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Natural valuation of the Polish marine areas (Baltic) based on phytobenthos

Waloryzacja przyrodnicza polskich obszarów morskich (Bałtyk) na podstawie fitobentosu

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Abstract: This paper aimed to develop a method for assessing the natural values of the Polish marine areas (PMA), excluding coastal lagoons, based on phytobenthos. The valuation method includes four criteria which refer to the qualitative and quantitative structure of phytobenthos. The method was tested at the stony bottom overgrown with macroalgae – in the coastal zone, near the localities of Ustka, Poddąbie and Rowy. The assessment showed that the most valuable was the boulder area in the vicinity of Rowy, due to the presence of macroalgae communities with five rare and three protected species. The least valuable was the stony bottom near Ustka, with small amounts of macroalgae and one protected species. The natural values were classified into four classes and presented on a map, what is very important from the practical point of view, especially if areas designated for future investments are considered. The map with natural values' distribution was created on the layers of surface sediments, which were developed on the basis of sonar and bathymetric data. The use of these data allowed for a precise delineation of subareas with different natural values. The natural valuation method presented in this article is a relatively simple tool that can be applied to determine the areas valuable in terms of phytobenthos in PMA.

Keywords: macroalgae, criteria, map of natural values, coastal zone

Streszczenie: Celem artykułu było opracowanie metody oceny walorów przyrodniczych polskich obszarów morskich (POM), z wyłączeniem zalewów przymorskich, na podstawie fitobentosu. Metodę waloryzacji oparto na 4 kryteriach, uwzględniających strukturę jakościowo-ilościową fitobentosu. Metodę przetestowano waloryzując makroglony dna kamienistego, występujące w strefie przybrzeżnej otwartego morza, w pobliżu miejscowości: Ustka, Poddąbie i Rowy. Z przeprowadzonej oceny wynika, że najcenniejszym obszarem było głazowisko w okolicy miejscowości Rowy, z uwagi na występowanie zbiorowisk makroglonów oraz obecność 5 gatunków rzadkich i 3 gatunków chronionych. Najmniej cennym – dno kamieniste przy Ustce, gdzie wśród znikomych ilości makroglonów występował 1 gatunek chroniony. Ważnym dla praktycznego zastosowania tej metody oceny walorów przyrodniczych, np. w rejonach przeznaczonych pod różnego rodzaju inwestycje, jest możliwość przedstawienia jej w czterostopniowej skali w postaci mapy cenności przyrodniczej, dla której jako podkład wykorzystano mapę osadów, opracowaną na podstawie danych sonarowych i batymetrycznych. Wykorzystanie tych danych pozwoliło na dokładne wydzielenie podobszarów o różnej cenności przyrodniczej. Opracowana i zaprezentowana w niniejszym artykule metoda waloryzacji przyrodniczej jest stosunkowo prostym narzędziem mogącym mieć zastosowanie do określenia rejonów cennych przyrodniczo w POM.

Słowa kluczowe: makroglony, kryteria waloryzacji, mapa cenności przyrodniczej, strefa przybrzeżna

INTRODUCTION

Natural valuation is currently one of the most important activity, usually performed as part of nature conservation, spatial planning, as well as, e.g., in the assessment of water bodies designated for various types of investments, including those that strongly affect the environment. Its purpose is to assess the natural values of the considered area. The term "natural value" is defined as "the intrinsic value of marine biodiversity, without reference to anthropogenic use" (Derous et al. 2007). In other words, it focuses on the features of species and communities themselves and not on the contamination or the extractable/usable part of the ecosystem (Šiaulys and Bučas 2015).

The result of valuation is a map of delimited areas with different natural values. Due to valuation, it is possible to indicate areas that can be invested and areas of conflicts with nature conservation. It allows to direct the process of managing and use of sea space to preserve the area's natural values (Kruk-Dowgiałło 2000 a, Matyjasiak 2012 a and b).

There is no one, universal method of natural valuation, representative for all assessed elements of the environment. The choice of method depends on the assumed objectives, environmental and geographical conditions of the study area, its size and type of data collected as part of the inventory studies (Matyjasiak 2012 a, Dynowska and Ciecierska 2013, Biesiadka and Nowakowski 2013). The use of relatively independent, mutually complementary criteria is considered as the most appropriate. They are used to assess the value of units located within a given area: ecosystems or their fragments (e.g., phytocoenoses), water reservoirs (ponds) or arbitrarily separated fragments of larger natural systems (e.g., kilometer-long sections of the river) (Matyjasiak 2012 a).

There are very few publications in the field of natural valuation in Poland, differing in the scope of the issues presented. They mainly refer to land areas (Dynowska and Ciecierska 2013, Biesiadka and Nowakowski 2013), where usually vascular plants are subjected to assessment (Zalewska et al. 2013, Dynowska and Ciecierska 2013). Vegetation is the most easily accessible element of the ecosystem, always present, relatively stable, and available for direct examination (Matuszkiewicz 2014).

Literature concerning natural valuation of the Polish marine areas (PMA) is very poor. The first valuation of the Polish sea area with the presentation of values on maps was performed in 1996–1999 – for the Puck Bay (Kruk-Dowgiałło 2000 a, Osowiecki and Żmudziński 2000) and in 1997 for the coastal waters in Słowiński National Park (Kruk-Dowgiałło 2000 b). These assessments were conducted for biotic components of the ecosystem (plankton, fauna and flora, ichthyofauna and avifauna) and abiotic components (water, sediment), expressed by quantitative and qualitative indicators. Further works on valuation of PMA were carried out by Kruk-Dowgiałło et al. (2011), who modified criteria proposed by Kruk-Dowgiałło et al. (2000 a), to assess the values of flora and benthic fauna on the Słupsk Bank. It is also worth mentioning the work of Węsławski et al. (2009), who modified the criteria developed by Derous et al. (2007) and used them to assess PMA, excluding lagoons, on the basis of flora and benthic fauna.

Considering the constantly increasing intensification of the use of sea areas in the Polish sector of the Baltic Sea (Michałek et al. 2018), there is a great need to continue work on the methods of natural valuation of the marine environment for its sustainable use and thus, the protection of marine resources.

The aim of the present paper was to develop a method for valuation of phytobenthos (macroflora) in the PMA and to test it in three stony areas in the Polish coastal zone: Rowy, Ustka, and Poddąbie (areas not investigated in terms of phytobenthos so far). The method was developed for PMA, excluding coastal lagoons such as, for example, the Szczecin Lagoon, the Kamieński Lagoon and the Vistula Lagoon. The lagoons are characterized by different environmental conditions (e.g., very low salinity, or even freshwaters), which determine the development of specific flora, different from that occurring along the Polish coast or in open waters, both in terms of quality, quantity, and distribution.

MATERIAL AND METHODS

Study areas and sampling

Field works were carried out in three study areas: Ustka, Poddąbie, and Rowy, located in the Polish coastal zone (Barańska et al. 2016, Fig. 1). The location of sampling stations was determined on the basis of bathymetric and sonar maps, which enabled identification of sediments and sea bottom structure characteristics in the study areas (Osowiecki and Kruk-Dowgiałło 2006, Research project PMSHE no N306296933, Brzezińska et al. 2013). A total of 32 sampling stations were designated (Fig. 1): 10 in Ustka, 10 in Poddąbie, and 12 in Rowy. The stations were located on the stony bottom within a depth range 5–17 m. A stony bottom is defined as at least 100 boulders in the area of 1 ha.

Field studies were performed in June-July 2016. At each sampling station, a diver collected video and photo documentation of seabed areas and estimated vegetation coverage (at an area of approx. 20 m^2). Additionally, the diver took one qualitative sample and one quantitative sample of phytobenthos by means of a DAK frame (catching area 0.04 m^2; Andrulewicz et al. 2004). Altogether, 57 samples were collected (27 qualitative and 30 quantitative samples), which were kept frozen until laboratory analyses. Samples were analyzed in terms of taxonomic composition and biomass, in accordance with the Polish national standards by Kruk-Dowgiałło et al. (2010).

The results of field studies and laboratory analyses are presented in detail in the work by Barańska et. al (2016). The same data was used in the present paper for the assessment of natural values in the study areas.

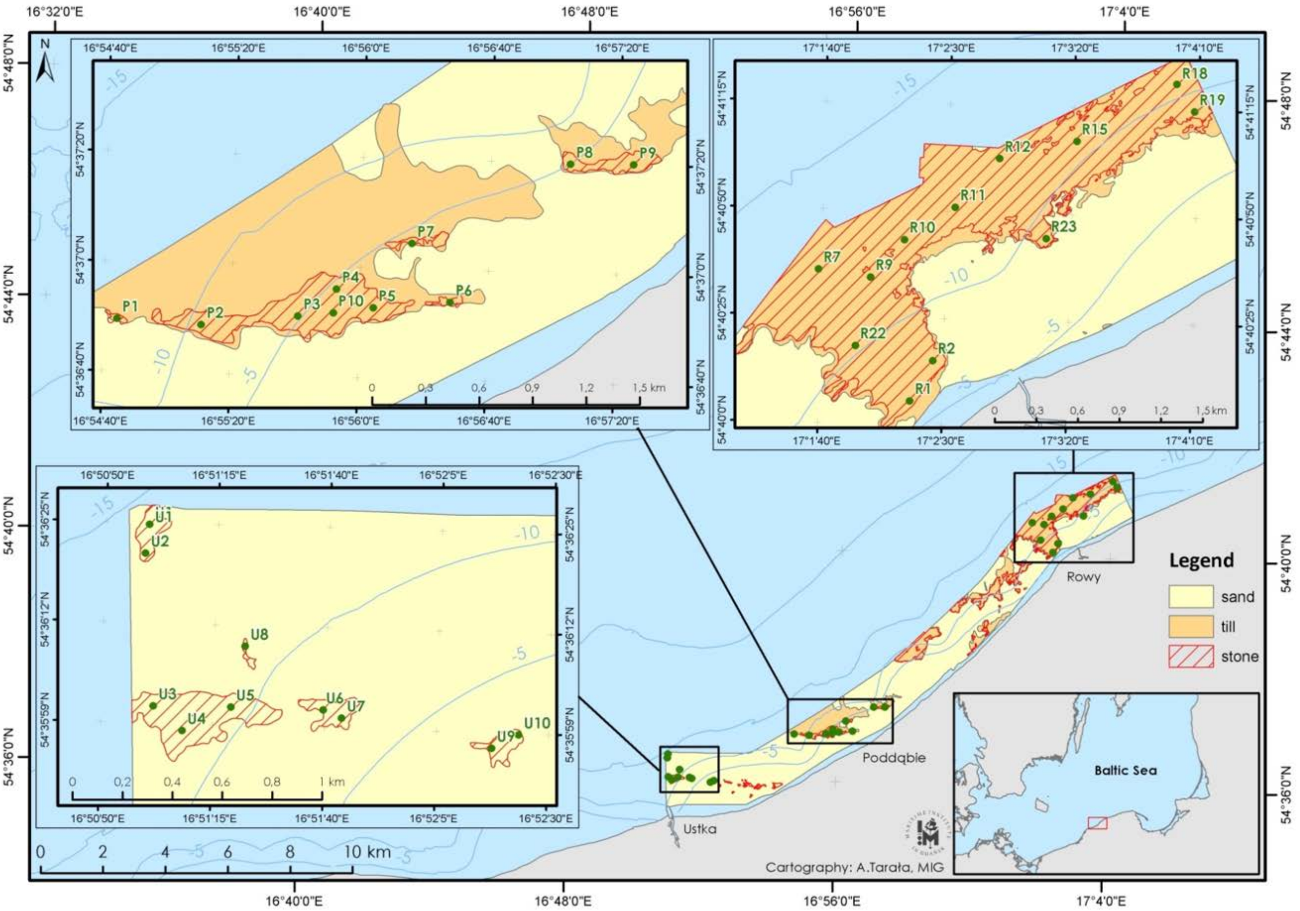

Fig. 1. Phytobenthos sampling stations used for the assessment of natural values of the stony bottom.

Tab. I. Criteria for the natural valuation of phytobenthos in the Polish marine waters.

CRITERION NO.	NAME OF THE CRITERION	DESCRIPTION
C I	Occurrence of phytobenthos (as single specimens or communities)	Phytobenthos is unique in the Polish zone of the Baltic Sea, thus, its presence increases natural preciousness of the considered area
C II	Occurrence of phytobenthos communities	A community is recognized when phytobenthos coverage exceeds 30%. Communities serve as a habitat for fauna, they are a significant element of the marine environment increasing biodiversity and productivity of the water area (Christie et al. 2009)
C III	Presence of rare, protected species	Some phytobenthos taxa are unique (rare) elements in the Polish marine waters, they occur over small areas and in high dispersion (Mirek et al. 2006). It can be a result of natural environmental conditions (absence of suitable substrata, too strong water dynamics) or anthropogenic degradation (eutrophication, contamination). Protection of these species is crucial to maintain biodiversity of the marine ecosystem and its undisturbed functioning. Protected species are given according to the Regulation of the Minister of Environment of 9 October, 2014 on the plant species protection (Journal of Laws 2014 No. 0 item 1409): *Furcellaria lumbricalis* (formerly: *F. fastigiata*), *Fucus vesiculosus*, *Zostera marina*, *Ceramium diaphanum*, *Ceramium tenuicorne*, *Ceramium virgatum* (formerly: *C. rubrum*), *Tolypella nidifica*, *Chara baltica*, *Chara aspera*. Species defined as rare according to the authros' expert knowledge : *Aglaothamnion tenuissimum*, *Desmarestia viridis*, *Coccotylus truncatus*, *Delesseria sanguinea*, *Potamogeton filiformis*, *Protohalopteris radicans* (formerly: *Sphacelaria radicans*), *Rhodomela confervoides*, *Sphacelaria* sp., *Chara* sp.(except *C. baltica* and *C. aspera*), *Chorda filum*, *Dictyosiphon foeniculaceus*.
C IV	Lack of dominance in biomass of species regarded as eutrophication indicators	The indicator species include filamentous brown algae: *Stictyosiphon tortilis*, Pylaiella and Ectocarpus genus and green algae of the following orders: Ulva, Cladophora and Chaetomorpha. Intensive development of these taxa indicates negative alterations in the marine environment. It is the result of eutrophication (Fletcher 1996, Kruk-Dowgiałło 1996, Valiella 1997, Eriksson 2002, Rinne et al. 2011, Blomqvist et al. 2012) and may pose a threat to other components of biocenosis (e.g., through the reduction of light availability, changes in the redox potential in sediments), thereby lowering the natural values of the area.

Tab. II. Scores given for each criterion in natural valuation based on phytobenthos.

SCORE	DESCRIPTION
C I – Occurrence of phytobenthos (as single specimens or communities)	
0	No
1	Yes
C II – Occurrence of phytobenthos communities	
0	No
1	Yes
C III – Presence of rare, protected species	
0	No
1	Yes (1 score for each rare/protected species)
C IV – Lack of dominance in biomass of species regarded as eutrophication indicators	
0	No
1	Yes

Tab. III. Classification of natural values.

SCORE	CLASS OF NATURAL VALUE
0	0 (lack of natural values)
(0-3>	1 (low)
<4-6>	2 (medium)
≥7	3 (high)

Natural valuation

The concept of natural valuation was based on the first works on biological valorization of the Polish marine areas (PMA), (Kruk-Dowgiałło 2000 a and b, Osowiecki and Żmudziński 2000, Kruk-Dowgiałło 2011). The present methodology was developed to assess the natural values of PMA, with the exception of coastal lagoons. All criteria from the previous methods were modified and combined into four so as to generally characterize the qualitative and quantitative structure of phytobenthos (Table I). A new system for score criteria (Table II), classification of natural values (Table III) as well as their graphic presentation was elaborated.

The assessment was conducted according to the following stages:

1. The criteria (Table I) were considered at each sampling station in order to be assigned a score (Table II). Each criterion received a score of 0 or 1. Criterion III (presence of protected, rare species) was an exception, as its maximum value depended on the number of protected and rare species identified at the station. When all criteria were considered, all scores were summed up and assigned to the station.

2. For a group of stations located in the seabed area homogeneous in terms of type of sediment and its structure (compact or dispersed) – the values were averaged. If only one station was located in the homogeneous seabed area, the sum of scores for all criteria at that station was given.

3. The average value for the group of stations/value for the station was assigned to the appropriate class of natural value (Table III).

A map with classes of natural value in particular homogeneous seabed areas was presented on layers of sediment types as a background (Brzezińska et al. 2013). The map was made in ArcGIS 10.1.

In order to compare the study areas, the class of natural value for each of the analyzed area was determined, i.e., scores for all stations within the particular study area were averaged.

RESULTS

The list of natural values at each station in the study areas is showed in the table (Table IV).

Criterion I (occurrence of phytobenthos) was met at all stations in Rowy, while in Poddąbie at 70% of stations, in Ustka at 30% of stations.

Criterion II (occurrence of phytobenthos communities) was met only in the area of Rowy – at 70% of stations. In Ustka and Poddąbie, phytobenthos was rare and overgrew stones as single specimens.

Criterion III (presence of rare, protected species) was met at all stations in Rowy. Five rare species (*Sphacelaria cirrosa*, *Aglaothamnion tenuissimum*, *Coccotylus truncatus*, *Rhodomela confervoides*, *Sphacelaria* sp.) and three protected species (*Ceramium diaphanum*, *Ceramium virgatum* and *Furcellaria lumbricalis*) were reported. In Poddąbie, the criterion was met at four stations – one rare species *Sphacelaria cirrosa* (station P4) and one protected species *Ceramium diaphanum*. In Ustka, protected species *Ceramium diaphanum* was present at two stations.

Natural values determined by criterion IV (lack of dominance in the biomass of species regarded as eutrophication indicators) were noted in Rowy – at 70% of stations, in Poddąbie – at 70% of stations, whilest in Ustka – at 20% of stations. Among the indicator species, the most common in the study areas were *Cladophora glomerata*, *Ectocarpus siliculosus* and *Pylaiella littoralis* (Barańska et al. 2016).

Analysis of the criteria showed that the most valuable area is Rowy – medium class of natural values while Ustka and Poddąbie – low class of natural value (Tab. IV, Fig. 2).

DISCUSSION

The occurrence as well as qualitative and quantitative structure of phytobenthos, and thus, its natural values, are shaped in the coastal zone of the Baltic Sea mainly by abiotic factors of the environment such as type of sediments, depth, availability of light, and water dynamics (Markager and Sand-Jensen 1992, Eriksson and Bergström 2005, Wallin 2011, Snickars 2014). In all areas investigated in the present paper, the envi-

Tab. IV. Analysis of criteria for the natural valuation of phytobenthos in three study areas (colors explained in Tab. III) .

STUDY AREA	SAMPLING STATION	C I OCCURRENCE OF PHYTOBENTHOS (AS SINGLE SPECIMENS OR COMMUNITIES)	C II OCCURRENCE OF PHYTOBENTHOS COMMUNITIES	C III PRESENCE OF RARE, PROTECTED SPECIES	C IV LACK OF DOMINANCE IN BIOMASS OF SPECIES REGARDED AS EUTROPHICATION INDICATORS	SUM AT SAMPLING STATION	AVERAGE FOR HOMOGENOUS SEABED AREA	AVERAGE IN STUDY AREA
Ustka	U1	0	0	0	0	0	0	0.6
	U2	0	0	0	0	0		
	U3	0	0	0	0	0	0.7	
	U4	0	0	0	0	0		
	U5	1	0	0	1	2		
	U6	0	0	0	0	0	0.5	
	U7	1	0	0	0	1		
	U8	0	0	0	0	0	0	
	U9	0	0	0	0	0	0.5	
	U10	1	0	1	1	3		
Poddąbie	P1	0	0	0	0	0	0	1.8
	P2	0	0	0	0	0	1.8	
	P3	0	0	0	0	0		
	P4	1	0	1	1	3		
	P5	1	0	1	1	3		
	P10	1	0	1	1	3		
	P6	1	0	0	1	2	2	
	P7	1	0	0	1	2	2	
	P8	1	0	1	1	3	2.5	
	P9	1	0	0	1	2		
Rowy	R1	1	1	2	0	4	5.1	5.1
	R2	1	1	1	0	3		
	R7	1	0	2	1	4		
	R9	1	0	1	1	3		
	R10	1	1	3	0	5		
	R11	1	1	2	1	5		
	R12	1	1	3	1	6		
	R15	1	1	4	1	7		
	R18	1	1	2	1	5		
	R19	1	1	2	1	5		
	R22	1	0	2	1	4		
	R23	1	1	4	1	7		

ronmental conditions are generally unfavorable to the development of macroalgae. Although, the surface for potential development of macroalgae is present (sandy bottom covered with outcrops of clay and stones, Fig. 1), the study areas are characterized by strong water dynamics (Kapiński 2007, Feistel 2008). Hydrological conditions cause temporary movement of sediments and periodic exposure or coverage of the stony surfaces, thus preventing macroalgae from stable fouling (Kautsky and Kautsky 1989, Eriksson and Johansson 2005). Another obstacle for development of macroalgae is a hard bottom in the form of stones rarely distributed on the sandy seabed (exposure to abrasive effect of sand). In the area of Ustka and Poddąbie, the hard bottom occurs sporadically, in dispersion and occupies small areas – 0.1 km² and 0.3 km², respectively (Brzezińska et al. 2013). In contrast, in Rowy, the hard bottom consists of compact stony structures covering ca. 2.4 km² of the seabed (Brzezińska et al. 2013) and thus forms a so-called boulder area. This type of substrate, despite its strong water dynamics, serves as a refugium for a thriving flora, whose natural values were emphasized by applying the new method of valuation. Here, macroalgae constitutes dense communities (Fig. 3), which are vastly distributed over the area. Communities are built mainly by red algae *Vertebrata fucoides* – species common in PMA, but

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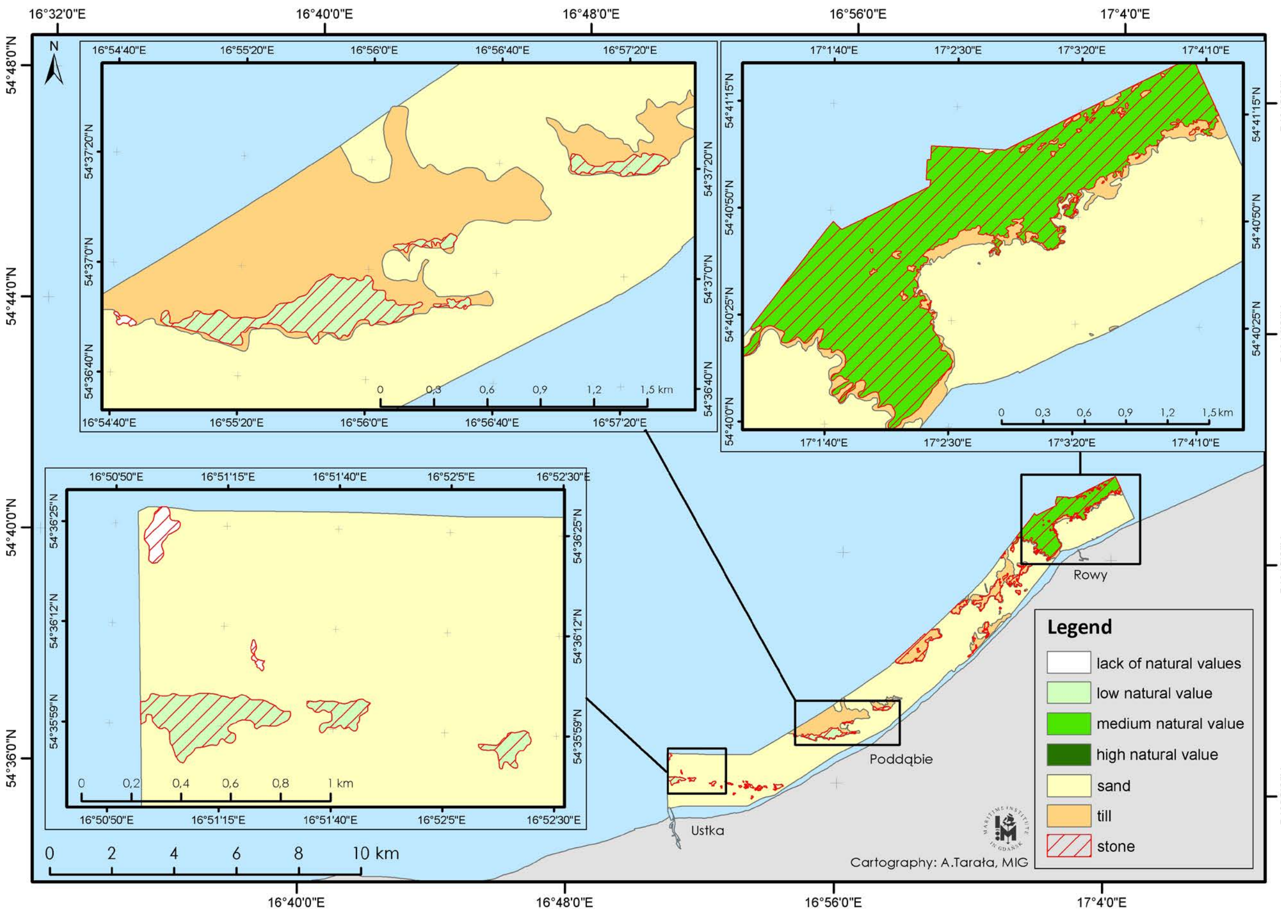

Fig. 2. Natural valuation of macroalgae on stony bottom near Ustka, Poddąbie and Rowy.

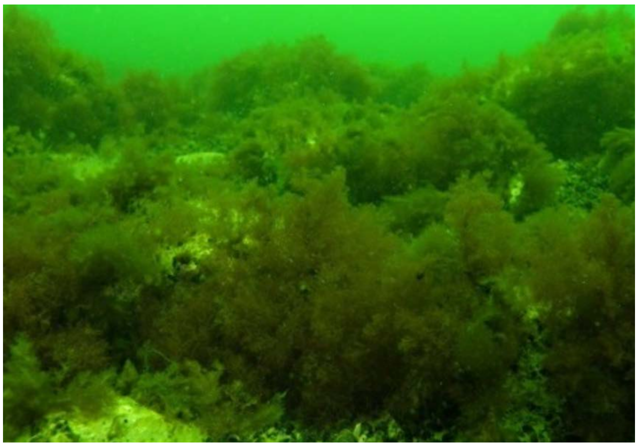

Fig. 3. Macroalgae communities in the Rowy boulder area in 2016 (Barańska et al. 2016).

among which numerous rare (5) and protected (3) species develop. In the Ustka and Poddąbie areas, the natural value was defined as low, due to the very low abundance of macroalgae (only single specimens), mainly red algae *Vertebrata fucoides* (Barańska et al. 2016) and the presence of a low number of rare (1) and protected (1) species (Tab. IV).

According to the introduced method, the Rowy area ranks in the medium class of natural value (Tab. IV, Fig. 2). It is justified, if Rowy is compared to the Słupsk Bank boulder, located about 25 km northwards from Ustka (Okołotowicz 1991, Andrulewicz et al. 2004, Brzeska 2009, Kruk-Dowgiałło et al. 2011, PMŚ 2010–2016), where there are dense communities of protected species (4), mainly *Furcellaria lumbricalis* and *Ceramium diaphanum*, and rare species (7). Indicator species occur as well – *Pylaiella littoralis* and *Ectocarpus siliculosus*, however in small amounts.

The current valuation method allowed to identify areas of different natural values of phytobenthos in the coastal zone of PMA. In contrast to the method used so far for PMA (Węsławski et al. 2009), the presented method includes only a few criteria and a few stages of valuation process, what makes it a simple tool for the assessment of natural values of phytobenthos in PMA.

The elaborated method should be developed in the future in terms of criterion III – the list of protected and rare species should be updated, criterion IV – list of indicator species should be verified. All may result in a slight shift of borders between natural valuation classes (updating of classification).

CONCLUSIONS

1. The natural valuation method presented in the article and implemented in three study areas: Ustka, Poddąbie, and

Rowy, takes into account the specificity of the occurrence of phytobenthos in PMA, and therefore can be applied to other regions of the Polish Baltic zone.

2. The hydroacoustic data (sonar and bathymetric data) enable precise determination of the phytobenthos sampling stations (acquisition of a comprehensive set of data on the quantitative and qualitative structure for the assessment of values) and precise delineation of areas with different natural values (map of the distribution of valuable areas).

3. The obtained map of natural valuation can provide useful information for ecosystem-based management in the studied areas indicating conflict zones and protection areas.

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