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Research Article

Features of winter zooplankton assemblage in the Central Trough of the Barents Sea

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Abstract

The Barents Sea is a highly productive shelf region. Zooplankton assemblages are a key component of the carbon cycle in Arctic marine ecosystems; they transfer energy from lower trophic levels to higher levels, including larval and young commercial fish. The winter state of the zooplankton community in the Central Through and their slopes (Barents Sea) was investigated in late November 2010. Vertical structure of water layer was characterised by pycnocline located below 80 m. The upper strata were occupied by transformed Atlantic Water, while winter Barents Sea Water with negative temperatures was in the bottom strata. Total zooplankton abundance varied from 162 to 1214 individuals/m^3. Biomass ranged from 88 to 799 mg wet mass/m^3. Copepods dominated in terms of total zooplankton abundance (average 99%) and biomass (92%). Maximum densities of *Calanus finmarchicus* and *Calanus glacialis* were registered in the frontal zone separating warm and cold water masses. Abundances of *Metridia longa* and *O. similis* were highest in cold waters. Three groups of stations differing in terms of the common copepod composition were delineated with cluster analysis. The age structure of *Calanus finmarchicus* and *Metridia longa* was characterised by a prevalence of copepodites IV–V. Total zooplankton abundance and biomass were correlated to water temperature and salinity, suggesting that hydrological conditions were the key driver of spatial variations of the zooplankton communities. High biomass of large copepods suggests potential significance of the investigated region for feeding of young and adult fish.

Keywords

Plankton, copepods, pelagic ecosystem, Arctic shelf

The Barents Sea is the largest shelf sea with a surface area and biological productivity equal to or exceeding those of the most productive seas of the Far East. The region is populated by flora and fauna with an abundance of commercial species (Anonymous 2011, Wassmann et al. 2006). The Barents Sea is a sea where valuable species of fish (cod, haddock, capelin) and invertebrates (king crab, great northern prawn) are produced commercially and numerous hydrocarbon deposits are being explored and operated. Coastal ecosystems of the Barents Sea where high primary production is recorded appear to be the most productive (Anonymous 2011).

Zooplankton communities constitute an important element of marine ecosystems, since they ensure transport of energy from primary producers to higher trophic levels. The supply of zooplankton determines the food reserve for ichthyoplankton and young fish. Coastal regions are the major feeding areas for juvenile herring and capelin (Wassmann et al. 2006). Most zooplankton studies in the Barents Sea (Timofeev 2000, Anonymous 2004) in summer were carried out in such regions. Available data on the winter state of zooplankton is scarce and chiefly reflects the conditions typical of coastal waters (Dvoretsky and Dvoretsky 2013, Dvoretsky and Dvoretsky 2015a, Dvoretsky and Dvoretsky 2015b). This study is relevant because information on the winter phase of the zooplankton's seasonal cycle will offer us a better understanding of the pelagic ecosystem's performance in the conditions of polar night, low temperature and a deficit of food resources. Since juvenile and full-grown capelins gather and feed in the central part of the Barents Sea in winter (Olsen et al. 2010), a study of the state of zooplankton as their food reserve appears to be of interest also for the applied sciences.

The purpose of this study was to investigate the taxonomic composition, quantitative distribution and biological features of certain dominant species of zooplankton in the central part of the Barents Sea at the beginning of the winter season.

Materials and methods

Samples were collected during the voyage by the research vessel Viktor Buynitskiy in the Barents Sea at the end of November 2010, under polar night conditions (see Fig. 1, Table 1). Prior to collecting the zooplankton samples, researchers completed water stratum profiling using the SEACAT SBE 19plus probe. The provided water mass characterisation is based on the hydrological criteria (Anonymous 2011, Anonymous 2004, Matishov et al. 2012). The zooplankton was collected using a Juday net (entry hole diameter 37 mm, filter sheet mesh size 168 um). The samples were collected in a 10–20 m stratum from the bottom to the surface. Collected plankton samples were fixed with formalin. The researchers analysed a total of 15 samples from 15 different stations.

The samples were treated in a laboratory on the shore using standard techniques (Anonymous 1971). Wet biomass of individual species and the total biomass were determined using nomographic charts, tables of weights of marine aquatic organisms and size-weight curves (Dvoretsky and Dvoretsky 2015a). Dry biomass was transformed into wet biomass with the help of conversion factors (Dvoretsky and Dvoretsky 2015a).

The resulting data were processed using descriptive statistics methods with calculation of mean values and their standard errors. Similarity of individual stations in terms of the zooplankton count was assessed using the Bray-Curtis index (Bray and Curtis 1957): $S_{jk} = 100\bullet(\Sigma 2\bullet \min (y_{ij}, y_{ik}))/\Sigma(y_{ij}+y_{ik})$, where y is the abundance of a certain species in the corresponding sample determined in Primer 5.0 software using the group mean technique. The Shannon indices and Pielou's evenness were used to determine the parameters of biological diversity of zooplankton communities. Linear regression analysis was used to identify the correlation between the oceanological aspects, depth of the sampling stations and quantitative characteristics of the zooplankton (abundance and biomass).

Findings

Vertical structure of the water stratum was characterised by presence of pycnocline, typically at a depth of 120–180 metres. At three sampling stations in the south-western part of the study region (stations 3-5), pycnocline was found in the 90-110 m stratum in an area with chilled near-bottom waters of the trough. At

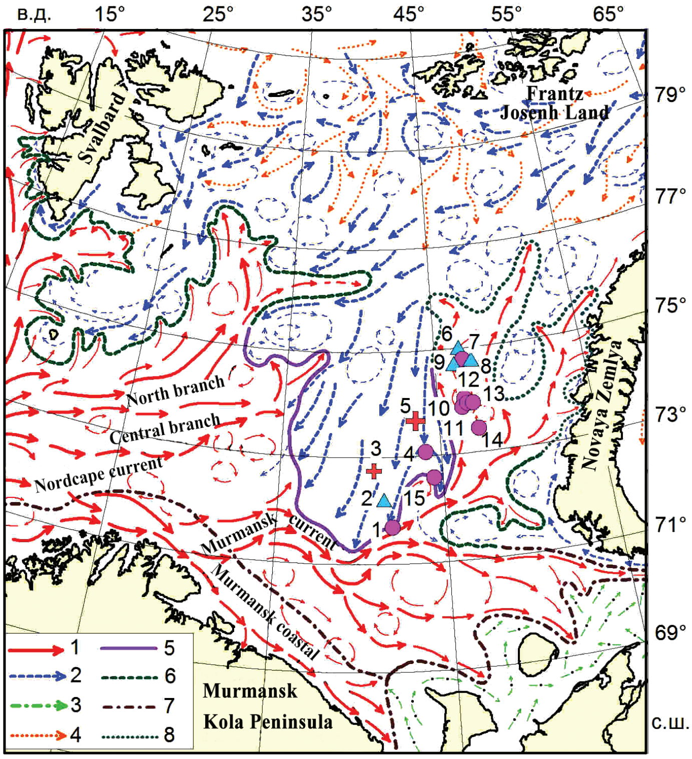

Fig. 1. Location of zooplankton sampling stations in the Barents Sea in November 2010 and main currents diagram [9]. 1 – warm currents, 2 – cold currents, 3 – local coastal currents, 4 – spread of deep Atlantic waters, 5 – thermic frontal zones, 6 – thermohaline frontal zones, 7 – haline frontal zones, 8 – mild, unsteady frontal zones. Group 1 stations are marked by circles, group 2 stations – by triangles, and group 3 stations – by crosses

Table 1. Characterisation of sampling stations and hydrological conditions (minimum / maximum / mean in sampling stratum) in the Barents Sea in November 2010

Station	Date	Time	Depth, m	Sampling stratum	Temperature, °C	Salinity, psu
1	25.11.2010	9:36	295	280–0	0.02/3.62/2.12	34.94/35.02/34.97
2	25.11.2010	15:19	300	290–0	0.03/3.07/1.69	34.94/35.02/34.96
3	25.11.2010	22:29	362	350–0	–0.02/2.26/0.93	34.89/34.98/34.94
4	26.11.2010	12:44	305	300–0	0.08/2.73/1.44	34.92/34.99/34.95
5	26.11.2010	23:37	375	350–0	–0.17/1.16/0.41	34.8/34.97/34.92
6	27.11.2010	13:15	236	230–0	0.52/2.6/1.89	34.83/34.98/34.89
7	27.11.2010	15:35	209	200–0	0.76/2.12/1.62	34.8/34.93/34.86
8	27.11.2010	18:46	226	200–0	0.7/2/1.65	34.79/34.95/34.85
9	27.11.2010	20:55	196	200–0	1.04/1.98/1.68	34.8/34.92/34.84
10	28.11.2010	9:05	238	230–0	0.49/3.09/2.32	34.81/35/34.89
11	28.11.2010	11:05	250	240–0	0.49/3.22/2.36	34.83/35.01/34.92
12	28.11.2010	12:28	274	265–0	1.01/3.18/2.34	34.83/35.01/34.92
13	28.11.2010	16:39	265	260–0	1.02/3.14/2.45	34.82/35.01/34.91
14	28.11.2010	20:12	313	300–0	0.3/3.16/1.85	34.89/35.01/34.95
15	29.11.2010	9:22	273	260–0	0.31/2.67/1.66	34.92/35/34.95

station 5, pycnocline was found at a depth of 80 metres. The top boundary of pycnocline at all the stations matched the top boundary of thermocline and halicline. The top stratum up to the pycnocline boundary was occupied by transformed Atlantic waters; polar waters with a lower temperature were found at station 5. Winter Barents Sea waters with below-zero temperatures in the centre were found in the near-bottom stratum, at a depth of 200 m and below.

A total of 29 taxons of zooplankton were identified in the samples (see Table 2). The number of taxons at sampling stations varied from 13 at station 12 to 24 at station 3. The total abundance of zooplankton varied from 162 to 1214 individuals/m^3. The biomass varied from 88 to 799 mg/m^3. Mean values in the study region were 456±29 individuals/m^3 and 406±27 mg/m^3, respectively.

Copepods prevailed in terms of abundance at all stations, their numbers varying from 161 to 1199 individuals/m^3 with a mean of 454±28 individuals/m^3, which accounted for 99–100% of the overall zooplankton abundance. The abundance of other groups combined was no more than 15 individuals/m^3, on average (2±1%). Copepods also prevailed in terms of biomass (80–725, 377±54 mg/m^3), accounting for 83-99 (92±1)% of the overall biomass of zooplankton. Subdominant species were represented by euphausiids (0–58, 21±4 mg/m^3) and chaetognaths (0.3–13, 6±1 mg/m^3), which accounted for 0–14 (6±1)% and 0.3–3 (1±0.2)% of the overall biomass, respectively.

Cluster analysis identified three groups of sampling stations that had a fairly similar abundance of dominant species, with a minimum similarity rate of 50% (see Fig. 2). The first group included 9 stations (1, 4, 7, 10, 11 and 13–15) located chiefly in the area affected by the warm Novaya Zemlya current. These stations had the highest mean values of water temperature and salinity (2.02±0.13°C and 34.86±0.02 psu). The dominant groups of species with the highest abundance were *C. finmarchicus* (31±3%), *O. similis* (23±3%) and *M. longa* (15±1%) (see Table 2). In terms of biomass, *C. finmarchicus* (44±2%) and *C. glacialis* (30±1%) prevailed.

At the stations from the second group, water temperature was on average 0.5°C lower than at the first cluster stations. This group included 3 stations in the northern part of the studied aquatorium (stations. 6, 8, 9) and one station in the south (station 2). The predominant species in the community were *M. longa* (30±1%) and *O. similis* (30±3%) . The biomass was chiefly made up of three species – *M. longa* (33±5%), *C. finmarchicus* (32±5%) and *C. glacialis* (20±4%). The total biomass was, on average, 4 times smaller than at the stations of other clusters.

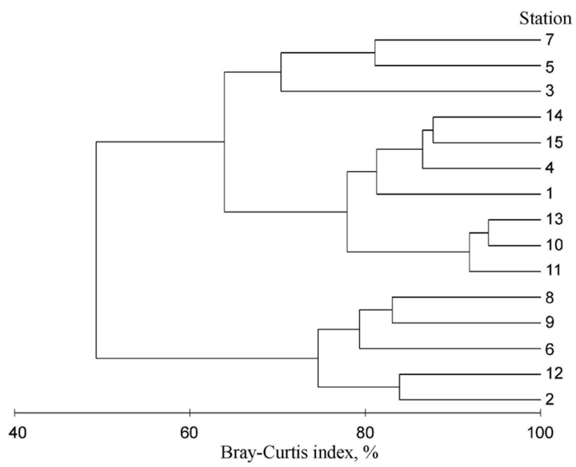

Fig. 2. Dendrogram of station similarity in terms of zooplankton count in the central part of the Barents Sea in November 2010

The third group included 2 deep-water stations (3 and 5). The mean water temperature at these stations was the minimum among all three clusters, since the stations were affected by the cold central current. The predominant species were *O. similis* (45±5%) and *M. longa* (22±3%) (see Table 2). Four species of copepods (*M. longa*, *C. finmarchicus*, *C. glacialis* and *C. hyperboreus*) accounted for over 88% of the overall biomass of zooplankton.

Significant dissimilarities (Tukey-Kramer test, $p<0.05$) were identified in the overall abundance (group 2 - group 3) and biomass of zooplankton (group 1 - group 2, group 2 - group 3), as well as the abundance of *C. finmarchicus* (group 1– group 2), *C. glacialis* (group 1– group 2), *M. longa* (group 1–group 2, group 2–group 3), *O. similis* (group 1–group 2, group 2– group 3), *Pseudocalanus* spp. (group 2– group 3), *P. elegans* (group 2– group 3), co-

Table 2. Composition, abundance (spec/m^3) and total biomass (mg of wet mass/m^3) of zooplankton among the groups identified by cluster analysis in the Barents Sea in November 2010

	Group 1		Group 2		Group 3	
Taxon/descriptor	**min–max**	**mean±SE**	**min–max**	**mean±SE**	**min–max**	**mean±SE**
Calanus finmarchicus	**79–199**	**145±12**	**12–53**	**34±10**	**25–212**	**119±93**
Calanus glacialis	**21–67**	**45±6**	**5–14**	**8±2**	**5–66**	**35±30**
Calanus hyperboreus	0–14	3±2	0–1	<0.1	1–5	3±2
Copepoda nauplii	–	–	0–0.5	0.1±0.1	0–0.5	0.2±0.2
Heterorhabdus norvegicus	0–0.5	0.2±0.1	–	–	0–0.4	0.2±0.2
Metridia longa	**44–107**	**70±8**	**50–111**	**67±15**	**123–219**	**171±48**
Microcalanus pusillus	6–31	19±4	1–22	10±5	10–10	10±0.2
Microcalanus pygmaeus	12–58	29±6	1–27	9±6	17–27	22±5
Microsetella norvegica	0–0.8	0.1±0.1	0–0.6	0.2±0.2	0–5	2.5±2.5
Oithona atlantica	2–30	9±3	3–5	4±1	13–16	15±2
Oithona similis	**34–250**	**113±22**	**58–67**	**63±2**	**249–493**	**371±122**
Paraeuchaeta norvegica	0–0.1	0.1±0.01	0–0.1	<0.1	0–0.1	<0.1
***Pseudocalanus* spp. I–IV**	**5–84**	**21±9**	**2–12**	**6±2**	**26–115**	**70±44**
Pseudocalanus acuspes V–VI	5–14	9±1	1–8	4±2	3–9	6±3
Pseudocalanus minutus V–VI	3–30	13±3	3–8	4±1	11–32	21±11
Themisto abyssorum	0–0.1	<0.1	0–0.1	<0.1	–	–
Thysanoessa inermis	0–1.2	0.7±0.2	0–0.5	0.2±0.1	0.3–1.7	1.1±0.7
Meganyctiphanes norvegica	0–0.1	<0.1	–	–	–	–
Pandalus borealis	0–0.047	<0.1	–	–	–	–
Aeginopsis laurentii	–	–	–	–	0–0.2	0.1±0.1
Aglantha digitale	0–0.1	<0.1	0–0.1	<0.1	0–0.8	0.4±0.4
Beroe cucumis juv.	0–0.1	0.1±0.01	0–0.1	<0.1	0–0.4	0.2±0.2
Mertensia ovum juv.	0–0.1	0.1±0.01	0–0.1	<0.1	0.1–0.5	0.3±0.2
Gastropoda larvae	–	–	–	–	0–1.2	0.6±0.6
Eukrohnia hamata	0–0.2	<0.1	–	–	0–0.3	0.1±0.1
Parasagitta elegans	**0.3–2.3**	**1±0.2**	**0.1–0.2**	**0.2±0**	**0.6–4.6**	**2.6±2**
Limacina helicina juv.	0–1	0.2±0.1	–	–	0–1.3	0.6±0.6
Oikopleura vanhoeffenni	0–0.3	0.1±0.01	0–0.2	0.1±0.1	1.8–3.7	2.7±0.9
Pisces larvae	–	–	0–0.03	<0.1	–	–
Total	**266–681**	**477±46**	**162–259**	**209±20**	**497–1214**	**855±358**
Copepods	**264–678**	**475±46**	**161–259**	**209±20**	**494–1199**	**846±353**
Euphausiids	0–1.2	0.7±0.1	0–0.4	0.3±0.1	0.3–1.7	1±0.7
Chaetognaths	**0.3–2.3**	**1±0.2**	**0.1–0.2**	**0.2±0.1**	**0.6–4.9**	**2.7±2.1**
Others	0.1–1.2	0.4±0.1	0.1–0.4	0.2±0.1	1.9–8	4.9±3.1
H’	1.79–2.09	1.88±0.03	1.54–1.88	1.71±0.08	1.54–1.77	1.66±0.12
J’	0.58–0.71	0.64±0.01	0.53–0.65	0.59±0.03	0.53–0.54	0.54±0.01
Biomass	**354–666**	**508±39**	**88–173**	**131±19**	**192–799**	**496±304**

Note. J – evenness, H’ – Shannon index. Significant dissimilarities ($p < 0.05$) are highlighted in bold.

pepods (group 2– group 3) and chaetognaths (group 2– group 3) (see Table 2).

The horizontal distribution of the four species with the greatest abundance had the following pattern. The highest densities of *C. finmarchicus* (> 150 individuals/m^3) were recorded at the frontal zone boundary dividing the warm and cold waters (stations 1, 3, 4, 11, 13, 15). The smallest abundance (< 30 individuals/m^3) was found in the area affected by Arctic waters. Maximum abundance of *C. glacialis* (> 50 individuals/m^3) was also found in the frontal zone, whereas minimum values (< 10 individuals/m^3) were identified in the area affected by Atlantic waters (stations 6, 8, 9). The abundance of *M. longa* reached its maximum (> 100 individuals/m^3) in the area affected by cold waters (stations 3, 5, 15), whereas minimum values (< 60 individuals/m^3) were found in warm waters (stations 8–10, 12). The count of *O. similis* was at its maximum (> 200 individuals/m^3) in the southern part of the study region affected by cold waters (stations 3–5), and the minimum count (< 60 individuals/m^3) was in the region with warm waters (stations 8, 9, 12).

The age composition of *C. finmarchicus* had the following pattern: the majority were represented by senior (IV–V) copepodites stages that made up around half the entire population of the species. About a quarter of the entire population was represented by grown individuals. A similar situation was identified for *M. longa*, but presence of stage I copepodites in the samples is indicative of spawning of this species in the central part of the Barents Sea.

Regression analysis demonstrated that the total abundance and biomass of zooplankton were inversely related to the mean temperature of the water stratum and directly related to its salinity (see Table 3). As for the abundance/biomass and salinity, this

Table 3. Linear regression relationship of the abundance (n, individuals/m^3) and biomass (b, mg of wet mass/m^3) of zooplankton versus the length of the sampling stratum, time of sample collection and hydrological aspects in the central part of the Barents Sea in November 2010

Equation	R^2	r	F	p
$Lg[N] = 0.003 \cdot L + 1.81$	0.463	0.680	11.200	<0.05
$Lg[N] = 0.0001 \cdot t + 2.60$	0.000	0.002	0.000	0.995
$Lg[N] = -0.307 \cdot T_1 + 2.74$	0.288	–0.537	5.260	<0.05
$Lg[N] = 0.031 \cdot T_2 + 2.52$	0.007	0.086	0.097	0.760
$Lg[N] = -0.127 \cdot T_3 + 2.83$	0.093	–0.304	1.328	0.270
$Lg[N] = 1.836 \cdot S_1 + -61.40$	0.196	0.443	3.170	0.098
$Lg[N] = 2.027 \cdot S_2 - 68.31$	0.077	0.278	1.087	0.316
$Lg[N] = 3.292 \cdot S_3 - 112.33$	0.339	0.583	6.679	<0.05
$Lg[B] = 0.003 \cdot L + 1.83$	0.206	0.454	3.379	0.089
$Lg[B] = -0.021 \cdot t + 2.82$	0.105	–0.324	1.523	0.239
$Lg[B] = -0.212 \cdot T_1 + 2.62$	0.079	–0.281	1.115	0.310
$Lg[B] = 0.237 \cdot T_2 + 1.90$	0.255	0.505	4.448	0.055
$Lg[B] = 0.095 \cdot T_3 + 2.36$	0.030	0.172	0.396	0.540
$Lg[B] = 2.522 \cdot S_1 - 85.38$	0.214	0.462	3.535	0.083
$Lg[B] = 5.323 \cdot S_2 - 183.92$	0.308	0.555	5.793	<0.05
$Lg[B] = 4.673 \cdot S_3 - 160.61$	0.395	0.629	8.497	<0.05

Note. L – length of sampling stratum, m; t – sample collection time, hrs; T_1, T_2, T_3 – temperatures: minimum, maximum and mean, °C; S_1, S_2, S_3 – salinity: minimum, maximum and mean, psu. R^2 – determination coefficient, r – correlation coefficient, F – Fisher's variance ratio, p – significance point.

relationship was statistically valid. In addition, the abundance demonstrated an increasing trend as the depth increased.

Discussion

Hydrological conditions in the studied aquatorium of the Barents Sea were rather uniform and the gradients of meat water temperature and salinity in the sampling stratum did not exceed 1.73 °C and 0.13 psu. Generally speaking, water temperature and salinity in the top quasi-uniform stratum during the study period were consistent with the long-time annual average values typical of the central part of the Barents Sea, allowing us to place the year 2010 in the category of normal years (Anonymous 2004). Water temperature observed in the near-bottom stratum in the study period was higher than the long-time annual average temperature values, which was consistent with data acquired during observation of heat content in the water masses in 2010–2011 (Anonyous 2012).

Assessment of the similarity of sampling stations in terms of the taxonomic composition of zooplankton revealed a very similar composition of the fauna at the stations, which was to be expected because similar waters were found to dominate at all the sampling stations. As a rule, the number of zooplankton species found in autumn-winter samples in the Barents Sea is rather small (Dvoretsky and Dvoretsky 2015a). The maximum number of taxons was found at station 3, which can be explained by the following factors. First of all, this station was located in the stream of the cold Central current, due to which the samples from this station contained such Arctic species as *A. laurentii*, *A. digitale* and *O. vanhoeffenni*. Second, the station was located at a significant depth, so the samples contained *P. norvegica*, *Th. abyssorum* and *E. hamata*. As stated above, the diversity of conditions (interfaces of different water masses, areas with non-homogeneous bottom topology) enables development of a rich zooplankton fauna (Timofeev 2000, Dvoretsky and Dvoretsky 2015a).

The distribution of dominant species of copepods was closely related to the arrangement of the water masses. As stated above, the boreal species *C. finmarchicus* is found across almost the entire aquatorium of the Barents Sea (Timofeev 2000, Dvoretsky and Dvoretsky 2015a), but its abundance is highest in warm waters. Copepod *O. Atlantica* was also found at all the sampling stations, and euphausiids *M. norvegica* – at five stations, which might be explained by the influence of Atlantic waters. Vertical water structure analysis demonstrated presence of Atlantic waters with different degrees of transformation in the study region. This is a logical result, since the central part of the sea is exposed to the warm Novaya Zemlya current. At the same time, note that samples also contained typical Arctic species *C. glacialis*, *C. hyperboreus*, *A. laurentii*, *A. digitale* and *O. vanhoeffenni*, which are associated with cold waters of the Central current (see Fig. 1). The abundance of cosmopolite copepod *O. similis* was highest at the stations exposed to Arctic waters. This result appears to be consistent with earlier data for the summer season, whereby the average abundance of this species was higher in the northern regions of the sea (Dvoretsky and Dvoretsky 2015a).

Evenness of fauna abundance (J) and the Shannon index (H') are frequently used to assess the structure of zooplankton communities. The mean values we obtained (J=0.61, H'=1.88) were low, approximately 1.2 – 1.5 times smaller than in the south of the Barents Sea in autumn (Fomin 1978). At the same time, the values of diversity indices were consistent with the numbers typical for the winter season within the confines of Murmansk coastal waters and Pechora waters (Dvoretsky and Dvoretsky 2015b, Dvoretsky and Dvoretsky 2014). Hence, the zooplankton community in the central part of the Barents Sea in November 2010 had a very simple organisation, with predominance of two or three dominant species, which is typical for the season (Dvoretsky and Dvoretsky 2015a).

Copepods *C. finmarchicus* and *M. longa* are some of the most dominant species of zooplankton in the central sector of the Barents Sea. A review of the state of their populations enables assessment of the trophic resources of plankton-feeder fish in a specific research season and influence of the climate on the community's biota. We discovered predominance of small crustaceans of senior age groups in the population of *C. finmarchicus* and *M. longa*. This ratio of different stages is typical of the autumn-winter season. As a rule, small crustaceans begin sinking into the depths of the Barents Sea as early as late July, and the wintering resource is represented by stage V copepods (Timofeev 2000). Remarkably, junior copepodites were also found in the *M. longa* population, though in smaller quantities. This result is to be expected, since *Metridia* spp. is an omnivorous species capable of reproducing throughout the year, including in autumn and winter (Haq 1967).

The study revealed that the quantity of zooplankton was correlated to the hydrological aspects. Relationsips of this sort are generally typical of the Barents Sea zooplankton in the winter season (see Table 3). Notably, the increase in abundance of zooplankton with the decrease in minimum temperature and increase in salinity can be explained by the fact that, during the winter, zooplankton tends to gather in the deep-water strata characterised by a lower temperature and higher salinity of waters (Timofeev 2000, Dvoretsky and Dvoretsky 2015a). On the other hand, salinity increase is obviously caused by the rich influx of Atlantic waters. It has been established that the dominant boreal species *C. finmarchicus* is associated with these waters (Wassmann et al. 2006, Timofeev 2000), which is why an increase of salinity as expected leads to an increase in the zooplankton biomass. Similar trends were observed for zooplankton near the Svalbard archipelago (Blachowiak-Samolyk et al. 2008).

Analysis of the quantitative distribution of zooplankton showed a close direct correlation between the abundance and biomass of the zooplankton and the depth of sampling (see Table 3). This result is explained by the lifecycle specifics of the dominant zooplankton species in the Barents Sea. Large plant-feeders of genus *Calanus* begin migrating into deeper strata at the end of summer and spend the autumn-winter season in deep-water troughs (Timofeev 2000, Falk-Petersen et al. 2007). On the other hand, the abundance of zooplankton did not depend on the time of sampling, which is most likely explained by the polar night. Records show that vertical migration of zooplankton in this period is not as significant as in periods with a distinct day-night cycle (Falk-Petersen et al. 2007, Bogorov 1974).

High biomass of large copepods might indicate that the study area potentially plays an important role in the nutrition of young and full-grown fish. In other words, the central part of the Barents Sea at the beginning of winter is characterised as an aquatorium with a high feeding potential for plankton-feeder fish. This is well demonstrated by a comparison with long-time data obtained in the summer season for standard strata of the Barents Sea (Atlantic waters): the biomass of feed zooplankton in June-July was 200–1000 mg wet mass/m^3 (Nesterova 1990), which is only slightly more (see Table 2) than we discovered in the winter season around the Central Trough.

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References

- Anonymous (1971) Instruktsiya po sboru i obrabotke planktona [Manual to collecting and treatment of plankton]. VNIRO, Moscow, 82 pp.
- Anonymous (2004) Climatic atlas of the Arctic Seas 2004: Part I. Database of the Barents, Kara, Laptev, and White Seas – Oceanography and Marine Biology. NOAA Atlas NESDIS 58. US Government Printing Office, Washington, 148 pp.
- Anonymous (2011) Kompleksnye issledovaniya bol'shikh morskikh ekosistem Rossii [Integrated investigations of the Russian Large Marine Ecosystems]. Kola Science Russian Academy of Sciences Press, Apatity, 516 pp.

- Anonymous (2012) Sostoyanie biologicheskikh syr'evykh resursov Barentseva morya i Severnoi Atlantiki v 2012 g. [Status of biological living resources of the Barents Sea and North Atlantic in 2012]. PINRO Press, Murmansk, 123 pp.
- Blachowiak-Samolyk K, Søreide JE, Kwasniewski S, Sundfjord A, Hop H, Falk-Petersen S, Hegseth EN (2008) Hydrodynamic control of mesozooplankton abundance and biomass in northern Svalbard waters (79–81°N). Deep-Sea Research Part II 55: 2210–2224. https://doi.org/10.1016/j.dsr2.2008.05.018
- Bogorov VG (1974) Plankton Mirovogo okeana [Plankton of the World Ocean]. Nauka, Moscow, 320 pp.
- Bray RJ, Curtis JT (1957) An ordination of the upland forest communities of southern Wisconsin. Ecological Monographs 27: 325–349. https://doi.org/10.2307/1942268
- Dvoretsky VG, Dvoretsky AG (2013) Zimnii zooplankton yugo-zapadnoi chasti Barentseva morya (mart 2007 g.) [Winter zooplankton from the south-western Barents Sea (March 2007)]. Rybnoe khozyaystvo 2: 74–78.
- Dvoretsky VG, Dvoretsky AG (2014) The biodiversity of zooplankton communities of the West Arctic seas. Russian Journal of Marine Biology 40: 95–99. https://doi.org/10.1134/S1063074014020035
- Dvoretsky VG, Dvoretsky AG (2015a) Ekologiya zooplanktonnykh soobshchestv Barentseva morya i sopredel'nykh vod [Ecology of zooplankton communities in the Barents Sea and adjacent waters]. Renome Press, St. Petersburg, 736 pp.
- Dvoretsky VG, Dvoretsky AG (2015b) Early winter mesozooplankton of the coastal south-eastern Barents Sea. Estuarine, Coastal and Shelf Science 152: 116–123. https://doi.org/10.1016/j.ecss.2014.11.016
- Falk-Petersen S, Timofeev S, Pavlov V, Sargent JR (2007) Climate variability and pos-sible effects on arctic food chains: The role of *Calanus*. Arctic Alpine Ecosystems and People in a Changing Environment. Springer Verlag, Berlin, 147–166. https://doi.org/10.1007/978-3-540-48514-8_9
- Fomin OK (1978) Nekotorye dinamicheskie kharakteristiki zooplanktona v pribrezh'e Murmana [Some dynamic features of zooplankton of Murmansk coast]. Zakonomernosti bioproduktsionnykh protsessov v Barentsevom more [Regularities of bio-production processes in the Barents Sea] Kola Science Russian Academy of Sciences Press, Apatity, 72–91.
- Haq SM (1967) Nutritional physiology of *Metridia lucens* and *M. longa* from the Gulf of Maine. Limnology and Oceanography 12(1): 40–51. https://doi.org/10.4319/lo.1967.12.1.0040
- Matishov GG, Dzhenyuk SL, Denisov VV, Zhichkin AP, Moiseev DV (2012) Climate and oceanographic processes in the Barents Sea. Ber. Polarforsch. 640: 63–73.
- Nesterova VN (1990) Biomassa planktona na putyakh dreifa lichinok treski (spravochnyi material). [Plankton biomass along the drift routes of cod larvae (reference material)]. PINRO Press, Murmansk 64 pp.
- Olsen E, Aanes S, Mehl S, Holst JC, Aglen A, Gjøsæter H (2010) Cod, haddock, saithe, herring, and capelin in the Barents Sea and adjacent waters: a review of the biological value of the area. ICES Journal of Marine Science 67: 87–101. https://doi.org/10.1093/icesjms/fsp229
- Timofeev SF (2000) Ekologiya morskogo zooplanktona [Ecology of the marine zooplankton]. MGPI Press, Murmansk, 216 pp.
- Wassmann P, Reigstad M, Haug T, Rudels B, Carroll ML, Hop H, Gabrielsen GW, Falk-Petersen S, Denisenko SG, Arashkevich E, Slagstad D (2006) Food webs and carbon flux in the Barents Sea. Progress in Oceanography 71: 232–287. https://doi.org/10.1016/j.pocean.2006.10.003
- Zar JH (1999) Biostatistical analysis (4th edn). Prentice-Hall, Inc., New Jersey, 931 pp.