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First Implementation of Marine Strategy Framework Directive for Benthic Habitats Assessment in the Bulgarian Black Sea

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Abstract. Benthic habitats are ecosystem elements required to be assessed under Descriptors 1, 6 – "Biodiversity" and "Seabed integrity" of the Marine Strategy Framework Directive. This study represents the first environmental status assessment of the Bulgarian Back Sea benthic broad habitat types accomplished according to the criteria and methodological standards of Commission Decision (EU) 2017/848. Adverse effects on habitats condition from eutrophication and pollution were assessed using the ecological indices S, H', AMBI and M-AMBI(n), and dissolved oxygen in bottom water for which good status thresholds were established under the MSFD monitoring programmes. These indicators were also considered as indicative of adverse effects from physical disturbance of the seabed. The proportion of each benthic habitat area adversely affected according to the integrated abiotic and biotic indicators was estimated in six Marine Reporting Units of the Bulgarian Black Sea. Three of the coastal and both of the shelf marine areas did not achieve good environmental status as regards the broad habitat types present. The only marine area in good environmental status was "Emine-Maslen nos" coastal zone. The results are useful for fulfilling the reporting obligation of Bulgaria under the Marine Strategy Framework Directive.

Key words: Bulgarian Black Sea, benthic broad habitat types, environmental status, Marine Strategy Framework Directive.

Introduction

The contribution of seabed habitats and sea-floor integrity to the overall goal of achieving good environmental status (GES) of Europe's marine waters is addressed by Descriptors 1 and 6 of Directive 2008/56/EC (EC., 2008) establishing a framework for community action in the field of marine environmental policy (hereafter Marine Strategy Framework Directive or MSFD).

Descriptor 1: Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions.

Descriptor 6: Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.

In Commission Decision (EU) 2017/848, these two aspects of GES have been brought together via a set of five criteria for the

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determination of GES in relation to a set of broad habitat types: D6C1 Physical loss; D6C2 Physical disturbance; D6C3 Adverse effects of physical disturbance on habitats; D6C4 Extent of habitat loss; D6C5 Extent of adverse effects on the condition of a habitat. D6C5 shall integrate the adverse effects from all relevant pressures addressed by Descriptors: D2 "Non-indigenous species", C3 "Commercially exploited species", D5 "Nutrient enrichment", D6 "Physical loss and physical disturbance", D7 "Hydrographical conditions", and D8 "Contaminants".

The relevant ecosystem elements of the seabed assessed under MSFD Descriptors 1 and 6 are the benthic broad habitat types. These are listed by Commission Decision (EU) 2017/ 848 Annex, Part II - Table 2 and equate to one or more habitat types at hierarchical level 2 of the "EUNIS marine habitat classification, 2019".

The study objective is to evaluate the environmental status of seabed habitats in the Bulgarian Black Sea using Commission Decision (EU) 2017/848 assessment framework.

In order to assess the state of a habitat across its distribution it is necessary to determine the extent of the habitat which is considered to be in a good condition or, conversely, not in good condition (adversely affected). These two aspects - quality and extent of quality - are reflected in the criterion D6C5, which requires the setting of threshold values for adverse effects and the maximum allowable extent of those adverse effects.

Material and Methods

The Bulgarian Black Sea is subdivided into eight Marine Reporting Units (MRUs) which represent areas with distinctive physio-geographical characteristics: five coastal, two shelf and one open sea area. In this study four of the coastal and both shelf MRUs were assessed as regards benthic habitats of the seabed sediments and dissolved oxygen in bottom water (Fig. 1).

Sampling for macrozoobenthos was carried out in October 2017 at 107 points. Altogether 238 qualitative samples for macrozoobenthos were collected by means of Van Veen Grab (0,1 m^2) (Fig. 1). Species composition and abundance were determined in the laboratory following the procedures of Todorova & Konsulova (2005).

Bottom seawater was also sampled in October 2017 at 174 stations by Niskin bottles (5 l) Rosette System attached to SEABIRD CTD probe. Dissolved oxygen measurements were performed by Winkler titration method (Grasshoff et al., 1999).

Brey-Curtis similarity (Bray-Curtis, 1957) on 4^{th} root transformed biomass and hierarchical classification analysis (Clarke et al., 2014) were employed to differentiate macrozoobenthic communities and associate them with the broad habitat types.

M-AMBI(n) (Sigovini et al., 2013) was used to assess adverse effects on benthic macroinvertebrates. The method combines AMBI (Borja et al., 2000), a biotic index based on species sensitivity/tolerance to pressures, with Shannon-Wiener diversity index (H') and species richness (S) as an arithmetic mean of their minimum-maximum normalized values. Thresholds for good status were developed by Todorova (2017) using the ecological quality ratio method from reference conditions in line with the Water Framework Directive (WFD) methodological approach for intercallibration of the biological quality element macrozoobenthos (Todorova et al., 2018). The thresholds and EQRs, given in Table 1 were established for several benthic habitat sub-types on sandy bottom ("*MSFD Monitoring Programmes*" (BSBD, 2020)). Due to data deficiency on reference conditions for muddy bottom habitats, their status was assessed relative to the current best

conditions using $EQR_{M\text{-}AMBI(n)}$=0.68 as a good status threshold.

The good status threshold for dissolved oxygen in bottom water was set at 75 % saturation in the coastal waters (Regulation № H-4 of 14.09.2012) and 4.69 mg/l for the shelf area (HELCOM, 2013). The extent threshold for good status of dissolved oxygen was set at 90 % of the total extent of each MRU.

Assessments of seabed habitats require the use of maps of habitat types as a prerequisite to estimate the extent of each habitat which is adversely affected. A predictive map of seabed habitats, covering all MSFD regions, including the Black Sea, is provided by the European project EMODnet (2020) Seabed Habitats according to the EUNIS typology, and also aggregated to MSFD broad habitat types (Fig. 1).

The extent to which good environmental status is achieved is expressed as an estimate of the proportion of adverse effects per habitat type and whether this has achieved the extent threshold value set at 20 % in the Bulgarian Black Sea (Todorova, 2017).

The extent of each habitat in good or not good status was estimated using GIS. Inverse Distance Weighted interpolation of $EQR_{M\text{-}AMBI(n)}$ point values at equal resolution of 500 m was employed to create raster. The squares with interpolated values were converted to "good" and "not good" classes in relation to the threshold value $EQR_{M\text{-}AMBI(n)}$=0.68. Dissolved oxygen maps were created using similar approach. The final maps of overall adverse effects were created by integration of the maps for M-AMBI(n) and dissolved oxygen according to the rule one-out-all-out for each square (Fig. 2). The resultant map was intersected with the EMODnet map of benthic broad habitats types. The proportion from the total extent of each habitat in good or not good status in each MRU was calculated using Zonal Statistic function in GIS. Finally, the proportion of habitats in good status from total number of habitats present in each MRU was estimated and compared to overall GES threshold of 80 % (e.g. MRUs achieve GES if 80 % of the present habitats are in good condition).

Results

Dissolved oxygen saturation in the coastal bottom water varied between 63 - 112 %. Only 7 values under the threshold of 75 % saturation were recorded across the coastal areas, two of which were found in the northernmost MRU "Sivriburun-Kaliakra".

Oxygen concentration in shelf bottom water varied between 1,3 - 11,5 mg/l with 34 % of the samples below the threshold of 4,69 mg/l (23,3 % in the "Northern shelf" and only 10,7 % in the "Southern shelf").

The extent (as proportion of total area) of each MRU with values of bottom water oxygen above the thresholds for good status is given in Table 2. Four MRUs achieved GES with more than 90 % of their extent having values of dissolved oxygen above the respective thresholds for coastal and shelf areas. In two MRUs - northern coastal area "Sivriburun-Kaliakra" and "Northern shelf" area - less than 90 % of the area was in good condition of oxygen, therefore these areas were not in GES.

The taxonomic composition of the macrofauna encompassed 146 species and higher taxa - 50 polychaetes, 28 bivalves, 9 gastropods, 41 crustaceans and 18 miscellaneous (sponges, anemones, nemerteans, turbellarians, oligochaetes, echinoderms and ascidians).

Six biotopes with characteristic communities were differentiated based on Brey-Curtis similarity classification which were allocated to 5 broad habitat types (Table 3).

Habitat condition according to the average $EQR_{M\text{-}AMBI(n)}$ was above the threshold for good status at 63 monitoring points and below the threshold at 44 monitoring points (Fig.1).

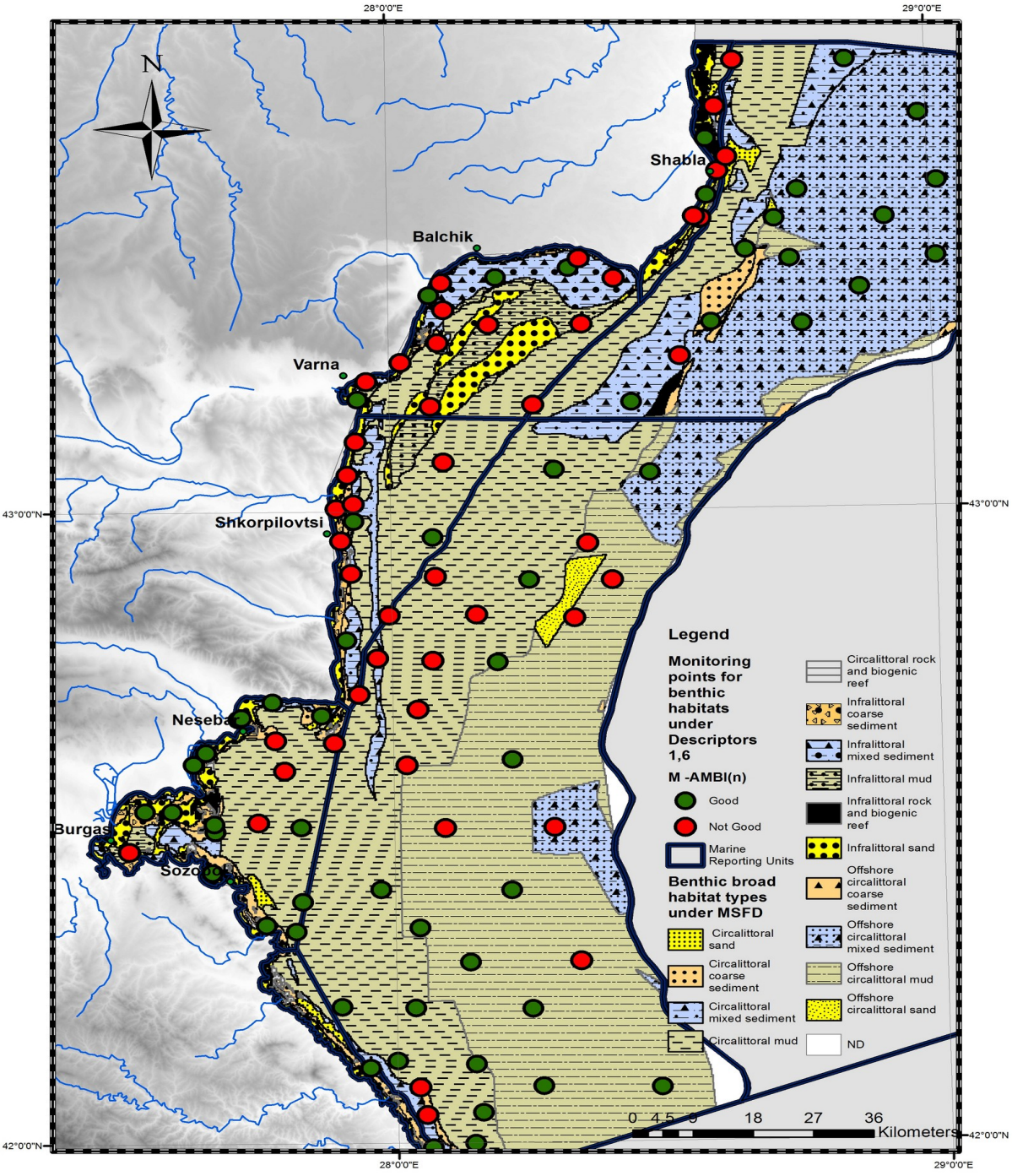

Fig. 1. Map of the study area in the Bulgarian Black Sea with outlined Marine Reporting Units, MSFD benthic broad habitat types and habitat condition according to $EQR_{M\text{-}AMBI(n)}$ at sampling points for macrozoobenthos.

Table1. Reference conditions and good status thresholds for ecological indices for some benthic habitat sub-types in the Bulgarian Black Sea.

Index	EQR	AMBI	H'	S	M-AMBI(n)
Habitat	Upper infralittoral meadium and fine sands dominated by *Donax trunculus*				
Reference conditions	1	0.5	3.1	18	0.91
Good status	0.68	2.26	2.11	12	0.62
Habitat	Infralittoral fine and medium sands dominated by *Chamelea gallina*, *Lentidium mediterraneum, Tellina tenuis*				
Reference conditions	1	0.3	3.4	30	0.87
Good status	0.68	2.12	2.31	20	0.59
Habitat	Infralittoral coarse and medium sands dominated by *Upogebia pusilla*				
Reference conditions	1	2.5	3.4	35	0.96
Good status	0.68	3.62	2.31	24	0.65
Habitat	Circalittoral shelly sands and gravel with diverse variable fauna				
Reference conditions	1	1.9	3.8	42	0.94
Good status	0.68	3.28	2.58	29	0.64

Table 2. Extent **(**% proportion of the total area) of MRUs that achieved good status thresholds for dissolved oxygen in bottom water.

MRU	Extent above thresholds, %	Status
Sivriburun-Kaliakra	70.31	Not in GES
Kaliakra-Galata	96.90	In GES
Galata-Emine	98.98	In GES
Emine-Maslen Nos	97.62	In GES
Norther shelf	84.43	Not in GES
Southern Shelf	99.87	In GES

Table 3. Benthic broad habitat types and biotopes identified in the study area.

Broad habitat type	Biotopes
Infralittoral sand	Upper-infralittoral **(**1 - 7 m) medium and fine sand dominated by *Donax trunculus* Infralittoral (5-15 m) fine and medium sand, dominated by *Chamelea gallina*
Circalittoral coarse sediment	Shallow circalittoral (17-35 m) shelly gravel and coarse sand with varied infauna (*Modiolus adriaticus, Gouldia minima*)
Circalittoral mud	Circalittoral mud with *Pitar rudis* и *Spisula subtruncata*
Offshore circalittoral mud	Offshore circalittoral mud with *Terebellides stroemi*
Circalittoral mixed sediments	Circalittoral mixed sediments with *Modiolula phaseolina*

The distribution of good and not good habitats condition over the habitats extent in the Bulgarian Black Sea is shown on Fig.2 which integrates the interpolated results for dissolved oxygen and $EQR_{M\text{-}AMBI(n)}$. Generally, the habitats condition of the coastal marine areas between the northern border and c. Emine and the central part of the shelf is not good as made evident on the figure.

Summary of benthic habitats status in the Bulgarian Black Sea in 2017 is presented in Table 4. Five from six examined MRUs did not achieve GES as regards benthic habitats. In three of the coastal MRUs none of the habitats present was in good status. MRU "Emine-Maslen nos" was singular coastal area in GES with 80 % (seven from eight) of the present habitats in good status, each of the habitats with less than 20 % of their total extent adversely affected. The "Northern shelf", although not in GES, achieved higher proportion - 62.5 % (five from eight) of the benthic habitats present in good condition as compared to the Southern shelf. The "Southern shelf" was not in GES with only 14.3 % (one from seven) of the habitats present in good condition.

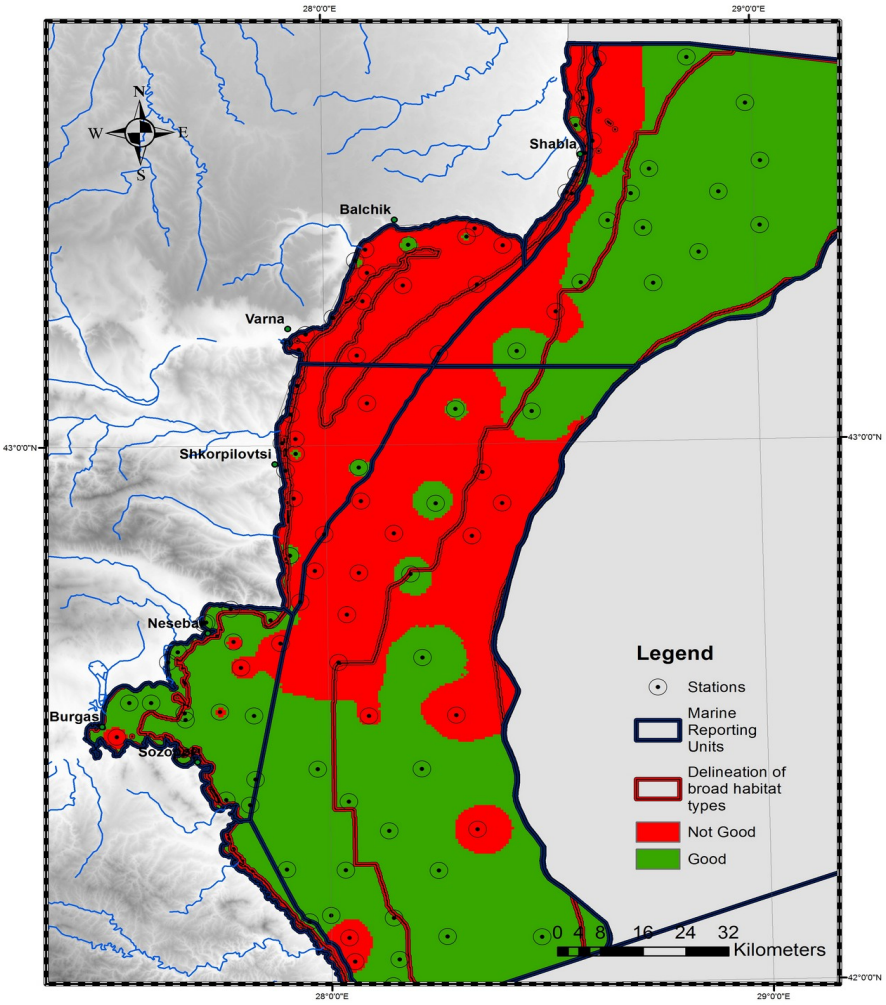

Fig. 2. Map of the study area in the Bulgarian Black Sea with Marine Reporting Units and extent of good and not good habitats status according to $EQR_{M\text{-}AMBI(n)}$ and dissolved O_2.

Table 4. Extent of adverse effects in broad habitat types (np-not present) as proportion (%) of total habitat area, proportion (%) of habitats in good status from overall number of habitats and general conclusion on environmental status in MRUs.

MRU	Sivri-burun-Kaliakra	Kaliakra-Galata	Galata-Emine	Emine-Maslenos	Northern shelf	Southern shelf
Broad benthic habitat types	**Extent of adverse effects (% proportion of total habitat area)**					
Infra-littoral sand	87.8	99.8	84.0	1.6	np	Np
Infra-littoral mud	np	100	100	45.8	np	Np
Infra-littoral mixed sediment	100	100	81.6	2.6	np	Np
Infra-littoral coarse sediment	100	94.2	100	0	np	Np
Circa-littoral sand	82.5	100	25.0	0	97.7	Np
Circa-littoral mud	98.1	100	96.8	16.9	76.1	54.4
Circa-littoral mixed sediment	100	100	76.1	12.5	0.0	58.3
Circa-littoral coarse sediment	100	100	95.4	0	44.5	66.5
Offshore circa-littoral sand	np	np	np	Np	0	6.0
Offshore circa-littoral mud	np	np	np	Np	0,0	30.6
Offshore circa-littoral coarse sediment	np	np	np	Np	7.8	35.7
Offshore circa-littoral mixed sediment	np	np	np	Np	1.3	41.7
	Proportion (%) of benthic broad habitat types in good status in MRUs					
	0	0	0	80	62.5	14.3
GES achieved in MRU	Not in GES	Not in GES	Not in GES	In GES	Not in GES	Not in GES

Discussion

Pressures on seabed habitats can have physical, biological and/or chemical effects on the habitat affected, therefore, habitat status is assessed through the changes in its abiotic and biotic characteristics. Bottom-water oxygen supply is a key abiotic factor governing the biogeochemistry of marine sediments and of vital importance to the communities of benthic invertebrates. Reduced dissolved oxygen concentration is indicative of increased biological oxygen demand from elevated levels of nutrients and organic matter and it has negative impact on benthic invertebrates ranging from physiological effects to mass mortality during anoxic events (Diaz & Rosenberg, 1995; 2008). Consequently, dissolved oxygen in bottom water was established as one of the primary criteria for assessing eutrophication adverse effects under MSFD. Permanent water stratification in the Black

Sea due to vertical salinity gradient results in decreasing dissolved oxygen with increasing depth, while summer thermocline further reduces the ventilation of bottom water from the atmosphere thus creating conditions for hypoxia over the shelf (Stanev et al., 2014; Friedrich et al., 2014). It is therefore essential to distinguish the natural from the anthropogenic changes in dissolved oxygen and establish specific thresholds for biological zones of different depth range in the Black Sea. The results for the extent of MRUs in good condition as regards dissolved oxygen suggest small deviations in oxygen levels caused by natural or anthropogenic factors. Altogether well oxiginated bottom waters during the sampling season were possibly related to isothermal conditions in the water column and stormy weather in October 2017 that enhanced vertical mixing. Noticeable exception was observed in the northernmost coastal MRU "Sivriburin – Kaliakra" with nearly 30 % of its area bellow threshold and the "Northern shelf" area with 15 % (Table 2). These areas were possibly affected by the Danube transboundary influence, as it has been demonstrated that Danube water discharge to the Black Sea has a major impact on the Roumanian and Bulgarian shelf nutrient budget and oxygen regime (Velikova et al., 2005). Khrischev et al. (1998) and Panin & Jip (2002) uphold the view of significant Danube sediment drift influence on the biogenic carbonate sediments in the Bulgarian shelf to the north of c. Kaliakra due to high bottom current velocity that carries away the fine grains and thus forms massive shell deposits.

Regardless of the type of pressure, the assessment of what constitutes an adverse effect on a natural habitat should be based firstly on changes to the species composition and their relative abundance within the community compared to an unimpacted or less impacted state. The multi-metric index M-AMBI(n) reflects the changes in species richness and diversity, and the relative abundance of five ecological groups of species: sensitive, indifferent, tolerant, secondary and primary opportunists. The assessment concept is based on the Pearson & Rosenberg (1978) successional model according to which disturbance–sensitive taxa decrease, while tolerant and opportunistic species increase along the increasing pressure gradient, coupled with decrease in species richness and evenness of distribution. In the Bulgarian Black Sea M-AMBI(n) is validated in the WFD intercallibration exercise against the predominant pressures in the coastal waters including point sources of pollutants: loads for BOD, suspended solids (SS), total heavy metals (HMET), detergents (DET), phenols (PHE), total petroleum hydrocarbons sources and defuse sources of pollutants from urbanization, tourism, and navigation (Todorova et al., 2018). As far as the shelf is affected by diffuse (navigation), transboundary (currents) and air-born pollution, M-AMBI(n) presumably indicates the negative effects on the benthic invertebrates.

Another key human activity that causes significant physical disturbance to the seabed in EU waters, including the Black Sea, are fisheries with mobile bottom contacting gears (ICES, 2019). Although a relationship was demonstrated between AMBI and physical disturbance from dredging and sand extraction (Muxica et al., 2005), M-AMBI(n) is not validated against the predominant physical disturbance from fisheries on the Bulgarian Black Sea shelf. It is therefore important to establish the distribution and intensity of fisheries associated abrasion on the seafloor and then validate the conventional and novel ecological metrics as suitable indicators for adverse effects from the specific pressure.

The current assessment involves several sources of uncertainty such as the unknown pressure-response relationship of M-AMBI(n) with physical disturbance on the seafloor and unestablished good status

thresholds for some benthic habitat types. Moreover, the adverse effects from other pressures, e.g. non-indigenous species and commercial exploitation were not examined in this study. The extent of adverse effects threshold shall be harmonized at regional and Union level, therefore the national threshold established at 20 % may be revised.

Regardless of the outlined deficits, this pilot study provided valuable experience in implementing the Commission Decision (EU) 2017/848 conceptual framework for assessing the environmental status of benthic habitats in the Bulgarian Black Sea. Using EMODnet seabed habitat maps enabled evaluating the extent of adverse effects on the habitats condition. The results are indicative of the benthic habitats status in the Bulgarian Black Sea in 2017 and provide useful information for fulfilling the reporting obligation of Bulgaria under MSFD.

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