modelling to calculate the distance of effect. This method is illustrated by Benda-Beckmann and co-author (2017, Fig.3) and it is based on harbour porpoise threshold for response to impulsive noise. The pressure map is computed considering all the grid cell falling in the modelled buffer. In the Mediterranean Sea, a paper from Drira and co-authors (2018, Fig.4), uses this latter approach and provide information on the disturbance by noise produced by loud low frequency sources from the Adriatic Sea based on a preliminary experiment. A simplified example workflow for computing the indicator is shown in Fig. 2, using the example of harbour porpoise during autumn 2015 (Merchant et al. 2018).

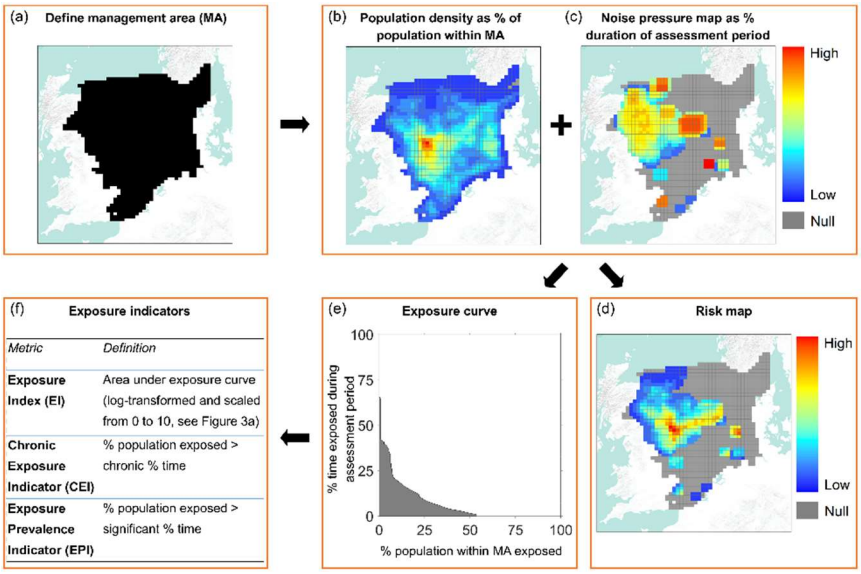


Figure 3; Example workflow for mapping risk and calculating exposure indicators (source: Merchant et al 2018). Example population density (b) is modelled North Sea harbour porpoise density during autumn (Sep.-Nov.), from Gilles et al. (2016). Noise pressure map (c) is based on impulsive noise data reported for the OSPAR maritime area in Sep.-Nov. 2015. Risk map (d) is derived overlapping Noise pressure map on a harbour porpoise distribution layer.

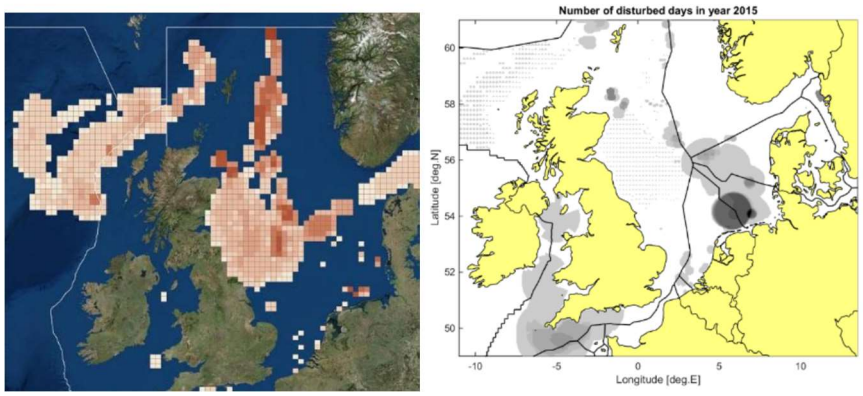


Figure 4. Example of pressure map based on the use of acoustic modelling to calculate the distance of effect. Map (a) shows noise events data from the OSPAR register and map (b) shows results of sound propagation modelling combined with a sound level threshold for disturbance of harbour porpoise using impulsive noise register data for the year 2015 (Benda-Beckmann 2017), based on the assessment framework described in Heinis et al. (2015).

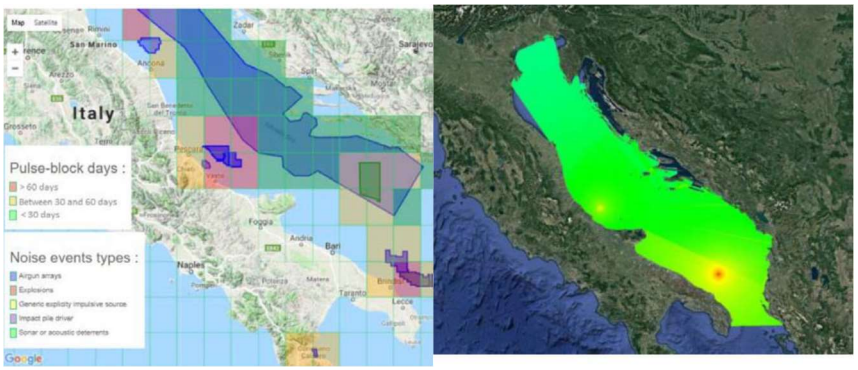


Figure 5. Example of the implementation in the Adriatic Sea of the sound propagation modelling step on noise event data contained in the ACCOBAMS noise register demonstrator tool (Drira et al. 2018). This work focusses on showing the extension of the influence area caused by impulsive noise (right map) compared to the limits of the current spatial grid (30x30 min, left map), to support the incorporation of such modelling in the calculation of D11C1 indicators.

6.2. Metrics involved in the assessment methodology

Concerning the pressure from impulsive noise, the metric recommended today for D11C1 is pulse-block days, i.e. the number of days that a certain threshold (pulse) is exceeded in an area (block), for a calendar year (Dekeling et al., 2014). The procedure to get indicator value consists simply in locating the activities that used noise sources and calculate how many days the noise sources were used. This calculation is done over a regular spatial grid and the result is a hotspot map. This metric is currently used in the noise register for the OSPAR, HELCOM and ACCOBAMS regions.

With regards to habitat, the habitat suitability modelling delivers a score spanning from 0 to 1 (unsuitable to highly suitable, respectively). Such score is assigned by the model to each grid cell of the habitat area used in the assessment.

The spatial extent of the exposure is calculated by multiplying the surface (km²) of each grid cell covered by noise events (including their buffer zones) by the habitat suitability score of the same grid cells, and then by summing up the obtained surfaces (km²).

The duration is calculated by summing up all the durations of noise events (days) over the assessment areas where only non-overlapping days are considered in the sum.

Specific methodology for these calculations is defined in Deliverable 6.2 of QUIETMED2.

6.3. Reference and baseline levels

The reference level (the value or range of values for pulse-block days at which impacts from anthropogenic pressures are absent or negligible) can be defined as zero exposure to the indicator species, especially if species such as the fin whale are considered. Fin whales were observed indeed to respond to loud impulsive signals as far as 285 km away from the source (Borsani et al. 2008, Castellote et al. 2012).

In terms of baseline levels, the proposal for the Mediterranean Sea is to adopt *current levels*. This choice means that the current levels will just be the values to be compared against subsequent values in future assessments and it does not imply that *current levels* are considered as acceptable.

In any case, such baselines (current levels) are not available today since the data gathering from countries to the INR-MED has not started yet. Realistically, baseline levels will be calculated for the first year with sufficient data in the INR-MED, and then they will be regularly updated during the first years of monitoring (averaged) to reduce inter-annual variability. This averaging process shall ideally stop after a number of years (to be defined) considered sufficient to reduce inter-annually variability.

6.4. Assessment criteria and targets

Assessment of GES against targets or desired state can be on a qualitative or quantitative basis.

The main approaches for target setting are:

1. Directional/trend-based;
2. Baseline values against which to measure change;
3. Thresholds.

The latest MSFD Commission Decision (2017/848/EU) requires that threshold values (point 3) should be set by Member States through cooperation at Union level, taking into account regional or subregional specificities, such that populations of marine animals are not adversely affected by anthropogenic impulsive sound sources. The methodology presented here provides a basis for defining TVs, according to the exposure of selected species to impulsive sound sources and therefore the risk on

populations. The methodological framework for calculating the EIs and for TVs setting is proposed in Deliverable 6.2 of QUIETMED2 and is not described here in detail.

Briefly, there is a preference for using the following approach:

- Spatial and temporal thresholds are set;
- If the spatial threshold is exceeded, the temporal threshold is inspected;
- The use of combined spatial and temporal thresholds can be used for informing GES.

Pending consensus on such thresholds, the indicator is also compatible with the remaining two approaches. Option 2 will be viable once the first baseline will be available (pending data gathering and analysis into the INR-MED), while option 1 will take time to establish a time series. Further, using baseline levels as a non-deterioration threshold (such as proposed for D10 - Marine Litters) would combine options 2 and 3.

6.5. Spatial scope and aggregation

The geographical scope of the indicator is driven by the estimated distribution of the indicator species, and/or recognised habitat of the indicator species. For some species, the region scale may be appropriate, while for others, smaller geographical scales (sub-regions) will be applicable. The TG Noise recommendation about not using a too much small geographical scales (e.g. to national scales) has been taken into account in this document. Moreover, geographical specificities in Mediterranean Sea must be considered (e.g. Adriatic Sea, Aegean Sea, etc.).

One option for aggregation could be to consider the "*One Out All Out*" approach at the subregion/region scales for each habitat, meaning that if one habitat does not reach GES, all the subregion is in non-GES. However, for heterogeneous areas (such as the Aegean-Levantine subregion) this approach may be unsuitable. This point needs further development.

6.6. Monitoring requirements

No additional noise monitoring is required beyond existing impulsive noise monitoring programs (pressure-based). However, coordination with initiatives related to D1/EO1 is highly desirable. Furthermore, there may be need of strong regional coordination to regularly implement such programmes as the ACCOBAMS Survey Initiative (2018) to obtain distribution and abundance data of cetacean populations by using a common protocol throughout the Mediterranean Sea.

6.7. Reporting

To achieve international coordination between MS in monitoring and assessment, agreements have to be made on reporting of the results. It should be also clear how the results will be fed into informing management measures. Reporting will

consider the MSFD and EcAp process cycles as well as ACCOBAMS needs in terms of monitoring, assessment and management of threats to cetaceans.

6.8. Visualisation

The methodology presented here produces risk maps, which visualise the distribution of risk in the ACCOBAMS Area for a given period (i.e., one year, or higher resolution as outlined in Commission Decision 2017/848). Graphs of indicator values across successive monitoring periods will also be important to evaluate trends.

6.9. Further development

This proposal shall be submitted to relevant processes in the Mediterranean Sea: ACCOBAMS and the Barcelona Convention, according to their agenda and timeline for adoption of such proposal for impulsive noise assessment methodological framework.

An implementation of this assessment methodology would be tested on data from INR-MED for different marine species yet to be defined. The meeting of the JNWG organised in Monaco on 25-26 June 2019, which included experts from the TG-noise, pointed the Fin whale and the Cuvier's beaked whale as target species for this exercise, bearing in mind that the discussion on species selection is not the scope of this document.

7. Convergence and divergence of North-East Atlantic and Mediterranean approaches

Initiatives on impulsive noise monitoring and assessment undertaken in the two macro-areas in the last 10 years are mainly driven by the MSFD and an overall consistency can be observed. Main convergence between the two processes are the following:

- The use of a regional register for noise events (International Noise Registers);
- The share of this tool with EMODnet Physics to permit a pan-European view of the data
- The adoption of a risk-based approach for assessment.

However, some divergences can be detected and are presented in the Table 3 hereafter.

North-east Atlantic	Mediterranean Sea
The ongoing process in OSPAR is for a new indicator named "Impulsive noise impact indicator" for the OSPAR area.	ACCOBAMS is supporting the idea that the primary need is not to develop a new indicator but rather providing guidance on how to carry out assessment for impulsive noise by using existing monitoring outputs for impulsive noise and for biodiversity.
The proposal for a new indicator of impulsive noise is undergoing a validation process in OSPAR.	No new indicator will be submitted by ACCOBAMS to the Barcelona Convention relevant body for pollution (MEDPOL); Instead, the methodology developed in this document, together with the outputs of Deliverable 6.2 of QUIETMED2, will be used to complete existing guidance on integrated monitoring and assessment programmes (IMAP) concerning Common Indicator 26 (impulsive noise).
There is a preference for combining the spatial and temporal components of the existing monitoring outputs for impulsive noise and for biodiversity in a unique Exposure Index (EI), including through the use of an exposure curve.	There is a preference for deriving separate spatial and temporal exposure indices. It is considered that such indices can be used to set thresholds and better inform GES assessment as well as management measures than a unique value.
Both population density data and habitat data are deemed relevant for the new OSPAR noise indicator, with a preference for population density data where available.	A clear preference for the use of habitat comes up as a result of this QUIETMED2 Activity (Activity 4).

Table 3. Atlantic and Mediterranean approaches on D11C1 assessment.

8. Conclusions and next steps

This Deliverable (D4.1) was aimed at developing a framework for the assessment of impulsive noise within the scope of D11C1 of the MSFD. The need for this activity arises from the evidence that, while the monitoring guidance developed in 2014 by the TG-Noise allowed the implementation of monitoring programmes, the aspects concerning the assessment were still in need of further development.

Several scientists and experts from the Mediterranean area as well as from the North-east Atlantic and the Baltic areas participated to the development of this document. The main conclusion of this activity (QUIETMED Activity 4) is that an overall consensus has been reached about the general framework for assessing impulsive noise in the Mediterranean region. This general framework can be used at the regional and subregional level by international organisations such as ACCOBAMS and relevant MAP components (such as MEDPOL) and/or adapted by countries for national assessments, where appropriate.

Furthermore, this general framework provides a stepwise structure for guiding the assessment and a shared basis for the setting of TVs as requested by Commission Decision 2017/848/EU to enable GES assessment. The methodology for setting TVs is the object of Deliverable 6.2 of QUIETMED2 project.

The assessment framework combines data from impulsive noise monitoring (Noise Register data) and data from biodiversity criteria (especially D1C4 – distributional range/habitat) and is based on an ecological risk-assessment approach. This approach entails estimating the likelihood of negative effects on the environment to occur as a result of exposure to a hazard. Here it is proposed to consider the likelihood as a function of exposure: the more the extent and duration of exposure, the greater the adverse effects are. Based on previous work from TG-Noise, negative effects are to be referred to displacement of cetaceans from their habitats. The overlap of noise events on habitats is used to calculate the exposure of marine wildlife habitats in terms of space and time. The computation of two indices is proposed:

- a spatial exposure index;
- a temporal exposure index.

The exposure indices can then be used to set TVs, as well as to analyse the trends in the extent and duration of exposure quarterly and yearly.

No dose-response curves are available for cetaceans in the Mediterranean Sea thereby preventing accurate prediction of the magnitude of the negative effects (e.g. how much cetaceans are displaced from their habitats), but scientific references do exist (not addressed in this document, but see section 6.3 for an overview) concerning ranges of impacts for different species supporting thus the feasibility of this approach. Dose-response studies represent a research topic with a great potential for improving the framework presented here.

Finally, the estimation of uncertainty is a crucial aspect of the risk assessment process but could not be addressed in depth during this QUIETMED2 Activity 4. It obviously deserves better consideration in future efforts to improve the methodology and deliver meaningful D11C1 assessments.

Next step will be to include the outputs described in this document into the Noise Register tool (Activities 8 and 9 of QUIETMED2).

Beyond QUIETMED2, outputs from this document will be submitted to ACCOBAMS and Barcelona Convention bodies in order to:

- Promote the use of the assessment framework (all or part) for the objectives of ACCOBAMS of assessing and reducing threats to cetaceans and their habitat, especially concerning Cetacean Critical Habitats (CCH);
- Incorporate this assessment framework into the Integrated Monitoring and Assessment Programme (IMAP) of the Barcelona Convention, especially concerning Candidate Common Indicator 26 (impulsive noise). The first opportunity is the current development of the EcAp-MED III Project (started in 2020).

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