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The Kiziltash estuary ecological characterization (Krasnodar region) based on its hydrobiological parameters

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Abstract. The hydrobiological indicators of the Kiziltash estuary on the qualitative and quantitative composition of phyto-, zooplankton and zoobenthos communities are presented. The research was carried out in 2018-2019 at 9 stations, three sites, three stations on each site. The dynamics of the average abundance and average biomass of phyto-zooplankton and zoobenthos over the study period is shown. The average indicators of the number and biomass of organisms are given and the main species are listed. During the study period, 73 species of microalgae belonging to 7 departments were identified in the phytoplankton: diatoms – 30 species, dinophytic – 23 species, green – 8 species, cyanobacteria – 5 species, haptophytic – 3 species, euglenic – 3 species, cryptophytic – 1 species. As part of the feeding zooplankton community, 17 species of organisms belonging to the following taxonomic groups were found: rotifers, oar-footed crustaceans, branched crustaceans, planktonic forms of shell crustaceans, larvae of small-lobed and multi-lobed worms; larvae of bivalves and gastropods. In single specimens, chironomid insect larvae and artemia eggs were found in the samples – juveniles of various-legged crustaceans, larvae and juveniles of worms, larvae of balanus. The dynamics of the average biomass and the average number of zoobenthos in three sections of the surveyed water area in the Kiziltash estuary during the study period is given. As part of the macrozoobenthos, 10 species were found in the surveyed water area, while gastropods and bivalves had the largest number of species. Gastropods dominated in numbers, and bivalve mollusks polychaetes dominated in biomass, crustaceans – barnacles and bokoplav and insect larvae were also found. The water area of the second section, located near the mouth of the Kuban River, was the most productive zone for phytoplankton, both in number and biomass, probably due to the increased content of organic substances. Coastal areas, less deep-water, are exposed to wind, therefore they have increased turbidity of water, which creates unfavorable conditions for the development of phytoplankton. Data on phytoplankton, zooplankton and zoobenthos obtained during the processing of hydrobiological samples of the Kiziltash estuary allowed us to conclude that the studied areas are suitable for growing oysters and mussels.

Keywords: phytoplankton, zooplankton, zoobenthos, abundance, biomass

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Научная статья

Экологическая характеристика Кизилташского лимана (Краснодарский край) по гидробиологическим показателям

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Аннотация. Представлены гидробиологические показатели Кизилташского лимана по качественному и количественному составу фито-, зоопланктонного и зообентосного сообществ. Исследования проводили в 2018–2019 гг. на 9 станциях, 3 участках, по 3 станции на каждом участке. Показана динамика средней численности и средней биомассы фито-зоопланктона и зообентоса за исследуемый период. Приведены средние показатели численности и биомассы организмов и перечислены основные виды. В составе фитопланктона за период исследования выявлено 73 вида микроводорослей, относящихся к 7 отделам: диатомовые – 30 видов, динофитовые – 23 вида, зеленые – 8 видов, цианобактерии – 5 видов, гаптофитовые – 3 вида, эвгленовые – 3 вида, криптофитовые – 1 вид. В составе кормового зоопланктонного сообщества было обнаружено 17 видов организмов, принадлежащих к следующим таксономическим группам: коловратки, веслоногие ракообразные, ветвистоусые ракообразные, планктонные формы ракушковых рачков, личинки малощетинковых и многощетинковых червей, личинки двустворчатых и брюхоногих моллюсков. В единичных экземплярах в пробах встречались личинки насекомых – хирономиды, яйца артемий – жаброногих ракообразных, молодь разноногих ракообразных, личинки и молодь червей, личинки балянусов – усоногих ракообразных. Приведена динамика средней биомассы и средней численности зообентоса на 3 участках обследованной акватории в Кизилташском лимане за период исследования. В составе макрозообентоса на обследованной акватории было обнаружено 10 видов, при этом наибольшее количество видов имели брюхоногие и двустворчатые моллюски. По численности доминировали брюхоногие моллюски, а по биомассе – двустворчатые моллюски полихеты, также встречались ракообразные – усоногий рак и бокоплав – и личинки насекомых. Акватория второго участка, расположенного вблизи устья р. Кубань, являлась наиболее продуктивной зоной по фитопланктону как по численности, так и по биомассе, вероятно, из-за повышенного содержания органических веществ. Прибрежные участки, менее глубоководные, подвержены ветровому воздействию, поэтому имеют повышенную мутность воды, что создает неблагоприятные условия для развития фитопланктона. Данные по фитопланктону, зоопланктону и зообентосу, полученные при обработке гидробиологических проб Кизилташского лимана, позволили сделать вывод о том, что исследуемые участки пригодны для выращивания устриц и мидий.

Ключевые слова: фитопланктон, зоопланктон, зообентос, численность, биомасса

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Introduction

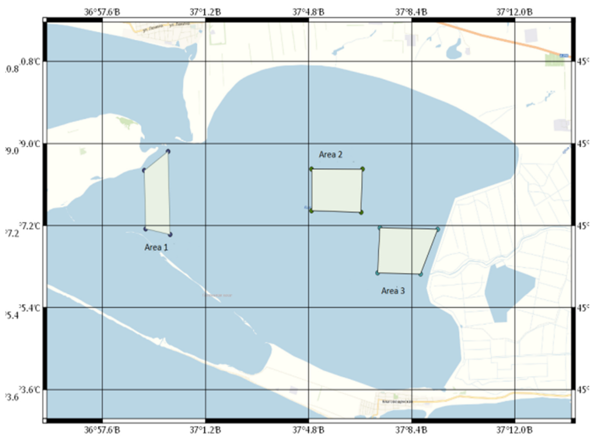
In terms of its size the Kiziltash Estuary Group is the largest in Kuban; it comprises the Kiziltash estuary, Bugaz, Tsokur, and the Lake Solenoe (the Salty Lake). The Kiziltash estuary itself is separated from the Bugaz estuary by a spit named Golenkaya (the Naked Spit). These estuaries have a continuous water flow between them and are connected to the Black Sea via a narrow strait (girlo).

In the past (the 19th century), these water bodies were a part of the Kuban River estuary. After the Kuban River watercourse had been artificially changed, the anthropogenic activity resulted in their salinization and subsequent transformation. At the present time, the Kiziltash estuaries can be considered highly productive water bodies; among other things, a fish farm for several species of mullets (*Mugilidae*) has been created in their area. Fresh and saline waters are forwarded to the limans via channels with controlled watercourses. Commercial fishing is not conducted [1]. At the present time, salinity of the Kiziltash estuary changes from 20 to 23‰ over the course of a year.

The researchers of the Azov-Black Sea Branch of the FSBSI "VNIRO" ("AzNIIRKH") have been the first to investigate the Kiziltash estuary and to assess its suitability for cultivation of oysters and mussels.

Materials and methods

Hydrobiological studies in the Kiziltash estuary were conducted in November, 2018 and February, April, and August, 2019. Samples were taken at 9 stations in three sampling areas – three stations per each area (Fig.).



Outline map of investigated areas in the Kiziltash estuary

Phytoplankton samples were taken in the surface water layer; sampling was performed using a Ruttner bathometer. At the laboratory, phytoplankton samples, which volume was around 1-1.5 liters each, were thickened by means of reverse-osmosis filtration using track membranes (1-2 μm). Phytoplankton samples were formalin-fixed with 2% formalin solution; for zooplankton samples, 4% formalin solution was used. Zoobenthos samples were ethanol-fixed using 75% ethanol solution. Sample processing was conducted according to the guidelines of [2].

Results and discussion

Phytoplankton. Over a period of the study, 73 species of microalgae were recorded in the phytoplankton community; they belonged in nine groups: diatoms (*Bacillariophyceae* Haeckel, 1878), represented by 30 species; dinoflagellates (*Dinoflagellata* Bütschli, 1885), represented by 23 species; green algae (*Chlorophyta* Pascher, 1914), represented by 8 species; cyanobacteria (*Cyanobacteria* Stanier ex Cavalier-Smith, 2002), represented by 5 species; haptophytes (*Haptophyta* Cavalier-Smith, 1986), represented by 3 species; euglenoids (*Euglenophyceae* Schoenichen in Eyferth & Schoenichen, 1925), represented by 3 species; and cryptophytes (*Cryptophyta* Cavalier-Smith, 1986), represented by 1 species.

Seasonal changes in microalgae species composition complied with these characteristic for the phytoplankton communities in the water bodies of southern latitudes.

The lowest number of phytoplankton species, 31 species, was recorded in autumn (November, 2018). The major part of phytocoenosis was comprised by diatoms and dinoflagellates with predominance of the *Cyclotella* (Brébisson, 1838) and *Gymnodinium* F. Stein, 1878 genera, respectively. Phytoplankton biomass was also at its lowest, with its average value being 219.5 mg/m^3; diatoms constituted more than 80% of total biomass of microalgae.

In winter (February, 2019), the species of *Nitzschia* Hassall, 1845 and *Glenodinium* (Ehrenberg, 1836) genera prevailed in phytoplankton species composition. Biomass increased up to 419.203 mg/m^3; the share of dinoflagellates was 53% of total biomass, and the share of diatoms was 45%.

In spring (April, 2019), the number of phytoplankton species increased (37), mostly on account of green algae g. *Chlamidomonas* Ehrenberg, 1833. Phytoplankton biomass increased drastically up to 1466.97 mg/m^3; the share of diatoms was 86% of total biomass.

The highest number of species from various taxonomic groups was recorded in summer (August, 2019); dinoflagellates of *Glenodinium* and *Gymnodinium* genera and diatoms of *Cyclotella* and *Thalassiosira* Cleve, 1873 genera prevailed. Phytoplankton was at the peak of its developmentits biomass was 1988.1 mg/m^3, on average. Dinoflagellates were the key component of microalgae biomass (more than 90%).

In terms of phytoplankton, the area of the second sampling site, located near the mouth of the Kuban River, was the most productive. Phytoplankton abundance and biomass was higher in this location, which could possibly be a consequence of an increased content of organic matter. The shallow-water sites closer to the shore (1 and 3) are subjected to wind activity, which creates unfavourable conditions for phytoplankton development.

The dynamics of average abundance and biomass of the Kiziltash estuary phytoplankton at three sampling sites of the investigated area for the period from November, 2018 to August, 2019 is given below (Table 1).

Table 1

Dynamics of average abundance and biomass of phytoplankton in the Kiziltash estuary*

Sampling site, No.	November, 2018	February, 2019	April, 2019	August, 2019
1	135 204.66	160.2 485.72	4624.8 1402.3	626.7 1080.97
2	188.1 285.57	152.8 477.08	791.5 1465	6297 2895.34
3	129 168.2	135.11 294.81	559.7 1533.6	–

* In the numerator Abundance, million cells/m^3; in the denominator Biomass, mg/m^3.

Average phytoplankton abundance at three sites of the investigated area in the Kiziltash estuary was 1051 million cells/m^3, and its average biomass was 1022 mg/m^3, respectively.

Zooplankton. Species composition of the zoocoenosis in the Kiziltash estuary durung the period of the study was similar to the zooplankton community of the north-eastern Black Sea, but its quantitative and qualitative parameters showed much lower values.

Identified species of zooplanktonic organisms fell into the category of forage zooplankton. Zooplankton community comprised 17 species of organisms, which belonged in the following taxonomic groups: rotifers (class Rotifera–Nemathelminthes) of *Synchaeta* Ehrenberg, 1832, *Keratella* Bory de St. Vinsent, 1882, and *Brachionus* Pallas, 1766 genera; copepods (order Copepoda) of *Oithona brevicornis* Giesbrecht, 1891 and *Acartia tonsa* Dana, 1849 species; cladocerans (order Cladocera) of *Bosmina longilostris* Leydig, 1860 and *Pleopsis polyphemoides* Leuckart, 1859 species; planktonic forms of ostracods (subclass Ostracoda); larvae of oligochaetes (class Olygochaeta) and polychaetes (class Polychaeta); larvae of bivalve molluscs (class Bivalvia) and gastropods (class Gastropoda). In isolated instances, the following organisms were found in samples: larvae of insects – chironomids (family Chironomidae), and eggs of brine shrimps *Artemia* sp. (subclass Branchiopoda); juvenile amphipods (order Amphipoda); larvae and juveniles of ribbon worms (class Nemertini); and larvae of balanus *Amphibalanus improvisus* Darwin, 1854 (subclass Cirripedia).

The dominant species among non-fodder zooplankton were bryozoans (class Bryozoa) and protists Foraminifera (subclass Rhizopoda).

In the autumn season (November, 2018), zooplankton community mostly consisted of the larvae of bottom invertebrates (gastropods and bivalve molluscs), as well as of rotifers and the larvae of ostracods and cladocerans. The larvae of gastropods and bivalve molluscs prevailed. Subdominant species were polychaetes at their larval stage, rotifers, and cladocerans. Occasionally, copepods Calanoida were also found in the samples. The highest abundance and biomass of zooplankton in the investigated area was recorded at the third sampling site. Average biomass of zooplankton in the autumn season was 2.37 mg/m^3, and its average abundance was 676.75 ind./m^3.

For the major part, zooplankton community in the winter season (February, 2019) consisted of the larvae of bottom invertebrates (bivalve molluscs) and ostracods. Occasionally, copepods and rotifers were also found in the samples. In terms of biomass, meroplankters (the larvae of bivalve molluscs) prevailed. The second place in the total zooplankton biomass was taken by the larvae of ostracods and by copepods, and the next were rotifers and cladocerans. Average biomass of zooplankton in the winter season was 4.29 mg/m^3, and its average abundance was 980.8 ind./m^3.

In the spring season (April, 2019), the major part of zooplankton community consisted of the larvae of bivalve molluscs and gastropods, as well as of rotifers, copepods, and cladocerans. Qualitative and quantitative parameters of zooplankton organisms showed much higher values in spring. In terms of abundance and biomass, planktonic forms of bivalve molluscs prevailed. Cladocerans prevailed at the first and the third sampling sites. Rotifers were the second in terms of abundance at all three sampling sites. In terms of biomass, polychaetes at various larval stages were subdominant species. In the investigated area, the highest abundance and biomass of zooplankton were recorded at the first and the third sampling sites. Average biomass of zooplankton in the autumn period was 190 mg/m^3, and its average abundance was 16237.4 ind./m^3.

In the summer season (August, 2019), the level of zooplankton development was low. The main species in the zooplankton community were copepods Calanoida, coastal forms of copepods Harpacticoida, and rotifers. Occasionally, cladocerans and the larvae of gastropods and bivalve molluscs were found. In terms of abundance, the larvae of bivalve molluscs prevailed, as well as rotifers. The second-order subdominant species were copepods. In summer, average biomass of zooplankton in the Kiziltash estuary was 17.1 mg/m^3, and its average abundance was 4741 ind./m^3, respectively.

The first and the third sampling sites, which were closer to the shore, demonstrated a higher level of zooplankton development than the second sampling site. At the first site, the major bulk of total zooplankton biomass was represented by copepods, and at the second site, rotifers overwhelmingly prevailed.

The dynamics of average abundance and biomass of the Kiziltash estuary zooplankton at three sampling sites of the investigated area for the period from November, 2018 to August, 2019 is given below (Table 2).

Table 2

Dynamics of average abundance and biomass of zooplankton in the Kiziltash estuary*

Sampling site, No.	November, 2018	February, 2019	April, 2019	August, 2019
1	539.26 / 2.08	980.8 / 4.29	18370 / 144.9	3860 / 18.7
2	692.03 / 2.35	–	8632 / 185	5623 / 15.5
3	797.22 / 2.67	–	21721 / 240.1	–

* In the numerator Abundance, ind./m^3; in the denominator Biomass, mg/m^3.

Average abundance of zooplankton in the Kiziltash estuary during the period of the study was 5659 ind./m^3, and its average biomass was 53.44 mg/m^3, respectively.

Zoobenthos. In the investigated area of the Kiziltash estuary, the bottom surface at the depths from 1.5 to 3 m was covered by gray and black silts. In the spring season, no hydrogen sulfide odor was observed, but in the summer season, it was present at the second sampling site. Red and filamentous green macroalgae were found on the bottom surface.

Macrozoobenthos species composition of the investigated area included 10 species. Polychaetes (class Polychaeta) were represented by the species *Nephtys hombergii* Savigny in Lamarck, 1818, and crustaceans (class Crustacea) were represented by the bay barnacle *Amphibalanus improvisus* Darwin, 1854 and by the amphipod species *Gammarus subtypicus* Stock, 1966. Among gastropods (class Gastropoda), the following species were recorded: *Hydrobia acuta* Draparnaud, 1805, *Retusa truncatula* Bruguière, 1792, and *Tritia reticulata* (Linnaeus, 1758). Among bivalve molluscs (class Bivalvia), there were *Abra segmentum* Recluz, 1843, *Cerastoderma glaucum* Bruguière, 1789, and *Mya arenaria* Linnaeus, 1758. Larvae of the insect species of Chironomidae family were also occasionally found in the zooplankton samples.

In the autumn season (November, 2018), 4 species of living organisms were found in the zoobenthos samples; they were the bivalve molluscs of *A. segmentum* and *C. glaucum* species, and the gastropods of

H. acuta and *T. reticulata* species. Average abundance of zoobenthos was 449 ind./m^2, and its average biomass was 42.3 g/m^2, respectively.

In the spring season (April, 2019), zoobenthos community was represented by 7 species: polychaeta *N. hombergii*, gastropods *H. acuta*, *R. truncatula*, and *T. reticulata*, and bivalve molluscs *A. segmentum*, *C. glaucum*, and *M. arenaria*. Average abundance of zoobenthic organisms was 244 ind./m^2, and their average biomass was 73.0 g/m^2, respectively.

In the summer season (August, 2019), 6 species of zoobenthic organisms were recorded: polychaeta *N. hombergii*, gastropods *H. acuta* and *R. truncatula*, bivalve mollusc *C. glaucum*, crustaceans *A. improvisus* and *G. subtypicus*, and larvae of chironomids. Average abundance of zoobenthic organisms was 647 ind./m^2, and their average biomass was 49.7 g/m^2, respectively.

In all three seasons (autumn, spring and summer), gastropods prevailed in terms of abundance, and bivalve molluscs prevailed in terms of biomass. The share of gastropods in the autumn season was 83.1% of total abundance and 34.3% of total biomass of zoobenthic organisms. In the spring season, these values were 65.6% for abundance and 4.9% for biomass. In the summer seasons, they were 42.3 and 9.7%, respectively. The share of bivalve molluscs in the autumn season was 16.9% of total zoobenthos abundance and 65.7% of total zoobenthos biomass. In the spring season, these values were 32.8% for abundance and 94.2% for biomass. In the summer season, they were 20.6 and 87.5%, respectively.

The highest abundance of zoobenthos was observed in the summer season, and its highest biomass was observed in spring. The highest values of zoobenthos abundance and number of species were recorded at the first sampling site, and the highest biomass was recorded at the second site.

The dynamics of average abundance and biomass of zoobenthos at three sampling sites of the investigated area in the Kiziltash estuary is given for the period from November, 2018 to August, 2019 (Table 3).

Table 3

Dynamics of average abundance and biomass of zoobenthos in the Kiziltash estuary*

Sampling site, No.	November, 2018	April, 2019	August, 2019
1	370 / 66	480 / 101	680 / 47
2	373 / 150	160 / 118	613 / 53
3	600 / 133	93 / 0.52	–

* In the numerator Abundance, ind./m^2; in the denominator Biomass, mg/m^2.

Over the period of the study, average abundance of zoobenthos in the Kiziltash estuary was 446.67 ind./m^2, and its average biomass was 55 g/m^2, respectively.

Conclusion

Status of the phytoplankton in the Kiziltash estuary was compliant with the seasonal level of development, characteristic for the phytoplankton community of the southern latitudes. Over the course of this study, 73 species of microalgae were identified in the phytoplankton species composition; they belonged in nine groups. The area of the second sampling site proved to be the most productive.

Zooplankton of the Kiziltash estuary, identified over the course of this study, was similar to the zooplankton community in the north-eastern part of the Black Sea; however, the values of its qualitative and quantitative parameters were lower. 17 species of zooplanktonic organisms were identified. The highest values of zooplankton abundance and biomass were observed at the third sampling site in the spring season.

Macrozoobenthos of the Kiziltash estuary comprised 10 species of organisms. Gastropods and bivalve molluscs were represented by the highest number of species. In terms of abundance, gastropods prevailed; bivalve molluscs prevailed in terms of biomass. The highest values of abundance in benthic organisms were recorded at the first sampling site, and the highest biomass was observed at the second site. Throughout the whole investigated area, the third sampling site showed the lowest number of species, abundance and biomass of zoobenthic organisms.

Low values of quantitative and qualitative parameters of zooplankton and zoobenthos, as well as high levels of microalgae productivity in the Kiziltash estuary offer the possibility to recommend the investigated area for the purposes of oyster and mussel cultivation.

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