Vestnik zoologii, **51**(5): 407–412, 2017
DOI 10.1515/vzoo-2017-0048

UDC 595.3(262.5)

HARPACTICOIDA (CRUSTACEA, COPEPODA) OF MUSSEL BEDS AND MACROALGAE ON THE ROCKY SUBSTRATES IN THE NORTH-WESTERN BLACK SEA

V. V. Portianko

Institute of marine biology of NAS of Ukraine,
vul. Pushkinska, 37, Odesa, 65011 Ukraine
E-mail: portianko_valentyn@ukr.net

Harpacticoida (Crustacea, Copepoda) of Mussel Beds and Macroalgae on the Rocky Substrates in the North-Western Black Sea. Portianko, V. V. — The role of harpacticoid copepods in total abundance, biomass and species diversity of meiobenthos on rocky substrates is described. The fauna of harpacticoid copepods consists of 19 species in algal beds, 23 species in mussel beds and 24 species in mixed aggregation of molluscs and macrophytes. In the macrophyte aggregation, the maximal abundance was registered in *Cladophora vagabunda* — 88 750 ind. × m^{-2}, while minimal was on *Laurensia paniculata* — 8250 ind. × m^{-2}. According to the frequency of occurrence, the habitat preferred by copepods was *Ceramium elegans*, but according to their percentage in total meiobenthos among macrophytes it was *Ulva intestinalis*, 56.6 %. The percentage of copepods in the pure mussel beds was higher comparing to mixed aggregation of molluscs and macrophytes.
Key words: Black Sea, sessile benthos, meiobenthos, Harpacticoida, rocky substrates

Introduction

Harpacticoid copepods are a group of benthic crustaceans, which can inhabit rocky substrate, feeding on bacterial/microalgae film (Azovsky et al., 2005; De Troch et al., 2005). The near-shore rocks form an appropriate substrate for numerous sessile organisms and epibionts attached to them, also for species associated with them, such as harpacticoid copepods (Brayko, 1985; Zaitsev, 2015).

The harpacticoid copepods in overgrowth of some macrophyte species in the eastern Black Sea were studied by Makaveeva (1979) and Kolesnikova (1991). In the north-western Black Sea, the harpacticoid copepods on several types of phytal substrate were studied by Garlitskaya (2010). The data about the harpacticoid copepods in epibenthos of rocky substrates is absent. The aim of our study was to describe the species composition of harpacticoid copepods and evaluate their contribution to total meiobenthos abundance and biomass in sessile benthos assemblage on rocky substrates in the north-western Black Sea.

Material and methods

The Zmiiniy Island is a large rocky massive in shallow zone of the north-western Black Sea, about 35 km distanced from the Danube delta (Zaitsev et al., 2006). Since 1998, the island and the coastal waters around it are included to the Natural heritage site, with 2.32 km^2 of total area. The salinity and hydrology of the island coastal waters are strongly dependent on the Danube flow and mixing with the open sea waters (Ivanov, Gorshovsky, 1999). The flow of the other rivers, such as the Dnister and the Dnipro, also influence the hydrological and hydrochemical regime of the island (Zaitsev et al., 2006).

Another water body with rocky substrates in the north-western Black Sea is the Gulf of Odesa (Zaitsev, 2006). This is a shallow gulf with average depth 8 m, and salinity from 15.2 ‰ in summer till 15.6 ‰ in winter (Garkavaya et al., 2000). The hydrological regime of the gulf is strongly dependent on the flows of the rivers Dnipro and Southern Bug.

The sessile benthos was scrapped from 0.01 m[2] square of rocks' surface on two different sites: the Zmiiniy Island (45°15′18″ N, 30°12′15″ E) and the Gulf of Odesa (46°31′32″ N, 30°45′16″ E) in summer 2014 and 2015 (table 1). Samples were taken of the sections of the benthic frame with a 10 × 10 area of openings trimmed with mesh net 70 μm. The live samples were filtered in succession through a system of benthic sieves with 1 mm (upper sieve) and 5 mm (bottom sieve) and 70 μm mesh size between them. After that, samples were fixed in 4 % formalin. Later, the samples were transported to the laboratory of the Institute of marine biology of NASU for the further study.

In the laboratory, the samples were stained with Rose Bengal. The meiobenthic organisms were calculated and collected in Bogorov camera under dissecting microscope (×32). The collected organisms were moved to 90 % ethanol for further storage. For the species identification the copepods were dehydrated in glycerol-alcohol solution (Hulings, Gray, 1971), then identified under the light microscope at ×200–400 magnification (Griga, 1969; Wells, 1976; Apostolov, 1988). Life forms were taken from the literature (Hicks et Coull, 1983; Chertoprud et al., 2006).

Results

The communities of sessile epibenthos in the studied regions are presented mainly by algal beds, mixes of molluscs and algae, and dense mussel settlements. We distinguished three types of epibenthic aggregations:

1) macrophytes aggregation: formed by beds of macroalgae *Ceramium elegans* (Ducluzeau, 1806), *Cladophora vagabunda* (Hoek, 1963), *Corallina officinalis* (Linnaeus, 1758), *Laurencia paniculata* (Kützing, 1849), *Polysiphonia denudata* (Greville et Harvey, 1833), *Ulva intestinalis* (Linnaeus, 1753);

2) molluscs/macrophytes aggregation (MMA): mixed assemblage of molluscs and macroalgae;

3) pure mussel beds (MP).

Algae aggregation

The species composition of harpacticoid copepods was comprised by 19 species, including one Ameiridae, four Miraciidae, two Dactylopusiidae, three Ectinosomatidae, two Harpacticidae, five Laophontidae, one Tisbidae and one Parastenheliidae (table 2). Ten species from the list are epibenthic inhabitants (*D. elisabethae, H. compsonyx, H. obscurus, H. curvata curvata, H. curvata microthros, H. stroemii stroemii, H. uncinata, P. spinosa spinosa, P. leuke, R. monardi*), three are phytal species (*D. tisboides, P. brevicornis, T. bulbisetosa*), three are unspecified interstitial species (*A. parvula parvula, A. cinctus, A. cinctus*), and three species are silt-dwelling (*E. melaniceps, H. herdmani, P. minor*). Four copepod species, namely *E. melaniceps*, *H. obscurus*, *T. bulbisetosa*, and *P. brevicornis*, occurred in more than 50 % types of algal aggregations and had high frequency. The maximal number of copepod species occurred in *C. vagabunda* (10 species), less in *U. intestinalis* (9 sp.), *C. elegans* (8 sp.), *C. officinalis* (4 sp.), *L. paniculata* (4 sp.), and the minimal number in *P. denudata* (3 sp.).

The average copepod abundance on phytal substrate was maximal comparing to all other groups of meiobenthos, except of *L. paniculata* (fig. 1). The maximal number of copepods occurred in *C. vagabunda* beds (8 8750 ind. × m^{-2}), and on all other types of algal aggregations this parameter was twice lesser.

The maximal percentage of harpacticoid copepods in total meiobenthos was maximal in *U. intestinalis* and minimal in *L. paniculata* (fig. 2).

Table 1. Number of samples collected in different sites

Year	Site	
	Zmiiniy Island	Gulf of Odesa
2014	5, mussel	8, mussel
2014	6, macroalgae	5, macroalgae
2014	4, mussel / macroalgae	4, mussel / macroalgae
2015	6, mHussel	9, mussel
2015	4, macroalgae	7, macroalgae
2015	5, mussel / macroalgae	4, mussel / macroalgae

MP cv. MMA

In total, 32 copepod species, including Ameiridae (2 species), Miraciidae (7 sp.), Canuellidae (1 sp.), Dactylopusiidae (3 sp.), Ectinosomatidae (1 sp.), Cletodidae (1 sp.), Harpacticidae (4 sp.), Laophontidae (6 sp.), Longipediidae (1 sp.), Normanellidae (2 sp.), Thalestridae (2 sp.), and Tisbi-

Table 2. Species composition and frequency (F, %) of harpacticoid copepods on different species of macrophytes

Species	Life form	*C. elegans*	*Cl. vagabunda*	*U. intestinalis*	*C. officinalis*	*P. denudata*	*L. paniculata*
Ameira parvula parvula (Claus, 1866)	not_int	100	75	–	–	–	–
Amphiascopsis cinctus (Claus,1866)	not_int	–	–	40	–	–	–
Amphiascus cinctus (Claus, 1866)	not_int	–	–	–	–	–	40
Dactylopusia tisboides (Claus, 1863)	phyt	100	–	–	–	75	–
Delavalia elisabethae (Por, 1959)	epiben	–	–	–	–	50	–
Ectinosoma melaniceps (Boeck, 1865)	silt_dw	100	60	40	–	–	50
Harpacticus compsonyx (Monard, 1926)	epiben	–	–	–	75	–	–
Harpacticus obscurus (Scott T., 1895)	epiben	100	100	60	100	80	–
Halectinosoma herdmani (Scott T. & A., 1896)	silt_dw	–	60	40	–	–	–
Heterolaophonte curvata curvata (Douwe, 1929)	epiben	70	–	–	–	–	–
Heterolaophonte curvata microthros (Marcus & Por, 1960)	epiben	–	–	–	25	–	–
Heterolaophonte stroemii stroemii (Baird, 1837)	epiben	–	60	25	–	–	–
Heterolaophonte uncinata (Czerniavski, 1868)	epiben	–	60	40	–	–	–
Paradactylopodia brevicornis (Claus, 1866)	phyt	80	75	40	–	–	–
Parastenhelia spinosa spinosa (Fischer, 1860)	epiben	70	–	–	–	–	100
Pseudobradya minor (Scott T. & A., 1895)	silt_dw	–	25	–	–	–	–
Robertsonia monardi (Klie, 1937)	epiben	–	–	25	–	–	–
Pontophonte leuke (Por, 1959)	epiben	–	25	–	–	–	–
Tisbe bulbisetosa (Volkmann-Rocco, 1972)	phyt	100	100	40	75	–	75

Note (here and then). not-int — unspecific interstitioal species, phyt — phytal, epiben — epibenthic, silt_dw — silt-dwelling.

dae (2 sp.), were recorded on the pure mussel beds, MP, and mixed molluscs/macrophytes aggregation, MMA (table 3). These two different aggregations were almost identical by the number of copepod species: 23 on MP and 24 on MMA. Fourteen species were common for both types of aggregations. Seven species were recorded only on PM, while 9 were only on MMA. The listed harpacticoid copepods are related to four life forms: 1) unspecific interstitial — 6 species (*A. parvula parvula, A. cinctus*, *B. imus*, *A. longirostris*, *A. subdebilis*, *A. cinctus*), 2) phytal — 8 species (*A. similis*, *D. tisboides*, *P. brevicornis*, *P. latipes*, *T. longimana*, *T. bulbisetosa*, *T. marmorata T. furcata*,), 3) silt-dwelling — 1 species (*E. melaniceps*), 4) epibenthic — 17 species (*A. longicornis*, *A. sarmatica*, *C. perplexa*, *D. elisabethae, E. sordidum*, *H. flexulosus*, *H. flexus*, *H. obscurus, H. littoralis*, *H. stroemii stroemii*, *H. uncinata*, *L. elongata elongata*, *L. thoracica*, *L. minor*, *N. serrata*, *P. harpactoides*, *P. leuke*).

The percentage of harpacticoid copepods on MP comprised from 1.7 % (3000 ind. × m^{-2}) to 92.3 % (48.000 ind. × m^{-2}) of total meiobenthos abundance and from 1.3 % (48 mg × m^{-2}) to 90.6 % (768 mg × m ^{2}) of its biomass. The maximal number and biomass were

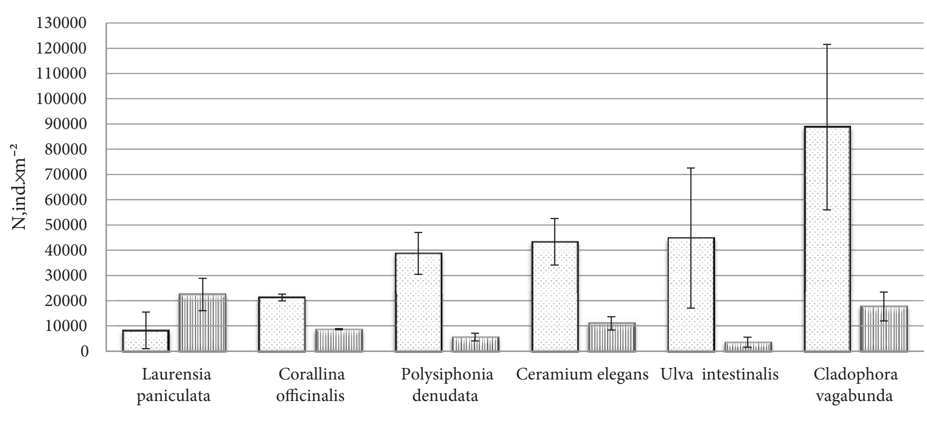

Fig. 1. Average number of harpactocoid copepods and the other meiobenthos per m^2 on different species of macrophyts.

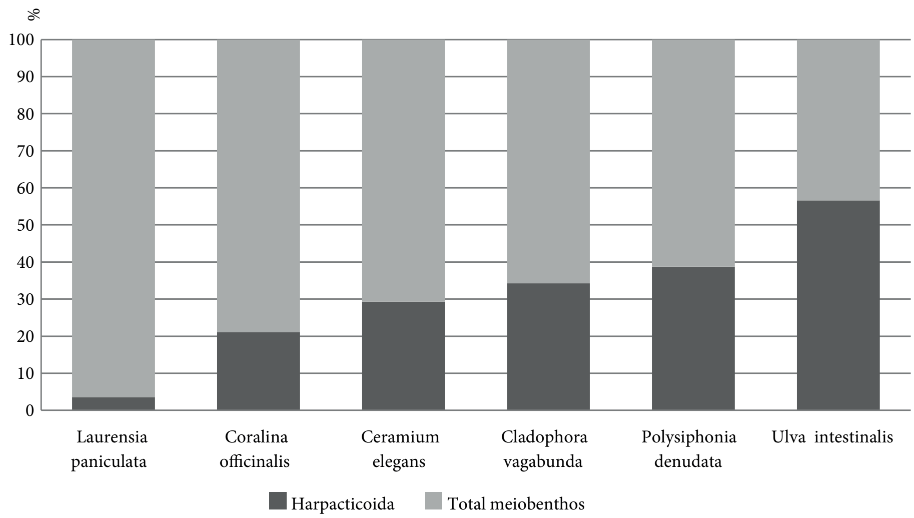

Fig. 2. Percentage of harpactocoid copepods in total meiobenthos community on different species of macrophyts.

173 500 ind.× m^{-2} and 2776 mg × m^{-2}, correspondently, but minimals were 1000 ind. × m^{-2} and 16 mg × m^{-2}, correspondently.

The number of copepods in MMA also varied. Their percentage was from 1 % (1000 ind. × m^{-2}) to 62.3 % (10 5000 ind. × m^{-2}) of total meiobenthos abundance and from 0.6 % (16 mg × m^{-2}) to 46.2 % (688 mg × m^{-2}) of its biomass. The maximal harpacticoid copepod abundance was 156 500 ind. × m^{-2}, but their maximal biomass was 2504 mg × m^{-2}. The corresponding minimal parameters were 1000 ind. × m^{-2} (abundance) and 16 mg × m^{-2} (biomass). The maximal average abundance of copepods, 55 400 ind. × m^{-2}, is typical for MP (fig. 3). On the substrate of MMA it was a little bit lower, 44 471 ind. × m^{-2}. The percentage of copepods in total meiobenthos abundance is rather similar in MP (30.9 %) and MMA (26 %).

Discussion

According to the published data (Makkaveeva, 1979; Kolesnikova, 1991; Garlitskaya, 2010), the phytal substrates in the Black Sea can be inhabited by two sub-communities

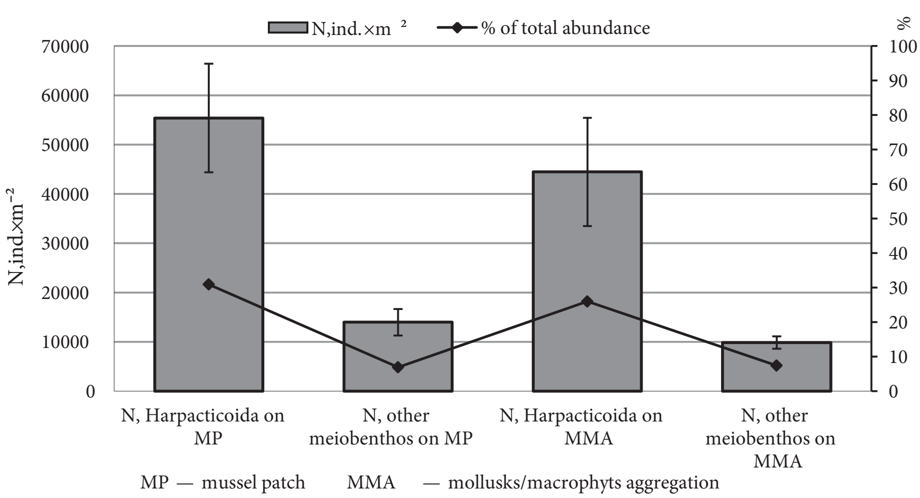

Fig. 3. Average number of harpactocoid copepods per m^2 and their percentage in total meiobenthos community.

Table 3. Species composition and frequency (F, %) of harpacticoid copepods in sessile epibenthos of two different types

Species	Life form	F, %		Type of fouling	
		MP	MMA	MP	MMA
Ameira parvula parvula (Claus, 1866)	not_int	100	85	+	+
Ameiropsis longicornis (Sars, 1907)	epiben	–	5	+	–
Amonardia similis (Claus, 1866)	phyt	–	10	+	–
Amphiascopsis cinctus (Claus,1866)	not_int	20	15	+	+
Amphiascus cinctus (Claus, 1866)	not_int	–	10	+	–
Amphiascus longirostris ((Claus, 1863) Huys 2010)	not_int	10	–	+	+
Amphiascoides subdebilis (Willey, 1935)	not_int	–	5	+	–
Asellopsis sarmatica (Jakubisiak, 1938)	epiben	–	5	+	–
Bulbamphiascus imus (Brady, 1872)	not_int	–	10	+	–
Canuella perplexa (Scott T. et A.,1893)	epiben	–	5	+	–
Dactylopusia tisboides (Claus, 1863)	phyt	100	90	+	+
Delavalia elisabethae (Por, 1959)	epiben	20	55	+	+
Ectinosoma melaniceps (Boeck, 1845)	silt_dw	60	70	+	+
Enchydrosoma sordidum (Monard, 1926)	epiben	10	35	+	+
Harpacticus flexulosus (Ceccherelli, 1988)	epiben	–	10	–	+
Harpacticus flexus (Brady et Robertson D.,1873)	epiben	10	–	–	+
Harpacticus obscurus (Scott T., 1895)	epiben	20	30	+	+
Harpacticus littoralis (Sars G. O., 1910)	epiben	20	15	+	+
Heterolaophonte stroemii stroemii (Baird, 1837)	epiben	30	15	+	+
Heterolaophonte uncinata (Czerniavski, 1868)	epiben	10	–	–	+
Laophonte elongata elongata (Boeck, 1873)	epiben	20	40	+	+
Laophonte thoracica (Boeck, 1865)	epiben	20	5	+	+
Longipedia minor (Scott T. & A., 1893)	epiben	–	5	+	–
Normanella serrata (Por, 1959)	epiben	30	45	+	+
Paradactylopodia brevicornis (Claus, 1866)	phyt	40	35	+	+
Paradactylopodia latipes (Boeck, 1865)	phyt	20	25	+	+
Parathalestris harpactoides (Claus, 1863)	epiben	–	5	+	–
Pontophonte leuke (Por, 1959)	epiben	10	–	–	+
Thalestris longimana (Claus, 1863)	phyt	–	5	+	–
Tisbe bulbisetosa (Volkmann-Rocco, 1972)	phyt	–	30	+	–
Tisbe furcata (Baird, 1837)	phyt	10	–	–	+
Tisbe marmorata (Volkmann-Rocco, 1973)	phyt	30	20	+	+

of harpacticoid copepods, i. e. copepods associated with the substrate inhabited by macrophytes, and copepods associated with macrophytes (Hicks, 1977, 1980; Hicks, Coull, 1983; Arunachalam, Balakrishnan, 1988; Arroyo et al., 2006).

Obviously, the abundance of phytal harpacticoid copepods might be higher on macrophytes beds (or, at least, this group might be more frequent in total meiobenthos diversity). However, according to our results, most of registered species were related to epibenthic group. The structure of macrophytes thallus and their rhizoid branching increase the heterogeneity of habitats (Palmer, 1988). Because the talli and rhizoids can accumulate some amount of sediments (which was observed by us several times), the heterogeneity of habitat increases even more. Also, the unevenness of rock surface contributes to sediment accumulation. Thus, the macrophyt talli form the complex habitat with the rocky substrate and sediments. It explains the presence of numerous epibenthic harpacticoid copepods in the macrophyte beds.

The harpacticoid copepods prefer three species of algae (table 2). The maximal frequency of harpacticoid copepods (100 %) was registered in *C. elegans*. Also, the copepod species with 25 % frequency were registered in *C. vagabunda* and *U. intestinalis*, so, their occurrence is close to accidental. Because the frequency of all copepod species in *C. elegans* varied from 70 % to 100 %, we consider this algae species as most preferred by copepods. Despite this, *C. elegans* occupies only fourth place (29.3 %) in total meiobenthos number. The aggregation of *P. denudata* with minimal copepod species number occupies the second place (38.8 %) in total meiobenthos, but *U. intestinalis* has maximal percentage (56.6 %) among the macrophytes by the presence of copepod species.

Despite of high abundance of epibenthic copepods on MP and MMA, only one species, *Delavalia elisabethae*, has high frequency (up to 55 % on MMA). All other species had lower frequencies. Each unspecific interstitial and phytal group of copepods has one dominant species: *A. parvula parvula* (100 % on PM, 85 % on MMA) and *D. tisboides* (100 % on PM, 90 % on MMA), correspondingly. The group of silt dwellers was presented by a single species, but with high frequency — *Ectinosoma melaniceps* (60% on MP, 70 % on MMA). So, only three of 32 harpacticoid copepod species have high frequency in both types of aggregations. All other species have lower frequency, or considered as rare/accidental. The percentage of harpacticoid copepods in total benthos was higher than all other meiobenthic groups: all other meiobenthos has only 6.9 % on MP (compared to 30.9 % of copepods) and 7.4 % on MMA (compared to 26 % of copepods).

I acknowledge Dr. Yuriy Kvach (Institute of Marine Biology of NASU, Odesa, Ukraine) for his help in the manuscript preparation.

References

Apostolov, A., Marinov, T. 1988. *Copepoda, Harpacticoida. Fauna Bulgarica*. Aedibus. Academiae Scientiarum Bulgaricae, Sofia, **18**, 1–384.

Azovsky, A. I., Saburova, M. A., Chertoprood, E. S., Polikarpov, I. G. 2005. Selective feeding of littoral harpacticoids on diatom algae: hungry gourmands? *Marine Biology*, **148** (2), 327–337.

Arroyo, N. L., Maldonado, M., Walters, K. 2006. Within-and between-plant distribution of harpacticoid copepods in a North Atlantic bed of *Laminaria ochroleuca*. *Journal of the Marine Biological Association of the UK*, **86** (2), 309–316.

Arunachalamm, M., Balakrishnanm, N. N. 1988. Harpacticoid copepods associated with the seagrass *Halophila ovalis* in the Ashtamudi Estruary, south-west coast of India. *Hydrobiologia*, **168** (1), 515–522.

Brayko, V. D. 1985. *Fouling in the Black Sea*. Naukova Dumka, Kiev, 1–123 [In Russian].

Chertoprud, E. S., Chertoprud, M. V., Kondar, D. V., Kornev, P. N., Udalov, A. A. 2006. Harpacticoida Taxocens Diversity on the Silt-Sand Littoral of Kandalaksha Bay (the White Sea). *Oceanology*, **46** (4), 1–10 [In Russian].

De Troch, M., Steinarsdottir, M., Chepurnov, V., Olafsson, E. 2005. Grazing on diatoms by harpacticoid copepods: species-specific density dependent uptake and microbial gardening. *Aquatic Microbial Ecology*, **39**, 135–144.

Garkavaya, G. P., Bogatova, Y. I., Berlinskiy, N. A., Goncharov, A. Y. 2000. Zoning of the Ukrainian sector of the North-Western Black Sea (by hydrophysical and hydrochemical parameters). *In*: Ivanov, V. A., et al., eds., *Ecological safety of the coastal and shelf zones and complex usage of the shelf sources*. EKOSI-Gidrofizika, Sevastopol, 9–24 [In Russian].

Garlitskaya, L. A. 2010. *Ecology of Harpacticoida (Crustacea, Copepoda) of the North-Western Black Sea*. PhD thesis, Institute of Biology of the Southern Seas of NAS of Ukraine, Sevastopol, 1–20 [In Russian].

Griga R. E. 1969. *The determinant of the fauna of the Black and Azov Seas*. Naukova Dumka, Kiev, 56–152 [In Russian].

Hicks, G. F. R. 1977. Species composition and zoogeography of marine phytal harpacticoid copepods from Cook Strait, and their contribution to total phytal meiofauna. *New Zealand Journal of marine and freshwater Research*, **11**, 441–469.

Hicks, G. F. R., Coull, B. C. 1983. The ecology of marine meiobenthic harpacticoid copepods. *Oceanography and Marine Biology: An Annual Review*, 21, 67–175.

Hulings, N. C., Gray, J. S. 1971. Manual for the study of meiofauna. *Smithsonian Contributions to Zoology*, 78, 1–84.

Ivanov, V. A., Gorshovsky, S. V. 1999. *Natural condition of the seaside of the Danube River and the Snake Island: modern condition of the environment*. EKOSI-Gidrofizika, Sevastopol, 1–268 [In Russian].

Kolesnikova, E. A. 1991. Meiobenthos of phythal of the Black Sea. *Ekologiya Morya*, **39**, 76–82 [In Russian].

Makaveeva, E. B. 1979. *Invertebrates of macrophytes grows in the Black Sea*. Naukova Dumka, Kiev, 1–228 [In Russian].

Palmer M. A. 1988. Dispersal of marine meiofauna: a review and conceptual model explaining passive transport and active emergence with implications for recruitment. *Marine Ecology Progress Series*, **48**, 81–91.

Wells, J. B. J. 1976. *Keys to aid in the identification of marine harpacticoid copepods*. The Aberdeen University Press Ltd., 1–215.

Zaitsev, Yu. P. 2006. *Introduction to ecology of the Black Sea*. Even, Odesa, 1–224 [In Russian].

Zaitsev, Yu. P. 2015. About the contour structure of hydrosphere. *Journal of Hydrobiology*, **51** (3), 3–24.

Zaitsev, Yu. P., Aleksandrov, B. G., Minicheva G. G. 2006. *North-western part of the Black Sea: biology and ecology*. Naukova Dumka, Kyiv, 1–701 [In Russian].

Received 29 March 2017
Accepted 24 October 2017