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SOME PECULIARITIES IN VERTICAL DISTRIBUTION OF METAZOAN MICROZOOPLANKTON IN THE BLACK SEA IN SPRING

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Based on material, received in the 84th and 93rd cruises of the RV “Professor Vodyanitsky”, vertical distribution of microplankton fraction of metazooplankton (MM) in the Black Sea in spring was analyzed. A total of 27 stations were examined both in the coastal zone and in the deep sea. The 10-L bottles of the CTD probes “Mark-III Neil Brown” and “Sea Bird 911” were used to collect 4–6 L of water from 4–11 horizons of the water column. The samples obtained were concentrated by the reverse filtration through the plankton net with the mesh size of 10 μm. Quantitative and systematic analysis of all samples was carried out totally in the Bogorov chamber using an MBS-9 stereo microscope. The main factors determining nature of the distribution are MM species composition, physical structure of the water column, and hydrodynamic processes affecting its stability/instability. Nauplii of Black Sea Copepoda and veligers of Bivalvia were the most numerous systematic groups in “spring” MM. Mollusc veligers determined abundance maxima in the lower layers of shallow water habitats, while copepods prevailed over large depths and determined total abundance peaks in the upper and middle water layers. Daily time series experiment showed that advective hydrodynamic processes can significantly affect MM vertical distribution, changing physical structure of the water column. For some species, in most cases, a correlation of their distribution with vertical profiles of temperature and salinity was revealed, which rarely manifested at total MM abundance level. A comparison of two spring seasons (2016 and 2017) showed the relationship between vertical distribution of MM abundance and temperature to be more pronounced in cases of low temperature. A change in the sign of correlation with temperature was detected during spring season for *Oithona similis*: an initially cold-loving species of Black Sea copepods. This revealed in a more superficial distribution of the maxima abundance of this species at lower seasonal temperatures, which could reflect a shift in temperature optimum for the species population and play the role of an adaptive reaction in conditions of seasonal changes in sea thermal characteristics.

Keywords: metazoan microzooplankton, abundance and species composition, vertical distribution, correlation with temperature and salinity, Black Sea

The assessment of trends in vertical distribution of abundance, biomass, and species diversity of zooplankton is important due to the role this group plays in matter and energy transfer from the surface to the depth in marine ecosystems. This transfer mediates availability of food resources and structure of trophic relationships over depth.

A pattern of vertical distribution of zooplankton as a complex organism with different biology is very complicated and requires its interpretation in the study of individual components of plankton community. As an ecological group, the zooplankton is rich by taxa, and its vertical distribution varies gradually.

As far as the Black Sea is concerned, the issue of zooplankton vertical distribution has been studied by a number of researches (Delalo et al., 1965 ; Petipa et al., 1963 ; Vinogradov et al., 1987). These studies and some others, including the more recent ones, were focused on the distribution of so-called net zooplankton, in which meso- and macrozooplankton fractions dominate, while the issue of distribution of metazoan microzooplankton (hereinafter MM) has not been studied. MM fraction is represented primarily by copepod naupliar stages; they used to be sampled by Niskin bottles (Seregin & Popova, 2016a ; Takahashi & Uchiyama, 2008 ; Ueda, 1987), by specialized plankton nets with a mesh size of less than 60–70 µm (Uye & Sano, 1995), or by other devices (Kršinić & Grbec, 2012). In general, crustaceans could contribute up to 90 % of total MM abundance. This group mediates the survival rate of many commercial fish species in the region (Klimova & Vdodovich, 2011).

MM habitat of holo- and meroplanktonic organisms in the Black Sea is constrained by the upper 50–100-m layer. Vertical distribution varies for different zooplankton species, sizes, and ontogenetic fractions (Kovalev, 1967 ; Shmeleva & Zaika, 1973 ; Takahashi & Uchiyama, 2008 ; Trudnowska et al., 2015 ; Ueda, 1987). It is influenced by season and hydrographic conditions (Takahashi & Uchiyama, 2008 ; Trudnowska et al., 2015), including the presence of thermo-, halo-, and pycnoclines (Landaeta et al., 2013 ; Lougee et al., 2002), wind mixing (Lagadeuc et al., 1997), and many other factors.

There are very few data on MM vertical distribution in the Black Sea. In Crimean waters in winter, abundance peaks were located at 5–15 and 40–60 m, whereas the biomass was distributed without clear peaks in the water column (Pavlovskaya, 1976). In summer, being the period of developed thermal stratification of the water column, the subsurface maximum of MM abundance is formed in the thermocline or beneath it (Seregin & Popova, 2010). MM vertical distribution spring pattern is yet to be defined. So, the aim of the present study was to assess metazoan microzooplankton spring vertical pattern, as well as to analyze environmental factors mediating this pattern.

MATERIAL AND METHODS

In total, 44 and 147 MM samples were collected in April 2016 and 2017, respectively, during two cruises of the RV "Professor Vodyanitsky". In 2016, 10 stations were located along Crimean Peninsula shelf, 12 miles offshore. In 2017, the sampling area was extended up to the central part of the Black Sea (Fig. 1, Table 1). Along with that, in order to reveal a diel variation of MM abundance, a daily time series experiment was carried out in the southern region, on the station in front of the Laspi Bay.

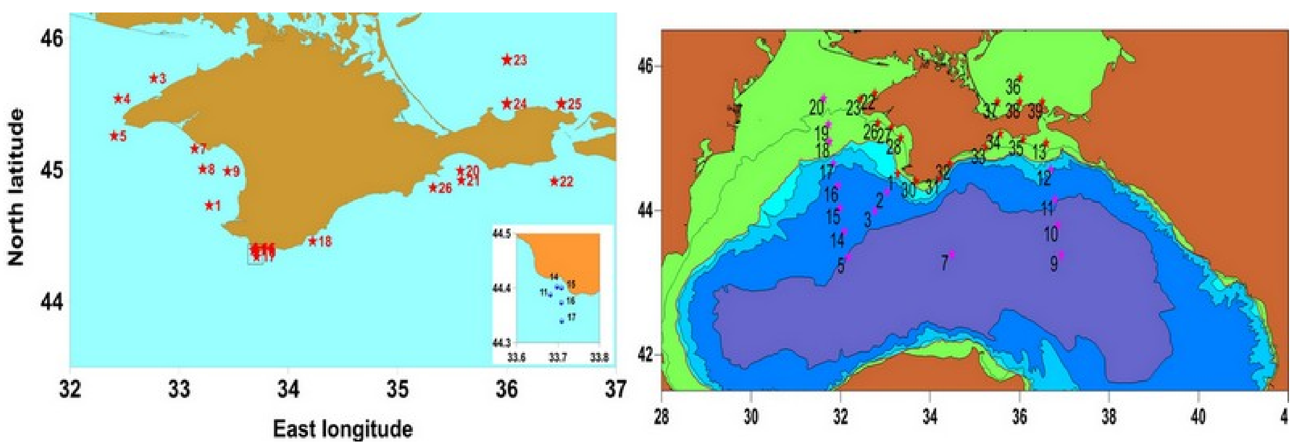

Fig. 1. Map of the stations of the 84th (left) and the 93rd (right) cruises of the RV "Professor Vodyanitsky" in the Black Sea and the Sea of Azov (2016 and 2017)

Table 1. Station numbers, coordinates, depths, and ranges of temperature (T) and salinity (S) changes on the sampling horizons (2016 and 2017)

Year	Station*	North lat., east long.	Total depth, m	Range of changes**		Sampling horizons, m
				T, °C	S, ‰	
2016	1	44°43.7′, 33°16.5′	97	11.5 / 10.3	18.21 / 18.17	0, 10, 20, 30
	3	45°41.6′, 32°46.1′	25.5	11.1 / 10.5	18.37 / 18.35	0, 5, 10, 18
	4	45°32.3′, 32°26.5′	38	11.0 / 8.5	18.38 / 18.31	0, 5, 15, 32
	7	45°09.5′, 33°08.5′	24	11.5 / 10.0	18.36 / 18.25	0, 8, 15
	11	44°23.3′, 33°40.9′	90	10.1 / 9.5	18.25 / 18.32	0, 10, 20, 30, 40, 50
	17	44°20.4′, 33°42.5′	93	10.9 / 10.3	18.21 / 18.21	0, 5, 10, 20, 30
	18	44°27.4′, 34°13.3′	86	11.0 / 10.4	18.18 / 18.00	0, 5, 15, 25, 30
	20	44°59.5′, 35°34.5′	26	10.6 / 9.6	18.25 / 18.17	0, 10, 21
	21	44°55′, 35°34.9′	39	11.9 / 11.0	18.13 / 18.09	0, 10, 20, 30
	26	44°51.7′, 35°19.4′	51	12.1 / 9.0	18.18 / 18.24	0, 10, 20, 30, 40
2017	1	44°30.2′, 33°16.3′	112	10.1 / 8.2	18.29 / 18.34	0, 5, 15, 30, 50
	3	43°59.4′, 32°45.9′	1796	10.1 / 8.2	18.13 / 18.52	0, 15, 28, 50
	5	43°21.2′, 32°09.9′	2030	9.7 / 8.6	18.69 / 20.39	0, 5, 10, 20, 30, 40, 50
	7	43°23.4′, 34°29.6′	2200	9.1 / 8.8	18.53 / 20.99	0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 116
	11	44°08.8′, 36°47.3′	1600	10.5 / 8.6	18.12 / 19.59	0, 10, 15, 25, 40, 60
	13	44°55.8′, 36°35.5′	43	9.4 / 8.8	18.24 / 18.24	0, 5, 15, 40
	14	43°42.3′, 32°05.1′	1894	9.4 / 7.5	18.57 / 18.76	0, 5, 10, 20, 30, 45
	15	44°02.0′, 31°59.0′	1515	9.6 / 8.3	18.46 / 18.49	0, 5, 15, 25, 45
	16	44°20.5′, 31°56.3′	1370	9.7 / 8.0	18.32 / 18.36	0, 8, 16, 32, 48
	18	44°57.1′, 31°44.9′	62	9.5 / 7.0	18.37 / 18.39	0, 8, 15, 36, 45
	20	45°33.0′, 31°37.3′	48	8.2 / 6.1	18.43 / 18.43	0, 7, 15, 36
	30	44°24.2′, 33°40.9′	70	9.0 / 7.7	18.15 / 18.41	0, 5, 12, 24, 40
	31	44°26.6′, 34°12.9′	86	9.2 / 8.0	18.26 / 18.39	0, 5, 14, 30, 55
	33	44°52.2′, 35°14.3′	44	8.7 / 8.2	18.02 / 18.19	0, 12, 20, 40

Note: * station numbers in 2016 and 2017 do not coincide; ** values in the upper / lower sampling horizon.

The 10-L bottles of the CTD probes "Mark-III Neil Brown" and "Sea Bird 911" were used to sample 4–6 L of water, which was filtered by the reverse filtration through the plankton net with the mesh size of 10 µm. Samples were preserved with 4 % buffered formaldehyde and kept in the freezer. Organisms were counted under the microscope MBS-9, with the magnification ×32. The Bogorov chamber and the ICES Zooplankton Methodology Manual (Harris et al., 2000) were used to count organisms. According to previous researches (Denda et al., 2017 ; Kovalev, 1980 ; Zaika et al., 1976), all individuals, fitting the size range of 50 to 500 µm, were treated as MM. Copepods were identified to species level, including naupliar stages (Opredelitel' fauny…, 1969 ; Sazhina, 1985).

All nauplii of the genus *Acartia* were identified as *Acartia clausi* Giesbrecht, 1889, since the related species *Acartia tonsa* Dana, 1849, also inhabiting the Black Sea, is present in its coastal water plankton in summer and autumn (Zaremba, 2017). This species sharply reduces its fecundity at temperatures below +20 °C (Peck et al., 2015), develops in shallow waters (Paffenhöfer & Stearns, 1988 ; Tester & Turner, 1991), predominantly in bays, where the water warms up to the bottom (Gubanova, 2000), and experiences low temperatures as dormant delayed-hatching eggs (Marcus & Lutz, 1994).

To identify the relationship of MM vertical distribution with water physical parameters, the value of the correlation coefficient was used (Urbakh, 1975). Temperature and salinity were used as the main factors reflecting hydrological structure of the water column. Water temperature and salinity were measured every time when sampling by CTD probes was carried out. The correlation was calculated for total number of MM, its groups (non-crustacean plankton, Copepoda, Bivalvia, etc.), and separate species (*Oikopleura dioica* Fol, 1872, various copepod species). The Sigmaplot 12.5v software was used to estimate the Pearson correlation coefficients and their reliability, as well as to construct plots of vertical distribution. The Golden Software Surfer 9v software was applied to map the water areas sampled and the spatial distribution of temperature.

RESULTS AND DISCUSSION

In 2016, average temperature of the surface layer of the water areas studied was +11.19 °C, and average salinity was 18.22 ‰. Vertical distribution of temperature and salinity in western shallow coastal regions (20–40 m) was relatively homogeneous in the upper 15-m mixed layer, with a subsequent gradual decline beneath it (Fig. 2). In response to this thermohaline structure, MM maximum was observed in the thermo- and halocline (stations 3 and 4) and contributed by bivalve larvae, predominantly. However, at st. 7, MM maximum was located in the upper mixed layer. This maximum was formed by *A. clausi*, while bivalve mollusc larvae were abundant in the thermocline.

As far as general trends of vertical distribution are concerned, the dominance of crustaceans (contributed up to 81 % to MM in the upper 5-m layer) was substituted by that of non-crustacean fraction, with the predomination of bivalve larvae. On species level, *A. clausi* dominated in the upper mixed layer, while *Paracalanus parvus* (Claus, 1863) and *Oithona similis* Claus, 1866 formed abundance maxima in deep layers.

In the southeastern coastal region, MM abundance reached 37 000 ind.·m^{-3}. The thermocline and halocline were not pronounced in shallow waters, so MM abundance declined from the surface to the bottom (see Fig. 2, st. 26). Bivalve larvae were numerous near the bottom (st. 22), while copepods dominated in the upper and middle layers, especially on "deep" stations.

The thermohaline characteristics of the southern coastal region were different compared to those of western and eastern regions. At st. 1, 11, and 17, the low-saline lenses were traced at 7–12-m depth. In response to these lenses, MM abundance declined, especially for *Acartia* and *Paracalanus* species (Fig. 2, st. 11 and 17). Maximum MM abundance (15 000 ind.·m^{-3}), contributed by *O. similis*, *P. parvus*, and *Pseudocalanus elongatus* (Brady, 1865), was observed at 30 and 50 m, while *A. clausi* was the most abundant in the upper mixed layer.

In 2016, no correlations in the distribution of total MM abundance, temperature, and salinity were found. However, the correlation between these parameters have persisted on species level. For instance, negative correlation with temperature was noticed in vertical distribution of *Oithona*, *Pseudocalanus*, and bivalve larvae abundance at st. 1, 17, and 26, while positive correlation was recorded for *Acartia* and *Paracalanus* abundance. At st. 11, abundance of *Oikopleura dioica* correlated positively with temperature and negatively with salinity (Table 2).

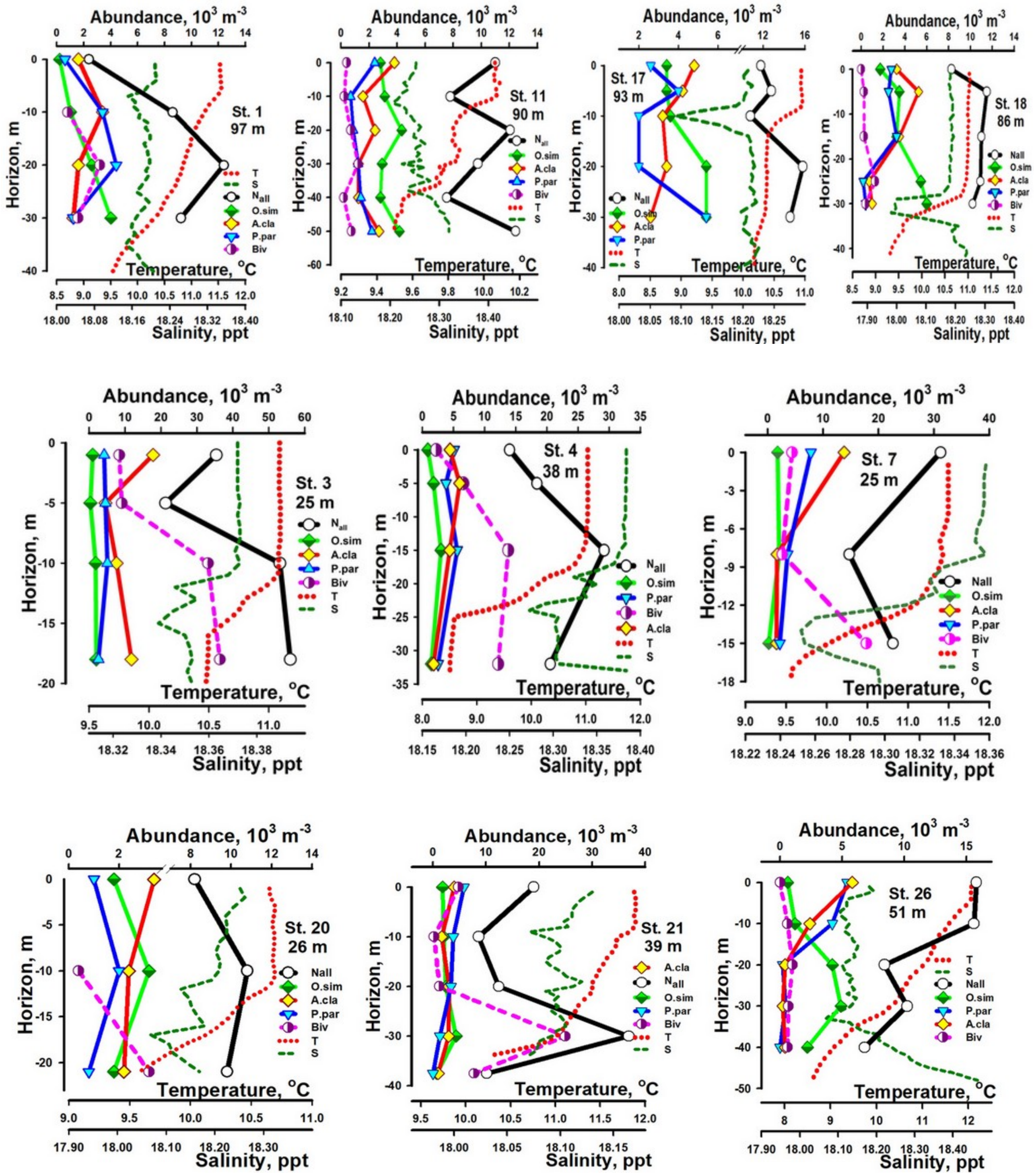

Fig. 2. Vertical distribution of water temperature (T), salinity (S), abundance of total metazoan microzooplankton (N_{all}), *Oithona similis* (O. sim), *Acartia clausi* (A. cla), *Paracalanus parvus* (P. par), *Pseudocalanus elongatus* (P. el), Bivalvia veligers (Biv) in the western (top row), southern and southwestern (middle row), and southeastern (bottom row) coastal waters of Crimea in spring 2016

Table 2. Correlation between metazoan microzooplankton abundance and temperature (T) and salinity (S) in the water column in spring 2016 and 2017

Station	Number of horizon	Correlation between total abundance and temperature: C_{corr}, *r*	temperature: Significance level, *P*	salinity: C_{corr}, *r*	salinity: Significance level, *P*	Significant correlations on species level: *r* – *P*
2016						
1	4	–0.66	0.342	–0.45	0.550	*O. similis* – T: –0.996 – 0.004**
3	4	–0.61	0.388	–0.60	0.405	*P. parvus* – S: 0.95 – 0.048*
4	4	–0.03	0.968	–0.08	0.917	
7	3					
11	6	–0.16	0.761	0.45	0.377	*O. dioica* – T: 0.86 – 0.028* *O. dioica* – S: –0.92 – 0.010**
17	5	–0.74	0.156	0.69	0.193	*O. similis* – T: –0.96 – 0.01* *P. elongatus* – T: –0.93 – 0.023* Bivalvia – T: –0.997 – 0.0002*
18	5	0.02	0.979	–0.02	0.972	
20	3	–0.09	0.940	–0.62	0.574	
21	4	–0.04	0.946	0.17	0.782	Copepoda – T: 0.88 – 0.048* Copepoda – S: 0.92 – 0.028* *P. parvus* – T: 0.95 – 0.011* *A. clausi* – S: 0.95 – 0.015*
26	5	0.86	0.061	–0.25	0.681	*P. elongatus* – T: –0.89 – 0.043*
2017						
1	5	0.43	0.470	–0.77	0.129	*A. clausi* – T: 0.97 – 0.005* *P. elongatus* – T: –0.92 – 0.026*
3	4	–0.41	0.59	0.55	0.451	*P. elongatus* – S: 0.99 – 0.042*
5	7	0.31	0.493	–0.86	0.014*	Copepoda – S: –0.86 – 0.013* *P. parvus* – S: –0.98 – 0.016*
7	11	–0.12	0.78	–0.88	0.0041**	*O. similis* – T: 0.89 – 0.016* *P. elongatus* – T: –0.85 – 0.008** Copepoda – S: –0.88 – 0.004** *P. parvus* – S: –0.93 – 0.02*
11	6	0.99	0.001**	–0.90	0.039	Copepoda – T: 0.99 – 0.0009** Copepoda – S: –0.89 – 0.045* *A. clausi* – T: 0.99 – 0.0056** *A. clausi* – S: –0.97 – 0.028* *O. similis* – T: 0.93 – 0.021*
13	4	–0.78	0.217	0.75	0.252	
14	6	–0.64	0.171	0.42	0.404	*P. elongatus* – T: –0.98 – $3.3 \cdot 10^4$** *P. elongatus* – S: 0.92 – 0.009**
15	5	–0.58	0.305	0.44	0.458	
16	5	0.51	0.376	–0.78	0.123	
18	5	–0.57	0.313	0.03	0.961	

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Station	Number of horizon	Correlation between total abundance and				Significant correlations on species level: *r* – *P*
		temperature		salinity		
		C_{corr}, *r*	Significance level, *P*	C_{corr}, *r*	Significance level, *P*	
20	4	0.76	0.241	0.08	0.916	*P. elongatus* – T: –0.99 – 0.011*
30	5	0.92	0.027*	–0.90	0.037*	Copepoda – T: 0.98 – 0.003*
						Copepoda – S: –0.98 – 0.004* *O. similis* – T: 0.90 – 0.037* *O. similis* – S: –0.92 – 0.027* *P. elongatus* – S: 0.89 – 0.041*
31	5	–0.07	0.906	–0.03	0.957	
33	4	0.90	0.097	–0.87	0.125	*A. clausi* – T: 0.96 – 0.045* *A. clausi* – S: –0.97 – 0.029* *P. elongatus* – T: –0.96 – 0.040* *P. elongatus* – S: 0.96 – 0.042*

Note: correlations are significant at $P \leq 0.05$ (*) and $P \leq 0.01$ (**).

April 2017 in the Black Sea was characterized by the lowest monthly average water temperature over the last 10 years of meteorological observations (WeatherArchive official site, 2020). Our data is consistent with this: surface temperature averaged +9.21 °C; temperature in various water areas was 1.5–3 degrees lower than in 2016 (Fig. 3). Salinity of the surface layer was slightly higher than in 2016 and averaged 18.34 ‰.

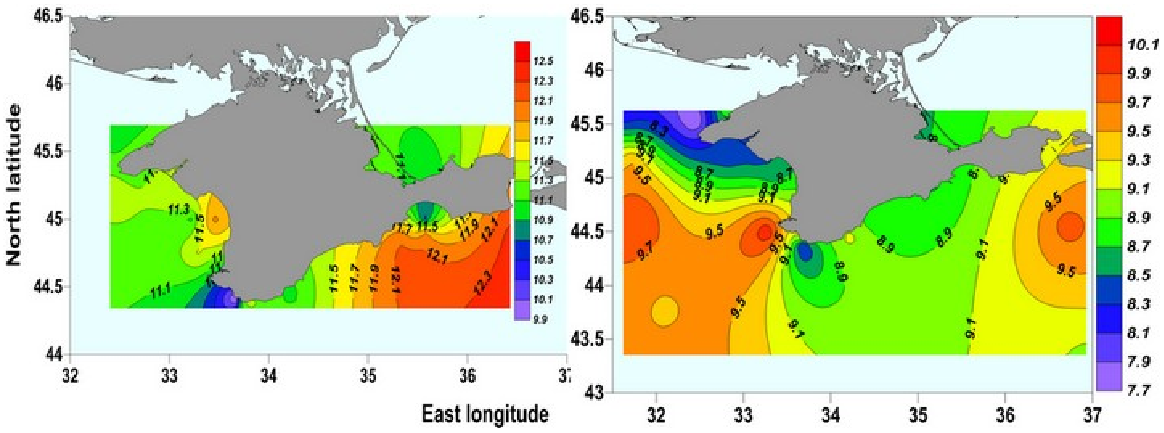

Fig. 3. Temperature of the surface layer of Crimean Peninsula Black Sea waters in spring 2016 (left) and 2017 (right)

Some examples of MM vertical distribution over three coastal regions are shown on Fig. 4. For interannual comparison, only matching stations were selected. In the southern region (in front of Sevastopol, st. 1), relatively invariant thermohaline structure of 110-m water column was observed over years. The upper mixed layer was confined by 5-m isobath, with a smooth temperature decline underneath it. Vertical distribution of MM abundance was similar to that in 2016. The subsurface total abundance maximum was located at 20–30 m. However, some differences persisted on species level. For instance, *A. clausi* abundance peak was observed on the surface in 2017, which was not the case a year earlier. Bivalve larvae were numerous in 2016, but their abundance was very low in 2017.

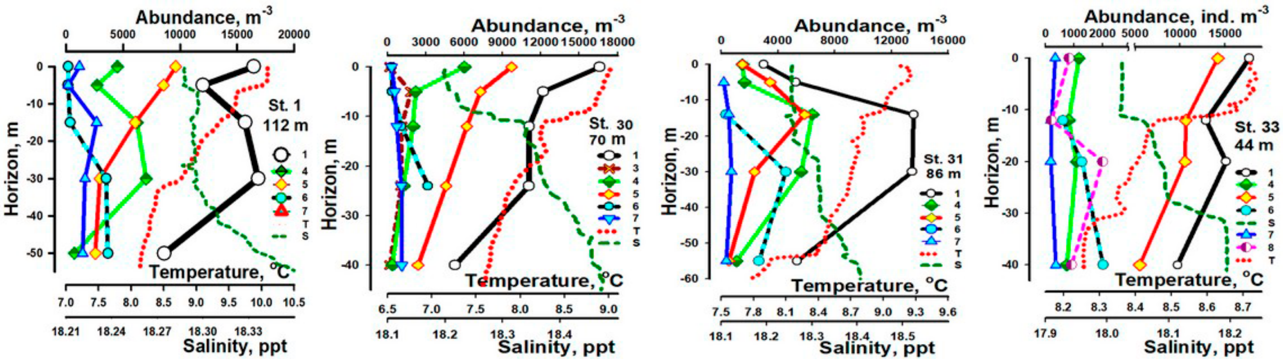

Fig. 4. Vertical distribution of water temperature (T), salinity (S), total abundance of metazoan microzooplankton (1) and non-crustacean plankton (3), abundance of copepods *O. similis* (4), *A. clausi* (5), *P. elongatus* (6), *P. parvus* (7), and Bivalvia veligers (8) in waters of the Sevastopol coastal zone (station 1), the southern (st. 30 and 31) and southeastern (st. 33) coast of Crimea in spring 2017

In the southern region (in front of the Laspi Bay) in 2016, total MM abundance maximum (16 000 ind.·m^{-3}) was located under the thermocline (Fig. 2, st. 11 and 17), whereas in 2017, the maximum (14 000 ind.·m^{-3}) was observed in the surface (Fig. 4, st. 30) or in 20–30-m upper part of the water column (Fig. 4, st. 31).

In the southeastern region (in front of Karadag), vertical distribution of MM abundance over two sampling years was similar for both near-shore and deeper stations. On species level, a more shoaled position of *O. similis* peaks was observed in 2017 compared to 2016.

In 2017, positive correlation between total MM abundance and temperature was observed at st. 11 and 30. Negative correlation between total MM abundance and salinity was registered at st. 5, 7, 11, and 30. If comparing all stations by species distribution, *O. similis* and *A. clausi* had positive correlation with temperature but negative with salinity. *P. parvus* abundance correlated negatively with salinity, whereas *P. elongatus* abundance correlated positively with salinity and negatively with temperature (see Table 2). Interestingly, *Oithona similis* had negative correlation with temperature in 2016, but positive one in 2017. Along with that, the subsurface abundance maximum of these species shoaled over two years.

The daily time series experiment, carried out in the southern region (in front of the Laspi Bay), enabled a short-term interplay between MM abundance and thermohaline characteristics to be analyzed. In the morning (8:00–12:00 a. m.), the upper mixed layer was poorly developed, so temperature declined almost linearly over depth. MM abundance peak was located on the surface (Fig. 5). In the afternoon, an upper mixed layer of 15–25 m was formed. MM abundance responded to that by descending to the lower boundary of the mixed layer and formed the subsurface maximum there (Fig. 5). So, the monotonic declining trend of MM abundance has transformed into a nonlinear vertical distribution with multiple maxima and minima.

It should be emphasized that temperature changes observed were not mediated by solar insulation of the upper layer. These changes were associated with horizontal advection of waters, which was reflected in transformations of temperature and salinity temporal profiles in the upper horizons of the water column (Fig. 6). These transformations indicated the penetration of cold and saline deep waters: an indicative of coastal upwelling, mediated by regional winds (Repetin, 2012).

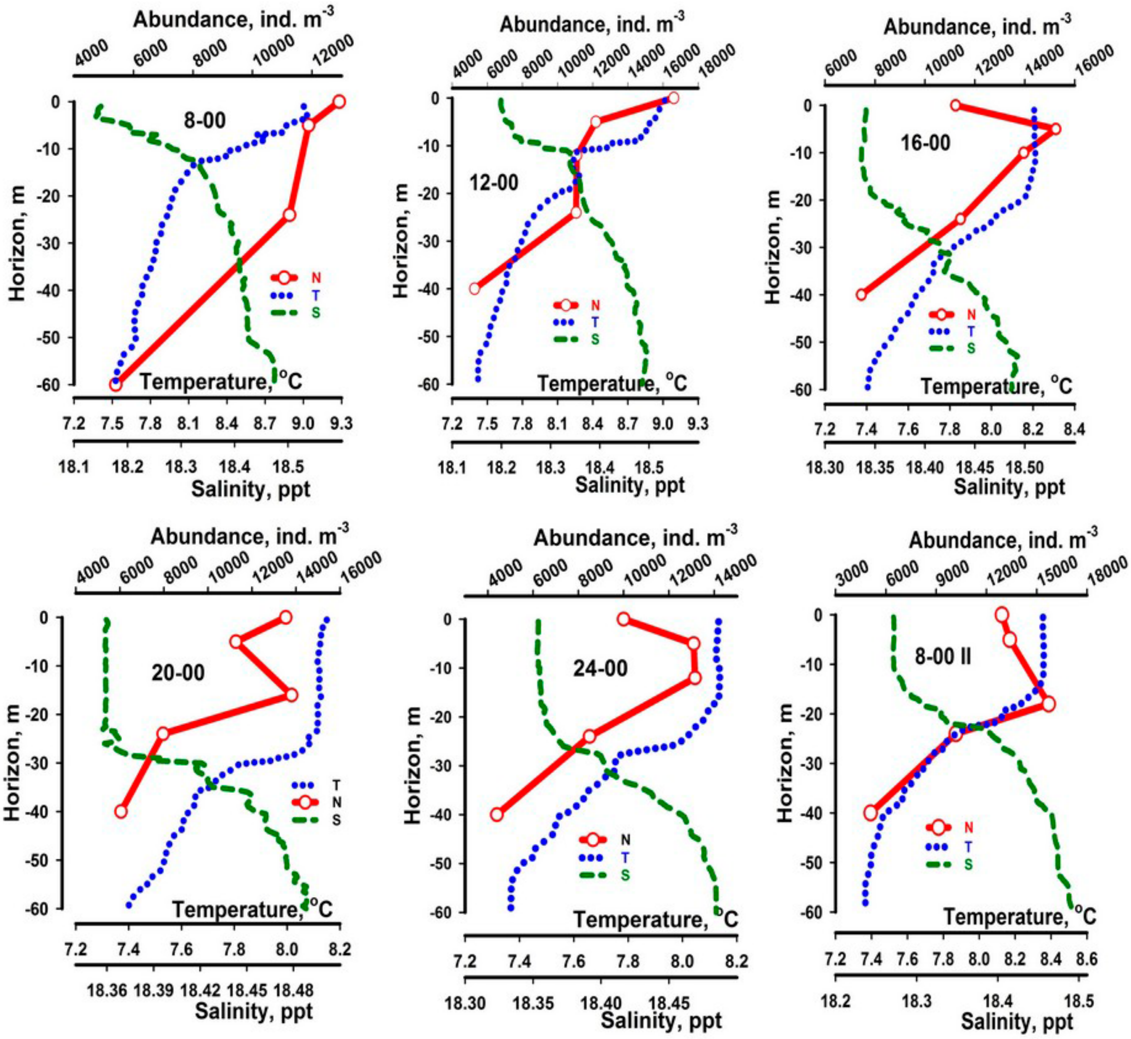

Fig. 5. Vertical distribution of temperature, salinity, and total metazoan microzooplankton abundance during the daily time series experiment at station 30 (Laspi Bay traverse, 30–31 March 2017)

During the time series experiment, the correlation between MM abundance and temperature was positive (0.7–0.9; $P < 0.05$), while the correlation between MM abundance and salinity was negative.

On the one hand, this experiment confirmed the stability of the correlations between MM distribution and physical characteristics of the water column in the temporal aspect. On the other hand, this experiment revealed the importance of hydrodynamic factor, capable of modifying hydrological structure of the water column in a short period of time.

Total MM abundance during two spring researches (2016 and 2017) was contributed mainly by copepod naupliar stages and bivalve larvae. Gastropoda larvae, *O. dioica*, and Rotatoria and Polychaete larvae were much less abundant. As known, temperature is one of the most critical abiotic factors, influencing biological functions of organisms at all levels (Hochachka & Somero, 2002). With regard to this factor, Black Sea copepods were divided into three groups: the first one – preferring low temperature, the second one – preferring high temperature, and the third one – being tolerant to a wide range of temperature changes. High temperatures are preferred by *Acartia tonsa*, *Oithona davisae*, and *Centropages ponticus* Karavaev, 1894. The first two species were not observed in our samples, while the third one contributed 1.5 % to total MM abundance in 2016, but was almost absent in samples a year later.

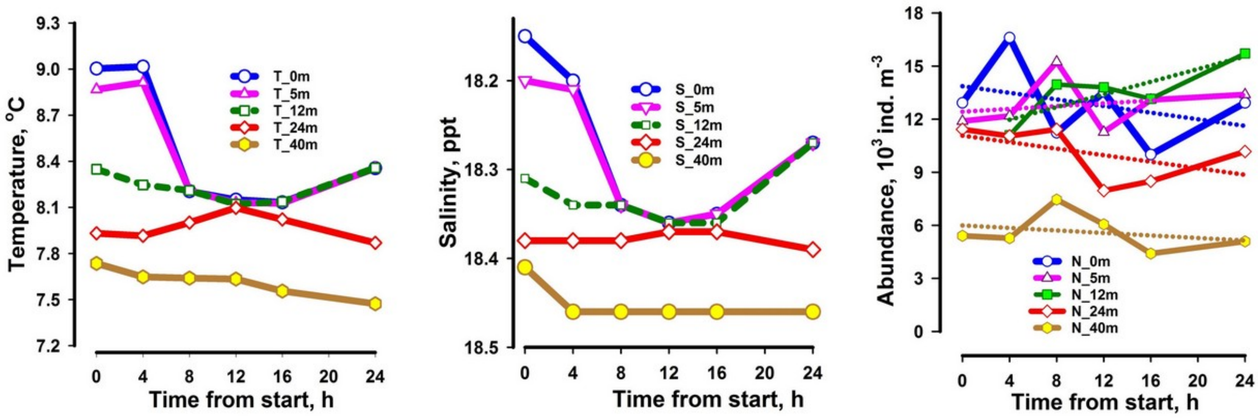

Fig. 6. Daily dynamics of temperature, salinity, and total metazoan microzooplankton abundance on sampling depths (surface, 5, 12, 24, and 40 m) on Laspi Bay traverse

Cold-loving species were represented by *Oithona similis*, *Pseudocalanus elongatus*, and *Calanus euxinus* Hulsemann, 1991. Species with a wide range of thermal tolerance were represented by *Acartia clausi* and *Paracalanus parvus*.

The cited diversity of thermal preferences explains low correlations between total MM abundance and temperature over stations sampled, since temperature preferences of cold-loving and more thermophilic species compensate each other. Another possible reason for the lack of correlations at some stations is the small number of horizons studied. Thus, all cases of statistically significant correlation between total abundance and temperature/salinity occurred at stations with a greater number of samples taken (horizons studied) (st. 5, 7, 11, and 30 in 2017).

On species level, certain correlations with temperature were observed. For instance, cold-loving *P. elongatus* has negatively correlated with temperature, while eurythermic *A. clausi* showed an opposite trend. Due to this, *Pseudocalanus* formed its maximum in deeper layers, while *Acartia* abundance maximum was observed on the surface.

Copepod fraction of MM showed different vertical patterns during summer and spring seasons. For instance, *O. similis* was completely absent in the surface waters at summer and lived mainly under the thermocline and in the bottom layers (Seregin & Popova, 2016b), whereas in mid-spring this species peaks were associated both with the lower horizons at +9.5…+10.3 °C and with the upper layers at +10.9…+11.0 °C (Seregin & Popova, 2019). Similar spring *vs* summer difference was observed in *P. elongatus* distribution, which preferred cold temperatures as well (Seregin & Popova, 2016b). *O. similis* summer pattern corresponds to the cold-loving status of this species, distributed over the World Ocean Arctic and temperate waters (Wend-Heckmann, 2013). For Black Sea waters, this species is a North Atlantic immigrant. *O. similis*, along with *C. euxinus* and *P. elongatus*, forms a deep-sea complex of cold-water copepods (Nikitin, 1926) and can be found year-round (Yildiz & Feyzioğlu, 2014). Adult forms and copepodites prefer summer layers with temperature about +8 °C (Kovalev, 1967). At lower temperatures in early spring, we registered further changes in vertical distribution of *O. similis* juvenile stages: an even more superficial distribution of this species abundance. As a result, there was a change in the sign of correlation with temperature from negative to positive, which suggests a corresponding change in species status (temporary) from cold-loving to somewhat more thermophilic. Such phenomena may reflect a shift in temperature optimum of a population (Verbitsky, 2012) and play the role of an adaptive reaction in conditions of seasonal changes in sea thermal characteristics. The mechanism of such reaction can be a fine-scale behavioral selection of preferable water characteristics by different zooplankton species and life stages (Trudnowska et al., 2015).

A. clausi was abundant in the upper mixed layer of the water column during both seasons. Despite the status of eurythermic, this species manifested itself rather as a warmth-loving species at spring temperatures. Therefore, correlation of *Acartia* with temperature was always positive. Along with *O. similis*, which has changed its temperature status, *A. clausi* was the most abundant species in 2017. So, these two species mediated a positive correlation of total MM with temperature.

Conclusion. Hydrological parameters of the environment (temperature and salinity) and species composition in specific habitats were the main drivers of vertical distribution of metazoan microzooplankton abundance. In addition, hydrodynamic processes (for instance, horizontal advection of waters) can significantly affect hydrological structure of the water column and MM distribution pattern.

The correlation between MM species abundance, temperature, and salinity was elucidated for most sampled stations during spring season. In particular, *A. clausi* abundance always correlated positively with temperature and negatively with salinity. This species manifested itself rather as a warmth-loving one at spring temperatures. A reversed correlation pattern was observed in *P. elongatus* abundance. On total MM abundance level, correlations with temperature and salinity were weak and observed in early spring in 2017; thus, the relationship between vertical distribution of MM abundance and temperature is more pronounced in cases of low temperature.

A change in the sign of correlation with temperature during spring season was determined for *O. similis*, an initially cold-loving species of Black Sea copepods. This manifested in a more superficial distribution of maximum abundance of this species at lower seasonal temperatures, which could reflect a shift in temperature optimum of species population and play the role of an adaptive reaction in conditions of seasonal changes in sea thermal characteristics.

Highlights:

1. Correlations with temperature were weak on total abundance level and were only observed in early spring period with lower temperatures.
2. On species level, correlation between abundance, temperature, and salinity was elucidated for most cases.
3. Different species exhibited different correlation with temperature: both positive (for instance, *Acartia clausi*) or negative (*e. g.*, *Pseudocalanus elongatus*). Some cold-loving species (*Oithona similis*) exhibited the change in the sign of correlation with temperature during a subsequent seasonal warming.

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НЕКОТОРЫЕ ОСОБЕННОСТИ ВЕРТИКАЛЬНОГО РАСПРЕДЕЛЕНИЯ МЕТАЗОЙНОГО МИКРОЗООПЛАНКТОНА В ЧЁРНОМ МОРЕ В ВЕСЕННИЙ ПЕРИОД

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По материалу, полученному в 84-м и 93-м рейсах НИС «Профессор Водяницкий», проанализировано вертикальное распределение микропланктонной фракции метазоопланктона (ММ) в Чёрном море в весенний период. Суммарно обследовано 27 станций как в прибрежной, так и в глубоководной частях мо́ря. Пробы воды для учёта численности ММ объёмом 4–6 л отбирали 10-литровыми батометрами зондов Mark-III Neil Brown или Sea Bird 911 (США) с 4–11 горизонтов водного столба. Полученные пробы концентрировали при помощи воронок обратной фильтрации и планктонного сита с размером пор 10 мкм. Количественный и систематический анализ всех проб проводили тотально в камере Богорова при помощи стереомикроскопа МБС-9. Основными факторами, определяющими характер распределения, являлись видовой состав ММ, физическая структура водного столба, а также гидродинамические процессы, воздействующие на его стабильность/неустойчивость. Наиболее многочисленными систематическими группами в «весеннем» ММ были науплиусы черноморских Copepoda и велигеры Bivalvia. Велигеры моллюсков обуславливали максимумы численности в нижних слоях мелководных местообитаний; над большими глубинами в составе ММ превалировали копеподы, определявшие пики общей численности в верхних и средних слоях воды. Суточный эксперимент по выявлению динамики вертикального распределения ММ показал существенное влияние на него адвективных гидродинамических процессов, воздействующих на физическую структуру водного столба. Для отдельных видов ММ в большинстве случаев выявлена корреляция их распределения с вертикальными профилями температуры и солёности, что редко проявлялось на уровне общей численности ММ. Сравнение двух весенних сезонов (2016 и 2017) показало, что связь вертикального распределения ММ и температуры проявлялась сильнее при более низких её значениях в море. Для исходно холоднолюбивого вида черноморских копепод, *Oithona similis*, обнаружена смена знака корреляции с температурой воды́ в процессе сезонного её изменения. В результате зарегистрировано более поверхностное распределение основных максимумов численности в более холодных условиях, что могло отражать изменение температурного оптимума вида и играть роль адаптивной реакции популяции при сезонных изменениях термальных характеристик моря.

Ключевые слова: метазойный микрозоопланктон, обилие и видовой состав, вертикальное распределение, корреляция с температурой и солёностью, Чёрное море