MONITORING UNDERWATER NOISE IN GREEK WATERS: KEY ISSUES IN IMPLEMENTING THE EU MARINE STRATEGY FRAMEWORK DIRECTIVE

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Abstract: *Hellenic Centre for Marine Research (HCMR) has been appointed under a ministerial decision as a responsible organization for carrying out the required actions for the monitoring of the quality of the Greek marine waters in the frame of the implementation of the law which concerns the National Strategy for protection and management of marine environment according to the EU Directive 2008/56/EU (Marine Strategy Framework Directive, MSFD). One of the aforementioned actions is underwater noise monitoring under the Descriptor 11, which is one of the eleven qualitative descriptors describing the Good Environmental Status (GES) of EU marine waters. In this context, key issues and their interconnection in implementing underwater noise monitoring in Greek waters, such as available and new infrastructure, existing knowledge and experience, associated national and European projects, strategic collaborations as well as next steps will be mentioned and discussed.*

Keywords: *Underwater noise, MSFD, monitoring, Greek marine waters, national strategy*

1. INTRODUCTION

Anthropogenic noise in the marine environment has been increased over the last 100 or so years due to the growing of diverse activities (commercial shipping, industrial activities including oil and gas exploration and production, commercial fishing, development of marine renewable energy etc.) [1]. Anthropogenic underwater noise, officially listed as source of pollution, is acknowledged as a very complex global issue that needs to be efficiently addressed. The Marine Strategy Framework Directive (MSFD, 2008/56/EC), a European policy-level initiative aiming to achieve Good Environmental Status (GES) of the European marine environment by 2020, has included underwater noise by means of Descriptor 11 (D11: "Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment"), which is one of the eleven descriptors characterizing GES. EC, recognizing the difficulties associated with field measurements and continuous monitoring of underwater sound, as well as the lack of data on current and historical noise levels at many European eco-regions (especially in the Mediterranean Sea), publishes updated reports, elaborated by the MSFD Technical SubGroup on Underwater Noise (TSG Noise), providing guidance for the Member States; see [2], [3].

Hellenic Centre for Marine Research (HCMR), which just in 2017 was designated as the responsible organization for implementing underwater noise monitoring under MSFD requirements, has been undertaking sound monitoring activities since 2008 by introducing smart hydrophones (Passive Aquatic Listeners) in its *in-situ* monitoring infrastructure. However, due to the lack of sustainable funding schemes, there are considerable knowledge gaps as regards underwater noise data in the Greek Seas. Furthermore, Greece has to face the challenge of harmonisation with the new EC Directive 2017/845 and Decision 2017/848 (repealing Decision 2010/477/EU) within a short time interval. As concerns D11, the recent EC Decision clarifies monitoring levels, units of measurement for the criteria and use of the criteria for two elements (anthropogenic impulsive and continuous low-frequency sound in water). Accordingly, Member States should establish threshold values for these levels through cooperation at Union level, taking into account regional or subregional specificities, and the outcomes of these criteria should also contribute to assessments under Descriptor 1.

In this work, an attempt was made to present the key issues in implementing MSFD monitoring requirements as regards D11 for Greek marine waters. To this end, it is considered appropriate to provide at first a brief history of the Greek reporting to EC in the MSFD framework and the relevant harmonisation of national legislation. In the following section, the treatment of the D11 criteria and indicators will be mentioned. Next, the existing infrastructure, experience, and results will be presented. A brief description of important collaborations and related projects will follow and next steps will be discussed.

2. GREEK MSFD REPORTING AND LEGISLATIVE FRAMEWORK

Greek legislation was harmonised with the MSFD 2008/56/EC in June 2011 (Law 3983/2011). Based on the national reporting for Art. 8, 9, 10, and related reporting on geographic areas and regional cooperation (Art. 3/4 & Art.5/6) [4], Greece approved the relative environmental targets and indicators for the marine waters for each descriptor in November 2012 (Decision No. 1175, B2939/2012). As regards D11, the environmental target was set as "the control of the energy levels in order them to not affect adversely the

marine environment" and the environmental indicator was set as "the measurement of underwater noise and estimation of effects on species, populations and main functional groups". The EC comments on national reporting [4] were the following: *GES definition* was assessed as partially adequate; GES was defined at descriptor and criteria level but did not cover clearly the criteria and indicators of the 2010 EC Decision and no thresholds were defined; the *initial assessment* was limited to a collection of information from existing literature without a clear objective to assess current status; no initial assessment was undertaken on the level of pressure from underwater noise (Descriptor 11), but sufficient justification was provided for this issue; the *environmental target* of D11 was considered inadequate, due to the fact that it is higher-level objective rather than a target, it is not smart (no thresholds or dates have been provided), target and the indicator are not completely consistent, and it is unclear how they will achieve GES [5]. The EC recommendations on the aforementioned national reporting were that Greece should improve GES definition, address knowledge gaps identified, further develop its approaches to assessing (quantifying) impacts from the main pressures, ensure that the targets cover all relevant pressures, are smart and sufficiently ambitious [6].

The economic crisis which stroke Greece had a huge delay effect – among others – on the normal progress of MSFD-related obligations. Just in November 2016, Greece approved the monitoring programmes for the continuous estimation of the environmental status of the marine waters (Decision No. 126635, B3799/2016) associated with the 2011 Law. The Special Secretariat for Water (SSW), Ministry of Environment and Energy, was designated as the competent authority for the formulation and the coordinated implementation of the monitoring programmes, and as responsible to communicate these programmes to EC. Furthermore, in the above Decision, the criteria and associated indicators for D11 were aligned with the ones suggested by TSG Noise for impulsive and continuous noise and with 2010 EC Decision. In December 2016, SSW submitted the Report on the monitoring programs of Greece for the Implementation of the Article 11 of the MSFD [7] and within a month (January 2017) the designation of competent and responsible bodies and definition of their obligations concerning the monitoring programmes were published in the Government Gazette (Decision No. 126856, B11/2017). In this Decision, the budget allocated for the MSFD monitoring programmes in the period 2014-2020 was about 8 M€ (see also Section 6). Also, Hellenic Centre for Marine Research (HCMR) and the Fisheries Research Institute (FRI) were designated as the responsible organisations for conducting the required actions regarding monitoring of the quality of the marine waters (HCMR being solely responsible for D11), under the supervision, coordination, evaluation and control of SSW.

3. CRITERIA AND INDICATORS

In this section the criteria, the related indicators and actions for D11, as mentioned in the Report on the monitoring programs of Greece for the Implementation of the Article 11 of the MSFD [7], will be briefly described. Following the TSG Noise suggestions, Greece has adopted two criteria for D11, one related to the *low and mid frequency impulsive sounds* (criterion 11.1) and one related to the *continuous low frequency sound* (criterion 11.2).

The environmental indicator corresponding to criterion 11.1 is 11.1.1: "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". In Greek marine waters, there is no established network or action for monitoring and/or accessing low and mid frequency impulsive sounds. The main accessible noise sources from such sounds may generated from seismic surveys for hydrocarbon exploration or research purposes. Given that the legislative framework related to the exploitation of offshore potential as renewable energy source is not mature yet, records concerning activities related to construction of offshore wind farms are not foreseen in the near future. Consequently, what is proposed is establishing a noise register with activities related to loud impulsive sounds, i.e. measured over the frequency band 10 Hz to 10 kHz, exceeding the energy source level 186 dB re 1 μPa² m² s or zero to peak source level 209 dB re 1 μPa² m² over the recorded areas. The aforementioned values are the thresholds suggested by TSG Noise as regards the categories "airgun" and "other pulse sound source". HCMR has recently contacted the Hellenic Hydrocarbons Resources Management (HHRM), the company providing the management of the Greek hydrocarbon resources, which has both historical and recent seismic data library/database. Both organisations are looking forward to a fruitful cooperation on creating the aforementioned noise register to address appropriately not only the indicator 11.1.1 as stated above, but also its updated version as stated in the recent EC Decision 2017/848.

The environmental indicator corresponding to criterion 11.2 is 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 centered 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". In this context, monitoring of continuous low frequency sound will be carried out: i) at five sites (one in Ionian, three in Aegean and one in Levantine Sea) by hydrophones (systems) incorporated to the national infrastructure of the POSEIDON monitoring network; ii) considering sound propagation models simulating shipping noise propagation, given that shipping noise is a main source of continuous low frequency sound. More details on the direct measurements at observation stations will be given in Section 4, while information on modelling actions will be given in Section 5.

4. EXISTING INFRASTRUCTURE, EXPERIENCE AND RESULTS

The POSEIDON monitoring, forecasting and information system for the Greek Seas (www.poseidon.hcmr.gr), implemented and maintained by HCMR, has included passive underwater acoustic measurements as part of its real-time operations. Specifically, low-duty-cycle long-term passive acoustic listeners (PALs) have been deployed on two operational buoys, one off Pylos in the Ionian Sea and the second off Athos in the northern Aegean Sea (see Fig. 1) at 500 m and 200 m depths respectively. The communication between the instruments and the surface buoy's CPU was achieved through an inductive modem that allowed the real-time data transmission through the POSEIDON telecommunication network [8]. Those PALs were equipped with a broadband, low-noise hydrophone (100 Hz to 50 kHz) and a real-time embedded operating and signal processing software for detecting and interpreting the sound spectra and providing sound classification and estimation of environmental, anthropogenic and biological parameters [9], [10]. For example, spectra consistent with vocalizations of cetaceans are present in the PAL data at both Athos and Pylos. High-frequency clicks and marine mammal calls can be identified by examining acoustic levels at 20 and 30 kHz (see, e.g., Fig. 2a). Figure 2b summarizes cetacean detection at Athos, showing that animals are present (vocalizing)

1%–3% of the time, with a higher level of detection during December–February. Of course, they need to be vocalizing to be detected, and so this is the minimum level of presence.

Fig. 1: Location of PAL deployments on HCMR POSEIDON buoys

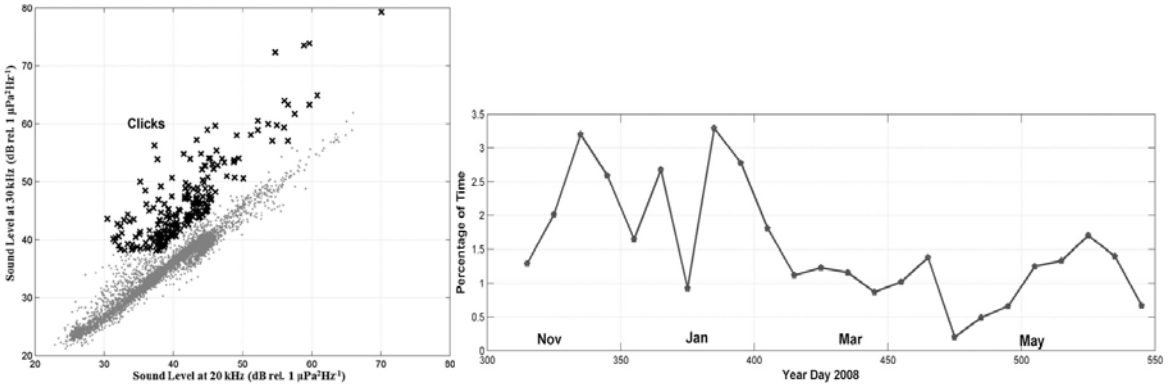

Fig. 2: (a) Data points from the Athos PAL during days 350–370 of 2008 (15 Dec 2008–4 Jan 2009) showing the classification of the clicks (black x*) from the wind speed (gray dots). Cetacean (probably striped dolphin) detection is shown using a comparison between sound level at 20 kHz and 30 kHz; (b) Summary of cetacean detections at Athos site during 2008.*

Although several time series of the above measurements are available from 2008, the scope and the corresponding sampling strategy were different from the one required according to the rationale of the Commission Decision 2010/477/EU. Furthermore, the 1/3 octave band centered at 63 Hz was not included in PALs recording capabilities. The first Greek results related to the indicator D11.2.1 were produced in the frame of EU FP7 project PERSEUS (coordinated by HCMR, Institute of Oceanography) [11], where one of its main objectives was to implement the principles and objectives put forward in the MSFD and promote them across the Southern European Seas. During 2013 a PAL system deployed on the buoy of the Saronikos gulf (see Fig. 1) for almost eight (8) months. According to TSG Noise recommendations [2], the hourly and daily bulk statistics, i.e. geometric and arithmetic averaged Sound Pressure Level (SPL) and 5th, 50th and 95th percentiles, have been computed from each sample, which is a 4-minute of 4.3 sec average SPL. The daily average SPL of the 2013 deployment measurements, the corresponding bulk statistics and the cumulative distribution plot of the 1/3-octave band centered at 125 Hz are shown in Figures 3a and 3b.

Motivated by including the sound monitoring of 1/3 octave band centered at 63 Hz, the PAL was upgraded to a new, long-term, miniaturized system, equipped with a high-

sensitive low-power broadband hydrophone with linear working frequencies down to 5 Hz and up to 90 kHz, advanced electronics and battery technologies, high internal data storage components (up to 128 Gb), capabilities of controlling the sampling strategy and automated sound analysis software classifying the sound source and providing a summary message about the marine environment. First results similar to those of Figures 3a and 3b for the 1/3-octave band centered at 63 Hz, obtained during a 2014 PAL deployment at Saronikos gulf, can be found in [11].

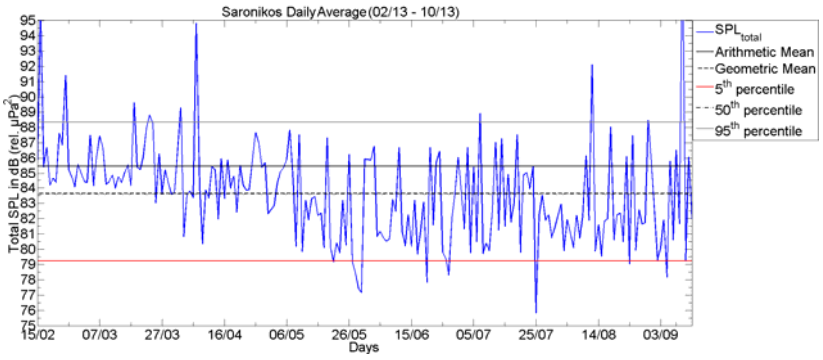

Figure 3a: Daily average SPL and corresponding bulk statistics (arithmetic and geometric average, 5th, 50th and 95th percentile) obtained from the PAL measurements during the 2013 deployment

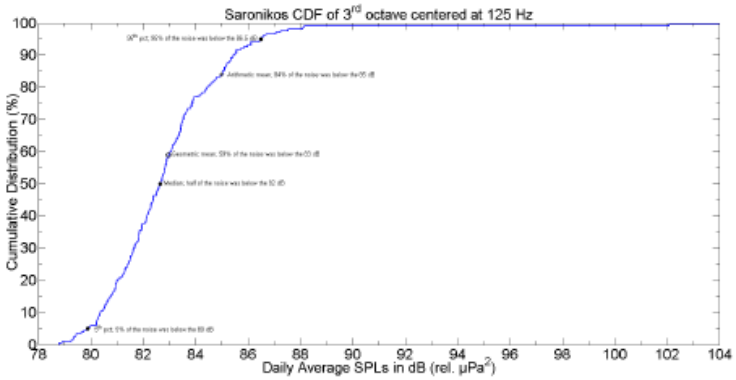

Figure 3b: CDF plot of the daily average SPL measurements taken at the 1/3-octave band centered at 125 Hz obtained from the PAL measurements during the 2013 deployment

5. RELEVANT PROJECTS AND COLLABORATIONS

A strategic collaboration for the efficient implementation of MSFD monitoring for D11 is that between HCMR and Foundation for Research and Technology-Hellas (FORTH). The Institute of Applied and Computational Mathematics (IACM) of the latter, and especially the wave propagation group, has a considerable expertise on basic and applied research in underwater acoustics by developing methods and tools for acoustic modeling and monitoring of the underwater environment; see, e.g., [12]. IACM-FORTH is a partner in the recently EU funded quietMED project ("Joint programme on noise (D11) for the implementation of the Second Cycle of the MSFD in the Mediterranean Sea"), which aims to improve the level of coherence and the comparability of the implementation of the Second Cycle of MSFD as regards D11 implementation in the Mediterranean Sea by enhancing cooperation among MS, the Barcelona Convention and other third non-EU

countries. The critical role of both HCMR and FORTH as regards monitoring and assessment of underwater noise was the motivation for a bilateral agreement (MoU) with specific mention to MSFD.

HCMR is the coordinator of the EU project MEDCIS ("Support Mediterranean Member States towards coherent and Coordinated Implementation of the second phase of the MSFD"), which was recently funded under the same programme call as quietMED project (DG ENV/MSFD Second Cycle/2016). In the frame of this project HCMR has a close collaboration with the School of Naval Architecture & Marine Engineering of National Technical University of Athens. One of the MEDCIS outputs will be a methodology contributing in defining the ocean shipping noise footprint applied to the pilot area of Hellenic-Italian adjacent waters (including areas visited by dolphins, sea turtles and large pelagic), characterized by marine traffic of ferry lines connecting Italy and Greece as well as larger commercial ships. The methodology will be based on detailed numerical simulation of the radiated noise from specific vessels and acoustic modelling work.

The contribution of EU FP7 project PERSEUS to the Greek noise monitoring under MSFD was mentioned in Section 4, where the most representative results related to the D11.2.1 were presented.

Last but not least, important is expected to be the contribution of EMSO (European Multidisciplinary Seafloor and water column Observatory) European RI, one of the targets of which is the implementation of MSFD. In this connection, a smart hydrophone, appropriate for continuous monitoring of ambient noise and marine life at a wide frequency range is planned to be set up during the first stage of the implementation of POSEIDON-Pylos observatory, which is consisted of a deep-sea seafloor and water column platform with acoustic connection to a surface buoy. The responsibility of this initiative has been undertaken by HCMR, which is an EMSO member.

6. NEXT STEPS

As mentioned in Section 2, there is a considerable delay on the progress of the national MSFD-related obligations. The unstable economic ground in Greece during the last years was the main cause of an over-two-years delay on submitting the report on the monitoring programmes. Furthermore, starting of the implementation of the monitoring programmes requires specific time-consuming steps. At present, a bilateral cooperation agreement contract has been signed between HCMR and FRI, whereas HCMR is solely responsible as regards appropriate actions for D11. A tripartite agreement among the competent and responsible parties (SSW, HCMR and FRI) is on the way. The procedure also includes the call of the implementation of the monitoring programme, the compilation of the technical bulletins and an open international tender for the participation of organisations with expertise on specific topics, such as marine mammals for D11 and D1. The latter is very important, since collaboration of HCMR with experts on marine mammals is more than essential as regards the assessment of the these descriptors. In short, starting of the implementation of the monitoring programmes cannot be accurately defined; however, it could not be later than the beginning of 2018.

Apart from the aforementioned foresights as regards the time plan of the monitoring programmes and the tight time limit for the first review of the initial assessment and determination of GES (mid 2018), one has to mention the limited budget for the MSFD monitoring programmes (see Section 2). Less than 8 M€ have been totally allocated for a period of six years, eleven descriptors with a significant number of new parameters and

locations to be monitored, and two implementing organisations with associated external experts' collaborations (e.g. NGO's specialised on relevant topics).

7. ACKNOWLEDGEMENTS

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