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RELATIONSHIPS BETWEEN THE PROPERTIES OF BOTTOM SURFACE SEDIMENTS AND THE CONDITION OF PHYTO- AND ZOOBENTHOS OF THE PUCK BAY (1987-1999)

Abstract

Basing on investigations of bottom surface sediments of the outer Puck Bay (1995, 1999) and the inner Puck Bay (1987, 1991, 1996), their condition and the absolute quality was determined in accordance with the adopted classification [3]. Carried out at the same time investigations of the condition and composition of phyto- and zoobenthos allowed determining the relationships between the biotic and abiotic components of the Puck Bay bottom. In the paper, results of correlation analysis are presented. They indicate strong relationships between selected systems of components. These results show also that loading of the sediments with organic matter has a significant influence on the properties of the environment and on the biocenoses of the investigated water area.

Introduction

The properties of the sediment environment and the composition of biocenoses are good indicators of the quality of the coastal zone's biotopes. Populations occurring in this zone are connected with each other by various biological relationships, matter and energy circulate, and in result the environment is shaped. The feedback between the bottom biocenosis and the sediment environment plays a basic role in the processes of development, stabilisation and regression of life in the coastal zone – the zone that plays the function of a barrier protecting the marine ecosystem against anthropogenic influences.

The many years of investigations of the chemistry of bottom surface sediments and of the phyto- and zoobenthos of the Puck Bay allow attempting a determination of relationships between selected systems of components, using statistical methods. Bottom sediments of the Puck Bay are supplied with organic matter depending on the amount of primary (biological) production and the size of inflow from land sources, and in dependence of the intensity of sedimentation, which is shaped by the hydrodynamic and depth conditions of the water area. The concentration of biogenes, the redox potential and pH, as well as other characteristics (bacterial activity, ion-exchange potential), depend on the inflow and on the content of organic matter [9]. The biological production of the basin is stimulated by eutrophication and by decomposition and mineralisation of organic matter in the sediments (and water), which together determine the progress of bio-geochemical changes. This exerts a basic influence on the state of the environment and biocenoses and on the trends of environmental and biocenotic changes.

Using the results of carried out in the years 1987-1999 investigations of the sediments and biocenoses of the Puck Bay, an attempt was made to determine the relationships between the state (quality) of the sediment environment and the changes of phytobenthos biomass (in that of rooted flora), and of the biomass of zoobenthos (in that of molluscs, crustaceans and oligochaeta). Obtained values of correlation between selected parameters, and especially the repeatability of these correlations, suggest that they can be used as indicators of biotope stabilisation. On the other hand, a disappearance of the relationships or changes of trend may indicate that the relationship between the environment and the cenoses of the basin is disrupted. The presented here relationships have the value of a quantitative assessment of transformation of the Puck Bay biotope in conditions of permanent eutrophication and anthropogenic pressure. Implementation of this method in investigations of the biotopes of other basins of the Southern Baltic will allow observing and comparing environmental and biocenotic changes, which precede general changes of the marine ecosystem.

The area of investigations

In the present work, results of earlier investigations of the properties of sediments in the inner and outer Puck Bay [5, 20, 23] were used. Simultaneously, the biomass and composition of phytobenthos [12, 13, 14] and zoobenthos [16, 17,18] were determined (Fig. 1).

The areas of the inner Puck Bay – the Puck Lagoon – and of the neighbouring outer Puck Bay are water basins, in which during the past 50 years have occurred largest environmental and biocenotic changes along the whole Polish coastline [2, 11, 18].

The Puck Lagoon is of a strongly eutrophicative and accumulative character, and large areas of its formerly sandy bottom became covered with clay and mud. The mud and clay contain large amounts of products of organic matter decomposition, and of biogenic and polluting compounds [19]. They are transported over the bottom by currents and waves, filling up all depressions of the seafloor. This specific for shallow water basins transport of fine bottom surface sediments, could have been one of the reasons for the disappearance of two basic phytobenthos species (red algae and rockweed), and for the significant depletion and species transformation of the underwater meadows [4]. Degradation of phytobenthos, especially of rooted flora, strengthened with the increase of biomass of brown algae (*Pilayella litoralis* and *Ectocorpus*) [13]. The high eutrophication of water and sediments, increased amounts of suspended matter in water, development of brown algae and increased loading of the environment by (native mainly) organic matter caused an increase of general zoobenthos biomass (mainly mollusc biomass) and a reduction of the biomass of some of its groups (e.g. crustaceans) [18].

Methodology

Since the middle of the 80ties, the following parameters of Puck Bay's bottom surface sediments were investigated: grain size composition, content of organic matter and organic carbon, total phosphorus and nitrogen content, content of inorganic compounds of phosphorus and nitrogen, redox potential level (Eh), pH, carbonate content, general bacteria NPL and coli NPL, micro-biological activeness, chemical composition of interstitial water, phosphorus and nitrogen exchange between the water and sediments, oxigenation of water just above the sediments, and others.

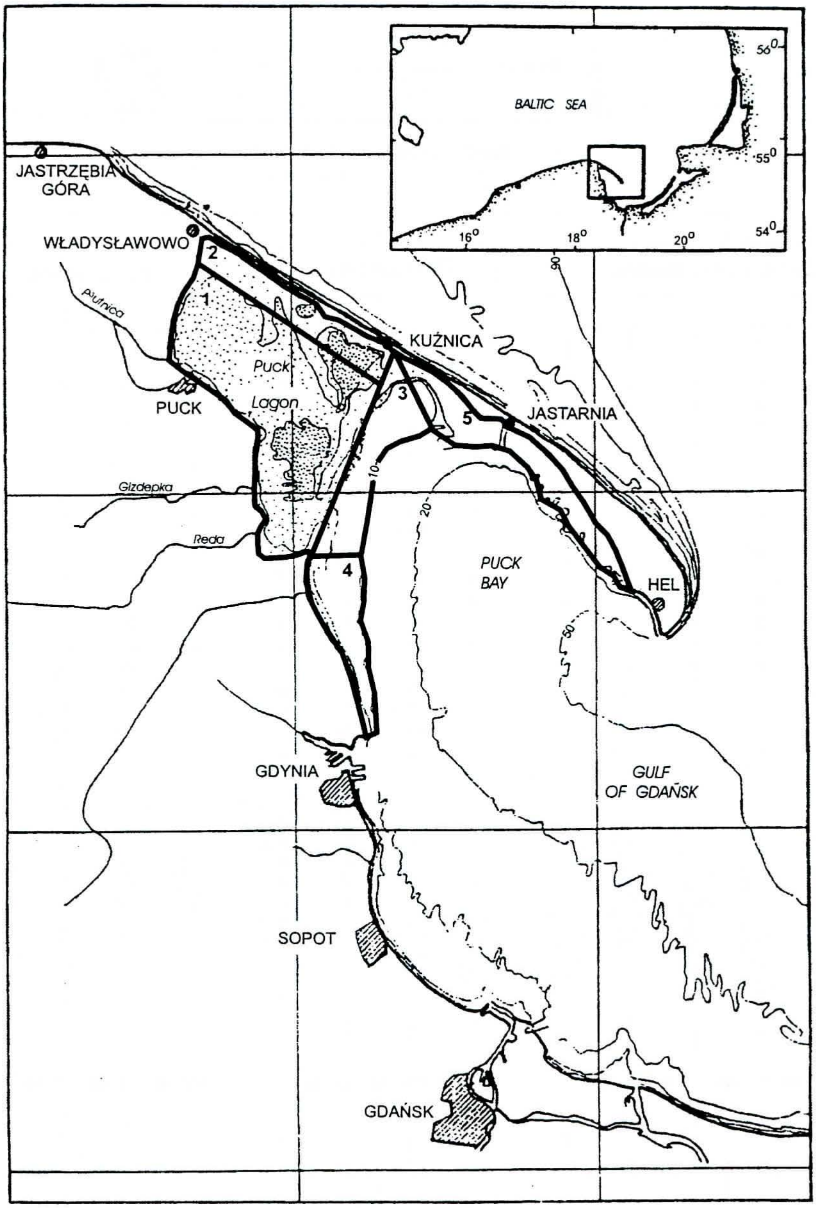

Fig. 1. Water areas of the Puck Bay investigated in the period 1987-1999

1 – 1987, 1996; 2 – 1991, 1996; 3 – 1995, 1999; 4 – 1995; 5 - 1999

In the present work are used results of investigations of bottom surface sediments obtained by the following methods:

1) organic matter content (loss at roasting) [10].
2) total phosphorus and nitrogen content after oxigenation in an acid environment [8],
3) redox potential (Eh) using type PtAgP-219W combined electrode,
4) acidity using an SAgP-220W electrode.

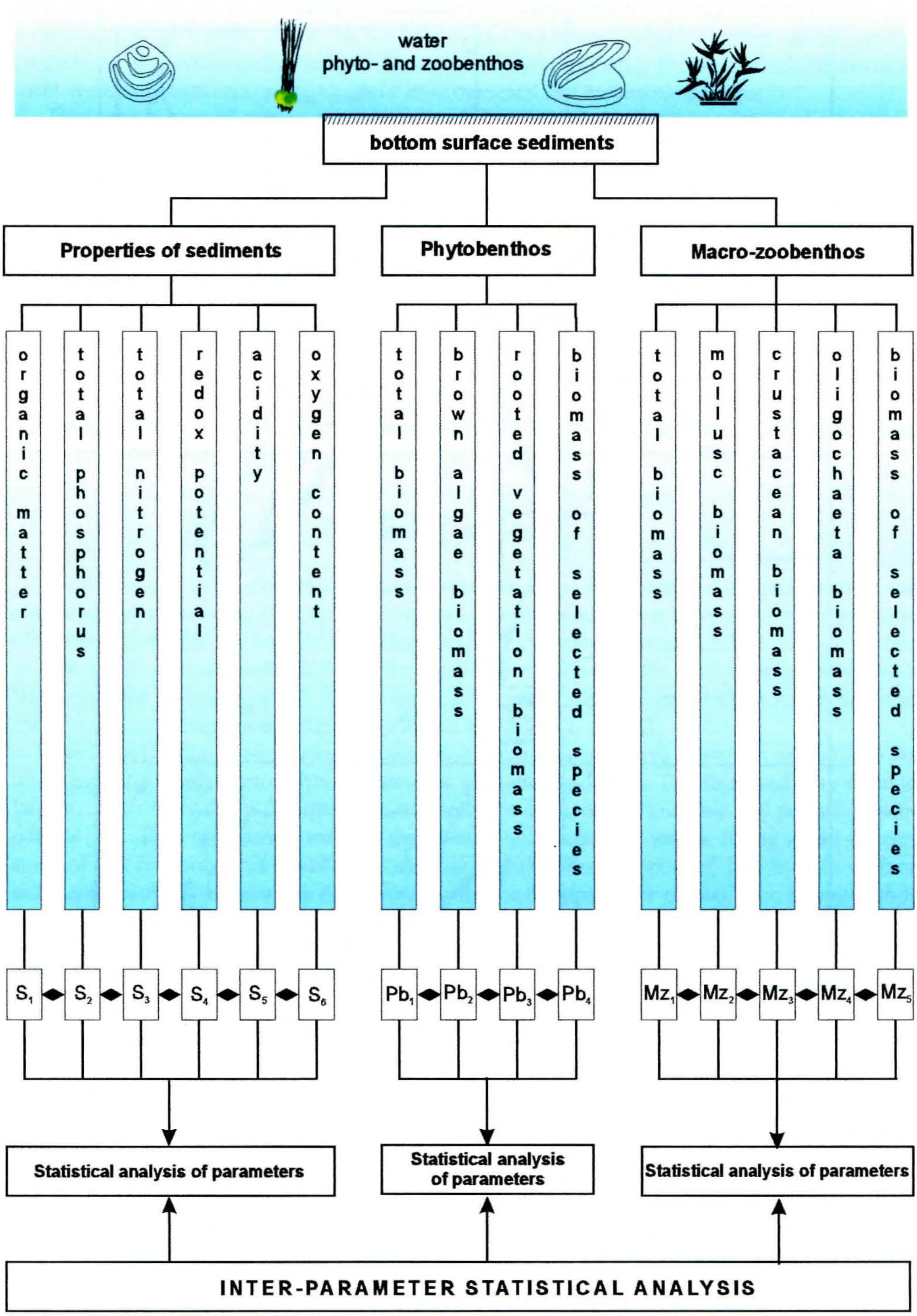

Fig. 2. Diagram of analysis of relationships between the properties of sediments and the condition of phyto- and zoobenthos in the Puck Bay

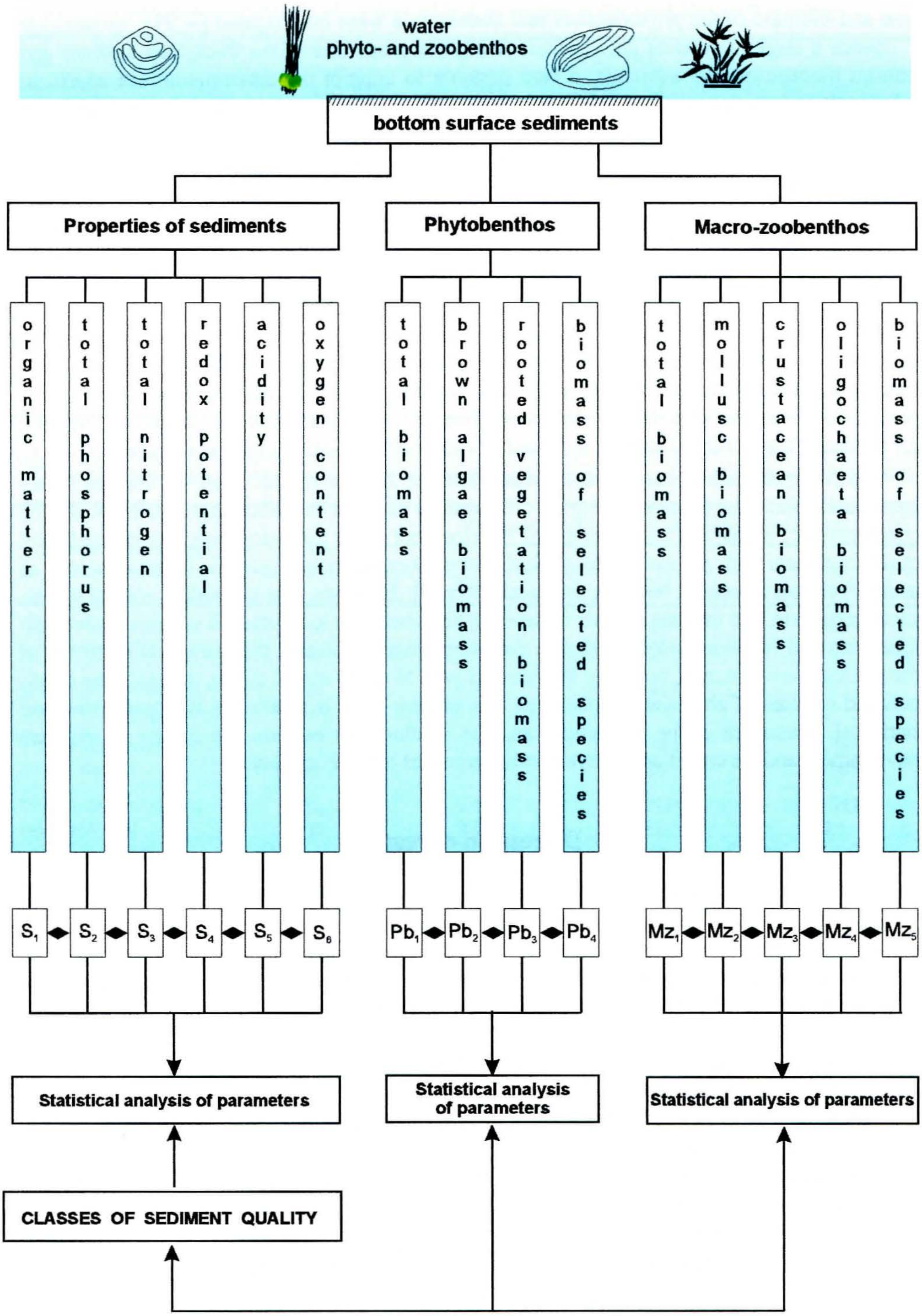

Fig. 3. Diagram of analysis of relationships between the properties of sediments and the condition of phyto- and zoobenthos in the Puck Bay

Simultaneously with the chemical investigations of the sediments, the species composition and biomass of the phytobenthos and zoobenthos were investigated [7, 21].

Since a large number of data characterising the properties of the Puck Bay seafloor and bottom biocenoses was available, it was possible to attempt the determination of statistical relationships between sets of various parameters. Correlation analysis was carried out determining the internal relationships between the chemical parameters of the sediments and the biotic parameters, and between systems composed of sediment parameters and the biomasses of phyto- and zoobenthos (Fig. 2).

In the analysis of relationships between the parameters of sediments and the elements of phyto- and zoobenthos (Fig. 3), use was made of the possibilities offered by the method of sediment quality classification. The method was developed in order to obtain a summary indicator, describing the quality of bottom sediments [3]. The method uses ranks of five parameters, i.e. the content of organic matter, total phosphorus, total nitrogen, redox potential and pH. The calculated in this way quality indicator was used for the valorisation of the sediment environment in the coastal zone of the Słowinski National Park and the Coastal Landscape Park [6], as well as of the coastal zone of the Sobieszewo Island. It was found that the method can be used for assessing the quality of various sediment environments – sandy as well as muddy.

The presented below results of calculations indicate that it is correct to use the summary sediment quality indicator for determining the relationships between the sediment environment and the components of phyto- and zoobenthos. The development of the summary (ranking-type) sediment quality indicator with the use of the available set of parameters was possible because there is an inter-dependency network between the parameters [9]. However, this network is subject to seasonal variations, and in some periods it can even disappear due to changes in organic matter sedimentation and variations in its distribution and mineralisation. Clearly, the changes of properties of the sediment environment, occurring in annual as well as multi-annual cycles, influence the condition and biomass of phyto- and zoobenthos. The present work is an attempt at a quantitative and statistical assessment of the interactions and the relationships between the quality of sediment environment and the condition of phyto- and zoocenoses of the Puck Bay.

Discussion of results

The scope of investigations of the sediments was not uniform throughout the whole analysed period. In 1987 only the organic matter content was measured, and in 1991 measurements were limited to the redox potential. It was therefore impossible to determine the sediment quality indicator. However, in the years 1995, 1996 and 1999, the five parameters of the sediments were analysed twice for the outer part of the Puck Bay and once for the inner Puck Bay. This allowed to determine the sediment quality at each measurement station and the average sediment quality for the investigated areas. Results of the investigations (Table 1), which generally were carried out at the end of June or beginning of July, indicate that there are differences in the loading of the seafloor with organic matter, resulting in differences of biogen content, redox level and pH.

The quality of deposits in both parts of the Puck Bay was (in the period 1995-1999) rather low (4.27-4.66), and it was much worse than in the coastal zone of the Słowinski National Park [6], wher in the strip between 0.0 and 10.0 m water depth the quality was good and very good (□2).

Coefficients of correlation between parameters of deposits in both parts of the Bay (Table 2) in the period 1995-1999 were statistically significant, though quite variable (from 0.1 to 0.001). The only exception was the relationship between organic content and redox potential in the data from inner Puck Bay from 1996, for which no significance was found, however at maintained negative trend.

Table 1. Characteristic of bottom surface sediments in the Puck Bay (1987-1999)

Parameters of sediments	Unit	Puck Bay				
		inner 1987	inner 1991	outer 1995	inner 1996	outer 1999
		mean values ($\bar{x} \pm SD$)				
Redox potential (Eh)	mV	–	+88 ± 93	+102 ± 162	+20 ± 117	-122 ± 61
Organic matter	% dm	2.09 ± 1.36	–	1.28 ± 1.84	1.83 ± 2.06	0.55 ± 0.19
Total P	μmolog^{-1} dm	–	–	2.41 ± 1.06	1.67 ± 0.78	2.49 ± 0.88
Total N	μmolog^{-1} dm	–	–	12.0 ± 6.9	17.66 ± 8.22	10.04 ± 4.54
pH	-log (H)	–	–	7.16 ± 0.31	7.36 ± 0.16	7.01 ± 0.15
Class of quality	–	–	–	4.27 ± 1.25	4.66 ± 0.97	4.64 ± 0.58

Table 2. Correlation between parameters of bottom surface sediments of the Puck Bay (1995-1999)

Analysed relationship	Symbols of coefficients	Value and significance of correlation coefficients		
		Outer Puck Bay 1995	Inner Puck Bay 1996	Outer Puck Bay 1999
Organic matter content – total P content	r_{xy} p	0.681 0.001	0.869 0.001	0.659 0.001
Organic matter content – total N content	r_{xy} p	0.868 0.001	0.884 0.001	0.491 0.01
Total P content – total N content	r_{xy} p	0.780 0.001	0.880 0.001	0.968 0.001
Organic matter content – redox potential	r_{xy} p	-0.449 0.01	-0.0195 n.i.	-0.323 0.1
Acidity – redox potential	r_{xy} p	0.662 0.001	0.474 0.01	0.691 0.001

Positive coefficients of correlation reflect relationships between the content of organic matter and the contents of total phosphorus and total nitrogen. The content of these biogens in bottom surface sediments is implicitly dependent on their loading by organic matter. The redox potential lowers with growth of organic matter content in the sediments. In effect there is a negative correlation between these parameters. The relationships between organic matter and redox potential were significant (except one case) though rather low-level. This may be a measure of participation of many factors (physical/chemical and biological) in the processes of decomposition and mineralisation of organic matter in the sediments.

On the other hand, the relationship between the redox potential and the pH of the sediments was highly significant. With decreasing redox potential, the acidity of the sediments increased, and at potential higher than 0 mV oxygen deficit appears and even hydrogen sulphide is generated. These are the main factors, which shape the species structure and the biomass of the zoobenthos.

In comparison with the rest of the open sea coastal zone, sandy deposits of the Puck Bay contain the highest amounts of organic matter, total phosphorus and total nitrogen. This means that they are most strongly eutrophicated and form a good basis for the development of meio- and macro-benthos. However, the lower acidity of sediments – though only slightly lower due to the buffer potential of the environment – resulting from the accumulation of acid products of metabolism, decomposition and mineralisation of organic matter, limits the development of phytobenthos and of some mollusc species. Oxygen deficits and appearance of nitrogen sulphide in conditions of negative redox potential indicate that the condition of the sediments is bad. In result the development of many species of bottom fauna may be stopped.

Another reason for disturbances in the species structure of bottom flora and fauna may be the accumulation of harmful substances in the organisms. Superposition of the harmful influences of these processes, expressed by an excess of organic matter, may in consequence result in partial or even complete disappearance of many species of plants and animals from the Puck Bay. In effect of multi-annual action of these processes, in place of a well develop biocenosis with high biodiversity a "reduced biocenosis" was generated in the Puck Bay. It is characterised by a high immunity to the factors that caused its formation, and shall stay in that form until these factors will disappear.

The biological investigations in the Puck Bay, carried out since the 50ties, and especially after 1985, concerned in fact a biocenosis shaped by anthropogenic factors. At the beginning of the 80ties a drastic reconstruction of the natural biocenoses of the Puck Bay took place [4]. Because of that, predicting the rate and direction of further changes of the area's biotope is impossible on the basis of already observed environmental and biocenotic changes. Basing on analyses of the available data, it may be only stated that it is highly probable that the biocenosis of the Puck Bay did not undergo significant changes of species in the period 1987-1999. Variations of phyto- and zoobenthos biomass were of cyclic character, typical for the formations. Also the biological production and loading of environment by organic matter of native origin changed cyclically. Correspondingly changed the properties of sediments, which then were transferred to the phyto- and zoocenosis systems.

State of biomass of bottom cenoses

The state of biomass of the total phytobenthos and of rooted flora (Table 3) indicates small variations in the inner part of the Bay (1987-1996) and an increase in the outer part (1995-1999). On the other hand, in both parts the biomass of brown algae distinctly decreased. Their participation in the general biomass of phytobenthos of the inner Puck Bay decreased from 74% in 1987 to 26% in 1996, and in the outer Puck Bay from 84% in 1995 to 47% in 1998 (Table 3). In effect the percentage of rooted plants increased and was about equal in both parts of the Bay.

In the period 1987-1996, the total biomass of zoobenthos decreased in the inner Puck Bay and increased in the outer part. The zoobenthos biomass was shaped mainly by changes in participation of the mollusc biomass. During that period the biomass of crustaceans and oligochaeta in the inner Puck Bay became much smaller. Due to lack of data, the changes of biomass of zoobenthos and of its families in the outer part could not be determined.

In the outer Puck Bay, the coefficient of correlation of total biomass of phyto- and zoobenthos was negative, while in the inner Puck Bay it was positive. This could indicate further degradation of the inner Puck Bay's biotope, proceeding at weaker anthropogenic influence, which disturbs the cyclic changes of the outer Puck Bay biocenosis.

Coefficients of correlation between the biomasses of phyto- and zoobenthos in both parts of the Puck Bay for the period 1987-1996 indicate the existence of a network of relationships between these formations (Table 4). Biomasses of molluscs and oligochaeta were significantly correlated with total phytobenthos biomasses. The strongest found correlation was between biomasses of rooted flora and of total zoobenthos (Table 4). The state and biomass of rooted flora describe environmental properties much better than the total biomass of phytobenthos because a significant part of the total biomass is formed by brown algae, which are moved over the bottom of the investigated water area.

Table 3. State of biomass of phyto- and zoobenthos in the Puck Bay (1987-1999)

Components of biocenosis	Unit	Puck Bay				
		inner 1987	inner 1991	outer 1995	inner 1996	outer 1997
		mean values ($\overline{X} \pm SD$)				
PHYTOBENTHOS						
total biomass	g dm m^{-2}	33.8 ± 14.6	48.9 ± 38.4	13.7 ± 15.8	41.0 ± 32.1	34.4 ± 52.7
total biomas (without E+P)		8.7 ± 9.9	29.1 ± 36.4	1.4 ± 2.9	30.6 ± 30.7	18.1 ± 31.2
ZOOBENTHOS						
total biomass	g wm m^{-2}	395.8 ± 335.6	52.2 ± 47.4	176.7 ± 209.6	72.9 ± 42.9	375.5 ± 226.2
biomass of molluscs		323.9 ± 333.6	24.2 ± 20.3	102.4 ± 193.5	54.3 ± 42.6	–
biomass of crustaceans		4.3 ± 3.3	4.16 ± 3.1	1.0 ± 0.66	0.6 ± 0.5	–
biomas of oligochaeta		0.8 ± 0.9	0.11 ± 0.09	1.9 ± 5.4	0.1 ± 0.15	–

E – *Ectocorpus;* P – *Pilayella litoralis*

Table 4. Correlation between biomasses of phytobenthos and zoobenthos of the Puck Bay (1987-1999)

Analysed relationship	Symbols of coeffi-cients	Value and significance of correlation coefficients				
		Inner Puck Bay 1987	Inner Puck Bay 1991	Outer Puck Bay 1995	Inner Puck Bay 1996	Outer Puck Bay 1999
Total phytob. biomass – total zoob. biomass	r_{xy} p	0.447 0.02	-0.635 0.001	-0.158 n.i.	0.328 0.1	-0.689 0.001
Total phytob. biomass – mollusc biomass	r_{xy} p	0.439 0.02	0.607 0.001	-0.389 0.05	0.373 0.01	–
Total phytob. biomass – crustacean biomass	r_{xy} p	-0.021 ni	0.674 0.001	0.381 0.05	0.389 0.1	–
Rooted flora biomass – total zoob. biomass	r_{xy} p	0.523 0.01	0.536 0.01	-0.332 0.1	0.428 0.05	0.525 0.01
Rooted flora biomass – mollusc biomass	r_{xy} p	0.654 0.001	0.148 n.i.	-0.347 0.1	0.210 n.i.	–
Rooted flora biomass – crustacean biomass	r_{xy} p	0.675 0.001	0.697 0.001	0.819 0.001	0.153 n.i.	–

Brown algae settle in bottom areas populated by rooted plants and increase, often quite significantly, the total phytobenthos biomass. In these areas the settled large masses of brown algae decompose and undergo mineralisation, negatively changing the characteristics of the sediments. In this way, weakening or even disappearance of phyto- and zoocenoses occurs over increasing areas of the Puck Bay bottom. These processes have intensified during the last 30 years.

The observed in the last decade reduction of eutrophication and decrease of brown algae biomass are the basic conditions for the improvement of the sediment environment of the Puck Bay. Maybe this will allow a reconstruction of the natural systems of rooted flora. It would be the most important step on the way to re-valorisation of that water area. However, this is a very long-term process.

Relationships between the properties of sediments and the biomasses of phyto- and zoobenthos

The starting point was to determine the influence of settled organic matter on the state of phyto- and zoobenthos biomass. Correlation between the content of organic matter in sediments and the biomasses of phyto- and zoobenthos and their components was calculated. Half of the investigated relationships showed statistical significance of correlation (Table 5), showing that organic matter plays an important role in the development of the cenoses. This is a result, which must be treated very seriously, though verification by further investigations is required.

Table 5. Correlation between phytobenthos and zoobenthos biomass and the content of organic matter in bottom surface sediments of the Puck Bay (1987- 1999)

Analysed relationship	Symbols of coefficients	Value and significance of correlation coefficients			
		Inner Puck Bay 1987	Outer Puck Bay 1995	Inner Puck Bay 1996	Outer Puck Bay 1999
Organic matter content – total zoob. biomass	r_{xy} p	0.018 n.i.	0.345 0.1	0.465 0.01	-0.085 n.i.
Organic matter content – mollusc biomass	r_{xy} p	0.081 n.i	0.248 n.i	0.164 n.i	–
Organic matter content – crustacean biomass	r_{xy} p	-0.551 0.01	-0.568 0.01	-0.189 n.i	–
Organic matter content – oligochaeta biomass	r_{xy} p	0.346 0.1	-0.108 n.i.	-0.193 n.i.	–
Organic matter content – total phyto. biomass	r_{xy} p	0.099 n.i.	-0.480 0.01	-0.133 n.i.	-0.497 0.01
Organic matter content – rooted flora biomass	r_{xy} p	0.516 0.01	0.708 0.001	-0.185 n.i.	-0.378 0.1

Basing on the spatial distributions of concentrations of organic matter and of the phyto- and zoobenthos biomasses, it is visible that organic matter limits the extent of areas populated by rooted flora and the development of the flora in the investigated areas. It also seems that there are some boundary (upper and lower) thresholds of organic matter content in sediments, which determine the possibility of occurrence of certain species of rooted flora and of concentrations of certain zoobenthos species. Exceeding of the upper limits of organic matter concentration in the sandy sediments of the Puck Bay was one of the reasons for the disappearance of many phytobenthos species and for the destroying of underwater meadows during the strongest eutrophication of environment in the 80ties.

Sediment quality coefficients were calculated for all stations investigated in 1995, 1996 and 1999. With these coefficients phyto- and zoobenthos biomasses were correlated (Table 6). The use of these correlations increased the amount of significant correlations (70%). This, by the way, supports the concept of a summary sediment quality indicator. All obtained values of correlation indicate that the reduction of total biomass of phytobenthos and of rooted flora, as well as of total zoobenthos biomass and its groups, is caused by the decreasing quality of sediments.

Since the quality of bottom sediments decreases with increasing organic matter content, and since the supply of organic matter and its sedimentation is a derivative of eutrophication of the water area, then finally eutrophication is the process, which shapes the whole of the vital functions of bottom biocenoses. Correlation analysis confirms that there are strong connections between the parameters characterising the eutrophication of the Puck Bay's sediment environment and the biotic elements of bottom phyto- and zoocenoses. In these conditions, the bottom biocenoses are subject to negative transformation, since their existence depends mainly on the properties and composition of the substratum on which they live, or from which they gather food.

Table 6. Correlation between phytobenthos and zoobenthos biomass and the mean quality of sediments in the Puck Bay (1995-1999)

Analysed relationship	Symbols of coefficients	Value and significance of correlation coefficients		
		Outer Puck Bay 1995	Inner Puck Bay 1996	Inner Puck Bay 1999
Total zoob. biomass – sediment quality class	r_{xy} p	-0.231 n.i.	-0.425 0.05	-0.297 0.1
Mollusc biomass – sediment quality class	r_{xy} p	-0.272 n.i.	-0.398 0.05	–
Crustacean biomass – sediment quality class	r_{xy} p	-0.711 0.01	-0.258 n.i.	–
Oligochaeta biomass – sediment quality class	r_{xy} p	-0.268 n.i.	-0.168 n.i.	–
Total phytob. biomass – sediment quality class	r_{xy} p	-0.938 0.001	-0.457 0.02	-0.511 0.01
Rooted flora biomass – sediment quality class	r_{xy} p	-0.567 0.001	-0.403 0.05	-0.430 0.05

In result of eutrphication of sediments in the coastal zone, the biocenoses have become significantly reduced, and at smaller biomass and reduced species composition they become unable to fulfil the important function of protecting and accelerating the marine ecosystem.

Summary

The observed relationships between the parameters of bottom sediments, and between them and the parameters of phyto- and zoocenoses of the Puck Bay, show that the primary cause of most of the changes of bottom biotope and biocenosis is eutrophication. Because of it are produced large amounts of plant and animal organic matter, which settle on the seafloor. Under its influence and due to processes of destruction (decay, decomposition, mineralisation), especially when the capacity of mechanisms removing the matter is exceeded, the properties of the sediments become cyclically disturbed. Periods with negatively changed properties of the sediments became increasingly long during the last 30 years, causing various reactions of bottom biocenoses, in that a reduction of the species composition and biomass of phyto- and zoocenoses. Also the dominants changed, mainly towards the development of marginal species of "weed" flora (brown algae) and animal (mussels) character. This generated far reaching changes within the ichtiocenosis, from which completely or partly disappeared many species of fish. The freed ecological niche became occupied by marginal species – the stickleback and the quickly colonising the area Caspian goby. The disturbance of the balance between production and reduction of organic matter resulted in a strengthening of catastrophic changes of the properties of bottom sediments, and next in destroying of the natural bottom biocenoses of the Puck Bay. In the period 1987-1999 the basic trend of the properties of Puck Bay bottom sediments consists in the reduction of the redox potential and acidity, which probably is connected with increased rates of decomposition of organic matter. The general warming of water during the last decade could have caused this acceleration through increasing microbiological activity in the sediments. In reduction conditions processes of de-nitrification and outflow of phosphates from the sediments intensified.

This last process, called "secondary eutrophication" increases the production of organic matter, additionally maintaining the bad condition of the sediments. The level of biogens in sediments of the Puck Bay is high, ensuring a sufficient basis for the development of rooted flora. This is confirmed by the strong relationship between the biomass of rooted flora and the total nitrogen content. It results that de-nitrification, by lowering the content of nitrogen in bottom sediments of areas with oxygen deficit and low redox potential, limits the extent and capacity for the development of rooted flora. In order to rebuild the phytal system of the Puck Bay, especially of the rooted flora systems, the lower boundaries of biogen content, in that of inorganic and total nitrogen, should be defined. Re-valorisation of the Puck Bay biocenoses is practically impossible without improving the quality of bottom sediments through a long-term reduction (by 50-70%) of the loading of the environment by organic matter.

The correlation analysis presented in this paper indicates a close internal binding of parameters of bottom sediments, which is dependent on the inflow and decomposition of organic matter. The state of the phytocenoses, the indicator of which is the biomass, proved to be dependent on the quality of sediments, measured by organic matter content or by a summary (ranking-type) sediment quality indicator covering the five investigated parameters. In effect of changes of the quality of bottom sediments and phytocenoses the bottom zoocenoses are transformed. The essence of zoocenosis change is shown by correlation analysis, which shows that there is a number of dependencies on the sediment environment and on the phytocenoses of the Puck Bay. Eutrophication disrupted the balance of environmental processes, generating a chain of negative biocenotic changes, which are most strongly evident in the Puck Bay and in the coastal zones of the Southern Baltic bays. To a significant extent, these changes covered nearly the whole Baltic ecosystem, which additionally is toxicated by pollutants.

Assessment of environmental/biocenotic changes in the Puck Bay provides a pessimistic forecast of the future of the Baltic ecosystem. The high susceptibility of the Baltic Sea to degradation resulting from its hydrographic/watershed and geographic/morphometric characteristics and from the climatic influences at maintained eutrophication, suggest that a non-reversible, negative from the natural and economical point of view, transformation of the Baltic Sea ecosystem is highly probable.

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