Turk. J. Fish.& Aquat. Sci. 23(9), TRJFAS22222
https://doi.org/10.4194/TRJFAS22222

Turkish Journal of FISHERIES and AQUATIC SCIENCES

RESEARCH PAPER

Influence the North-western Part of the Black Sea Habitat Factors on the Meiobenthic Polychaetes

Olena Bondarenko[1,*], Ludmyla Vorobyova[1]

[1] Institute of Marine Biology of the NAS of Ukraine, Pushkinska St. 37, Odessa, 65048 Ukraine.

How to Cite

Bondarenko, O., Vorobyova, L. (2023). Influence the North-western Part of the Black Sea Habitat Factors on the Meiobenthic Polychaetes. *Turkish Journal of Fisheries and Aquatic Sciences*, *23(9)*, *TRJFAS22222.* https://doi.org/10.4194/TRJFAS22222

Article History
Received 15 July 2022
Accepted 01 March 2023
First Online 06 March 2023

Corresponding Author
Tel.: +380487378280
E-mail: olena.bondarenko@gmail.com

Keywords
Meiobenthos
Temporary meiofauna
Polychaetes
Habitat factors

Abstract

In pseudomeiobenthos, juveniles of 28 polychaetes species were recorded, of which *Alitta succinea* (Leuckart, 1847), *Polydora cornuta* Bosc, 1802, and *Prionospio cirrifera* Wiren, 1883 dominated in density. Based on the results of analysis of variance (ANOVA), a significant dependence of the variability of the α-diversity of juveniles of polychaetes on the type of substrate and the temperature of the bottom water layer was established. It is shown that the local diversity of polychaetes juveniles is the highest on the shell (here we refer to the type of substrate) and decreases with increasing degree of substrate silting. With an increase in the temperature of the near-bottom water layer, the α-diversity of juveniles of polychaetes increases, which is associated with the timing of reproduction of most polychaetes species. A close positive correlation was found between the densities of juveniles and adults of *P. cornuta*. This confirms the important role of the presence of *P. cornuta* settlements in the macrozoobenthos in the selectivity of their locations by pelagic larvae during transition to the bottom. It has been established that in the study area, the active transition of pelagic larvae of polychaetes to the bottom occurs at a depth of up to 40 m.

Introduction

The study of population regulation processes is one of the priority tasks for hydrobiologists. It is known that the meiobenthic community of organisms includes both permanent (or eumeiobenthos) and temporary (or pseudoobenthos) components, each of which is characterized by its own set of the taxa (Bourgis, 1950; Hidings & Gray, 1971). Meiobenthic polychaetes are an integral part of the temporal component of the meiobenthos. In addition, the temporary component includes oligochaetes, turbellarians, molluscs, and others. All of them are good food for young fish (Vorobyova, 1999; Vorobyova *et al.*, 2019) At present, most researchers from various countries are studying representatives of the permanent component of the meiobenthos. There is practically no information on polychaetes larvae in the benthos (Vorobyova, 2021). This is also typical for the study of the meiofauna of the Black Sea and, in particular, for its North-Western Part of the Black Sea (NWBS).

Juveniles of polychaetes spend a rather short period in the meiobenthos, however, at this time they actively participate in the life of this community. The long-term and seasonal dynamics of the total abundance of polychaetes, their confinement to the type of substrate and in various biocenoses has been shown (Vorobyova, 1999; Vorobyova & Sinegub, 2014; Vorobyova, 2021). This allows us to obtain general ideas about the dynamics of their quantitative characteristics,

Published by Central Fisheries Research Institute (SUMAE) Trabzon, Türkiye

but does not provide any information about the species structure. Recently, for the NWBS a number of works have been carried out to study the species composition of polychaetes from permanent meiobenthos, quantitative indicators were given, their distribution has been analyzed depending on the main abiotic factors (Vorobyova *et al.*, 2008; Vorobyova & Bondarenko, 2009; Bondarenko 2009, 2010). This paper presents the results of long-term studies of this group of animals in the NWBS.

Polychaetes in the eumeiobenthos are represented by a small number of species. In total, about 250 species of eumeiobenthic polychaetes belonging to 25 families are known in all the world's oceans (Giere, 2009). Despite the low species diversity, the density of eumeiobenthic polychaetes can reach very high values. According to literature data, about 20 species of eumeiobenthos polychaetes are known from the Black Sea, belonging to 10 families: Dinophilidae, Nerillidae, Parergodrilidae, Polygordiidae, Protodrilidae, Saccocirridae, Hesionidae, Syllidae, Pisionidae, Sabellidae (Vinogradov, 1949, Marinov, 1977, Kiseleva, 2004, Şahin & Çınar, 2012 etc.).

The replenishment of the population with juveniles and the growth of its numbers largely depend on the successful settling of larvae and their development in the benthos. For a long time it was considered that the metamorphosis of larvae takes place in the water column, after which they massively sink to the bottom and often to an unsuitable substrate, where their mass death takes place. Later it became known that the larvae do not metamorphize and sink to the bottom, but actively search for a suitable type of substrate. The processes of transport of larvae to settlement sites and the factors affecting their settling remain poorly understood (Pineda, 2000). It is known that the settling of larvae of a number of species is stimulated by the settlement of adults of their own or closely related species and the presence of a bacterial film (Kiseleva, 1967; Beckmann *et al.*, 1999; Huang & Hadfield, 2003; Sebesvari *et al.*, 2006). Settling of larvae and their further metamorphosis are one of the key and critical stages in the process of population replenishment, and settled juveniles are one of the most vulnerable age categories (Qiu & Qian, 1998). Mortality of settled larvae is commensurate with that of the pelagic stage of development and reaches 90% of the number of individuals that migrated to the bottom (Gosselin & Qian, 1997). The purpose of this work is to study the role of habitat factors in the formation of the meiobenthic polychaetes on the northwestern shelf of the Black Sea in the modern period.

Material and Methods

The work is based on the materials of expeditionary studies of 2003-2005, 2007, 2010 in the NWBS. Sampling was carried out according to the scheme of stations (Figure 1) using a Petersen grab (opening area 0.1 m^2). At each station, depending on the type of substrate, from the monolith brought by the bottom grab, 2–3 parallel quantitative samples were taken with a sampler with an area of 10×10 cm. The samples were washed through a system of benthic sieves. To capture the meiobenthos, a nylon mill sieve with a mesh size of 90 µm was placed next to the lower sieve. Samples were fixed with 4% formalin and simultaneously stained with Rose Bengal dye. To

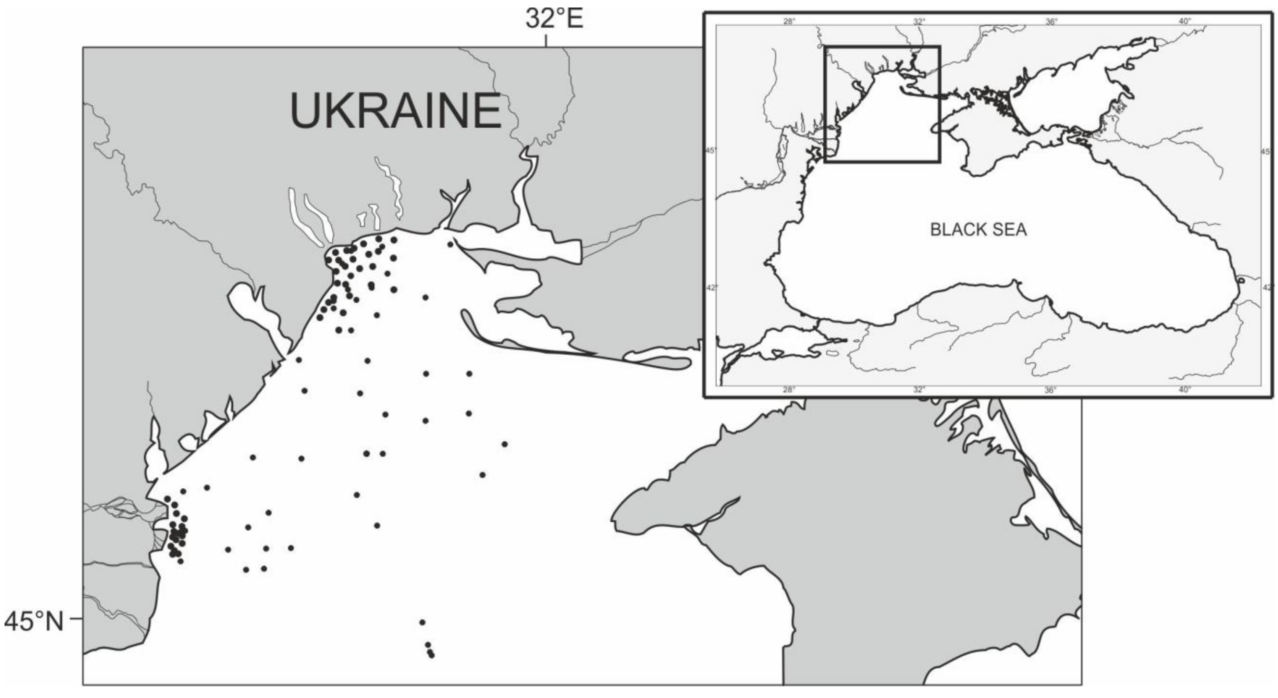

Figure 1. Scheme of meiobenthos sampling stations in the the North-Western Part of the Black Sea.

establish the significance of salinity, sediment type, temperature of the bottom water layer in the variability of the number of species and the abundance of juveniles of polychaetes, multivariate analysis of variance (ANOVA) was used. The role of each of these factors was evaluated with the exclusion of the influence of other analyzed indicators. To assess the degree of relationship between the density of juveniles of some polychaetes species that passed into the benthal and the population density of their adults, the Pearson correlation coefficient was calculated. Given the aggregate nature of the distribution, the analysis of the number of juveniles of polychaetes as a function of depth was performed on the basis of geometric means.

Result and Discussion

Traditionally, the main attention in the study of meiobenthos is paid to eumeiobenthos, which plays the most significant role in the formation of the total abundance. However, pseudomeiobenthos can often play a dominant role in the total biomass, also accounting for a significant part of meiobenthos production. In the NWBS, the biomass of the temporal component can reach 37–57.7%, the production of 35–84.5% (Vorobyova, 1999; Vorobyova & Bondarenko, 2007). A number of species of macrozoobenthos polychaetes surpass mollusks and some crustaceans in their calorific value (Kiseleva, 2004). Meiobenthic polychaetes also play a significant role in the formation of the food base for juveniles of the fish.

In the juveniles of polychaetes of the NWBS (except for bays), on various types of substrates juveniles of 28 species of polychaetes from 12 families were recorded during the study period: Phyllodocidae (5 species), Nephtyidae (1), Glyceridae (1), Polynoidae (2), Sigalionidae (1), Nereidae (5), Spionidae (7), Capitellidae (2), Terebellidae (1), Ampharetidae (1) Pectinaridae (1) and Serpulidae (1) (Table 1).

The species composition and distribution of the abundance of polychaetes are closely dependent on several environmental factors. Juveniles Polychaeta worms differ in ecological characteristics from adults of their own species. This determines the need to study this age category separately from representatives of macrozoobenthos. Using dispersion analysis, an assessment was made from the influence of the type of bottom sediments, salinity and temperature of the bottom water layer on the formation of α-diversity and the density of juveniles of polychaetes in the NWBS.

The results of the analysis of variance showed that among the studied factors, the variability of the local diversity of juveniles of polychaetes, settled and developing on the bottom, is statistically significantly affected by the type of substrate and the temperature of the near-bottom water layer (Table 2). The influence

Table 1. List of the Polychaeta species found in the North-Western Part of the Black Sea on various types of substrate

Family	Species	Substrate				
		Shell	Shell/sand	Shell/silt	Sand/silt	Silt
Phyllodocidae	*Genetyllis tuberculata* (Bobretzky, 1868)			+		
Phyllodocidae	*Phyllodoce mucosa* Öersted, 1843			+		
Phyllodocidae	*Eulalia viridis* (Linnaeus, 1767)				+	
Phyllodocidae	*Eumida sanguinea* (Örsted, 1843)				+	
Phyllodocidae	*Mysta picta* (Quatrefagues, 1865)		+			+
Nephtyidae	*Nephtys hombergii* Savigny in Lamarck, 1818			+	+	+
Glyceridae	*Glycera tridactyla* Schmarda, 1861			+	+	
Polynoidae	*Harmothoe imbricata* (Linnaeus, 1767)	+				
Polynoidae	*Harmothoe reticulata* (Claparède, 1870)	+	+	+	+	+
Sigalionidae	*Pholoe inornata* Johnston, 1839		+	+		
Nereidae	*Nereis zonata* Malmgren, 1867	+				
Nereidae	*Alitta succinea* (Leuckart, 1847)	+	+	+	+	+
Nereidae	*Hediste diversicolor* (O. F. Müller, 1776)				+	
Nereidae	*Perinereis cultrifera* (Grube, 1840)	+				
Nereidae	*Platynereis dumerilii* (Audouin et M.-Edwards, 1834)	+				
Spionidae	*Scolelepis (Parascolelepis) tridentata* (Southern, 1914)		+			
Spionidae	*Aonides paucibranchiata* Southern, 1914			+		
Spionidae	*Spio filicornis* (Müller, 1776)		+			
Spionidae	*Pygospio elegans* Claparède, 1863		+			
Spionidae	*Dipolydora quadrilobata* (Jacobi, 1883)			+		+
Spionidae	*Polydora cornuta* Bosc, 1802	+	+	+	+	+
Spionidae	*Prionospio cirrifera* Wiren, 1883	+	+	+	+	+
Capitellidae	*Capitella capitata* (Fabricius, 1780)	+	+	+	+	+
Capitellidae	*Heteromastus filiformis* (Claparède, 1864)	+	+	+	+	+
Terebellidae	*Amphitritides gracilis* (Grube, 1860)			+		
Ampharetidae	*Melinna palmata* Grube, 1870			+	+	+
Pectinariidae	*Lagis koreni Malmgren, 1866*				+	
Serpulidae	*Spirobranchus triqueter* (Linnaeus, 1767)	+				

of salinity on the available material has not been reliably established.

Substrate type is one of the main abiotic factors influencing the formation of species composition of juveniles of polychaetes (Kiseleva, 1967a, Kiseleva, 1967b). It is known that when settling from the water column, the larvae of many species are able to actively choose the substrate that is optimally suited for their metamorphosis (Kiseleva, 1967a, Kiseleva, 1967b). In case of its absence, they can prolong the planktonic phase for some time (Pineda, 2000). At the same time, the larvae of some species do not show selectivity to the substrate upon transition to the benthal. Under experimental conditions, the larvae of *Nereis zonata* Malmgren, 1867 and *Platynereis dumerilii* (Audouin et M.-Edwards, 1834) even used a surface water film as a substrate (Kiseleva, 1967a). The larvae of *Polydora ciliata* (Johnston, 1838) choose the type of soil for settling according to the particle size. They can use them as building material for the primary living tube. In the absence of the necessary substrate, they are able to delay metamorphosis. (Kiseleva, 1967b). Consequently, the role of the edaphic factor in the formation of the species composition of polychaetes is manifested both in the selectivity of species to its quality and in their further elimination after settling on unsuitable substrates.

The largest number of juveniles of polychaetes species in the sample in the NWBS were recorded on a shell and a shell with the sand, and the smallest number, on silty sand and silt. Accordingly, the number of species decreased with an increase in the degree of silting of the substrate (Figure 2).

On the silted sand, juveniles of only two species, *A. succinea* and *P. cornuta*, were most often found (64.5 and 61.3%, respectively). On silts, the highest occurrence rates were in juveniles of *P. cirrifera* (51.6%) and *Heteromastus filiformis* (Claparède, 1864) (52.7%), as well as in *A. succinea* (48.4%) and *P. cornuta* (43.0%). Juveniles of these species were often found (in more than 50% of collected samples) on all other types of substrate. On the shell with sand, juveniles of *Capitella capitata* (Fabricius, 1780) and *Spio filicornis* (Müller, 1776) were recorded with the same frequency.

Thus, with an increase in the degree of silting of the substrate, the local diversity of juveniles of polychaetes decreased. The largest number of species in the sample was characterized by shell and shell with sand, the smallest – by silty sand and silt. On a shell and shell with the sand, juveniles of *A. succinea*, *P. cornuta*, *P. cirrifera, H. filiformis, C. capitata* and *S. filicornis* were most often found. On silty shell *A. succinea, P. cornuta P. cirrifera* and *H. filiformis* were most often found. On silty sand were most often found *A. succinea* and *P. cornuta*. Juveniles of species with law densities for the NWBS, such as *Genetyllis tuberculata* (Bobretzky, 1868), Eulalia viridis (Linnaeus, 1767), *Eumida sanguinea* (Örsted, 1843), *Glycera tridactyla* Schmarda, 1861, as a rule, were noted in the typical habitats for adults of their species.

The influence of the temperature factor on the local diversity of juveniles of polychaetes is expressed in a slight but significant increase in the number of species: the number of species increases from 2.6±0.2 species at a temperature of 4.6–8.0°C to 4.1±0.3 at 20.1–24°C. The noted change in α-diversity is explained by an increase

Table 2. Results of ANOVA variability of α-diversity and abundance (ind./m^2) of juveniles of polychaetes in the North-Western Part of the Black Sea

Parameter	α-Diversity		Abundance	
	F	*P*	*F*	*P*
Salinity	3.18	0.0761	0.20	0.6567
Temperature	15.87	0.0001	0.57	0.4506
Substrate type	9.08	<0.0001	1.27	0.2837

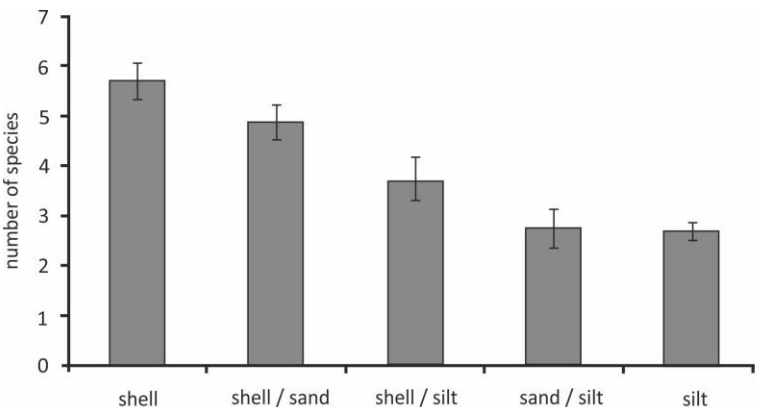

Figure 2. Number of juveniles of polychaetes species in a sample on different substrates in the North-Western Part of the Black Sea.

in the total number of species and an increase in their occurrence rates with an increase in the temperature of the bottom water layer. As a rule, the larvae of most species of Polychaeta develop in plankton during the spring-summer and summer-autumn periods (Kiseleva, 2004).

In the NWBS at low temperatures (4.6–8.0°C), juveniles of *P. cirrifera* (57.6%), *A. succinea* and *H. filiformis* (44.1% each) were most meet in samples. The rest of the species were extremely rare. The occurrence of juveniles of specimens of *P. cirrifera* and *H. filiformis* at different temperatures of the bottom water layer changed a little (41.3–70.9% and 41.2–62.1%, respectively). They were not directly dependent on this factor. The occurrence of juveniles of *A. succinea* and *P. cornuta* were characterized by the most pronounced positive dependence on the temperature regime.The maximum rates of their occurrence (93.1% and 96.9%) were registered at a temperature of 20.1–24°C. Juveniles of representatives of the Phyllodocidae family, rarely found in the NWBS, were noted at a temperature of the bottom water layer of more than 8.0°C, *H. imbricata* – in the range of 7.0–12.0°C. Juvenile specimens of *Dipolydora quadrilobata* (Jacobi, 1883), which recently spread in the waters of the NWBS (Todorova & Panayotova, 2006; Begun *et al.*, 2010; Băncilă *et al.*, 2022), were noted at a temperature of 5.0–10.0°C.

The influence of the temperature factor on juveniles of polychaetes worms is manifested in an increase in their diversity with an increase in temperature. First of all, this is due to the timing of reproduction and settling of larvae of many species from the water column to the bottom.

If the variability of the local diversity of polychaetes is statistically significantly affected by temperature and the type of substrate, then no dependence of the variability of their total abundance on the analyzed environmental factors was found on this material (see Table 2). This can also be explained by the fact that the total abundance of juveniles of polychaetes in the NWBS was formed mainly by juvenile individuals of *Alitta succinea* (Leuckart, 1847), *Prionospio cirrifera* Wirén, 1883, and *Polydora cornuta* Bosc, 1802, eurybiont species living in a wide range of fluctuations of the studied factors. They characterized by high fecundity and have planktonotrophic pelagic larvae. Favorable conditions develop for their development in the NWBS, and their transition to the bottom and the formation of abundance there is controlled by factors that are not taken into account in this study.

A study of the spatial distribution of juveniles of the dominant polychaetes species relative to their adult forms was carried out by us on the example of the Odessa Sea Region in December 2005. This is the period of active transition of larvae from the pelagic zone to the benthic zone and this analysis was carried out for *P. cornuta*, *P. cirrifera*, *C. capitata* and *M. palmata*.

The results of the correlation analysis show a positive linear relationship between the density of *P. cornuta* juveniles and the density of its adults. The correlation coefficient for these variables was r=0.84 at P<0.05 (Table 3). Thus, it can be said with a high degree of probability that the larvae of *P. cornuta* select the settling sites under natural conditions. They most actively colonize areas of the bottom that are inhabited by adults of their own species. Similar conclusions for *P. cornuta* were obtained under laboratory conditions when studying the factors affecting the settling of its larvae (Sebesvari, 2007). For the Black Sea species of this genus *P. ciliata*, it was also found in a series of laboratory experiments that one of the factors contributing to the settling of its larvae in the benthal is the presence of individuals of its own species (Kiseleva, 1967).

Adults of *P. cirrifera* prefer shell and silted shell, but its juveniles were found at all substrate types and depths studied. The correlation coefficient of the numbers of juveniles and adults of this spionid was r=0.41 at P=<0.05, which indicates the absence of a close relationship between these indicators. It follows from this that the presence or absence of adults of *P. cirrifera* does not have any effect on the settling of its larvae. Nevertheless, the largest numbers of juveniles of this species were noted on the shell and in the places of settlement of the adult forms. Thus, we assume that the larvae of *P. cirrifera*, settling on all types of substrate available to them, successfully pass the stage of metamorphosis only on the substrates typical for the habitation of its adults.

The correlation coefficient between the numbers of adults of *C. capitata* and its juveniles was only r=0.29 at P>0.05, which indicates the absence of a relationship between them. It is known that the larvae of this species actively choose the substrate for settling. Twenty times more of them settle on a natural substrate rich in organic matter than on an artificial one (Butman, Grassle & Webb, 1988).

A close linear relationship between juveniles and adults was recorded in another species, *M. palmata*, which is dominant in the NWBS. The correlation coefficient of indicators of their number was r=0.87, with P<0.05. This connection is explained by the

Table 3. Results of correlation analysis between the abundances of adults and juveniles of the some polychaete species in the North-western Part of the Black Sea

Species	*Pearson's r*	*P*
P. cornuta	0.84	<0.0001
P. cirrifera	0.41	0.0406
C. capitata	0.29	0.1576
M. palmata	0.87	<0.0001

peculiarities of the biology of this species. Its lecitrophic larvae have a short period of development in the pelagic zone (Guillou, 1983).

We have analyzed the nature of changes in the quantitative parameters of juveniles of polychaetes depending on the depth. It does not directly affect the distribution of bottom animals, but is an integral factor that reflects changes in temperature, salinity, type of substrate, and a number of other biotic factors (Galtsova, 1991). The distribution of quantitative indicators of the dominant juveniles of polychaetes species (*A. succinea, P. cornuta* and *P. cirrifera*) at different depths of the Ukrainian shelf was analyzed (Figure 3). Juveniles of *A. succinea* were present at all studied depths. Their greatest abundance was typical for depths of 5–10 and 11–15 m, which coincides with the distribution of adults of this species. The maximum density of *A. succinea* juveniles was recorded at a depth of 11–15 m and amounted to 9,600 ind./m^2. With the growth of the values of this factor, its quantitative indicators decreased (Figure 3). It is known that in the Black Sea, adults of *A. succinea*, as a rule, live in the coastal zone (Kiseleva, 2004). During the period of intense eutrophication, they spread to a depth of 35–40 m. Probably, the ability of the larvae to settle at these depths contributed to the rapid development of bottom areas that were freed up after the degradation of the *Melinna palmata* Grube, 1870 biocenosis (Losovskaya & Sinegub, 2002; Vorobyova *et al.*, 2017).

Juveniles of *P. cornuta*, like the juveniles of the species mentione above, were found at all studied depths, but they were most numerous in the range of 5–10 m, 11–15 m and 16–20 m (Figure 3). In these ranges, the maximum density was registered, which amounted to 49,017 ind./m^2.

Juveniles of *P. cirrifera* were recorded at depths greater than 5 m. The highest numbers of juveniles of *P. cirrifera* were recorded at 11–15 m. This characteristic remained high with increasing depth (see Figure 3). In the entire range of depths, accumulations of their juveniles were noted, the density of which exceeded several tens of thousands of specimens per 1 m^2. Thus, at a depth of 5–10 m and 11–15 m, the maximum abundance of this species was 40,841 ind./m^2; at 11–15 m, 62,160 ind./m^2; 21–30 m – 71,977 ind./m^2, at a depth of 31–40 m – 20,000 ind./m^2. It is known that *P. cirrifera* in the Black Sea is distributed to a depth of 110 m (Kiseleva, 2004).

Conclusion

Analysis of the material collected in the NWBS during five years made it possible to determine the species composition of the meiobenthos polychaetes and some of their ecological characteristics. In the pseudomeiobenthos of the NWBS (except for bays), juveniles of 28 species of polychaetes from 12 families were recorded during the study period: Phyllodocidae (5 species), Nephtyidae (1), Glyceridae (1), Polynoidae (2), Sigalionidae (1), Nereidae (5), Spionidae (7), Capitellidae (2), Terebellidae (1), Ampharetidae (1) Pectinaridae (1) and Serpulidae. Among the 28 species of juveniles of polychaetes, of which *A. succinea*, *P. cornuta* and *P. cirrifera* dominated in density during the study period.

The results (ANOVA) showed that the variability of their local diversity is statistically significantly affected by the type of substrate and the temperature of the bottom water layer. Under the conditions of the NWBS, a close positive correlation was established between the

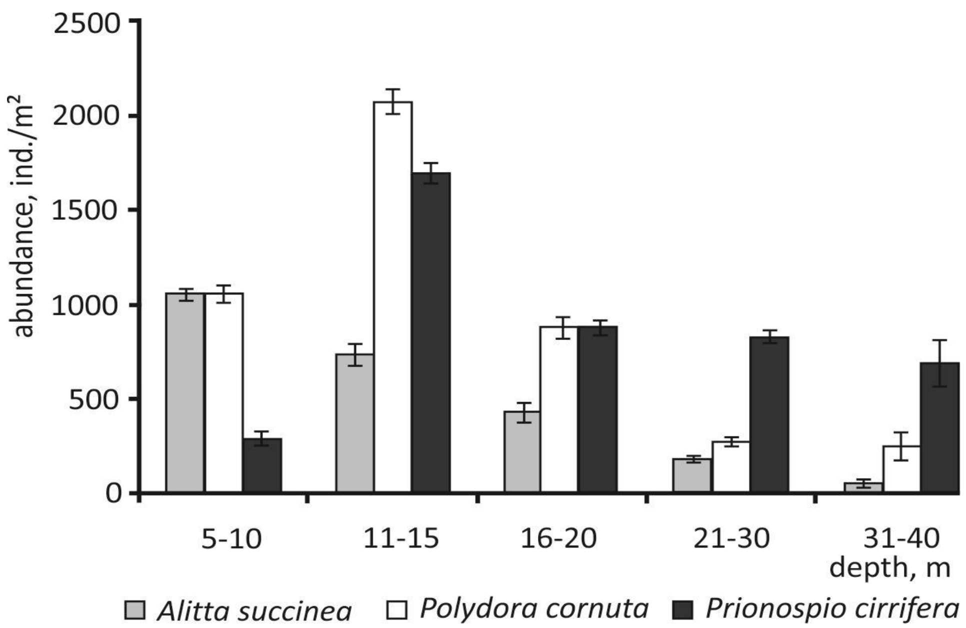

Figure 3. Abundance (ind./m^2) of the dominant species of juveniles of polychaetes at various depths in the North-Western Part of the Black Sea.

density of adult *P. cornuta* in the macrozoobenthos and the density of their juveniles. Juveniles of *P. cornuta* actively choose the habitats of adults of their species for migration to the benthos. The transition of juvenile *P. cirrifera* from the pelagial to the benthic zone is most likely not associated with the settlements of their adults. Relationship between juveniles and adults of *C. capitata* was not found. The high correlation between juveniles and adults of *M. palmata* is explained by the peculiarities of its biology.

In the NWBS, the active transition of pelagic larvae of the dominant polychaetes species to the benthic zone occurs at a depth of up to 40 m. The highest numbers of juveniles of *A. succinea* were recorded at a depth of at 5 m to 15 m, *P. cornuta* – at 5 m to 20 m, *P. cirrifera* – at 15 m to 40 m. Pelagic larvae of the dominant polychaetes species in the NWBS are active at depths of up to 40 m. During our studies, juveniles of polychaetes were present in the range of depths that are typical for adults of their species.

Ethical Statement

The study of meiobenthic polychaetes is part of the scientific theme of the Institute of Marine Biology of the National Academy of Sciences of Ukraine, approved by the Scientific Council of the Institute.

Funding Information

The study of meiobenthic polychaetes and expeditionary sampling in the north-western part of the Black Sea were carried out according to the planned research topics “Fundamental regularities of the formation of biological diversity and bioresource potential of contour biotopes of ecosystems of the Azov-Black Sea basin”, which were funded from the budget of the Institute, approved by the National Academy of Sciences of Ukraine.

Author Contribution

Both authors made an equal contribution to the article “Influence the North-Western Part of the Black Sea Habitat Factors on the Meiobenthic Polychaetes”.

Conflict of Interest

Both authors declare that they have no known competing financial or non-financial, professional or personal conflicts that could arise and affect the results reported in this article.

Acknowledgements

We would like to thank our colleague Ivan Synegub for the high-quality sampling during the expeditions and for the professional approach to sample processing in the laboratory of the Institute of marine biology of the NAS of Ukraine.

References

Băncilă, R.I., Skolka, M., & Zenetos, A. (2022). Alien species of the Romanian and Bulgarian Black Sea coast: state of knowledge, uncertainties, and needs for future research. *Aquatic Invasions*, 17(3), 353–373, https://doi.org/10.3391/ai.2022.17.3.02

Beckmann, M., Harder, T., & Qian, Y. (1999). Induction of larval attachment and metamorphosis in the serpulid polychaete *Hydroides elegans* by dissolved free amino acids: mode of action in laboratory bioassays. *Marine Ecology Progress Series*, 190, 167–178. https://doi.org/10.3354/meps190167

Begun, T., Teaca, A., & Gomoiu, M.-T. (2010). State of macrobenthos within Modiolus phaseolinus biocoenosis from Romanian Black Sea continental shelf. *Geo-Eco-Marina*, 16, 5-18. https://doi.org/10.5281/zenodo.56945

Bondarenko, O.S. (2009). Species composition and features of polychaete distribution in the western Black Sea. *Ekologiya Morya*, 78, 22-27 (in Russian).

Bondarenko, O.S. (2010). Description the state of worms of the Odesa marine region is in a modern period. *Scientific Issue Ternopil Volodymyr Hnatiuk National Pedagogical University. Series: Biology*, 3(44), 22–25 (in Ukrainian).

Bourgis, B. (1950). Methode pour l'etude quantitative de la microfaune de fonde marine (meiobenthos). *Vie Milieu*, 1(1), 23-38.

Butman, C., Grassle, J. & Webb, C. (1988). Substrate choices made by marine larvae settling in still water and in a flume flow. Nature 333, 771–773. https://doi.org/10.1038/333771a0

Galtsova, V.V. (1991). Meiobenthos of marine ecosystems on the example of free-living nematodes. Proceedings of the Zoological Institute of the Academy of Sciences of the USSR. 224, 236 p. (In Russian).

Giere, O. (2009). *Meiobenthology: the microscopic motile fauna of aquatic sediments*. Berlin Heidelberg, Springer-Verlag.

Gosselin, L.A., & Qian, P.-Y. (1997). Juvenile mortality in benthic marine invertebrates. *Marine Ecology Progress Series*, 146, 265–282. https://doi.org/10.3354/meps146265

Guillou, M. (1983). Dynamics and Biological Cycle of a Melinna palmata (Ampharetidae) Population During the Recolonisation of a Dredged Area in the Vicinity of the Harbour of Brest (France). *Marine Biology*, 73, 43–50, https://doi.org/10.1007/BF00396284

Hidings, N., & Gray, J. (1971). *A manual for the study of meiofauna* (Smithsonian Contributions to Zoology. 78). Smithsonian Institution Press. https://doi.org/10.5479/si.00810282.78

Huang, S., & Hadfield, V.J. (2003). Composition and density of bacterial biofilms determine larval settlement of the polychaete *Hydroides elegans*. *Marine Ecology Progress Series*, 260, 161–172. https://doi.org/10.3354/meps260161

Kiseleva, G.A. (1967a). Influence of substrate on settling and metamorphosis of larvae of benthic animals. *Bottom biocenoses and biology of benthic organisms of the Black Sea*, 71–84 (in Russian).

Kiseleva, G.A. (1967b). Settling of larvae of *Polydora ciliata* (Jonston) on various substrates. *Bottom biocenoses and biology of benthic organisms of the Black Sea*, 85–90 (in Russian).

Kiseleva, M.I. (2004). *Polychaetes (Polychaeta) of the Asov and Black Sea*. Kola Science Centre, Murmansk Marine Biological Institute (In Russian).

Losovskaya, G.V., & Sinegub, I.A. (2002). Detrivorous polychaetes in the ecosystem from the Odessa region of the Black Sea. *Ekologiya Morya*, 62, 5-9 (in Russian).

Marinov, T. (1977). *Polychaete worms. Fauna of Bulgaria*. Sofia, Publishing house Bolgaria, AS (In Bulgaria).

Pineda, J. (2000). Linking larval settlement to larval transport: assumptions, potentials and pitfalls. *Oceanography of the Eastern Pacific*, I, 84–105.

Qiu, J.-W., & Qian, P.-Y. (1998). Combined effects of salinity and temperature on juvenile survival, growth and maturation in the polychaete *Hydroides elegans*. *Marine Ecology Progress Series*, 168, 127–134. https://doi.org/10.3354/meps168127

Şahin, G.K. & Çınar M.E. (2012). A check-list of polychaete species (Annelida: Polychaeta) from the Black Sea. *Journal of the Black Sea/Mediterranean Environment,* 18(1), 10-48.

Sebesvari, Z. (2007). Sediment-associated cues for larval settlement of *Polydora cornuta* and *Streblospio benedicti* (Polychaeta, Spionidae). Dissertation, Institute of Chemistry and Biology of the Marine Environment, Oldenburg

Sebesvari, Z., Esser, F. & Harder, T. (2006). Sediment-associated cues for larval settlement of the inbenthic spionid polychaetes *Polydora cornuta* and *Streblospio benedicti*. *Journal of Experimental Marine Biology and Ecology*, 337(1), 109–120. https://doi.org/10.1016/j.jembe.2006.06.007

Todorova, V., & Panayotova, M. (2006). Alien aquatic fauna from the Bulgarian Black Sea and coastal lakes – an inventory of introductions and impacts. NEOBIOTA. From Ecology to Conservation, in: 4th European Conference on Biological Invasions, Vienna (Austria), 27–29 September 2006. Book of Abstracts, 251–252.

Vorobyova L.V., & Bondarenko A.S. (2007). Polychaetes as a component of meiobenthos. Collection of scientific papers. *Environmental safety coastal and shelf zones*, 15, 473-481 (In Russian).

Vorobyova, L.V. & Bondarenko, O.S. (2009). Meiobenthic bristle worms (Polychaeta) of the western Black Sea shelf. *Journal of the Black Sea/Mediterranean Environment*, 15(2/3), 109–121.

Vorobyova, L.V. & Sinegub, I.A. (2014). Zoobenthos of biocenoses of the Odessa Sea Region of the Black Sea. *Optimization and Protection of Ecosystems*, 11, 198–206 (In Russian).

Vorobyova, L.V. (1999). *Meiobenthos of the Ukrainian shelf of the Black andAzov seas*. Kiev, Naukova dumka (in Russian).

Vorobyova, L.V. (2021). The role of environmental factors in the formation of temporary meiofauna of the Odessa sea region of the Bkack Sea. *Scientific Issue Ternopil Volodymyr Hnatiuk National Pedagogical University Series Biology,* 81(1-2), 39-45, https://doi.org/10.25128/2078-2357.21.1-2.5

Vorobyova, L.V., Bondarenko, O.S. & Izaak, O.S. (2008). Meiobenthos polychaetes in the northwestern Black Sea. *Oceanological and Hydrobiological Studies*, 37(1), 43–55. https://doi.org/10.2478/v10009-007-0039-9

Vorobyova, L.V., Kulakova, I.I. & Olephir, I.V. (2017). *Odessa Region of the Black Sea: hydrobiology of pelagic and benthic zones*. Odessa, Astroptint (in Rusian).

Vorobyova, L.V., Kulakova, I.I., Bondarenko, O.S. & Portyanko, V.V. (2019). *The Black Sea Interaction Zones: meiobenthos of litho-contour in theNorthwestern shelf*. Odesa, Fenix (in Rusian)