Holoplankton of the port area of the Taman Peninsula: Kerch Strait, Black Sea

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Abstract Taxonomic composition and seasonal dynamics of holoplankton (mesoplankton) have been studied in the seaports of the Caucasus and Taman in 2017-2021. Holoplankton communities are characterized by a small number of dominant species. Organisms with a detritus nutrition strategy, such as rotifers, have developed along with copepods in the semi-closed Caucasus port with limited water exchange, low water transparency and a higher trophic status. The total abundance of holoplankton was 1.5-2 times higher in comparison with similar indicators of the Taman port. In the open Taman port good water exchange and natural self-purification of waters, the significant part of the total number of holoplankton constituted copepods (on average 81.8%). It was revealed that from 2013 to the present, the species composition and abundance of holoplankton in the Taman port have been mostly intact.

Keywords: holoplankton, taxonomic density, seasonal dynamics, seaports, Caucasus, Taman

1. Introduction

The Kerch Strait with the adjacent waters of the Azov-Black Sea basin is the most important transport artery, a zone of intensive navigation and functioning of port complexes, as well as a fishing area [1, 2]. The presence of large terminals and ports, the construction of the Tuzli dam, dumping of soil, transshipment of liquid and dry cargo, oil and other industrial pollution processes result to the violation of the natural process of sedimentation, changes in water dynamics, contamination of bottom sediments. These processes constitute a key factor in the restructuring of the macrozoobenthos structure, which presents the basis of the food base of commercial fish of the strait [3]. In the northern part of the Kerch Strait on the Chushka Spit, the second largest cargo turnover in the Azov-Black Sea basin is the seaport of Kavkaz, which provides a crossing through the Kerch Strait to the Crimea.

In the north-eastern part of the Black Sea on the Taman Peninsula, there is the Taman seaport, which is a transshipment center for land and sea transportation. The planned volume of cargo transshipment in the port is up to 30-35 million tons of cargo per year, including oil, petroleum products, ammonia, mineral fertilizers, oil and grain. Good water exchange in the area of port berths and the intensive mixing of coastal waters with the open sea contribute to the processes of self-purification and, as a result, the low level of water pollution. In 2013-2014, in the area of the port of Taman, the monitoring of holoplankton and meroplankton (larvae of benthic invertebrates) was started [4]. The full-season monitoring of the dynamics of the holoplankton structure and its current state in the Caucasus port has not been carried out before.

The aim of the study is to analyze the current status of taxonomic composition and seasonal dynamics of the numerical abundance and biomass of holoplankton (mesoplankton) in the seaports of Kavkaz and Taman.
Holoplankton is a part of zooplankton organisms that spend their entire life cycle in a water column (pelagic zone), except of the bottom stage of rest (eggs, etc.). Holoplankton represented by metazoan invertebrates plays an important role in the nutrition of fish, jellyfish, ctenophores, mollusks and other planktonic and benthic hydrobionts.

2. Materials and methods
The Taman Peninsula is located in the west of the Kuban Plain and is washed by the Black and Azov Seas, as well as the Kerch Strait connecting them. The Chushka Spit separates the Sea of Azov from the Black Sea. The semi-closed seaport of Kavkaz is located on the Chushka Spit in the northern part of the Kerch Strait (Fig. 1).

The shallow and relatively narrow Kerch Strait belongs to the water area of the Sea of Azov and connects it with the Black Sea. Its length is 43 km, its width ranges from 4 to 42 km. The greatest depths at the entrance to the Strait are more than 10.5 m from the Sea of Azov and 18 m from the Black Sea. Moving towards the middle of the strait, the depth gradually decreases and is about 5.5 m in a larger area. The main role in the formation of the currents of the Kerch Strait belongs to a wind [5]. In addition to a wind, the water circulation in the Strait depends on the difference in sea levels at the ends of the strait, due to the level fluctuations and differences in the fresh water balance of the Black and Azov Seas. The authors concluded, that the predominant transfer of water in the Strait is from the Sea of Azov to the Black Sea. The water temperature in the Kerch Strait in the autumn-winter period is usually 2-4 °C higher than in the open sea. In summer water exchange between the Azov and Black Seas decreases the water temperature in the strait compared to the coastal zone of the sea. At the borderline of the Black Sea and Azov Sea, there is a frontal zone with large salinity gradients (from 11% in the north to 17% in the south in the strait). The zone plays an important role for the distribution of plankton and bottom communities.

The open-type Taman port is located in the south-west of the Taman Peninsula in Cape Zhelezny Rog in the village of Volna (Figure 1). The cape stretches for 1.3 km and is located at an altitude of 65 m above the sea level.

Zooplankton was collected in different seasons of 2017-2020 in the berths of the port of Kavkaz. In the area of the port of Taman the depth ranged from 5 to 16 m in 2018-2021.
Crustacean copepods, large rotifers and other organisms > 200-500 µm were collected by a medium-sized Juday net (entrance hole diameter 25 cm, mesh size 100 µm) using total catches. The samples were fixed with a 2-4% solution of neutral formaldehyde and processed in the laboratory according to the standard method. A biomass was calculated according to the standard methods [5].

3. Results and discussion

The Sea Port of Kavkaz. 25 taxa have been found in the holoplankton, including 1 - Dinophyta (Noctiluca scintillans), 4 - Rotifera, 2 - Ctenophora, 3 - Cladocera, 13 – copepoda, 1 – Chaetognatha, 1 – Appendicularia (Table 1). Among the inhabitants of the Sea of Azov, brackish-water copepod species Eurytemora affinis are noted. Copepods constitute in average 53.8 % of the total zooplankton population.

| Table 1 Taxonomic composition of holoplankton in the sea ports of the Taman Peninsula |
|-----------------------------------|-----------------|-----------------|
| Taxa                             | Port of Kavkaz  | Port of Taman   |
| DINOPHYTA                        |                 |                 |
| Noctiluca scintillans (Macart.)  | +               | +               |
| Kofoid&Swezy                     |                 |                 |
| ROTIFERA                         |                 |                 |
| Synchaeta vorax Rousselet        | ++              | +++             |
| S. baltica Ehr.                  | +++             | +++             |
| Keratella cochlearis (Gosse)     | +               | +               |
| Trichocerca marina Daday         | +               | +               |
| CTENOPHORA, TENTACULATA          |                 |                 |
| Mnemiopsis leidyi A.Agassiz      | +               | +               |
| CTENOPHORA, ATENTACULATA         |                 |                 |
| Beroe ovata Mayer                | +               | +               |
| CLADOCERA                        |                 |                 |
| Penilia avirostris Dana          | +               | +               |
| Pleopis polyphemoides (Leuck.)   | +               | +               |
| Evadne tergestina (Claus)        | +               | ++              |
| Evadne spinifera Müller          | –               | +               |
| COPEPODA, CALANOIDIA             |                 |                 |
| Calanus euxinus (Hulsemann)      | +               | +               |
| Pseudocalanus elongates (Boeck)  | +               | +               |
| Paracalanus parvus (Claus)       | ++              | ++              |
| Acartia clause Ciesbr.           | +++             | +++             |
| A. tonsa Dana                    | +++             | +++             |
| Centropages ponticus Karav       | ++              | ++              |
| Pontella mediterranea (Claus, 1863) | –       | +               |
| Eurytemora affinisaffinis (Poppe, 1880) | +   | –               |
| COPEPODA, CYCLOPOIDA             |                 |                 |
| Oithona davisae Ferrari, Orsi    | +++             | +++             |
| O. similis Claus                 | +               | ++              |
| Sapphirina sp.                   | –               | +               |
| COPEPODA, HARPACTICOIDA          |                 |                 |
| Harpacticus spp.                 | +               | +               |
| Ameira sp.                       | –               | +               |
| Metis ignea Phillippi            | –               | +               |
| Ectinosoma abrau (Kricz.)        | +               | +               |
| Canuella perplexa T. et A. Scott.| +               | –               |
| Onychocamptus mohammed Blanch. Et Rich. | + | – |
| COPEPODA, POECILOSTOMATOIDIA     |                 |                 |
| Saphirella sp.                   | –               | +               |
CHAETOGNATHA
Parasagitta setosa Muller + +
APPENDICULARIA
Oicopleura dioica Fol. + +

Note: – no species, + species detected, ++ common species, + + + mass species

The average annual number of holoplankton forage organisms (excluding Noctiluca, ctenophores) varied in the range of 1.6-56.4 thousand ind/m$^3$ (the average values 9.5 thousand ind/m$^3$), biomass 9.3-32.2 mg/m$^3$ (average values 28 mg/m$^3$). High numerical density of holoplankton organisms was observed in February (56.4 thousand ind/m$^3$) and March (8.6 thousand ind/m$^3$), when rotifers of the genus Synchaeta dominated the holoplankton (Figure 2a).

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The share of these organisms in the total number of holoplankton reached 86-99.8%. The species Synchaeta baltica dominated among rotifers. The holoplankton biomass during the periods of population growth (February) rose to 91.4 mg/m$^3$ (Figure 2b). High values of the abundance and biomass of crustaceans, mainly copepods, noted in September and October, were 3-3.2 thousand copies/m$^3$ and 27.2-32.2 mg/m$^3$. At this time, the thermophilic copepod species Oithona davisae (Cyclopoida) developed in noticeable numbers in the port. This species has recently moved into the Black and Azov Seas with the ballast waters of merchant ships [6]. During the study period, the population of the species was actively spawning. The proportion of oviparous females and nauplii was 80%. The contribution of O. davisae to the total holoplankton reached 60-96%. The share of other copepod species (copepods), such as Acartia tonsa and Centropages ponticus in September in this area was no more than 11-26% of the total number of the holoplankton. At the end of June and July the number of predatory ctenophore zooplanktonophagus M. leidyi was visually high in the holoplankton. The predator migrates annually from the Black Sea to the Sea of Azov in May-June, develops there until November, and then disappears [7]. The seasonal dynamics of zooplankton during the period of the predatory invader has lost the traditional summer maximum. In the Sea of Azov, the period of intensive development of zooplankton occurs in May at the early approach of the ctenophore, and in May – June at the late approach [8]. In August, the predator spreads throughout the sea, including the Taganrog Bay, which leads to the degradation of holoplankton and meroplankton (larvae of bottom animals) [9]. In our studies, the minimum values of the number and biomass of holoplankton (1.6-1.7 thousand copies/m$^3$ with a biomass of 12-15 mg/m$^3$) were noted in July during the development of the comb and in December, when a seasonal decline in holoplankton reproduction occurs with a decrease in temperature.

The seaport of Taman. 29 taxa were found in the holoplankton, including 1 – Dinofyta, 4 – Rotifera, 2 – Ctenophora, 4 – Cladocera, 16 – Sopepoda, 1 – Chaetognatha, 1 – Appendicularia, mainly marine
fauna (Table 1). Copepods constituted a significant part of the total zooplankton population of the open Taman port (81.8 %). The average annual number of holoplankton forage organisms varied in the range of 0.75-10 thousand copies/m³ (average values – 4.9 thousand copies/m³), biomass varied in 1.68-60.3 mg/m³ (average values – 19.9 mg/m³). High rates of zooplankton abundance were noted in December (6.3 thousand copies/m³), when the proportion of rotifers in plankton was high (75 %) (Figure 3a).

![Figure 3. Dynamics of holoplankton: numerical abundance (N, 10³ ind./m³), biomass (B, mg/m³) and share of taxonomic groups in total number and biomass of holoplankton of the seaport of Taman](image)

In September and November, the peaks in the number of holoplankton (10-8.3 thousand copies/m³) were formed by copepods of *O. davisae* (96-85 % of the total number of holoplankton). Additionally, in June, other copepods *A. tonsa* (41% of the total number of holoplankton) and *C. ponticus* (24%) were noticed. The biomass during the periods of holoplankton abundance increase reached its maximum values in June and September (0.6-0.4 mg/m³, respectively). In May and July, holoplankton developed weakly. In July, a low density of holoplankton was observed due to its eating by the predatory ctenophore *M. leidyi*. Visually, the plankton at this time was dominated by individuals of ctenophores with a size of 30-60 mm. In May 2021, a seasonal decline in the development of oar-footed crayfish was registered due to an unusually low water temperature of 15 °C for this year [9]. A comparative analysis of the long-term dynamics of holoplankton showed that from 2013-2014 [9] to 2018-2021 the species composition and abundance of holoplankton practically did not change, and the biomass decreased by three times. This phenomenon is caused by the fact that in recent years plankton included a small number of predatory zooplanktonophages *Parasagitta setosa*, which give a very high biomass.

4. Conclusion
The fluctuations in the water temperature and the press of the predatory comb affected significant seasonal fluctuations in the number of holoplankton in the seaports of the Caucasus and Taman underwent. The peaks of zooplankton abundance were noted in winter and autumn; in summer its density decreased as a result of eating by the predatory ctenophore *Mnemiopsis leidyi*. Holoplankton communities were characterized by a small number of dominant species. In winter and early spring, the holoplankton was dominated by rotifers of the genus *Synchaeta*, in autumn – copepods *Oithona davisae*, in early summer – copepods *Oithona davisae, Acartia tonsa*, *Centropages ponticus*.

The detected differences in the taxonomic composition and quantitative distribution of holoplankton in the ports are mainly caused by various water exchange conditions, physical, geographical and ecological features of the studied areas. In the semi – closed port of Kavkaz with limited water exchange, low water transparency and, as a result, a higher trophic status, specific conditions were created for the development of organisms in the detritus feeding strategy-rotifers. The share of copepods on average
was 53.8% of the total number of holoplankton. Moreover, the total abundance of holoplankton was 1.5-2 times higher compared to similar indicators of the port of Taman. In the open port of Taman with good water exchange and natural self-purification of waters, copepods constituted significant part of the total number of holoplankton (on average 81.8%). It was revealed that from 2013 to the present, the species composition and abundance of holoplankton in the port of Taman have practically not changed.

The obtained results demonstrate the ecological state of the holoplankton in the seaports of the Caucasus and Taman and may be useful for further monitoring of these areas.

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