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MEIOFAUNA OF VARIOUS BIOTOPES OF THE UPPER SUBLITTORAL OF THE ODESSA BAY

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In the article, for the first time for the shelf of the northwestern part of the Black Sea, the features of the formation total abundance and biomass of permanent (permanent members) and temporary (temporary members) components of meiobenthos in the upper sublittoral of the Odessa Bay (2.5–11 m). The material was presented by quantitative samples collected in 2012, in the coastal zone of the Odessa Bay. During the research period, from 9 to 13 groups of meiobenthos were found on various substrates: Foraminifera, Nematoda, Harpacticoida, Ostracoda, Halacaridae, Kinorhyncha, Turbellaria, Oligochaeta, larvae and juveniles of Polychaeta, Bivalvia, Gastropoda, Balanus. There are 9 large taxa on the sandy substrate, 12 on the shell, and 10 taxa on the stony substrate with algae cover. An analysis of the distribution of individual meiobenthic on various substrates showed their significant differences. Nematoda dominated on the sandy substrate. The main role was played by polychaetes and juvenile bivalves. On the shell rock, the total abundance of meiobenthos varied at different stations from 2500 ind. m^{-2} to 269000 ind. m^{-2} (average – 143300 ind. m^{-2}), the main part of it was formed by eumeiobenthos (72.7 %). In the periphyton of rocky substrate, the meiobenthos consisted of 10 large taxons. Turbellaria, Kinorhyncha and Gastrotricha were absent. The total number of meiobenthos varied from 59000 ind. m^{-2} to 341000 ind. m^{-2} (on average 156107 ind. m^{-2}). The proportion of eumeiobenthos in the total number of organisms was 67.4 %. On the mixed substrate, the formation of the total abundance of meiobenthos occurred mainly due to 6 groups (Nematoda, Harpacticoida, Ostracoda, Oligochaeta, Polychaeta, juveniles of Bivalvia). Concentration of the total meiobenthos varied from 83000 ind. m^{-2} to 146500 ind. m^{-2} (on average 120500 ind. m^{-2}). Nematoda dominated, the subdominant group was Harpacticoida. The paper considers the formation of quantitative indicators of the main groups of meiobenthos (Foraminifera, Nematoda, Harpacticoida, Ostracoda, Halacaridae, temporary meiofauna) depending on the type of substrate.

Key words: meiofauna, Odessa Bay, sublittoral, various substrates.

Introduction

In the upper sublittoral of the Black Sea (10–11 m) the richest food base for fish larvae and juveniles is formed. The purpose of our research is to study the formation of quantitative characteristics of representatives of large taxa (total abundance and biomass) of the meiobenthic community in the upper sublittoral of the Odessa Bay. Earlier, studies of the end of the last century (Vorobyova 1999) and the first decades of the 21st century were devoted to these issues (Vorobyova et al. 2017; Vorobyova et al. 2019; Vorobyova 2021; Vorobyova 2021a). The study of the features of the formation of the ecological characteristics of the meiobenthos on various substrates of the northwestern part of the Black Sea is of great importance. Based on the indicators of the dominance of large taxa in the total abundance of meiobenthos, one can judge the formation of a food base for representatives of larvae and juveniles of the fish. According to meiobenthic indicators, it is possible to rank the types of bottom substrates according to the accumulation of organic substances.

Material and research methods

The analysis was based on the results of 96 sample processing in the upper sublittoral of the Odessa Bay in 2012. The samples were collected by diver according to the following scheme (Fig. 1). Sections A and B, located perpendicular to the coast, covered a depth of 2–6 m to 11.7 m. Section C was located at a depth of 11–11.7 m, and section D, which, like section C, is located parallel to the shore – at a depth of 6.0-6.7 m. In this work, we consider the quantitative characteristics of only large taxa, which play a significant role in the formation of general indicators (abundance and biomass) of the meiobenthos. Samples were taken with a benthic frame 10x10 cm, washed through a system of benthic sieves, under the last of which (1 mm) mill gas was substituted with a mesh size of 90 μm. Samples were fixed with 4 % formalin and simultaneously stained

with Rose Bengal dye. The material was processed in the laboratory using optics.

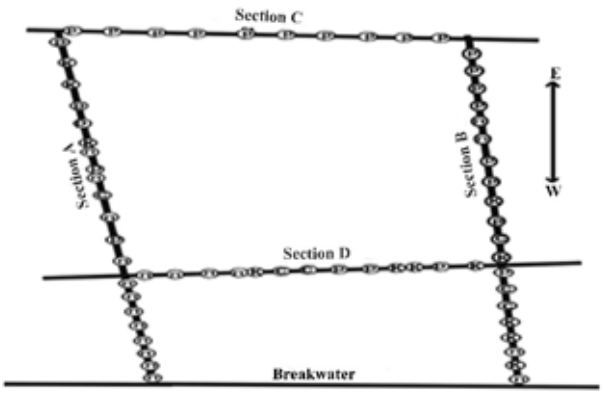

Fig. 1. The distribution scheme of bottom biocenoses in the area of the Marine research station of Odessa National Mechnikov University (Odessa Sea region) in July 2012 (k – stony substrate, п – sand, p – shell, c – mixed substrate)

Results and discussion

During the research period, from 9 to 13 groups of meiobenthos were found on various substrates: Foraminifera, Nematoda, Harpacticoida, Ostracoda, Halacaridae, Kinorhyncha, Turbellaria, Oligochaeta, larvae and juveniles of Polychaeta, Bivalvia, Gastropoda, Balanus. There were 9 large taxa on the sandy one, 12 on the shell, and 10 taxa on the stony substrate with algae cover. At the same time, turbellarians, kinorhynchus and balanus larvae were noted only in one sample out of 96. Representatives of eumeiobenthos predominated in various biotopes, which accounted for 61.5 % on stony substrate, 72.7 % on shell rock, 67.6 % on sandy and on mixed one – 64.7 %. Thus, the proportion of the total abundance of these two categories of meiobenthos in the entire study area was within the same limits. The total number of meiobenthos on different substrates varied significantly. It was minimal on mixed substrate, and maximal – on rocks with algae.

The total biomass of meiobenthos on different types of substrates ranged from 1893 mg m^{-2} to 3101 mg m^{-2}. The permanent (eumeiobenthos) component played the main role in the formation of the total abundance of meiobenthos, whereas the decisive role in the formation of the total biomass belonged to the pseudomeiobenthos (temporary component). So, on sandy substrate, it was 81.6 %, on a shell – 79.4 %, on stones with algal overgrowth – 74.6 %, on a mixed substrate – 78.6 %.

The analysis of the distribution of individual meiobenthic taxa on various substrates showed their significant differences. Nematoda dominated on the sandy substrate, Ostracods were absent. This is due to their ecological features and the possibility to develop mainly on the algal substrate. Juvenile Gastropoda were also absent. Most of the total abundance was formed by eumeiobenthos, accounting for 67.4 % of the total number of organisms. The total biomass (variations from 437.4 to 5764.4 mg m^{-2}) averaged 2807.5 mg m^{-2}, which was mainly formed by representatives of pseudomeiobenthos (81.6 %). The main role in the latter was played by polychaetes and juvenile bivalves.

On the shell rock, the total abundance of meiobenthos varied at different sites from 2500 ind. m^{-2} to 269000 ind. m^{-2} (average 143300 ind. m^{-2}), the main part of it was formed by eumeiobenthos (72.7 %). Nematoda prevailed, leaving 54.1% of the total. The total biomass was slightly lower than on the sandy substrate – an average values made 1893 mg m^{-2} (the range is 125.4–7675.8 mg m^{-2}). These parameters, were formed mainly by polychaetes and bivalves as well as on the sand. Turbellarians, Kinorhyncha were met with single specimens. The remaining representatives of large taxa had a low abundance.

In the periphyton of rocky substrate, the meiobenthos consisted of 10 large taxa. Turbellaria, Kinorhyncha and Gastrotricha were absent. The total abundance varied from 59000 ind. m $^{-2}$ to 341000 ind. m^{-2} (156107 ind. m^{-2} on average). The proportion of eumeiobenthos in the total number of organisms was 67.4 %. The proportion of pseudomeiobenthos was quite high (32.6 %). The total biomass of meiobenthos varied widely – 739.38 mg m^{-2} to 5873.0 mg m^{-2} (3104.42 mg m^{-2} on average). Harpacticoida dominated, Nematoda was the subdominant group. Thus, crustaceans and juvenile bivalve mollusks mainly developed on the stony substrate among algal fouling, which was also reflected in the study of the lithocontour of the northwestern part of the Black Sea (Vorobyova at al., 2019). The relatively high accumulation of nematodes is associated with silt that deposited on the settlements of Bivalvia.

On the mixed substrate, the formation of the total abundance of meiobenthos occurred mainly due to 6 groups (Nematoda, Harpacticoida, Ostracoda, Oligochaeta, Polychaeta, juveniles of Bivalvia). Indicators of the total abundance varied from 83000 ind. m^{-2} to 146500 ind. m^{-2} (120500 ind. m^{-2} on average). Nematoda dominated, the subdominant group – Harpacticoida. The proportion of eumeiobenthos in the total abundance of organisms was 64.7 %. The total biomass of meiobenthos ranged from 1805.1 mg m^{-2} to 3708.6 mg m^{-2} (2458.3 mg.m^{-2} on average). The main role in its formation belonged to pseudomeiobenthos – 78.5 % of the total meiobenthos biomass. The main part of the biomass of pseudomeiobenthos was formed by polychaetes – 49.4 %.

Foraminifera

Their study is of great scientific interest. The importance of representatives of the taxocene

Foraminifera in marine ecosystems was previously mentioned by us (Vorobyeva 1999; Vorobyova et al. 2017; Vorobyova et al. 2019; Vorobyova 2017). The most important abiotic factors for benthic Foraminifera are, along with salinity, the type of bottom substrate, the depth of the marine area under consideration, water temperature, the amount of dissolved oxygen, and the content of organic matter. It is known that the most productive substrate for foraminifera is silt, a mixture of silt, sand, and detritus (Phleger 1960; Vorobyova 1999). The study of the meiobenthos over the past 17 years has shown that the minimum indicators of representatives of the taxocene Foraminifera in the Odessa Sea Region are confined to sandy and rocky substrates, as well as to the shell rock (Vorobyova et al. 2017; Vorobyova 2019).

During our studies in 2012 Foraminifera were absent on the mixed substrate. On the sandy bottom they were noted at one of the stations (A, 240-5000 ind.·m^{-2}). On a shell rocky substrate, they developed at three of the 16 stations, mainly where the mollusks formed dense settlements. Their average density is 1789 ind. m^{-2}, which is 1.5 % of the total abundance of meiobenthos (Fig. 2). On the shell rock, their occurrence was about 50 % and the abundance at a depth of 6 to 11 m varied from 4000 to 18000 ind. m^{-2} (average – 4480 ind. m^{-2}). At the same time, the share of foraminifers in the total abundance of meiobenthos was 4.2 %.

Nematoda

A great contribution to the study of the faunal composition and quantitative characteristics of the Nematoda of the Ukrainian shelf of the Black Sea was made by I.I. Kulakova (Kulakova 1989; Vorobyova, Zaitsev, and Kulakova 1992; Kulakova 2002). Among the free-living nematodes of the Black Sea, the largest numbers of species are eurybionts. The distribution of nematodes is impacted mainly by the characteristics of the substrate and in particular the size of the interstitial spaces that can serve as a refuge for nematode. It is impacted by the diversity of biotopes at a minor extent (Gerlach 1953, 1958). The highest density of nematodes was on sandy soil (Fig. 3). The abundance of Nematoda varied from 2300 ind. m^{-2} to 484000 ind. m^{-2} (100972 ind. m^{-2} on average). Their maximum accumulation is confined to transect D, located near the breakwater parallel to the coast (depth 6.4 m). On the sandy substrate nematodes were the dominant group, accounting for 50.4 % of the total abundance of meiobenthos and 76.78 % of the total abundance of eumeiobenthos.

Harpacticoida

Harpacticoida are the crustaceans that live in all marine waters, at different depths and various bottom sediments (silt, sand, shell rock, stony rock and mixed substrates). The abundance of crustacean settlements varies significantly (Fig. 4). The minimum indicators are noted on the shell (average – 12580 ind.·m^{-2}). Here, the occurrence of Harpacticoida is high. They were present at 23 stations out of 25. But their participation in the formation of the total abundance is rather low and made 8.3 %. The abundance of crustaceans on sandy and mixed substrates differed slightly. On the sand it averaged 28723 ind.·m^{-2}, and on the mixed substrate it was 20345 ind.·m^{-2}. The maximum concentrations of Harpacticoida, of course, are recorded in the periphyton of a stony substrate. In 2012, the abundance of Harpacticoida on a stony substrate in algal-mussel fouling averaged 45143±12060 ind.·m^{-2}. The nature of the distribution of Harpacticoida on this substrate was described by V.V. Portyanko (2019). The author indicates that the density of Harpacticoida varied significantly from 1000 ind.·m^{-2} to 156500 ind. m^{-2} They dominated in the formation of the total number of meiobenthos. Here their share was 45 % of the total number of organisms, their share was the highest – 62.3 %. The proportion

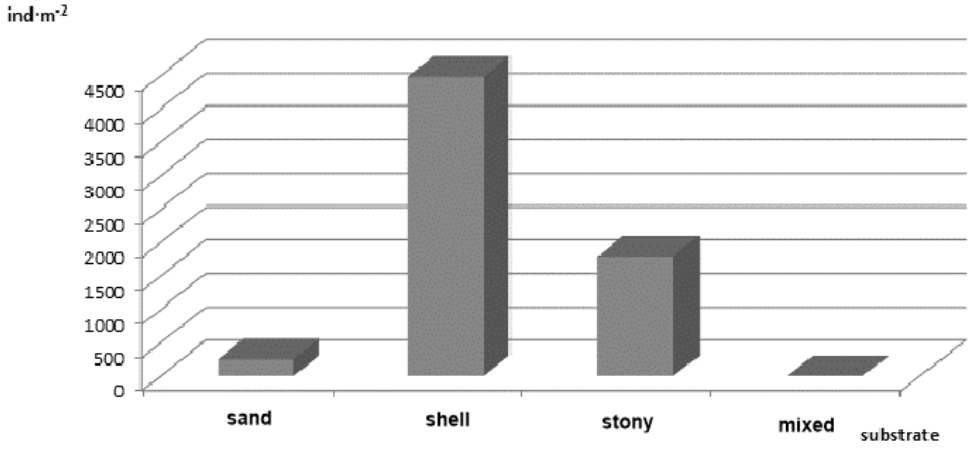

Fig. 2. The average abundance of Foraminifera (ind.·m^{-2}) on various substrates in the upper sublittoral of the Odessa Bay

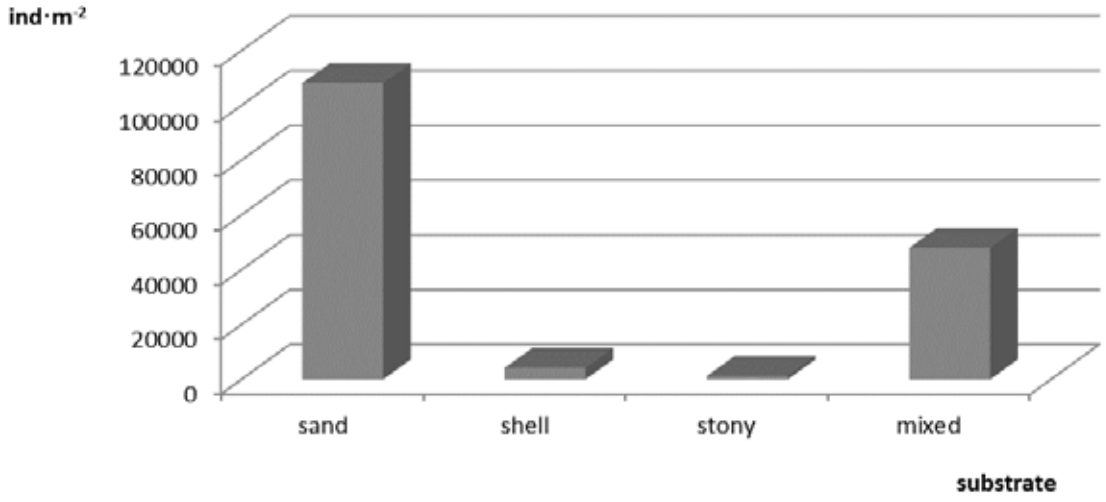

Fig. 3. The average abundance of Nematoda (ind.·m^{-2}) on various substrates in the upper sublittoral of the Odessa Bay

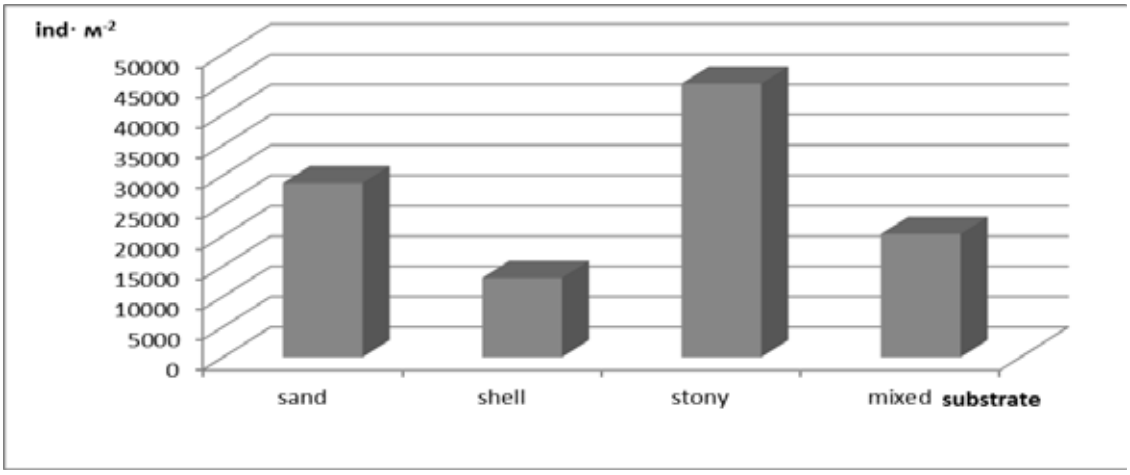

Fig. 4. Average numbers (ind. m^{-2}) of Harpacticoida on various substrates in the upper sublittoral of the Odessa Bay

of Harpacticoida in the total abundance of meiobenthos in 2012 averaged 26.1 %, in biomass – 21.6 %.

Ostracoda

Ostracoda are mobile benthic crustaceans and are included in the meiobenthos category by their size. There is a small number of species that live in planktonic. The abundance of Ostracoda settlements to a greater extent than for other taxa of the meiobenthos is formed depending on the type of substrate. Crustaceans are poor swimmers; they prefer places with small bottom currents and biotopes with good development of periphyton. According to many literary data Ostracoda are omnivorous animals. They prefer to feed on the remains of small organisms and play a significant role in the transformation of organic matter. Representatives of this taxon, having a relatively high calorie content (Vorobyova, Targonskaya 1998), are an excellent food object for juvenile fish. At present there is information about the faunal composition of Ostracoda in the coastal zones of the northwestern part of the Black Sea (Uzun 2016, 2021). The minimum accumulations of Ostracoda are characteristic of sandy substrate. Here the occurrence of Ostracoda in the period of our research was 27.7 %. The average abundance was 778 ind.·m^{-2}. On the shell, their occurrence was – 72.0 %. The average abundance was 4741 ind.·m^{-2}, which is 4.1% of the total abundance of meiobenthos. As can be seen from the presented graph (Fig. 5), the maximum concentrations of ostracods live on a stony substrate among the growth of algae and mussels. The average number was 17815 ind. m^{-2}. Their share in the total number of meiobenthos was 8.4 %, and in the eumeiobenthos – one seventh.

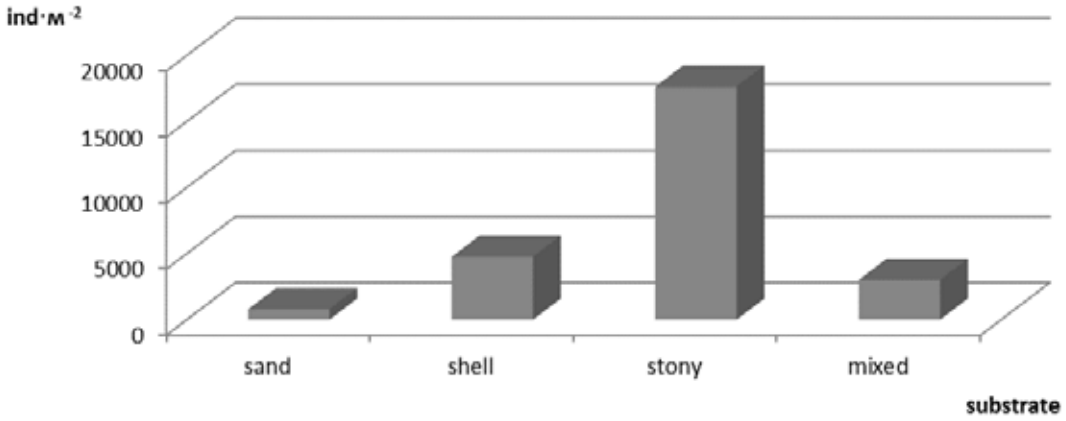

Fig. 5. Average numbers (ind.·m^{-2}) of Ostracoda on different substrates in the upper sublittoral of the Odessa Bay

Halacaridae

In the middle of the last century, 26 species of sea mites were known for the Black Sea (Sokolov, and Yankovskaya 1972). In the list of fauna of the northwestern part of the Black Sea (Vinogradov 1967), Halacaridae were not mentioned at all. In the coastal zone subjected to wave action the branched algal thalli with a high specific surface area serve as a refuge for meiobenthic organisms. Representatives of the meiofauna actively inhabit finely branched, cylindrical macrophytes, which have high specific surface area of thalli. Single-celled organisms serve as a food source for herbivorous Halacaridae, and suspended organic matter consumed by detritivores. In the studies of M.V. Gelmboldt 1995–2001 in the NWBS (Gelmboldt 2003), 18 species (11 genera) were noted; in the Odessa Bay and adjacent water areas, 8 species (7 genera).

In this paper we demostrate the spatial distribution of the abundance of Halacarids and their role in the formation of the total abundance of meiobenthos. During the period of our research, sea mites were found on all types of substrates (Fig. 6).

On the sandy substrate, the occurrence of mites was only 22.2 %. The abundance of their settlements was 808 specimens m^{-2}, which amounted to 0.4 % of the total number of meiobenthos and 0.3 % of its biomass. On the shell rock, the occurrence of Halacaridae was two times higher than on the sandy substrate (58.3 %). This is quite obvious, since on this substrate there are more dead small animals and microalgae that these animals feed on. The average abundance of halakarids was 2019 ind.·m^{-2}, the maximum indicator was recorded at station B240 and made 18000 ind.·m^{-2}. The share of the abundance of mites was 1.9 % of the total

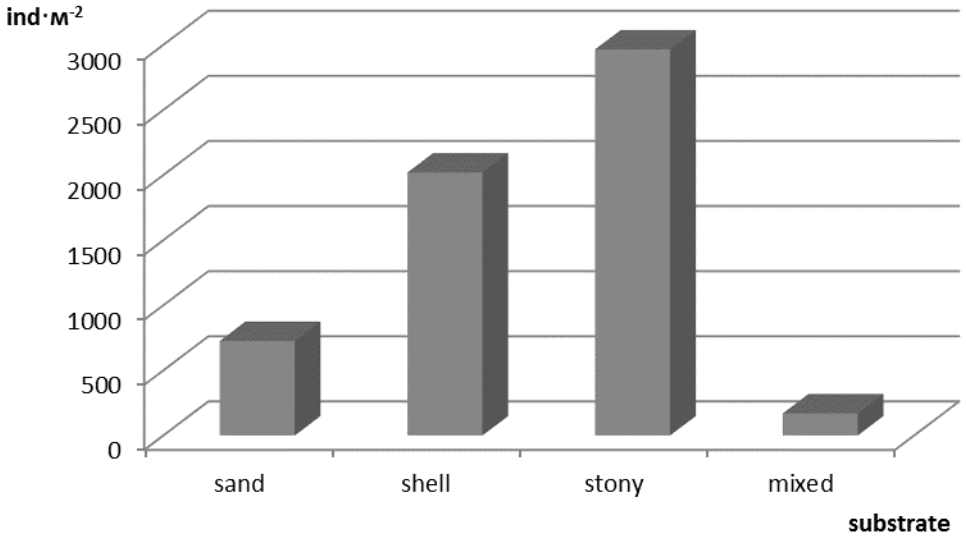

Fig. 6. Average abundance (ind.·m^{-2}) of Halacaridae on various substrates in the upper sublittoral of the Odessa Bay

meiobenthos, and the share of biomass was 2.2 %. On the stony substrate Halacaridae were noted at 50 % of stations out of 24. The average density of mites colonies was 2964 ind. m^{-2}, which was 1.9 % of the total abundance of meiobenthos. The absence or minimal presence at a depth of up to 8 m is explained by the fact that sandy sediment was presented here. Deeper there were the rocky substrate and shell rock.

Pseudomeiobenthos (temporary meiofauna or pseudomeiobenthos)

As it is known from literary sources the representatives of the temporary meiobenthos component (temporary meiofauna or pseudomeiobenthos) play a significant role in marine ecosystems. The same important role was pointed out in our previous studies on the meiobenthos of the northwestern part of the Black Sea (Vorobyova 1999). The role of pseudomeiobenthos in the formation of quantitative indicators of meiobenthos (abundance and especially biomass) is significant. Possessing relatively high population abundance and biomass, they create a high-calorie food base for juveniles of benthic and demersal fishes, as well as for some representatives of macrozoobenthos. It is known that for representatives of pseudomeiobenthos the type of substrate is of the greatest importance. The maximum concentrations of oligochaetes during the study period were noted on a mixed substrate, where their population density was 5750 ind. m^{-2}. The minimum abundance of oligochaete settlements is typical for a stony substrate (Fig. 7). On sandy substrate, the occurrence of oligochaetes was 50.1 %, the average abundance was 4889 ind.$\cdot m^{-2}$. The average biomass was 302.0 mg$\cdot m^{-2}$. On the shell rock, the quantitative indicators did not differ much. The average abundance of polychaetes in the upper sublittoral of the Odessa Bay on different substrates differed slightly (Fig. 7). The maximum indicators of abundance were noted on sandy substrate (19144 ind.$\cdot m^{-2}$), the biomass was low – 26.0 mg$\cdot m^{-2}$, which was almost one third of the biomass of the entire pseudomeiobenthos. On the stony and mixed substrate, the quantitative indicators of polychaetes at 100 % occurrence on both substrates differed very slightly. On the stony substrate, the abundance of polychaetes was 18787 ind.$\cdot m^{-2}$, whereas the biomass was 1127.14 mg$\cdot m^{-2}$. On the mixed substrate the indicators were the following: abundance 20830 ind.$\cdot m^{-2}$, biomass 49.4 mg$\cdot m^{-2}$. On the shell rock, the abundance of juvenile polychaetes was the lowest 14839 ind.$\cdot m^{-2}$ (with biomass 26.0 mg$\cdot m^{-2}$). When comparing, it should be noted that the population density of juvenile polychaetes on almost all substrates was up to 50% of the average values of the entire temporal component of the meiobenthos. Juvenile mollusks, the representatives of the Bivalvia and Gastropoda taxocene, formed the maximum quantitative indicators on the stony substrate (Fig. 7).

Thus, the results of this study reflect the formation of quantitative indicators of the main meiobenthos taxa depending on one of the most important environmental factors – bottom substrates. The obtained characteristics of the meiobenthos of the upper sublittoral of the Odessa

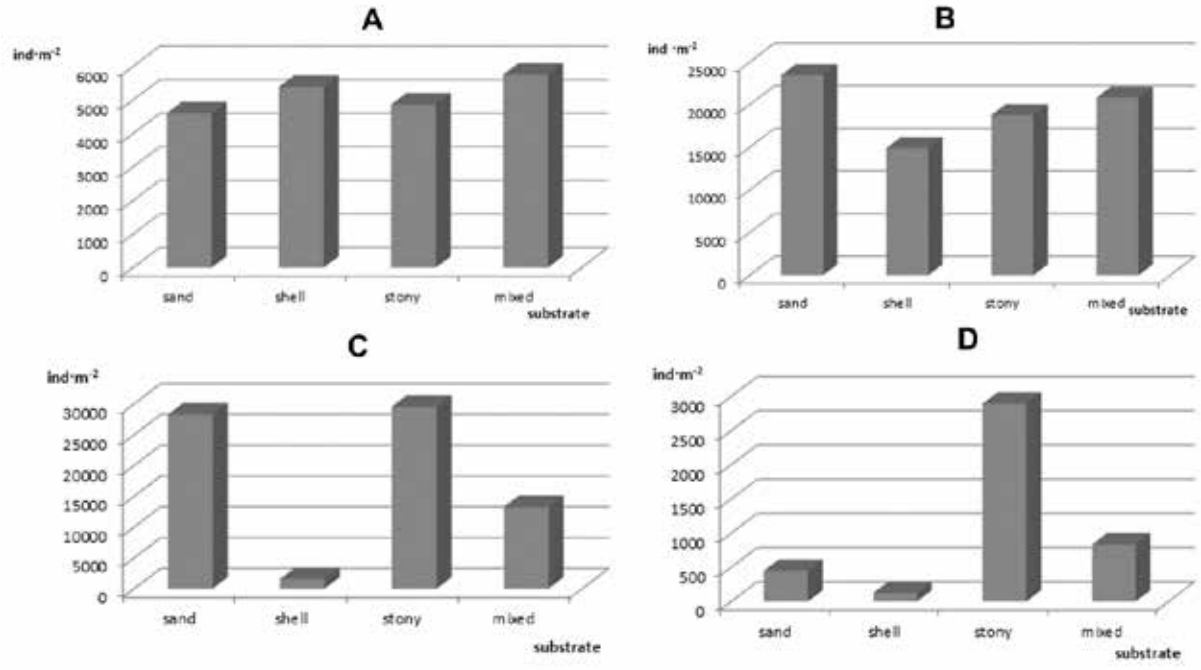

Fig. 7. The abundance of the main taxa of pseudomeiobenthos on different types of substrates. (A – Oligochaeta, B – Polychaeta, C – Bivalvia, D – Gastropoda)

Bay can be interpreted for the coastal zones of the water areas adjacent to it in order to determine the location and size of bottom areas with the best food supply for juvenile fish.

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МЕЙОБЕНТОС РІЗНИХ БІОТОПІВ ВЕРХНЬОЇ СУБЛІТОРАЛІ ОДЕСЬКОЇ ЗАТОКИ

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У статті вперше для шельфу північно-західної частини Чорного моря розглянуті особливості формування загальної чисельності та біомаси постійного (permanent) та тимчасового (temporary) компонентів мейобентосу у верхній субліторалі Одеської затоки (глибина 2,5-11 м). Матеріалом були кількісні проби, відібрані в 2012 р. в прибережній зоні Одеської затоки. За період досліджень на різних субстратах виявлено від 9 до 13 груп мейобентосу: Foraminifera, Nematoda, Harpacticoida, Ostracoda, Halacaridae, Kinorhyncha, Turbellaria, Oligochaeta, larvae and juveniles of Polychaeta, Bivalvia, Gastropoda, Balanus. На піщаному – 9 крупних таксонів, на черепашнику – 12, на кам'янистому субстраті з водоростями – 10 таксонів. Аналіз розподілу окремих мейобентонтів на різних субстратах показав їх суттєві відмінності. На піщаному субстраті домінували нематоди. Велику роль відіграли поліхети та молодь двостулкових молюсків. На черепашнику чисельність мейобентосу змінювалася на різних станціях від 2500 екз. м$^{-2}$ до 269000 екз. м$^{-2}$ (середнє – 143300 екз. м$^{-2}$), основну його частину утворював евмейобентос (72,7 %). У перифітоні скельного субстрату мейобентос складався з 10 великих таксонів, Turbellaria, Kinorhyncha та Gastrotricha були відсутні. Чисельність мейобентосу коливалася від 59 тис. екз. м$^{-2}$ до 341000 екз м $^{-2}$ (середнє – 156107 екз. м $^{-2}$). Частка евмейобентосу в загальній кількості організмів становила 67,4 %. На змішаному субстраті формування загальної чисельності мейобентосу відбувалося переважно за рахунок 6 груп (Nematoda, Harpacticoida, Ostracoda, Oligochaeta, Polychaeta, молодь Bivalvia). Концентрація загального мейобентосу коливалася від 83 тис. екз. м$^{-2}$ до 146500 екз. м$^{-2}$ (середній – 120500 екз. м$^{-2}$). Домінували нематоди, субдомінантна група – гарпактикоіди. У статті розглянуто формування кількісних показників основних груп мейобентосу (Foraminifera, Nematoda, Harpacticoida, Ostracoda, Halacaridae, temporary meiofauna) залежно від типу субстрату. Отримані нами характеристики можна інтерпретувати для прибережних зон акваторій, що прилягають до затоки, з метою визначення розташування та розмірів ділянок дна з найкращим кормом для молоді риб.

Ключові слова: мейофауна, Одеська затока, субліторaль, різноманітні субстрати.