THE POPULATION STATUS OF CARDIIDAE (BIVALVIA) AS A BIOINDICATOR FOR WATER QUALITY IN THE NORTH-WESTERN PART OF THE SEA OF AZOV

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Abstract

An attempt was made to evaluate the suitability of using mollusc populations from the family Cardiidae as a biological indicator to monitor ecological water quality in the north-western part of the Sea of Azov. It is known that some qualitative indices of mollusc populations reflect large-scale changes occurring in benthos communities of the region. In this research, the monitoring of aquatic organisms was carried out using such indices as population density, age distribution dynamics, characteristics of behaviour, etc. Temporal and spatial dynamics of these indices allow the detection of changes in environmental factors which in their turn determine basic and crucial functions of water bodies. Among other molluscs, representatives of the family Cardiidae stand out for their ability of rapid occupation of new locations (due to the presence of a pelagic larval stage), and their adult individuals are rather tolerant to fluctuations in salinity and other factors. The aim of this research was to reveal the variability range for basic qualitative characteristics of bivalve populations in the north-western part of the Sea of Azov and to estimate if these molluscs are suitable to be bioindicators of the environmental status of the region.

Keywords: ecology, monitoring, bioindication, bivalves, the Sea of Azov.

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1. Introduction

Aquatic ecosystems are generally recognized as indicators of the overall ecological health of the area. The bodies of water act as natural filters receiving significant portions of pollutants from various sources [1]. Hydrobiological indicators along with hydrochemical and hydrophysical methods play important roles in determining the pollution level of a water body and the biological value of its water as a habitat for living organisms.

Methods of biological indication occupy an important place among the known methods of assessing statuses of aquatic ecosystems. Currently, they are the most reliable and cheap methods of evaluating environmental quality, since they provide an integrated impact assessment of all factors, both anthropogenic and natural [1, 2]. The demand for ecological monitoring by bioindication methods is ever-increasing. There are facts confirming existence of the environmental factors which influence on indices and biotic processes in an ecosystem (population density, species composition dynamics, characteristics of behavior, etc.). Such environmental factors as salinity, illuminance, temperature, water regime, presence of nutrients and others are of functional importance for aquatic organisms at all stages of their life cycle. The converse consistency is also true. For instance, species composition of organisms gives an idea of the type of physical environment. Bioindication therefore can be defined as the detection and identification of ecologically significant loads judging from the responces of living organisms and their communities to them. This is fully applied to all types of anthropogenic pollution [3].

Intensifying biomonitoring and bioindicative studies of ecosystems prioritize the issue of finding objects that can serve as indicators of the environmental status and its changes under the influence of different natural and anthropogenic factors.

The method of bioindication is regarded to be enabling to achieve objectives of ecological monitoring in cases when a combination of factors of anthropogenic pressure on ecological communities makes the direct measurements difficult or inconvenient. The modern practice of bioindication uses a phenomenological approach when a researcher generalises the facts of different species behavior in a particular environment.

The aim of our research is to consider specific issues of water pollution bioindication in the northern part of the Sea of Azov by studying the status of mollusc populations of the family Cardiidae (Bivalvia).

Benthos is known to be able to reflect the overall quality of water, since benthic communities act as continuous monitors of moving water masses. They respond to a large variety of factors determining water quality [4]. These characteristics make zoobenthos (and especially molluscs as filter feeders) important indicator organisms for the evaluation of water bodies' status. The lifestyle of Cerastoderma molluscs is largely sedentary at the juvenile stage, whereas in the previous stages (veliger, veliconcha and pediveliger) they are pelagic organisms. These bivalves reflect the status of the study area and the adaptation level of natural communities to pollution, because they are anti-synanthropic and belong to natural groups in contrast to synanthropic organisms which are closely associated with humans.

The Sea of Azov is a small and very shallow body of water. Its estuarial nature determines its high productivity. Despite a relatively low water transparency, in summer months the Sea of Azov warms up to the bottom heating benthic deposits. Its shallowness enables nutrients to pass easily into the water with sea waves [5].

The integrated environmental quality assessment of aquatic natural communities of the Sea of Azov has referred to its north-western part as being weakly polluted. To identify a list of substances necessary for the research and to determine the appropriate locations for taking samples of the genus Cerastoderma in the north-western part of the Sea of Azov it is useful to make a detailed analysis of the pollution level in this area.

A set of studies on the ecosystem pollution of the Sea of Azov by the substances toxic for hydrobions has included as follows: heavy metals (mercury, copper, lead, cadmium, iron, manganese, chromium), arsenic, oil components (volatile, non-volatile hydrocarbons, resin substances), and chlororganic compounds (DDT, DDD, DDE, isomers of HCH, polychlorinated biphenyls – PCBs) in water and bottom sediments [6, 7].

In 2013, the total content of petroleum products in the waters of the study area did not exceed the maximum allowable values for fishponds. In the surface layer, concentrations of petroleum products varied from 0.07 to 0.021 mg/l, in the bottom layer – from 0.011 to 0.025 mg/l. In terms of spatial distribution, the elevated concentrations (compared to adjacent waters) were observed near Fedotova Spit, in the open part of Obytichna Spit and in the central part of the study area [8]. In fractional composition, the ratio of resin components and non-volatile hydrocarbons constituted 1:1, indicating continuous inflow of petroleum products to the study area.

The total content of petroleum products in bottom sediments ranged from 0.14 to 1.85 mg/g dry wt. In spatial distribution of petroleum products their minimal concentrations were recorded in the coastal area, due to the predominance of sand fraction in sediments, which practically does not absorb oil. The sediments containing over 1 mg/g dry wt. of petroleum products occured in the central part of the water area and to the south of Arabatska Spit.

The fractional composition was dominated by the non-volatile hydrocarbons thereby indicating the inflow of petroleum products from the open regions of the Sea of Azov. The opposite situation was observed at the coastal stations where the resin substances prevailed.

Compared to 2012, there were no significant changes in the total content of petroleum products in the water column and surface layers of bottom sediments. However, the fractional composition of petroleum components in bottom sediments substantially changed: decreased content of resin components and increased concentrations of volatile hydrocarbons were recorded (**Table 1**).

The hydrological regime of the Sea of Azov has an impact on its faunal composition: extreme temperature fluctuations lead to the dominance of eurythermal species; the shallowness contributes to the distribution of stenobathic species and complete absence of more or less pelagic ones. The unstable salinity remains the most important factor determining the availability of brackish-water and euryhaline marine organisms [9].

As a result of the attached flora activity the Sea of Azov and adjacent estuaries are constantly enriched with nutrients thereby forming a favourable environment for the molluscs.

The Sea of Azov has a specific structure of food chain. There are no pelagic predators requiring a certain minimum of water transparency. In the Sea of Azov, due to massive plankton growth, the water transparency is low (lower than in the Black Sea), and the predators therefore feed mainly on groundfish (bullheads).

In the years with a natural runoff regime of rivers, the Cerastoderma biocenosis in the Sea of Azov played a major role occupying 31 % of the sea area in spring and 38 % in autumn [10]. Further regulation of the river runoff has brought about significant changes in the sea regime and determined specific development of marine benthic communities including that of Cerastoderma. Molluscs of this genus prefer dense substrates. They reach their maximum development on shelly soils with admixture of silt and on shelly sand soils. Being oxyphilic organisms, representatives of the genus Cerastoderma rarely can be found in the central part of the Sea of Azov, known by its almost annual fish suffocation phenomena, and are widespread at 1–2 m and up to 11 m depths reaching their maximum development at a depth of 1–3 m. They are able to endure salinity fluctuations from 3 to 30 ‰ (at the optimum of 7–10 ‰) and are typical natural filters, feeding on plankton and suspended detritus in the bottom layer of water [11].

Table 1
Characteristics of fractional composition of petroleum products in bottom sediments in the north-western part of the Sea of Azov (at average concentrations, mg/g dry weight)

Date	Total content	Resins	Non-volatile hydrocarbons
August 2012	0.68	0.43	0.25
July 2013	0.61	0.30	0.31

2. Aim

The aim of the research is to reveal the variability range for basic qualitative characteristics of bivalve populations in the north-western part of the Sea of Azov and to estimate if these molluscs are suitable as bioindicators of the environmental status of the region.

3. Materials and Methods

The study was carried out over the period of 2008–2013. In the course of the research we have done qualitative and quantitative analysis of bivalve samples, collected from 3 stations located at Molochnyi Estuary, 11 stations at the northern coast of the Sea of Azov (between the village of Stepanivka Persha and the end of Biriuchyi Island Spit) and from 10 stations at Utliukskyi Estuary. During the analysis we identifed bivalve species inhabiting the studied areas and estimated biomass of representatives of particular species.

The tables below, placed in the Results section, present the data for part of the stations, selected by us as the most representative ones.

The molluscs were gathered from fresh beach-cast seaweed and also in the sea at a distance of 500–1500 m from the shore, at a depth of 0.5–4.5 m.

The material was collected, initially treated and fixed using standard hydrobiological methods [12].

To determine the mollusk biomass they were preliminarily dried on filter paper and then weighed on a laboratory balance.

The identification of mollusk species was based on a traditional conchological method taking into account the main diagnostic features and measurements of the shell [13].

To analyse samples, the methods of statystical processing of quantitative indices assisted by relevant computer software were applied. Series of evaluations of the average biomass and abundance of mollusks of the genus Cerastoderma in the north-western Sea of Azov over the period 2008–2013 along with their distribution data were also used.

4. Results

The species *C. clodiense* of the genus Cerastoderma, common in the Sea of Azov, in the northern part of the sea and adjacent estuaries can be found in all biocenoses except the Mytilaster community on rocks [14]. In complex biocenoses of Utliukskyi Estuary and the Azov Sea spits it forms colonies up to 1,500 ind/m² with the biomass equalling to 730 g/m². It can be found on all types of soil but, as a representative of infauna, prefers denser substrates. It occurs everywhere within the studied depth range reaching maximal development at a depth of 1–3 m. Similar to other species of Cerastoderma, *C. clodiense* is sensitive to the presence of hydrogen sulfide in the environment and dies if exposed to its impact for a sufficiently long period.

In regards to salinity, typical euryhaline undemanding organisms can endure salinity up to 30 ‰. However, in 2013, the salinity increased to 50–80 ‰ (Utliukskyi Estuary) causing mass mortality of the Cerastoderma and drastic decrease of its biomass (to 1 g/m²). The general distribution range includes desalinated water areas of the Mediterranean Sea and the Black Sea, and all areas of the Sea of Azov [15, 16].

Increase in the density of aquatic organisms, living in communities, gives positive results only within a certain physiological optimum, specific for each species [17]. There must be a balance between the species density and natural environment (**Table 2**).

Table 2

Density dynamics of molluscs of the genus Cerastoderma at sampling stations in the north-western part of the Sea of Azov, g/m²

Region	2008	2009	2010	2011	2012	2013
Molochnyi Estuary						
Station 1	36	23	21	40	34	35
Station 2	4	–	–	3	5	–
Station 3	13	10	12	7	13	10
The Sea of Azov						
Station 3	85	120	74	65	87	–
Station 10	74	95	68	48	76	–
Station 11	90	110	85	70	93	–
Utliukskyi Estuary						
Station 12	97	85	80	73	77	–
Station 13	110	105	87	75	90	97
Station 14	86	93	74	67	55	105
Station 20	74	52	–	–-	43	–

Similar to abundance, biomass also varies in time and space (**Table 3**). It is characterized by the relative value and indicates a primary or secondary role of a particular taxon in community structure.

For Molochnyi Estuary, the highest biomass index for the period of 2008–2013 was recorded in 2012 and equalled 1.27 g/m², the lowest level was recorded in 2010 and equalled 0.79 g/m².

As it is shown in **Table 3**, Molochnyi Estuary is characterized by relatively low biomass indices of the genus Cerastoderma, which, however, have more or less even temporal distribution.

The spatial distribution of aquatic organisms is influenced by various ecological factors of aquatic environment such as currents, water level, temperature, illuminance, transparency and turbidity of water masses, weather conditions, presence of macrophytes and many other factors (**Table 4**).

Table 3

Biomass dynamics of genus Cerastoderma of molluscs of the genus Cerastoderma at sampling stations in the north-western part of the Sea of Azov, g/m^2

Region	2008	2009	2010	2011	2012	2013
Molochnyi Estuary						
Station 1	2.59	1.67	1.51	2.88	2.44	2.56
Station 2	0.29	–	–	0.21	0.38	–
Station 3	0.92	0.72	0.87	0.50	0.95	0.73
The Sea of Azov						
Station 3	6.37	9.14	5.77	5.12	7.48	–
Station 10	5.55	7.07	5.22	3.79	6.46	–
Station 11	6.78	8.39	6.68	5.67	7.90	–
Utliukskyi Estuary						
Station 12	8.34	6.97	6.88	6.27	6.62	8.34
Station 13	9.35	7.98	7.30	6.45	7.47	9.13
Station 14	7.13	7.25	5.55	5.76	4.18	–
Station 20	5.55	4.16	–	–	–	–

Table 4

Distribution of molluscs of the genus Cerastoderma at sampling stations in Molochnyi and Utliukskyi Estuaries

Species	Stations												
	Molochnyi Estuary			Utliukskyi Estuary									
	I	II	III	12	13	14	15	16	17	18	19	20	21
Cerastoderma clodiense	+	+	+	+	+	+	+	+	+	+	+	+	+
C. lamarcki	+		+	+	+	+	+	+	+	+	+	+	+
C. umbonatum	+		+	+	+	+	+	+	+	+	+	+	+

The spatial distribution of benthic organisms mostly depends on bottom topography, general structure of sediments and other features of a water body's bed (**Table 5**).

Table 5

Distribution of molluscs of the genus Cerastoderma at sampling stations in the north-western part of the Sea of Azov

Species	Stations										
	The Sea of Azov										
	1	2	3	4	5	6	7	8	9	10	11
Cerastoderma clodiense	+	+	+	+	+	+	+	+	+	+	+
C. lamarcki	+	+	+	+	+	+	+	+	+	+	+
C. umbonatum	+	+	+	+	+	+	+	+	+	+	+

Calculating the value of occurrence (absolute frequency) we should take into account that the accuracy of this index depends on the size of the study area, number of samples, amount of collected material, etc [18].

The results calculated by the equation (1) are listed in **Table 6** and indicate dynamics of the absolute frequency index for the three bivalve species: *Cerastoderma clodiense*, *Cerastoderma lamarcki* and *Cerastoderma umbonatum* in the study area.

$$p_i = {}^{m_i}\!/_{M} \cdot 100\ \%, \tag{1}$$

where p_i – is the index of absolute frequency of the taxon; m_i – the number of samples where the taxon was found; M – the total number of samples.

Maximal values of this index were observed in the northern part of the Sea of Azov for all the three species of the Cerastoderma [19].

In Utliukskyi Estuary the absolute frequency index made up 90 %. In Molochnyi Estuary it was lesser synchronised: 100 % for *Cerastoderma clodiense*, and 67 % for *Cerastoderma lamarcki* and *Cerastoderma umbonatum* **(Table 6).**

Table 6

Index of absolute frequency (%) for molluscs of the genus Cerastoderma in the north-western part of the Sea of Azov

Species	Study area of research		
	Molochnyi Estuary	The Sea of Azov	Utliukskyi Estuary
Cerastoderma clodiense	100	100	90
C. lamarcki	67	100	90
C. umbonatum	67	100	90

The absolute frequency varies not only in space but also in time. **Table 7** shows the value of this index and its temporal dynamics but now calculated for the genus Cerastoderma basing on the data obtained from sampling stations (the Sea of Azov – 3, 10, 11; Molochnyi Estuary – 1 2, 3; Utliukskyi Estuary – 12, 13, 14, 20) **(Table 7).**

Table 7

Dynamics of absolute frequency (%) in 2010–2013 for moluscs of the genus Cerastoderma in the north-western part of the Sea of Azov

Study area	Year					
	2008	2009	2010	2011	2012	2013
Molochnyi Estuary	100	67	67	100	100	67
The Sea of Azov	100	100	100	100	100	100
Utliukskyi Estuary	100	100	75	75	75	50

Given the occurence scale and absolute values of this index the species *Cerastoderma clodiense*, *Cerastoderma lamarcki* and *Cerastoderma umbonatum* are guide forms in all water areas of research.

5. Discussion

Studying population characteristics of bioindicator species is among the most promising directions for indicator surveys. A population is characterized by a set of characteristics, of which a group is the only carrier. Some of these characteristics are population density, fertility, mortality, age structure, distribution and growth rate. The populations also have genetic properties, related directly to their ecology, such as adaptivity, reproductive fitness and continuity [20].

An attempt was made to evaluate the suitability of using mollusc populations from the family Cardiidae as a biological indicator to monitor ecological water quality in the north-western part of the Sea of Azov. It is known that some qualitative indices of mollusc populations reflect large-scale changes occurring in benthos communities of the region. In this research, the monitoring of aquatic organisms was carried out using such indices as population density, age distribution dynamics, characteristics of behaviour, etc. Temporal and spatial dynamics of these indices allow the detection of changes in environmental factors which in their turn determine basic and crucial functions of water bodies. Among molluscs, representatives of the family Cardiidae stand out for their ability of rapid occupation of new locations (due to the presence of pelagic larval stage), and their adult individuals are rather tolerant to fluctuations in salinity and other factors. The results of our research, focused on revealing the variability range for basic qualitative characteristics of bivalve populations in the north-western part of the Sea of Azov, enables to affirm that these molluscs can serve as bioindicators of the environmental status of the region.

Analysing the obtained data we should note a gradual increase in the dominance of molluscs of the genus Cerastoderma in the south-western part of the Sea of Azov over the period of 2008–2013. The similar situation was also recorded in Molochnyi Estuary. A gradual reduction in the dominance of these species was observed in Utliukskyi Estuary. We assume these processes to be associated with the impact of environmental factors.

At the same time, the following factors shoud be taken into account when using soft tissue of molluscs of the genus Cerastoderma as a biomonitoring indicator: the impact of invasions on pollutant accumulation processes, differences in pollutant accumulation capacity of tissues of different organs and their ability to quickly absorb and remove toxins since it is important for the evaluation of the impact of peak emissions.

6. Conclusions

1. High indices of absolute frequency demonstrated by molluscs of the genus Cerastoderma in the north-western part of the Sea of Azov have indicated a wide distribution range of molluscs of this taxon that is highly important for the baseline monitoring.

2. Molluscs of the genus Cerastoderma have met the criteria required for bioindicators. They are eurybiontic and belong to the organisms unable to move long distances. At the same time they are antisynantropic organisms.

3. Key indicator characteristics of the species using in bioindication are the criteria of availability, individual properties of organisms and quantitative indices.

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