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Dynamics of macrozoobenthos in the Eastern Sivash during different salinity regimes

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In current paper we presented the dynamics of the macrozoobenthos in Eastern Sivash depending on temporal and spatial salinity fluctuations from pleiomesohaline to polyhaline and hyperhaline. We shown that the highest species richness and biomass were observed in polyhaline conditions at the lowest salinity values, and the maximum density was in pleiomesohaline conditions. The lowest species riches and biomass were observed in hyperhaline conditions.
Keywords: Eastern Sivash; macrozoobenthos; distribution; abundance; biomass

Introduction

The group of macrozoobenthos is an important link of all hydro ecosystems, and, in particular, estuaries. Stable and long-term localization on certain biotopes, sensitivity to external influences makes macrozoobenthos a convenient object for assessing the impact of many natural and anthropogenic factors. The indigenous aquatic ecosystems are characterized by the significant dynamics of abiotic and biotic elements, high productivity and unique biodiversity. They are characterized by an increase in the influence of some abiotic factors on water biota in comparison with biotic interactions (Stolyarov, 2013). The natural conditions of the Eastern Sivash, which by its parameters belong to the regional ecosystems, are formed under the influence of anthropogenic interference. One of the most important environmental factors that determines the structure and dynamics of its bottom biocenoses is the salinity (Anistratenko et al., 2007; Anistratenko et al., 2011; Khaliman et al., 2015), which is determined by estuaries' water balance. The main source of the Eastern Sivash branching from the 1960's is the drainage wastewater from the North-Crimean Canal. Local importance in this process has the Azov Sea and the river Salgir (Antonovskiy, Degtyarenko, 2009).

According to the estuaries classification of the Northwest Black Sea Coast (North-western ..., 2006), the Eastern Sivash, depending on the regime of salinity, belonged to the following types: pleiomesohaline (8-15 ‰), polyhaline (15 - 45 ‰) and hyperhaline (more than 45 ‰) in different periods of existence.

Due to configuration of the coastline in the eastern Sivash (Vorobiev, 1940; Vorovka, 2013), there are distinguished five plesa stretches - Henicheske (I pleso), Shchaslyvtses'ke (II pleso), Strilkovske (III pleso), Pivdenne (IV pleso) and Chongarske (V pleso). Separate Eastern Sivash stretches have the same type of salinity during the same period, which, as the influence of the Azov Sea decreases, increases in the direction of the Pivdenne pleso. By 1955 (Almazov, 1960) Henicheske, Shchaslyvtses'ke and Pivdenne plesa had the average water salinity of 21-44 ‰, 24,8-87 ‰ and 120-163 ‰, respectively. According to O.M. Almazov (1960) in 1955, the I pleso belonged to polyhaline water areas (15.4 - 35.5 ‰), and II and IV to hyperhaline (38.3 - 83.9 and 139 - 155.9 ‰, respectively). The intensive development of the rice cultivation, which was accompanied by the creation of irrigation systems, led to the flow of fresh drainage water to the Eastern Sivash. This was the main reason for the erosion of the reservoir, especially its Strilkovske and Pivdenne estuary stretches.

Since the beginning of the 1990s, there has been a tendency to increase the level of Sivash's salinity. The reduction of volumes of freshwater discharges into the reservoir due to decreasing irrigation scales can be considered the objective reason for this phenomenon.

According to the modern data on hydrochemistry of the Eastern Sivash, for the Henicheske (2003 - 2014) and the Strilkovske plesa (2003-2009, 2012, 2014), the pleiomesohaline type of salinity was typical, with the Henicheske pleso in 2011 for a short

time turned into polygaline state. Shchaslyvtsevske, Pivdenne and Chongarske plesa in the beginning of XXI century were characterized as polyhaline water areas. The hyperhaline water area was the Pivdenne pleso in 2013.
Dynamic changes in salinity of the Eastern Siwash have led to significant changes in the structure of macrozoobenthos as an important component of its ecosystems. So, with the increase in salinity, the brackish water species of invertebrates were replaced by euryhaline, with fluctuating the density and biomass of the bottom groups.

Material and methods

The sampling of benthos was carried out at the stations of the Eastern Siwash during 2003-2014. Collection and processing of the material were carried out according to standard hydrobiological methods (Zhadin, 1960; Methods ..., 2006). For the material selection was used bottom grab with a capture area of 0.0225 m2 and metal frame with an area of 0.15 m2. The collected material was fixed with 4% formalin solution. The whole macrozoobenthos was defined to species level according to (Anirastatenko, 2011; Kiselev, 2004; Grintsov, Sezgin, 2011, etc.), in some cases – to order. For each species, the density was determined: N, ind./m^2, and biomass - B g/m^2. In total, 132 samples were processed. The following scale was used to estimate the frequency of the species occurrence: constant species - frequency of occurrence more than 50%; minor - 25-50%; random - less than 25% (Stocker, Bergmann, 1977).

Results and discussion

In the history of the Eastern Sivash research (Tarasov, 1927; Pauli, 1936; Vorobiev, 1940; Vinogradova, Vinogradov, 1960; Antonovskiy, Gaponova, 2008; Antonovskiy, Degtyarenko, 2009; Antonovskiy, Krutikova, 2012; Marushkina, 2013; Khaliman et al., 2015), 95 taxa of macrozoobenthos were mentioned. During our research in 2003-2014 we recorded 79 species, which represented 7 classes, 20 orders, 38 families, and 49 genera (Table 1). The highest taxonomic richness was registered for Gastropoda - 38 species. Among other groups, there were 17 species of Malacostraca, 9 species of Polychaeta, and 8 species of Bivalvia. Insecta and Maxillopoda were the least abundance and presented by one species each. We indicated, but not identified the species of Insecta (order Coleoptera) and Arachnida.

Table 1. Taxonomic composition of macrozoobenthos in Eastern Sivash under different salinity conditions

Class	Order	Abundance of species		
		Pleiomesohaline	Polyhaline	Hyperhaline
Polychaeta	Phyllodocida	5	6	1
	Spionida	1	2	-
	Terebellida	1	-	-
Gastropoda	Bulliformes	3	3	-
	Cerithiiformes	1	3	-
	Littoriniformes	2	3	-
	Neritopsiformes	2	2	-
	Pyramidelliformes	3	4	-
	Rissoiformes	22	21	2
Bivalvia	Astartida	2	2	-
	Cyrtodontida	1	1	-
	Venerida	4	5	1
Malacostraca	Amphipoda	6	10	1
	Cumacea	-	1	-
	Decapoda	1	3	-
	Isopoda	3	3	2
Maxillopoda	Cirripedia	1	1	-
Insecta	Diptera	1	1	-
	Coleoptera	-	1 (n/i)	-
Arachnida	Aranei	-	1 (n/i)	-
Total: 7	**20**	**59**	**73**	**7**

Note: n/i - not identified, (-) absent.

During the pleiomesohaline stage of the Eastern Sivash existence, 59 species of benthic hydrobionts were recorded. The species richness of macrozoobenthos in polyhaline conditions was somewhat higher - 73 species. During the hyperhaline conditions, that were observed only in 2013 in the IV pleso, there were registered 7 species in total.
In the waters of Eastern Sivash, under the pleiomesohaline conditions, the smaller taxonomic richness of macrozoobenthos was observed: species of the Polychaeta class *Glycera convoluta* (Keferstein, 1862) and *Spio filicornis* (Muller, 1776) were not observed. Of the Gastropoda class there were no species of *Bittium jadertinum* (Brusina, 1865), *Cerithidium submammillatum* (Rayneval in Rayneval, Hecke et Ponzi, 1854), *Thalassobia moitessieri* (Bourguignat, 1876), *Eulimella phaula* (Dautzenberg et Fisher, 1896), *Pseudopaludinella arenarum* (Bourguignat, 1876), and from the class Bivalvia - the species *Cerastoderma umbonatum* (Wood, 1850). In the pleiomesohaline conditions, the species richness of crustaceans sharply decreased from 17 to 11 species. In the less saline conditions were not registered amphipods *Microdeutopus gryllotalpa* (Costa, 1853), *Gammarus*

subtypicus (Stock, 1966), *Hyale preostii* (Milne-Edwards, 1830), *Pontogammarus maeoticus* (Sowinsky, 1894), *Iphinoe maeotica* (Sowinskyi, 1893), as well as decapods *Crangon crangon* (Linnaeus, 1758) and *Rhithropanopeus harrisi tridentata* (Maitland, 1874). Also from the Insecta class at 8-15 ‰ salinity, representatives of the Arachnida class were not registered - spider larvae and family Carabidae Latreille, 1802 Also from the Insecta class at 8-15 ‰ salinity, representatives of the Arachnida class were not registered - spider larvae and family Carabidae Latreille, 1802.

Instead, in polihaline conditions, we did not notice polychaetes *Lagis neapolitana* (Claparede, 1868), gastropods from the family Rissoidae Gray, 1847 - *Rissoa parva* (da Costa, 1778) and *R. rufilabrum* (J. Alder, 1815). Under the conditions of the hyperhaline regime 52,5 ‰, were registered only polychaetes *Neanthes succinea* (Frey et Leuckart, 1847), from the class Gastropoda - *Hydrobia macei* (Paladilhe, 1867) and *P. leneumicra* (Bourguignat, 1876), from the class Bivalvia - *Abra ovata* (Philippi, 1836), and *Corophium volutator* (Palas, 1766), *Idotea balthica* (Pallas, 1772), *Sphaeroma pulchellum* (Colosi, 1921) - of the class Malacostraca.

Analyzing the species composition of the macrozoobenthos of the Eastern Sivash, it should be noted that both in the pleiomesohaline and polyhaline conditions, constant species were *Mytilaster lineatus* (Gmelin in Linnaeus, 1791), *A. ovata* and *I. balthica*. *M. lineatus* (76%) was the absolute dominant in the pleiomesohaline regime, and *A. ovata* (63%) – in polihaline conditions. In the pleiomesohaline conditions, the group of minor species was headed by *Hediste diversicolor* (Muller, 1776) and *C. glaucum* (Poiret, 1789) (47%). The frequency of the occurrence of the Hydrobiidae *H. acuta* (Draparnaud, 1805), *H. euryomphala* (Bourguignat, 1876), *H. mabilli* (Bourguignat, 1876), *H. macei* (Paladilhe, 1867), *P. leneumicra* (Bourguignat, 1876), bivalvia *P. Exiguum* (Gmelin, 1791), crustaceans *G. aequicauda* (Martynov, 1931), *S. pulchellum* (Colosi, 1921) and *Chironomus salinarius* (Kieffer, 1915) made up 26-37%. The aforementioned species, together with the polychaete *N. succinea* (Frey et Leuckart, 1847), occupy a minor position also under the conditions of polyhaline regime.

The most numerous in both cases was a group of random species. Among species with a maximum frequency within the given range, in the conditions of the pleiomesohaline regime, *N. succinea* and *Balanus improvisus* (Darwin, 1854) were noted. Uniformly registered species include polychaetes *Harmathoe imbricata* (Linnaeus, 1767), *Phyllodoce (Anaitides) mucosa* (Oested, 1843), *Polydora ciliata* (Johnston, 1838), *L. apocalypticus* (Claparede, 1868), gastropods *Cylichnina variabilis* (Milaschewitsch, 1912) , *Retusa striatula* (Forbes, 1844*), R. parva* (da Costa, 1778), as well as crustacean *C. volutator* (Palas, 1766) and *Palaemon adspersus* (Rathke, 1837).

In polyhaline conditions in the Eastern Siwash water area, 60 species of macrozoobenthos comprised a group of randomly occuring. Among them, the most frequent occurrence had *R. truncatula* (Bruguire, 1792). Singly in the samples were found polychaeta *Spio filicornis* (Muller, 1776), gastropods *C. submammillatum*, *Th. moitessieri* (Bourguignat, 1876) and *Th. rausiana* (Radoman, 1974), *Truncatella subcylindrica* (Linnaeus, 1766), bivalvia *Lucinella divaricata* (Linnaeus, 1758), crustaceans *Ampelisca diadema* (Costa, 1853), *Microdeutopus gryllotalpa* (Costa, 1853), *H. pontica*, *Stenothoe monoculoides* (Montagu, 1815) , *C. crangon* (Linnaeus, 1758), *R. harrisi tridentata* (Maitland, 1874), *S. serratum* (Fabricius, 1787)

In both regimes, were recorded once *Chrysallida (Chrysallida) incerta* (Milaschewitsch, 1916), *Chrysallida (Parthenina) interstincta* (J. Adams, 1797), as well as amphipods H. pontica, S. monoculoides.

The highest density of the macrozoobenthos of the Eastern Sivash was in the pleiomesohaline conditions. It comprised 817 ± 119 ind./m^2. In polihaline conditions, the density of bentonites was 391 ± 37 ind./m^2. With a salinity above 45 ‰ this indicator was 609 ± 304 ind./m^2 (in May).

The mean biomass of macrozoobenthos was the highest in polyhaline conditions - 37.03 ± 19.68 g/m^2. In the pleiomesohaline conditions, the biomass was 18.21 ± 2.62 g/m^2, and in the hyperhaline - 13.7 ± 6.81 g/m^2 (Fig.1).

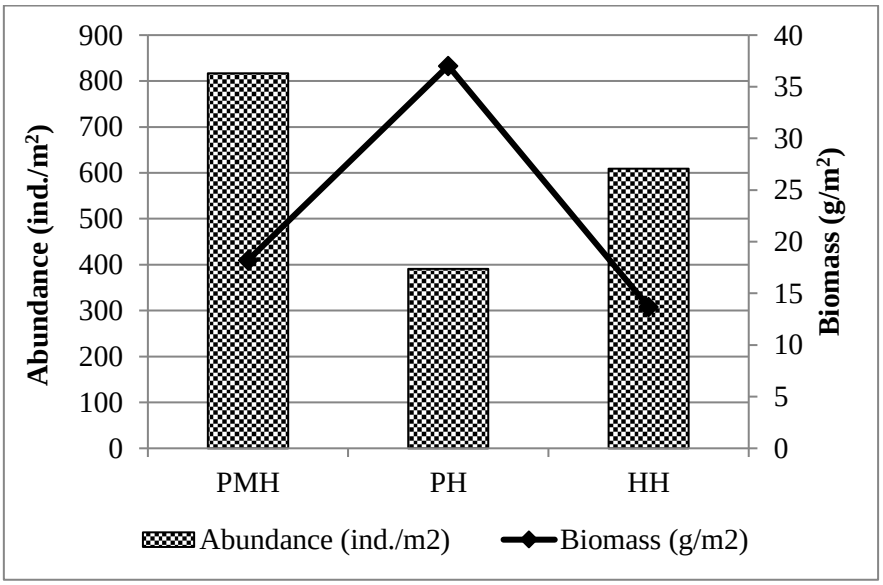

Fig. 1. Dynamics of the density and biomass of macrozoobenthos of Eastern Sivash in different salinity regimes. Here and in Figs 2-4, PMH - pleiomasohaline conditions, PH - polyhaline conditions, HH – hyperhaline conditions

In general, both in the pleiomesohaline and polyhaline conditions, there was a clear tendency to increase the density of bottom hydrobionts from March to August due to the intensive development of species of the genus *Hydrobia* (Hartmann, 1821) and *Pseudopaludinella (*Bourguignat in Mabille, 1877) from the family Hydrobiidae Troschel, 1857 (Fig. 2).

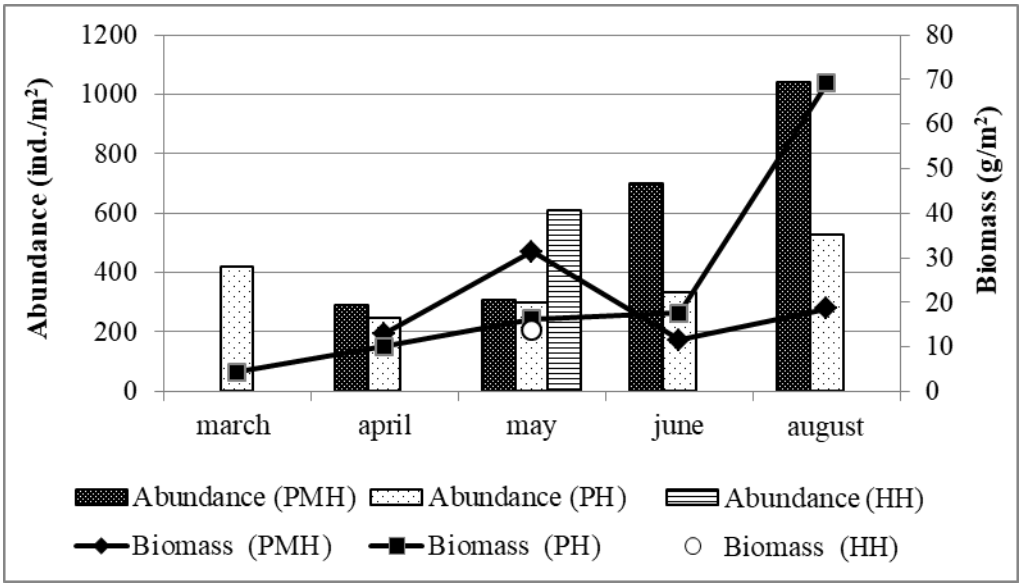

Fig. 2. Seasonal dynamics of density and biomass of macrozoobenthos of Eastern Sivash in different salinity conditions.

In the pleiomesohaline conditions, the density of bentonites in April was 289 ind./m^2, and in May - 306 ind./m^2. In June, this indicator has more than doubled and reached 699 ind./m^2. The highest density was observed in the August - 1035 ind./m^2 (see Fig. 2).

In polihaline conditions, the average density of macrozoobenthos was high in March (420 ind./m^2), after which it decreased in April and began to increase gradually until August (see Fig. 2). The high density of benthos in March was formed mainly by to the mollusk *M. lineatus*, the abundance of which in this period was 2 489 ind./m^2. The April value of this indicator was 246 ind./m^2, in May - 297 ind./m^2, in June - 333 ind./m^{2}and August - 528 ind./m^2 (see Fig. 2).

In pleiomesohaline conditions, the highest average rates of biomass development were observed in May (31.31 g/m^2). In April, biomass amounted to 12.92 g/m^2, in June - 11.51 g/m^2, in August - 18.52 g/m^2 (see Fig. 2).

In polyhaline conditions, biomass increased from March to August from 4.38 to 69.17 g/m^2. In April, its value was 10.14 g/m^2, in April - 16.25 g/m^2, in June - 17.52 g/m^2 (see Fig. 2)

Figure 3 demonstrates the percentage correlation of major macrozoobenthos taxa with density indicators in different salinity conditions.

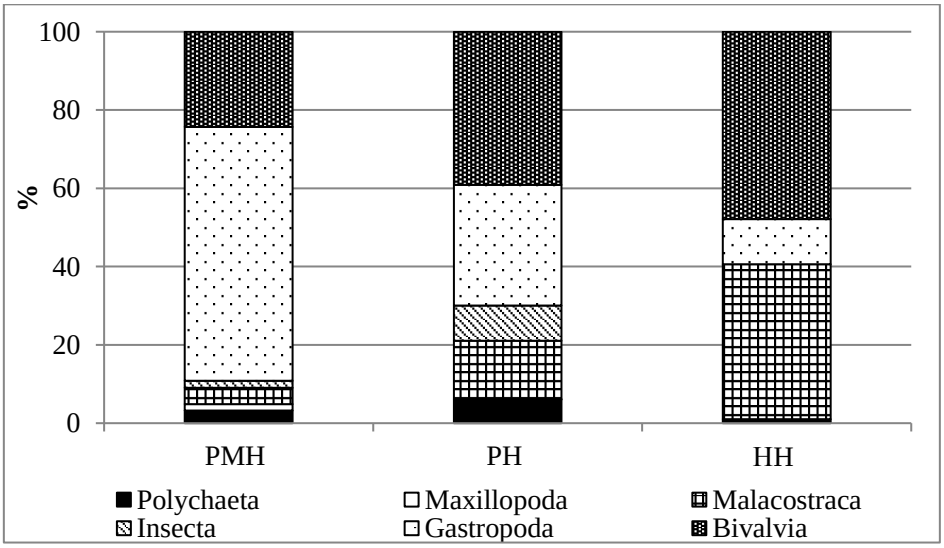

Fig. 3. The density of the main macrozoobenthos taxonomic groups towards salinity conditions.

In the pleiomesohaline conditions, the largest proportion of individuals in density composed gastropods, which accounted for 64.9% of the total abundance of registered individuals. Another big group was bivalvia (24.3%). The least numerous groups

were crustaceans (4.1%), polychaetes (3.2%), insects (1.8%) and maxillopods (1.7%). In polyhaline conditions, the percentage of gastropod (39.1%) decreased, and vice versa, the amount of bivalve increased to 39.1% (Fig. 4).

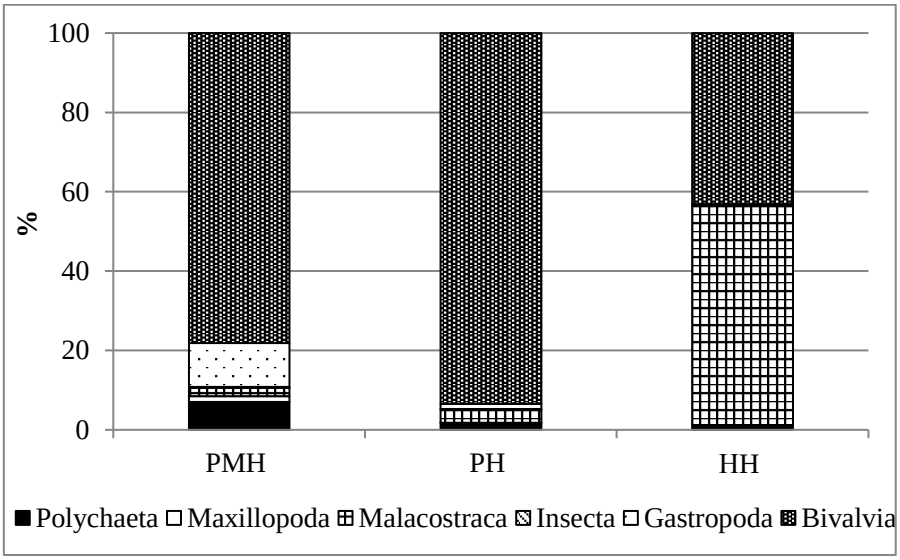

Fig. 4. The biomass of the main macrozoobenthos taxonomic groups towards salinity conditions.

The share of other taxonomic groups in higher salinity conditions also increased. The content of crustaceans was 14.9%, polychaetes - 6%, and insects - 9%. The share of Maxillopoda decreased to 0.17%. Spider larvae accounted for only 0.01% of the total abundance of individuals. In hyperhaline conditions, the macrozoobenthos were represented by four classes of invertebrates. The most numerous was the bivalve, which accounted for 47.91%. Crustaceans also had high abundance (35.6%). The polychaetes decreased significantly up to levels 11.46% and 1.03% (Fig. 4).

In pleiomesohaline conditions, the bivalve mollusks were the absolute dominants. Their share in total biomass was 78.1%. Gastropods were 11.1%, polychaetes - 7%, crustaceans - 2.1%, and maxillopods - 1.5%. The larvae of insect-tendipendids represented the smallest share in total biomass – 0.2%. In polyhaline conditions, the proportion of bivalve molluscs increased to 93.4%. The share of the other classes was insignificant and did not exceed 2%. In hyperhaline conditions, the crustaceans and bivalve mollusks were the dominants, representing 55.2 and 43.1% respectively (Fig.4).

Conclusions

95 taxa of macrozoobenthos were historically recorded and we registered some 79 during our research in Eastern Sivash within 2003-2014. We recorded 59 species of benthic hydrobionts in pleiomesohaline stage of the Eastern Sivash. The species richness of macrozoobenthos was higher in polyhaline conditions and made 73 species. We registered the hypergaline conditions in 2013 in the fourth pleso of the water area and sampled here only 7 species. The highest density of the macrozoobenthos of the Eastern Sivash was observed during pleiomesohaline conditions. We determined it as 817 ± 119 ind./m^2.

In polyhaline conditions, the density of bentonites was 391 ± 37 ind./m^2 and 609 ± 304 ind./m^2 (in May, when the salinity was more than 45 ‰). The mean value of the macrozoobenthos biomass was the highest in polyhaline conditions – 37.03 ± 19.68 g/m^2. In the pleiomesohaline conditions, the biomass was 18.21 ± 2.62 g/m^2, and in the hyperhaline - 13.7 ± 6.81 g/m^2.

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