European Marine Strategy Framework Directive

Monitoring Guidance for Underwater Noise in European Seas

PART I - EXECUTIVE SUMMARY & RECOMMENDATIONS

MSFD Technical Sub-Group on Underwater Noise

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SUMMARY

The Marine Strategy Framework Directive (MSFD) requires European Member States (MS) to develop strategies for their marine waters that should lead to programmes of measures that achieve or maintain Good Environmental Status (GES) in European Seas. As an essential step in reaching good environmental status, MS should establish monitoring programmes for assessment, enabling the state of the marine waters concerned to be evaluated on a regular basis. Criteria and methodological standards on GES of marine waters were published in 2010 (Commission Decision 2010/477/EU). Two indicators were described for Descriptor 11 (Noise/Energy): Indicator 11.1.1 on low and mid frequency impulsive sounds and Indicator 11.2.1 on continuous low frequency sound (ambient noise).

As a follow up to the Commission Decision, the Marine Directors in 2010 agreed to establish a Technical Subgroup (TSG) for further development of Descriptor 11 Noise/Energy. TSG (Underwater) Noise in 2011 focused on clarifying the purpose, use and limitation of the indicators and described methodology that would be unambiguous, effective and practicable; the first report [Van der Graaf et al., 2012][1] was delivered in February 2012. Significant progress was made in the interpretation and practical implementation of the two indicators, and most ambiguities were solved.

In December 2011, EU Marine Directors requested the continuation of TSG Noise, and the group was tasked with recommending how MS might best make the indicators of the Commission Decision operational. TSG Noise was asked first to provide monitoring guidance that could be used by MS in establishing monitoring schemes for underwater noise in their marine waters. Further work includes providing suggestions for (future) target setting; for addressing the biological impacts of anthropogenic underwater noise and to evaluate new information on the effects of sound on marine biota with a view to considering indicators of noise effects.

The present document is **Part I** of the **Monitoring Guidance for Underwater Noise in European Seas** and provides MS with the information needed to commence the monitoring required to implement this aspect of MSFD. TSG Noise has focused on ambiguities, uncertainties and other shortcomings that may hinder monitoring initiatives and has provided solutions, and describes methodology for monitoring both impulsive and ambient noise in such a way that information needed for management and policy can be collected in a cost-effective way. TSG Noise has no doubt that further issues will arise once monitoring starts, but hopes the principles laid out in this guidance will help resolve these.

The Monitoring Guidance for Underwater Noise is structured, as follows:

- **Part I: Executive Summary & Recommendations**,
- Part II: Monitoring Guidance Specifications,and
- Part III: Background Information and Annexes.

Part I of the Monitoring Guidance is the executive summary for policy and decision makers responsible for the adoption and implementation of MSFD at national level. It provides the key conclusions and recommendations presented in Part II that support the practical guidance for MS and will, enable assessment of the current level of underwater noise.

Part II, is the main report of the Monitoring Guidance. It provides specifications for the monitoring of underwater noise, with dedicated sections on impulsive noise (Criterion 11.1 of the Commission Decision) and ambient noise (Criterion 11.2 of the Commission Decision)

[1] The 1st TSG Noise Report (27 February 2012) available online: http://ec.europa.eu/environment/marine/pdf/MSFD_reportTSG_Noise.pdf

designed for those responsible for implementation of noise monitoring/modelling, and noise registration.

Part III, the background information and annexes, is not part of the guidance, but is added for additional information, examples and references that support the Monitoring Guidance specifications.

1. INTRODUCTION TO UNDERWATER NOISE

There are many kinds of anthropogenic energy that human activities introduce into the marine environment including sound, light and other electromagnetic fields, heat and radioactive energy. Among these, the most widespread and pervasive is underwater sound. It is likely that the amount of underwater sound, and therefore associated effects on the marine ecosystem have been increasing since the advent of steam-driven ships, although there have been very few studies that have quantified these changes. The numbers of anthropogenic electromagnetic fields are increasing due to the increasing number of power cables crossing our seas but these emissions are relatively localised to the cables. Light and heat emissions are also relatively localised, but may have significant local effects (Tasker *et al*. 2010).

Sound energy input can occur on many scales in both space and time. Anthropogenic sounds may be of short duration (*i.e.* impulsive) or be long lasting (*i.e..* continuous); impulsive sounds may however be repeated at intervals (duty cycle) and such repetition may become diffuse with distance and reverberation and become indistinguishable from continuous noise. Higher frequency sounds transmit less well in the marine environment whereas lower frequency sounds can travel far. In summary, there is great variability in transmission of sound in the marine environment.

Marine organisms which are exposed to noise can be adversely affected both on a short timescale (acute effect) and on a long timescale (permanent or chronic effects). Adverse effects can be subtle (e.g. temporary reduction in hearing sensitivity, behavioural effects) or obvious (e.g. injury, death). These adverse effects can be widespread (as opposed to localised for other forms of energy) and, following the recommendations of Tasker et al (2010), in September 2010 the European Commission identified the main orientations for monitoring of underwater noise that should be used to describe Good Environmental Status (GES).

Two indicators were published for Descriptor 11 (Noise/Energy) of the MSFD 2008/56/EC in the EC Decision 2010/477/EU on criteria and methodological standards on GES of marine waters. These are: Indicator 11.1.1 on 'low and mid frequency impulsive sounds' and Indicator 11.2.1 on 'Continuous low frequency sound' (ambient noise). As a follow up to the EC Decision, the Marine Directors agreed to establish a technical sub-group (TSG) for further development of Descriptor 11 Noise/Energy. This report compiles the recommendations of TSG Noise. Text box 1 shows the extract of the EC Decision specifically for the indicators of Descriptor 11.

Text Box 1: Extract of the indicators for Descriptor 11 (Noise/Energy) from EC Decision 2010/477/EU

Descriptor 11: Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.

Together with underwater noise, which is highlighted throughout Directive 2008/56/EC, other forms of energy input have the potential to impact on components of marine ecosystems, such as thermal energy, electromagnetic fields and light. Additional scientific and technical progress is still required to support the further development of criteria related to this descriptor, including in relation to impacts of introduction of energy on marine life, relevant noise and frequency levels (which may need to be adapted, where appropriate, subject to the requirement of regional cooperation). At the current stage, the main orientations for the measurement of underwater noise have been identified as a first priority in relation to assessment and monitoring, subject to further development, including in relation to mapping. Anthropogenic sounds may be of short duration (e.g. impulsive such as from seismic surveys and piling for wind farms and platforms, as well as explosions) or be long lasting (e.g. continuous such as dredging, shipping and energy installations) affecting organisms in different ways. Most commercial activities entailing high-level noise levels affecting relatively broad areas are executed under regulated conditions subject to a license. This creates the opportunity for coordinating coherent requirements for measuring such loud impulsive sounds.

11.1. Distribution in time and place of loud, low and mid frequency impulsive sounds

- Proportion of days and their distribution within a calendar year over areas of a determined surface, as well as their spatial distribution, in which anthropogenic sound sources exceed levels that are likely to entail significant impact on marine animals measured as Sound Exposure Level (in dB re 1 µPa 2 .s) or as peak sound pressure level (in dB re 1 µPa peak) at one metre, measured over the frequency band 10 Hz to 10 kHz (11.1.1)

11.2. Continuous low frequency sound

- Trends in the ambient noise level within the 1/3 octave bands 63 and 125 Hz (centre frequency) (re 1µPa RMS; average noise level in these octave bands over a year) measured by observation stations and/or with the use of models if appropriate (11.2.1).

This report provides guidance to Member States for establishing monitoring programmes for these indicators of underwater sound. In this executive summary, only the *key* conclusions and recommendations are provided.

The TSG Noise conclusions and recommendations are further developed and specified in Parts II (Technical Specifications) and III (background information, examples and annexes).

2. TSG NOISE KEY CONCLUSIONS AND RECOMMENDATIONS

2.1 Monitoring Guidance for Impulsive Noise

This chapter contains the conclusions and recommendations provided by the TSG Noise for the establishment of monitoring programmes of **impulsive noise** as covered by the EU MSFD indicator "11.1. Distribution in time and place of loud, low and mid frequency impulsive sounds".

A basic principle of the MSFD is that it addresses the ecosystem rather than individual animals or species (consideration 5: the development and implementation of the thematic strategy should be aimed at the conservation of the marine ecosystems). This indicator addresses the cumulative impact of activities, rather than that of individual projects or programme (those are addressed by other EU legislation); effects of local/singular activities are not covered. This indicator alone is not intended, nor is it sufficient, to manage singular events, but Environmental Impact Assessments (EIA) can be used to assess, and where necessary, to limit the environmental impacts of individual projects.

Indicator 11.1.1 on low and midfrequency impulsive sounds:
The proportion of days and their distribution within a calendar year, over geographical locations whose shape and area are to be determined, and their spatial distribution in which source level or suitable proxy of anthropogenic sound sources, measured over the frequency band 10 Hz to 10 kHz, exceeds a value that is likely to entail significant impact on marine animals (11.1.1).

TSG Noise suggested that "considerable" displacement is the most relevant effect of loud low and mid-frequency sounds that can practicably be measured - this may lead to population effects and thus should be addressed by Indicator 11.1.1. "Considerable" displacement means displacement of a significant proportion of individuals for a relevant time period and at a relevant spatial scale. The indicator addresses the cumulative impact of sound generating activities and possible associated displacement, where effects may occur at the ecosystem level.

The initial purpose of monitoring impulsive noise is to quantify the pressure on the environment, by making available an overview of all loud impulsive low and mid-frequency sound sources, throughout the year, in regional seas. This will enable MS to get a reasonably complete overview of the occurrence of all the activities that produce the relevant sounds that place pressure on the environment, which has not previously been achieved. It will also make it easier to assess cumulative effects of the pressure on the environment (see First report of TSG Noise, Feb 2012).

TSG Noise recommends monitoring of indicator 11.1.1 by **setting up a register of the occurrence of these impulsive sounds**. This is the first step to establish the current level and trend in these impulsive sounds.

Airguns, pile-driving, explosives, and sonar working at relevant frequencies and some acoustic deterrent devices are the **most important sound-sources that should be considered for inclusion in the register**. Additional sources that could also be of concern include boomers, sparkers and scientific echo sounders. TSG Noise recommends thresholds for uptake in the register. Thresholds were derived that will ensure that *all* sources that have a *potential* for significant population level effect will be included in the register. However, the use of these (relatively low) thresholds will result in sources with a relatively low potential for significant

impact also being registered. TSG Noise concluded that there is a need for more detail in the register than just the day and location; of this additional information, the source level is the most important.

The **information required** to derive pulse-block days (the number of days that a certain threshold (pulse) is exceeded in an area (block)), are:

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

  Essential (minimum)
  - Source level or proxy;

Additional data will be beneficial for improved assessment - where available the following may also be recorded:

- Source spectra;
- Duty cycle;
- Duration of transmissions (and actual time/time period);
- Directivity;
- Source depth;
- Platform speed

It is possible that many operators (e.g. navies using sonar) may have concerns about releasing sensitive information. Where detailed information of source properties is requested it is proposed that source level may be recorded in bins (of e.g. 10 dB) rather than using a precise figure.

The **main aim of the registry** is to provide an overview of all loud sounds. If the registry leaves out certain sound sources it would not fulfil the aim of addressing cumulative effects of impulsive noise; it is therefore recommended that information on all sources should be included [see Van der Graaf *et al*., 2012]. TSG Noise therefore suggest that **data on explosives and military activities** (of which the sole purpose is defence or national security) **should also be included in the register**, but notes that this should be on a voluntary basis as this is a national policy issue.

TSG recommends that **a common register be set up at least on a Regional Sea level**, the format of which must ensure future compatibility. This cannot be conclusively decided until the register location and management are decided, but there are some factors that could be agreed upon, such as:

- Use of a common language (English)
- Use of a common format for date in accordance with the appropriate standard (ISO 8601) (YYYY-MM-DD or YYYYMMDD)
- Use of a common format for position (latitude and longitude, decimal degrees)
- Use of a common map projection (unprojected data – WGS84)
- Use of a common template (i.e. setting out the order in which information is recorded)

For some of the data (e.g. seismic survey data) the use of a grid (based on standard licensing blocks) may be practicable to collect (part of) the data on impulsive noise. Member States may choose to use such a grid to organise data (for instance, use the above-mentioned blocks to store data instead of the actual positions of a piling activity). Member States may also choose to use such a grid for other purposes e.g. presenting data, assessment purposes and for future management action.

In such cases, the actual choice of grid definition, and the size of the grid cells, is a choice that should be made by Member States and this can be based on practical considerations, e.g. where data are registered in standard hydrocarbon licensing blocks. For easier interpretation of results in a common register for a regional sea, TSG Noise would recommend one standard grid size to be used by Member States.

If the grid chosen by Member States is to be used for assessment purposes, it should be noted that it may not be of the same spatial scale as the area actually affected by the noise source. The number of days (or proportion/percentage of a longer period) over which activities occur should not necessarily be interpreted as a direct measure of habitat loss (holes in distribution). A correction factor could be applied when comparing results that are generated using different grid sizes, or if the grid sizes are not appropriate for definitions of targets. There may also be issues for grid cells in coastal areas or at boundaries between Member States. For these blocks some additional considerations may apply.

Minimum noise thresholds have been defined for low and mid-frequency sources as a basis for including sources in the register. For background and explanation of these values see Part III of the Monitoring Guidance (chapter 2.1)

For impact pile-drivers no minimum threshold should be used and all pile-driving activities should be registered.

For sonar, airguns, acoustic deterrents and explosives, minimum thresholds should be used for uptake in the registers. The generic source level (SL) threshold for inclusion in the register for non-impulsive sources is 176 dB re 1 µPa m, whereas the threshold for inclusion of impulsive sources is an energy source level (SL_E) of 186 dB re 1 μPa^2 m^2 s. For airguns and explosives it is more convenient to convert these to proxies of zero to peak source level ($SL_{z\text{-}p}$) and equivalent TNT charge mass (m_{TNTeq}), respectively.

The recommended thresholds for these source levels and proxies of short duration sound sources are listed below.

- Explosive: m_{TNTeq} > 8 g
- Airgun: $SL_{z\text{-}p}$ > 209 dB re 1 µPa m
- Other pulse sound source SL_E > 186 dB re 1 μPa^2 m^2 s
- Low-mid frequency sonar: SL > 176 dB re 1 µPa m
- Low-mid freq. acoustic deterrent: SL > 176 dB re 1 µPa m
- Other nonpulse sound source: SL > 176 dB re 1 µPa m

Where levels are reported in bins instead of a precise level, it is proposed that they report source level as follows:

Sonar or acoustic deterrents (source level, rounded to nearest decibel):

- Very low: 176-200 dB re 1 µPa m
- Low: 201-210 dB re 1 µPa m
- Medium: 211-220 dB re 1 µPa m
- High: above 220 dB re 1 µPa m

Generic explicitly impulsive source (energy source level, rounded to nearest decibel):

- Very low: 186-210 dB re 1 μPa^2 m^2 s
- Low: 211-220 dB re 1 μPa^2 m^2 s
- Medium: 221-230 dB re 1 μPa^2 m^2 s
- High: above 230 dB re 1 μPa^2 m^2 s

Airgun arrays (zero to peak source level, rounded to nearest decibel):

- Very low: 209-233 dB re 1 µPa m
- Low: 234-243 dB re 1 µPa m
- Medium: 244-253 dB re 1 µPa m
- High: above 253 dB re 1 µPa m

Explosions (equivalent TNT charge mass, rounded to nearest 10 g if less than 10 kg and to nearest 1 kg otherwise)

- Very low: 8 g to 210 g
- Low: 220 g to 2.1 kg
- medium: 2.11-21 kg
- high: 22-210 kg
- Very high: above 210 kg

Impact pile driver (hammer energy, rounded to nearest 10 kJ)

- Very low: less than 280 kJ
- Low: 290 kJ-2.80 MJ
- Medium: 2.81-28 MJ
- High: above 28 MJ

The register can be used to estimate **the spatial and temporal impact on the environment** (the total period and total habitat loss by impulsive noise sources) and for determining the **baseline level**.

The register will describe the **pressure** on the environment the spatial and temporal distribution of impulsive noise sources. Pressure indicators and pressure-based targets may be used if a clear understanding of the relationship between pressure, state and impact exists. More specifically, this indicator is designed to provide information describing temporal and spatial distribution of impulsive noise sources, through the year and throughout regional seas, to enable assessment of possible cumulative impacts of displacement on marine species at the population level. Current data on bio-acoustic impacts are mostly limited to short-term individual responses. Cumulative exposures from multiple noise sources over large geographic scales and long durations can be modelled, but little is known about the effects ofdisplacement caused by cumulative acoustic exposure. The data gathered in the register will enable MS to estimate the size of the area affected by anthropogenic impulsive noise sources. Using information on response thresholds in received levels for particular species, the area of displacement can be estimated. **Further steps are needed to assess** how displacement affects a species at the **population level**. This requires **considerable research**, even for well-studied species, and results are likely to vary between species.

Once operational, the register will provide Member States a quantified assessment of the spatial and temporal distribution of impulsive noise sources, throughout the year, in regional seas; his assessment can be **used to help decide policy targets** and to **establish the baseline** for the current situation. Once a baseline and targets have been set, the register can be used for **management purposes** (e.g. regulating planning and licensing activities) and to assist in marine spatial planning, incorporating displacement mitigation guidelines and **reducing the potential for cumulative impacts**.

2.2 Monitoring Guidance for Ambient Noise

This chapter provides a guide for **the monitoring of ambient noise** as covered by the EU MSFD indicator 11.2.1.

To make indicator 11.2.1. operational and to comply with the Commission Decision of 2010 (CD): to monitor trends, advice on scope and optimal approach are provided.

> *Indicator 11.2.1: Trends in the annual average of the squared sound pressure associated with ambient noise in each of two third octave bands, one centred at 63 Hz and the other at 125 Hz, expressed as a level in decibels, in units of dB re 1 µPa, either measured directly at observation stations, or inferred from a model used to interpolate between or extrapolate from measurements at observation stations* [Van der Graaf, 2012].

TSG Noise concludes that the **combined use of measurements and models** (and possibly sound maps) is the best way for Member States to ascertain levels and trends of ambient noise in the relevant frequency bands. Member States should be careful to balance modelling with appropriate measurements.

The use of modelling for indicators and noise statistics, and possibly the creation of noise maps, ensures that trend estimation is more reliable and cost-effective, for the following reasons:

i. Use of models reduces 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*)

ii. Use of models reduces the number of stations required to establish a trend over a fixed amount of time (similar reasoning), therefore reducing the cost of monitoring

iii. Modelling helps 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)

The use of models provides MS with an overview of actual levels and their distribution across the sea area, thereby enabling identification of a departure from GES. In addition, there are advantages of using modelling that could contribute to a greater understanding of potential impacts of noise,

The use of mapping has some history and in implementing the MSFD and one can make use of previous experience. Relevant EU experience and regulation is summarised in part II providing some useful background for the MSFD.

This report provides concrete advice on **specifications for noise monitoring systems**. TSG Noise notes that there are no international standards for monitoring underwater ambient noise, for modelling and for data storage. TSG Noise concludes that such standards are needed. **TSG Noise therefore recommends that international standards be developed for the measurement, modelling and data storage of ambient noise** with application to underwater noise monitoring, including the measurement of radiated sound from important sources such as airgun arrays and underwater explosions (standards for the measurement of radiated sound from ships and impact pile driving are already under development by ISO).

TSG Noise advises **Member States within a sub region to work together in setting up n ambient noise monitoring systems**. No precise locations for deploying equipment necessary to monitor relevant frequency bands of ambient noise have yet been defined. However, TSG

Noise is providing a set of guidelines for **monitoring strategy** and guidance **for reporting results**.

It is the responsibility of the MS to define exact locations for the monitoring of Indicator 11.2.1. The indicator is a pressure-indicator that should be used to document trends and not to provide a complete coverage of all noise for the area of interest. If a trend is detected in an area, it should also provide evidence about the trend in other areas (for example an MPA).

The prime objective for the monitoring programme is to establish the trend. However, since the benefit of using models is acknowledged, the monitoring programme should pursue two linked objectives with separate specific monitoring strategies:

- **Category A Monitoring** - to establish information on the ambient noise in a location and to ground truth noise prediction,

- **Category B Monitoring**- to reduce uncertainty on source levels to be used as the input for modelling.

Following these strategies, TSG Noise recommends an **initial set of guidelines for placement of measurement devices**:

1- Where there are few measuring stations per basin, priority should be given to monitoring in order to ground truth predictions (category A), since this monitoring is less sensitive to the influence of individual ships that might bias the averaged sound pressure levels. Monitoring may be more cost effective if existing stations are used for monitoring other oceanographic features;
2- Member States should make sure that they have access to data on the noise characteristics of individual ships
3- In deep water, monitoring devices to ground truth predictions (category A) should be placed in areas of low shipping density. The range at which elevated noise levels may occur is greater in deep water as low frequency sound can propagate long distances;
4- 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;
5- In waters subject to trawling, use locations that are protected from fishing activities or locations where trawling is avoided due to bottom features (e.g. underwater structures/wrecks) and/or to use trawl safe protection;
6- 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;
7- In all underwater noise monitoring, the location should be chosen taking into account site-specific properties such as tide, sediment and currents; it is important that the rig is silent and rig design should take account site-specific considerations.
8- Calibrate sensors at the same pressure as encountered at the planned deployment depths (for clarification see part III chapter 2.10)

The advantages and disadvantages of different averaging methods (arithmetic mean, geometric mean, median and mode) were reviewed, and TSG Noise **recommends that Member States adopt the arithmetic mean** to establish **average ambient noise levels.** The value found will be dominated by the noisiest contribution. Therefore, monitoring in the established high pressure areas (such as commercial traffic lanes) will be emphasised by this contribution. Any other contribution, especially contribution at the regional scale will be de-emphasised. As a consequence, significant pressure fluctuation at a region scale will be disregarded by only listening near traffic lanes.

In order to establish the statistical significance of the trend, additional statistical information about the distribution is necessary. Until better advice becomes available, it is recommended that the **complete distribution be retained in the form of sound pressure levels as a function of time**, **along with a specified averaging time**

Monitoring indicator 11.2.1 will enable MS to quantify the environmental **pressure** (expressed as ambient noise level) as well as trends in ambient noise levels within the two frequency bands. Pressure indicators and pressure-based targets may be used if a clear understanding of the relationship between pressure, state and impact exists. Since there **is very little information available on the effects of increased ambient noise level, TSG Noise cannot give concrete advice on interpretation of results at this stage**.

In addition to the advice needed to develop and deploy the systems needed to monitor the indicator, TSG Noise concluded that *trends* only will not be sufficient to describe GES. To describe GES *levels*, based on a wider overview of the area, a combination of modelling / measurements and possible mapping will be needed. Next to that, much greater **understanding of the relationship between the environmental pressure caused by ambient noise and the state of the ecosystem is needed before GES can be understood**.