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ACCOBAMS Proposal on common indicators related to EO11

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ECOLOGICAL OBJECTIVE 11: ENERGY INCLUDING UNDERWATER NOISE

1. Introduction

Anthropogenic energy introduced by human activities into the marine environment includes sound, light and other electromagnetic fields, heat and radioactive energy. Among these, the most widespread and pervasive is underwater sound (Dekeling et al., 2013). Sound energy input can occur at varying spatial and temporal scales. Anthropogenic sounds may be of short duration (i.e. impulsive) or be long lasting (i.e. continuous). Sound transmission in the marine environment is very variable. Lower frequency sounds can travel far (tens to thousands of kilometres, as demonstrated with the ATOC experiments) whereas higher frequency sounds transmit less well in the marine environment (hundreds of meters to few kilometres). Sources of marine noise pollution include ship traffic, oil and gas exploration and exploitation, industrial and military sonar use, telemetry devices and acoustic modems, the use of experimental acoustic sources, undersea explosions, and finally offshore and inshore industrial construction works. Such activities are growing throughout the Mediterranean.

Marine organisms can be adversely affected both on short and long timescales (and include acute or chronic and temporary or permanent effects). Adverse effects can be subtle (e.g. temporary reduction in hearing sensitivity, stress effects causing reduced immunity), or more obvious (e.g. injury, death). The former may be difficult to observe and evaluate while the latter may in some circumstances be related to specific sound exposures. Management concern is primarily associated to the negative effects of noise on sensitive protected species, such as some species of marine mammals, though there is growing awareness that an ecosystem-wide approach also needs to be considered.

In the framework of the UNEP/MAP, the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention) defines pollution as follows: "*Pollution" means the introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results, or is likely to result, in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of seawater and reduction of amenities* (article 2-a). With regard to assessment and monitoring purposes, underwater noise is concretely being considered by the Contracting Parties to the Barcelona Convention for the first time under the ongoing implementation of the Ecosystems Approach process (**Decision 17/6**). Eleven Ecological Objectives (EO), and respective operational objectives and indicators have been agreed for the Mediterranean through **Decision 20/4** during the COP 17. Indeed, following the definition contained in the Decision 20/4, the EO11 is achieved when **noise from human activities causes no significant impact on marine and coastal ecosystems**. However, during the last Meeting of Contracting Parties (COP 18, Istanbul, 2013), **Decision 21/3** provided a specific list of descriptions of good environmental status and targets for the other EOs, contrary to EO11, which was not taken into account in this Decision.

The present document outlines the importance of assessing and monitoring noise in the Mediterranean, and describes the issues related to the choice of indicators, with a view to bring forward the work carried out so far by UNEP/MAP, and in coherence with other international legal frameworks operating in the area (such as ACCOBAMS and the European Union Directives).

1.1. Underwater noise in the Mediterranean Sea

The Mediterranean basin is an almost enclosed sea area highly exploited by humans, where all the aforementioned noise-producing human activities take place on a regular basis. Some features belonging specifically to the Mediterranean region need to be taken into account while addressing underwater noise impacts:

- The presence of highly sensitive and/or endangered species
- The heavy human development of the coastal region

It has been demonstrated that the use of mid-frequencies military sonar is the cause of several mass stranding events of Cuvier's beaked whales occurring along the coasts of the Mediterranean Sea during the last 20 years at least. No such correlation with strandings has been demonstrated in relation to other impulsive sources such as seismic airguns, although there is concern that such sources may play a role in increasing stress on marine fauna. It should be remembered as well that the Mediterranean harbours one of the most critically endangered mammal populations in the world, i.e. the Mediterranean Monk Seal. Further, based on recent IUCN assessments, population trends of protected cetacean species are decreasing (e.g. the bottlenose dolphins and sperm whales, IUCN 2012).

Several international legal frameworks addressing environmental protection and conservation recognise noise as a pressure factor that need to be assessed, monitored and where necessary mitigated. In this context, the Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic area (ACCOBAMS) is concretely working toward a wide adoption of operational measures aimed at mitigating the impacts of noise on marine mammals. The main tools include:

- ACCOBAMS Resolution 4.17 (*Guidelines to address the impact of anthropogenic noise on cetaceans in the ACCOBAMS area*, adopted by Parties in 2010), in which operational measures and procedures are outlined for each noise-producing human activity;
- *Guidance on underwater noise mitigation measures* (ACCOBAMS, 2013), a practical document aimed at guiding industrial companies in the implementation of procedures to reduce the risk of inducing acoustic impacts.

2. The choice of indicators for monitoring and assessing anthropogenic underwater noise

In terms of the effects of noise, underwater sounds can be classified as impulsive or continuous acoustic signal. It is well known that high powered impulsive noise may cause direct acute effects such as hearing loss, tissue damages and death to individuals of sensitive species like cetaceans. It may also cause permanent effects, such as when animals are displaced permanently from an important feeding area. Furthermore, continuous noise entails a chronic exposure mainly associated with behavioural changes potentially leading to negative effects at the population level over time. Hence **relevant indicators should be developed in order to consider, and appropriately manage, these two categories of noise**. Besides the types of sound (impulsive or continuous), the frequency emission spectrum of acoustic signals is relevant for designating indicators, as distance travelled by sound waves depends on the frequency. Furthermore, marine species have different frequency sensitivities to sounds. Therefore, **frequencies should be also considered as a determining factor**.

In order to be in full coherence with the European Union (EU) Marine Strategy Framework Directive (MSFD) and to harmonise measures, it is proposed that the base for developing an assessment strategy (and thus indicators) be the guidance for implementing the Descriptor 11 of the MSFD (Dekeling et al, 2013; Ferreira et al, 2013). This guidance is already used in part of the Mediterranean region (EU Countries bordering the area). Further, the MSFD explicitly give instructions to Member States to apply an ecosystem-based approach to the management of human activities in order to attain the GES. With the Commission Decision 2010/477/EU, two indicators are retained addressing low and mid frequency impulsive sound and low frequency continuous sound.

Concerning low and mid frequency impulsive sound, it should be clear that this indicator, according to the basic principle of the MSFD, addresses the ecosystem rather than individual animals or species, and the cumulative impact of activities, rather than that of individual projects or programmes. Such concepts can be applied to the objectives of the UNEP/MAP and in the framework of the EcAp process. Hence, impulsive noise can be monitored by setting up a **register of anthropogenic activities** which use sound sources exceeding a certain source level threshold. By knowing the date and location of such activities, **the proportion of days within a given period, and over a given geographical scale, in which activities generating impulsive sounds (as defined) take place** can be computed, monitored and managed. An additional proposal could be to introduce field measures to verify the data to be recorded in the register of impulsive sources.

With regards to the indicator for ambient noise, the primary objective thereof should be **to detect a trend in sound levels over a given temporal scale, considering a consistent range of frequencies**. The MSFD recommends monitoring ambient noise levels, using simple averaging methods of sampling units over a year in the 63 and 125 Hz third-octave frequency bands. However, for the UNEP/MAP needs, further options could be proposed in terms of both frequency range and temporal scale. As a first approach, the frequency range of interest could be expanded up to 1 kHz, as many fish and baleen whales may be covered by reporting energy up to 1 kHz. Moreover, ships are known to produce noise in a much wider band than the two octaves indicated by MSFD. Additionally, if we are concerned about GES for sensitive and vulnerable toothed whales, it would be relevant to include higher frequency bands, i.e. nearer their best hearing. In all cases, a special concern should be given to shipping noise as this is the major contributor to ambient noise level in the marine environment. In this regard, it seems important to understand the contribution of each ship to the general noise picture in order to classify ships according to their noise impact and hence address priorities for operational targets (and mitigation measures). This can be done by combining noise measures with AIS tracking of ships passing close to the measuring point (Pulvirenti et al., 2014 in press). Also it could be useful to introduce some noise measurement option for every underwater infrastructure as it is already the case with the EMSO network of infrastructures (Favali et al., 2013). Finally, as a strong seasonal component exists in levels of some human activities (e.g. recreational craft) throughout the Mediterranean Sea, and given that these aspects have never been deeply studied, a finer temporal scale for averaging could be proposed (e.g. seasonal/trimester).

3. Monitoring Strategy

The monitoring strategy depends on several factors, including the types of noise sources to be monitored, the choice among in-situ measurements or models and mapping or a combination, the spatial and temporal scales, the frequency and location of sampling sites, the definition of baseline values and thresholds, the sound metrics to compute results and the summary statistics to show such results. Such variability is reflected in different monitoring strategies addressed in the following paragraphs.

3.1. Impulsive noise indicator (11.1.1)

Taking the UNEP/MAP COP17 definition (2012), the indicator for impulsive noise is defined as follows: *Proportion of days and geographical distribution where loud, low and mid-frequency impulsive sounds exceed levels that are likely to entail significant impact on marine animals*.

In order to be in coherence with the definition from TSG Noise, impulsive sounds are to be interpreted as **source levels or suitable proxies of anthropogenic sound sources**. Issues related to the implementation of monitoring of impulsive noise are discussed in the following sections.

3.1.1. Sound sources

There is general agreement on sound sources to be monitored. However, it is not likely that the activities using low noise sources contribute to a non-achievement of GES. Hence, impulsive sound sources to be assessed, and included in the register, are those which exceed a certain source level threshold. The TSG Noise proposes such thresholds, which could be used as well for the EO11. The list hereafter describes the sources of impulsive noise together with the recommended thresholds[1] for inclusion in the register:

- Explosive ($m_{tnt\text{-}eq}$ > 8 g)
- Airgun ($SL_{z\text{-}p}$ > 209 dB re 1 µPa m)
- Impact pile driver (no thresholds, all activities are included in the register)
- Low mid-frequency sonar (SL > 176 dB re 1 µPa m)
- Low mid-frequency acoustic deterrent devices (SL > 176 dB re 1 µPa m)

In order to establish the register, for each of the above activities, the basic information required to derive the number of days in which activities using impulsive sources occur in an area, is:

- Position data (geographic position (lat/long), licensing block/area)
- Date of operation
- Source properties: Source level or proxy

3.1.2. Spatial scales

The spatial distribution of impulsive sound sources can be easily represented under the form of cartography by means of a spatial grid. Such a grid could be used for the following tasks:

- Collecting and storing data
- Presenting cartographic data
- Assessment purposes
- Other management actions

Thus, grid cell size needs to be defined. Options considered by the TSG Noise are based either on administrative or biological reasoning. For instance, in the UK, data concerning seismic surveys are registered in standard hydrocarbon licensing blocks that are 10 minutes latitude by 12 minutes longitude. A different option could be to base the grid on estimated impact. Based on studies carried out in the North Sea, the reported range of displacement effects for harbour porpoises from pile driving has been of the order of 20 km (Tougaard et al, 2012). This means an area of about 1250 km^2. This implies that if in a grid cell of about the same surface over which a pile driver is active, then it can be assumed that porpoises are absent in that cell, and hence the potential habitat loss can be estimated. The problem with this is that harbour porpoises, which presently represent the best reference about displacement effects, are absent in the Mediterranean Sea. Such information for Mediterranean species should be gathered. An additional issue is the great variability in the oceanographic features of the Mediterranean Sea and its coastal region, which is in contrast with the relatively homogeneous environment of the North Sea where data about porpoise displacement were achieved. Extrapolating such information from a zone to another could be problematic in the Mediterranean. On the other hand, it could represent a starting point in absence of better data.

[1] Units used for source level thresholds for inclusion in the register are described in ANNEXE II

3.2. Ambient noise indicator (11.1.2)

UNEP/MAP COP17 (2012) define the indicator for ambient noise as follows: *Trends in continuous low frequency sounds with the use of models as appropriate*. Issues related to the implementation of a monitoring of ambient noise are discussed in the following sections.

3.2.1. In-situ measurements, models and noise mapping

The use of in-situ acoustic measurements is essential for:

- Gathering fundamental field data to establish information on the ambient noise in a given location
- Reducing uncertainty on source levels to be used as the input for modelling
- Increasing evidence base to improve management decisions

The use of models is essential for:

- Reducing the time required to establish a trend, with a fixed number of measurement stations (the expected trend in shipping noise, based on observations in deep water, is of the order of 0.1 dB/year; and therefore it takes many years, possibly decades, to reveal such small trends without the help of spatial averaging)
- Reducing the number of stations required to establish a trend over a fixed amount of time (similar reasoning to above), therefore reducing the cost of monitoring
- Helping with the choice of monitoring positions and equipment (selecting locations where the shipping noise is dominant as opposed to explosions or seismic surveys being dominant).
- Producing noise maps, which are a valuable tool to quickly understand the ensonification levels over large areas, and a fundamental tool to calculate the extent of potentially impacted (non-GES) areas
- Predicting future scenarios and therefore testing different noise reduction strategies, e.g. by answering simple questions such as what happens if we reduce by XX dB the noise of 1% (or 20% etc.) of the circulating ships? Will this be a significant reduction?

3.2.2. Location of sampling sites

Recommendations for the placement of measurement devices are listed as follows:

- Monitoring in both high traffic and low traffic areas, also searching and including spots where the noise is supposed to be the lowest
- Monitoring may be more cost effective if existing oceanographic s;tations included noise monitoring along with the other oceanographic variables already being monitored;
- Consider local topography and bathymetry effects e.g. where there are pronounced coastal landscapes or islands/archipelagos it may be appropriate to place hydrophones on both sides of the feature;

- As far as possible avoid locations close to other sound producing sources that might interfere with measurements e.g. oil and gas exploration or offshore construction activities. Areas of particularly high tidal currents may also affect the quality of the measurement.

3.2.3. Frequency range issues

MSFD indicator 11.2.1 specifies narrow frequency bands where noise from shipping is most likely to dominate over other sources, i.e. they are chosen to be most representative of the environmental pressure from shipping noise. These are the third-octave band centred at 63 Hz and 125 Hz.

For the purposes of the UNEP/MAP, an approach considering a wider range of frequencies could be considered. For example, noise could be assessed summing the power contained in the third-octave bands centred at frequencies 32, 63, 125, 250, 500, and 1000 Hz. This could be more relevant from an ecological point of view, since marine fauna like baleen whales and fish are sensitive to low frequency sounds. Additionally, mid-frequency bands could be considered (2-10 kHz), as the Cuvier's beaked whale, one of the species known to be highly sensitive to noise in this frequency band, is found in several areas of the Mediterranean Sea in relatively high abundance. Indeed, besides being often impacted by mid-frequency sonar exercises (Podestà et al., 2006), it has been highlighted that noise from shipping could disrupt the foraging behaviour of Cuvier's beaked whales (Aguilar de Soto et al, 2006).

3.2.4. What metrics and summary statistics?

The metric recommended for calculating ambient noise levels of the Descriptor 11 of the MSFD is the level in decibels (dB) of the squared sound pressure expressed in units of dB re 1 μPa. Such a metric can be adopted for the ambient noise indicator of the EO 11.

With regards to summary statistics, PART III of the last available report from TSG Noise (Ferreira et al, 2013) widely discusses the relevance of different averaging methods for calculating the value in decibels of the squared sound pressure over a period (1 year for the MSFD objectives). TSG Noise supports the use of the arithmetic mean of the sample units, as this is robust to changes or differences in sample duration. In addition, values in percentile appear very useful to convey information about how much time noise levels are maintained. **Figure 1** shows an example of 3 years of measurement in the 63 Hz third octave band made at the CTBTO Cape Leeuwin station (Dekeling et al, 2013).

While the arithmetic mean could be at a level considered as being a GES, a certain percentile (e.g. the 95^{th} percentile) could exceed some threshold level considered as dangerous. This would mean that in a 5% of the time, during the averaging period, levels are not a GES. Hence, one could ask whether this is acceptable or not. In conclusion, both statistics (mean and percentile values) should be employed to evaluate an area being a GES or not.

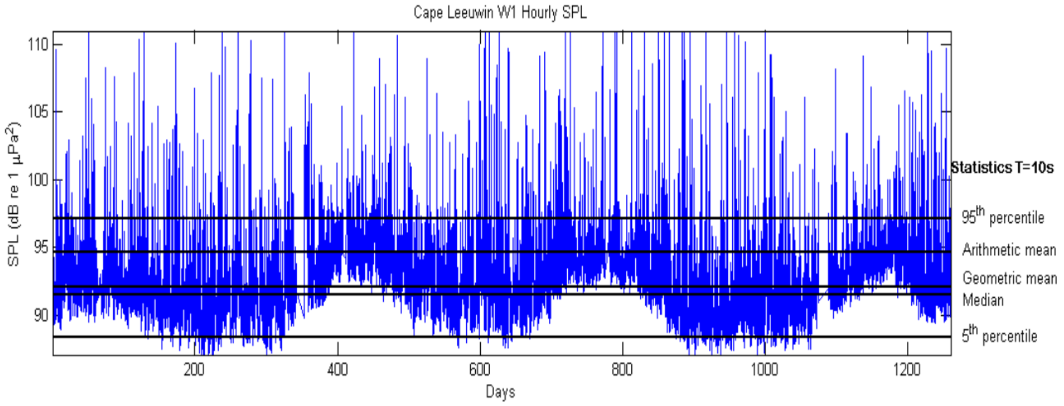

Figure 1 Monitoring noise in the 63 Hz third-octave band with different summary statistics over three year measurements in cape Leuween (taken from Dekeling et al, 2013).

3.3. Approaches for the achievement and maintenance of GES

For both indicators (impulsive and ambient noise), three different approaches can be implemented for GES determination:

- Setting thresholds
- Setting a downward trend in indicator values
- Using both thresholds and trends

Problems with both indicators are the lack of knowledge on baseline conditions, and on the effects of noise on the environment. Considering indicator 1, the number of days within a given period in which the use of loud impulsive noise sources occur across a sea area is unknown in the Mediterranean region. Further, it is unknown what value of this indicator could be considered as a threshold for GES achievement. The same considerations apply to indicator 2: knowledge about ambient noise levels throughout the Mediterranean is very limited, and the effects of noise are not sufficiently known to determine whether existing levels are too high, or if GES is being achieved.

As stated in the last TSG Noise report, where a system is assessed or suspected not to be at GES due to noise, a trend towards a reduction in noise producing activities as well as reducing ambient noise levels would be certain to be moving towards GES. One approach to setting targets would be to start with a trend and then move towards limits (thresholds) as more data become available on the relationship between pressure, state, and impacts. On the other hand, this is likely to take many years and inhibit the achievement of GES in the required timescales. Another approach would be to set precautionary thresholds for both indicators, using the full range of tools available to enable noise reduction across all sectors. This way, GES would be more probably achieved in the required timescales.

ANNEX I
Data sheet for Ecological Objective 11: Energy including underwater noise

ECOLOGICAL OBJECTIVE 11: **noise from human activities causes no significant impact on marine and coastal ecosystems**

Indicator N°	Description (Decision COP17)	Operational objective (Decision COP17)	State/Pressure	Parameter description	Assessment method	Guidelines	Reference method	Recommendations/ Needs
11.1.1	Proportion of days and geographical distribution where loud, low and mid-frequency impulsive sounds exceed levels that are likely to entail significant impact on marine animals	11.1 Energy inputs into the marine environment, especially noise from human activities is minimized	Pressure	**Pulse-block days** (the number of days per block in which activities using loud source levels occur)	Register of occurrence of impulsive noise-producing activities	Monitoring Guidance for Underwater Noise in European Seas (Dekeling et al, 2013)	Method proposed by the TSG Noise for impulsive noise (Dekeling et al, 2013)	
11.1.2	Trends in continuous low frequency sounds with the use of models as appropriate	11.1 Energy inputs into the marine environment, especially noise from human activities is minimized	Pressure	**Sound Pressure Level (dB)** (Arithmetic mean over a period) **Percentile SPL (dB),** meaning how much time certain threshold (dB) are exceeded	In-situ measurements Models and mapping	Monitoring Guidance for Underwater Noise in European Seas (Dekeling et al, 2013)	Method proposed by TSG Noise for ambient noise (Dekeling et al, 2013)	

ANNEX II
Data sheet for Ecological Objective 11: Energy including underwater noise

Units used for source level thresholds for inclusion in the register

Sources other than sonars and acoustic deterrents are rarely characterised by their source level (expressed in dB). For such sources it is convenient – and for some sources, essential – to find a proxy that is more widely used and still makes sense. Quantities proposed for thresholds for inclusion of a noise source in the register are described below:

- **Sonar** and other non-pulse sounds of short duration (including **acoustic deterrents**): Source level (SL) in dB re 1µPa.

- **Explosions**: the strength of explosions is widely reported in terms of TNT equivalent charge mass (m_{TNTeq}), meaning the mass of TNT that would release the same amount of explosive energy.

- **Seismic Airgun**: the strength of airgun arrays is widely reported in terms of their far-field source signature (product of distance from the airgun array and far-field sound pressure at that distance, usually in the vertical direction, immediately beneath the array), the maximum magnitude of which is known as “source strength” A (Dragoset, 2000). This quantity is related to the zero-to-peak source level (SL_{z-p}) according to:

  SL_{z-p} = 10 log10 (A2/(uPa^2 m^2)) dB

  Therefore, the SL_{z-p} value (expressed in dB re 1 µPa) can be used as threshold level for the purposes of indicator 11.1.1.

- **Pile driving**. The strength of impact pile drivers is sometimes reported in terms of source level, but doing so leads to problems of interpretation. Instead, hammer energy (expressed as a value in Joules) is proposed as a suitable proxy.

Thresholds of source levels or proxies have been chosen in order to quantify the “significant impact” described in the definition of indicator 11.1.1. The TSG Noise interprets “significant impact” as “displacement, i.e. severe and/or sustained and/or long-term avoidance of an area” (Ferreira et al, 2013). Therefore, a decision has to be taken about the range or area within which causing displacement can be considered to be significant. In line with TSG Noise choice, a range of 1000 m can be used as initial value. Hence, an activity inducing **noise levels exceeding a certain behavioural response threshold 1000 m far from source is considered as causing significant impact (i.e. displacement as defined above)**. This finally means that the noise source has to be taken up in the register. The last issue is what behavioural response threshold are considered in this decisional process. Ferreira and co-authors (2013) provide the peer-reviewed references used to establish such response thresholds. Once theses behavioural response thresholds has been chosen, source levels, and hence proxies where appropriate, have been calculated via a transmission loss model (for further details see Ferreira et al, 2013). This is the value that is recommended as threshold for inclusion of noise sources in the register.

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