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CASE REPORT

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Biotic typology of polish marine areas based on bottom macrofauna communities

Typologia biotyczna polskich obszarów morskich na podstawie zespołów makrofauny dennej

Authors' Contribution:
A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection

Magdalena Błeńska[ABDEFG],

Andrzej Osowiecki[BDE]

Zakład Ekologii Wód, Instytut Morski w Gdańsku, Polska

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Abstract: The aim of this study was to develop methodological assumptions of the biotic typology and, based on these assumptions, determine the biotic types in the Polish Marine Areas. The biotic typology proposed in this paper is based on the analysis of the structure and the classification of macrozoobenthos. This group of organisms can be regarded as the main component structuring the biotic types due to their sedentary way of life and less susceptibility to spatial and seasonal changes compared with pelagic biota. Soft and hard bottom sediments occurring in the Polish Marine Areas were taken into consideration. The basic criterion of the biotic typology was to identify the predominant components of the seabed zoocoenoses – animal species and communities, from which the biotic type takes its name. As a result of the classification process the Polish Marine Areas were divided into six sub-areas of different environmental characteristics (a type of sediment, salinity and water dynamics); each of them inhabited by different macrozoobenthos communities. Consequently, the following biotic types were determined: I) Chironomidae-Oligochaeta, II) *Macoma balthica-Marenzelleria* sp., III) *Bylgides sarsi-Macoma balthica*, IV) Hydrobiidae-*Cerastoderma glaucum*, V) *Pygospio elegans*-Hydrobiidae, VI) *Mytilus trossulus*-Gammaridae. The proposed typology is the first comprehensive attempt at classification of the Polish Marine Areas taking into account both biotic and abiotic elements of the marine environment.

Keywords: biotic typology, macrozoobenthos, Baltic Sea, Polish Marine Areas

Streszczenie: Celem pracy było przygotowanie założeń metodycznych typologii biotycznej oraz, na podstawie tych założeń, wyznaczenie typów biotycznych w polskich obszarach morskich. Proponowaną w niniejszej pracy typologię biotyczną oparto na wynikach analizy struktury i klasyfikacji zbiorowisk makrozoobentosu będących głównym składnikiem nadającym charakter typom biotycznym ze względu na trwałe związanie z miejscem występowania i nie podleganie zmianom przestrzennym i sezonowym w takim stopniu, jak biocenozy toni wodnej (pelagialu). Analizą objęto dno miękkie (piaszczyste i muliste) oraz twarde (kamieniste) polskich obszarów morskich. Podstawowym kryterium zaproponowanej typologii biotycznej było określenie dominujących składników zoocenoz dna morskiego – gatunków i zbiorowisk, od których dany typ biotyczny bierze swą nazwę. W wyniku przeprowadzonej klasyfikacji dokonano podziału polskich obszarów morskich w oparciu o te składniki środowiska, które w głównym stopniu kształtują biotop (siedlisko) i wpływają istotnie na strukturę gatunkową zamieszkujących go zbiorowisk makrozoobentosu (tj. rodzaj osadu, zasolenie i dynamika wód). W rezultacie wyróżniono następujące typy biotyczne: I) Chironomidae-Oligochaeta, II) Macoma balthica-Marenzelleria sp., III) Bylgides sarsi-Macoma balthica, IV) Hydrobiidae--Cerastoderma glaucum, V) Pygospio elegans-Hydrobiidae, VI) Mytilus trossulus-Gammaridae. Zaproponowana w niniejszej pracy typologia jest pierwszą kompleksową próbą klasyfikacji polskich obszarów morskich uwzględniającą zarówno elementy ożywione, jak i nieożywione środowiska morskiego..

Słowa kluczowe: typologia biotyczna, makrozoobentos, Morze Bałtyckie, polskie obszary morskie

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Introduction

The first attempt to develop a typology of the Polish Marine Areas (PMA) was made in 2004, 23]. In accordance with EU Water Framework Directive (WFD) recommendations [13], the authors proposed the division of PMAs based on the abiotic components of the environment. They determined 3 types of coastal waters and 5 types of transitional waters, subdivided into 11 and 9 water bodies respectively. In accordance with the Marine Strategy Framework Directive (MSFD) [14], the Polish Marine Areas were divided into 8 sub-basins, which unlike WFD included also open sea waters. An attempt to elaborate ecosystem typology of the Gulf of Gdańsk based on expert judgement considering both chemical and biological parameters was performed in 2004 by Andrulewicz *et al.* [2]. Urbański *et al.* [43] developed a typology classification scheme of the Gulf of Gdańsk based on the abiotic factors: wave exposure and turbidity.

Water bodies designated for the WFD as well as sub-basins designated for the MSFD purposes are the basic management units subjected to the assessment of environmental quality (WFD) or the assessment of the environmental status (MSFD). One of the essential objects of these assessments is macrozoobenthos, whose quality status is determined by the multimeric B index value [37]. The indexing algorithm takes into account species composition, abundance and macrozoobenthos taxa sensitivity to degradation of the marine environment [32]. A variety of seabed sediment types and hydrological regimes in the Polish maritime areas reflect the diversity of macrozoobenthos communities that are specific for each habitat – biotic type. Dissimilarities in the zoobenthos taxonomic composition and abundance domination structure in individual biotic types imply the need to determine specific reference conditions and specific classification scheme based on B index. Subdivision of PMA into biotic types based on dominating species is a prerequisite for proper assessment of the environment quality/status required by EU marine directives.

The aim of this study was to prepare the methodological assumptions of a biotic typology based on macrozoobenthos and delimitation of the biotic types in the Polish Marine Areas.

Subject and scope of study

The biotic typology presented in this paper is based on analyses of the structure and the macrozoobenthos classification available in the subject literature [44, 34, 30, 1, 31, 17, 22, 25] as well as results of macrozoobenthos research conducted within the HELCOM COMBINE monitoring programme [35, 36, 19,20, 21]. Macrozoobenthos community consists of benthic invertebrate species that due to their sedentary way of life and less susceptibility to spatial and seasonal changes compared with pelagic biota shape the form and structure of the biotic type. Macrozoobenthos is regarded as a good indicator of the water bodies quality assessment [38, 39, 12] as it reflects the ongoing eutrophication alteration in the abundance, biomass and species composition [6, 40]. The studied area included soft bottoms (sandy and silty sediment) and hard bottom (boulder areas) in the Polish Marine Areas (southern Baltic Proper).

Macrozoobenthos research in Polish Marine Areas

Only a few papers report the macrozoobenthos studies that cover the entire area of PMA. Most of the research projects were focused on selected smaller regions. Among them the southern and western part of the Gulf of Gdansk, especially Puck Bay were the most thoroughly studied [45, 30]. The least research was carried out in the northernmost regions of the PMA i.e. Southern Middle Bank and Słupsk Furrow.

One of the most extensive studies on the Southern Baltic macrozoobenthos communities were conducted in 1948-1954 at 272 sampling stations by Demel and Mańkowski [8, 9] and Demel and Mulicki [11]. The authors provided the maps of macrozoobenthos biomass and the dominant species distribution. In the years 1956-1957 Mulicki and Żmudziński [28] during their macrozoobenthos research recorded the presence of large areas of 'benthic deserts' (azoic areas) in the Bornholm Deep and the Gdansk Deep. The quantitative data due to over 60-year period that has elapsed since the above-mentioned studies are mainly of historical value, however, the state of hypoxia or anoxia at the bottom of the southern depths still remains [24, 5]. Another extensive macrozoobenthos research in the entire PMA was conducted by Warzocha [44] in 1978-1983. The author presented classification and characteristics of the bottom macrofauna structure and on that basis specified five dominant benthic fauna communities in the Southern Baltic Sea: *Macoma balthica-Mya arenaria* at sandy bottoms, *Mytilus edulis* (*trossulus*)*-Gammarus salinus* typical of hard stony substratum, *Macoma balthica-Mesidotea (Saduria) entomon* and *Astarte borealis-Astarte eliptica* at sandy/silty bottom. The deepest area was inhabited by the community *Scoloplos armiger-Macoma balthica*.

Principles and methodology of the biotic types determination

The basic assumption adopted in developing the biotic typology was to determine the dominant components of benthic biocoenoses – species forming the communities and the distribution of these communities in the Polish Marine Areas. Species structure of the particular macrozoobenthos community is shaped by the following factors: i) type of sediment, ii) water dynamics, and iii) salinity and temperature. Of these factors, the type of sediment plays the key role, as the macrozoobenthos organisms dwell in its surface layer or live on the surface. Assuming that areas of similar environmental conditions represent the same biotic types, a model of their delineation was elaborated (Fig. 1).

The model of the biotic types delineation consists of three main phases (Fig. 1). In the first phase, the seabed was divided into categories due to the predominant type of substrate. In the second phase, other abiotic factors determining the macrozoobenthos composition (salinity and water dynamics) were taken into consideration. This allowed further diversification of regions within the previously specified categories. In the third phase, the specified areas of similar environmental conditions were given the

Fig. 1. Model of the biotic types delineation in Polish Marine Areas

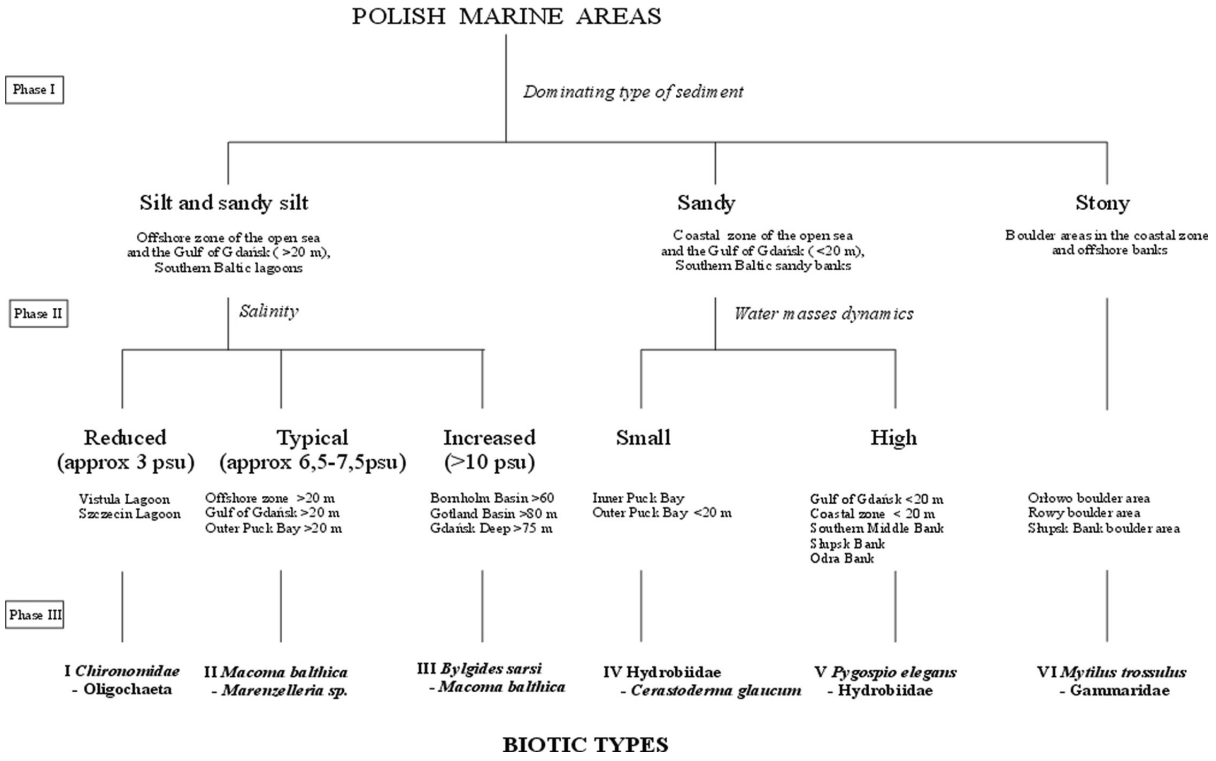

Fig. 2. Classification of the biotic types in the Polish Marine Areas.

name, reflecting the most abundant and commonly occurring macrozoobenthos species. Abundance was considered to be more suitable than biomass parameter determining the structure of zoobenthos communities due to a wide range of species biomass values. A grown individual of the bivalve *Mya arenaria* can exceed up to 1000 times the biomass of a crustacean or a polychaete individual. Bivalves and snails for estimating wet weight are traditionally weight with shells that also significantly affects the biomass value. That is the reason why B index, like most other indices used in the Baltic States for assessing ecological status based on macrozoobenthos, does not include the species biomass [4, 3]

Results

Determination of biotic types

The biotic typology of PMAs was performed in three consecutive phases in accordance with the model presented in Fig. 1. In the first phase, the seabed was divided into three categories: i) areas dominated by silt and sandy silt, ii) areas covered with sand and silty sand and iii) seafloor covered with pebbles and boulders (Fig. 2). Then, in phase II, other abiotic factors (salinity or water dynamics), determining the composition of macrozoobenthos, were taken into consideration. This allowed further diversification of regions. Considering the salinity, the areas were divided into three categories: i) typical of the Polish Marine Areas surface waters (approx. 7 psu), ii) reduced in some coastal regions due to the inflow of fresh water (approx. 3 psu) and iii) increased in areas located below the halocline (> 10 psu). Regarding the water masses dynamics, the areas were divided according to the degree of shielding against wind generated water currents and wave exposure. As a result, in phase III altogether 6 types of biotic types were determined: I) Chironomidae-Oligochaeta, II) *Macoma balthica-Marenzelleria* sp., III) *Bylgides sarsi-Macoma balthica*, IV) Hydrobiidae-*Cerastoderma glaucum*, V) *Pygospio elegans*-Hydrobiidae, VI) *Mytilus trossulus*-Gammaridae.

Description of the biotic types

The biotic type I Chironomidae-Oligochaeta covers the entire area of the Vistula Lagoon and the Szczecin Lagoon (Fig. 3). Both water bodies are sheltered from the immediate influence of the open sea waters. Most parts of the bottoms are covered with soft muddy substratum, thus, the bottom fauna is dominated by species feeding on organic matter (detritusophages). The species that occur in this biotic type are tolerant to salinity changes. The community consists of 12 taxa [25], of which the most common are larvae of insects and oligochaetes, both regarded as bio-indicators of the bottom environment excessively loaded with organic matter [25].

The biotic type II Macoma balthica-Marenzelleria sp. is located in the outer part of the Puck Bay, the internal part of the Gulf of Gdańsk and open sea waters. It extends from 20 m depth down to the halocline. The bottom is covered with silty-sand and, particularly at deeper parts, the silt of thin consistency (Fig. 3). The periodical deficit of oxygen can occur in the near-bottom water layer and the sediments. Species dwelling this biotic type feed on organic matter collected from the surface layer of sediments or filter it from the water column. The community consists of 10-13 taxa at the open sea bottom [35, 36, 19, 20, 21] and 14 in the Gulf of Gdańsk [44]. The bivalve *Macoma balthica* dominates in the abundance structure (*ibidem.*).

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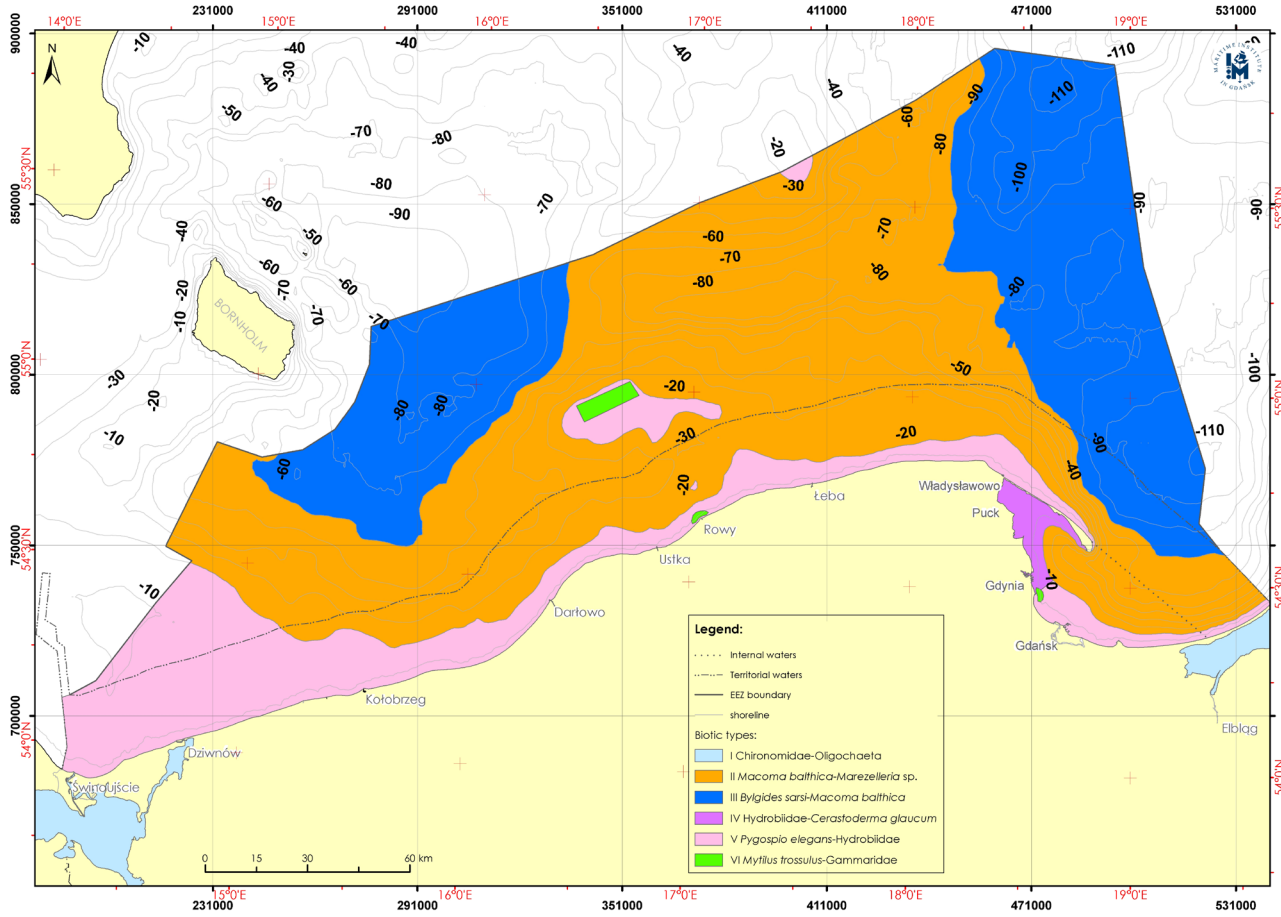

Fig. 3. The geographical range of the biotic types in the Polish Marine Areas (prep. by A. Tarała).

The biotic type III Bylgides sarsi-Macoma balthica covers southern slope of the Bornholm Basin (below 40-60 m), the slopes of the Gdańsk Basin (below 75 m) and Gotland Basin (below 80 m), (Fig. 3). Silty sediments of the areas situated below the halocline are often devoid of macroscopic life. Periodically, after the inflow of oxygenated water masses from the North Sea, the bottom is, for a limited period of time, inhabited by the most resistant to oxygen deficit opportunistic species: *Bylgides sarsi*, *Scoloplos armiger* and *Macoma balthica* [35, 36, 19, 20, 21]. The community consists of 11 taxa, mainly polychaetes [44].

The biotic type IV Hydrobiidae-Cerastoderma glaucum covers the entire Puck Lagoon (inner part of the Puck Bay) and the outer part of the Puck Bay down to 20 m depth (Fig. 3). The predominance of fine-grained sand and silty sand, as well as small water dynamics, shaped the macrozoobenthos community typical of shallow enclosed bottoms. The abundance of organic matter in the water column and sediments creates favourable conditions for the mass occurrence of filter feeders (*Mytilus trossulus*) and deposit feeders: snails (Hydrobiidae) **and bivalves (Cerastoderma glaucum) [30, 17].**

The biotic type V Pygospio elegans-Hydrobiidae covers the shallow bottom areas along the coastal zone and the Southern Baltic sandy banks down to approx. 20 m (Fig. 3). Some regional differences resulting from the degree of eutrophication can be observed in this type. The bottom areas in the vicinity of the Vistula River and the Oder River outlets are more eutrophicated than shallow zone along the open coast. Also wave exposure, strong water currents and the sediments consisting of fine and coarse sands can be regarded as main abiotic factors affecting the biota. The opportunistic species (resistant to dynamic environmental conditions) and preferring sandy bottoms (psammophilous): polychaete *Pygospio elegans* and snails of Hydrobidae family [34, 30] are the main components of the community.

The biotic type VI Mytilus trossulus-Gammaridae includes stony bottoms of the Słupsk Bank, at the feet of the active cliffs (e.g. Orłowski Cliff) and shallow boulder areas along the open coast (e.g. near the village of Rowy), (Fig. 3). The diversified community consists of 26-28 macrozoobenthos taxa [1, 31, 22]. The blue mussel *Mytilus trossulus* dominates in terms of abundance and biomass. Among the crustaceans, the largest group consists of Gammaridae family species (*ibidem*.).

Discussion

The benthic biocoenoses (phytobenthos and zoobenthos), due to their sedentary way of life and less susceptibility to spatial and seasonal changes, compared with the pelagic biota, are considered to be the main component structuring the marine biotic types. Since

the phytobenthos occupies only a small part of shallow bottoms within the Polish Marine Areas (down to 13 m it forms communities; at 20 m depth only single specimens of plants can be found [22, 41]), the biotic typology proposed in this paper is based on the analysis of the structure and the classification of macrozoobenthos communities that as functional integrated assemblages of organisms have been the subject of studies since the beginning of research on marine biocoenoses [7, 10,42, 18, 33].

Mills [26] compared several definitions, both in plant and animal biology and formulated definition: 'a community is a group of organisms occurring in a particular environment, presumably interacting with each other and with the environment, and separable from other groups by means of an ecological survey'. According to the author terms 'community' and 'assemblage' are synonymous. This definition has been commonly accepted and widely used in later studies [16, 18, 15,]. Morin [27] provided an overview of the different approaches to delineate communities: (1) physically, by discrete habitat boundaries, (2) taxonomically, by the identity of a dominant indicator species, (3) interactively, by the existence of strong interactions among species, or (4) statistically, by patterns of assemblages among species.

In the present paper, the authors applied the 1st, 2nd and 4th method of community determination specified by Morin [27]. In the delineation of the habitat boundaries, the abiotic components of the environment such as substrate type, salinity and water dynamics were analysed. Primarily these physical and chemical factors shape the macrozoobenthos structure, i.e. its taxonomic composition, abundance and biomass [46]. Some biotic factors such as inter-species interactions (dominance of the population in the community) or biotic potential of the species (ability to survive despite unfavourable environmental conditions) and the availability of food also significantly affect the distribution and abundance of macrozoobenthos species [29].

The biotic type classification, proposed by the authors, overlaps to some extent with the classification prepared by Warzocha [44]. The boundary of fine sand and silty sand occurrence in both cases was set at 20 m depth. Similar depth values were also applied, to distinguish the boundaries of the southern Baltic deeps represented by the biotic type *Bylgides sarsi-Macoma balthica* in this study and *Scoloplos armiger-Macoma balthica* in Warzocha [44] paper. However, it should be kept in mind that the proposed boundaries are approximate, in fact, the transition from one type to another occurs in a smooth manner.

The biotic type *Mytilus trossulus*-Gammaridae, the equivalent of *Mytilus edulis* (*trossulus*)-*Gammarus salinus* type in Warzocha [44] classification, was delimited in this study not only at the Słupsk Bank stony reefs, but also at the bottom of the active cliff feet and boulder areas located along the shallow open coast waters. Similarly, the current typology was extended to new areas: the Szczecin and Vistula Lagoons, as well as the Puck Bay inner, were the site specific biotic types: Chironomidae-Oligochaeta and Hydrobiidae-*Cerastoderma glaucum* were determined. The proposed typology, however, does not include the Słupsk Furrow within the depth range of 60-90 meters where Warzocha [44] determined the type *Astarte borealis-Astarte elíptica*. This area is relatively small and very poorly investigated. There is no current data on the quantitative and qualitative structure of benthic macrofauna community because the Słupsk Furrow has been excluded from the National Monitoring Programme of the Baltic Sea since 2008.

Conclusions

The proposed typology is the first comprehensive attempt at classification of the Polish Marine Areas taking into account both biotic and abiotic elements of the marine environment.

Classification of marine areas based on the analysis of key environment components (the type of sediment, salinity and water masses dynamics) that shape the biotope (habitat) and thus, significantly affect the macrozoobenthos communities allowed to delineate the areas inhabited by animal communities of different taxonomic composition and quantitative structure. This is the first step in the process of identifying the reference conditions and B index value class boundaries of the ecological quality assessment, which is indispensable for conducting a credible evaluation of the ecological status of sub-basins in the Polish Marine Areas.

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Corresponding author: Magdalena Błeńska, Instytut Morski w Gdańsku, Polska; e-mail: Magdalena.Blenska@im.gda.pl