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Mesozooplankton Assemblages in Northwestern Part of Black Sea

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Abstract: Structure and distribution of mesozooplankton complexes in two northwestern Black Sea regions are analyzed and compared for June 2006 and May 2009. The aim of the study is to assess the mesozooplankton distribution in relation to environmental parameters: temperature, salinity and fluorescence. The community is dominated generally by copepods and meroplanktonic organisms. The average mesozooplankton numerical abundance and biomass of 1764.10 ± 1233.9 ind. m^{-3}; 62.01 ± 36.7 mg. m^{-3} in 2006 and 2507.04 ± 1747.7 ind. m^{-3}; 63.37 ± 46.69 mg. m^{-3} in 2009 are registered. Increasing trend from north toward south direction is evident. High numerical abundances are found in anticyclonic gyres (Constantza and Kaliakra) with predominant mesozooplankton distribution in the waters between the coast and Rim Current. Maximum mesozooplankton abundance is registered along the coastline with very productive waters areas (Danube delta, Kaliakra, Varna and Burgas bays) in comparison with the other regions of Black Sea. Hierarchical clustering is applied to assess species associations based on a matrix of similarities between species. Cluster analysis differentiated three main groups with 65% similarity of Bray-Curtis in 2006 and 67% in 2009.

Key words: zooplankton, distribution, Romanian Black Sea, Bulgarian Black sea

Introduction

Black sea is isolated semi-enclosed basin (part of the World Ocean (ultimately connected to the Atlantic Ocean via the Mediterranean and the Aegean Seas and various straits) with low water exchange and significant freshwater inflow. These features make the marine system very sensitive and during the last three decades of the past century its environment and biota suffered the impact of many contaminants with natural and anthropogenic origin (Mee 1992, Kovalev *et al.* 1998).

In ecological aspect, three periods in the evolution of Black Sea ecosystem are distinguished. The referent one – up to 1970 is characterized with natural shift of seasonal succession and lack of anthropogenic nutrient enrichment (Prodanov *et al*. 2001, Oguz 2005, Moncheva *et al*. 2008). As a result of intensive eutrophication from the mid 70s to the early 90s ecological instability was observed and degradation such as increasing of essential nutrients concentration, frequent and extensive phytoplankton blooms, hypoxia/anoxia, increased mortality of benthic organisms, lost of biodiversity, etc. In shallow waters the mesozooplankton had extremely high density and biomass due to the mass development of non-trophic or opportunistic zooplankters as *Noctiluca scintillans, Aurelia aurita, Acartia clausi* whereas some of the other elements decreased – *Centropages ponticus* (= *C. kroyeri*), *Oithona similis, Penilia avirostris* and even disappeared – *Anomalocera pattersoni, Labidocera brunescens, Oithona nana* (BSC 2008). The conditions were favourable for invasion of predatory ctenophore *Mnemiopsis leidyi* (Konsulov, Kamburska 1998). Being an important predator and competitor for food resources its impact on the mesozooplankton biocoenose and fish stocks complicated the ecological situation. It resulted in decreasing of mesozooplankton density, weaker grazing on the phytoplankton and trophic limitation of planktivorous pelagic fishes. The structural change in food web affected marine ecosystem functioning. From mid 90s up to now the recent period has began. It is recognized as a phase of relative recovery with decrease in nutrients level and improvement of environmental chemical parameters, reduction of algal blooms, relatively stable benthic communities and restoration of fish stocks (Shtereva *et al.* 1998, Moncheva *et al.* 2001). But the 'post- eutrophication' regime was markedly different from the classical phytoplankton-zooplankton-fish chain of the similarly low nutrient 'pre-eutrophication' regime before 1970. The post eutrophication state cannot be considered as a major improvement or restoration of the northwestern coastal ecosystem (Oguz, Velikova 2010).

The recent study area exhibits some new hydrological and hydrographic features which control to a large extent the spatial distribution of the mesozooplankton. Black sea is characterized with low salinity up to 18‰ in the surface layer in open sea. In the northwestern and western regions due to the powerful influence of Danube River it decreases to 15-16‰ and less. The surface temperature varies seasonally between 6-8 °C and up to 28-30 °C (Rozhdestvenski 1986, Zaitsev 1998).

Structure, spatial distribution patterns and state of the mesozooplankton community in the north-western and western sectors of Black Sea (Bulgaria and Romania) in spring of 2006 and 2009 are described and compared.

Material and Methods

The zooplankton data collated in this study is derived from two Black sea regions: North-Western (NWBS) along Romanian coast and Western (WBS) in front of Bulgarian coast (Fig. 1). Two sampling cruises in June 2006 and May 2009 were carried out on board the R/V 'Akademik' of Institute of Oceanology – BAS, Varna. Samples were collected by vertical hauls in different depth layers: offshore from the anoxic layer to the surface and inshore from 2 m above the bottom to the surface at speed 0.5 m/s using a Juday quantitative net (0.1 m^2 mouth opening area, 200 μm mesh size). As a whole, 186 zooplankton samples were collected from 87 sites in the north-western area (within 44°.49'N 29°.47'E – 44°.49'N 30°.30'E and 42°.7'N 28°.0'E – 43°.22'N 31°.0'E in 2006; 45°.0'N 29°.45'E – 45°.0'N 31°.0'E and 43°.10'N 28°.0'E – 43°.15'N 30°.45'E in 2009) along inshore-offshore transects off the coastline (Fig. 1 a, b). Before preservation in buffered 4% formalin solution, gelatinous species were sorted out, counted and measured. Species abundance per cubic meter was calculated according to Dimov's method (Dimov 1959). Biomass (mg. m^{-3}) was estimated by using individual standard weights (Petipa 1959).

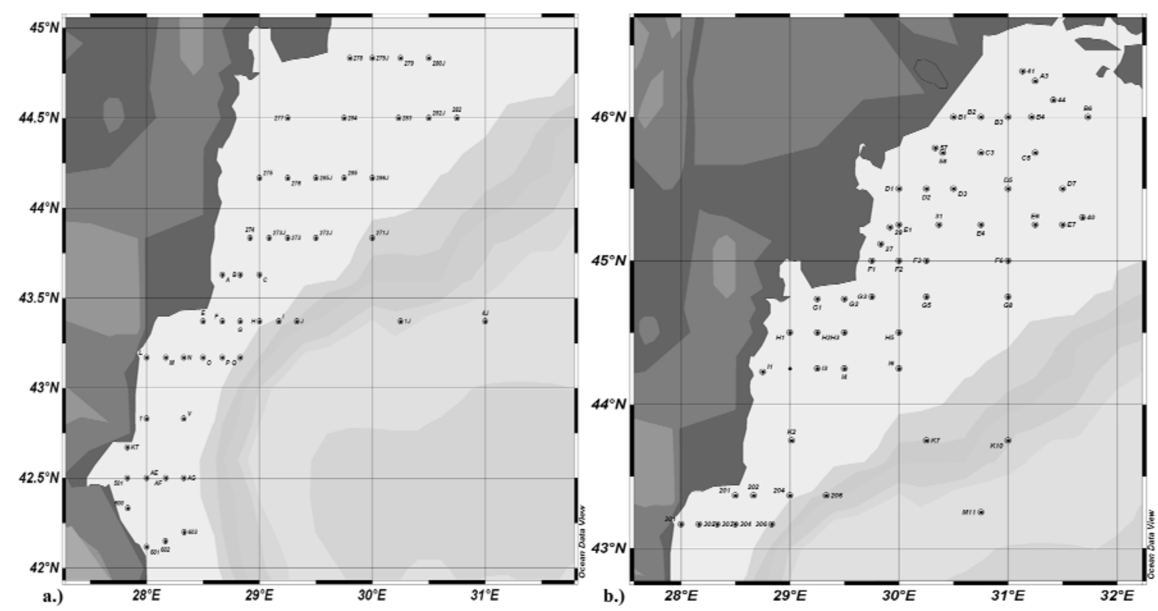

Fig. 1. Maps of sampling area in June 2006 (a) and May 2009 (b).

Simultaneously with the zooplankton sampling, some hydrophysical and hydrochemical parameters were measured *in situ* by Seabird Electronics CTD Device: temperatures (°C), salinity and fluorescence (fluorescence gradient measured *in situ* by fluorimeter readings showed the vertical profile of chlorophyll ‘a’). Data derived from samples collected at different depth intervals were grouped depends of temperature gradient as follows: SHL (surface homogenous layer), TC (thermocline) and USHL (under surface homogenous layer).

Statistical analyses were performed using the statistical software PRIMER 5 (PRIMER-E Ltd. 2001). Cluster and SIMPER analysis were applied to reveal similarities/dissimilarities in the zooplankton structure among the study areas (Clarke, Warwick 2001).

Results and Discussions

Hydrophysical and hydrochemical conditions

The hydrographic structure of study area in June 2006 was characterized with well discernable two-layer stratification in term of temperature and salinity profiles. In both areas the average temperature in the surface layer was between 17.2 and 20.2 ˚C (Fig. 2 a, b). The seasonal thermocline in the first period was localized in the layer 10-30 m depth with temperature ranging from 19.3 to 8.16 ˚C for the western region (Fig. 2 a) and from 19.6 to 7.9 ˚C for the northwestern area (Fig. 2 b). The temperature of the deeper water remains consistent with the layer of cold intermediate water (CIL), characterized by core temperatures of ~6 ˚C within the layer 30-56 m depth along Romanian coast and rather thicker stratum (from 33 to 88 m) and higher core temperature of ~7 ˚C in front of Bulgarian area (Fig. 2 a, b). In May 2009 the surface homogenous layer was limited between upper 0-5 m depth with mean temperature of 13.5 ˚C in Bulgarian and 14.9 ˚C in Romanian sector. The thermocline was situated in the layer 5-20 m depth with temperature ranging from 15.3 to 8.8 ˚C for the northwestern area (Fig. 3 b). In the western area the layer was between 5-50 m depth with temperature from 13.5 to 8.5 ˚C (Fig. 3 a). The CIL was characterized by core temperatures of ~7 ˚C within the layer 20-40 m depth along Romanian coast but it is not formed in front of Bulgarian one due to relatively mild previous winter with average air temperature of ~ 4 ˚C (http://bulgarian.wunderground.com) (Fig. 3 a, b).

The average salinity in the surface layer in spring of 2006 varied between 8.7 and 16.5‰ (Fig. 2 d) in Romanian and 13.3 and 18.4‰ in Bulgarian waters (fig. 2 c). The only exception were the minimal values of ~ 4‰ measured in the surface layer in front of Constantza. The values in 2009 varied from 7.9 to 18.2‰ in the northwest (Fig. 3 d) and from 13.5 to 18.2‰ in the western areas (Fig. 3 c).

In both years (Fig. 2 and 3 e, f) the depth of the chlorophyll ‘a’ maximum in the study areas was observed at about 10 m depth where the fluorescence maximum was recorded (Slabakova, Slabakova 2008).

Zooplankton community structure

As a result of the provided investigations 28 taxa were registered in both parts of the sea. In each of the periods (June 2006 and May 2009) a total of 27 and 24 mesozooplankton species were registered respectively, divided into phyla Protozoa, Ctenophora, Nemathelminthes, Annelida, Arthropoda, Mollusca, Chaetognatha, Chordata.

Abundance and biomass

An average mesozooplankton (without *Noctiluca scintillans*) abundance of 1764.10 ± 1233.9 ind. m^{-3} in 2006 and 2507.04 ± 1747.7 ind. m^{-3} in 2009 was recorded. In terms of biomass the values were almost similar in both study years 62.01 ± 36.7 mg. m^{-3} and 63.37 ± 46.69 mg. m^{-3}, respectively.

The community in entire area was dominated by the group of Copepoda, representing 61% of the abundance (82% of the biomass) in 2006 and 60% (85%) in 2009.

Bulgarian area. A total of 22 mesozooplankton species were found in June 2006. The community abundance and biomass were 1855.73 ±1383.37 ind. m^{-3} and 60.47 ± 36.95 mg. m^{-3}, respectively. Significant domination of the group of copepods was observed – 54% of the abundance (78% of biomass), co-dominated by Meroplankton 26% (9%) and Cladocera 13% (4%), and the rarer Appendicularia, Chaetognatha and Ichthyoplankton (Table 1). Among Copepoda the most important species in terms of numerical abundance were *Acartia clausi, Pseudocalanus elongatus, Paracalanus parvus* whereas *Calanus euxinus, A. clausi* and *P. elongatus* prevailed in biomass (Table 2).

A lower number of 20 mesozooplankton species was recorded in May 2009. Nevertheless, the

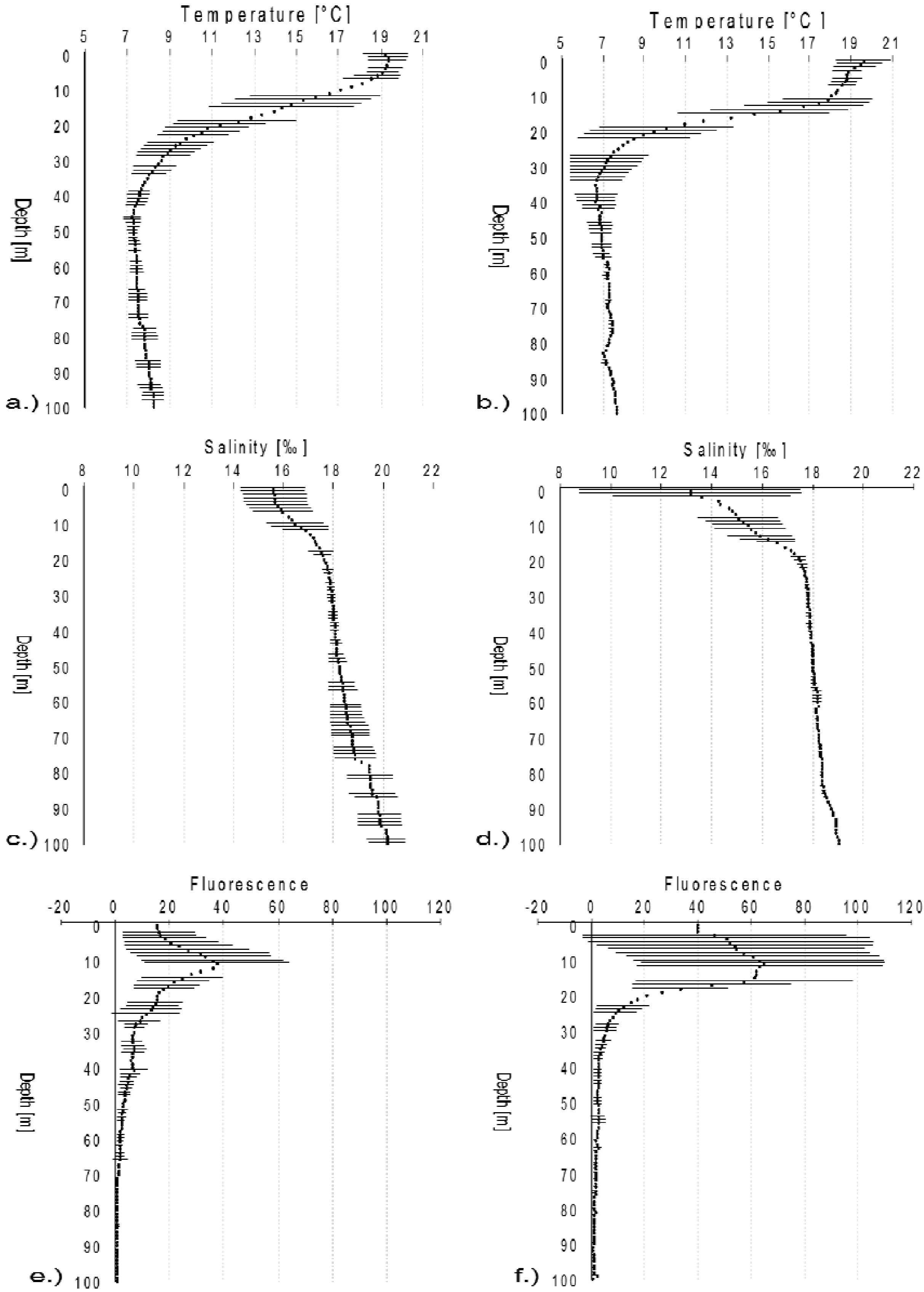

Fig. 2. Vertical profiles of temperature, salinity and fluorescence in June 2006: Temperature distribution along (a) Bulgarian coast and (b) Romanian coast; Salinity distribution along (c) Bulgarian coast and (d) Romanian coast; Fluorescence distribution along e) Bulgarian coast and (f) Romanian coast.

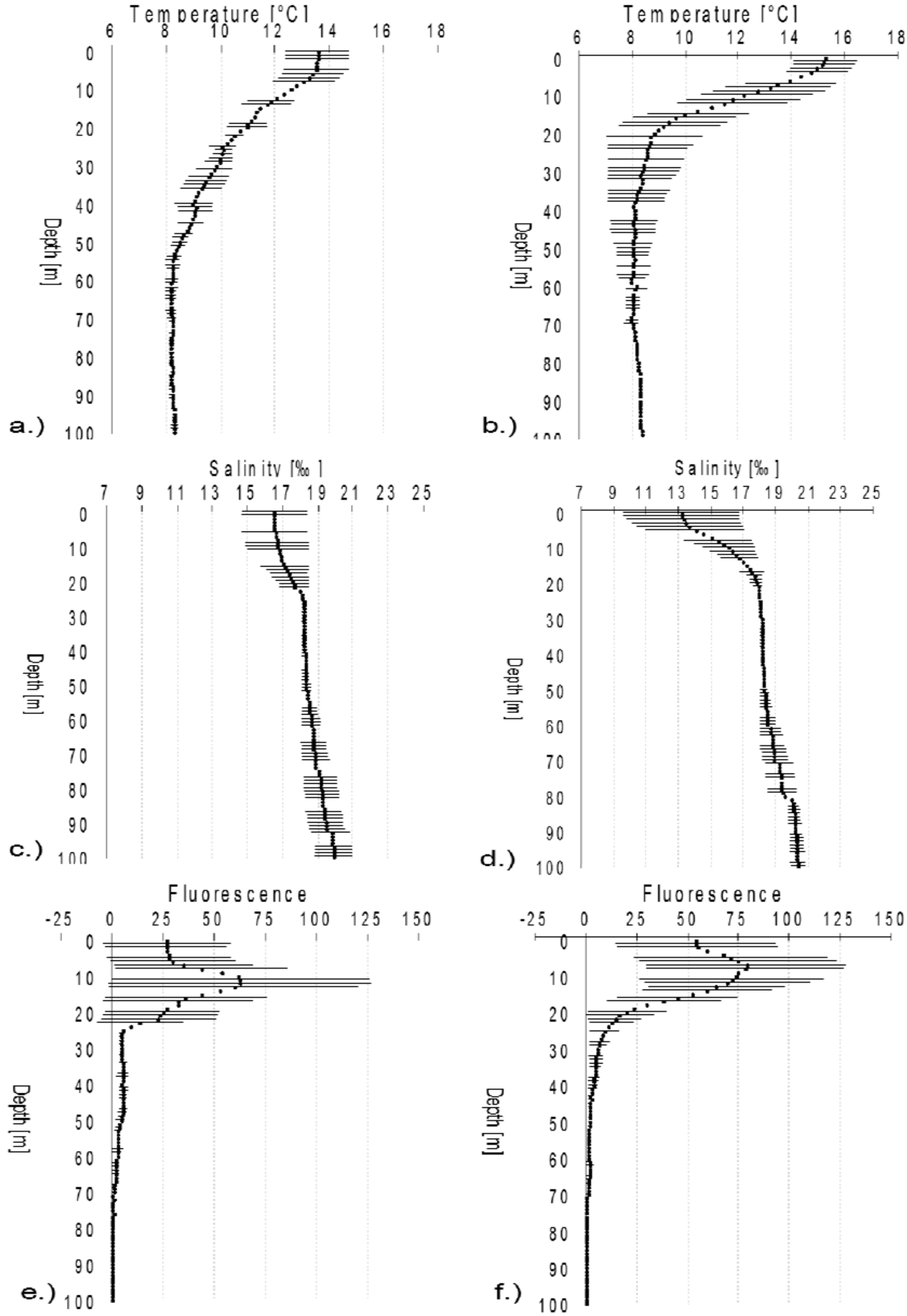

Fig. 3. Vertical profiles of temperature, salinity and fluorescence in May 2009: Temperature distribution along (a) Bulgarian coast and (b) Romanian coast; Salinity distribution along (c) Bulgarian coast and (d) Romanian coast; Fluorescence distribution along e) Bulgarian coast and (f) Romanian coast.

Table 1. Participation of an essential mesozooplankton groups (%) in the structure of communities in 2006 and 2009 (Legend: WBS – Western Black Sea; NWBS – Northwestern Black Sea; AB – abundance; BM – biomass).

	2006				**2009**			
	WBS		**NWBS**		**WBS**		**NWBS**	
Group (%)	AB	BM	AB	BM	AB	BM	AB	BM
Copepoda	54	78	68	86	58	86	62	84
Cladocera	13	4	10	2	4	1	8	3
Meroplankton	26	9	14	4	21	6	16	7
Chaetognata	< 1	8	< 1	6	< 1	2	< 1	3
Appendicularia	7	1	7	1	17	4	13	3
Ichthyoplankton	< 1	< 1	< 1	1	< 1	< 1	< 1	< 1

mesozooplankton quantity was higher 3074.93 ± 2506.73 ind. m^{-3} (76.12 ± 35.99 mg. m^{-3}). The percentages of the main mesozooplankton groups are presented in Table 1. Identically with the previous period the same species dominated copepods assemblage in terms of abundance and biomass.

Romanian area. Romanian waters were distinguished with larger number of species (26 in 2006 and 24 in 2009) due to the presence of mixohaline and freshwater plankton organisms such as *Cyclops strenuus, Tisbe furcata, Eurytemora affinis, Daphnia gr. longispina, Mesopodopsis slabberi*. Generally, the abundance and biomass in both years were lower in comparison with the WBS region 1630.81 ± 993.01 ind. m^{-3} (64.25 ± 37.01 mg. m^{-3}) and 2223.1 ± 1186.82 ind. m^{-3} (56.99 ± 50.77 mg. m^{-3}), respectively.

A significant reverse in *N. scintillans*: mesozooplankton ratio with 86%:14% in 2006 and 12%: 88% in 2009 was observed. In both years in front of Bulgarian coast the average abundance and biomass were respectively 1.4 and 6.8 times higher than those in Romanian area, with values of 12 738 ind.m^{-3} (892 mg.m^{-3}) in 2006 and 764 ind.m^{-3} (54 mg.m^{-3}) in 2009.

Horizontal distribution

The river inflow and local anticyclones determine the distribution of mesozooplankton in the northwestern and the adjacent western area of Black Sea where its quantity was high due to the significant primary production in nutrient rich waters. The influence of Danube River extends southward along Bulgarian coast. As a result of the increased water dynamics in front of Bulgarian and Romanian coasts, patchiness in mesozooplankton distribution with high density of plankton animal organisms was observed.

The distribution of mesozooplankton in the surface homogeneous layer exhibited heterogeneity of numerical abundance. Its quantitative attributes manifested a classical pattern of surface distribution decreasing along the axis coast – open sea. In spring of 2006 no clear distribution pattern in direction from North (Romanian) towards South (Bulgarian) area was discerned. However, the spreading of Copepoda and Cladocera groups as main contributors of mesozooplankton abundance followed the hydrographic features of the Black Sea (Fig. 4). High numerical abundances were found in anticyclonic gyres (Constantza and Kaliakra) and mainly distributed in the waters between the coast and Rim Current. Maximum mesozooplankton abundance was identified along the coastline at areas nominated as 'hot spots' (Danube delta, Kaliakra, Varna and Burgas Bays) and very productive waters in comparison with the rest regions of Black Sea (Kamburska *et al.* 2006). *N. scintillans* was more abundant in Southern Romanian part where chlorophyll maximum was observed (Slabakova, Slabakova 2008). Its population density has been found to be dependent on food availability, which tends to stay in shallow, coastal areas, where phytoplankton thrives. *Noctiluca* is also a major contributor to the population density of zooplankton. Competition between mesozooplankton and *Noctiluca* for the same food resources could be an important factor, considering the high production of the species when compared to herbivorous and omnivorous zooplankters (Yilmaz *et al.* 2005).

Three main groups with 65% similarity were determined by cluster analyze. 17 species and taxa were accounted for 26% of average dissimilarity (SIMPER test) between groups A (coastal area) and B (anticyclonic zone between Constantza and Kaliakra). Benthic larvae (Gastropoda, Cirripedia and Polychaeta) contributed about 33% of discrimi-

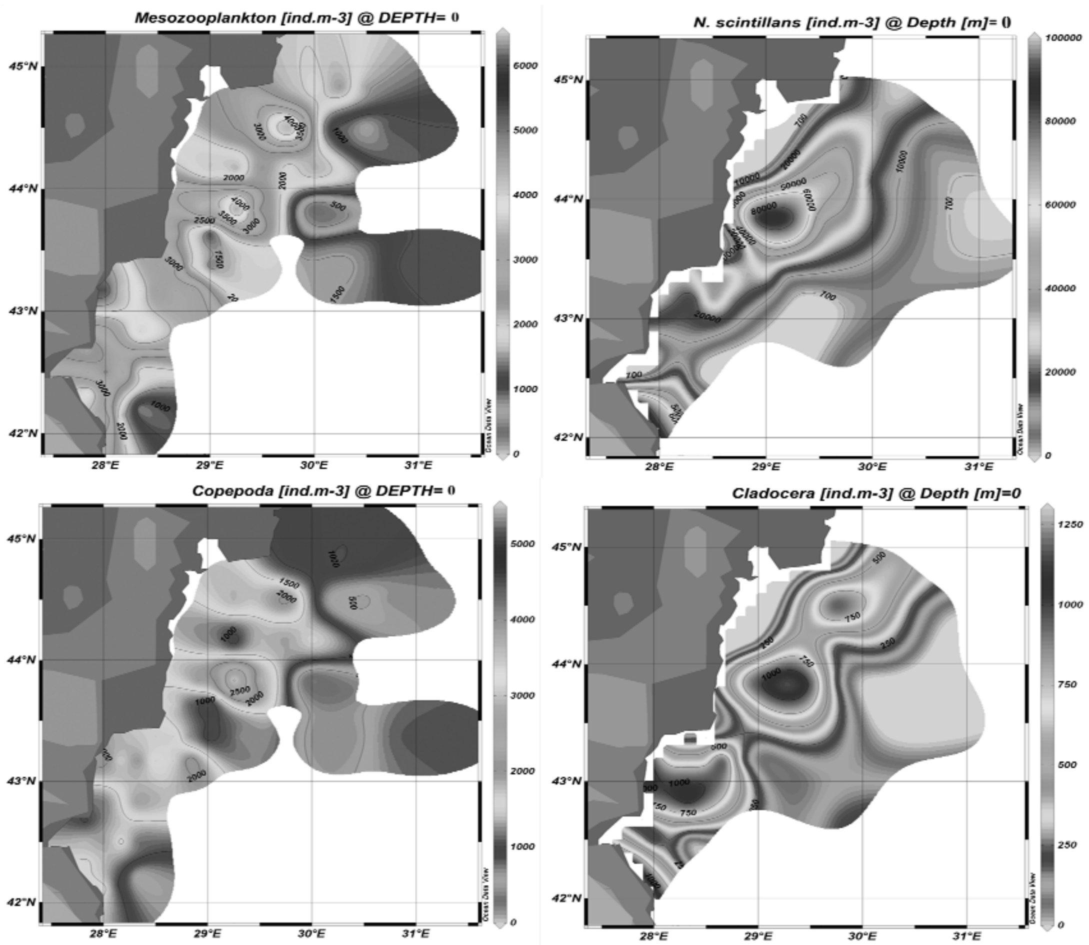

Fig. 4. Spatial abundance distribution (ind. m^{-3}) of mesozooplankton, *N. scintillans*, copepods and cladocerans in the upper surface layer in June 2006.

nation, occurring mostly at western stations. Main contributors to dissimilarity between the two groups were also *P. elongatus, C. ponticus* and *Pleopis polyphemoides* (totally 18%).

31% of dissimilarity was found between group A and C (southward of Kaliakra). Copepoda species *A. clausi, C. ponticus* (mainly below Kaliakra), *Oithona similis* and *P. elongatus* contributed about 35% of discrimination.

An average dissimilarity of 44% between groups B and C was accounted due to the presence of benthic larval stages (Cirripedia, Polychaeta and Gastropoda) with 31% and *Acartia tonsa, P. elongatus, P. parvus, C. ponticus* and *P. polyphemoides* (totally 24%) in front of Kaliakra.

In spring 2009, an increasing trend of mesozooplankton density was observed from low abundant NWBS part toward south. Significant values were recorded in the coastal zone southward of Kaliakra (7378.4 ± 5089.2 ind. m^{-3} and 74.1 ± 40.8 mg. m^{-3}) due to the species of Copepoda, Appendicularia and the larval stages of invertebrate benthic organisms in shallow waters along the Bulgarian coastline whereas they decreased northward. The most remarkable peculiarity of community structure in 2009 was the noticeably smaller quantity of *N. scintillans* in comparison with the previous one in the spring of 2006 (Fig. 5).

In May 2009 two main groups with 67% similarity were determined. 14 species and taxa were accounted for 33% of average dissimilarity between groups A (coastal area) and B (offshore). Benthic larvae (Cirripedia, Gastropoda, Polychaeta and Lamellibranchia) presented about 32% of discrimination, occurring mostly at inshore stations. Main contributors to dissimilarity between the two groups were also *N. scintillans*, *P. elongatus, C. euxinus, Oicopleura dioica* in open sea and *P. polyphemoides, A. tonsa, P. parvus, Harpacticoida sp.* in coastal area.

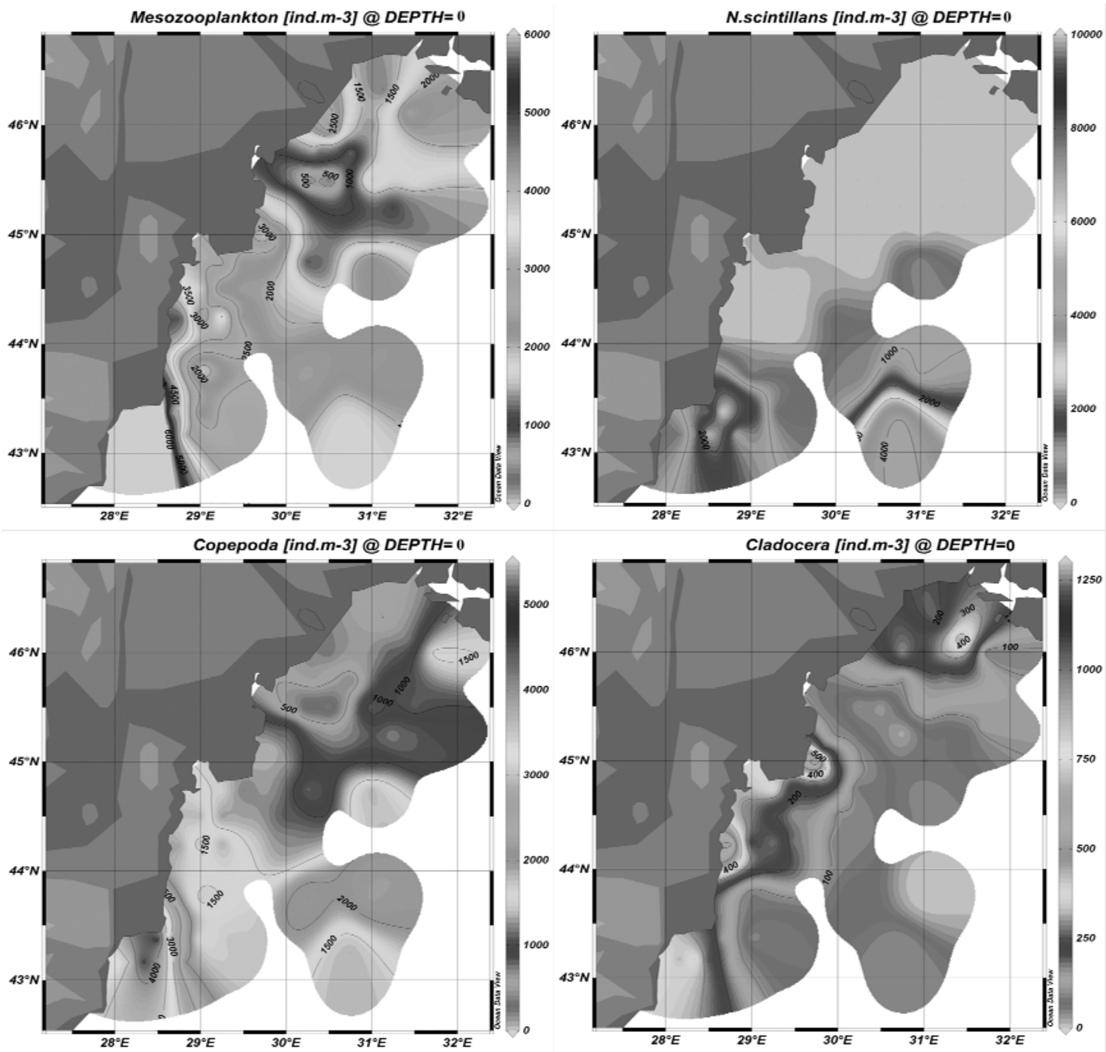

Fig. 5. Spatial abundance distribution (ind.m^{-3}) of mesozooplankton, *N. scintillans*, copepods and cladocerans in the upper surface layer in May 2009.

Table 2. Structure of copepoda's group (%) in 2006 and 2009 by regions (Legend: WBS – Western Black Sea; NWBS – Northwestern Black Sea; AB – abundance; BM – biomass).

	2006				2009			
	WBS		NWBS		WBS		NWBS	
Species (%)	**AB**	**BM**	**AB**	**BM**	**AB**	**BM**	**AB**	**BM**
Acartia clausi (Giesbrecht, 1889)	44	25	36	20	35	22	34	28
Acartia tonsa (Dana, 1849)	4	2	2	1	2	1	1	1
Paracalanus parvus (Claus, 1863)	17	4	11	3	20	6	12	4
Pseudocalanus elongatus (Boeck, 1872)	21	17	39	32	25	25	31	29
Calanus euxinus (Hulsemann, 1991)	3	50	2	42	2	46	2	37
Centropages ponticus (Karavaev, 1894)	4	3	2	2	< 1	< 1	< 1	1
Eurytemora affinis (Poppe, 1880)	0	0	< 1	< 1	0	0	< 1	< 1
Oithona similis (Claus, 1866)	6	< 1	6	< 1	12	1	14	1
Cyclops strenuus (Fisch, 1851)	0	0	< 1	< 1	0	0	< 1	< 1
Tisbe furcata (Baird, 1837)	0	0	< 1	0	0	0	0	0
Harpacticoida sp.	1	0	3	0	3	0	5	0

Vertical distribution

The vertical distribution of mesozooplankton was described within three discrete layers in the water column in respect to the variability of main physico-chemical characteristics. At all sampling stations the numerical abundance in both areas showed decreasing trend in depth.

N. scintillans had a major share of the total abundance in the whole water column in spring of 2006. In Bulgarian sector the values were 87% (SHL), 79% (TC), 83% (USHL); in Romanian – 90% (SHL), 93% (TC), 89% (USHL), respectively. Mesozooplankton community was dominated as a percentage by copepod species followed by Meroplankton, Cladocera and Appendicularia. Seven common copepod species were found out during the study period. *A. clausi* (~ 54%), *P. parvus* (about 22%) and *C. ponticus* (less than 2%) were distributed mostly in the upper layers (SHL and TC), *P. elongatus* (~ 43%) mainly within the layer with temperature about 8 ˚C, *C. euxinus* (6% of abundance and 55% of biomass) throughout the USHL, *O. similis* (about 8% of abundance) above the cold intermediate and the upper layers. *C. strenuus, T. furcata* and *E. affinis,* presented along Romanian coastline only, were registered with a very low concentration (0.36%, 0.003% and 0.02%) in the upper strata.

In May 2009 the numerical shares of *N. scintillans* in the water column in Bulgarian sector were 36% (SHL), 32% (TC), 28% (USHL) and in Romanian – 12% (SHL), 12% (TC), 4% (USHL), respectively.

Mesozooplankton community was dominated as a percentage by copepod species followed by Meroplankton, Appendicularia and Cladocera. The values of Copepoda in WBS region were 29% (SHL), 49% (TC), 60% (USHL); in NWBS – 58% (SHL), 75% (TC), 82% (USHL), respectively. The same copepod species were found out during the study period. The shares of *A. clausi*, *C. ponticus* and *P. parvus* in the upper layers (SHL and TC) were 31% and 21%, respectively. *P. elongatus* (~ 56%) and *C. euxinus* (6% of abundance and 64% of biomass) were found mainly within USHL, *O. similis* (about 16% of abundance) above the cold intermediate and the upper layers. *E. affinis* found in Romanian surface layer were with concentration of 0.0007%.

Conclusion

Nested patchiness was a common feature of mesozooplankton communities and spatial heterogeneity occurs on a hierarchical continuum of scales. Zooplankton quantitative attributes in spring 2006 and 2009 manifested a classical pattern of surface distribution: a decreasing trend along the coast-open sea axis. The stability of ecosystem and its trophic potential were confirmed by the high spring mesozooplankton density parameters. High numerical abundances were found in anticyclonic gyres (Constantza and Kaliakra) with predominant mesozooplankton distribution in the waters between the coast and Rim Current. The vertical distribution of the zooplankton within three discrete layers demonstrated a similar trend for both study regions. The relatively low dissimilarity factor showed similar community structure and diversity in both investigated areas.

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