

# DIVERSITY AND DISTRIBUTION OF FREE-LIVING NEMATODES WITHIN PERIAZOIC LEVEL ON THE ROMANIAN SHELF OF THE BLACK SEA

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**Abstract:** Based on 13 samples collected within the FP7 HYPOX project in two periods (14-24 May 2010 and 02-08 April 2011), the paper presents the taxonomic diversity and abundances of free-living marine nematodes within the periazoic level. There were found 52 taxa with a broad variability regarding their distribution at depths ranging from 100 to 200 m. The dominant species were the following: *Sabatieria abyssalis*, *Linhomoeus* sp., *Oncholaimus cam-pylocercoides*, *Halanonchus bullatus* and *Odontophora angustilaimus*. The only species found at depths up to 180-200 m were *Linhomoeus* sp., *S. abyssalis*, *Viscosia* sp., and *Terschellingia longicaudata*.

**Key words:** Black Sea, periazoic level, Nematoda diversity, quantitative distribution.

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## 1. INTRODUCTION

Black Sea is a land-locked basin, ca 2,200 m deep, atypical among others due to its anoxic part, practically almost a separate basin occupying about 87% of the sea volume. It is separated by a strong pycnocline, located at about 100 m depth. The difference in density and the lack of vertical currents prevent mixing and subsequent ventilation of the sub-pycnocline waters from the surface ones (Sorokin, 2002).

The particular distribution of sea floor habitats made researchers call the band between 100-200 m depth "the periazoic level" (Băcescu, 1963). It represents about 2.7% of the Black Sea surface, having a greater extent at the Romanian littoral. According to Zernov (1913) – his opinion was, later, accepted by Antipa (1941) – life on phaseolinic muds at depths greater than 100 m continues up to the margin of the continental slope. Later on, Jakubova (1935) and Nikitin (1962), while studying the deep biotopes, described two main communities characteristic of these depths: the *Modiolula* and the deep muddy *Mytilus* habitats, although a third one was suggested by Nikitin (1938). These communities are spread on the Romanian shelf up to 120 - 130 m depth at most.

The phaseolinic muds are replaced by the calcareous white muds, in-between with ferromanganese concretions, built on subfossil break-shells of *Modiolula*. Between 90 m and 160 m, interrupting the calcareous muds, there occur frequent spots/strips with fossil broken shells of *Dreissena rostriformis*, *D. distincta* and even *D. polymorpha*, along with *Micromelania spica* and other Caspian species. It represents about 9/10 of the sediment volume, thus named "facies" or "dreissenifer substratum".

A second band, named phaseolinic facies, consisting of white muds, extends between 150 - 200 m depth up to the limit of the continental slope. The scientific observations confirmed here the existence of very abundant skeletal remains and diatoms frustules.

In the upper margin of the periazoic, there are species originating in phaseolinic biocoenosis (*Terebellides*, *Apseudopsis*, *Pachycerianthus*, *Callipallene*, etc) which almost disappear below 150 m depth, excepting few tolerant thionobionts such as *Eugyra*. The only constant species is the hydrozoa population of *Bougainvillia muscus (ramosa)*, very abundant in the past, was once considered a real biocoenosis (Băcescu et al., 1971).

Dominant organisms besides bacterial microbiota remain nematodes and foraminifers (of which, the most common species is *Ammonia tepida*). First mention about the nematodes within the periazotic of the Romanian shelf was made by Băcescu *et al.* (1971). The authors listed 4 taxa (*Enoplus euxinus*, *Sabatiera clavicauda* syn. *S. pulchra*, *Desmoscolex*, *Oxystomina*). Recent research confirm the existence of these species in the periazotic except *Desmoscolex*, low abundances of which were accounted for in 2009, 2010 and 2011 at depths not exceeding 60 m.

The trophic resources at this depth are of allochthonous origin, that is, „planktonic rain” of fresh or dead organic material from the water column, but also endogenous products consisting of fecal pellets, exuviate, bacterial by-products and fresh biomass, etc. Lack of sufficient oxygen leads to organic matter degradation by means of oxygen bound in nitrates, and, especially, in sulfates, which generates hydrogen sulphide.

The white mud biocoenosis is bordering in its superior part, the bathyal (according to marine biological terminology) zone of the Black Sea, covered by reduced blackish mud, inhabited by specialized microbiotic communities.

The hydrogen sulphide (H<sub>2</sub>S) presence is already detectable beginning with 100 m depth. Also, ammonium reaches concentrations of about 100 mmol N m<sup>-3</sup> on the bottom due to an intense denitrification process, absence of oxygen and organic matter degradation. Hydrogen sulphide exhibits a similar pro-

file with concentration reaching 380 mmol m<sup>-3</sup> on the bottom (Grégoire and Soetaert, 2010). The boundary of H<sub>2</sub>S varies between summer and spring (Zaitsev and Mamaev, 1997).

The studies of nematodes in the periazotic of the Black Sea have been revived by the Ukrainian researchers (Sergeeva *et al.*, 2011, 2012, 2013; Zaika and Sergeeva 2012; Sergeeva and Zaika, 2013) at the beginning of the 2000s. They published a series of results regarding the biodiversity at depths ranging between 400 and 2250 m. The nematodes seem to be the most diverse taxa, 17 species being cited (Table 1).

Recent investigation of the NW Black Sea methane seeps situated at depths ranging between 76 and 234 m, resulted in identification of 36 species of nematodes, with densities between 200 and 13,900 ind./m<sup>2</sup> (Vorobyova and Kulakova, 2009). Sergeeva and Gulin (2007) reported densities of 1 to 29 ind./10 cm<sup>2</sup> of nematodes (reviewed in Vanreusel *et al.*, 2010) from an active methane seepage area in the NW Black Sea at depths between 182 - 252 m corresponding to Dnieper Canyon location.

## 2. MATERIAL AND METHOD

The study is based on 13 samples collected in 2010 and 2011 within the FP7 Hypox Project in Sf. Gheorghe and Mangalia areas situated in the periazotic of the Romanian Black Sea shelf (Fig. 1). The sampling was performed during two expeditions (14-26 May 2010 and 1-10 April 2011) on board the

**Table 1.** Nematodes taxonomic composition and distribution on the Black Sea shelf and anaerobic zone (after Sergeeva, 2000)

Nematoda Taxa	Depth, m						
	470-570	600-700	1300-1340	1700	1800-2000	2080-2121	2250
1. <i>Neochromadora sabulicola</i> (Fil.)					+		+
2. <i>Chromadora</i> sp.1				+	+	+	
3. <i>Ch. nudicapitata</i> Bast.							+
4. <i>Euchromadora striata</i> (Eber.)							+
5. <i>Chromadorida</i> gen.sp					+		
6. <i>Monoposthia costata</i> (Bast.)							+
7. <i>Microaimus kaurii</i> Wieser				+		+	
8. <i>Cobbionema</i> sp.1		+					
9. <i>Quadricoma loricata</i> Fil.	+						
10. <i>Desmoscolex</i> sp.		+					
11. <i>Tricoma</i> sp		+					
12. <i>Theristus</i> sp.	+						
13. <i>Eurystomina assimilis</i> (De Man)				+		+	+
14. <i>Enoplus quadridentatus</i> Berl.							+
15. <i>Oncholaimus</i> sp. 1						+	
16. <i>O. dujardinii</i> De Man				+			
17. <i>Enoploides cf. brevis</i> Fil.						+	

R/V Mare Nigrum. The collecting device was Multicorer Mark II. Regularly, 1 or 2 tubes (0.0075 m<sup>2</sup> area of the tube mouth), were retained for nematodes collection. The top 5 cm of sediments from the tubes were washed on a 90 µm sieve and nematodes were retrieved manually from sample. Individuals were placed on slides in glycerin and species identified on microscope Zeiss “Primo Star”. Total density of nematodes per sample was estimated at 1 m<sup>2</sup>. For identification taxonomic keys from Filipjev (1918 - 1922); Platonova, 1968; NeMys on-line database (<http://nemys.ugent.be>) were used.

Statistical analysis was performed with PRIMER v.5. Ecological univariate indices: frequency, dominance, ecological significance were calculated. The diversity analysis methods we employed were 2 weighted univariate diversity indices of species richness (S), Shannon – Wiener Diversity index (H') , Simpson’s Index of Diversity (1-λ), and one equitability indices, J' (Pielou’s). SIMPER method was performed in order to analyze the most contributing species to similarity and dissimilarity between bathymetric intervals.

### 3. RESULTS

A total of 52 species (Annex 1) were found belonging to 2 orders and 20 families. The first 5 dominant species after indices of ecological significance were: *Sabatieria abyssalis*, *Linhomoeus* sp., *Oncholaimus campylocercoides*, *Halanonchus bullatus*, and *Odontophora angustilaimus* (Fig. 2).

Only 4.25% of species (*S. abyssalis* and *Linhomoeus* sp.) were euconstant. Frequencies ranging between 50-75% recorded representative species of typical bathyal habitats found worldwide (*Desmodora* sp., *Oncholaimus campylocercoides*, *Halanonchus bullatus*, *Tricoma platycephalus*). However, abundance differences were noted in case of species *Desmodora* sp., *S. pulchra*, *Tricoma platycephalus*, *O. angustilaimus* that recorded low numbers (22.77% of total dominance) opposite to *Halanonchus bullatus* and *O. campylocercoides*. About 19 % of species had less than 50% presence totaling 22.78% of species’ dominance. The remaining species (68%) have been accidentally found. This fact points out

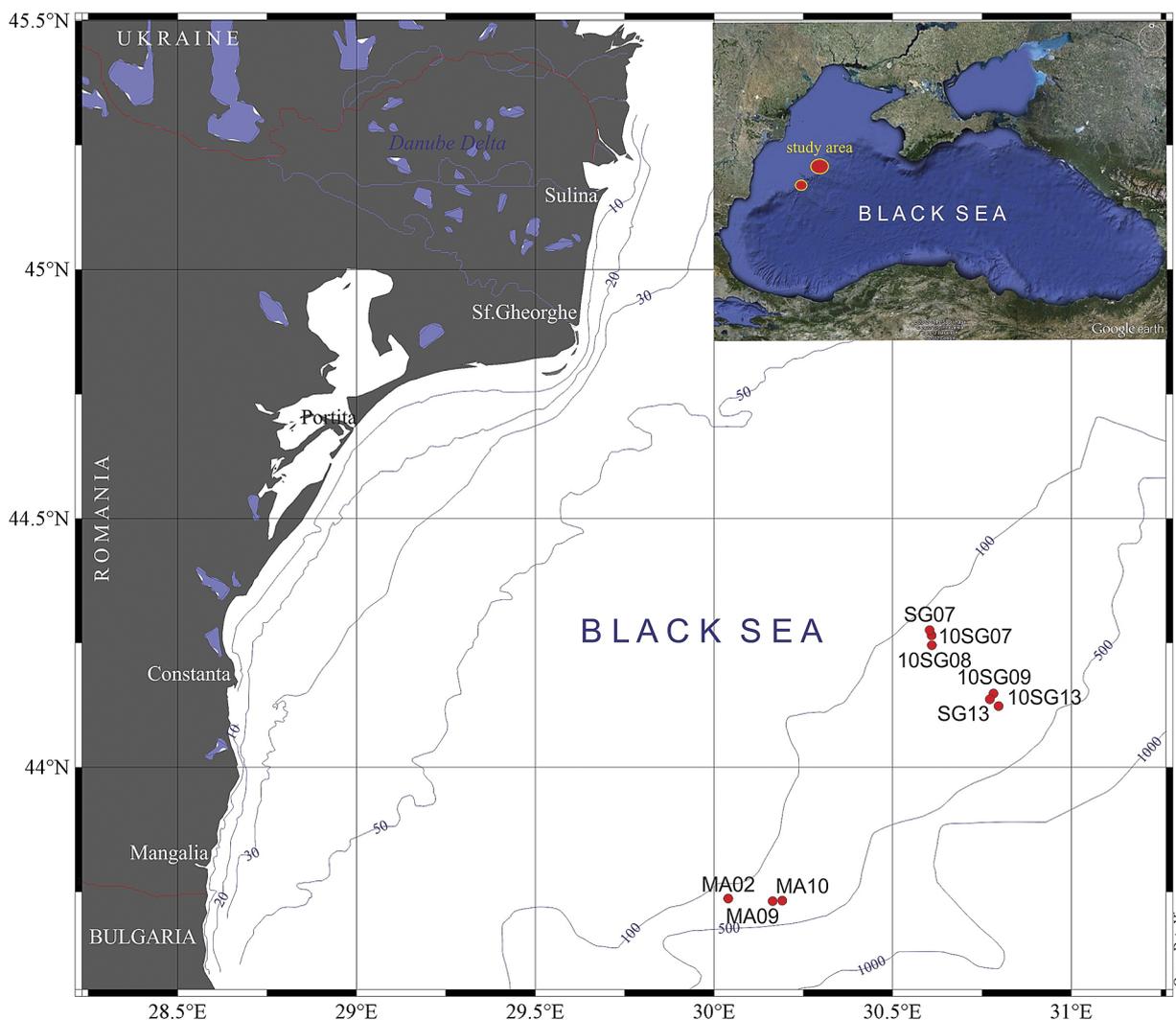
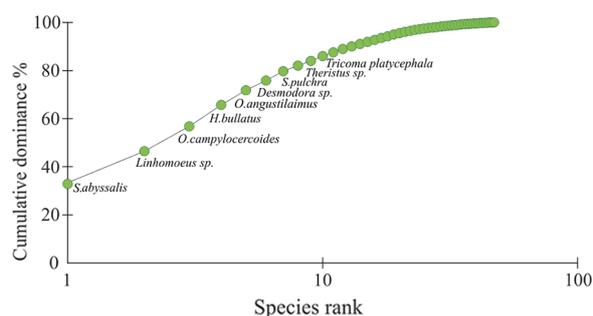


Fig. 1. Sampling area map

the heterogenic character of species distribution in terms of abundance and the occurrence of nuclei of high diversity at specific depths. Most of the accessory species were randomly distributed among samples collected in bathymetric interval 90-140 m. Many of these species are more mobile than others due to the robust body conformation of predator species, such as *Metachromadora macroutera*, epigrowth/deposit feeder (*Axonolaimus ponticus*, *Halaphanolaimus pellucidus*, *Eleutherolaimus longus*) or as elongated, slender one of deposit feeders (*Halalaimus sp.*), which may help them to detect the favourable conditions for living. Role of patch dynamics in the maintenance of deep-sea biodiversity were successfully tested using nematodes by several authors (Rice and Lamshead, 1992).



**Fig. 2.** Cumulative curve after species rank.

Diversity index ( $H'$ ) has been characterized by significant variability between the samples and has been negatively correlated, in general, with depth increases towards the anoxic biotope. The highest diversity ( $H'$ ) had the samples from the interval 98 -144 m of which it can be distinguished that from 98 m, characterized by moderate populations abundance but high diversity and equitability. Concerning the monthly

variability of nematode population structure, larger population number as well as higher diversity was found in May than in April. This change was reflected mostly in the samples collected between 95-110 m depth. The lowest Simpson's diversity recorded the station from 168 m depth with both reduced species richness and abundances. On the contrary, the highest diversity according to Simpson's index ( $1-\lambda$ ) was recorded at 119 m, where there was a good equilibrium between specific diversity and abundance of nematodes populations (Table 2).

The most contributing species to the similarity (similarity percentages; cut off for low contributions: 90.00%) (Table 3) and dissimilarity (cut off for low contributions: 55.00%) at different depths were calculated by SIMPER method. There were established four bathymetric intervals between 90 and 200 m. These were as follow: the first depth interval (90 - 120 m) - characterized by both macrobenthic (Gomoiu *et al.*, 2009) and meiobenthic fauna presence, the second depth interval (120 - 150 m), where the oxygen depletion favours the meiobenthic communities thriving (Kynorincha, Nematoda, Foraminifera), the third (151 - 180 m) and the fourth one (181 -200 m) characterized by severe hypoxia and occurrence of hydrogen sulfide, the habitat formed here hosting only a limited number of meiobenthic species, including nematodes. Thus, the presence of tolerant/resistant nematodes species to oxygen deficit is distinguished.

The average similarity between the depth groups analyzed ranged between 33.88% and 40.28%, the highest value was for the group 121- 150 m and the lowest for 151-180 m (Table 3). As the depth increases the smaller number of species contributes to the similarity between groups. *Linhomoeus sp.* is the main contributor species to similarity in depth groups 121-150 m, respectively 151-180 m (Table 3).

**Table 2.** Univariate analysis of samples

Samples	Depth (m)	S	N	J' (Pielou's)	H' (loge)	1-λ
10MA02	110.8	13	106,932.00	0.63	1.61	0.62
10MA09	150.5	8	16,492.00	0.77	1.61	0.75
MN90MA09	184	5	5,852.00	0.83	1.33	0.70
10MA10	200	7	5,852.00	0.79	1.54	0.72
MN90MA10	218	0	0.00	0.00	0.00	0.00
10SG07	98	24	34,465.72	0.78	2.49	0.84
MN90SG07	107	17	23,674.00	0.41	1.17	0.43
10SG08	114	20	91,903.00	0.66	1.98	0.79
MN90SG08	119	17	9,463.00	0.85	2.39	0.88
10SG09	143.4	16	42,990.50	0.72	1.99	0.79
MN90SG09	148	8	5,985.00	0.83	1.73	0.79
10SG13	161.5	7	1,596.00	0.92	1.79	0.81
MN90SG13	168	4	1,862.00	0.65	0.90	0.46

S = species richness; N = number of individuals (indv.m<sup>-2</sup>)

**Table 3.** Results of the SIMPER analysis (similarity) carried out on Nematoda composition at four depth intervals

SIMPER (Factor groups: bathymetric intervals: 90-120 m; 121-150 m; 151-180 m)			
Similarity Percentages - species contributions (Cut off for low contributions: 90.00 %)			
<b>Group 90 - 120 m</b>			
Average similarity: 39.58			
Species	Average Abundance	Average Similarity	Contribution %
<i>Sabatieria abyssalis</i>	22,718.23	12.65	31.95
<i>Halanonchus bullatus</i>	6,695.53	8.14	20.56
<i>Desmodora sp.</i>	1,457.95	4.08	10.31
<i>Oncholaimus campylocercoides</i>	9,994.87	2.06	5.21
<i>Cobbionema acrocerca</i>	1,253.17	1.59	4.02
<i>Halalaimus sp.</i>	400.66	1.41	3.56
<i>Tricoma platycephala</i>	807.3	1.24	3.14
<i>Halaphanolaimus pellucidus</i>	211.46	1.19	2.99
<i>Eleutherolaimus longus</i>	172.23	1.13	2.86
<i>Odontophora angustilaimus</i>	3,611.72	1.04	2.63
<i>Linhomoeus sp.</i>	3,539.24	1.04	2.63
<i>Paramonhystera elliptica</i>	400.66	0.63	1.6
<b>Group 121 - 150 m</b>			
Average similarity: 40.28			
Species	Average Abundance	Average Similarity	Contribution %
<i>Linhomoeus sp.</i>	5,346.57	10.98	27.26
<i>Theristus sp.</i>	1,822.46	8.67	21.52
<i>Sabatieria abyssalis</i>	2,758.52	7.4	18.37
<i>Odontophora angustilaimus</i>	1,391.44	4.71	11.7
<i>Sabatieria pulchra</i>	2,126.83	4.08	10.12
<i>Desmodora sp.</i>	448	1.71	4.24
<b>Group 151 - 180 m</b>			
Average similarity: 33.88			
Species	Average Abundance	Average Similarity	Contribution %
<i>Linhomoeus sp.</i>	443.33	15.25	45.02
<i>Sabatieria pulchra</i>	1,152.67	10.54	31.1
<i>Sabatieria abyssalis</i>	798	5.91	17.44
<b>Group 181 - 200 m</b>			
Less than 2 samples in group			

Analyzing the total species composition on depth intervals, it has been found that the greatest number of species were in the 90 – 120 m interval – 43 species, while the lowest, between 181 – 200 m – 9 species found. There were 17 species found, between 121 – 150 m, very close to the number of species found in interval 151 – 180 m – 15 species.

Paired comparison of 50% species contribution to the dissimilarity between different depth intervals revealed the greatest difference between the superior limit of periazoic (90 – 120 m) and the limit where the tiobiotic habitats start to prevail (151 – 180 m, respectively 181 – 200 m). Species with the greatest average dissimilarity share were *S. abyssalis*, *Theristus sp.*, *Linhomoeus sp.*, *S. pulchra* and *Halanonchus bullatus*. Between 120 – 151 m depth and 151 – 180 m, respectively 181 – 200 m, the highest average dissimilarities yielded *S. pulchra*, *Theristus sp.*, *Sabatieria abyssalis*, *Viscosia sp.* The last depth intervals compared (151 – 180 m; 181 – 200 m) had the lowest average dissimilarity, only 5 species contributing to 50% cumulative dissimilarity: *Sabatieria abyssalis*, *S. pulchra*, *Viscosia sp.* and *Terschellingia longicaudata*.

#### 4. DISCUSSIONS

Although the Black Sea is considered a deep sea, the life spreading on its NW part is limited mostly up to the margin of the continental shelf and 180 – 200 m depth. The eutrophication phenomena altered also the biogeochemical fluxes. The increase in primary production induced by eutrophication enhanced the consumption of oxygen in the upper layer and the export of detritus to the deep anoxic layer increasing its ammonium and sulfide content (Konovalov and Murray, 2001).

In spite of these conditions, our study demonstrates the presence of 52 species of nematodes, at a depth, ranging from 100 to 200 m, with an uneven distribution and variability from the diversity and abundance point of view. Most of them are also known from the shallower waters (*Sabatieria pulchra*, *Terschellingia longicaudata*, *S. abyssalis*, *Axonolaimus ponticus*, *Linhomoeus sp.* etc.) and it could be said that there is no taxon - specificity found for the periazoic level. According to Vanreusel and coauthors (2010), it seems that shallow water relatives, rather than typical deep-sea taxa, have successfully colonized the reduced sediments of seeps at large water depth.

From the physiological point of view, taking into consideration the species with the most advanced distribution into the anoxic zone (150 - 200 m depth) (*Sabatieria pulchra*, *Terschellingia longicaudata*, *S. abyssalis*, *Linhomoeus sp.*, *Tricoma platycephalus*, *Viscosia sp.*), they are from the category of non-selective and selective deposit feeders, tolerant to oxygen depletion and thiobiotic species. The elongated body conformation of *Linhomoeus sp.*, *Terschellingia*, *Viscosia* could be, according to Jensen (1986), an adaptive character related to low oxygen partial pressure, and epidermal uptake of dissolved organic matter as additional nourishment of thiobiot-

ic species. A high input of organic matter into the sediments is characteristic of the NW Black Sea. It has been found that, in oxygen deficient environments, the degradation of POM is less efficient than in oxygenated water column (e.g., Devol and Hartnett, 2001). In the Black Sea, the lower efficiency of POM degradation in anoxic conditions was confirmed during the “KNORR 88” expedition (Murray and the Black Sea Knorr Expedition, 1991). For instance, the study of the composition (e.g., the fatty acid signature, pigment composition) of the large sinking particles flux revealed a composition that remained almost unchanged when sinking through the anoxic water column (Wakeham and Beier, 1991). It also has been estimated that about 20% of the phytoplankton gross primary production is exported to the anoxic waters. This input into the sediments could be an important food source for a great bulk of nematodes. Besides chemical degradation, the bacterial decomposing of organic matter in anoxic sediments is a very intense process that may help nematodes to use a part of dissolved or particulate organic matter for themselves. Active degradation in the sediments is confirmed by the high concentrations of dissolved organic compounds (e.g., formate, acetate, glucose, and fructose) (Albert *et al.*, 1995). Our study showed greater populations abundances in May 2010 than in April 2011. This could evince the dependence of inputs from the column waters that are more intense in spring than in winter, which coincide with the Danube nutrients discharge and water blooming. In 2010, high debits of the Danube caused an increased flux of nutrients and an early blooming. Usually, in deeper areas, high maximum fluxes and concentrations in the sediments occur in summer and autumn, 4–5 mmol C m<sup>-2</sup> day<sup>-1</sup>, and low fluxes occur in the winter and early spring, when fluxes are nearly zero, with an annual average flux of 0.39 mol C m<sup>-2</sup> year<sup>-1</sup> (Hay *et al.*, 1990; Muramoto *et al.*, 1991). The presence of nematodes species (mainly *S. pulchra* and *S. abyssalis*, *Linhomoeus sp.*) which are known from the muddy enriched organic matter and sulphur biotopes may be rather the evidence for a specialization to organic matter intake. Also, the presence of sulphurous bacterial mats could enhance the survival of these species. For many nematodes species a remarkable symbiosis with the bacterial community was demonstrated. This would contribute, on the one hand, to the detoxification of sulphur compounds by sulphur oxidation (Schiemer *et al.*, 1990) but also may constitute an important food source (Ott and Novak, 1989) (e.g., *Oncholaimus campyloceroides* was found able to consume white bacterial mats in a shallow vent from Milos, Mediterranean Sea (Giere, 2009). At depths ranging from 121 m to 150 m, the most common species/genera, besides those mentioned above, were *Desmodora sp.*, *Theristus sp.*, *Odontophora angustilaimus*, while *Tricoma platycephalus* reached further depths up to 150 – 180 m. These species are all known also from bathyal habitats (Miljutin *et al.*, 2010; Vanreusel, 2010). They are not necessarily specialized on sulphur-oxidizing ecto- or endo-symbiosis. No ecto- or endo-symbiotic species was found at deep seeps or vents (in chemosynthetic environments). The already famous group Stilbonematinae

that comprise nematodes with sulphur-oxidizing ectosymbionts, live in sheltered intertidal and subtidal marine, sulphide-rich sediments, where they migrate around the redox boundary depth (Ott *et al.*, 1991; Hentschel *et al.*, 1999) or in shallow sublittoral hydrothermal vents (Kamenev *et al.*, 1993; Thiermann *et al.*, 1997) and no evidence of their presence in deep vents has been found until now. Additional physiologic mechanisms must intervene in nematodes response to reduced and hypoxic conditions. It has been suggested, for example, the higher respiratory rate or a special hemoglobin system present in some nematodes species.

## 5. CONCLUSIONS

Based on our results, from the analysis of 13 samples in two expeditions (May 2010 and April 2011), we may say that, from about 52 species found in periazoic area, less than 10% can be considered resistant species in hypoxic/anoxic conditions (*Sabatieria pulchra*, *S. abyssalis*, *Terschellingia longicaudata*, *Linhomoeus* sp., *Viscosia* sp.). The species *Desmodora*,

*Theristus*, *Odontophora* could be considered tolerant. Most of the species were found in bathymetric intervals: 98 – 120 m and 121 – 150 m, which indicates a possible migration from the margin of phaseolinic community at times of organic matter enrichment. The various substrate formed by phaseolinic and calcareous muds may also contribute to finding a variety of niches for nematodes living.

Researches in the area should go on, in order to elucidate the role of nematodes as one of the most important group that are able to thrive in harsh conditions, such as those in the Black Sea hypoxic and anoxic environment.

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## REFERENCES

- ALBERT, D., TAYLOR, C., MARTENS, C. (1995). Sulfate reduction rates and low molecular weight fatty acid concentrations in the water column and surficial sediments of the Black Sea. *Deep Sea Research*, **42**, 1239 – 1260.
- ANTIPA, GR. (1941). Marea Neagră. I. Oceanografia, bionomia și biologia generală. *Publ. Fond. "V. Adamachi"*, Acad. Rom., **10** (55), 313 pp.
- BĂCESCU, M. (1963). Contribution à la biocoenologie de la Mer Noire. L'étage périazoïque et la faciès paleo-dreissenifère et leurs caractéristiques. *Rapp. et Pr. Verb. d. Réun. C.I.E.S.M.M.*, **17** (2), 107-122.
- BĂCESCU, M., MÜLLER, G., GOMOIU, M.-T. (1971). Cercetări de ecologie bentală în Marea Neagră. Analiza cantitativă, calitativă și comparată a faunei bentale pontice. *Ecologia marină*, **4**, 357 p.
- DEVOL, A., HARTNETT, H. (2001). Role of the oxygen deficient zone in transfer of organic carbon to the deep ocean. *Limnology and Oceanography*, **46**, 1684 – 1690.
- FILIPJEV, I.N. (1918-1922). Free-living Nematodes of the Sevastopol area // *Trudy osob. zool. lab. Sevastop. biol. St. Vol. (2)* 4, 614 p. (in Russian).
- GIERE, O. (2009). Meiobenthology, the microscopic motile fauna of aquatic sediments. Springer-Verlag Berlin Heidelberg, 527 p.
- GRÉGOIRE, M., SOETAERT, K. (2010). Carbon, nitrogen, oxygen and sulfide budgets in the Black Sea: A biogeochemical model of the whole water column coupling the oxic and anoxic parts. *Ecological Modelling*, **221**, 2287- 2301
- GOMOIU, M.-T., BEGUN, T., TEACA, A. (2009). Ecological state of North-Western Black Sea macrobenthos on offshore bottoms deeper than 50 m. EGU-2009 Conference: Session HS9.2 "Lakes and enclosed Seas", Vienna, Austria 19–24 April 2009.
- HAY, B., HONJO, S., KEMPE, S., ITEKKOT, V., DEGENS, E., KONUK, T., IZDAR, E. (1990). Interannual variability in particle flux in the southwestern Black Sea. *Deep Sea Research*, **37**, 911–928.
- HENTSCHEL, U., BERGER, E.C., BRIGHT, M., FELBECK, H., OTT, J.A. (1999). Metabolism of nitrogen and sulfur in ectosymbiotic bacteria of marine nematodes (Nematoda, Stilbonematinae). *Mar Ecol Prog Ser*, **183**, 149–158.
- JAKUBOVA, L.I. (1935). K raionirovaniju Cernogo moria na osnove sostava fauny bentosa i ego raspredelenia u beregov Cernogo moria. - *Dokl. Acad. Nauk.*, **1** (4) (in Russian).
- JENSEN, P. (1986). Nematode fauna in the sulphide-rich brine seep and adjacent bottoms of the East Flower Garden, NW Gulf of Mexico. *Mar Biol*, **92**, 489–503.
- KAMENEV, G.M., FADEEV, V.I., SELIN, N.I., TARASOV, V.G. (1993). Composition and distribution of macro- and meiobenthos around sublittoral hydrothermal vents in the Bay of Plenty, New Zealand. *N Z J Mar Freshw Res*, **27**, 407-418.
- KONOVALOV, S., MURRAY, J. (2001). Variations in the chemistry of the Black Sea on a time scale of decades. *Journal of Marine Systems*, **31**, 217–243.
- MILJUTIN, D.M., GAD, G., MILJUTINA, MARIA M., VADIM O. MOKIEVSKY, FONSECA, GENEVOIS, VERÓNICA, ESTEVES, A.M. (2010). The state of knowledge on deep-sea nematode taxonomy: how many valid species

- are known down there? *Mar Biodiv* 40:143–159 DOI 10.1007/s12526-010-0041-4.
- MURAMOTO, J., HONJO, S., FRY, B., HAY, B., HOWARTH, R., CISNE, J. (1991). Sulfur, iron and organic carbon fluxes in the Black Sea: sulfur isotopic evidence for origin of sulfur fluxes. *Deep Sea Research II*, **38** (Suppl. 2A), 1151–1188.
- MURRAY, J., THE BLACK SEA KNORR EXPEDITION (1991). Black sea oceanography. Results from the 1988 Black Sea expedition. *Deep Sea Research II*, **38** (Suppl. 2A), 1266.
- NIKITIN, V.N. (1938). Nijnia granitza donnoi fauny i ee rasprostranenie v Tchernom More. *Dokl. Acad. Nauk.*, **21** (7).
- NIKITIN, V.N. (1962). Kolicestvenoe raspredelenie donnoi makrofauny v Chernom More u beregov Kavkaza. *Dokl. Acad. Nauk. SSSR*, **143** (4), 968-971.
- OTT, J., NOVAK, R. (1989). Living at an interface: Meiofauna at the oxygen/sulfide boundary in marine sediments. In: J.S.Ryland & P.A. Tyler (Eds.): *Reproduction, Genetics and Distributions of Marine Organisms*. Olsen & Olsen, Fredensborg, 415-422.
- OTT, J.A., NOVAK, R., SCHIEMER, F., HENTSCHEL, U., NEBELSICK, M., ET AL. (1991). Tackling the sulfide gradient: a novel strategy involving marine nematodes and chemoautotrophic ectosymbionts. *PSZN I: Mar Ecol*, **12**, 261-279.
- PLATONOVA, T.A. (1968). Round worms class – Nematoda/Key for Black and Azov Sea fauna (in Russian). *Nauk Dumka*, 111-183.
- RICE, A. L., L. AMBSHEAD, P. J. D. (1992). Patch dynamics in the deep-sea benthos: the role of a heterogeneous supply of organic matter; In: Boucher, Guy and P.J.D., Lamshead, (1995) - *Ecological Biodiversity of Marine Nematodes in Samples from Temperate, Tropical, and Deep-Sea Regions Conservation Biology Volume 9*, No. 6, 469-497.
- SCHIEMER, E, NOVAK, R., OTT, J. (1990). Metabolic studies on thiobiotic free-living nematodes and their symbiotic microorganisms *Marine Biology*, **106**, 129-137.
- SERGEEVA, N. G, GULIN M. B. (2007). Meiobenthos from an active methane seepage area in the NW Black Sea. *PSZN I: Mar Ecol* 28: 152–159 in Vanreusel A, De Groote A, Gollner S, Bright M (2010) *Ecology and Biogeography of Free-Living Nematodes Associated with Chemosynthetic Environments in the Deep Sea: A Review*. PLoS ONE 5(8): e12449. doi:10.1371/journal.pone.0012449.
- SERGEEVA, N.G. (2000). Meiobenthos of the Black Sea anaerobic zone. *Proceedings The Black Sea Ecological Problems*. Odessa, 258-262 (in English).
- SERGEEVA, N.G., KONOVALOV, S., KOLESNIKOVA, E., CHEKALOV, V. (2011). Response of meiobenthos communities to hypoxia in the Black Sea coastal zone (Tarkhankut, Crimea). – INQUA 501 Seventh Plenary Meeting, Odessa, Ukraine, 151-154.
- SERGEEVA, N.G., GOODAY, A.J., MAZLUMYAN, S.A., ET AL. (2012). Meiobenthos of oxic/anoxic interface in the south-western region of the Black Sea: abundance and taxonomic composition. – In: A.V. Altenbach et al. (eds.): *Anoxia: Evidence for Eukaryote Survival and Paleontological Strategies, Cellular Origin, Life in Extreme Habitats and Astrobiology*, 21, 369-402.
- SERGEEVA, N.G., ZAIKA, V.E. (2013). The Black Sea Meiobenthos in Permanently Hypoxic Habitat. *Acta zool. bulg.*, **65** (2), 139-150.
- SERGEEVA, N.G., MAZLUMYAN, S.A., CAGATAY, N., LICHTSCHLAG, A. (2013). Hypoxic Meiobenthic Communities of the Istanbul Strait's (Bosporus) Outlet Area of the Black Sea. – *Turkish Journal of Fisheries and Aquatic Sciences*, **13**, 33-41.
- SOROKIN, Y.I. (2002). *The Black Sea: Ecology and Oceanography. Biology of Inland Waters*. Backhuys Publishers, Leiden. 875 p.
- THIERMANN, F., AKOUMIANAKI, I., HUGHES J.A., GIÈRE, O. (1997). Benthic fauna of a shallow-water gaseohydrothermal vent area in the Aegean Sea (Milos, Greece). *Mar Biol*, **128**, 149–159.
- VANREUSEL, A., DE GROOTE, A., GOLLNER, S., BRIGHT, M. (2010). Ecology and Biogeography of Free-Living Nematodes Associated with Chemosynthetic Environments in the Deep Sea: A Review. *PLoS ONE* 5(8): e12449. doi:10.1371/journal.pone.0012449.
- VOROBYOVA, L.V., KULAKOVA, I.I. (2009). Contemporary state of the meiobenthos in the western Black Sea, 126 p.
- WAKEHAM, S., BEIER, J. (1991). Fatty acid and sterol biomarkers as indicators of particulate matter source and alteration processes in the Black Sea. *Deep Sea Research II*, **38** (Suppl. 2A), 943–968.
- ZAIKA, V.E., SERGEEVA, N.G. (2012). Deep-water benthic polychaetes (*Vigornella zaikai* and *Protodrilus* sp.) in the Black Sea as indicators of the hydrogen sulfide zone boundary. – *Vestnik zoologii*, **46** (4), 19-27.
- ZAITSEV, YU., MAMAEV, V. (1997). Biological diversity in the Black Sea. A study of change and decline. *Black Sea Environmental Series*, **Vol 3**, UN Publications, 208 p.
- ZERNOV, S.A. (1913). K voprosu ob izutchenii Jizni Tchernogo Moria. *Zap. A.N.*, 8, 32 (1).
- [HTTP://NEMYS.UGENT.BE/](http://NEMYS.UGENT.BE/) (2015). NeMys: World Database of Free-Living Marine Nematodes Vanaverbeke J, Bezerra TN, Braeckman U, De Groote A, De Meester N, Deprez T, Derycke S, Guillini K, Hauquier F, Lins L, Maria T, Moens T, Pape E, Smol N, Taheri M, Van Campenhout J, Vanreusel A, Wu X, Vincx M.

**Annex 1.** The qualitative composition and univariate indices (average density, frequency (F%), dominance after density (D%) and Ecological significance index (W)) of free-living nematodes populations found within the periazoic level of the NW Black Sea shelf

No. crt.	SPECIES	Average density (ind.m <sup>-2</sup> )	Frequency (F%)	Dominance after density (D%)	W (Ecological significance index)
1	<i>Axonolaimus ponticus</i> Filipjev, 1918	3,279.50	36.36	1.05	6.18
2	<i>Axonolaimus setosus</i> Filipjev, 1918	266.00	9.09	0.09	0.88
3	<i>Bathylaimus cobbi</i> Filipjev, 1922	133.00	9.09	0.04	0.62
4	<i>Bathylaimus australis</i> Cobb, 1894	215.41	9.09	0.07	0.79
5	<i>Cheironchus bulbosa</i>	665.00	9.09	0.21	1.39
6	<i>Chromadorina gracilis</i> (Filipjev, 1922) Wieser, 1954	605.50	9.09	0.19	1.33
7	<i>Prochromadorella mediterranea</i> (Micoletzky, 1922) Micoletzky, 1924	422.91	18.18	0.14	1.57
8	<i>Chromadora</i> sp.	133.00	9.09	0.04	0.62
9	<i>Cobbionema acrocerca</i> Filipjev, 1922	5,012.69	27.27	1.60	6.61
10	<i>Paracanthonchus caecus</i> (Bastian, 1865)	2,717.93	18.18	0.87	3.98
11	<i>Daptonema</i> sp.	1,147.64	18.18	0.37	2.58
12	<i>Daptonema elegans</i> (Kreis, 1929)	12,110.00	9.09	3.87	5.93
13	<i>Desmodora</i> sp.	7,822.03	63.64	2.50	12.62
14	<i>Dichromadora gracilis</i> (Kreis, 1929)	215.41	9.09	0.07	0.79
15	<i>Eleutherolaimus longus</i> Filipjev, 1922	2,505.41	36.36	0.80	5.40
16	<i>Enoploides amphioxi</i> Filipjev, 1918	422.91	18.18	0.14	1.57
17	<i>Enoploides cirrhatus</i> Filipjev, 1918	289.91	9.09	0.09	0.92
18	<i>Enoplus euxinus</i> Filipjev, 1918	1,211.00	9.09	0.39	1.88
19	<i>Eurystomina assimilis</i> (de Man, 1876)	399.00	9.09	0.13	1.08
20	<i>Halalaimus</i> sp.	2,597.29	45.45	0.83	6.15
21	<i>Halaphanolaimus pellucidus</i> Southern, 1914	2,138.29	36.36	0.68	4.99
22	<i>Halanonchus bullatus</i> Southern, 1914	29,138.21	63.64	9.32	24.36
23	<i>Halichoanolaimus robustus</i> (Bastian, 1865) de Man, 1886	1,330.00	9.09	0.43	1.97
24	<i>Linhomoeus</i> sp.	32,970.92	90.91	10.55	30.97
25	<i>Mesacanthion conicum</i> (Filipjev, 1918)	215.41	9.09	0.07	0.79
26	<i>Metachromadora macroutera</i> Filipjev, 1918	4,745.00	27.27	1.52	6.43
27	<i>Metoncholaimus demani</i> (Zur Strassen, 1894)	3,021.66	18.18	0.97	4.19
28	<i>Nemanema filiforme</i> (Filipjev, 1918)	936.15	18.18	0.30	2.33
29	<i>Odontophora angustilaimus</i> (Filipjev, 1918)	19,799.45	63.64	6.33	20.08
30	<i>Oncholaimus campylocercoides</i> De Coninck & Schuurmans Stekhoven, 1933	43,353.48	54.55	13.87	27.50
31	<i>Oxystomina clavicauda</i> (Filipjev, 1918)	266.00	9.09	0.09	0.88
32	<i>Quadricoma loricata</i> Filipjev, 1922	1,251.73	18.18	0.40	2.70
33	<i>Quadricoma media</i> (Reinhard, 1881)	430.82	9.09	0.14	1.12
34	<i>Quadricoma pontica</i> Filipjev, 1922	2,113.38	18.18	0.68	3.51
35	<i>Quadricoma</i> sp.	266.00	9.09	0.09	0.88
36	<i>Quadricoma nematodoides</i>	936.15	18.18	0.30	2.33

No. crt.	SPECIES	Average density (ind.m <sup>-2</sup> )	Frequency (F%)	Dominance after density (D%)	W (Ecological significance index)
37	<i>Paramonhystera elliptica</i> Filipjev, 1918	1,602.65	18.18	0.51	3.05
38	<i>Prosphaerolaimus</i> sp.	2,673.30	9.09	0.86	2.79
39	<i>Rhabdodemia pontica</i> Platonova, 1965	6,433.51	36.36	2.06	8.65
40	<i>Sabatieria abyssalis</i> (Filipjev, 1918)	11,6696.28	90.91	37.33	58.26
41	<i>S. longicaudata</i> Filipjev, 1922	1,049.22	18.18	0.34	2.47
42	<i>S. pulchra</i> (Schneider, 1906)	12641.99	54.55	4.04	14.85
43	<i>Sphaerolaimus macrocirculus</i> Filipjev, 1918	2,287.11	18.18	0.73	3.65
44	<i>Sphaerolaimus dispar</i> Filipjev, 1918	1,897.96	18.18	0.61	3.32
45	<i>Sphaerolaimus ostreae</i> Filipjev, 1918	430.82	9.09	0.14	1.12
46	<i>Sphaerocephalum</i> sp.	399.00	9.09	0.13	1.08
47	<i>Spirinia zosterae</i>	2,210.63	27.27	0.71	4.39
48	<i>Terschellingia longicaudata</i> de Man, 1907	532.00	18.18	0.17	1.76
49	<i>Theristus</i> sp.	6,180.22	45.45	1.98	9.48
50	<i>Tricoma platycephala</i> Filipjev, 1922	4,567.74	63.64	1.46	9.64
51	<i>Tripyloides marinus</i> (Bütschli, 1874)	133.00	9.09	0.04	0.62
52	<i>Viscosia</i> sp.	2,247.57	27.27	0.72	4.43