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LONG-TERM CHANGES IN THE MACROZOOBENTHIC COMMUNITIES OFFSHORE CAPE KALIAKRA (WESTERN BLACK SEA)

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МНОГОГОДИШНИ ПРОМЕНИ В БЕНТОСНИТЕ СЪОБЩЕСТВА ПРЕД НОС КАЛИАКРА (ЗАПАДЕН ЧЕРНОМОРСКИ РЕГИОН)

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Резюме: *През 2001, 2006-2007, 2009-2011 и 2013 г. бяха проведени изследвания в региона от 1 до 10 мили пред н. Калиакра с цел да се установят промените в таксономичната структура, разпределението и количествените характеристики на макрозообентосните съобщества. За целия период видовият състав наброяваше 85 таксона. Доминиращи по отношение на видовия състав и числеността бяха Polychaeta. Зообентосната численост демонстрираше два максимума: през 2001, изградена от Melinna palmata и Phoronis psammophila; и през 2007 с доминиране на мекотелния вид Modiolula phaseolina. Доминиращите видове бяха типични за "циркалиторалните тини с Melinna palmata" и "съобществата на долния глинест циркалиторал с Modiolula phaseolina". Сравнението на пролетните стойности през изследвания период с тези от периода на максимална еутрофикация (1982-1985) показва увеличаване делът на полихетите, ракообразните и групата Varia при изграждането на биомасата и съществено, но краткосрочно увеличение на дела на молуските през 2009, когато Rapana venosa достига биомаса от 3380 g.m^{-2}. Активно развитие на молуските също беше наблюдавано и на 1 миля през 2007 г. с доминиране на Mytilus galloprovincialis – 253,558 g.m^{-2}, и на 1 миля през 2001 - 206,2 g.m^{-2}, благодарение на инвазивния мекотелен вид Mya arenaria.*

Ключови думи: *Черно море, профил Калиакра, макрозообентос, численост, биомаса*

INTRODUCTION:

The Black Sea long-term change and decline with consequent signs of recovery since 1995 have been extensively discussed for years (Zaitsev and Mamaev, 1997; Daskalov, 2003; Daskalov et al., 2007; Oguz&Gilbert, 2007; Oguz&Velikova, 2010). The comparison of the average multi-annual abundance and biomass of the zoobenthos for the periods 1954-1957, 1983-1985 and 1998-2002 refers to three major periods of the Black Sea ecosystem evolution: pristine, progressive eutrophication and contemporary, respectively (BSC, 2008). The latter is known as the period of de-eutrophication of the Black Sea due to the reduction of human pressures observed in the region and it continues up-to-date.

The first investigations of the biocoenological distribution of zoobenthos in Bulgarian Black Sea waters covered the period 1954-1957 г. (Kuneva-Abadjieva&Marinov, 1960). Total 128 taxa were reported at that time, they were distributed in 4 communities of the sublittoral soft-bottom: "sandy bottom community", "*Melinna palmata* coastal mud community", "*Mytillus galloprovincialis* community" and "*Modiolula phaseolina* mud community". More than 30 years later, Marinov&Stoykov (1990) published data and analysis on the macrozoobenthos species composition and quantitative parameters observed at 3 transects along the Bulgarian coast in the period 1982-1985. Later on Marinov&Stoykov (1995) summarized the biocoenological distribution and quantitative parameters of zoobenthos in the marine region between Durankulak and Cape Kaliakra (north Bulgarian Black Sea coast) (Fig.1). A new approach to the biocoenological classification of the zoobenthos communities in the Bulgarian Black Sea waters was given by Todorova&Konsulova (2003). For the period 1996-1997 and 1998-2002, changes of benthic communities along the Bulgarian Black Sea coast were analyzed by Todorova (Todorova&Konsulova, 2000, BSC, 2008). Recent study of the macrozoobenthos from the North part of the Bulgarian Black Sea coastal area show relatively good state of the environment for 2011 (Uzunova, 2012) .

The aim of the present work is to analyze the long term changes of the composition, distribution and quantitative parameters of macrozoobenthic communities offshore C. Kaliakra (Western Black Sea) and to conclude on the previous and current status of these communities.

MATERIAL AND METHODS

In 2001, 2006-2007, 2009-2011 and 2013 zoobenthos samples were collected under several national and international projects of the Institute of Fish Resources – Varna. The stations were situated at 1 to 10 miles distance in front of the Cape Kaliakra (the Bulgarian Black Sea) at the depth range of 15.5 - 85 m (fig.1). In the area of investigation soft bottom habitats (mud and clay substrata) predominate.

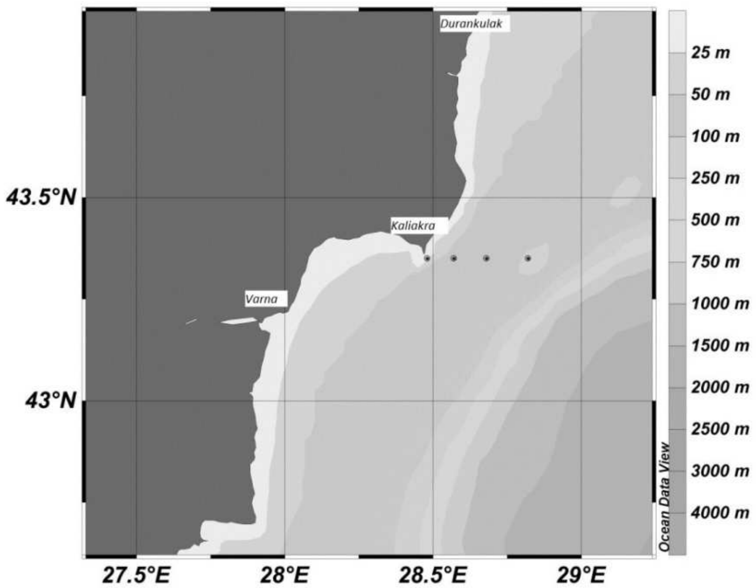

Fig. 1 Map of sampling points at the Cape Kaliakra transect (north Bulgarian Black Sea waters).

Sampling was carried out using van Veen grab (opening 0,1 m^2). On board RV "Prof. A. Valkanov" and RV "Akademik" samples were sieved and presereved in 4% formaldehyde solution according Todorova&Konsulova (2005). In laboratory sorting and taxonomic identification at a species level were performed (except for the groups *Turbellaria*, *Nemertea*, *Nematoda*, and *Oligochaeta*). Three main groups of benthic organism were recorded, namely, Polychaeta, Mollusca, and Crustacea. The rest of the organisms found in the samples were included in the forth group – "Varia". Quantitative parameters (abundance (N) - ind.m^{-2} and biomass (B) – g.m^{-2}) were calculated under a square meter. Statistical analysis was performed by the PRIMER software package programs of the Plymouth Marine Laboratory. Marine biotic index - AMBI (Borja *et al.* 2000; Borja *et al.* 2003) and multivariate AMBI (M-AMBI) (Borja *et al.* 2007), were estimated using the AMBI 4.0 software (AZTI-Tecnalia).

RESULTS AND DISCUSSION

In the period of investigation (2001-2013), total 85 macrozoobenthos taxa were identified. Most numerous were polychaetes with 28 species (33%), followed by crustaceans – 24 (28%), mollusks – 23 (27%) and "Varia" group – 7 species and 3 higher taxa (12%). Distribution of species numbers by years and distance from coast is presented in Table 1.

Community structure was mainly dominated by Polychaeta, typical for soft bottom muddy substrata, and this was especially visible with the increase of sea depth. Exceptions were observed in coastal waters at 1mile offshore in July 2006, at 3 miles in June and August 2007, and in June 2009 when various small bivalve mollusks dominated in the community.

Table 1. Species number at the Cape Kaliakra transect during the years of investigation

Date	Miles offshore	Polychaeta	Mollusca	Crustacea	Varia	Total
June 2001	1	13	10	4	2	29
	3	8	7	3	3	21
	10	7	0	0	3	10
July 2006	1	4	7	1	1	13
June 2007	1	4	4	4	0	12
	3	5	8	4	1	18
	5	2	4	5	1	12
Aug. 2007	1	8	2	4	0	14
	3	3	9	4	2	18
	5	8	3	2	3	16
	10	8	4	6	3	21
June 2009	1	8	5	6	1	20
	3	4	5	3	1	13
	10	7	2	6	3	18
Nov. 2009	1	9	0	2	1	12
Sept.2010	1	4	4	2	2	12
	10	11	2	7	7	27
July2011	1	9	4	4	3	20
Aug. 2011	1	7	3	2	2	14
June 2013	1	8	2	5	3	18

Maximum species number was established in 2001 in coastal waters (Kaliakra - 1 mile) and the diversity naturally diminished with the increase in depth. In some years a huge reduction in the species number was recorded, associated with a complete absence of mollusks (e.g. at 10 miles in 2001 and at 1 mile in November 2009). Interesting fact was the decrease in species diversity at 1 mile offshore in 2007, in comparison to the 3 miles-zone offshore. The species number started increasing in 2010, however, it mainly occurred at 10 miles offshore, with the visible contribution of *Polychaeta, Crustacea* and *"Varia"* groups. Among mussels, the major species for the community of the investigated area, *Modiolula phaseolina* (Philippi, 1844), was found in large quantities in all 10 miles samples of Cape Kaliakra.

During the investigated years, the species with highest frequency of occurrence were the polychaete *Nephthys hombergii* Savigny in Lamarck, 1818 (80%), *Melinna palmata* Grube, 1870 (75%) and the bivalvae mollusks *Abra prismatica* (Montagu, 1808) (60%), *Spisula subtruncata* (da Costa, 1778) (60%) and the amphipod crustacean *Ampelisca diadema* (Costa, 1853) (60%).

Quantitative parameters

Abundance

In 2001, the total macrozoobenthos abundance (fig.2) was maximal in the areas up to 50 m depth: at 1 mile and 3 miles offshore. The dominant species in 2001 at 1- mile offshore were *Melinna palmata* (Polichaeta) and *Phoronis psammophila* (Cori 1889) (Varia), which proliferated to 4260 ind.m^{-2} and 1470 ind.m^{-2}, respectively. At 3 miles offshore the same species were most abundant, with a density of 3990 and 2000 ind.m^{-2}, respectively *M. palmata* is characteristic for the "upper circalittoral silt community" which is largely distributed in the investigated area.

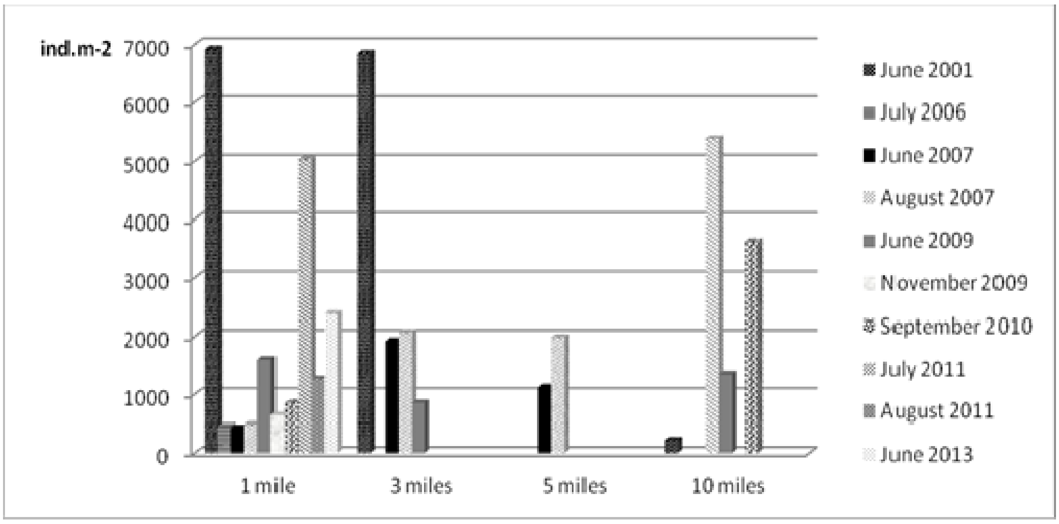

Fig. 2 Macrozoobenthos abundance (ind.m^{-2}) at the Cape Kaliakra transect by miles offshore for the investigated years.

In August 2007 the abundance maximum was registered at 10 miles offshore, where the depth was 80 m. Values of this parameter usually decrease with the increase in depth. However, in this case the dominant species at 10-miles offshore was *M. phaseolina* with the density of 4000 ind.m^{-2}. The community there belongs to the determined by Todorova and Konsulova (2003) “lower circalittoral clay community with *Modiolula phaseolina”*. In the period 2006-2011, in the area 1-mile offshore the macrozoobenthic abundance was very low and built mainly by the polychaete species *M. palmata* and *Nephthys hombergii*, and occasionally by the bivalve mollusk *Spisula subtruncata*. The species *Mytilus galloprovincialis* was presented in low quantities or was completely unavailable.

The species diversity was evaluated using the Shannon-Weaver index, AMBI and multivariate AMBI. Through the years of observation, H’ fluctuated with maximal values of recorded in the area 1 mile offshore (Table 2): in July 2006 (3,04), August 2007 (3,16), June 2009 (3,03) and June 2013 (3,10). According to the classification scale of this diversity index for water bodies with muddy sediments (Trayanova *et al.* 2007), values of H’ in the range of 2,5-3.3 correspond to good ecological status. The AMBI index values, based on the species sensitivity to disturbance, in most cases were less than 3,3, which according to Borja et al. (2000, 2003) meant also good ecological status of the zoobenthic community at 1 mile offshore. AMBI values for July and August 2011 were the only exception. M-AMBI followed the maxima of H’ and at most stations its values responded to good or even high ecological status of the near-coast zone. Exception with moderate status was only observed in August 2011 at 1 mile offshore Cape Kaliakra.

Table 2 Diversity (H’), AMBI and M-AMBI 1 mile offshore Cape Kaliakra

Stations/year	AMBI	Diversity	M-AMBI	Status
June 2001	2.59	2.02	0.80	Good
July 2006	1.57	3.04	0.80	Good
June 2007	2.38	2.99	0.73	Good
August 2007	1.99	3.16	0.80	Good
June 2009	1.92	3.03	0.85	High
November 2009	3.49	2.74	0.62	Good
September 2010	1.61	2.45	0.72	Good
July 2011	4.93	2.37	0.57	Good
August 2011	4.23	2.34	0.54	Moderate
June 2013	2.61	3.10	0.79	Good

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Table 3 Diversity (H'), AMBI and M-AMBI, based on abundance, at 1 mile offshore Cape Kaliakra

Stations	AMBI	Diversity	M-AMBI	Status
K3 June 2001	2.39	1.77	0.63	Good
K3 June 2007	2.40	1.99	0.61	Good
K3 August 2007	2.61	1.86	0.59	Good
K3 June 2009	1.89	2.68	0.64	Good
K5 June 2007	2.56	1.69	0.50	Moderate
K5 August 2007	2.64	1.68	0.55	Moderate
K10 June 2001	2.05	2.71	0.60	Good
K10 August 2007	0.41	1.69	0.75	Good
K10 June 2009	1.15	2.68	0.75	Good
K10 September 2010	2.16	3.80	0.89	High

Same indices, calculated for the area between 3-10 miles offshore Cape Kaliakra (Table 3) demonstrated low values of the diversity index (H'), probably due to the natural decrease in species number and in community complexity with depth. Nevertheless, in these areas the ecosystem status was good to high most of the time, except for 5 miles offshore Cape Kaliakra in June and August 2007, when probably due to local events.

Comparison of spring abundances observed in different periods (progressive eutrophication and contemporary) is presented in Fig.3.

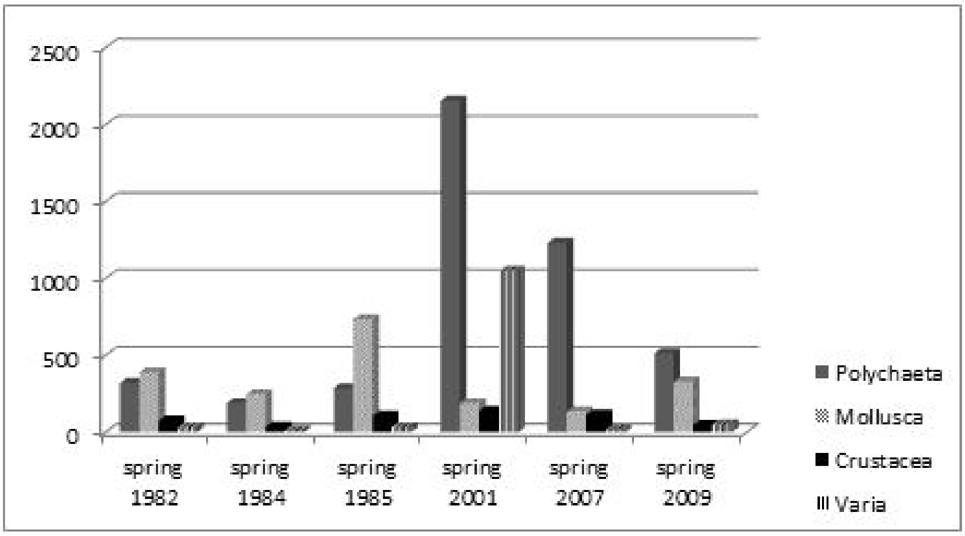

Fig. 3 Spring macrozoobenthos abundance (ind.m^{-2}) in 1982-2009 (data from Marinov&Stoykov, 1990 for the years 1982, 1984 and 1985, which cover the period of progressive eutrophication of the Black Sea).

Obvious increase in the mean spring macrozoobenthos abundance was observed in the investigated area in 2001 and 2007 as compared with previous investigations. It was due to polychaete and crustacean high abundance, whereas mollusks were in low densities, most probably due to the *Rapana venosa* grazing pressure.

Biomass

In the investigated years (2001-2013), macrozoobenthos biomass was formed mainly by mollusks (fig. 4), with an inter-annual maximum observed in spring 2009. The main species, which

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created the high biomass in 2009, were the snail *R. venosa* with 3380 g.m-^{2}, the blue mussel *M. galloprovincialis* (237,43 g.m-^{2}) and the invasive bivalve mollusk *Mya arenaria* (134,796 g.m-^{2}). Nearly 5-fold lower peak was observed in spring 2007, when *M. arenaria* dominated in the biomass, followed by *M. galloprovincialis*.

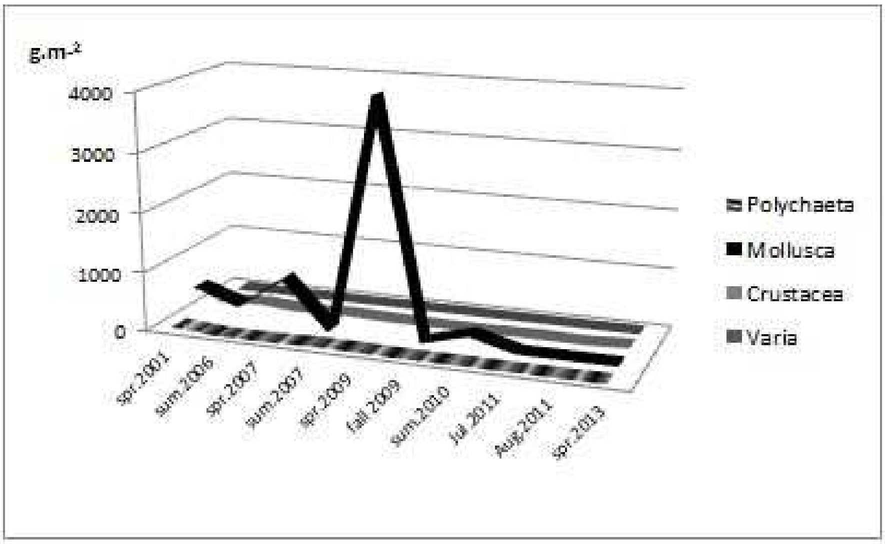

Fig. 4 Biomass (g.m-^{2}) of the four groups of macrozoobenthos during the investigated years

The comparison of the total average spring biomasses in 2001-2013 with data from the period of progressive eutrophication (1982-1985) showed increasing values of polychaetes, crustaceans and "Varia" group in the biomass formation and significant, but short-lived increase of mollusk's biomass in 2009 (fig. 5). The species *R. venosa* (3380 g.m-^{2}), *M. galloprovincialis* (237,43 g.m-^{2}), *S. subtruncata* (153,35 g.m-^{2}) and the invasive *Anadara inaequivalvis* (134,796 g.m-^{2}) had the largest shares in the total macrozoobenthos biomass.

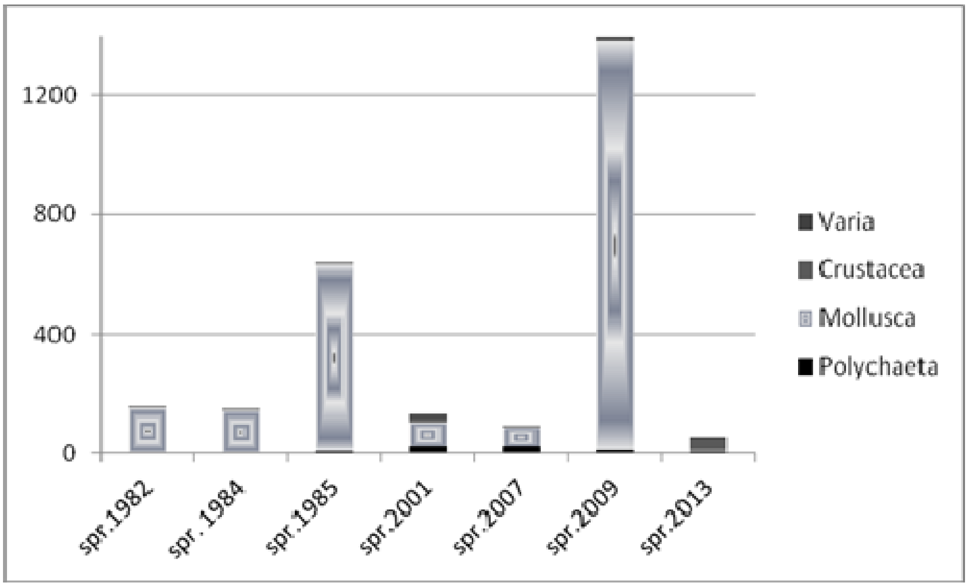

Fig.5 Spring biomass (g.m-^{2}) of the four macrozoobenthos groups during the investigated years, compared to historical data

Multivariate analyses – community structure

The community structure analyses are presented in Fig.6 and 7. Cluster analyses results demonstrate clear differences of the sampled stations by depth and substrata. Two major cluster groups are formed (fig.6). In the first group, samples from the “lower circalittoral clay community with *Modiolula phaseolina”*, located at a distance 10 miles offshore, are included. The second group comprises all samples collected at stations situated at 1 to 5 miles offshore. This second cluster is subdivided into 3 subgroups. For II.1 and II.2 most common species are the polychaete worms *M. palmata* and *N. hombergii*, which are characteristic for the “upper circalittoral community with *M. palmata*”. For group II.1 important species is also *Upogebia pusilla* (Petagna, 1792).

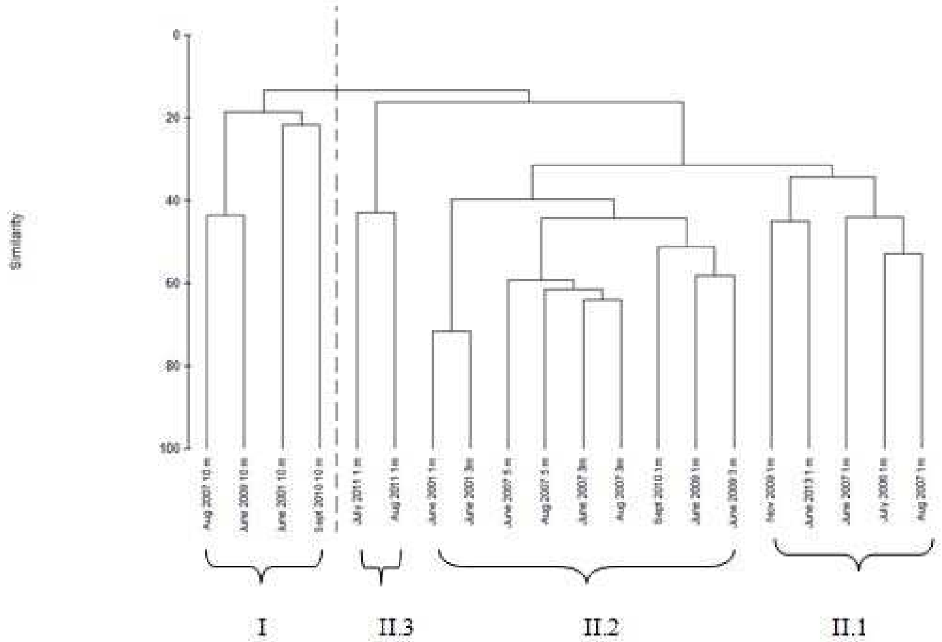

Fig.6 Dendrogram for hierarchical clustering (using group-average linking) of Kaliakra transect samples between 2001-2013, based on Bray-Curtis similarity matrix of abundance (√-transformed)

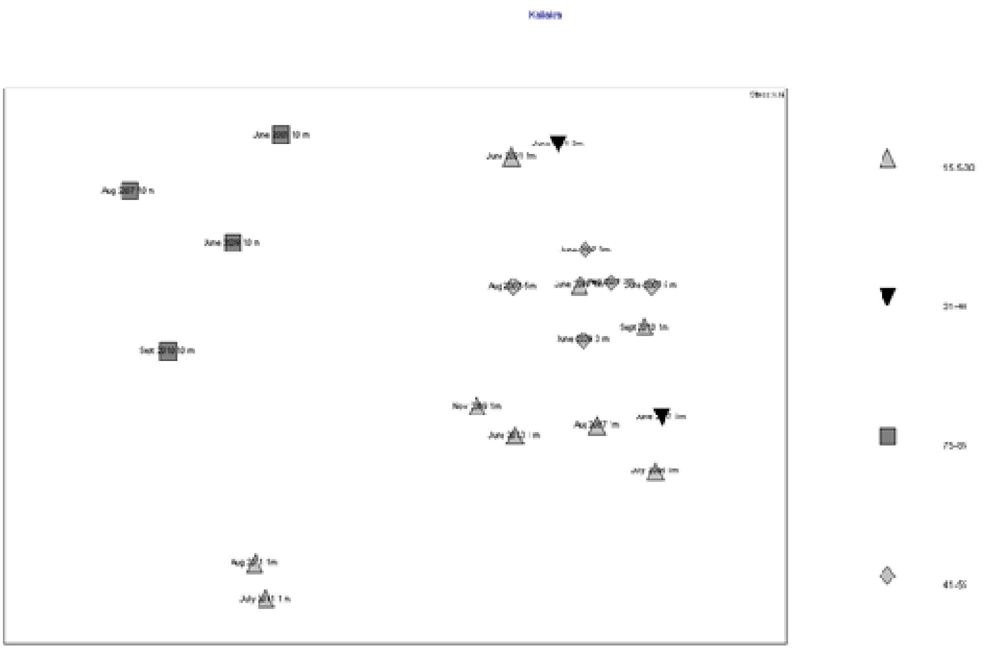

Fig. 7 MDS-plot of stations sampled at the Kaliakra transect according to the depth factor (grey triangle -15.5-30 m; inverted triangle - 31-40 m; squire – 75-85 m; rhomb - 41-55 m depth)

The MDS-plot of macrozobenthos distribution demonstrates the de-coupling of the deep water communities from those of coastal waters. Two coastal samples from July and August 2011 (1 mile offshore) are also quite dissimilar from the rest of the pool. Dominant by abundance there were the polychaete species *Spio filicornis* (O. F. Muller, 1776) and *Heteromastus filiformis* (Claparede, 1864). No *M. palmata* was found in these dissimilar coastal samples, and thus, we consider them to belong to an "impoverished circalittoral silt community", attributed to the near shore silt with lack of the polychete worm *M. palmata* (fig.7 – II.3 and fig.7).

For 2001-2013, the data analyses undertaken and comparison with previous investigations showed a relatively good macrozoobenthos species diversity in coastal waters (off Cape Kaliakra). Species number fluctuated between 12 and 14, with the exception of 2001 and 2011-2013. Comparison with the period of progressive eutrophication (1982-1985) (Marinov&Stoykov, 1990) showed increase of species number to 85 for the current period. *Polychaeta* keep leading position by species number over the rest of the groups as stated by Todorova (BSC, 2008). The number of *Crustacea* and *Mollusca* is near to equal during the investigated years, which is a good sign of a crustacean recovery. However, the lack of the mollusks such as *M. arenaria*, *A. inaequivalvis*, blue mussel and *R. venosa* in the samples since 2009 to present is due probably to overexploitation of the resource. For Rapana the abundance decrease may well also be related to insufficiency of prey and consequent increase in their natural mortality. In personal observations along the whole Bulgarian coast a huge amount of blue mussel's shells together with Rapa whelk shells in proportion 3:1 was found. Stock assessment and pressure/impact analysis of these species are necessary to properly evaluate their condition.

The long-term macrozoobenthos abundance and biomass data reviewed (1982-2013) testified to the general increasing role of polychaete in the structure of the zoobenthic abundance and decrease of molluscs share in the biomass during the contemporary period. Similar findings were reported by Todorova (BSC, 2008) for 2001-2003.

The average multi-annual biomass for the Kaliakra transect for the period 2007-2013 was 1847,65 g.m-^{2}, which is 5-fold higher compared to the average values calculated for the period 1982-1985. However, since 2009 the biomass values had dropped significantly down to 5.563 g.m-^{2} as observed in August 2011, then in June 2013 a small rise to 49.75 g.m-^{2} was recorded (fig.4). Dominant by biomass were polychaetes and crustaceans respectively, and the abundance values keep relatively high due to opportunistic polychaete species (fig.2).

The biocoenological distribution within the investigated area, as demonstrated by multivariate analyses (fig. 7), is characterized by three types of communities, namely: "upper circalittoral community with *M. palmata*" (depths in the range of 15,50 - 40 m); "impoverished circalittoral silt community" (40-55 m depths); and "lower circalittoral clay community with *M. phaseolina*", concentrated at depths of around 75-80 m.

M-AMBI index for the north region manifested good status of the water body at 1 mile offshore Cape Kaliakra with moderate level of disturbance in 2011. In 2013 good status according to this parameter was established. Thus, the values of diversity evidenced the relatively good status of the environment for the investigated area (Cape Kaliakra).

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