

Preliminary study on community structures of meiofauna in the middle and eastern Chukchi Sea

Dingyong Huang¹, Jianjia Wang¹, Qianhui Zeng^{1,2}, Jiaguang Xiao¹, Peng Tian¹, Sujing Fu³, Feng Guo¹, Wentao Niu^{1*}

¹Third Institute of Oceanography, Ministry of Natural Resources, Xiamen 361005, China

²Ocean College, Shandong University, Weihai 264209, China

³Key Laboratory of the Coastal and Wetland Ecosystem of Ministry of Education, Xiamen University, Xiamen 361005, China

Received 31 December 2019; accepted 14 June 2020

© Chinese Society for Oceanography and Springer-Verlag GmbH Germany, part of Springer Nature 2021

Abstract

Sediment core samples were collected from 17 stations in the middle and eastern Chukchi Sea during the sixth Chinese National Arctic Research Expedition (CHINARE-Arctic) in summer 2014. The samples were analyzed for composition, abundance, biomass, vertical distribution, size spectra, and ecological indexes of meiofauna. A total of 14 meiofauna taxa were detected, and the free-living marine nematodes comprised the most dominant taxon, accounting for 97.21% of the average abundance. The abundance and biomass of meiofauna were within ranges of $(218.12 \pm 85.83) - (7\ 239.38 \pm 1\ 557.15)$ ind./ $(10\ \text{cm}^2)$ and $(130.28 \pm 52.17) - (3\ 309.56 \pm 1\ 751.80)$ $\mu\text{g}/(10\ \text{cm}^2)$, with average values of $(2\ 391.90 \pm 1\ 966.19)$ ind./ $(10\ \text{cm}^2)$ and $(1\ 549.73 \pm 2\ 042.85)$ $\mu\text{g}/(10\ \text{cm}^2)$ (according to dry weight) respectively. Furthermore, 91.26% of the individuals were distributed in the top layer of 0–5 cm of surface sediment, and 90.84% had sizes of 32–250 μm . Group diversity index of meiofauna in the survey area was low, and the variation of abundance was the main difference in meiofauna communities among all stations. Abundance and biomass of meiofauna were not significantly correlated with environmental factors except concentration of nutrient Si in bottom seawater. Abundance of meiofauna in shallow water of marginal seas in the Pacific sector of the Arctic Ocean is likely at a same level and higher than that in most of China sea areas, suggesting that the shallow water of the summer Chukchi Sea is a continental shelf area with rich resources of meiofauna. The Chukchi Sea is important for studying the ecosystem of the Arctic Ocean and environmental responses. However, studies on meiofauna in the Chukchi Sea are still not enough, and in the future, natural and human disturbances may increase due to global warming, the Arctic channel opening, and other factors. Thus, more studies on meiofauna should be required, in order to know more about how the Arctic benthic community would alter.

Key words: Arctic Ocean, Chukchi Sea, meiofauna, community structure, abundance

Citation: Huang Dingyong, Wang Jianjia, Zeng Qianhui, Xiao Jiaguang, Tian Peng, Fu Sujing, Guo Feng, Niu Wentao. 2021. Preliminary study on community structures of meiofauna in the middle and eastern Chukchi Sea. Acta Oceanologica Sinica, 40(6): 83–91, doi: 10.1007/s13131-021-1777-3

1 Introduction

Meiofaunas are widely distributed in the seabed and form a particular animal community in sediment. Meiofaunas are small in size and large in quantity, and have short life cycles, high turnover rates, asynchronous breeding, and no planktonic phase. These characteristics make them an important indicator for monitoring marine ecosystems and assessment of ecosystem health system (Du et al., 2018).

The Chukchi Sea is the largest marginal sea of the Arctic Ocean, locating at the north of the Bering Strait (Wu et al., 2019). This area is a channel where Pacific seawater enters the Arctic Ocean Basin and one of the areas that the change of Arctic sea ice is most obvious (Steele et al., 2008; Gemery, 2012; Barber et al., 2015; Lee et al., 2019). Ecosystem reorganization may be triggered, mostly basing the changing seasonal sea-ice conditions, and the benthic community would be altered through the food web (Grebmeier et al., 2006; Gemery, 2012). The Chukchi

Sea is important for studying the ecosystem of the Arctic Ocean and environmental responses (Wu et al., 2019). Compared to other Arctic regions, the Chukchi Sea is considered highly productive, and, on the continental shelf of the Chukchi Sea, high abundance and biomass of epibenthic organisms can be found (Ravelo et al., 2014). Strong pelagic-benthic coupling and high level of primary production of shallow water contribute to this thrive benthic community, although the abundance of meiofauna are variable, ranging from 90 ind./ $(10\ \text{cm}^2)$ to $>5\ 000$ ind./ $(10\ \text{cm}^2)$ (Snider et al., 1984; Soltwedel, 2000; Alves, 2015; Hajduk, 2015; Zeng, 2016).

However, in many of the Arctic and sub-polar regions, meiofauna used to be neglected (Hajduk, 2015). International research on meiofauna in sediments used to involve the Laptev Sea (Vanaverbeke et al., 1997; Chertoprud et al., 2018; Portnova et al., 2019), the Beaufort Sea (Bessière et al., 2007), the Canadian Basin (concerned with the larger free-living nematodes) (Sharma and

Foundation item: The National Youth Science Fund under contract No. 41606207; the National Natural Science Foundation of China under contract No. 41876176; the Chinese Polar Environment Comprehensive Investigation and Assessment Programs under contract No. CHINARE2013-03-05.

*Corresponding author, E-mail: wentaoniu@tio.org.cn

Bluhm, 2011) and even more in the Atlantic Arctic sector (Pfnankuche and Thiel, 1987; Soltwedel et al., 2005; Andreasen, 2019), while, the Chukchi Sea was rarely a focus (Lin et al., 2014). This study analyzes sediment core samples collected from 17 shallow water stations in the middle and eastern Chukchi Sea during the sixth CHINARE-Arctic in July to August 2014. The aim is to understand the characteristics of the meiofauna community in detail and provide foundational data for studying the impacts of global climate change and human activities on the polar marine ecosystem.

2 Materials and methods

Meiofauna samples were collected from 17 stations in the Chukchi Sea shelf area 67°–75°N, 157°–169°W, depth ranging of 32–185 m, in summer 2014 (Fig. 1). Sediments were collected by a box-corer or multi-tube sampler one time at each station. The sampling area of box-corer was 0.25 m² and the diameter of multiple-corer was 9.8 cm. Three tubes with an inner diameter of 2.9 cm were inserted into sediment of the box-core or one tube of the multi-tube sampler to obtain three cores of sub-samples with thickness of 10 cm. Each core was divided into three layers from surface to bottom: 0–2 cm, 2–5 cm, and 5–10 cm immediately. All samples were preserved in 8% formaldehyde solution, and then sealed and stored at room temperature.

Sample processing in the lab was as follows. The samples were poured into the top layer of five-layer screens, which had screen apertures of 500 µm, 250 µm, 125 µm, 65 µm, and 32 µm from top to bottom (Mokievsky et al., 2004). They were then carefully rinsed with tap water filtered by filter of 5 µm pore size and the remained samples on each sieve were transferred to small sieves (screen aperture: 32 µm) separately, then, small sieves were immersed in a dyeing cylinder containing 0.1% Tiger Red solution (Rose Bengal Na Salt, C₂₀H₂O₅C₁₄I₄Na₂). After fully mixing, the samples were left to be stained for 30 min.

The stained samples were rinsed gently with filtered tap water until the color of water became light and transferred to vessels for microscopic examination. Meiofaunas were picked out under a dissection microscope and counted by taxon.

Excel and PRIMER 5 software were used to analyze the data and determine the abundance, biomass, and ecological indexes of meiofauna (Schonberg et al., 2014). Biomass was directly calculated by a conventional and convenient method based on conversion of the average individual dry weight (Widbom, 1984; Liu

et al., 2005; Wu and Mu, 2009; Liu et al., 2014) (Table 1). Statistical Product and Service Solutions 17.0 was used to carry out the correlation analysis and the station map was constructed by Ocean Data View 4 software.

Table 1. Individual dry weight of meiofauna taxon

Taxon	Individual dry weight/µg	Taxon	Individual dry weight/µg
Nematoda	0.40	Kinorhyncha	2.00
Copepoda	1.86	Tanaidacea	15.00
Polychaeta	14.00	Isopoda	15.00
Oligochaeta	14.00	Ostracoda	26.00
Bivalva	4.20	Others	3.50
Amphipoda	15.00		

3 Results

3.1 Composition

A total of 14 taxa of meiofauna were detected from the 17 stations in the Chukchi Sea: free-living marine Nematoda, benthic Copepoda (most of them were Harpacticoida), Polychaeta, Kinorhyncha, Oligochaeta, Tanaidacea, Isopoda, Cladocera, Cumacea, Bivalva, Tardigrada, Amphipoda, Ostracoda, and the indetermined taxon which included Nauplius and the rest of the individuals. At the 17 stations, Nematoda was the most abundant taxon, accounting for 97.35% of the average value, while the proportions of other taxa were very low (Polychaeta, 0.72%; Copepoda, 1.11%), as shown in Table 2. A relatively large number of Kinorhyncha were detected at a few stations and formed the second or third most dominant taxon at some stations. For example, 2.94% of the individuals were Kinorhyncha at Station 14S01 near Point Barrow locating in the Northeast Chukchi Sea, making it the second most dominant taxon after Nematoda.

3.2 Abundance

The average abundance was (2 391.90±1 966.19) ind./(10 cm²) overall (Table 2). The highest abundance, (7 239.38±1 557.15) ind./(10 cm²), was found at Station 14S01, which also had the highest abundance in the previous CHINARE-Arctic (Fig. 2). The second highest abundance of (6 158.37±4 488.87) ind./(10 cm²) occurred at Station 14R03, locating in the south Chukchi Sea. The third and fourth highest abundances were close to each other, (4 183.17±1 444.21) ind./(10 cm²) and (4 008.47±1 372.94) ind./(10 cm²), respectively, for Station 14R02 and Station 14S02.

Abundance at three stations (Station 14R09, Station 14S03 and Station 14R08) with bigger depth (185 m, 169 m and 181 m) in the North Chukchi Sea were relatively low: (218.12±85.83) ind./(10 cm²), (622.05±141.30) ind./(10 cm²) and (630.63±233.01) ind./(10 cm²), respectively.

3.3 Biomass

The average biomass was (1 245.04±1 007.09) µg/(10 cm²). Different from the composition of abundance, the maximum biomass, up to (3 309.56±1 751.80) µg/(10 cm²), appeared at Station 14R03 in the south Chukchi Sea (Fig. 3). This value was much higher than the other stations, even in the previous CHINARE-Arctic as well. The second highest value was at Station 14S01 near Point Barrow, (3 688.51±759.26) µg/(10 cm²). Station 14S02 (also near Point Barrow) had the third highest biomass, (2 184.13±744.85) µg/(10 cm²). The lowest value was (138.84±50.39) µg/(10 cm²) at Station 14R09, which also had the lowest abundance. Like the composition of abundance, Nematoda was still the most

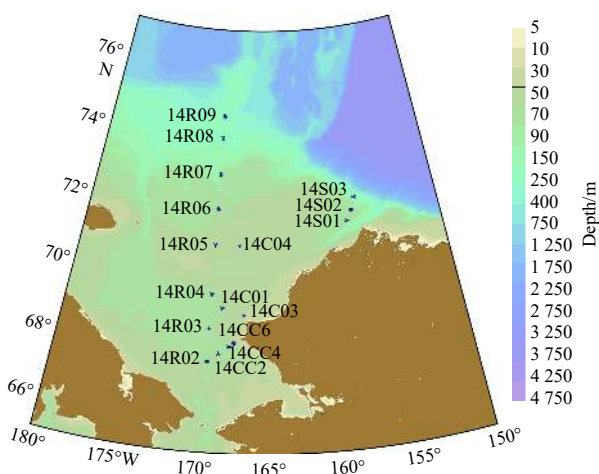


Fig. 1. Map of sampling stations.

Table 2. The abundance of meiofauna with standard deviation

Station	Depth /m	Nematoda		Copepoda		Polychaeta		Kinarhyncha		Total abundance of station / (ind.·(10 cm ²) ⁻¹)
		Abundance/ (ind.·(10 cm ²) ⁻¹)	Proportion/%	Abundance/ (ind.·(10 cm ²) ⁻¹)	Proportion/%	Abundance/ (ind.·(10 cm ²) ⁻¹)	Proportion/%	Abundance/ (ind.·(10 cm ²) ⁻¹)	Proportion/%	
14R02	50	4 174.59±1 457.55	99.79	0	0	7.57±13.12	0.18	0	0	4 183.17±1 444.21
14R03	54	5 680.23±4 553.07	92.24	442.30±130.29	7.18	9.59±7.16	0.16	8.08±6.31	0.13	6 158.37±4 488.87
14R04	52	1 223.39±366.13	98.06	7.57±1.51	0.61	14.14±15.77	1.13	1.51±1.51	0.12	1 247.63±382.04
14R05	43	2 819.41±1 110.31	97.18	27.27±1.51	0.94	13.63±8.02	0.47	38.88±30.46	1.34	2 901.21±1 140.40
14R06	51	2 289.26±648.69	97.30	9.59±9.86	0.41	30.29±25.84	1.29	21.71±17.56	0.92	2 352.88±698.35
14R07	73	2 192.82±536.48	97.93	14.14±16.62	0.63	25.25±14.87	1.13	4.04±4.37	0.18	2 239.27±514.87
14R08	181	611.95±229.46	97.04	6.56±3.81	1.04	5.55±5.73	0.88	5.05±3.15	0.80	630.63±233.01
14R09	185	208.02±82.26	95.37	6.56±5.73	3.01	2.02±2.31	0.93	0.50±0.87	0.23	218.12±85.83
14C01	50	1 347.60±189.44	97.73	10.10±8.61	0.73	7.57±4.54	0.55	7.57±4.01	0.55	1 378.91±191.67
14C03	32	1 636.41±591.41	97.89	10.60±5.46	0.63	15.65±8.88	0.94	7.07±4.63	0.42	1 671.75±594.62
14C04	45	1 506.65±936.75	96.98	7.07±3.81	0.45	14.14±11.47	0.91	22.22±12.88	1.43	1 553.61±928.03
14CC2	57	2 103.45±482.71	99.98	0.50±0.87	0.02	0	0	0	0	2 103.96±483.54
14CC4	49	1 097.67±1 199.21	98.02	15.15±17.86	1.35	5.05±3.81	0.45	0	0	1 119.89±1 218.38
14CC6	43	1 021.94±462.76	98.92	4.54±4.01	0.44	4.04±4.63	0.39	0.50±0.87	0.05	1 033.04±462.06
14S01	64	6 932.91±1 508.52	95.77	65.64±26.47	0.91	21.21±10.60	0.29	213.07±57.57	2.94	7 239.38±1 557.15
14S02	72	3 876.69±1 323.67	96.71	19.19±14.94	0.48	29.79±13.23	0.74	80.79±32.36	2.02	4 008.47±1 372.94
14S03	169	609.93±135.16	98.05	0.50±0.87	0.08	11.61±6.31	1.87	0	0	622.05±141.30
Mean	75	2 313.70±1 862.52	97.35	38.08±105.28	1.11	12.77±9.25	0.72	24.18±52.85	0.66	2 391.90±1 966.19

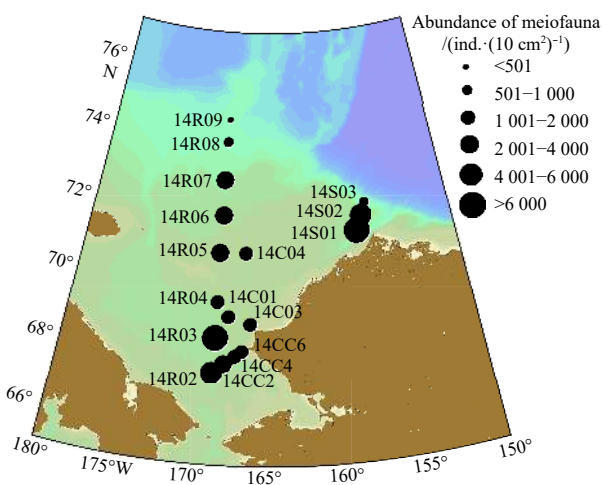


Fig. 2. Distribution of abundance of meiofauna.

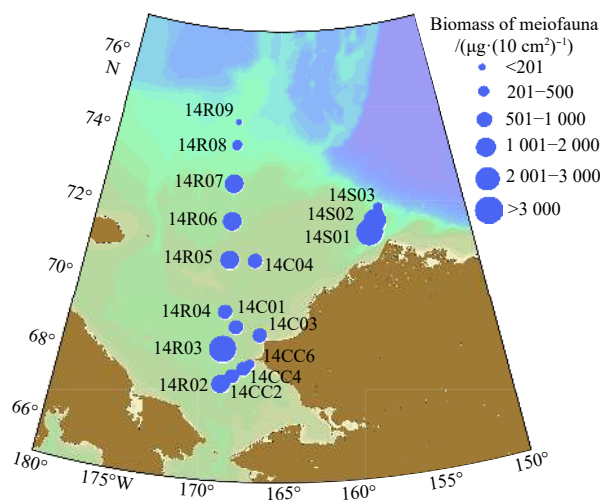


Fig. 3. Distribution of biomass of meiofauna.

dominant taxon in terms of biomass, accounting for 73.77% of the average (Fig. 4), followed by Polychaeta (17.81%), Copepoda (3.78%), and Kinorhyncha (2.43%). The proportions of other taxa were very low.

3.4 Vertical distribution

The abundance proportions of meiofauna distributed in sediments at 0–2 cm, 2–5 cm, and 5–10 cm were 60.75%, 30.51%, and 8.74%, respectively, showing a decrease from the upper layer to the bottom layer (Cai et al., 2012). The sampling efficiency of the layer at 0–5 cm was as high as 91.26% (Fig. 5). The vertical distribution of the dominant taxon Nematoda was very similar to that of the entire meiofauna community, while the abundance and occurrence rate of other taxa were too low, leading to an inconspicuous vertical distribution characteristic.

3.5 Size spectra

In this study, the size of meiofauna is defined as between the

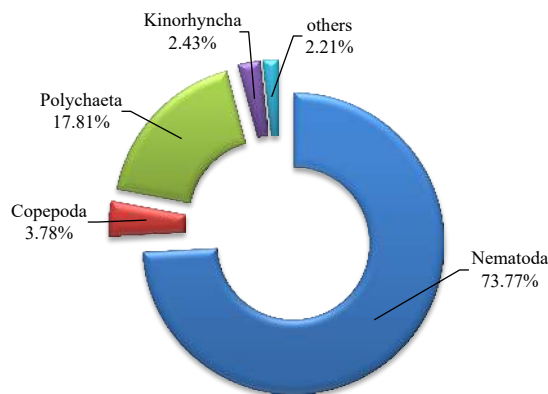


Fig. 4. Biomass compositions of meiofauna.

smallest aperture of the sieve it could pass and the largest aperture of the sieve it was retained. Results showed that the sizes of

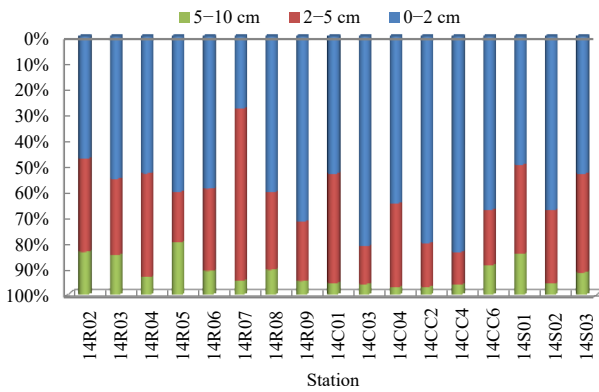


Fig. 5. Vertical distributions of meiofauna.

most individuals of meiofauna (90.84%) were within 32–250 μm , among which individuals of 65–125 μm accounted for the highest proportion (42.15%), followed by 125–250 μm (37.79%) and 32–65 μm (10.90%), as shown in Fig. 6a.

The size composition of dominant taxa was also different (Fig. 6b). Nematoda were mainly in the size of 65–250 μm , and the propor-

tion of larger or smaller individuals was relatively small. Copepoda were mainly 125–250 μm , followed by 250–500 μm , and the proportion of small individuals was relatively low. Polychaeta were larger and mainly 250–500 μm , followed by 125–250 μm , and few individuals were smaller than 125 μm . While Kinorhyncha were dominated by smaller individuals within 65–125 μm , followed by 125–250 μm , and only a few ones were up to 250 μm . Among the four dominant taxa, Nematoda and Kinorhyncha had higher proportions of small individuals 32–125 μm , while Polychaeta and Copepoda were larger in size.

3.6 Ecological indexes

There were 76% of the stations had more than 5 taxa, among which Stations 14C01 and 14S01 had the most taxa (10 taxa) (Table 3). The evenness index (J') and diversity index (H') averaged 0.079 7 and 0.141 5, respectively, and the highest value (1.137 0) of richness index (d) appeared at Station 14C01. Numerical difference was mainly caused by the big proportion of Nematoda, which also made the dominance index (λ) greater than 0.9. On the whole, that the abundance of the dominant taxon Nematoda was so high and the other groups were relatively low resulted in the low evenness and diversity of the meiofauna community in this area.

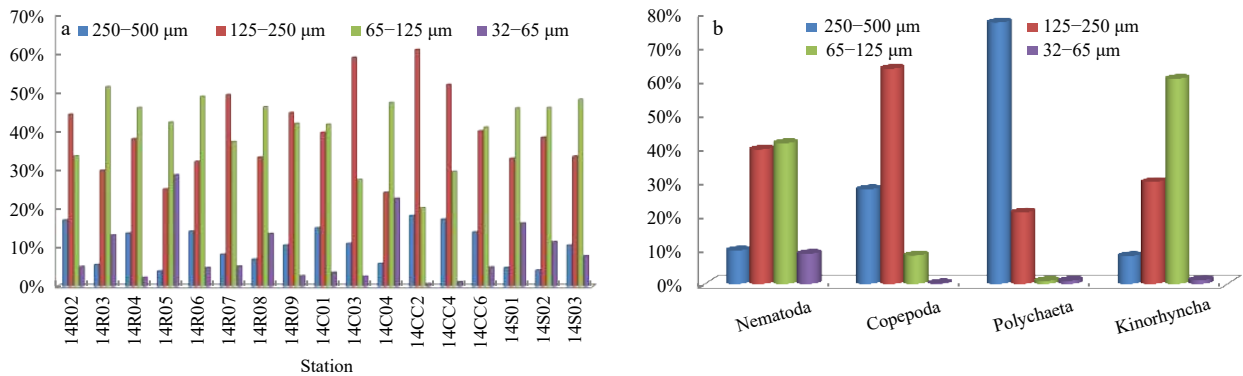


Fig. 6. Size spectra of meiofauna. a. Size spectra of meiofauna at each station; b. size spectra of dominant taxa.

Table 3. Ecological indexes of meiofauna

Station	d	J'	H'	λ
14R02	0.332 5	0.011 3	0.015 7	0.995 9
14R03	0.531 4	0.167 6	0.300 3	0.855 9
14R04	0.640 0	0.064 4	0.115 5	0.961 7
14R05	0.577 6	0.089 4	0.160 2	0.944 7
14R06	0.591 9	0.086 5	0.155 0	0.946 9
14R07	0.595 4	0.069 2	0.124 0	0.959 1
14R08	0.701 3	0.096 6	0.173 0	0.941 9
14R09	0.659 1	0.144 7	0.232 9	0.910 6
14C01	1.137 0	0.063 9	0.147 1	0.955 2
14C03	0.616 9	0.071 8	0.128 7	0.958 3
14C04	0.747 0	0.089 1	0.173 5	0.940 8
14CC2	0.120 0	0.003 2	0.002 2	0.999 5
14CC4	0.389 4	0.081 9	0.113 6	0.960 9
14CC6	0.655 9	0.041 0	0.073 5	0.978 6
14S01	0.940 4	0.092 4	0.212 8	0.918 1
14S02	0.668 2	0.091 2	0.177 4	0.935 8
14S03	0.281 0	0.090 5	0.099 4	0.961 8
Mean	0.599 1	0.079 7	0.141 5	0.948 6

Note: d , richness index; J' , evenness index; H' , diversity index; λ , dominance index.

3.7 Community similarity

Using the abundance of all meiofauna taxa of each station, cluster and multidimensional scaling (MDS) analysis diagrams were constructed by Primer 5 software. The results showed that 16 of 17 stations were grouped into a cluster with high abundance as a key feature at the similarity coefficient of 44.92% (Figs 7a, b and 8). The remaining station excluded from this cluster was Station 14R09, which was grouped by itself due to extra low abundance station.

Between the similarity coefficients (44.92%, 55.22%), two groups (including 16 stations) with relatively different abundance can be further divided. Four stations with the highest

abundance (HA) were Station 14R02 and Station 14R03 in the south of the Chukchi Sea and Station 14S01 and Station 14S02 near Point Barrow. These four were grouped together as Combination 1, which had a similarity coefficient of 75.57% and an average abundance of $(5\,397.35 \pm 1\,567.96)$ ind./ (10 cm^2) . The remaining 12 stations were grouped into Combination 2 (low abundance, LA), which had a similarity coefficient of 55.22% and average abundance of $(1\,571.24 \pm 709.74)$ ind./ (10 cm^2) . Considering the large dominance of Nematoda at all stations, it can be seen that the variation of abundance was the main difference in meiofauna communities among all stations.

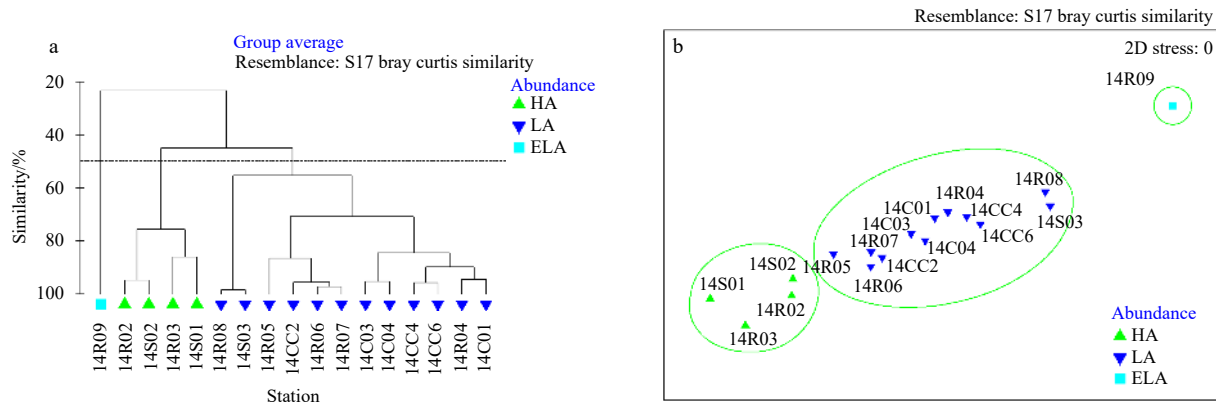


Fig. 7. Cluster and MDS analysis. a. Cluster analysis; b. MDS analysis. HA, group with the highest abundance; LA, group with low abundance; ELA, group with extra low abundance.

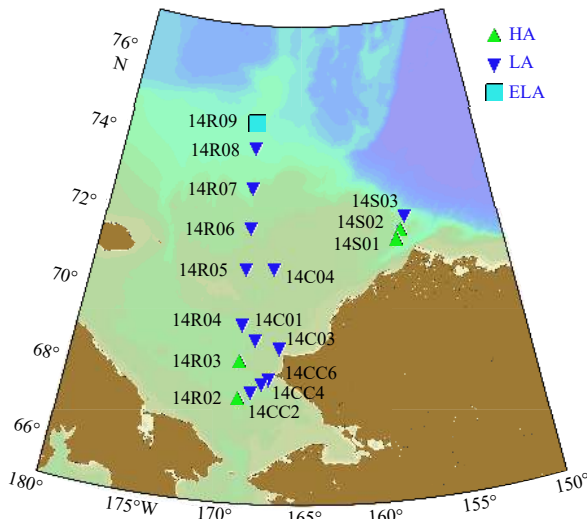


Fig. 8. Distribution of groups of meiofauna. HA, group with the highest abundance; LA, group with low abundance; ELA, group with extra low abundance.

3.8 Correlation with environmental factors

Environmental factors were shown in Tables 4 and 5, issued by the Resource-sharing Platform of Polar Samples (<http://birds.chinare.org.cn>). Table 6 showed that the correlations of the abundance and biomass of meiofauna with environmental factors were all not significant except concentration of nutrient Si in bottom seawater (abundance with Si, $p=0.008<0.01$; biomass with Si, $p=0.01<0.05$; both $n=11$) (Tables 1, 3 and 4). At the same time, the abundance and biomass of meiofauna were both positively correlated with silt content ($n=7$), abundance of zooplankton ($n=5$), concentration of nutrient P in bottom seawater ($n=11$) and DIN in bottom seawater (total of concentrations of NO_3^- and NO_2^- , $n=11$), and the latter two correlations were stronger. On the other side, the correlations with depth ($n=17$), sand content ($n=7$), and sorting coefficient of the sediment ($n=7$) were all negative. The negative correlation was strongest for sorting coefficient of the sediment, followed by depth. Correlations with the median diameter (Md) ($n=7$), clay content ($n=7$), north latitude (NL) ($n=17$), and average diameter (Mz) of sediments ($n=7$) were very weak. Correlation analysis between ecological indexes and environmental factors revealed that evenness index (J') was ex-

Table 4. Environmental factors for some stations

Station	$Md(\Phi)$	$Mz(\Phi)$	$\delta(\Phi)$	Sand/%	Silt/%	Clay/%	Zooplankton/(ind. $\cdot\text{m}^{-3}$)
14R07	6.655	6.463	1.783	11.84	66.51	21.64	168.22
14R08	6.441	6.222	1.797	13.32	70.72	15.96	204.43
14R09	6.772	6.680	1.779	7.70	64.05	28.25	269.15
14C01	5.802	5.953	1.577	10.38	77.41	12.23	338.94
14S01	6.282	6.270	1.739	11.05	70.39	18.56	-
14S02	6.701	6.668	1.384	3.48	79.24	17.28	434.33
14S03	6.238	5.980	1.858	15.29	72.61	12.09	-

Note: -, no data. Md , median diameter; Mz , average diameter; δ , sorting coefficient of the sediment.

Table 5. Concentrations of nutrients in bottom seawater

Sample	Depth/m	Sampling depth/m	P/($\mu\text{mol}\cdot\text{L}^{-1}$)	DIN/($\mu\text{mol}\cdot\text{L}^{-1}$)	Si/($\mu\text{mol}\cdot\text{L}^{-1}$)
14R02	50	46	1.81	14.66	24.92
14R03	54	50	0.79	0.57	8.46
14R04	52	49	0.89	0.80	5.32
14R05	43	-	-	-	-
14R06	51	48	1.05	3.30	19.15
14R07	73	66	2.26	22.93	61.47
14R08	181	-	-	-	-
14R09	185	-	-	-	-
14C01	50	47	0.79	0.79	7.52
14C03	32	-	-	-	-
14C04	45	41	0.96	1.62	5.61
14CC2	57	54	1.41	13.09	12.28
14CC4	49	44	0.81	0.99	4.56
14CC6	43	40	0.63	0.32	8.00
14S01	64	59	1.84	14.62	47.22
14S02	72	-	-	-	-
14S03	169	-	-	-	-

Note: -, no data.

Table 6. Spearman correlation coefficient

		Abundance				Abundance of meiofauna	Biomass of meiofauna	d	J'	H'	λ
		Nematoda	Copepoda	Polychaeta	Kinorhyncha						
Md	Coe.	-0.107	0.126	0.036	-0.107	-0.107	-0.179	-0.357	0.607	0.571	-0.571
	Sig.(Bil.)	0.819	0.788	0.939	0.819	0.819	0.702	0.432	0.148	0.180	0.180
	n	7	7	7	7	7	7	7	7	7	7
Mz	Coe.	0.036	0.288	0.143	0.000	0.036	0.000	-0.321	0.571	0.643	-0.643
	Sig.(Bil.)	0.939	0.531	0.760	1.000	0.939	1.000	0.482	0.180	0.119	0.119
	n	7	7	7	7	7	7	7	7	7	7
δ	Coe.	-0.571	-0.721	-0.357	-0.750	-0.571	-0.536	-0.607	0.143	-0.500	0.500
	Sig.(Bil.)	0.180	0.068	0.432	0.052	0.180	0.215	0.148	0.760	0.253	0.253
	n	7	7	7	7	7	7	7	7	7	7
Sand	Coe.	-0.250	-0.505	-0.143	-0.464	-0.250	-0.250	-0.357	-0.143	-0.679	0.679
	Sig.(Bil.)	0.589	0.248	0.760	0.294	0.589	0.589	0.432	0.760	0.094	0.094
	n	7	7	7	7	7	7	7	7	7	7
Silt	Coe.	0.286	0.09	0.393	0.357	0.286	0.321	0.286	-0.464	-0.321	0.321
	Sig.(Bil.)	0.535	0.848	0.383	0.432	0.535	0.482	0.535	0.294	0.482	0.482
	n	7	7	7	7	7	7	7	7	7	7
Clay	Coe.	0.107	0.396	0.000	0.071	0.107	0.036	-0.107	0.464	0.643	-0.643
	Sig.(Bil.)	0.819	0.379	1.000	0.879	0.819	0.939	0.819	0.294	0.119	0.119
	n	7	7	7	7	7	7	7	7	7	7
Depth	Coe.	-0.162	-0.113	-0.029	-0.102	-0.162	-0.190	0.049	0.488*	0.288	-0.278
	Sig.(Bil.)	0.535	0.666	0.911	0.697	0.535	0.465	0.852	0.047	0.262	0.279
	n	17	17	17	17	17	17	17	17	17	17
Zooplankton	Coe.	0.300	0.359	0.300	0.700	0.300	0.300	0.500	-0.100	0.500	-0.500
	Sig.(Bil.)	0.624	0.553	0.624	0.188	0.624	0.624	0.391	0.873	0.391	0.391
	n	5	5	5	5	5	5	5	5	5	5
NL	Coe.	-0.279	0.077	0.363	0.317	-0.279	-0.228	0.404	0.623**	0.527*	-0.515*
	Sig.(Bil.)	0.277	0.768	0.152	0.215	0.277	0.379	0.107	0.008	0.030	0.035
	n	17	17	17	17	17	17	17	17	17	17
P	Coe.	0.592	-0.073	0.478	0.106	0.592	0.574	-0.205	-0.005	-0.046	0.055
	Sig.(Bil.)	0.055	0.831	0.137	0.757	0.055	0.065	0.545	0.989	0.894	0.873
	n	11	11	11	11	11	11	11	11	11	11
DIN	Coe.	0.536	-0.136	0.388	-0.009	0.536	0.518	-0.282	-0.091	-0.145	0.136
	Sig.(Bil.)	0.089	0.689	0.238	0.979	0.089	0.102	0.401	0.790	0.670	0.689
	n	11	11	11	11	11	11	11	11	11	11
Si	Coe.	0.745**	0.027	0.402	0.202	0.745**	0.709*	-0.118	0.000	0.082	-0.073
	Sig.(Bil.)	0.008	0.937	0.221	0.552	0.008	0.015	0.729	1.000	0.811	0.832
	n	11	11	11	11	11	11	11	11	11	11

Note: Coe., coefficient; Sig., significance; Bil., bilateral; * $p < 0.05$; ** $p < 0.01$; d , richness index; J' , evenness index; H' , diversity index, λ , dominance index; δ , sorting coefficient of the sediment.

tremely significant positively correlated with NL ($p=0.008<0.01$, $n=17$), so did diversity index (H') and dominance index (λ) but at significant level ($p=0.030<0.05$ and $p=0.035<0.05$, respectively, both $n=17$). Besides, J' was significant correlated with depth ($p=0.047<0.05$, $n=17$). However, due to the small amount of stations for correlation analysis of some environmental factors, the significance of correlations may not be fully detected.

4 Discussion

In the four times of CHINARE-Arctic (the 1st, 4th, 5th, and 6th), the 5th expedition showed lower abundance of meiofauna, but the results of the other three expeditions were very close and had an average of about 2 680 ind./(10 cm^2). Excluding the three stations with bigger depth in this study (Station 14R08, Station 14R09, and Station 14S03), depths of the other 14 stations were 32–73 m and similar to the other three expeditions in the Chukchi Sea (Table 7). Comparing with the results of the other three expeditions, the average abundance of these 14 stations was higher, and Station 14S01 showed the highest abundance of all expeditions.

The Chukchi Sea is the confluence of the Pacific Ocean and Arctic Ocean and shows an efficient organic carbon “sink” area (Grebmeier, 1993). The microbial activities here were not significantly inhibited by the low temperature, and the southern Chukchi Sea featured a high rate of oxygen respiration in the sediment and high benthic biomass (Grebmeier, 1993). Even on the Arctic shelf, where is in the northeast of the Chukchi Sea and adjacent to Point Barrow, microzooplankton and mesozooplankton consume no more than half of the total water column primary production, meaning that the benthic community likely had big quantities of organic matter for food (Campbell et al., 2009; Schonberg et al., 2014). Therefore, it is predictable that the large amount of organic carbon and microorganisms could sustain a flourishing meiofauna community, and this was supported by the Combination 1 (HA) before-mentioned. Besides, despite major of the 17 stations were grouped into the Combination 2 (LA), the abundance was still more than 1 000 ind./(10 cm^2) at each station except Station 14R08 and Station 14S03 with the bigger depths (>100 m). However, the Chukchi Sea also had some areas of low benthic biomass, for example, Station 14R09 in the

North Chukchi Sea. Hajduk (2015) also found that, in the eastern and northern Chukchi Sea, the abundance of meiofauna was only 9–13 ind./ cm^2 in the shallow Alaskan water (depth rang of 20–45 m) during August to October 2012 and even lower than some polar seas with greater depth.

In the Beaufort Sea (east of the Chukchi Sea), the average abundance of meiofauna was (2 746±448) ind./(10 cm^2) and six taxa: free-living marine Nematoda, benthic Copepoda, crustacean Nauplii, Polychaeta, Turbellarian, and Kinarhyncha were included (Bessière et al., 2007). The abundance of Nematoda accounted for 87% of the total abundance of meiofauna at the stations with depths of around 50 m (Bessière et al., 2007). Vanaverbeke et al. (1997) reported that the abundance of meiofauna was (2 683±299) ind./(10 cm^2) at a station with depth of 65 m in the Laptev Sea of the Arctic Ocean, which was at a similar north latitude to the Chukchi Sea, and the abundance of Nematoda accounted for 92% of the total. Portnova et al. (2019) analyzed the meiofauna community at 9 stations (depth arrange from 10 m to 91 m) in the Laptev Sea shelf, and their results showed that 14 major taxonomic groups were found and the abundance of meiofauna was (272±212) ind./(10 cm^2) to (2 534±1 980) ind./(10 cm^2), and nematodes constituted the dominant taxon (68%–91%) followed by harpacticoid copepods (2%–7%). This study has quite similar data to these reports despite the dominance of nematodes is higher. Combining with the results of China's previous Arctic expeditions in addition (Table 7) (Chen, 2003; Lin et al., 2014; Zeng, 2016), it seems that the average abundances of meiofauna are at the same high level in the shallow water areas of the marginal seas in the Pacific Sector of the Arctic Ocean (PSAO), and this is considered to be likely related to the high average advected and *in situ* food supply (Hajduk, 2015). Although the finest sieve used in sample analysis was different in the aforesaid reports, this abundance was higher than that in most of China seas (Zhang et al., 2017), and the shallow water of the summer Chukchi Sea is a continental shelf with rich resources of meiofauna (Table 8).

Grain size of sediment is a key factor in shaping meiofauna distribution (Alves, 2015), especially in the depth interval 0–200 m (Mokievsky et al., 2004). While, in the summer Chukchi Sea, Lin

Table 7. Meiofauna in shallow water of the Chukchi Sea

CHINARE-Arctic	Sample time	Depth/m	Diversity index (H')	Abundance/(ind.·(10 cm^2) ⁻¹)		Reference
				Range	Mean	
6th	Jul.–Aug. 2014	32–73	0.135 7	1 033.04–7 239.38	2 799.40	this study
5th	Jul.–Sept. 2012	26–64	0.090 4	76.24–5 359.59	1 470.52	Zeng (2016)
4th	Jul.–Sept. 2010	44–52	–	1 217–4 868	2 640	Lin et al. (2014)
1st	Jul.–Aug. 1999	40–92	–	2 039.5–3 019.1	2 598.33	Chen (2003)

Table 8. Abundance of meiofauna in other seas

Location	Sample time	Depth/m	Abundance of meiofauna/(ind.·(10 cm^2) ⁻¹)	Reference
Kongsfjorden	2014, 2015	260–350	1 310–3 890	Mazurkiewicz et al. (2019)
Barents Sea and Nansen Basin	1980	240–3 920	233–4 339	Pfannkuche and Thiel (1987)
Laptev Sea shelf	2015	10–91	272–2 534	Portnova et al. (2019)
Laptev Sea	1993	65–3 237	418–2 683	Vanaverbeke et al. (1997)
Beaufort Sea	2003, 2004	24–549	230–5 000	Bessière et al. (2007)
South Yellow Sea	2013	46–83	≤2 174.6	Xu et al. (2015)
Southern Coast of Shandong Province	2006	10–30	396.26–946.81	Wu and Mu (2009)
Changjiang River Estuary and East China Sea	2012	19.5–104	64–1 501	Shi et al. (2015)
Taiwan Strait	2006–2007	7–80	2.27–1 198.91	Zhang (2009)
Northern South China Sea	2010	87–1 600	234.28–2 140.88	Liu et al. (2014)

et al. (2014) found that concentrations of nutrients P and Si in bottom seawater was the primary factor causing the difference of meiofaunal abundance, followed by depth and sand fraction of sediments. This study got the similar result to Lin et al. (2014) that concentration of nutrient Si in bottom seawater was extremely significant with meiofaunal abundance, followed by concentrations of nutrient P and DIN which were both sampled in bottom seawater and nearly significant with abundance. However, the other environmental factors, such as depth, zooplankton and grain size of sediments, were all not significant with abundance, although it may be less rigorous due to not large enough amount of stations for some environmental factors. The Cluster and MDS analysis, as well as the correlations of meiofauna community and environmental factors (NL, depth), showed no regularities in the pattern of geographical distribution of the meiofaunal abundance and biomass. This may be resulted from the large microscale heterogeneity (Mokievsky et al., 2004).

5 Conclusions

In the summer of 2014, meiofauna were surveyed at 17 stations in the middle and eastern Chukchi Sea during the sixth CHINARE-Arctic. A total of 14 taxa were detected. Nematoda was the most abundant taxon, accounting for 97.21% of the average, while the proportions of the other taxa were very low. The abundance and biomass of meiofauna were within (218.12 ± 85.83) ind./ (10 cm^2) to $(7\ 239.38 \pm 1\ 557.15)$ ind./ (10 cm^2) and (138.84 ± 50.39) $\mu\text{g}/(10 \text{ cm}^2)$ to $(3\ 309.56 \pm 1\ 751.80)$ $\mu\text{g}/(10 \text{ cm}^2)$, respectively, and the averages were $(2\ 391.90 \pm 1\ 966.19)$ ind./ (10 cm^2) and $(1\ 245.04 \pm 1\ 007.09)$ $\mu\text{g}/(10 \text{ cm}^2)$, respectively. The sampling efficiency of the layer of surface sediment at 0–5 cm was up to 91.26%, and 90.84% of meiofauna were in the size spectra of 32–250 μm .

Although the abundance of meiofauna in the survey area was at a high level, the group diversity index of meiofauna was low. The similarity coefficients of meiofauna communities between most stations were more than 55.22%, and the variable abundance was the main source of difference. The correlations of the abundance and biomass of meiofauna with environmental factors were not significant at some stations except concentration of nutrient Si in bottom seawater.

Considering the importance of meiofauna in environmental qualities monitoring (Zhang et al., 2017), studies on meiofauna in the Chukchi Sea are still not enough. In the future, with the increasing of natural and human disturbances in the Chukchi Sea, for instance, the significant warming trend at a rate of about $+0.5^\circ\text{C}/\text{decade}$ since 1982 over the Arctic Ocean (Daryabor and Bjerrum, 2018) and the opening of the Arctic channel (Wang et al., 2017), more studies on meiofauna should be required, in order to know more about how the Arctic benthic community would alter.

Acknowledgements

We sincerely thank the crew of the sixth Chinese National Arctic Research Expedition for collecting the samples. The environmental data were issued by the Resource-sharing Platform of Polar Samples (<http://birds.chinare.org.cn>), and maintained by the Polar Research Institute of China (PRIC) and Chinese National Arctic and Antarctic Data Center (CN-NADC).

References

Alves A S R S. 2015. Use of benthic meiofauna in evaluating marine ecosystems' health: How useful can free-living marine nematodes be for Ecological Quality Status (EQS) assessment in trans-

itional waters? [dissertation]. Coimbra: University of Coimbra

Andreassen M H. 2019. Community composition, population structure and phylogeny of coastal sympagic meiofauna in eastern Svalbard [dissertation]. Bergen: University of Bergen

Barber D G, Hop H, Mundy C J, et al. 2015. Selected physical, biological and biogeochemical implications of a rapidly changing Arctic marginal ice zone. *Progress in Oceanography*, 139: 122–150, doi: [10.1016/j.pocean.2015.09.003](https://doi.org/10.1016/j.pocean.2015.09.003)

Bessière A, Nozais C, Brugel S, et al. 2007. Metazoan meiofauna dynamics and pelagic-benthic coupling in the Southeastern Beaufort Sea, Arctic Ocean. *Polar Biology*, 30(9): 1123–1135, doi: [10.1007/s00300-007-0270-6](https://doi.org/10.1007/s00300-007-0270-6)

Cai Lize, Fu Sujing, Yang Jie, et al. 2012. Distribution of meiofaunal abundance in relation to environmental factors in Beibu Gulf, South China Sea. *Acta Oceanologica Sinica*, 31(6): 92–103, doi: [10.1007/s13131-012-0256-2](https://doi.org/10.1007/s13131-012-0256-2)

Campbell R G, Sherr E B, Ashjian C J, et al. 2009. Mesozooplankton prey preference and grazing impact in the western Arctic Ocean. *Deep-Sea Research Part II: Topical Studies in Oceanography*, 56(17): 1274–1289, doi: [10.1016/j.dsr2.2008.10.027](https://doi.org/10.1016/j.dsr2.2008.10.027)

Chen Liqi. 2003. Marine Environment and Air-Sea Interaction in the Arctic Region (in Chinese). Beijing: China Ocean Press, 1–339

Chertoprud E, Abramova E, Korsun S, et al. 2018. Composition of Harpacticoida (Crustacea, Copepoda) of the Laptev Sea in comparison with faunas of adjacent Arctic seas. *Polar Biology*, 41(4): 697–712, doi: [10.1007/s00300-017-2229-6](https://doi.org/10.1007/s00300-017-2229-6)

Daryabor F, Bjerrum C J. 2018. Monitoring Arctic environmental changes through the application of the next generation coupled regional climate model. *Modern Approaches in Oceanography and Petrochemical Sciences*, 1(3): 37–39

Du Yongfen, Gao Shu, Liu Xiaoshou, et al. 2018. Meiofauna and nematode community characteristics indicate ecological changes induced by geomorphic evolution: a case study on tidal creek systems. *Ecological Indicators*, 87: 97–106, doi: [10.1016/j.ecoind.2017.12.037](https://doi.org/10.1016/j.ecoind.2017.12.037)

Gemery L. 2012. Spatial and temporal variability in benthic ostracode assemblages in the northern Bering and Chukchi seas, 1976 to 2010 [dissertation]. College Park: University of Maryland

Grebmeier J M. 1993. Studies of pelagic-benthic coupling extended onto the Soviet continental shelf in the northern Bering and Chukchi seas. *Continental Shelf Research*, 13(5–6): 653–668, doi: [10.1016/0278-4343\(93\)90098-1](https://doi.org/10.1016/0278-4343(93)90098-1)

Grebmeier J M, Overland J E, Moore S E, et al. 2006. A major ecosystem shift in the northern Bering Sea. *Science*, 311(5766): 1461–1464, doi: [10.1126/science.1121365](https://doi.org/10.1126/science.1121365)

Hajduk M. 2015. Density and distribution of meiofauna in the north-eastern Chukchi Sea [dissertation]. Fairbanks: University of Alaska Fairbanks

Lee Y, Min J O, Yang E J, et al. 2019. Influence of sea ice concentration on phytoplankton community structure in the Chukchi and East Siberian Seas, Pacific Arctic Ocean. *Deep-Sea Research Part I: Oceanographic Research Papers*, 147: 54–64, doi: [10.1016/j.dsr.2019.04.001](https://doi.org/10.1016/j.dsr.2019.04.001)

Lin Rongcheng, Huang Dingyong, Guo Yuqing, et al. 2014. Abundance and distribution of meiofauna in the Chukchi. *Acta Oceanologica Sinica*, 33(6): 90–94, doi: [10.1007/s13131-014-0493-7](https://doi.org/10.1007/s13131-014-0493-7)

Liu Xiaoshou, Xu Man, Zhang Jinghui, et al. 2014. Abundance and biomass of deep-sea meiofauna in the northern South China Sea. *Journal of Tropical Oceanography (in Chinese)*, 33(2): 52–59

Liu Xiaoshou, Zhang Zhinan, Huang Yong. 2005. Abundance and biomass of meiobenthos in the spawning ground of anchovy (*Engraulis japonicus*) in the southern Huanghai Sea. *Acta Oceanologica Sinica*, 24(3): 94–104

Mazurkiewicz M, Górska B, Renaud P E, et al. 2019. Seasonal constancy (summer vs. winter) of benthic size spectra in an Arctic fjord. *Polar Biology*, 42(7): 1255–1270, doi: [10.1007/s00300-019-02515-2](https://doi.org/10.1007/s00300-019-02515-2)

Mokievsky V O, Udalov A A, Azovsky A I, et al. 2004. On the quantitative distribution of meiobenthos on the shelf of the world ocean.

- Oceanology, 44(1): 99–109
- Pfannkuche O, Thiel H. 1987. Meiobenthic stocks and benthic activity on the NE-Svalbard shelf and in the Nansen Basin. *Polar Biology*, 7(5): 253–266, doi: [10.1007/BF00443943](https://doi.org/10.1007/BF00443943)
- Portnova D, Fedyaeva M A, Udalov A A, et al. 2019. Community structure of nematodes in the Laptev Sea shelf with notes on the lives of ice nematodes. *Regional Studies in Marine Science*, 31: 100757, doi: [10.1016/j.rsma.2019.100757](https://doi.org/10.1016/j.rsma.2019.100757)
- Ravelo A M, Konar B, Trefry J H, et al. 2014. Epibenthic community variability in the northeastern Chukchi Sea. *Deep-Sea Research Part II: Topical Studies in Oceanography*, 102: 119–131, doi: [10.1016/j.dsr2.2013.07.017](https://doi.org/10.1016/j.dsr2.2013.07.017)
- Schonberg S V, Clarke J T, Dunton K H. 2014. Distribution, abundance, biomass and diversity of benthic infauna in the Northeast Chukchi Sea, Alaska: Relation to environmental variables and marine mammals. *Deep-Sea Research Part II: Topical Studies in Oceanography*, 102: 144–163, doi: [10.1016/j.dsr2.2013.11.004](https://doi.org/10.1016/j.dsr2.2013.11.004)
- Sharma J, Bluhm B A. 2011. Diversity of larger free-living nematodes from macrobenthos (> 250 μm) in the Arctic deep-sea Canada Basin. *Marine Biodiversity*, 41(3): 455–465, doi: [10.1007/s12526-010-0060-1](https://doi.org/10.1007/s12526-010-0060-1)
- Shi Benze, Yu Tingting, Xu Kuidong. 2015. Abundance and biomass of meiofauna in the Yangtze Estuary and East China Sea in summer, with special reference to changes over the past ten years. *Acta Ecologica Sinica (in Chinese)*, 35(9): 3093–3103
- Snider L J, Burnett B R, Hessler R R. 1984. The composition and distribution of meiofauna and nanobiota in a central North Pacific deep-sea area. *Deep-Sea Research Part A: Oceanographic Research Papers*, 31(10): 1225–1249
- Soltwedel T. 2000. Metazoan meiobenthos along continental margins: a review. *Progress in Oceanography*, 46(1): 59–84, doi: [10.1016/S0079-6611\(00\)00030-6](https://doi.org/10.1016/S0079-6611(00)00030-6)
- Soltwedel T, Portnova D, Kolar I, et al. 2005. The small-sized benthic biota of the Hakon Mosby Mud Volcano (SW Barents Sea slope). *Journal of Marine Systems*, 55(3–4): 271–290, doi: [10.1016/j.jmarsys.2004.09.001](https://doi.org/10.1016/j.jmarsys.2004.09.001)
- Steele M, Ermold W, Zhang Jinlun. 2008. Arctic Ocean surface warming trends over the past 100 years. *Geophysical Research Letters*, 35(2): L02614
- Vanaverbeke J, Arbizu P M, Dahms H U, et al. 1997. The metazoan meiobenthos along a depth gradient in the Arctic Laptev Sea with special attention to nematode communities. *Polar Biology*, 18(6): 391–401, doi: [10.1007/s003000050205](https://doi.org/10.1007/s003000050205)
- Wang Zhe, Zhang Ren, Ge Shanshan, et al. 2017. Natural environment risk division of the Arctic northeast channel-Taking the Northern Sea Area of Russia as an example. *The Ocean Engineering (in Chinese)*, 35(5): 61–70
- Widbom B. 1984. Determination of average individual dry weights and ash-free dry weights in different sieve fractions of marine meiofauna. *Marine Biology*, 84(1): 101–108, doi: [10.1007/BF00394532](https://doi.org/10.1007/BF00394532)
- Wu Yue, Cao Shunan, He Jianfeng, et al. 2019. Community structure of picoeukaryotes in the Chukchi Sea and their relationship with environmental factors. *Chinese Journal of Polar Research (in Chinese)*, 31(1): 25–33
- Wu Shaoyuan, Mu Fanghong. 2009. Meiobenthos in southern coast of Shandong province in winter. *Oceanologia et Limnologia Sinica (in Chinese)*, 40(6): 682–691
- Xu Man, Liu Xiaoshou, Liu Qinghe, et al. 2015. Assemblage composition and distribution of meiofauna in the southern Yellow Sea cold water mass during summer and autumn. *Chinese Journal of Applied Ecology (in Chinese)*, 26(2): 616–624
- Zeng Qianhui. 2016. Meiofaunal communities in the study area of the Bering Sea and Chukchi Sea in summer (in Chinese) [dissertation]. Xiamen: Third Institute of Oceanography, State Oceanic Administration
- Zhang Yuhong. 2009. Density and biomass of meiofauna in the Taiwan Strait and its adjacent waters (in Chinese) [dissertation]. Xiamen: Xiamen University
- Zhang Zhinan, Zhou Hong, Hua Er, et al. 2017. Meiofauna study for the forty years in China: Progress and prospect. *Oceanologia et Limnologia Sinica (in Chinese)*, 48(4): 657–671