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The abundance and distribution of free-living marine nematodes of the Piltun-Astokhskoye oil and gas field (North-East Sakhalin)

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Summary. Although offshore oil and gas production platforms are a potential source for a number of toxic compounds, their impact on the meiofauna is insufficiently studied. In the vicinity of the oil and gas production platform MOLIKPAQ (North-East Sakhalin, the Sea of Okhotsk), the relative abundance of meiofauna assemblages ranged from 23.5 to 406.0 ind. 10 cm^{-2}. The dominant group, nematodes, ranged from 6 to 385 ind. 10 cm^{-2}. The maximum nematode density was at the distance of 250 m from the platform coupled with the highest petroleum hydrocarbons concentration (6.52 mg g^{-1}) and the lowest values of the Shannon-Wiener diversity and Pielou's evenness indices (1.25 and 0.33, respectively). In total, 69 nematode species were found. Disturbance in the structure of nematocenes, decrease of number species, drop of biological diversity indices, as well as increase in dominance of some nematode species of occurred in response to the introduction of PHCs as a stress factor. CLUSTER, MDS and SIMPER analyses clearly distinguished site groupings related to the different concentrations of PHC and sediment granulometry. The significant differences of nematode assemblages occurred in the response to the appearance of even low-level PHC contamination sediment. These results suggest that nematode assemblages can be used to detect non-catastrophic levels of oil contamination.

Key words: Free-living marine nematodes, meiofauna, petroleum hydrocarbons, the Sea of Okhotsk.

Currently, there is a worldwide expansion of oil extraction from under the sea. Many coastal areas are already significantly contaminated with petroleum-derived hydrocarbons (Frithsen *et al.*, 1985; Danovaro, 2000). Russia, with abundant land and undersea reserves of oil and gas hydrocarbons, belongs to the countries where oil recovery may be particularly important in social and economic plans. Recently the Sea of Okhotsk has become a subject of investigation for offshore oil exploitation by the oil producing platform MOLIKPAQ (Piltun-Astokhskoye oil and gas field, North-East Sakhalin).

During the past years researchers have conducted a number of studies on the impact of oil on benthic meiofauna and the structure and functioning of natural ecosystems (Alongi *et al.*, 1983; Gray *et al.*, 1990; Danovaro *et al.*, 1995; Carman *et al.*, 1997; 2000; Danovaro, 2000; Patin, 2001; Montagna *et al.*, 1986; 2002). New techniques have enhanced our ability to investigate the dynamics of benthic communities in petroleum-impacted ecosystems.

Petroleum hydrocarbon effects on meiofauna have been little studied compared with the number of investigations conducted on macrofauna (Heip *et al.*, 1985). Despite the fact that oil companies are usually obliged to monitor effects of their activity on marine life, among the papers devoted to the petroleum there are no published accounts of effects on the meiobenthos of the Sea of Okhotsk.

The majority of ecotoxicological studies have concentrated on the potential role of meiobenthic organisms for pollution monitoring. Two dominant groups of meiobenthos, marine nematodes and harpacticoides are discussed in details in the literature (Ferris & Ferris, 1979; Platt & Warwick, 1980; Lambshead, 1986; Schratzberger *et al.*, 2000). For a variety of reasons (high abundance and diversity, short generation) this large group has been suggested for this monitoring role (Schratzberger *et al.*, 2000). Therefore, meiofauna have evoked considerable interest as potential indicators of pollution among marine benthos (Platt & Warwick, 1980; Lambshead, 1986; Coull & Chandler, 1992). In addition, free-living nematodes have been shown to be sensitive to a range of anthropogenic disturbances (Boucher, 1980; Somerfield *et al.*, 1995; Fadeev & Fadeeva, 1999). Thus, large-scale studies of marine nematodes usually take precedence in applied monitoring programmes (Schratzberger *et al.*, 2000; Guo *et al.*, 2001).

The purpose of present work is to detect the effects of petroleum hydrocarbons on nematode community structure and to identify natural and anthropogenic influences on bottom sediments nearest the platform area at the MOLIKPAQ (Piltun-Astokhskoye oil and gas field, northeast shelf of Sakhalin Island).

MATERIAL AND METHODS

The influence of petroleum recovery on the petroleum hydrocarbon (PHC) contamination and meiobenthos adjacent to the MOLIKPAQ platform (northeast Sakhalin, the Sea of Okhotsk) was studied during September and October, 2004. Transects were located at a polygon in coordinates 52°40'15.57"N – 52°45'42.11"N and 143°31'15.67"E – 143°36'40.44"E at depths of 23 to 33 m (Fig. 1). Four transects included stations at distances of 125, 250, 1000, 3000 and 5000 m from the platform. The map of stations in the Piltun-Astokhskoye area is given in Fig. 1, and the coordinates the stations are in Table 1.

Samples were obtained using a modified Van Veen grab (collection area 0.2 m^2) at depths of 23 to 33 m, on sandy sediments. At each location, the grab was deployed three times. Three subsamples for meiofaunal analysis from the grab were collected using a tubular 20 cm^2 bottom sampler to a depth of 5 cm. Subsamples were fixed in 4% neutral formaldehyde seawater solution and then transported to the laboratory. A sieving method was implemented for the extraction of organisms with the use of 63 µm mesh. Before sieving, the samples were stained in Rose Bengal solution. Finally the organisms were sorted and counted under

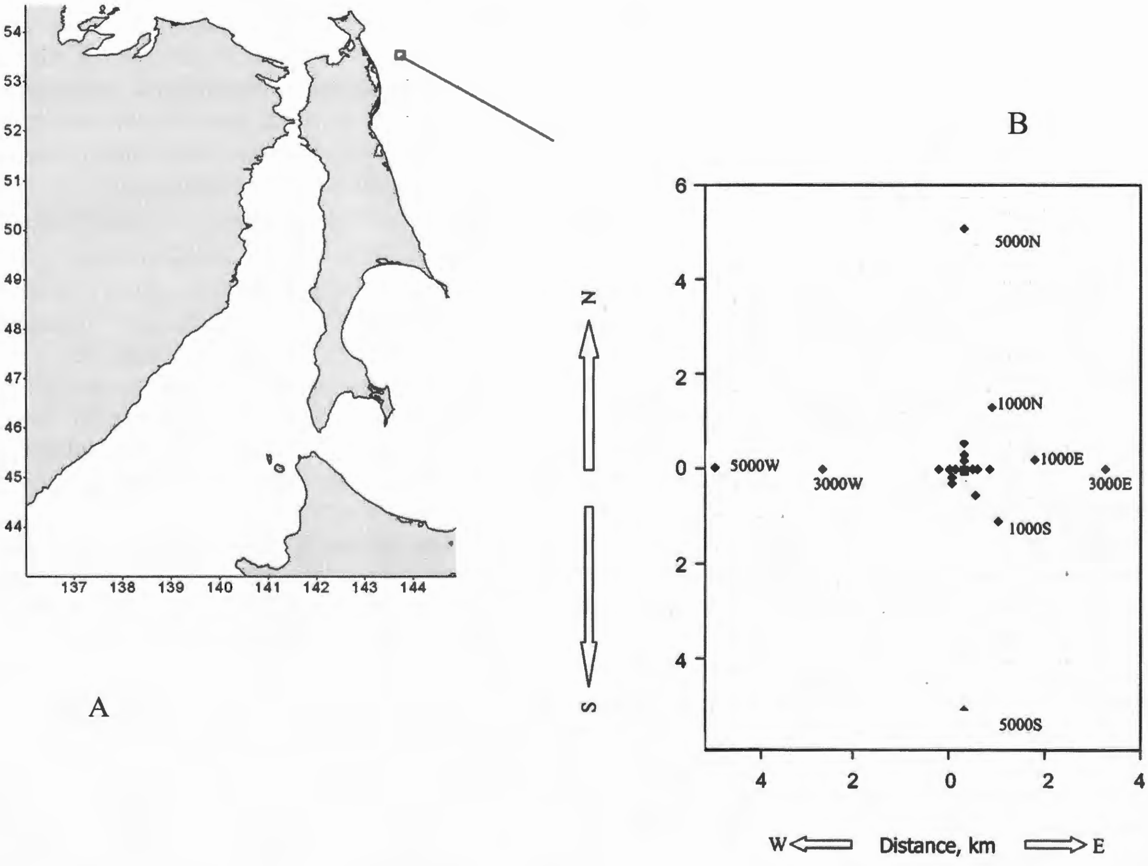

Fig. 1. Off-scale scheme of the sampling stations near the MOLIKPAQ platform: A – map of the study area; B – sampling stations. 3000E – distance (m) from the MOLIKPAQ platform. Stations 125 – 250 are only showed.

a stereomicroscope. After counting the principal taxa of the meiobenthos, all nematodes were extracted and mounted on slides for detailed taxonomic investigation. Up to a maximum of 100 nematodes per sample were picked out randomly from the sample with the most nematodes and permanent mounts in glycerol were made.

Table 1. Coordinates and description of the sampling stations in the Piltun-Astokhskoye oil and gas field.

Station N	Depth, (m)	Latitude, N.	Longitude, (W)	Sediment fraction	PHC, µg g^{-1}
125E	30	52042'58.64"	143034'07.38"	*GrPs*	<0.50
125S	32	52042'53.47"	143033'44.42"	*GrPs*	<0.50
125W	32	52042'59.04"	143033'48.75"	*GrPs*	<0.50
250N	31	52043'08.54"	143033'58.63"	*Gr*	2.90
250W	33	52042'59.19"	143033'42.09"	*Gr*	<0.50
1000E	30	52042'57.62"	143034'53.97"	*Ps*	<0.50
1000N	33	52043'32.79"	143034'00.06"	*Gr*	<0.50
1000S	30	52042'24.89"	143033'56.07"	*GrPs*	1.35
3000E	29	52042'55.28"	143036'40.44"	*Ps*	1.03
3000W	23	52043'02.34"	143031'15.67"	*Ps*	1.44
5000N	33	52045'42.11"	143034'07.66"	*Ps*	0.50
5000S	23	52040'15.57"	143033'48.49"	*Ps*	0.55
5000W	33	52043'02.34"	143031'00.16"	*Ps*	<0.50

Note: Gr – gravel-pebble fractions (> 1 mm); *GrPs* – gravel-pebble and sand fractions; *Ps* – coarse and medium sand (0.25-1 mm).

Subsamples were taken from the uppermost 5 cm of the sediment from the grab at each site for analysis of sediment particle size and petroleum hydrocarbons. Petroleum hydrocarbons were extracted by hexane. The extract was purified by column chromatography with Al_2O_3, and total concentration of PHC was determined by gas chromatography using a flame-ionized detector. The lowest limit of detection was made up to 0.5 µg g^{-1} of a dry sample weight.

Principal components analysis (PCA) was performed to show the spatial differences between environmental factors. Hierarchical clustering (CLUSTER) analysis and non-metric multidimensional scaling (MDS) on relative nematode abundances were applied to spatial grouping based on the Bray-Curtis similarity index (in PRIMER version 5). Formal significance tests for differences in nematode community structure between the zones were performed using the one-way ANOSIM analysis. Diversity patterns were visualized by k-dominance curves (Lambshead *et al.*, 1983). Analysis of similarity percentages (SIMPER) was used to identify nematode species for differences between stations based on fourth root transformed data. Nematodes are classified in trophic or functional groups based on the morphology of their buccal cavity (Wieser, 1953). Species number (S), average density (N, ind. 10 cm^{-2}), Pielou's evenness index (JT) and Shannon-Wiener diversity (HT) were calculated to describe the diversity and evenness of nematode assemblages of the nematode associations of the Piltun-Astokhskoye oil and gas field.

RESULTS

The structure of the sediments. Characteristic features of the investigated part of the Sakhalin's north-eastern coast within the Piltun-Astokhskoye area were the high activity of hydro- and lithodynamic processes and limited diversity of types of bottom deposits (prevalence of gravel and sandy sediments).

Two distinct currents are formed within the boundaries of the studied area, the near-shore stream 40-80 km wide and the off-shore stream, which move from north to the south at velocities not exceeding 15-30 cm s^{-1} (Pischainik & Arkhipkin, 1999). Both water currents occur down to 100 m and deeper. The intensive lithodynamics and movements of deposits connected with these currents should be taken into account when analyzing the anthropogenic influence on bottom deposits and natural variability of petrol hydrocarbons level (PHC) both in time and in space.

The spatial distribution of granulometric composition indices of the three main lithologic fractions was analyzed for basic polygons: gravel and pebble (particles over 2 mm), sand (0.05-2 mm), clay and dust particles (smaller than 0.05 mm), as well as averaged distribution curve for each of basic and test polygons drawn. For a more complete characterization of the sediment composition the following parameters were calculated: median diameter (average size of ground particles, *Md*), coefficients of sorting (S_o) and skewness (S_k) (Table 2).

The bottom deposits at a polygon were represented with gravel and coarse-grain sands with average size of particles 220-538 µm. In the area of the oil platform coarse deposits prevailed (*Md* = 1.1-5.4 mm) (Table 2). The deposit was well sorted (So<2.5), reflecting homogeneity of particles in sediments. The well sorted sediments are formed in the zones with a high hydrodynamic activity, where there is constant undulatory mixing of materials. Skewness of sediment particles size distribution in relation to the median shows that the mode goes through the coarse area of the spectrum; that is coarse-grain fractions predominate in the deposit ($S_k<1$). A regular decrease of the median size of deposit particles was observed along all directions from the platform; at a distance of 1 km the gravel and pebble sediments are replaced by sandy ones (*Md* = 0.26 mm).

Table 2. Sediment grain size analysis.

STATION, N	Q_3	Q_1	*Md*	S_o	S_k
125E	4.00	0.90	1.91	2.11	0.99
125S	5.08	1.20	2.70	2.06	0.84
125W	2.12	0.63	1.10	1;83	1;10
250N	5.90	1.88	4.16	1.77	0.64
250W	5.20	1.73	3.44	1.73	0.76
1000E	0.85	0.44	0.59	1.39	1.07
1000N	5.29	1.50	3.50	1.88	0.65
1000S	2.35	0.50	0.87	2.17	1.55
3000E	0.60	0.25	0.35	1.55	1.22
3000W	0.66	0.29	0.45	1.51	0.95
5000N	0.32	0.21	0.26	1.23	0.99
5000S	0.64	0.41	0.51	1.25	1.01
5000W	0.60	0.35	0.40	1.50	0.93

Note: Md – median diameter (mm), Q_3, Q_1 – quartile deviation, S_0– skewness indicate the degree of sorting of the sediments, S_k – asymmetry factor.

Level of petrol hydrocarbons. Substantial spatial and temporal variability in distribution of PHCs was noted. At four stations, the average concentration of PHCs exceeded the background value (<0.5 μg g^{-1}): 250N – 2.90 μg g^{-1}, 1000S – 1.35 μg g^{-1}, 3000W – 1.44 μg g^{-1}, 3000E – 1.03 μg g^{-1} (Fig. 1, Table 1). Some increase of the PHC contents to the south and the north of the platform area is connected with hydrodynamic activity; however, it could also be a result of oil-product transport in these directions.

Ordination by PCA of the environmental data revealed that the sampling stations were more or less aggregated into two groups (Fig. 2). The first two components (eigenvalues 2.0 and 1.12) accounted for 78% of the total variance of the original four variables (depth, *Md*, S_0, PHC; as listed in Tables 1 & 2), suggesting that the two-dimensional ordination gave an appropriate representation of the similarity between the sampling stations. The PC2 axis (87%) represents mainly increasing values of PHC, while the PC1 axis represents increasing values of median grain size, S_0 and depth (Fig.2, Table 2). Median grain sizes decreased with increasing distance from the MOLIKPAQ platform.

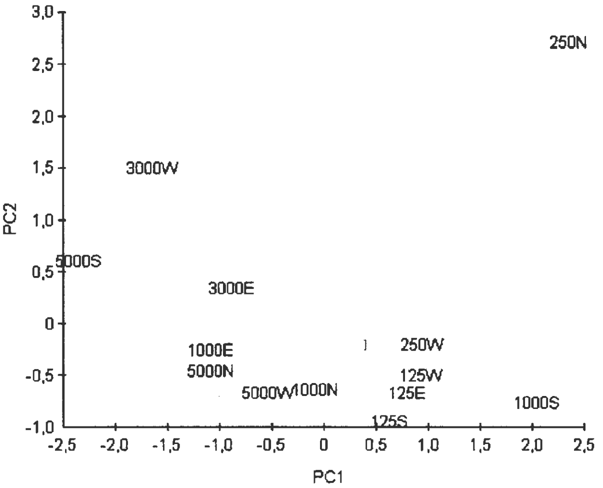

Fig. 2. PCA ordination transformed sediment data from sampling stations.

The composition of meiofauna. Fourteen major groups of meiobenthos were identified from the 39 samples of bottom sediments taken at the studied area (Table 3). The total density of populations varied from 23.5 to 406.0 ind. 10 cm^{-2}. The average density was 89.9 ± 18.2 ind. 10 cm^{-2}.

Table 3. Spearman correlation coefficient ($\alpha<0,05$) between abundance of meiobenthic groups and sediment characteristics *Md* and S_0

Group	*Md*	S_o
Nematoda	0.08	0.07
Harpacticoidea	0.50	0.09
Foraminifera	-0.12	0.50
Ostracoda	-0.31	-0.32
Gastrotricha	-0.18	-0.21
Turbellaria	-0.04	-0.30
Bivalvia	**0.72**	0.15
Polychaeta	0.38	0.33
Amphipoda	**0.68**	0.35
Cumacea	0.02	-0.19
Gastropoda	0.18	**-0.54**
Echinoidea	0.12	**-0.54**
Oligochaeta	-0.24	-0.35
Mysidacea	-0.22	-0.24
Eumeiobenthos	0.08	0.15
Meiobenthos (total)	0.17	0.06

Note: *Md* – median diameter(mm), S_0 – skewness.

The taxonomic composition of meiobenthos varied throughout the entire water area studied, and it changed from station to station. Eumeiobenthos was represented by Nematoda, Harpacticoidea, Foraminifera, Ostracoda, Turbellaria, Gastrotricha. In the pseudomeiobenthos Bivalvia, Polychaeta, Amphipoda, Cumacea, Gastropoda, Echinoidea, Oligochaeta, Mysidacea, Nemertini were found. Through the entire area, the greatest occurrence and abundance was observed for five groups, the Nematoda, Bivalvia, Harpacticoidea and Polychaeta. At almost every station the free-living nematodes represented the dominant group (from 6 to 385 ind. 10 cm^{-2}), the percentage abundance ranging from 21 to 100 % (mean: 68%).

Minor positive correlation (0.58, $P<0.05$) is revealed between the biological diversity of meiobenthos (HT) and the average size of particles in a fraction (*Md*). The abundance of the meiobenthos as a whole and of different taxonomic groups was not correlated with the average sizes of ground particles, with exception of bivalves and amphipods whose abundance was positively correlated with the median diameter (Table 3). Interrelations of density of whole meiofauna and its separate groups with the sorting coefficient, excepting some groups, differed from those with median diameter. This can be explained by lower range of sediment particles' variability and the prevalence of sand with some gravel and sand sediment in the study area.

Table 4. Species number (S), average density (D±SE, ind. 10 cm^{-2}) and standard error, Pielou's evenness index (JT), Shannon-Wiener diversity (HT) of the nematode associations of the Piltun-Astokhskoye oil and gas field.

Station	S	D	SE	J	H log2
125E	17	26.0	5.1	0.87	3.56
125W	16	30.0	3.4	0.92	3.66
125S	19	43.0	13.8	0.80	3.40
250W	21	46.1	5.6	0.65	2.84
250N	14	159.0	150.1	0.33	1.25
1000E	17	20.5	9.8	0.91	3.72
1000 S	17	40.0	5.8	0.82	2.84
1000N	13	19.0	9.8	0.84	3.11
3000E	16	44.0	4.8	0.85	3.41
3000 W	11	34.5	11.7	0.93	3.79
5000W	17	35.5	1.6	0.88	3.60
5000S	18	28.5	11.3	0.91	3.78
5000N	21	37.5	12.1	0.90	3.96

Composition of free-living nematodes. A total of 69 nematode species from 27 families were found in all samples in the Piltun-Astokhskoye area. Number of species at a station varied from 11 to 21 (Tables 4 & 5). Although systematic placement of some species still requires more precise identification, it is possible to see some peculiarities in quantitative distribution of free-living nematodes in this region. Only 42 (56%) of the species were allocated to known species. Some of the known species were very close to original descriptions, but were not expected to be found in the Piltun-Astokhskoye area (the north-east shelf of Sakhalin), and are thus marked as having affinity (aff.) with known species. Thirty species were identified only to genus level. Most of the species and individuals belonged to four families: Xyalidae (13), Chromadoridae (9), Oncholaimidae (7), and Thoracostomopsidae (5). The rest of the species were equally distributed among the families.

A general analysis of the species composition indicated that the most widespread and abundant species were: *Anticoma behringiana* (occurrence 76%), *Actinonema* sp. (61%), *Enoplolaimus medius, Neochromadora poecilosoma, Pomponema belogurovi* and *Xyala* sp. (53%). The species *Leptolaimus elegans, Microlaimus* sp., *Metadesmolaimus canicula, Sabateria armata, Ascolaimus elongatus, Chromadora heterosomata* and *Prochromadorella* sp. occurred in 38% of the samples.

ANOSIM results showed that the species composition of nematode assemblages at all locations were significantly different from each other at $P<0.05$ (Table 4). Some indices most widely used in biodiversity studies were calculated (Table 4). Indices of specific diversity and Pielou's evenness indices of nematofauna varied widely. The Shannon index varied from 1.25 (250 m from the platform) to 3.96 (5 km to the North from the platform), and the evenness from 0.33 (250 m to the North from the platform) to 0.93 (3 km to the West from the platform) (Table 4). Species diversity and the positions of the sampling stations according to their distance from the platform are presented in Fig. 3. The oil input seems to produce an increase in nematode density at the distance of 250 m north of the platform, where the content of petroleum hydrocarbons was maximal (6.52 mg g^{-1}) and the lowest values of the Shannon-Wiener diversity (H' = 1.25) and Pielou's evenness (J=0.33) indices were detected. This was related with the overall dominance of a few of the most widespread species.

Cluster analysis confirmed the results of ordination, and detected three major groups (I, II and III), shown in Fig. 4. The MDS-analysis generally also showed a low stress value (0.15), indicating a good discrimination between different locations (Fig. 5). The stations 250N and 1000S were separated from the rest at a low similarity level (Bray-Curtis similarity 19.2%), located at a distance of 250-1000 m from the oil platform at 30 m. This zone is characterized by gravel-pebble

(>1 mm) and sand fractions where concentrations of PHCs were 7-10 times above background levels. The differences indicate changes in nematode assemblages in response to the appearance of even low-level PHC concentrations.

The low Bray-Curtis similarity (23.4 %) was observed between clusters II and III. Significant differences in assemblage structure between these clusters appeared to be correlated with corresponding changes in sediment granulometry. The cluster II included nematode assemblages 6 station, located at distances up to 250-1000 m from oil platform (Table 1, Fig. 3) on coarse sands and gravels. The other 5 stations (cluster III) were located on medium sands at 3000-5000 m from the oil platform (Fig. 3).

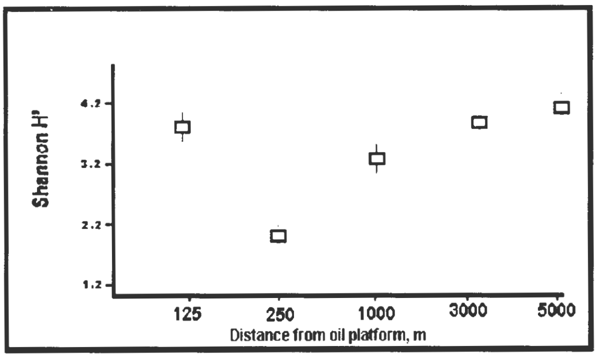

Fig. 3. Shannon-Wiener diversity (HT) of nematode associations (mean and 95% intervals) in the distance zones the MOLIKPAQ platform.

Separate SIMPER analysis based on fourth root transformed nematode species abundance was also performed to indicate the contribution of nematode species to the three main station groups (Table 5). There were strong dissimilarities between I and II species assemblage (75.34%) and between I and III (74.26%) with 26 and 19 species, respectively, accounting for the distinction. The results showed that each group had different dominant species. The dominant species (contributions of each species are listed in parenthesis) of group I were *Prochromadorella* sp. (57.69%) and *Neochromadora poecilosoma* (15.49%). *Prochromadorella* sp. was also a good discriminator between groups I and II and between groups I and III, the contribution percentages being 49.66% and 44.47%, respectively. Three species, *Anticoma behringiana* (18.47%), *Neochromadora poecilosoma* (16.06%) and *Actinonema* sp. (18.47%), were the dominant species of group II. *Pomponema* sp. (11.54%), *Xyala* sp. (10.61%) and *Microlaimus* sp. (9.76%) dominated in group III. These species accounted for 19.9% of the overall average dissimilarity (81.94%) in nematode assemblages between stations II and III. *Anticoma behringiana* (contribution of dissimilarity 11.92%) was the obvious discriminator between groups II and III. The significant differences between nematode assemblages at different stations were not only due to changes in abundance of this numerically dominant species. According to k-dominance curves, nematode assemblage group I was more dominant, whereas groups II and III were the most diverse (Fig. 6).

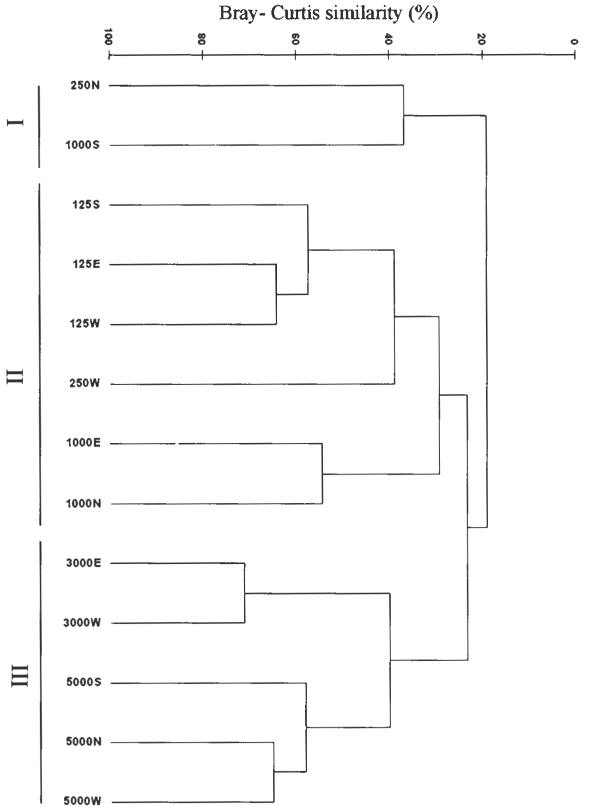

Fig. 4. Analysis of Bray-Curtis similarities between √-transformed weighted average abundances from each station: dendrogram derived by hierarchical clustering using group average linkage.

Analysis of the feeding types according to Wieser (1953) showed changes in the trophic structure of associations of nematodes in sediments at different distances from the platform. The high values for dominance and the unequally distributed feeding type (80% epistrate feeders, 2A) are indicative of the stress in group I (Fig. 7, I). High dominance is caused by *Prochromadorella* sp. and *Neochromadore poecilosoma.*

The dominance of epistrate feeders was reduced with decrease of median grain sizes at increased distance from the MOLIKPAQ platform. Epistrate feeders (37%) and selective deposit feeders (31%) are dominant for group II. *Anticoma behringiana*, a typical enrichment opportunist, was associated with high bacterial activity at two stations (3000W, 3000E) with higher level of PHCs concentrations (Fig.7, Table 5).

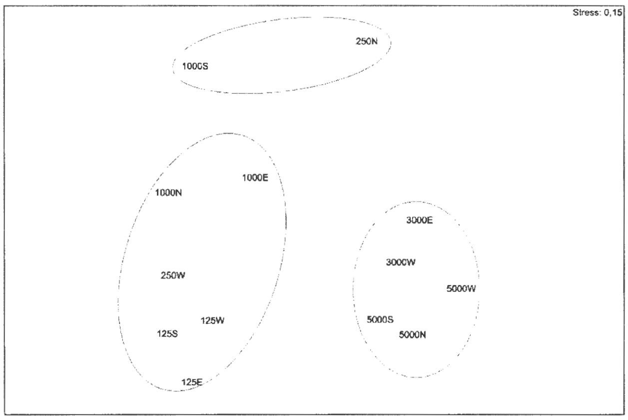

Fig. 5. The MDS ordinations of nematofauna data (grab samples) near the MOLIKPAQ platform. Similar stations of the disposal area surrounded by line (Bray-Curtis similarity, √-transformed data).

Group III is differentiated from the other groups by the high proportion of the predators and the nonselective deposit-feeding nematodes (1B+2B) in medium-grained sandy sediment (Fig. 7, III). Thirteen species of non-selective deposit-feeders and six bacterial feeders represented 46% of nematode abundance. The predators were represented by nine species. The most dominant species was the predator *Pomponema belogurovi*.

To determine the dependence between PHC level and population density of nematodes, Spearman correlation coefficients between these two parameters were calculated. The tendency for

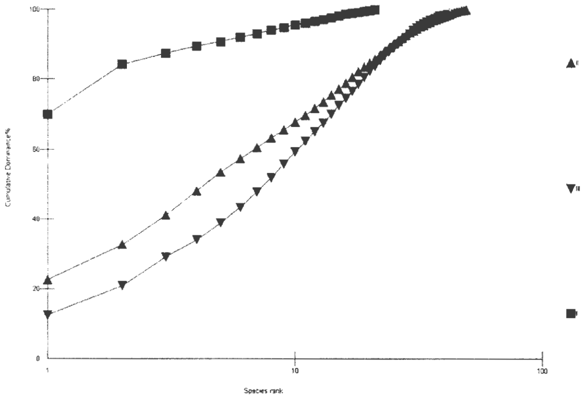

Fig. 6. *k* – dominance curves for three nematode groupings: ■ – I group, ▼– II group, ▲ – III group.

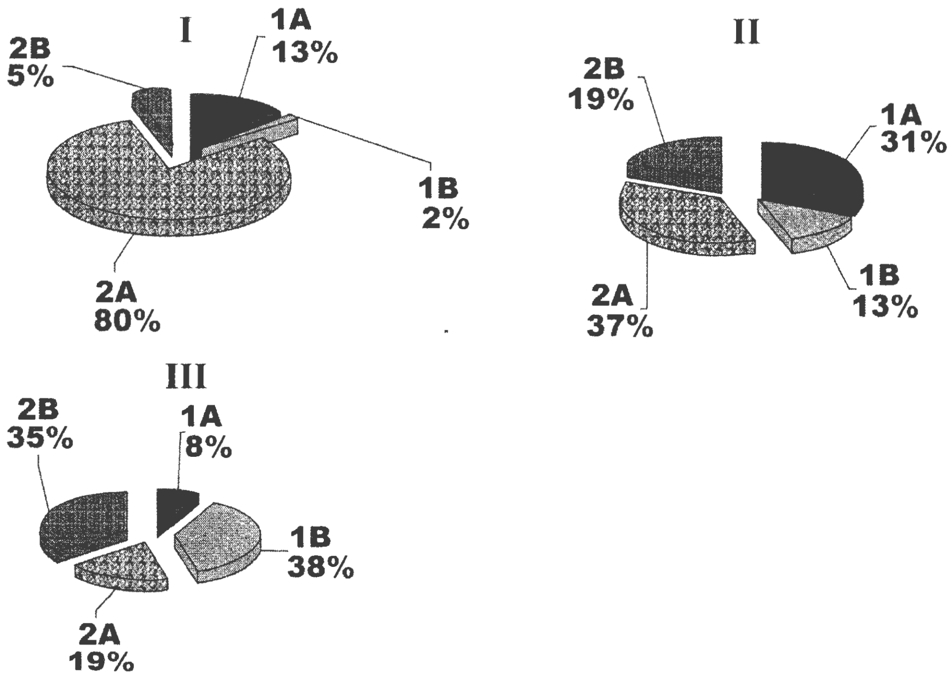

Fig. 7. Trophic structure of nematode assemblages near the MOLIKPAQ oil platform: Feeding types: 1A – the selective deposit feeders; 2A – the epistrate feeders, 1B – the nonselective deposit feeders; 2B – predatores/omnivores. I, II and II correspond to the groups in the dendrograms on Fig.4.

Table 5. Nematode species contribution (%) to similarity (SIMPER) according to the three assemblages indicated in the dendrogram, see Fig. 4.

№	Species	I	II	III
1	*Prochromadorella* sp.	57.696	–	1.25
2	*Neochromadora poecilosoma* (De Man, 1893)	32.76	16.06	9.41
3	*Anticoma behringiana* Platonova, 1976	<1	18.47	–
4	*Pomponema sp.*	–	<1	11.54
5	*Sphaerolaimus gracilis* De Man, 1876	<19	–	–
6	*Paracanthonchus longus* Allgen, 1934	<1	<1	–
7	*Actinonema* sp.	–	10.69	–
8	*Enoplolaimus medius* Pavlyuk, 1984	<1	6.31	6.57
9	*Xyala* sp.	<1	1.11	10.61
10	*Microlaimus* sp. 1	<1	1.07	9.76
11	*Rhynchonema* sp.	–	<1	<1
12	*Chromadora heterostomata* Kito, 1978	–	12.69	–
13	*Chaetonema* sp.	–	<1	9.43
14	*Gonionchus latentis* Fadeeva, 1984	–	–	<1
15	*Oxyonchus* sp.	–	–	<1
16	*Sphaerolaimus limosus* Fadeeva, 1983	–	–	<1
17	*Paramonohystera buetschlii* (Bresslau et Stekhoven, 1935) *aff.*	–	<1	<1
18	*Sabatieria armata Gerlach, 1952*	<1	<1	2.86
19	*Dichromadora amphidiscoides* Kito, 1981	–	–	<1
20	*Leptolaimus elegans* (Schuurmans Stekhoven et De Coninck, 1933)	<1	<1	5.49
21	*Trileptium sp.*	–	2.27	5.74
22	*Oxystomina elegans* Platonova, 1971	–	4.97	–
23	*Euchromanema cervicornia* Kulikov et Dashchenko, 1991	–	3.22	–
24	*Axonolaimus seticaudatus Platonova, 1971*	–	<1	2.73
25	*Metadesmolaimus canicula* (Wieser et Hopper, 1967)	<1	2.42	<1
26	*Chromaspirina* sp.	–	<1	1.25
27	*Cyartonema* sp.	–	2.88	–
28	*Cobbia trefusiaeformis* de Man, 1907	–	–	2.73
29	*Desmodora* sp.1	–	–	2.73
30	*Acanthopharynx* sp.	–	2.71	–
31	*Enoploides rimiformes* Pavluk, 1984	<1	<1	<1
32	*Mesacanthion* sp.	<1	<1	<1
33	*Daptonema* sp.	–	<1	<1
34	*Odontophora angustilaimus*	<1	<1	<1
35	*Acantholaimus* sp.	–	2.52	–
36	*Cervonema* sp.	–	–	2.29
37	*Hypodontolaimus plurisetus* Baranova et Dashchenko, 1992	–	2.26	–
38	*Epsilonema* sp.	<1	<1	–
39	*Oncholaimium* sp.	<1	<1	–
40	*Bathylaimus australis* Cobb, 1894 *aff.*	–	<1	<1
41	*Ascolaimus elongatus* (Bьtschlii, 1974)	–	–	1.35
42	*Gammanema* sp.	–	–	<1
43	*Theristus* sp.	–	–	<1
44	*Spirinia parasitifera* (Bastian, 1865)	–	–	<1

Table 5 (continued). Nematode species contribution (%) to similarity (SIMPER) according to the three assemblages indicated in the dendrogram, see Fig. 4.

№	Species	I	II	III
45	*Sabatieria palmaris Fadeeva et Belogurov, 1984*	–	–	<1
46	*Daptonema articulatum* Lorenzen, 1977 *aff.*	–	<1	–
47	*Paramonohystera halerba* Fadeeva et Belogurov, 1987	–	<1	–
48	*Oncholaimus brachycercus* de Man, 1889	–	<1	–
49	*Viscosia poseidonica* Belogurov et Belogurova, 1977	–	<1	–
50	*Paramonohystera pellucida* (Cobb,1920)	–	<1	–
51	*Metalinhoemoeus* sp.	<1	–	–
52	*Diplopeltoides* sp.	–	–	<1
53	*Adoncholaimus fuscus* (Bastian, 1865)	–	–	<1
54	*Paralinhomoeus* sp.	–	<1	–
55	*Viscosia epapillosa* Platonova, 1971	–	<1	–
56	*Phanoderma platonovae* Belogurov, 1980	–	<1	–
57	*Pontonema papilliferum* (Filipjev, 1916)	–	<1	–
58	*Oncholaimellus sachalinensis* Belogurov et Belogurova, 1981	<1	–	–
59	*Halalaimus leptoderma* Platonova, 1971	<1	–	–
60	*Graphonema metuliferum Kito, 1981*	<1	–	–
61	*Thalassomonhystera refrigens* (Bresslau et Stekhoven, 1935)	<1	–	–
62	*Cyatholaimus* sp.	–	<1	–
63	*Daptonema longissimecaudatum* (Kreis, 1935) *aff.*	–	<1	–
64	*Theristus brevisetosus* Alekseev, 1992	–	<1	–
65	*Microlaimus* sp. 2	–	<1	–
66	*Monoposthia costata* (Bastian, 1865)	–	<1	–
67	*Tarvaia* sp.	–	<1	–
68	*Thalassoalaimus* sp.	–	<1	–
69	*Tricoma* sp.1	–	<1	–

directly proportional dependence of nematode population density on PHC concentration in the bottom sediments was revealed. Only the nematodes *Prochromadorella* sp., *Oncholaimellus sachalinensis*, *Sphaerolaimus gracilis* and *Thalassomonhystera refrigens* had values of the coefficient equal to 0.81 (for the first species) and 0.80 (for the rest) at P=0.001. From the data obtained we can conclude that population density of these species was positively correlated with the increase of PHC level in the sediment.

DISCUSSION

Effects of petroleum hydrocarbons on meiofauna have been little studied compared with the number of investigations conducted on macrofauna (Boucher, 1980; Montagna *et al.*, 1986; 2002; Carman *et al.*, 1995; 1996; 2000; Danovaro *et al.*, 1995). There no available comparable data from the Sea of Ochotsk. A preliminary baseline study of free-living marine nematode assemblages was provided in this area. The nematode abundances were somewhat lower than those detected for the Sea of Japan (Fadeeva, 2007).

The present study focuses on comparison of the spatial structures of nematode assemblages that originate from one pool of species but vary according to differing conditions of the habitat, which is of special interest. This enables the contribution of environmental variables in nematofaunal structure formation to be evaluated. Sediment granulometry is the most important factor in determining nematode assemblage structure (Heip *et al.*, 1985; Schratzberger *et al.*, 2000; Guo *et al.*, 2001). Variations in the structure of the nematode assemblages will be related to the habitat characteristics, including grain size, hydrodynamism and, importantly, industrial contaminants. Offshore platforms produce a high volume of potentially toxic substances, including hydrocarbons.

Disturbance in nematofaunal structure, decrease in the number of species, reduction in the biological diversity indices, and changes in the nematode species dominance occurred in response to the introduction of PHCs as a stress factor in the vicinity (within 250-1000 m) of the oil and gas production platform MOLIKPAQ. Diversity decreased with increased proximity to a platform, but the actual agents responsible for this response are more difficult to demonstrate. Thus, considerable differences exist in quantitative parameters and species compositions between these two benthic nematode assemblages in areas of similar environmental conditions (sediment type, depth, *etc.*). Alterations due to pollution can be explained solely by change in concentration of PHCs. A reduction in species richness was expected where environmental conditions were more extreme, and the abundance and distribution of organisms are controlled by physical factors such as extremes of PHC and grain size. Environmental effects associated with concentration of PHCs change the surrounding communities over a relatively short time. The results suggest that nematode assemblages can be used to detect non-catastrophic levels of PHC contamination.

It is known that a short-term impact of relatively low concentrations of PHC, slightly exceeding background levels (1-10 μg/g), depends on environmental variables, primarily on temperature (Danovaro, 2000). The results of various samplings show that most of the petroleum products is removed from the upper 5 cm sediment layer (Fleeger & Chandler, 1983).

Difference between contaminated and uncontaminated sediment is explained by the dominance of the epistrate feeder, *Prochromadorella* sp., which appeared to be less sensitive or even tolerant of hydrocarbon stress. The increase in the proportion of epistrate feeders was apparently caused by growth of benthic microalgae from the photic zone. It is widely known that microphytobenthos (diatoms and phytomastigins) are more tolerant of the impact of oil, than macro- and meiobenthos (Danovaro, 2000). Increase of PHC concentration in the upper sediment layer has a stimulating effect on the bacterial biomass and the microbenthos; according to data from both field and experimental studies, density of bacteria in all size classes increases (Parsons *et al.*, 1984; Carman *et al.*, 1996; Danovaro, 2000). According to some authors, the meiofaunal organisms can consume bottom microalgae and chemosynthesizing bacteria, which in turn utilize PHC and H_2S (Montagna *et al.*, 1986; 2002).

At the sites of natural oil seepage and in the areas of considerable PHC pollution the development of numerous mats of sulphate-oxidizing bacteria, *Beggiatoa* sp., has been observed, among which the population density of meiobenthos was high (Spies & DesMarias 1983; Montagna *et al.*, 1986; Kiyashko *et al.*, 2001). Increase of the abundance of these organisms is a consequence of the organic carbon input to the sediment.

Nematodes show rapid responses to oil pollution because of their sensitivity to hydrocarbons and short generation time (Boucher, 1980; Danovaro, 2000; Fadeeva & Davydkova, 2005). Obviously, the opportunistic species suggested as pollution indicators predominate only in communities subjected to very heavy pollution (Fadeeva *et al.*, 2003). There are data showing that some species of marine nematodes and polychaets are capable of utilizing PHC carbon, thus promoting self-cleaning of sediments in the sites of natural seepage of oil and following anthropogenic pollution (Montagna *et al.* 1986; Kiyashko *et al.*, 2001).

These and related studies should provide us with new information on the short-term ecological effects of petroleum pollution. Further study is required to identify the actual mechanisms by which PHC carbon affects benthic food webs and the role that indirect effects play in modifying contaminant effects. Understandings of these aspects are needed in order to describe and predict adequately the ecological impact of petroleum hydrocarbons and thus develop reliable predictive models and mitigation strategies.

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Фадеева Н.П., Масленников С.И. Численность и распределение свободноживущих нематод на Пильтун-Астохском нефтегазоносном месторождении (северо-восточный Сахалин).

Резюме. Газо-нефтедобывающие платформы – потенциальный источник загрязнения моря, однако их воздействие на мейофауну изучено недостаточно. В районе газо-нефтедобывающей платформы МОЛИКПАК (северо-восточный Сахалин, Охотское море) плотность поселения мейобентоса изменялась от 23.5 до 406.0 экз./10 см^2. Ведущей по плотности поселения группой были свободноживущие нематоды (от 6 до 385 тыс. экз/м^2). Наибольшие значения плотности поселения нематод были отмечены на расстоянии 250 м от платформы, где содержание нефтеуглеводородов было максимальным (6.52 мг/г) при самом низком значении индекса видового разнообразия (H′=1.25) и низкой выравненности (по Пиелоу, J=0.33). В целом было обнаружено 69 видов нематод. Изменения в структуре таксоценов нематод, уменьшение числа видов, падение индексов биологического разнообразия, также как увеличение некоторых индексов доминирования произошли в ответ на появление PHCs в донных осадках как стрессового фактора. CLUSTER-, MDS- и SIMPER- анализы четко указали на группировки нематод, связанные как с обогащением PHC, так и с отличиями в гранулометрии донных осадков. Значительные различия в сообществах нематод возникли в ответ даже на появление в грунте низких концентраций нефтеуглеводородов. Эти результаты дают возможность предположить, что сообщества нематод также могут использоваться для выявления некатастрофических уровней нефтяного загрязнения.