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MEIOFAUNAL BIODIVERSITY IN A MARINE PROTECTED AREA: A CASE STUDY IN THE ROCKY AND SEDIMENTARY SHORES OF THE SNAKE ISLAND (NORTH-WESTERN BLACK SEA)

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Meiofaunal Biodiversity in a Marine Protected Area: a Case Study in the Rocky and Sedimentary Shores of the Snake Island (North-Western Black Sea). Uzun, O. Ye. & Kvach, Y. V. — This study provided a preliminary comparative analysis of meiobenthic assemblages in different habitats of the Snake Island Marine Protected Area (MPA). Meiobenthos was studied in three habitats: Exposed Black Sea upper infralittoral rock with Corallinales turf (MB142), Mytilid dominated exposed Black Sea upper infralittoral rock with foliose algae (no Fucales) (MB143) and Black Sea infralittoral sand and muddy sand without macroalgae (MB542). A total of 10 higher meiobenthos taxa were recorded in the different habitats: 5 permanent groups (Platyhelminthes, Nematoda, Harpacticoida (Copepoda), Ostracoda, Halacaridae) and 5 temporary groups (Oligochaeta, Polychaeta, Bivalvia, Gastropoda, Cyrripedia). The preliminary study of meiobenthos in the habitats of the Snake Island MPA showed that habitat MB143 was more favourable for meiobenthos, with the highest mean density and biomass (190 655 ± 23 004 ind.-m-2 and 3170.90 ± 412.15 mg-m-2, respectively). The comparative nMDS and cluster analyses based on the density of meiobenthos taxa in the Snake Island MPA showed that the meiofauna of both MB142 and MB143 differed significantly from the MB542 habitat, with Bivalvia and Ostracoda making the largest percentage contribution to these differences. The meiobenthos assemblages in the different habitats of the Snake Island MPA were similar to the other regions of the Black Sea with some unique features (e. g. relatively lower total meiobenthos density, high percentage of ostracodes on the algal substrate, etc.). Further studies on the characteristics of meiobenthos taxa assemblages in other Black Sea MPAs could lead to the estimation of meiobenthos assemblage patterns and their possible use in biomonitoring.
Key words: meiobenthos, MPA, benthic habitats, EUNIS.

Introduction

Increasing anthropogenic pressures on marine ecosystems have affected almost all oceans, their biodiversity, resilience and functionality, leading to severe negative impacts in coastal areas, which may be exacerbated by climate-related changes (Cardinale et al., 2012; Gissi et al., 2021; Jouffray et al., 2020). The cumulative effect of these changes is a global threat to benthic marine ecosystems and consequently to their biodiversity.

The North-Western Black Sea (NWBS) is the water area under significant anthropogenic influence. The specificity of the hydrological and hydrochemical brackish water conditions in the Ukrainian part of the NWBS was formed under the influence of four rivers: Dnipro, Southern Bug, Dniester and Danube, whose total inflow is almost 80 % of the total inflow into the sea basin (Zaitsev et al., 2006). Therefore, the region has a high productivity of the shelf ecosystem and became a transition zone from mesotrophic to eutrophic status (Bogatova et al., 1990; Goncharov et al., 2013).

Marine Protected Areas (MPAs), both fully and partially, have been established as a management tool to conserve marine species and habitats and their associated ecosystem functions and services. However, knowledge of seafloor habitats and biodiversity in MPAs is extremely limited (Greathead et al., 2020).

More than 82 % of the total area of MPAs in the Black Sea is located in Ukraine, with the highest percentage in the northwestern shelf area (Alexandrov et al., 2017). One of the MPAs in the NWBS is the nearshore aquatic zone of Snake (Zmiiniy) Island (Alexandrov et al., 2017). The diversity of bottom landscapes near the island provides suitable habitats for numerous sessile and associated epibenthic organisms (Brayko, 1985; Zaitsev, 2015). The first comprehensive studies of aquatic organisms in the Snake Island water area were carried out in 1999 (Zaitsev et al., 1999). The benthic fauna of Snake Island is in better condition than in other parts of the Ukrainian Black Sea shelf, such as the Yahorlyk Gulf and the Karadag region (Alexandrov et al., 2017; Kovalova et al., 2017). For example, the coastal waters of the island are characterized by the presence of a relatively rich fish fauna, which is included in the Red Data Book of Ukraine (Snigirov et al., 2012; Snigirov & Medinets, 2010).

Most ecological monitoring studies of MPA benthos have focused on macrofauna, while knowledge of meiobenthos is extremely limited. Meiobenthos is an ecological group that includes small metazoans (body sizes ranging from 32 to 1000 μm) that play a key role in the functioning and processes of marine ecosystems (Giere, 2009). The response of meiobenthos taxa to different environmental conditions and anthropogenic impacts is used for bioindication and can potentially become a widespread subject of water quality monitoring (Alnashiri et al., 2018; Kulakova, 2023; Magni et al., 2022; Morad et al., 2017; Ürkmez et al., 2014).

In the NWBS, the quantitative characteristics of meiobenthos taxa are well studied (Vorobyova et al., 2008; 2017; Vorobyova & Kulakova, 2009). They can colonize all types of habitats, both natural and artificial substrates, including plastic marine debris (Vorobyova, 1999 a; Snigirova et al., 2020; Snigirova et al. 2022; Uzun & Portianko, 2021). However, recent data on the meiobenthos community in the nearshore waters of Snake Island are fragmentary (Kulakova & Vorobyova, 2019; Portianko, 2017; Vorobyova et al., 2017; 2019; Uzun, 2022). Thus, the aim of this research is a preliminary comparative analysis of meiobenthos taxa assemblages of different habitats in the nearshore marine protected area of Snake Island.

Material and Methods

Research area

The study was conducted in the nearshore waters of Snake Island (45°15'7" N; 30º12'12" E) in the South Harbor (fig. 1). Snake Island, also known as Zmiiniy (in Ukrainian) or Serpent Island, is the only rocky formation (tectonic uplift) in the most extensive Black Sea shelf, located 35 km east of the Danube delta, covering an area of 0.205 km^2 (Zaitsev, 1992).

The part of the Snake Island and its coastal waters were included in the Natural Heritage Site as a zoological reserve of national importance by Decree No. 1341/98 signed by the President of Ukraine on 9.12.1998. The hydrological and hydrochemical regime of the coastal waters of the Snake Island is influenced by all the major rivers of the NWBS, forming a zone of coexistence of fresh and brackish waters (Zaitsev, 1992). During the study the water temperature ranges from 19 to 23 ºC and the salinity from 15 to 22 ‰. The coastline of Snake Island is represented by rocky shores and partly by a sandy bottom.

Sampling and processing meiobenthos

The meiobenthos samples were collected from the bottom by scuba diving at depths between 1 and 5 m during the summers of 2013–2015. Sampling was carried out in three habitat types according to the EUNIS habitat classification (https://www.eea.europa.eu/data-and-maps/data/eunis-habitat-classification-1): Exposed Black Sea upper infralittoral rock with Corallinales turf (MB142), Mytilid dominated exposed Black Sea upper infralittoral rock with foliose algae (no Fucales) (MB143) and Black Sea infralittoral sand and muddy sand

Fig. 1. The map-scheme of the study area near the Snake Island (north-western Ukrainian shelf of the Black Sea).

without macroalgae (MB542). There were recognized 6 types of substrates formed by dominant species in the MB143 habitat. From each habitat and substrate type of MB143 randomly was taken by one replicant sample in 2013 and 2014, and by three replicants in 2015. Two samples of MB143 and one sample of MB142 in 2015 became qualitative after transportation and didn't count in this research. There weas no significant difference between year of sampling (ANOSIM global $R = 0.304$, $p = 0.001$), so for the further faunal analysis among habitats all quantitative samples were included.

The samples were collected using 0.1 m^2 benthos frame by scuba diving separately into the plastic bags and then transported to the Institute of marine biology NAS of Ukraine. In the laboratory each sample was washed through fine-meshed nets (1 mm cell upper net and 70 μm cell lower net). After that they were stained with Rose Bengal and then preserved in 4 % buffered formaldehyde solution (Hulings & Grey, 1971). The samples were splitted on 10 subsamples and one of them was used for the quantitative analysis of meiofauna. The abundance of meiobenthos taxa was counted under light microscope (×32 magnification) in the Bogorov chamber. Then, the abundances were recalculated to density of individuals per square meter ($ind.\cdot m^{-2}$). The biomass was defined using the shape and body sizes of nomograms as $mg\cdot m^{-2}$ (Chislenko, 1968; Vorobyova & Torgonskaya, 1998). The percentage of each meiobenthic taxon to the total density and biomass was estimated.

Data statistical analysis

The data of meiobenthos taxa abundance and biomass were initially logarithm transformed as appropriate *log (x + 1)*, to balance the contributions of common and rare taxa. Hierarchical agglomerative clustering (CLUSTER analysis), with the unweighted pair-group average cluster model, was applied to recognize groups of samples with similar meiobenthic taxonomic composition and density. The similarity profile test (SIMPROF) was applied to determine significant differences between the clusters (Clarke et al., 2008). A non-metric multidimensional scaling (nMDS) was carried out to analyze the differences based on meiobenthos density in collected samples (Clarke et al., 1993). The similarity between the samples was estimated by using the Bray–Curtis similarity. The significance of the differences in meiobenthos among these similarity matrices was tested by the one-way analysis of ANOSIM test. Initially, a global R statistic was calculated to determine whether significant differences exist between all groups. If differences were significant at a global level, then pairwise comparisons between sample groups were conducted to test for differences between pairs. In global tests, the null hypothesis (i.e. 'no difference between groups') was rejected at a significance level of $p < 0.05$. The SIMPER analysis was calculated to estimate the contribution of each meiobenthos taxa (%) to the overall similarity within the substrate types. Multivariate analyses were carried out using PRIMER version 6 software package (Clarke et al., 2014).

Results

Meiobenthic community structure of different habitat types of the Snake Island MPA

Habitat MB142 in the marine protected area of the Snake Island was formed by the articulated coralline species *Corallina officinalis* (Linnaeus, 1758). The average density of total meiobenthos was 112 000 ± 1528 ind.·m^{-2} and average total meiobenthic taxa biomass reaches 2125.22 ± 5.19 mg·m^{-2}. Within meiofauna distinct the "permanent" (eumeiobenthos) and the "temporary" (pseuomeiobenthos) taxa, members of the last belong to meiofaunal size category only as newly settled larvae of macrofauna (Giere, 2009; Vorobyova, 1999 b). There were registered 4 permanent (Nematoda, Harpacticoida (Copepoda), Ostracoda, Halacaridae) and two temporary (Bivalvia, Polychaeta) meiobenthos taxa.

The MB143 habitat, formed by *Mytilus galloprovincialis* with foliose algae in the studied MPA, was more preferable for meiobenthos, the average density (190 655 ± 23 004 ind.·m^{-2}) and biomass (3170.90 ± 412.15 mg·m^{-2}) of which were highest. In the MB143 habitat of the Snake Island MPA were registered a largest number of higher taxa, which include 5 permanent (Platyhelminthes, Nematoda, Harpacticoida (Copepoda), Ostracoda, Halacaridae) and 5 temporary (Oligochaeta, Polychaeta Bivalvia, Gastropoda, Cirripedia) groups of meiobenthos.

In the biotope MB143 were recognized 6 substrates types represented by dominant blue mussel species *Mytilus galloprovincialis* (Lamarck, 1819) with five species of foliose algae: *Ceramium elegans* (Ducluzeau, 1806), *Cladophora vagabunda* (Hoek, 1963), *Ulva intestinalis* (Linnaeus, 1753), *Polysiphonia denudata* (Greville et Harvey, 1833), *Laurencia paniculata* (Kützing, 1849).

On *Cladophora vagabunda* were registered the highest average means of density and biomass of the total meiobenthos, which made up 265 750 ± 50 485 ind.·m^{-2} and 4503.08 ± 887.21 mg·m^{-2} respectively (fig. 2). The lowest average density was on the *Ulva intestinalis* (80 600 ± 41 285 ind.·m^{-2}) and biomass (1315.25 ± 208.11 mg·m^{-2}) was on *Polysiphonia denudata*.

The highest percent contributions in the meiobenthos assemblages on algal substrates were made up mainly by Harpacticoida, Ostracoda and Bivalvia (fig. 3). Percentage of Harpacticoids was biggest on the *Ulva intestinalis* and made 55.58 %. Ostracodes were the abundant group in meiobenthos on the *Laurencia paniculata*, parentage of which was 42.21 %. On *Mytilus galloprovincialis* substrate 74.92 % of meiobenthos assemblage was represented by bivalves.

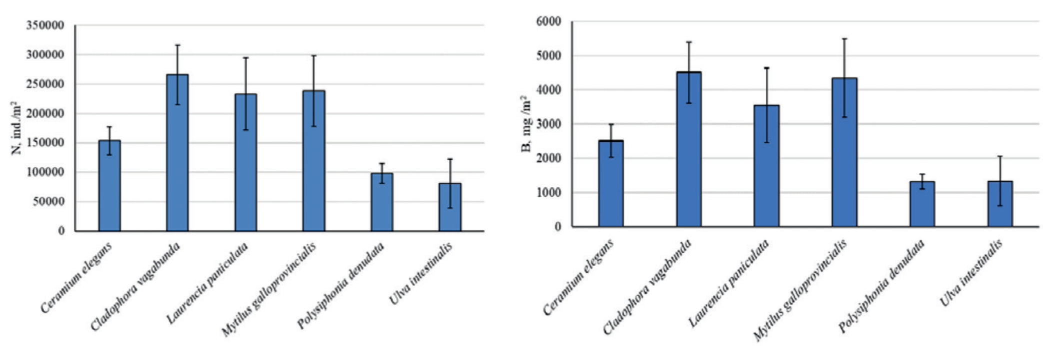

Fig. 2. The average density (N, means ± SE ind.·m^{-2}) and biomass (B, means ± SE mg·m^{-2}) of the total meiobenthos of different substrate types in the MB143 habitat of the Snake Island MPA (Black Sea).

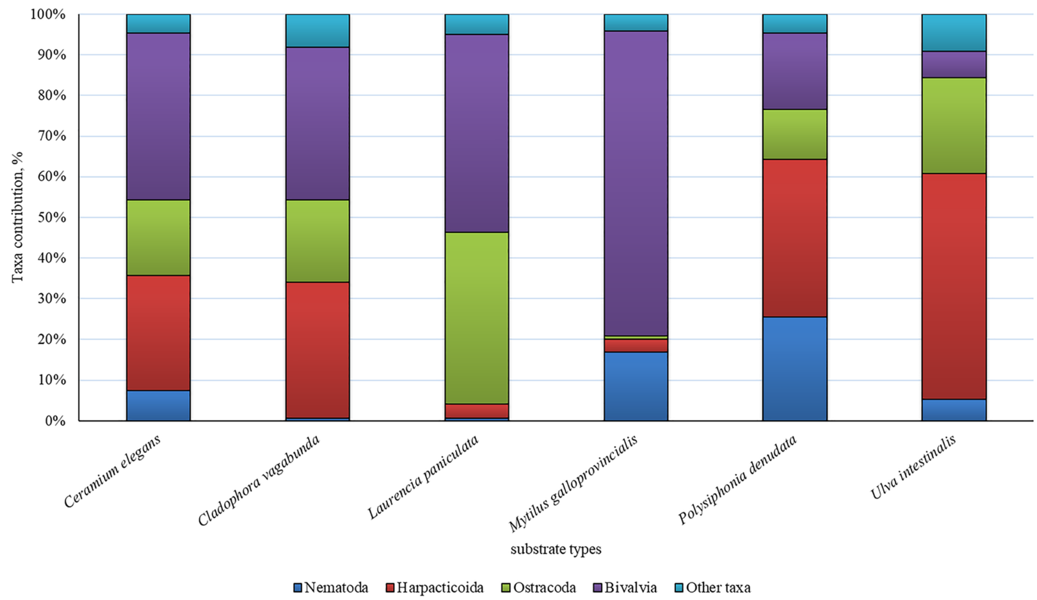

Fig. 3. Meiobenthic community structure of different substrate types in the MB143 habitat of the Snake Island MPA (Black Sea).

Habitat MB542 of the Snake Island MPA was represented mainly by sand with partly fine broken shells. The average density and biomass of meiobenthos in this habitat were low, making up 21 800 ± 675 ind.·m^{-2} and 726.77 ± 168.6 mg·m^{-2} respectively. In this habitat were registered a low number of meiobenthos taxa, including 4 permanent groups (Platyhelminthes, Nematoda, Harpacticoida (Copepoda), Ostracoda). From the temporary meiobenthic taxa in the MB542 habitat only Oligochaeta and Polychaeta were recorded.

In the MB142 habitat permanent meiobenthos taxa were more than 2.5 times abundant (fig. 4). Average density of them was 81 000 ± 1528 ind.·m^{-2} which is 72.32 % of the total. Despite that, 67.44 % of the average biomass index was formed by temporary meiobenthos taxa, which made 1433.33 ± 13.33 mg·m^{-2}.

The biggest means of average density and biomass both permanent and temporary meiobenthos were registered in the MB143 habitat. Almost the equal percent contributions to the average density mean were made by both permanent (52.22 %) and temporary (47.78 %) meiofauna organisms, which made up respectively 99 552 ± 14.849 ind.·m^{-2} and 91 103 ± 18 385 ind.·m^{-2} (fig. 4). The temporary meiobenthos percentage in this habitat were more than twice bigger in the average biomass and made up 67.87 % (2152.14 ± 392.82 mg·m^{-2}).

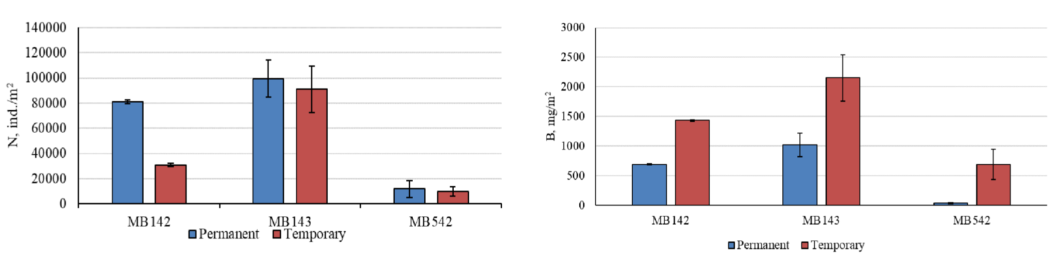

Fig. 4. The average density (N, means ± SE ind.·m^{-2}) and biomass (B, means ± SE mg·m^{-2}) of the total meiobenthos with contribution permanent and temporary taxa in the different habitats of the Snake Island MPA (Black Sea).

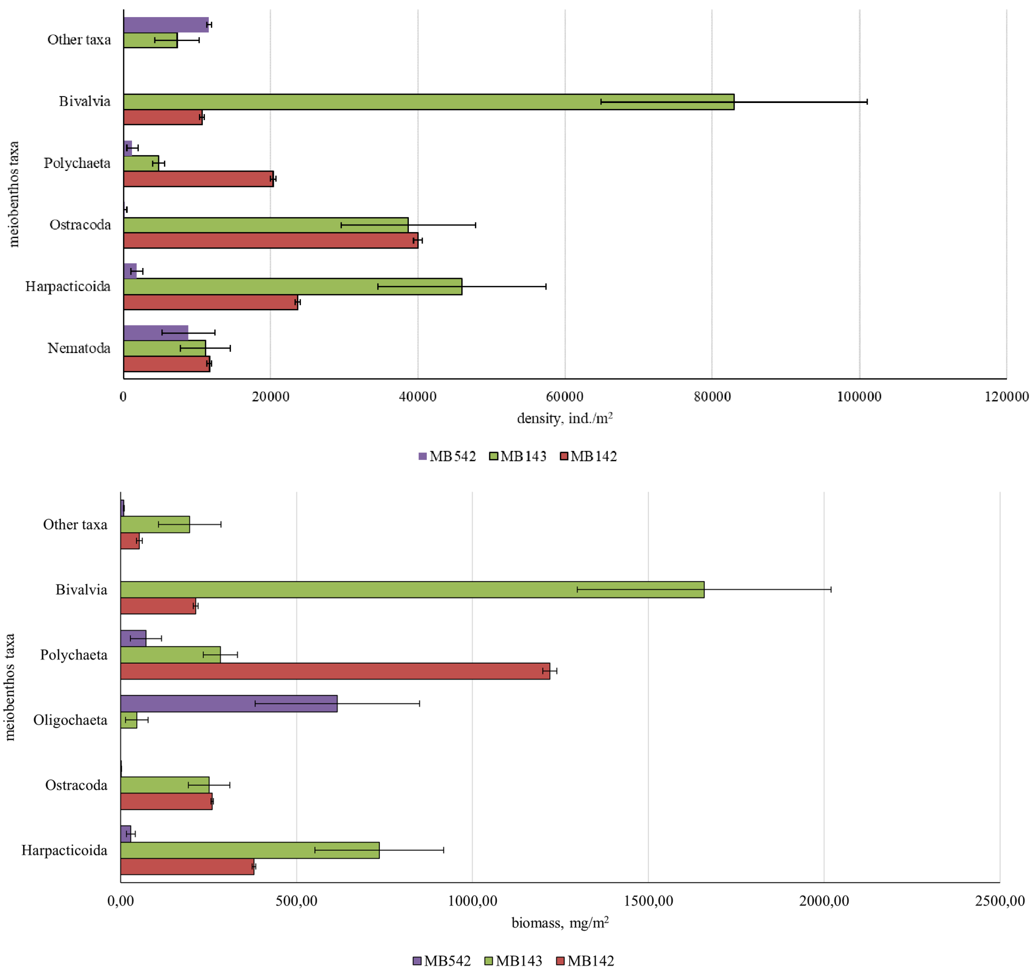

Fig. 5. The average density (N, means ± SE ind.·m^{-2}) and biomass (B, means ± SE mg·m^{-2}) of each meiobenthic taxon in the different habitats of the Snake Island MPA (Black Sea).

In the MB542 habitat average density of the permanent taxa was 11 800 ± 385 ind.·m^{-2}, which made 54.13% of the total meiobenthos (fig. 4). However, temporary meiobenthos taxa significantly prevailed in the formation of the average total biomass, amounting to 94.67 % (688 ± 78.2 mg·m^{-2}).

The Ostracodes had a higher density (40 000 ± 577 ind.·m^{-2}) in the MB142 habitat (fig. 5), that made 35.71 % of the total meiobenthos (fig. 6). Their percentage in the total meiobenthos biomass was 12.23 %, that made up 260 ± 3.75 mg·m^{-2}. The biggest contribution to the biomass of the total meiobenthos was made by Polychaeta (57.41 %), which made up 1220 ± 20 mg·m^{-2}. Among the permanent meiobenthic taxa, the highest average biomass was noted for harpacticoid copepods (378.67 ± 5.33 mg·m^{-2}), the percentage of which made up 17.82 %.

In the MB143 habitat type, significantly prevailed Bivalvia, average density and biomass of which were much larger than on other habitats, and made up 82931 ± 18 050 ind.·m^{-2} and 1658.62 ± 361 mg·m^{-2} respectively (fig. 5). Bivalvia, Harpacticoida and Ostracoda made the largest percent contribution in average density, which were 43.50 %, 24.11 % and 20.29 % respectively, of the total meiobenthos (fig. 6). Percentage of the Bivalvia (52.31 %) and Harpacticoida (23.19 %) were biggest in the average meiobenthos taxa biomass.

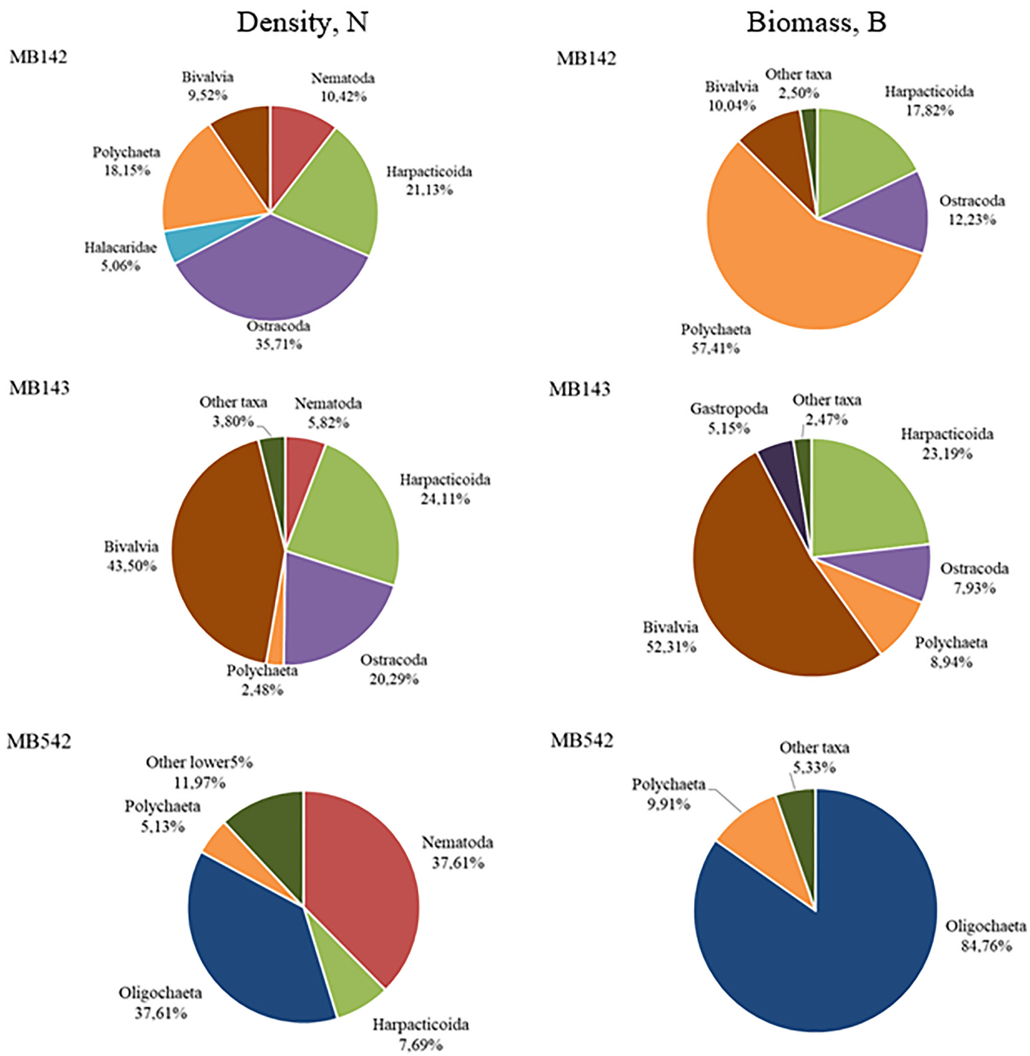

Fig. 6. The contribution (%) of each meiobenthic taxon to the average density and biomass in the different habitats of the Snake Island MPA (Black Sea).

In the MB542 habitat the average densities of Nematoda and Oligochaeta were 8800 ± 3583 ind.·m^{-2} and 8800 ± 295 ind.·m^{-2} respectively (fig. 5), which made the largest equal percent contribution to the total meiobenthos — 37.61 % each (fig. 6). At the same time, the percentage of Oligochaeta in the total meiobenthos biomass reached 84.76 %, which made up 616 ± 233.64 mg·m^{-2}.

Comparative statistical analysis of meiobenthic assemblages in the different habitats of the Snake Island MPA

Hierarchical agglomerative clustering (cluster analysis) by the unweighted pair-group average cluster model and SIMPROF test recognized two significantly different groups of samples (fig. 7). MB143 and MB142 were with similar meiobenthos taxonomic composition and density. Meiobenthos assemblages of the MB542 differed from other habitats covered by algae and mussels and was similar to them on 42.7 %.

The analysis of the meiobenthos assemblages' density by nMDS showed heterogeneity between samples (fig. 8). However, the biggest part of all samples comprising MB142 and

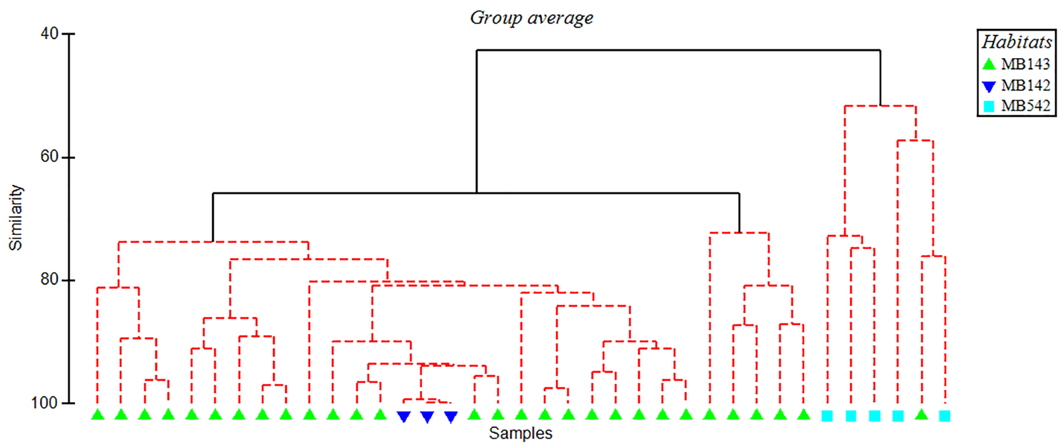

Fig. 7. Cluster analysis dendrogram based on meiobenthos density on the different habitats in MPA of the Snake Island (Black Sea).

MB143 habitats distinct from the meiobenthic assemblages from the MB542 habitat with prevalence of sands. The stress on the plot counts 0.14, which indicates a satisfactory level of the obtained nMDS analysis results.

The results of the ANOSIM pairwise test showed that MB542 habitat significantly highly differed both from MB142 ($R = 0.723$, $p = 0.018$) and MB143 ($R = 0.905$, $p = 0.001$) habitats of the Snake Island MPA. The significant dissimilarity between MB142 and MB143 habitats was absent ($R = 0.256$, $p = 0.093$).

The SIMPER analysis showed that MB142 and MB143 differed from each other by the meiobenthos taxa density only on 20.92 %, that is insignificant (table 1). The largest contribution to the observed differences was made by Halacaridae, with a percentage

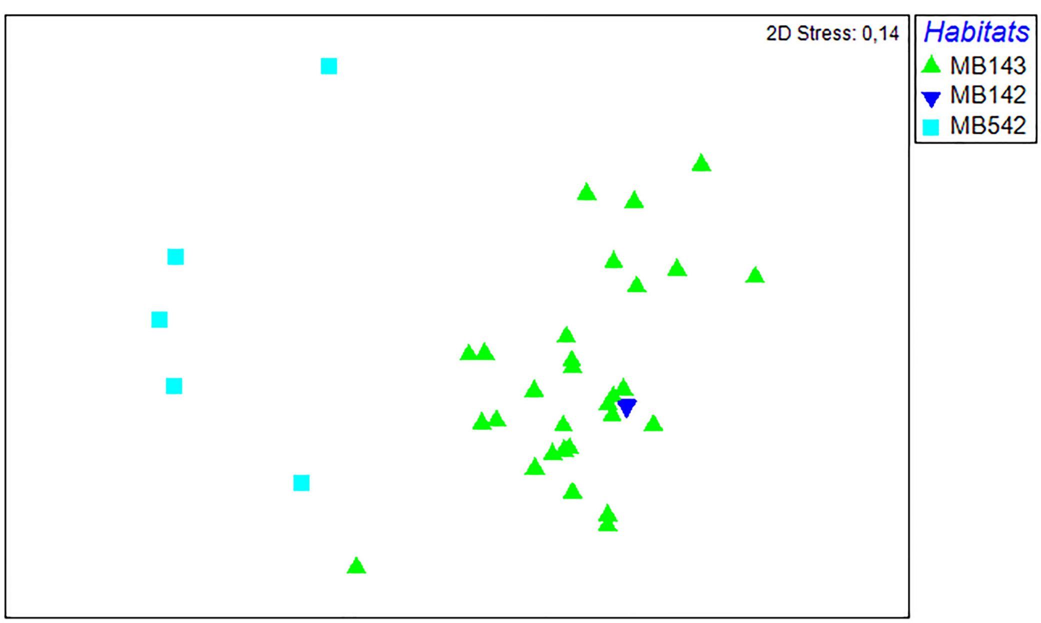

Fig. 8. Plot of the non-metric multidimensional scaling (nMDS) based on the by Bray–Curtis similarity index for logarithmic values of meiobenthos taxa density in the recognized habitats of the Snake Island MPA (Black Sea).

Table 1. The results of SIMPER analysis with meiobenthic taxa contribution (%) to the overall dissimilarity within different habitats of the Snake Island MPA (Black Sea)

Compared habitats					
Groups MB142 & MB143		Groups MB142 & MB542		Groups MB143 & MB542	
Contribution of each taxon					
Halacaridae	25.72	Bivalvia	17.24	Bivalvia	20.50
Nematoda	11.95	Ostracoda	17.11	Ostracoda	16.39
Polychaeta	11.75	Halacaridae	16.01	Oligochaeta	13.46
Gastropoda	10.95	Oligochaeta	13.10	Platyhelminthes	10.93
Ostracoda	8.98	Platyhelminthes	10.73	Harpacticoida	10.75
Bivalvia	8.93	Polychaeta	10.21	Polychaeta	8.35
Harpacticoida	7.44	Harpacticoida	9.85	Nematoda	7.69
Platyhelminthes	6.90			Halacaridae	5.85
Average dissimilarity between habitats					
20.92		61.17		58.58	

of 25.72 %. Nematoda, Polychaeta, Gastropoda, Ostracoda, Bivalvia, Harpacticoida and Platyhelminthes were the most typical taxa, contributing from 6.9 to 11.95 % to the within species dissimilarity.

The significant difference in taxonomic community structure, which was demonstrated by the ANOSIM tests, between MB142 and MB542 habitats is biggest. The average dissimilarity between these habitats made up 61.17 %, with a relative equivalent taxa contribution: Bivalvia, Ostracoda, Halacaridae, Oligochaeta, Platyhelminthes, Polychaeta and Harpacticoida.

The average dissimilarity between meiobenthic assemblages of the MB143 and MB542 habitats was 58.58 %. Percentage of the Bivalvia in these differences was the biggest and made 20.50 %. Also, a contribution more than 10 % to the overall dissimilarity between MB143 and MB542 habitats meiobenthos were made by Ostracoda, Oligochaeta, Platyhelminthes and Harpacticoida.

Discussion

As a result of our preliminary study in the Snake Island MPA, a first comparative analysis of the meiobenthos assemblages in the different habitat types (MB142, MB143 and MB542 according to the EU Habitats Directive classification) was provided. Previous studies of the meiobenthos in the near rocky-shore waters of Snake Island focused on the main meiobenthos taxa with the detailed comparison of density and biomass formed on the different algal substrates and on certain taxonomic groups (Kulakova & Vorobyova, 2019; Portianko, 2017; Vorobyova et al., 2019; Uzun, 2022). The higher density and biomass of the total meiobenthos taxa were registered in the MB142 and MB143 habitats of the Snake Island MPA, while the lowest values of these indices were observed in the MB542 habitat. It is evident that the complex structure of the epibenthos, covered by hard substrates, provides greater protection for meiobenthos, which increase species diversity and densities, determining the often-exceeded abundance in the surrounding sediments (Coull, 1999; Hull, 1997; Rutledge & Fleeger, 1993). The series of experiments also showed that substrate complexity is an important factor in reducing fish predation on meiofauna (Coull & Wells, 1983).

However, the meiobenthic fauna in the different habitats of the Snake Island MPA shows some peculiarities. The biomass and density of the total meiobenthos of the studied region are lower compared to these indices of meiobenthic taxa recorded on the hard substrates in the other water areas of the NWBS. For example, in the Gulf of Odessa, in the shallow waters on the natural hard substrates covered by mytilids with foliose algae, more diverse and abundant assemblages of meiobenthos were formed, dominated by Nematoda, Harpacticoida (Copepoda), Bivalvia and Polychaeta (Vorobyova et al., 2020; Vorobyova, 2022) than in the MB142 and MB143 habitats of the Snake Island MPA. The density of meiofauna recorded in the MB542 habitat of the Snake Island MPA is lower than in the Danube foreland, where harpacticoid copepods are more abundant (Vorobyova et al., 2012). On the sedimentary substrate of the shallow areas along the Romanian Black Sea coast, the meiobenthos density was higher (Filimon & Abaza, 2015) than in the MB542 habitat of the Snake Island MPA.

The Snake Island waters are under the strong influence of the Danube riverine flow, which is considered to be the main source of nutrients in the western Black Sea coastal region and is highly affected by hazardous organic pollutants (Gasparotti, 2014; 2015). It contributes about 65–80 % of the nutrient load to this region (Zessner et al., 2005). Meiobenthos organisms can rework sediment particles and contribute to the mineralisation of organic matter and nutrient regeneration (Coull, 1999; Schratzberger & Ingels, 2018). Meiobenthic organisms, especially nematodes, play an important role in the turnover of much of the energy produced as consumers of benthic diatoms and bacteria (Palacín et al., 1992). The meiofauna has an intermediate trophic position and high secondary production, while their community structure is strongly dependent on the presence of organic matter, which reflects the variation and quality of the food source (Giere, 2009; Van der Heijden et al., 2018; Magni et al., 2022). Thus, higher densities of meiofaunal taxa have been observed in the regions with the most intense eutrophication processes, which decrease with time (Palacín et al., 1992; Murrell & Fleeger, 1989;). The similar observation was also reported from the marine area with limited anthropogenic stress of the southwestern Black Sea near Iğneada (Turkey), where the quantitative means of meiobenthos taxa were lower compared to the central part of the Turkish Black Sea coast (Ürkmez et al., 2016 a; b).

In addition, meiofauna are a food source for fish (gobiides, blenniides, anchovies, grey mullets, etc.) and for macrofauna (Carpentier et al., 2014; Magni et al., 2022; Schückel et al., 2013; Vorobyova et al., 2004). The low pressure of fishing, hydrotechnical construction and shore protection activities in the Snake Island MPA could lead to a good ecological condition of benthic communities, e.g., in the ichthyofauna of Snake Island (Alexandrov et al., 2017; Kovalova et al., 2017; Snigirov & Medinets, 2010). In this aquatic zone, high abundance and species diversity of fish were recorded, with the prevalence of gobiides among other NWBS regions (Khutornoi, 2001; 2004). Thus, the lower density of meiobenthos taxa could be explained as a result of their consumption by both benthivorous and planktivorous fishes (Magni at al., 2022).

Permanent and temporary taxa contributed almost equally to the total meiobenthos density in habitats MB143 and MB542, whereas permanent meiofauna taxa were more than twice as abundant in habitat MB142. The density of the temporary meiofauna component depends on a variety of environmental factors as well as on the ontogenetic life stages of these organisms. The biomass indices of the total meiobenthos in all habitats studied were dominated by temporary meiobenthos taxa. This is explained by the larger body size and correspondingly higher mass of temporary meiofauna organisms (Vorobyova & Kulakova, 2009).

A high proportion of ostracodes (up to 42.21 % on *Laurencia paniculata* substrates) of the total meiobenthos was found in the MB143 habitat of the Snake Island MPA compared to other NWBS nearshore areas (Vorobyova et al., 2016). Algal structural complexity is associated with higher abundance, species richness and diversity of ostracodes (Hull, 1997; Yousef, 2013; Uzun, 2022). Moreover, ostracodes could be used as sensitives for ecological monitoring of environmental pollutants (Alves, 2013; Parameswari, 2020). Thus, the high density and biomass of ostracodes could indicate their preference for the MB452 habitat and favourable ecological conditions for them in the observed water body.

Comparative nMDS and cluster analyses based on the density of meiobenthos taxa in the Snake Island MPA showed that the meiofauna of both MB142 and MB143 differed from that of MB542 habitats (within a certain degree of heterogeneity of meiobenthic assemblages), the dissimilarities of which were significantly confirmed by the ANOSIM pairwise test. This pattern has been documented in many studies comparing meiobenthos associated with soft sediments and hard substrates of the NWBS (Bondarenko & Vorobyova, 2023; Vorobyova, 1999 b; Vorobyova et al., 2017; 2019). Macrobenthic organisms provide a variety of habitats for many species with different lifestyles, suggesting their important role in structuring the associated assemblages in MPAs (Sbrocca et al., 2021).

The results of the SIMPER analysis showed that the differences between MB542 and other habitats were mainly caused by the densities of bivalves and ostracods, which are mainly found in MB142 and MB143 of the Snake Island MPA. The same contribution of meiobenthic taxa is reflected in other comparative studies where it has been shown that soft bottom meiofauna is dominated by nematodes, whereas hard bottom assemblages are generally dominated by crustaceans (copepods, isopods, nauplii and amphipods) and bivalve larvae (Beckley, 1982; Coull et al., 1983; Danovaro, 2002).

Thus, the meiobenthic assemblages in the different habitats of the Snake Island MPA were similar to the other regions of the Black Sea with some unique features (e. g. relatively lower total meiobenthos density, high percentage of ostracodes on the algal substrate, etc.). All investigations confirm the unique environmental conditions of Snake Island, and new research is needed focusing on species composition and comparative analysis of other NWBS marine regions with different levels of anthropogenic pressure. Further studies on the characteristics of meiobenthos taxa in other MPAs could lead to the estimation of patterns of meiobenthos formation and for their possible use in biomonitoring.

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