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Meiobenthos in Estuary Part of Ha Long Bay (Gulf of Tonkin, South China Sea, Vietnam)

Olga Pavlyuk[1], Yulia Trebukhova[2]*, Nguyen Vu Thanh[3], and Nguyen Dinh Tu[3]

[1]*A.V. Zhirmunsky Institute of Marine Biology, Far East Branch, Russian Academy of Sciences, Vladivostok 690041, Russia*
[2]*Far Eastern State Marine Biosphere Natural Reserve, Far East Branch, Russian Academy of Sciences, Vladivostok 690041, Russia*
[3]*Department of Nematology, Institute of Ecology and Biological Resources, Vietnamese Academy of Science and Technology, 18 Hoang Quoc Viet, Cau Giay, Hanoi, Vietnam*

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Abstract – The distribution of the taxonomical composition and the density of meiobenthos depending on some factors of environment has been studied in bottom sediments of the northern estuary part of Ha Long Bay (Cua Luc estuary). The basic factor of influence on meiobenthic community structure was the granulometric composition of sediment. The greatest taxonomic diversity is noted in the silted sands, lowest - in the silty sediments. The density of meiobenthic community was higher in the silty sediments. Slightly expressed correlation between the density of nematodes and the percentage of silty particles in the sediments is detected (Spearman rank correlation coefficient was 0.49±0.21, p=0.035). The nematodes were dominant at all stations. In total, representatives of 66 species of nematodes belonging to 17 families and 52 genera were identified.

Key words – density, meiobenthos, nematodes, granulometric composition of sediment, salinity

1. Introduction

Ha Long Bay is situated in Northern Vietnam within the Quang Ninh province, approximately 170 kilometres east of Hanoi. The Bay is on the western coast of the Bac Bo (Tonkin) Gulf, and it covers an area of approximately 1500 square kilometres. Ha Long Bay is a UNESCO World Heritage Site, and includes some 1,600 islands and islets forming a spectacular seascape. Abundant mainland drain - numerous rivers and streams has a great influence at the Bay, especially its northern estuary part (Cua Luc estuary). Salinity regime in Ha Long Bay is very changeable during the year. The Bay is also the scene where a largest deep sea port at Cai Lan is situated (21ºN, 107ºE) with a huge container terminal, a coal transfer complex, and other port facilities. Bottom dredging works are conducted regularly in the Bay.

There are only a few studies done on meiobenthos in Vietnam coastline of South China Sea, although meiobenthos is an important component of marine ecosystems. In particular, some investigations concerned with the species composition and distribution of free-living marine nematodes, were conducted in the coastal zone of the central Vietnam (Nguyen Vu Thanh *et al.* 2002). The structure of meiobenthic community of Nha Trang Bay (Pavlyuk and Trebukhova 2006), and mangrove forests of southern part of the South China Sea (Quang Ngo Xuan *et al.* 2007) were analyzed as well. So far only one study has investigated the composition and distribution of free-living marine nematodes in Ha Long Bay (Nguyen Vu Thanh and Nguyen Dinh Tu 2003). Nevertheless, the knowledge about the abundance and ecology of the meiofauna groups of higher taxonomical level (orders or classes) is essential for a better understanding of the structures and functions of benthic communities.

The main aim of present investigation is to study the taxonomic composition and the distribution of the meiobenthos depending on some environmental characteristics at the estuary part in Ha Long Bay.

2. Materials and Methods

Meiobenthos samples collected between 12th and 13th of

*Corresponding author. E-mail: trebukhova@gmail.com

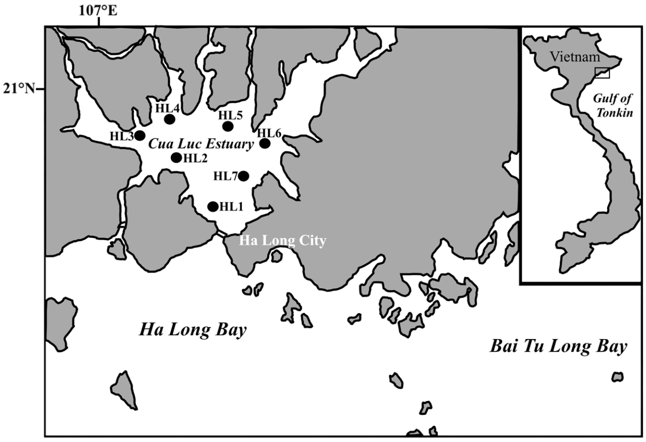

Fig. 1. Map showing the study area in Cua Luc Estuary, with sampling station locations.

March 2007 during the dry season in the northern part of Ha Long Bay (Cua Luc estuary) were used for this research (Fig. 1). The sediment samples were taken with a standart Ponar dredge grab of 150 mm high, 13.7 kg weight and covering a surface area of 230 mm×250 mm. Meiofauna was subsampled using cores of 3.5 cm mouth diameter (10 cm^2 surface area) and 30 cm height. The cores were pushed down into the sediment for 5 cm. Per station, four replicates were taken and collected in bottles. The samples were washed through 1mm and 38 ìm nylon sieves, fixed by hot 10% formaldehyde solution and stained with Rose Bengal. Meiofauna was extracted by flotation with Ludox-TM50 (specific gravity of 1.18). Nematodes were gradually transferred to anhydrous glycerine and mounted onto permanent slides. Meiofauna was identified to higher taxonomical level (order, class) and all animals were taken into account except for foraminiferans.

The Shannon-Wiener diversity index (H), the Simpson domination index (C) and Pielou evenness index (e) were used in the characterisation of the nematode community structure:

$$H = -\Sigma n_i / N \log n_i / N$$

$$C = \Sigma(n_i / N)^2$$

$$e = H / \log S$$

where n_i – is community density of each species,
N – total density of communities,
H – index of Shannon-Wiener,
S – number of species.

The Wieser classification (Wieser 1953), based on the structure of the mouth cavity of animals, was used for the estimation of the trophic structure of the nematode community. According to this classification, four groups of feeders were defined: selective deposit feeders (1A), non-selective deposit-feeders (1B), epistratum feeders (2A) and omnivores (2B).

Chemical properties of the bottom layer determined with Water Quality Checker model WQC – 22A (Table 1).

Seven samples from seven stations were selected to analyze the influence of the sediment granulometric composition at the structure of meiobenthos community. Granulometric composition of the sediments was determined by the separation of the sediment samples of natural humidity by two fractions: below 0.1 mm and above 0.1 mm (Table 1). Even this rough classification allowed us to determine two basic types of the sediments: silted sands (stations HL3, HL5 and HL7) and heterogenous silts with the small admixture of sand (stations HL1, HL2, HL4 and HL6). Spearmen rank correlation coefficient was used to determine the dependence of the quantitative meiobenthic distribution on the silty particles content in sediments.

Hierarchical cluster analyses (Ward's method) was used for allocation of nematode taxocenes. Statistica 6.0 software was used for statistical analysis of material.

Table 1. Sampling stations, depth and environmental characteristics in Ha Long Bay

Station number	Depth, (m)	T, °C	S, PSU	O_2, mg/l	Sediment granulometry (%)	
					grain size >0.1 mm	grain size <0.1 mm
HL1	2	19.6	30	5.22	9.32	45.23
HL2	12	19.4	33	5.23	1.20	33.06
HL3	2	19.3	33	4.9	46.62	28.53
HL4	1	19.5	30	5.1	8.72	41.48
HL5	0.5	19.5	34	4.87	60.70	24.97
HL6	14	19.8	30	4.85	2.63	31.15
HL7	5	19.8	30	4.46	48.37	15.41

3. Results

Meiofauna communities in sublittoral sediments of northern part of Ha Long Bay were represented by 11 taxonomical groups and generally dominated by nematodes and harpacticoid copepods (Fig. 3). The average density was low, constituting 180.8±13.1 inds/10 cm^2.

During our sampling period, the seawater salinity was 30-34PSU, the other environmental factors showed no great variations within the study area (Table 1). The stations were generally characterized by silty sediments, but sediments at stations HL3, HL5 and HL7 tended to be more sandy as percentage of sand grains (>0.1 mm) was generally prevailed (Fig. 2), while, portion of silt grains (<0.1 mm) was higher at stations HL1, HL2, HL4 and HL6, which were represented by heterogenous silts with the small admixture of sand.

The highest density of meiobenthos (295.3±98.4 inds/10 cm^2) is found in heterogenous silt sediments at station HL2, where a depth was 12 m, and a salinity in the benthic layer of water was 33 PSU. Three taxonomic groups were present: Nematoda, Harpacticoida and Polychaeta. Nematodes were dominant at 96.6% of the total meiobenthos density (Fig. 4). The lowest density of meiobenthos (110.5±28.1 inds/10 cm^2) is also found in silty sediments at station HL1, where depth was 2 m, and salinity – 30 PSU. The taxonomic composition of meiobenthos included 4 groups: Nematoda, Harpacticoida, Halacarida and Polychaeta. Nematodes dominated at 54.2% of the total meiobenthos density (Fig. 4). In the silty sediments the highest number of taxonomic groups – 7 is found at the station HL4 (Fig. 4).

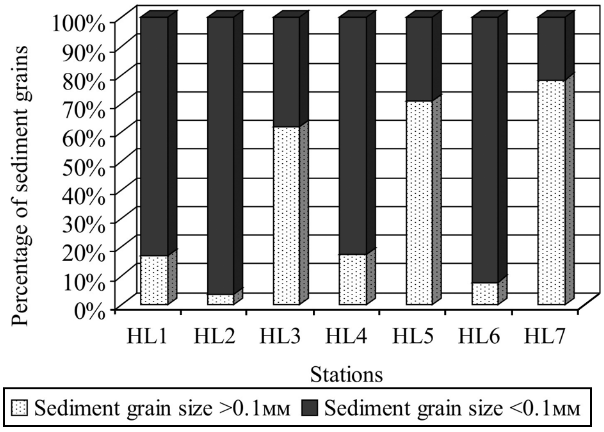

Fig. 2. The percentage of sediment grains size >0.1mm and <0.1 mm at stations.

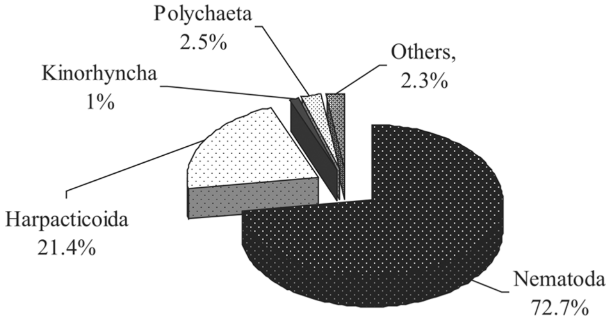

Fig. 3. The percentage of major meiobenthic groups in the Bay. "Others" included such groups: Halacarida, Hydrozoa, Oligochaeta, Bivalva, Amphipoda, Cumacea.

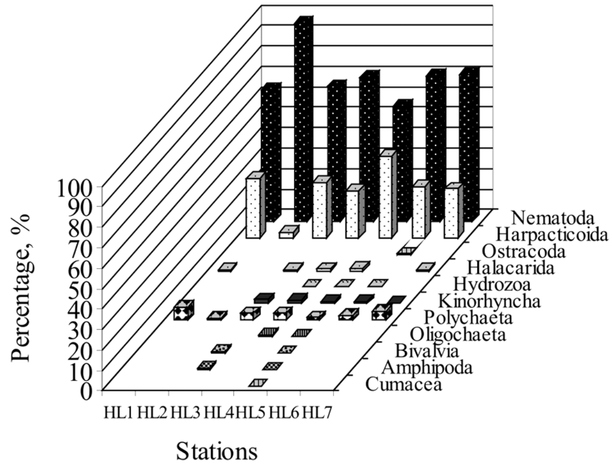

Fig. 4. The percentage of meiobenthic groups at stations.

In silted sand sediments taxonomic composition of meiobenthos varied from 7 to 10 groups. At station HL5, where a depth was 0.5 m, and salinity – 34 PSU, taxonomic composition included 10 groups: Nematoda, Harpacticoida, Halacarida, Hydrozoa, Kinorhyncha, Polychaeta, Oligochaeta, Cumacea, Bivalvia and Amphipoda (Fig. 4). The average density of meiobenthos was determined to be at 227.2±72.8 inds/10cm^2. Nematodes made 66.1% of the total meiobenthos density, besides the highest density of Harpacticoids was recorded (68.7±22.8 inds/10 cm^2) (Fig. 4).

The Spearman rank correlation coefficient was computed between density of meiofauna and salinity, and no correlation was found.

Thus, nematodes were dominant at all stations in the area of research at more than 70% of the total meiobenthos density. Fig. 3-4 shows that the essential part of meiobenthos was presented by harpacticoid copepods, which comprised from 2.7% to 40% of total density. In temporary meiobenthos, polyhaetes were dominant (2.5%). Fig. 5. demonstrates an abundance of dominated meiobenthic groups (nematodes

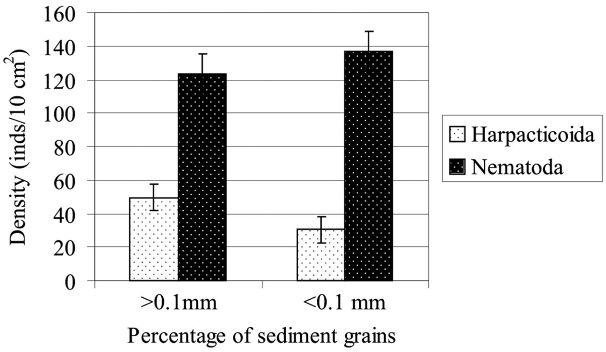

Fig. 5. Relationships between the proportion of sediment particles > 0.1 mm and < 0.1 mm size and abundance of nematodes and harpacticoids.

and harpacticoids) and its relationships with the percentage of sediment particles >0.1 mm and <0.1 mm size. Average density of nematodes was lower in the sediments with the content of silty particles less than 30%, but density of harpacticoids – higher than in the silts (Fig. 5).

In the study area taxonomical diversity and densities of meiofauna were generally lower to that reported for another areas of the South China Sea. Comparisons with southern part of South China Sea (Nha Trang Bay) reveal that the density of meiofauna was much more higher in Nha Trang Bay (1406.7±455.6 ind. 10^{-2}) and taxonomical composition was more diverse as a whole (Pavlyuk and Trebukhova 2006).

A total of sixty six species belonging to 17 families and 52 genera were identified in Ha Long Bay. The species composition, trophic groups and portions of each species of nematodes at the seven stations are shown in Table 2.

The highest density of nematodes was registered in silty sediments at the station HL2 (285.3±89.8 inds/10 cm^2).

Table 2. Species composition, trophic groups and portions of nematodes at stations in Ha Long Bay

Species	TG	Stations						
		HL1	HL2	HL3	HL4	HL5	HL6	HL7
Order Enoplida								
Family Thoracostomopsidae								
Mesocanthion sp.	2B	1.3	–	–	0.7	11	2	13.3
Family Phanodermatidae								
Phanoderma sp.	2B	–	–	–	–	1.6	–	–
Family Anticomidae								
Anticoma sp.	1A	–	–	–	2.2	2.4	–	–
Paracticoma sp.	1A	–	–	–	–	17	–	–
Family Oxistominidae								
Halalaimus sp.	1A	1.3	–	0.7	–	1.6	–	–
Oxystomina sp.	1A	–	–	0.7	2.2	–	3.3	–
Oxystomina $sp._1$	1A	–	–	–	0.7	–	–	–
Family Oncholamidae								
Viscosia sp.	2B	–	–	–	–	–	0.6	–
Viscosia $sp._1$	2B	–	–	–	–	0.8	0.6	–
Family Enchelidiidae								
Belbolla sp.	2B	–	–	0.7	–	2.4	–	–
Calyptronema sp.	2B	1.3	–	1.5	–	–	–	–
Calyptronema $sp._1$	2B	–	–	–	–	1.6	–	–
Ledovitia sp.	2B	–	–	–	–	4	–	0.8
Polygastrophora sp.	2B	–	–	2.3	–	–	–	–
Symplocostoma sp.	2B	–	–	–	0.7	–	–	–
Order Chromadorida								
Family Chromadoridae								
Dichromadora sp.	2A	–	–	–	–	10	–	0.8
Euchromadora sp.	2A	6.6	–	10	–	–	–	0.8
Graphonema sp.	2A	–	–	–	–	4	–	–
Parapinnanema sp.	2A	–	–	–	–	4	–	–
Spilophorella sp.	2A	–	–	–	–	–	0.6	–

Table 2. (Continued) Species composition, trophic groups and portions of nematodes at stations in Ha Long Bay

Species	TG	Stations						
		HL1	HL2	HL3	HL4	HL5	HL6	HL7
Family Comesomatidae								
Comesomoides sp.	1B	–	2.6	–	–	–	–	–
Dorylaimopsis sp.	2A	6.6	1.3	3.1	27.2	-	1.3	12.5
Dorylaimopsis sp$_1$	2A	–	–	–	–	9.7	–	–
Hopperia sp.	1B	–	–	1.5	10.6	–	–	–
Laimella sp.	1B	13.2	4	2.3	–	2.4	0.6	4.7
Metacomesoma sp	1B	–	–	2.3	–	–	0.6	2.3
Paracomesoma sp.	1B	–	5.3	–	2.2	–	–	–
Pierrickia sp.	1B	–	–	–	–	–	1.3	–
Sabatiera sp.	1B	11.8	1.3	6.1	24.3	–	–	–
Sabatiera sp.$_1$	1B	1.3	17.3	–	–	–	2.6	0.8
Sabatiera sp.$_2$	1B	1.3	1.3	–	–	0.8	15.7	–
Sabatiera sp.$_3$	1B	–	–	–	–	–	16.5	5.5
Setosabatieria sp.	1B	–	2.6	–	–	0.8	2.6	3.1
Vasostoma sp.	1B	–	–	–	–	–	2.6	9.3
Family Cyatholaimidae								
Paralongicyatholaimus sp.	2A	–	–	–	–	–	–	1.5
Family Selachinematidae								
Cheironchus sp.	2B	–	–	–	–	5	–	1.5
Choanolaimus sp.	2B	–	–	–	–	1.6	–	–
Gammanema sp.	2B	–	–	–	–	0.8	–	–
Halichoanolaimus sp.	2B	–	–	–	–	1.6	–	–
Family Desmodoridae								
Chromaspirina sp.	2A	–	–	–	3	3.2	0.6	–
Desmodora sp.	2A	1.3	–	5.4	0.7	–	–	0.8
Metachromadora sp.	2A	–	–	–		0.8	–	–
Parachromadora sp.	2A	–	–	–	0.7	–	–	–
Family Microlaimidae								
Bolbolaimus sp.	2A	–	–	0.7	–		–	–
Paramicrolaimus sp.	2A	–	1.3	–	–		–	–
Order Monhysterida								
Family Xyalidae								
Amphimonhystrella sp.	1B	–	–	–	0.7	–	–	2.3
Daptonema sp.	1B	9.2	9.4	15.2	0.7	1.6	7.2	1.5
Daptonema sp.$_1$	1B	6.6	4	–	–	–	0.6	–
Daptonema sp.$_2$	1B	–	–	–	–	1.6	3.2	–
Elzalia sp.	1B	–	–	–	–	0.8	–	0.8
Paramonohystera sp.	1B	–	–	–	–	–	–	7.8
Theristus sp.	1B	–	1.3	2.3	–	–	–	–
Theristus sp.$_1$	1B	–	–	–	–	0.8	10	–
Family Sphaerolaimidae								
Doliolaimus sp.	2B	18.4	7.6	7.6	–	0.8	5.2	–
Metasphaerolamus sp	2B	5.2	7	7	–	–	–	1.5
Sphaerolamus sp.	2B	6.6	4	–	–	2.5	2.6	19.5
Family Siphonolaimidae								
Siphonolaimus sp.	2B	–	–	–	–	–	–	1.5
Family Linchomoeidae								
Eumorpholaimus sp.	1B	–	–	0.7	–	–	–	–
Metalinchomoeus sp.	1B	–	1.3	–	3.7	–	0.6	–
Terschillingia sp.	1B	–		0.7	1.5	0.8	–	–
Terschillingia sp.$_1$	1B	6.6	13.4	–	–	0.8	3.2	–
Terschillingia sp.$_2$	1B	–	2.6	0.7	6	–	–	–
Family Axonolaimidae								
Axonolaimus sp.1	1B	1.3	2.6	4.6	0.7	-		0.8
Parodontophora sp.	1B	–	12	18.4	–	1.6	0.6	6.3
Parodontophora sp.$_1$	1B	–	–	3.1	–	0.8	12	–
Parodontophora sp.$_2$	1B	–	–	–	11.3	0.8	3.2	–

Note: "-" species not found at this station; TG – trophic groups.

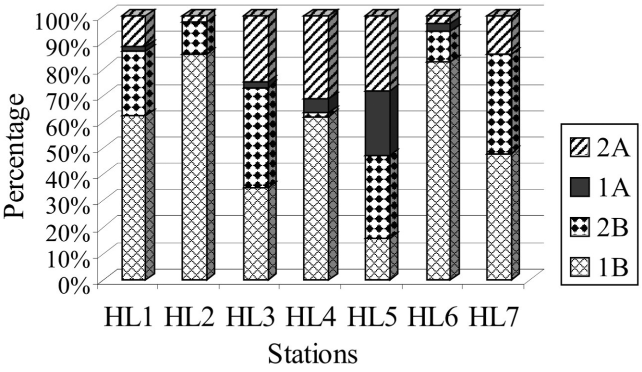

Fig. 6. Percentage of nematodes belonging to different trophic groups at stations. Trophic groups: (1A) selective deposit-feeders; (1B) non-selective deposit-feeders; (2A) epistratum feeders; (2B) omnivores.

Twenty species of nematodes were found, *Sabatieria* sp., *Doliolaimus* sp. and *Terschellingia* sp. dominated (Table 2). Figure 6 shows the distribution of nematode species belonging to different trophic groups at the station. Non-selective deposit-feeders generally dominated among nematodes with the different feeding types (1B, 81.3%), while epistratum feeders (2A) were the lowest (Fig. 6). Index of species diversity was at 3.75, Simpson domination index – 0.09 and Pielou evenness index – 1.92, respectively (Fig. 7).

The lowest density of nematodes (73.9±32.3 inds/10 cm^2) is marked at station HL1. Seventeen species of nematodes were found. *Doliolaimus* sp., *Laimella* sp. and *Sabatieria* sp. dominated (Table 2). Dominant trophic group was non-selective deposit-feeders (1B, 62.2 %) (Fig. 6). At this station indices of nematode species diversity (3.61) and evenness (1.85) were lower than at the station HL2, domination index was at the same level (0.09) (Fig. 7).

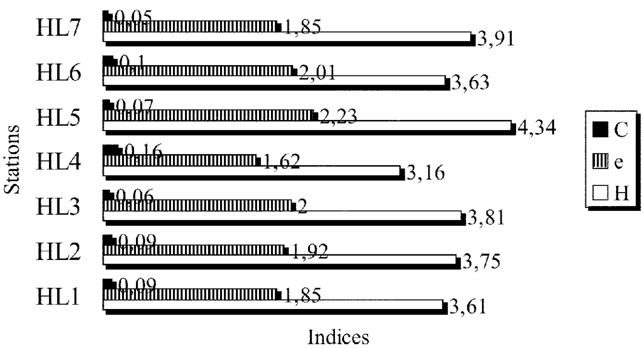

Fig. 7. Indices of Shannon-Wiener diversity (H), Pielou evenness (e) and Simpson domination (C) at stations.

In sandy sediments the highest density of nematodes (150.1±52.3 inds/10 cm^2) is detected at the station HL5. Thirty three species were found, *Mesocanthion* sp., *Paranticoma* sp. and *Dichromadora* sp. dominated (Table 2). Omnivores (2B, 34.2%) and epistratum feeders (2A, 31%) were the dominant trophic groups (Fig. 6). The Shannon-Wiener index was significantly higher at this station (4.34), domination index (0.05) – lowest (Fig. 7). The lowest density of nematodes was found at station HL3 (100±35.2 inds/10 cm^2). Twenty four species detected, dominated by *Parodontophora* sp., *Doliolaimus* sp. and *Daptonema* sp. (Table 2). Omnivores was the dominant trophic group (2B, 38.1%) (Fig. 6). Indices of species diversity, evenness and domination index were 3.81, 2.0 and 0.06 respectively (Fig. 7).

Thus, in sandy sediments with low percentage of silty particles indexes of species diversity were higher, and domination index was lower than in the silts. Fig. 6 shows that non-selective deposit-feeders (1B) and omnivores (2B) were generally dominant feeding group at all stations, while selective deposit feeders (1A) were lowest in abundance at most stations, except for station HL5, and ranging from 2% to 7% per station. In the sandy sediments epistratum feeders (2A) and omnivores (2B) generally prevailed among nematodes with different feeding types. In general, as the content of the silty fractions in sediment increases, it leads to increasing of number of deposit-feeding nematodes.

The cluster analysis was used to estimate similarity between nematode species composition in the seven stations, and to distinguish nematode taxocenes. Fig. 8 shows that

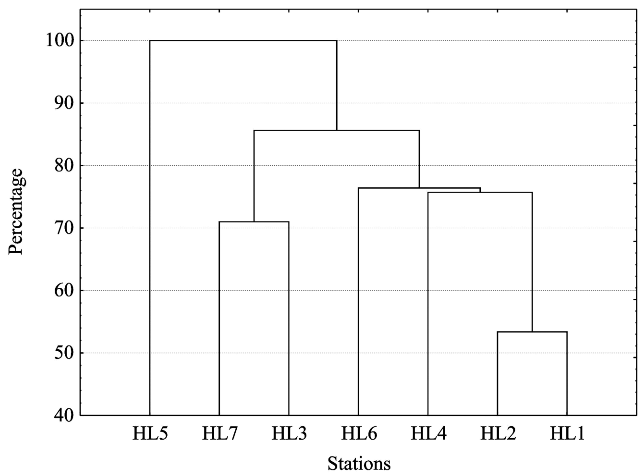

Fig. 8. Hierarchical cluster analysis (Ward method, Euclidean distances) based on the nematode species composition.

stations clustered into two main groups. Stations HL3, HL5 and HL7 with mostly sandy sediments formed taxocene I. The average density of nematodes was determined to be at 123.3±18.2 inds/10 cm^2. Fifty two species of nematodes were found, *Sphaerolaimus* sp., *Mesocanthion* sp., *Parodontophora* sp., *Paranticoma* sp. and *Daptonema* sp. dominated. Stations HL1, HL2, HL4 and HL6 with mostly silty sediment particles formed taxocene II (Fig. 8). The average density of nematodes was determined to be at 137.5±39.3 inds/10 cm^2. Forty one species of nematodes were found, *Doliolaimus* sp., *Sabatieria* sp., *Sabatieria* sp_1, *Sabatieria* sp_2, and *Dorylaimopsis* sp. dominated.

The correlation analysis showed the dependence of nematode density on the silty particles content (the Spearman rank correlation coefficient was 0.49±0.21, P=0.035).

4. Discussion

Several authors stressed the importance of salinity as a key factor that determines the nematodes species diversity and densities in estuaries and coastal lagoons (Gerlach 1953; Bouwman 1983). There are two seasons in the Ha Long Bay and its estuary zone – dry and rainy, both depend on the distribution of atmospheric precipitations during the year. Rainy period lasts from April until October; the salinity of surface water during this period is low – from 11.7 to 30.5 PSU. Dry period lasts from October to the end of March. The mainland drain of fresh waters in the estuary part of the Bay is reduced and in certain cases sea water penetrates the numerous rivers and the streams. Salinity during this period varies from 30.0 to 33.4 PSU (Nguyen Vu Thanh and Nguyen Dinh Tu 2003). Previous study of the nematode species composition done in the Bay during the rainy period showed that a certain tendency is observed in decreasing of the number of nematode species and reduction in the indices of species diversity (Nguyen Vu Thanh and Nguyen Dinh Tu 2003). It worth noting that sampling for the present study was carried out in March, at the end of the dry season, and nematode species composition consisted exclusively of marine species, but density was low. Probably, changes between dry and rainy period influence on density and taxonomical diversity of meiobenthos. In a study of meiobenthic communities in the estuary of the Chornaya (Black) River (Kandalaksha Bay, White Sea), Udalov *et al.* (2005) suggested that the distribution of animals in estuaries depends not only on salinity, but on a variety of other factors, specific to that particular estuary. Sediment type was a key factor that determined the distribution of nematode densities (Udalov *et al.* 2005).

Meiobenthic animals, nematodes in particular, depend not only on the size of the sediment particles but also at the degree of sediment pore space filling. The limiting factor of influence on the density of the animals in the sandy sediments is the minimal size of the capillary passages in which they are able to live (Galtsova 1991). If there is 7% or more of silt-clay fractions in the sediment, it is enough to fill the slits between the large particles. The sediment with more than 15% small fractions is the homogeneous silty environment (Crisp and Williams 1971).

Analysis of sediment granulometry (Table 1) showed that practically all sediments of the estuary part of Ha Long Bay contain more than 15% particles with the size less than 0.1 mm and they are homogeneous living environment for meiofaunal organisms. Probably, this is an explanation for low correlation between the content of silty particles and the density of nematodes.

Research of the qualitative and quantitative meiobenthic composition was done depending on the sediments grain size composition in Wrangel Bay located in the eastern part of Nachodka Bay (East/Japan Sea) (Pavlyuk *et al.* 2003). Nachodka Bay is the largest deep water port of Russian Far East where bottom dredging works are conducted regularly. The average density of nematodes (92.6±13.1 inds/10cm^2) was lower compared with that in Ha Long Bay. Nematodes were the dominant group and their density in the silty sediments was somewhat higher than in fine sand sediments. No correlation was found between the density of the meiobenthic animals and the concentration of silt fractions in sediments. Bottom dredging, perfomed in the Bay, has greatly changed meiobenthic communities (Pavlyuk *et al.* 2003).

The estuary part of the Ha Long Bay is exposed constantly as to anthropogenic impact from the sea port (bottom dredging works), and to mainland drain of fresh waters which result in significant changes of salinity within a year. In general, differences in composition and distribution of meiobenthic communities in Ha Long Bay appeared to be connected with changes in granulometric composition of bottom sediments. The silted sediments are characterised by the low species diversity and higher density of the animals than the slightly silted sands.

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