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

D6.1 Preliminary GES assessment of D11 underwater noise in the Mediterranean Sea and Black Sea regions.

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3	Service hydrographique et océanographique de la marine	Shom	France
4	Politecnico di Milano-Department of Civil and Environmental Engineering	POLIMI-DICA	Italy
5	Hellenic Centre for Marine Research	HCMR	Greece
6	Inštitut za vode Republike Slovenije/Institute for water of the Republic of Slovenia	IZVRS	Slovenia
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Abstract

This document is the Deliverable “D6.1 Preliminary GES assessment of D11 underwater noise in the Mediterranean Sea and Black Sea Region” (5th May 2023) of the QUIETSEAS project funded by the DG Environment of the European Commission within the call “DG ENV/MSFD 2020 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 (GES) of marine waters and specifications and standardised methods for monitoring and assessment, and repealing Decision 2010/477/EU) and Programmes of Measures according Article 13 of the MSFD. QUIETSEAS aims to support the practical development of the second implementation cycle under the MSFD for D11 (underwater noise).

The object of this document is to testing applicability of the methodologies and tools to promote the consolidation of indicators by performing an operational pilot on GES assessment for D11 (D11C1 and D11C2) in the Mediterranean Sea and Black Sea Region.

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List of Abbreviations

CTN	Centro Tecnológico Naval y del Mar
ACCOBAMS	Permanent Secretariat of the 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
UM	University of Malta -The Conservation Biology Research Group
POLIMI-DICA	Politecnico di Milano-Department of Civil and Environmental Engineering
SPA/RAC	Specially Protected Areas Regional Activity Centre
ICES	International Council for the Exploration of the Sea
Shom	Service hydrographique et océanographique de la marine
MHD	Maritime Hydrographic Directorate
MSFD	Marine Strategy Framework Directive
GES	Good Environmental Status
MS	Member States
MED	Mediterranean Sea
BS	Black Sea
CA	Competent Authority
NR	National representative
SO	Specific Objective
TB	Thematic Block

1. Introduction.

The QUIETSEAS Project is funded by DG Environment of the European Commission within the call “DG ENV/MSFD 2020”. This call funds MSFD development, in particular, the preparation of the next 6-year cycle of implementation.

The QUIETSEAS project aims to enhance cooperation among Member States (MS) in the Mediterranean Sea Region (MED) to implement the third Cycle of the Marine Directive and in particular to support Competent Authorities and strength strengthen cooperation and collaboration in the Mediterranean Sea and Black Sea regions through the following specific objectives:

- Specific objective 1 (SO1): To identify relevant indicators for criterion D11C2 (Anthropogenic continuous low-frequency sound in water).
- Specific objective 2 (SO2): To promote the consolidation of relevant indicators for D11 and support the operationalisation of indicators on the state, pressure and impacts of underwater noise in close coordination with TG Noise.
- Specific objective 3 (SO3): To promote harmonisation of regional work on threshold values with TG Noise recommendations.
- Specific objective 4 (SO4): To develop effective and efficient mechanisms for GES assessment and regional coordination by providing management tools for harmonization, reporting and assessment of D11.
- Specific objective 5 (SO5). To demonstrate the potential effectiveness of coordinated mitigation measures to reduce shipping noise.
- Specific objective 6 (SO6): To promote (sub)regional cooperation in order to ensure i) coordination across the region/ subregions ii) the involvement of Competent Authorities iii) long-term dissemination of the results.

To achieve its objectives, the project is divided in 4 work packages (thematic blocks) and 9 activities whose relationships are shown in Figure 1.

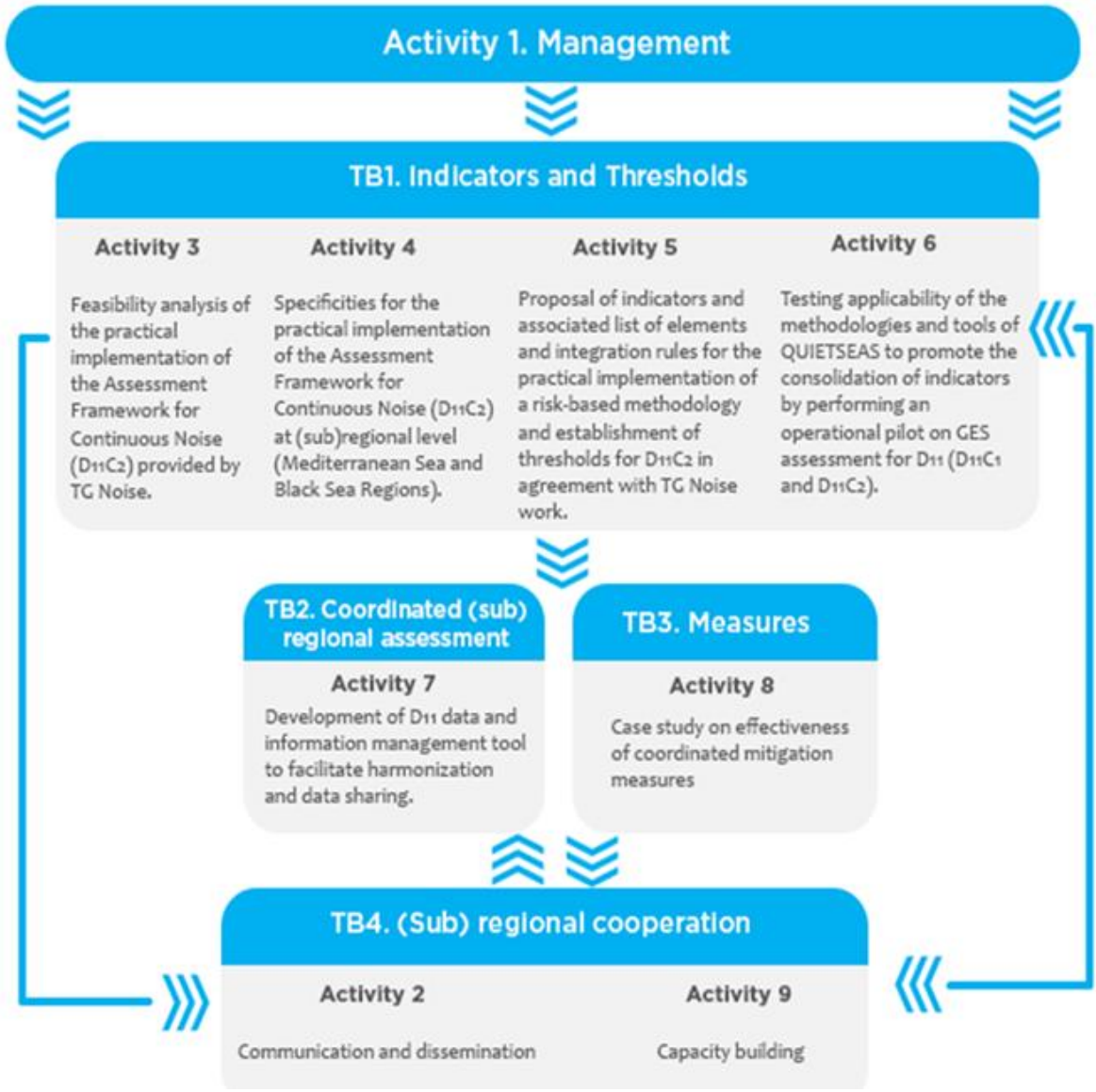

Figure 1.Work Plan Structure

The project is developed by a consortium made up of 10 entities coordinated by CTN and it has a duration of 28 months starting on 1st February 2021.

2. Definition of threshold values in Commission Decision 2017/848/EU.

The Marine Framework Directive (2008/56/EC) (MSFD) provides a framework for the development of strategies for achieving good environmental status (GES) in the marine environment through 11 descriptors. EU member states are required to achieve and maintain GES in European waters (European Commission, 2008). The 2008 directive was amended and replaced by the 2017 directive (European Commission 2017), in which methodological standards and specific indicators for each descriptor were established to ensure that anthropogenic impacts are maintained at levels that do not deteriorate the marine environment and ensure the achievement of GES. The EU adopted Commission Decision 2010/477/EU in 2010, which was later revised and replaced by Commission Decision 2017/848/EU establishes criteria and methodological standards for GES and standardised methods for monitoring and assessment. Underwater noise is included in the GES assessment framework through descriptor 11 (D11: "Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment") ensuring that human activities that introduce energy into the marine environment do not cause pollution, i.e. that noise generated by human activities, that is not tolerable by the populations living in the marine environment.

2.1. Descriptor 11 for GES definition.

The 2017 Commission Decision categorizes primary and secondary criteria for each GES descriptor and stipulates that for underwater noise, threshold values must be defined by Member States through cooperation and standardised methodologies for impulsive noise (D11C1) and continuous noise (D11C2).

Thresholds for descriptor 11 have been discussed and defined within the Expert Technical Group on Underwater Noise (hereinafter TG Noise) on the behalf of the EU Directorate-General for the Environment (DG ENV) (TG Noise Recommendation for impulsive noise (Deliverable 2) and TG Noise Recommendation for continuous noise (Deliverable 4)).

3. TG Noise proposed methodology for establishing D11C2 threshold values and GES assessment.

The European Commission Decision 2017/848/EU specifically required: i) the application of a risk-based approach for the assessment criteria; ii) the setting of the thresholds on the basis of the precautionary principle, and reflecting the potential risks for the marine environment, and iii) to separate the thresholds for anthropogenic impulsive (D11C1) and continuous (D11C2) noise in the water.

The methodology proposed by TG Noise for continuous noise (TG Noise, DL3, 2021) provides a sequential approach to perform the assessment and quantify the habitat area impacted by continuous noise. This type of approach is based on the one already published for impulsive noise (D11C1) (Heinis et al., 2015; Merchant et al., 2018; OSPAR, 2017; Dekeling et al., 2020).

The methodological framework proposed by TG Noise is based on 9 gradual steps as follows:

Step 1. Define Indicator Species and their Habitats

Indicator species should be chosen on the basis of their conservation status, on the risks caused by noise pollution or on the basis of the threat of extinction.

The factors to be taken into account for the species selection are therefore:

- sensitivity to continuous noise.
- conventions/agreements (IUCN conservation status).
- species or habitats on RAC lists with relevance to the Marine Strategy Framework Directive (Palialexis et al., 2018).
- threat status of the species to other anthropogenic pressures.
- species that support vital ecosystem services (e.g. nutrient availability).
- species characteristics requiring special considerations.

Step 2. Define The Level of Onset of Biologically adverse Effects (LOBE)

The LOBE is an essential point to determine for the assessment of D11C2. LOBE is the noise level at which animals begin to experience adverse effects. Above this level, there is a risk of effects that may affect the animals' reproduction, welfare and survival.

Step 3. Determine Time Periods for Assessment

Three time periods need to be defined:

- observation period related to monitoring (seconds or minutes, up to 1 day or 1 month).

- analysis period related to the analysis time window determining the thresholds (TG Noise recommends one month).

- assessment period related to the MSFD reporting period (monthly, seasonal or annual).

Step 4. Assess The Acoustic Status by Monitoring

The assessment of acoustic status requires information on the acoustic environment of the sea and ship traffic. It can be carried out through direct measurements or by means of modelling.

Step 5. Establish Reference Condition

Regardless of anthropogenic noise in the oceans, natural environmental sounds will always be present, so the natural state contains sounds that depend on meteorological, geological and biological activities. This assessment can either be done by modelling or by direct measurements.

Step 6. Establish Current Condition

The current condition depends on natural ambient sound and anthropogenic noise and can be assessed by modelling or through measurements that must be representative for the entire habitat.

Step 7. Evaluate Grid Cells Condition

The assessment is meant to be done on an analysis grid, and it can be done in two ways for each grid cell (TG Noise, DL3, 2021):

- by assuming a fixed value of LOBE and comparing it with the cell arithmetic mean or median value for both current and reference conditions.

- by subtracting the cell current condition from the reference condition where LOBE is expressed as a fixed ratio between the two conditions.

When LOBE is exceeded within the cell unit, the cell condition is not tolerable and cell habitat is considered impacted.

Step 8. Determine Habitat Status

Habitat Status is assessed by evaluating the proportion of habitat grid cells in which the condition is not tolerable. Habitat Status is considered acceptable if the fraction of impacted habitat is less than the tolerated threshold (see TG Noise recommendation-DL4).

Step 9. Assess the MRU Status

If the MRUs are equal to habitats, then an MRU is considered to be in GES if the fraction of the impacted habitat in does not exceed the threshold value. If the MRUs are not identical to habitats, the GES in an MRU is assessed by combining the statuses of habitats

that together constitute the MRU. Notice that there may be more than one habitat within an MRU.

The evaluation of GES is very sensitive to the choice of LOBE and strongly depends on the selection of the target species.

4. The application of PUHA (Potentially Usable Habitat Area) for the assessment of the Habitat Status.

The assessment of habitat status can be done in terms of PUHA (Potentially Usable Habitat Area) which can be calculated for selected target species on the basis of their habitat suitability, HS or predicted presence probability (Azzellino et al., 2012).

Based on the presence probability evaluated for each cell unit within the analysis grid, PUHA can be computed as shown below (Figure 2):

$$PUHA = \sum_{i=1}^{n} HS \times a_i \qquad \text{(Eq. 1)}$$

Figure 2. PUHA equation

where HS is the Habitat Suitability (e.g. the species presence probability as function of the cell physical characteristics) and ai is the area of the i-th unit cell.

Example: Considering a grid with cell size of 20*20 km, the total area of the cell unit is 400 km^2 having various bathymetric characteristics which may result in different suitabilities for different species (e.g. sp1, sp2, sp3).

So, assuming that in the same cell unit the suitability is:

- HSsp1 = 65%

- HSsp2 = 25%

- HSsp3 = 75%

then, PUHAs for HS higher than zero will be the following for the three species:

- PUHAsp1 = (0.65x400) = 240 km^2

- PUHAsp2 = (0.25x400) = 100 km^2

- PUHAsp3 = (0.75x400) = 300 km^2

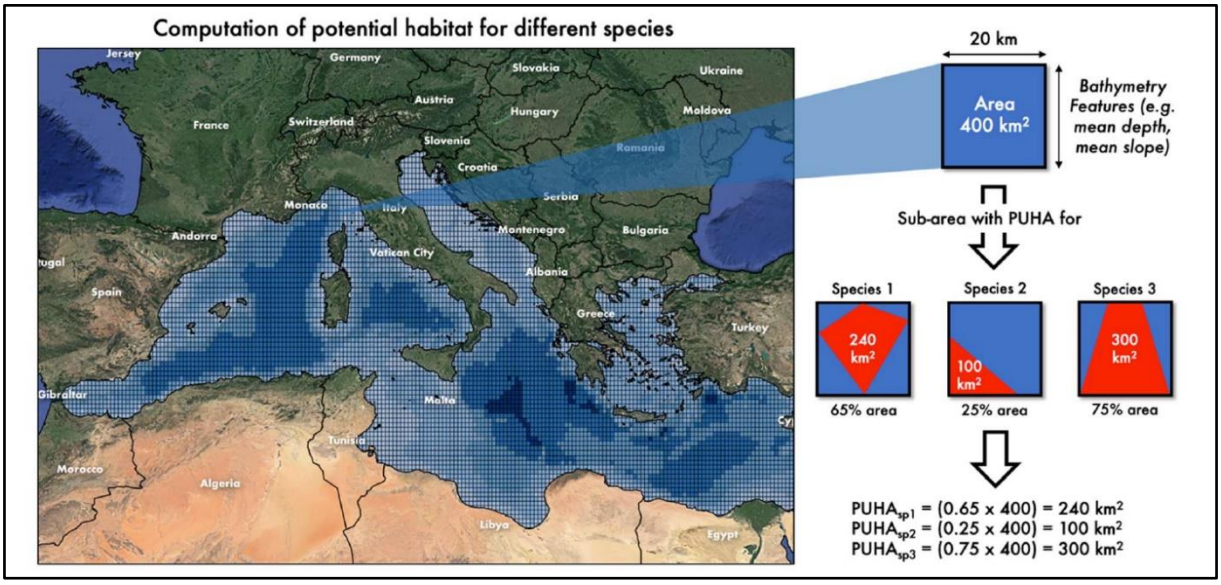

Figure 3. Example of PUHA calculation

Finally, the cumulative PUHA can be evaluated, by summing PUHA values of all cell units within the assessment area.

Next step requires the noise map to be overlaid to the PUHA map, the identification of cell units where the noise levels are higher than LOBE, and, finally, the assessment of the proportion of the overall PUHA that is impacted within the assessment area in the considered time period. The status of the habitat is then assessed by comparing the portion of PUHA with noise levels above LOBE in the assessment area with the recommended tolerable threshold (e.g. 20% in the monthly scenario).

5. Pilot study applications of the methodology in the Mediterranean and Black Sea area.

5.1. Mediterranean Sea region.

As pilot study area for the Mediterranean Sea, the Northwest Mediterranean Sea Slope and Canyon System IMMA (Important Marine Mammal Areas) was assumed. Such an area has oceanographic and geomorphologic features that promote high levels of primary productivity. The area encompasses the Provence-Corso-Ligure basin and the portion of the Gulf of Lion up to the Balearic sub-basin, and it contains habitats that support a wide diversity of cetacean species regularly found in the Mediterranean Sea, such as the fin whale (https://www.marinemammalhabitat.org/).

The species selected as target for this area is the fin whale (Balaenoptera physalus), a species regularly found in the IMMA area. The species is classified as vulnerable in the Mediterranean Sea (ACCOBAMS/IUCN global status) and is exposed to the continuous noise generated by the high fluxes of vessel traffic in the area (Step 1).

Fin whale LOBE was defined considering behavioural disturbance, (i.e. the effects that noise has on the foraging or lactation time of the offspring that may accumulate and lead to effects on survival and reproduction (Castellote et al., 2012). Thus, LOBE was set as 100dB re 1 µPa in the frequency band of 63 Hz (Step 2).

The current condition was modelled simulating ship noise from AIS data on vessel traffic, considering a monthly average shipping density. Different models can be used based on size, speed and category of vessels in order to predict a SL (Source Level) at different depths. In QUIETSEAS, the RANDI 3.1 model (Breeding et al., 1996) was previously used in Deliverable 8.1, leaded by Shom.

In addition, the spatial resolution of the grid, the time period of the analysis and the investigated frequency bands were decided based on the auditory sensitivity of the target species and the size of the assessment area.

The analysis was run on a 10' x 10' grid, and a monthly average navigation density was assumed as the reference scenario. The investigated frequency band was 1/3 octave centered on 63 Hz (Step 4 and Step 6).

Figure 4 shows a noise map (SPL) for the month of August in the year 2019, over the 10'x10' grid; noise levels are simulated assuming the monthly average density of naval traffic, and for the third octave band centred on 63 Hz.

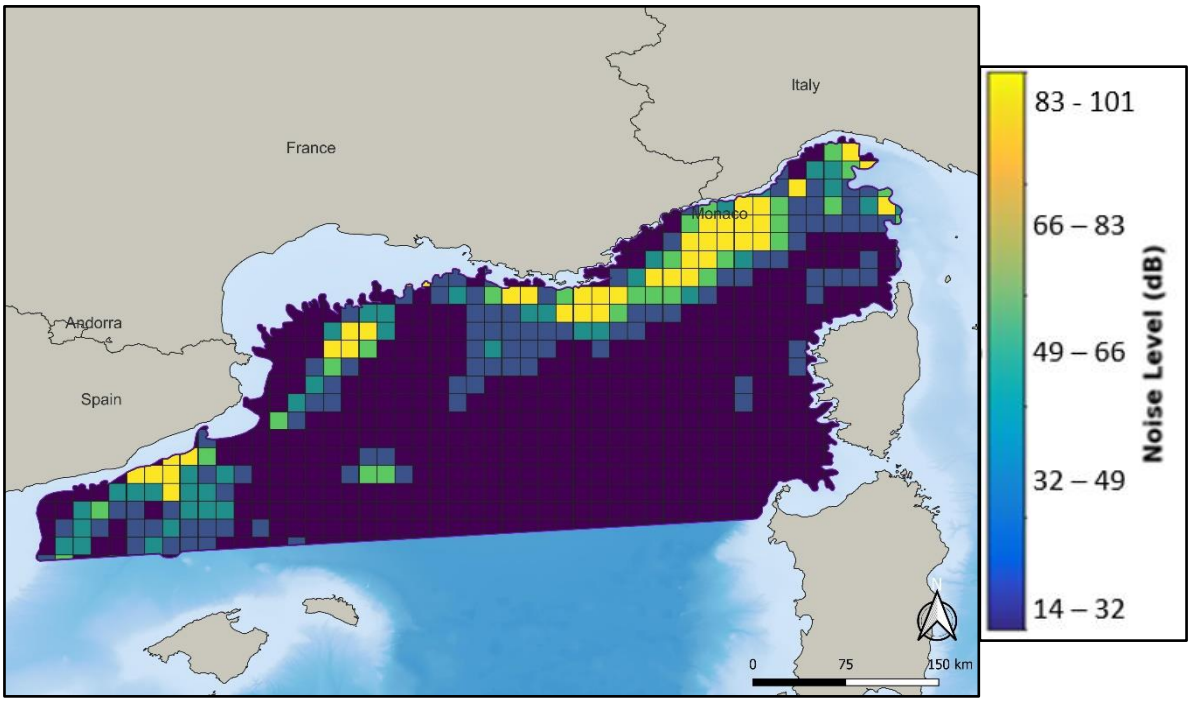

Figure 4. Shipping noise for 1/3 octave band centred on 63 Hz over a month in the IMMA area. Colour scale represents frid cell monthly average SPL.

Furthermore, the time observation window of the noise model was set to 1 month and the temporal analysis window for assessing the habitat state was also consistently set to 1 month (Step 3). As regards the reference condition we assumed that 100% of the target species habitat is exposed to sound levels below LOBE (Step 5).

The grid cell condition is also assessed on a monthly average basis by comparing the predicted SPL and the defined LOBE (100 dB re 1 µPa). If the average SPL within a cell was higher than LOBE, then that cell was defined as significantly affected or impacted (Step 7). Thus, considering the LOBE, grid cells in which the noise level was greater than or equal to 100 dB re 1 µPa in the 63 Hz band were considered impacted and highlighted in red, while those cells in which the noise levels were lower are highlighted in blue. Figure 3 clearly shows that within the IMMA only one cell in the area appears to have values above 100 dB and is therefore impacted by noise (Figure 5).

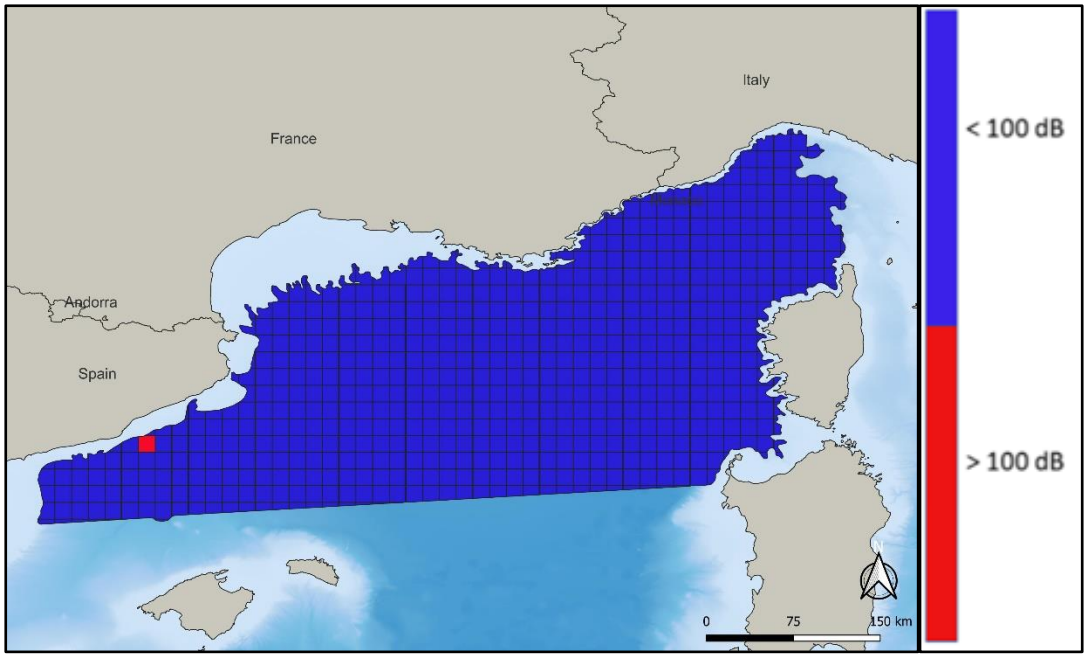

Figure 5. Assessment conditions of individual grid cells in IMMA area: blue cells represent grid cells which are not significantly affected by noise for the set LOBE while the red cells represent grid cells which are significantly affected by noise for the set LOBE. The Temporal Observation Window and The Temporal Assessment Window are set for 1 month.

The models used to calculate the Habitat Suitability (HS) were developed based on a long data series of observations collected in an area of about 25,000 km^2 within the Pelagos Sanctuary (northwestern Mediterranean area, see Azzellino et al., 2012). Fin whale presence/absence data were correlated to physiographic covariates (e.g. cell statistics of bathymetry and slope) obtained from GEBCO (https://www.gebco.net/data_and_products/gridded_bathymetry_data/).

By means of GIS tools, it was possible to calculate the sea bed slope, which is another robust predictor for of the presence probability of the target species.

The assessment was done in terms of PUHA (Potentially Usable Habitat Area) which was calculated for the fin whale on the basis of the species habitat suitability, HS.

The PUHA calculated was then overlapped with the noise maps and the habitat status was assessed by calculating the fraction of the investigated area that was above LOBE and therefore significantly impacted by noise, and then comparing this fraction to the tolerable threshold of 20% (Step 8). The tolerable threshold refers in fact to the 20% of habitat that is exposed to average noise levels above LOBE (Figure 6).

In the example given, only the 0.08% of the fin whale PUHA is exposed to levels above LOBE. The status of the fin whale habitat within the IMMA is therefore considered tolerable.

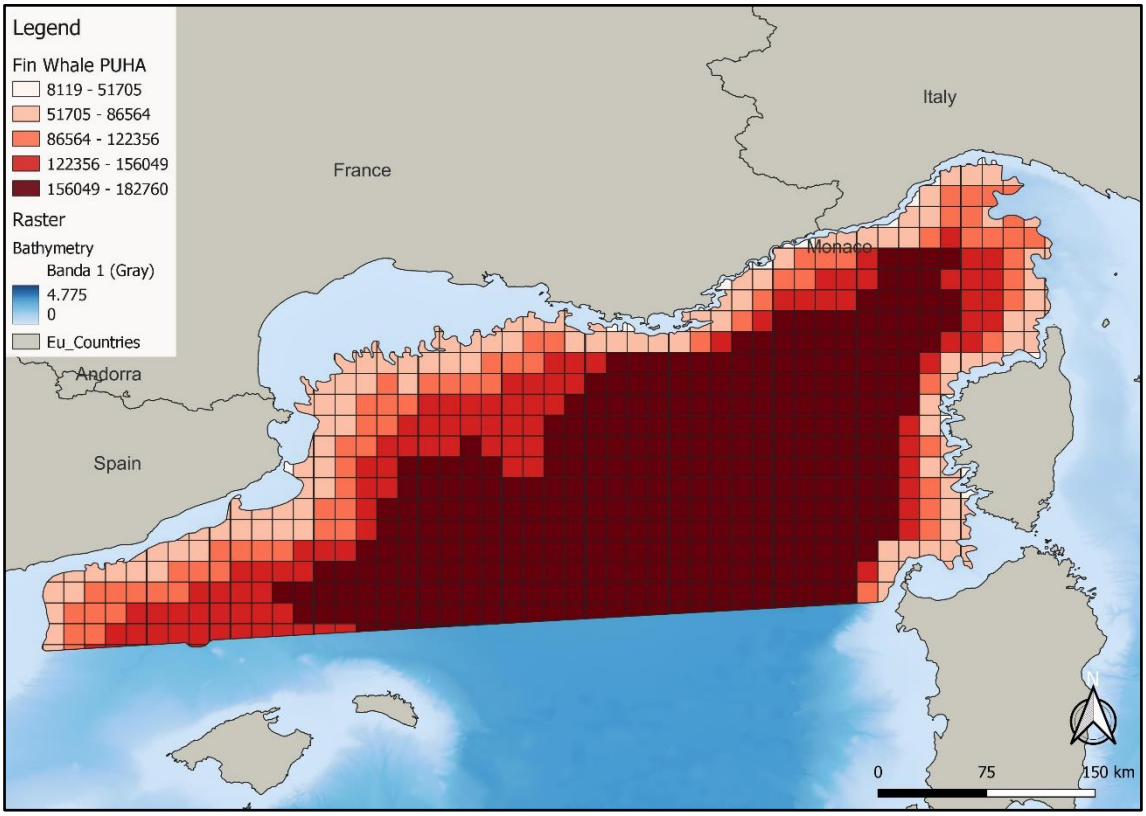

Figure 6. Habitat status assessed in terms of PUHA for fin whale (km²).

Thus, having determined that the status of the habitat is tolerable, it can be concluded that the GES is maintained (Step 9).

Extending the study area to the whole Western Mediterranean Sea area shows how the percentage of impacted habitat changes. The number of impacted cells, exposed to noise levels greater than or equal to 100 dB re 1 µPa at 63 Hz, is much larger than in the IMMA area (Figure 7 and figure 8). Overlapping the noise map with the fin whale PUHA in the western Mediterranean Sea, makes the percentage of PUHA exposed to levels above 100 dB to rise to 3%. However, the status of the habitat can still be considered tolerable.

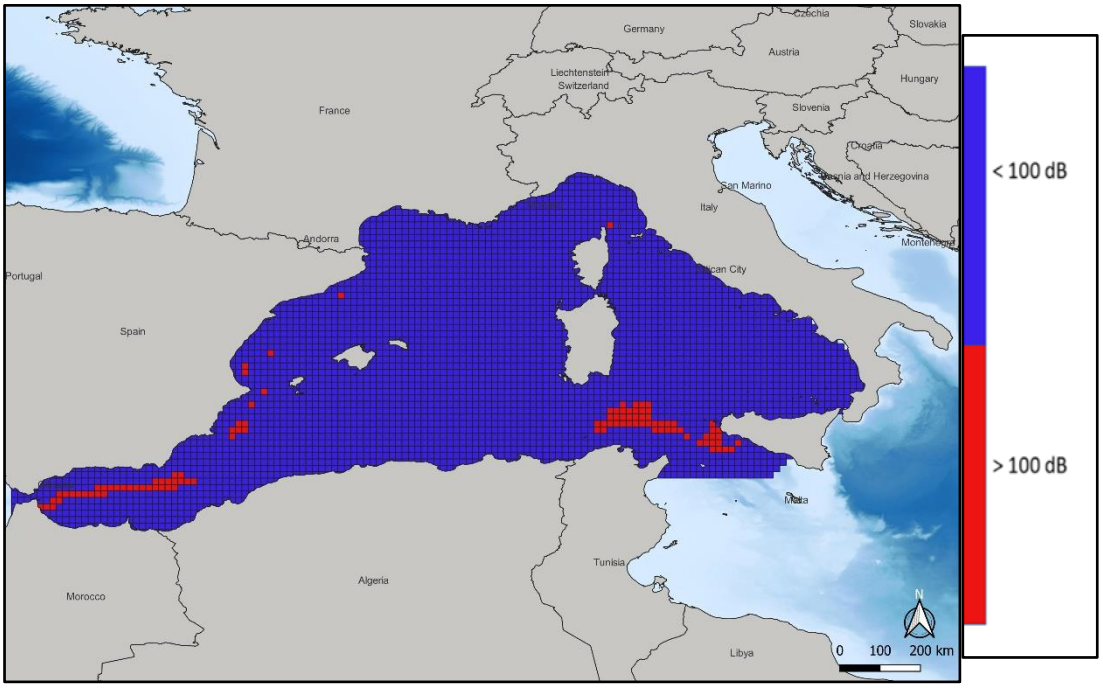

Figure 7. Assessment conditions of individual grid cells: blue cells represent grid cells which are not significantly affected by noise levels higher than LOBE while the red cells represent grid cells which have noise levels significantly higher than LOBE.

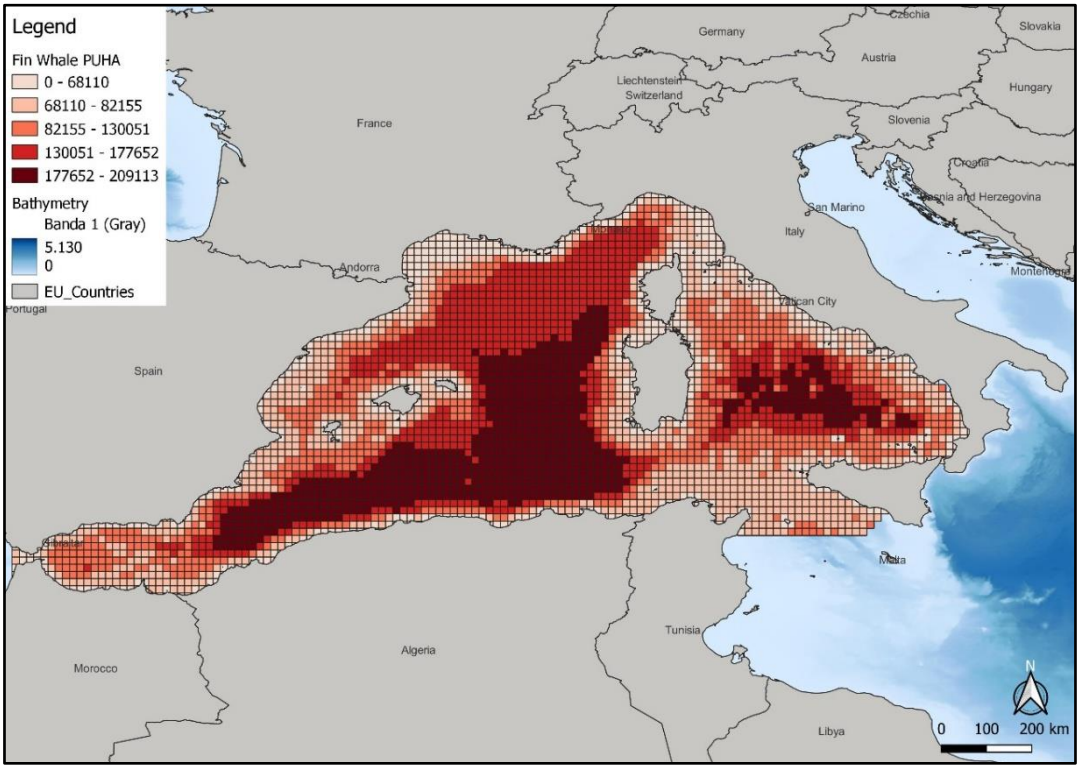

Figure 8. Fin whale Potentially Usable Habitat Area (PUHA, km^2) in the Western Mediterranean Sea.

5.2. D11C1 assessment for GES definition in the IMMA area.

The Western Mediterranean IMMA was also assessed for D11C1. The methodology for assessment of descriptor D11C1 requires also information on the habitat of noise-sensitive species, making it possible to assess the risk of negative impacts on the species populations. As for D11C2, the methodology requires the quantification of the extent of the species habitat that is above the Level of Onset of Biological Effects (LOBE) (TG Noise, DL2) although the thresholds concerning impulsive noise are different being 10% of impacted habitat over the annual scenario and lower than 20 over the daily scenario.

The assessment for impulsive noise in the IMMA was made using the data available in the INR-MED dataset, containing the data reported by the Contracting Parties to the ACCOBAMS for the Mediterranean Sea region. The attempt was to consider the same assessment period assumed for continuous noise. However, no data on impulsive noise sources were available for the month of August in 2019. So, to present an example of the combined assessment of D11C1 and D11C2, the month of November 2019 was therefore considered. A 20-km fixed buffer was used to approximate the noise propagation of impulsive noise sources (e.g., pile driving in ports). The 20 km buffer was assumed as it is used in the scientific literature (Merchant et al., 2017; Tougaard et al., 2009). The map (Figure 9) shows how these impulsive noises are present along the French coast and occupy a very low percentage (0.0006%) of the IMMA area.

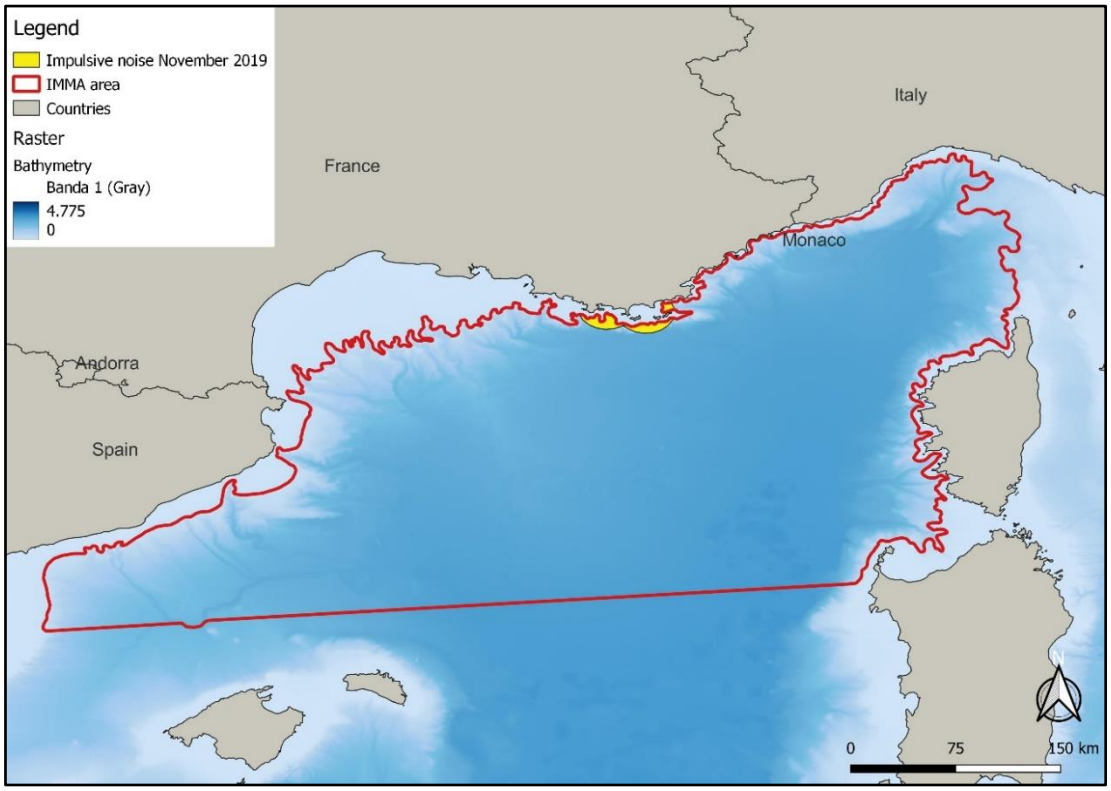

Figure 9. IMMA area showing impulsive noise events (yellow areas).

The habitat status is considered tolerable when 10% or a lower proportion of the target species habitat is impacted by impulsive noise above LOBE. The 10% is in fact considered sufficiently conservative and precautionary to be selected as the boundary between tolerable and non-tolerable status, i.e., as the threshold over which GES turns to no-GES. Thus, overlapping the areas impacted by impulsive noise with the fin whale PUHA, the resulting impacted area is the 2.08%. So, the status of the fin whale habitat is considered tolerable.

It might be relevant to assess both the noise descriptors for the GES assessment, as both types of noise may be present in the same time period in the area considered and consequently, cumulatively impact the habitat of the target species.

5.3. Black Sea region.

In this second case study, the methodology is applied to the Black Sea. The area is a closed basin with a great variety of habitats but relatively low biodiversity (Oguz and Ozturz, 2011, Selifonova, 2011).

Three cetacean species regularly occur in the Black Sea: the common Black Sea dolphin (*Delphinus delphis ponticus*) (Barabash 1935), the Black Sea bottlenose dolphin (*Tursiops truncatus ponticus*) (Barabash-Nikiforov 1940) and the Black Sea porpoise (*Phocoena phocoena relicta*) (Abel 1905; Sánchez-Cabanes et al., 2017). These species are distinct subspecies from those of the Mediterranean Sea, being endemic to the Black Sea. For this pilot study, the selected target species is the harbour porpoise, which regularly occurs in coastal areas, and it is therefore subjected to high underwater noise levels caused by the high vessel traffic density associated to the ports (Step 1). Again, the LOBE is set at 100dB re 1 µPa in the 63Hz frequency band considering the behavioural disturbance. (Step 2).

The current condition was modelled as in the Mediterranean Sea example: the frequency band is 1/3 octave centred on 63Hz was considered, with a spatial resolution of 10'x10' assuming the average monthly shipping density (Step 4). The temporal analysis window to assess the state of the habitat was set to 1 month (Step 3). A continuous noise map was generated by SHOM for the month of August of the year 2019 for the entire Black Sea basin as shown below (Step 6) (Figure 10).

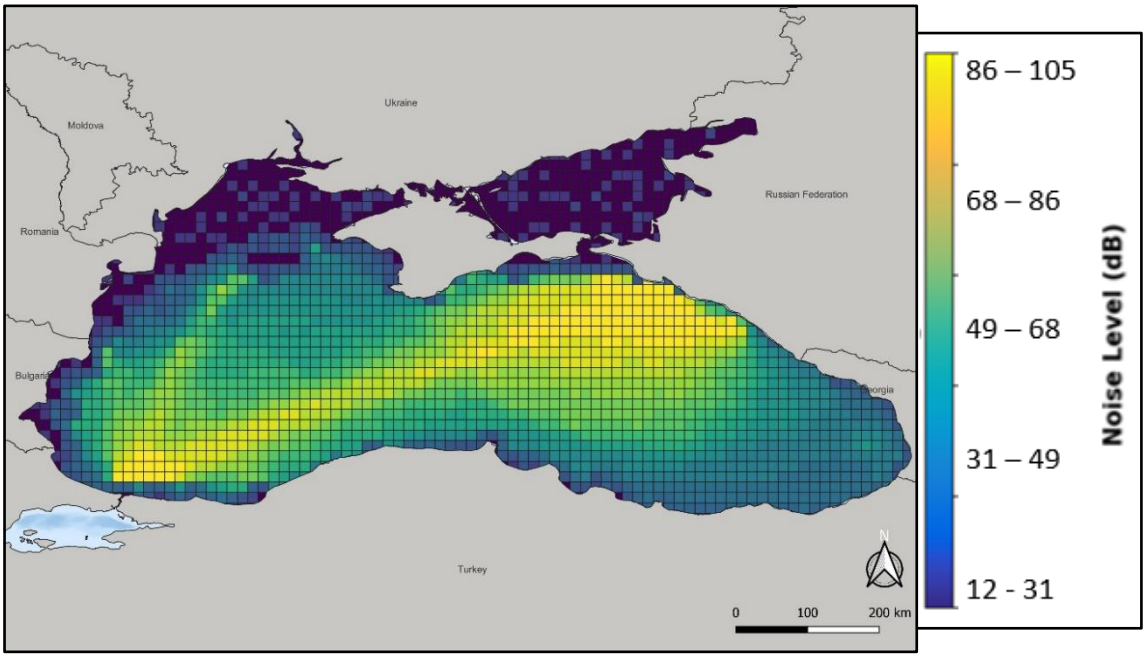

Figure 10. Shipping noise for one third octave band centred on 63Hz over a month (august 2019). In the Black Sea area, colour scale represents grid cell monthly average SPL.

The status of the grid cell was then evaluated by comparing on the average monthly scenario the predicted SPL and the LOBE set at 100 dB re 1 µPa. It can be observed that in most of the Black Sea basin the cells have noise levels below LOBE and are therefore not significantly impacted by noise (Step 7) (Figure 11).

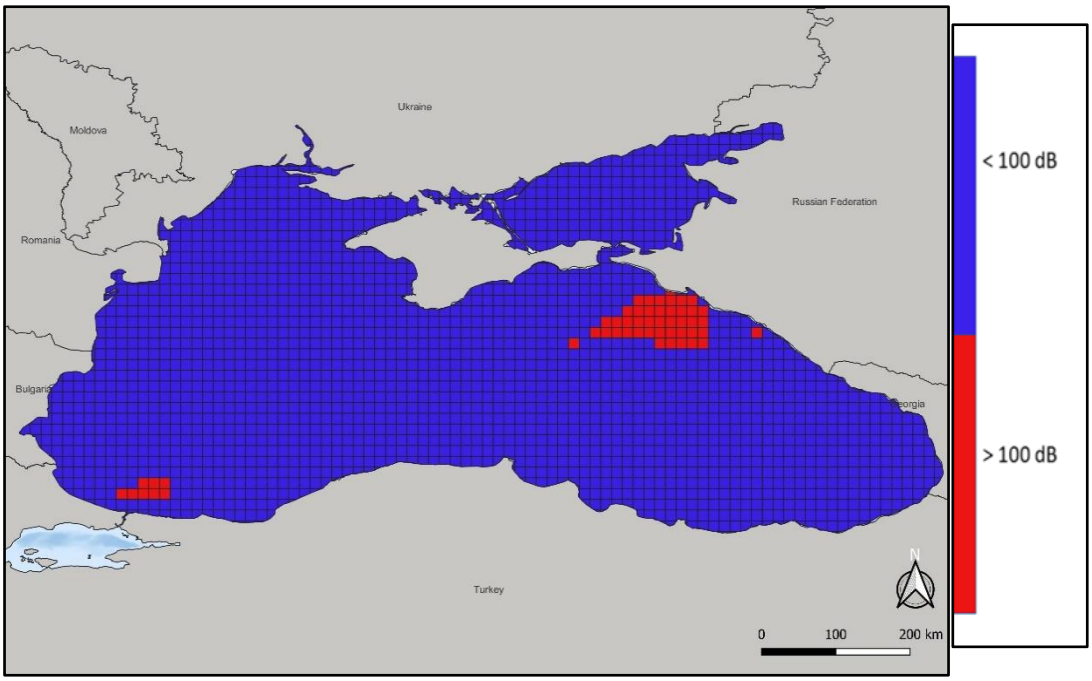

Figure 11. Status assessment of the individual grid cells in Black Sea: blue cells represent grid cells which are not significantly affected by noise (noise levels lower than LOBE) while the red cells are significantly affected by noise (noise levels higher than LOBE).

Also, in the case of the Black Sea the target species PUHA was calculated by means of presence/absence models fitted on the data collected through the EU-funded CeNoBS project, in collaboration with, and co-funded by ACCOBAMS under the ACCOBAMS Survey Initiative (ASI) (Paiu et al., 2021).

The noise map was overlaid to the PUHA calculated for the harbour porpoise allowing to assess the status of the habitat, and to calculate the area significantly affected by noise (Step 8). Also, in this example, only the 3% of the harbour porpoise PUHA is exposed to noise levels above 100 dB, (LOBE) so well below the tolerable threshold of 20%.

So, the status of the target species habitat is tolerable (Figure 12).

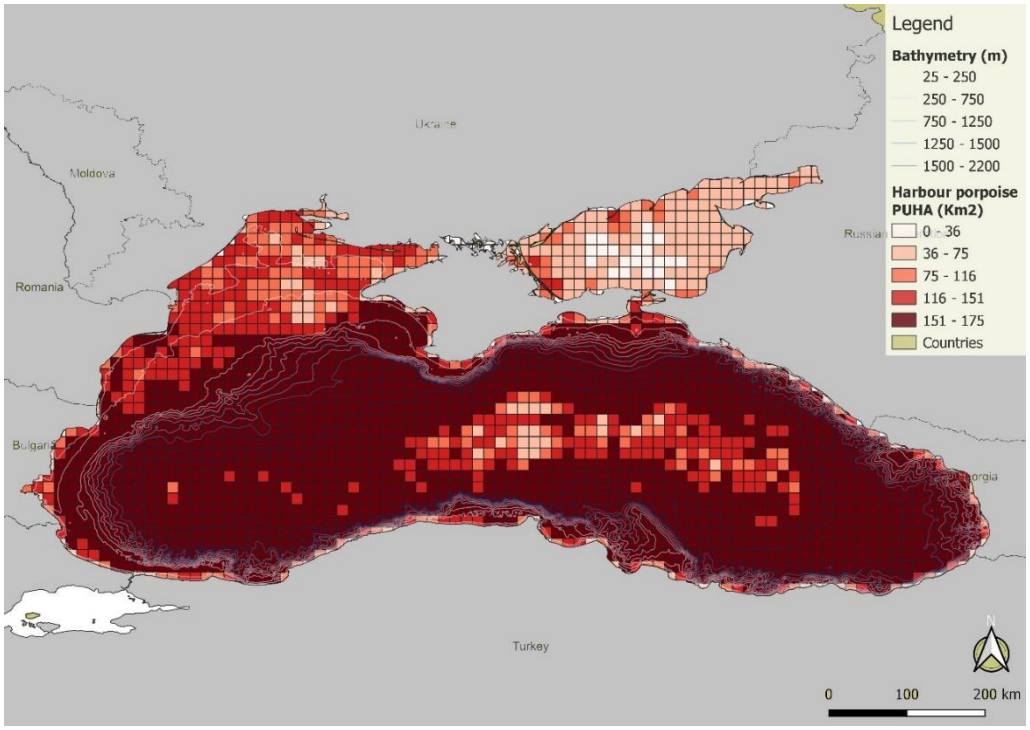

Figure 12. Habitat status assessed in terms of PUHA for harbour porpoise (km^2) in the Black Sea.

The table below shows also the percentages of PUHA exposed to levels above 100 dB re 1 µPa it respects to bottlenose dolphin and common dolphin, when applying the same methodology. For all species, when LOBE is set to 100 dB re 1 µPa, the percentage of impacted habitat does not exceed the 10% threshold.

Species	Total PUHA (Km^2)	PUHA exposed (Km^2)	% PUHA exposed
Bottlenose dolphin	180.908	8.385,4	4,63%
Common dolphin	231.156	7.823,7	3,38%

Table 1. Percentages of PUHA exposed to two different dolphin species.

6. Gaps in the applicability of the methodology and definition of the GES.

The TG Noise developed the proposed methodology to describe D11 descriptor thresholds (D11C1 impulsive noise and D11C2 continuous noise) as well as the definition of GES to ensure that anthropogenic noise levels do not exceed levels that adversely affect marine animal species. The TG Noise recommends that MS continue to carry out sound monitoring programs to ensure not only more data but also higher data quality. In addition, it is advisable to fill existing knowledge gaps on indicator species, but also on the entire marine ecosystem by continuing to cooperate to provide options for setting thresholds. This is important since the assessment of GES is closely related to the chosen values of duration and tolerable area, so it is crucial that the choice of parameters is done in a logical manner to ensure an adequate assessment of ecosystem conditions.

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