STATE OF MACROBENTHOS WITHIN *MODIOLUS PHASEOLINUS* BIOCOENOSIS FROM ROMANIAN BLACK SEA CONTINENTAL SHELF

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Abstract. This study is based on data concerning the macrobenthos fauna from *Modiolus phaseolinus* biocoenosis, obtained in 2006 - 2007 from 56 stations distributed on the North-Western continental shelf of the Black Sea. A total of 95 taxa belonging to 19 phyla were found. The average density of macrobenthic community was about 5249.11 indv.m^{-2} while their average biomass was 257.76 g.m^{-2}. At all stations, the Polychaeta contributed most to the multi-species biocoenosis structure. All results point to a slight recovery of the *Modiolus phaseolinus* biocoenosis. When compared to long-term studies on macrobenthos, it is evident that the results represent only a momentary state in the succession of the open-sea communities, which have been affected by past changes, and will be subject to future changes in accordance with the variable environment, affected by climate.

Key words: *Modiolus* biocoenosis, circalittoral, offshore site, macrobenthos, biodiversity, abundance.

1. INTRODUCTION

The north-western part of the Black Sea represents an embayment having as the offshore limit an imaginary straight line linking the shores between Cap Caliacra (Bulgaria) and Cap Tarhkanhut (Ucraina); the zone having a surface of about 63900 km^2, a volume of water of 1910 km^3 and an average depth of 30 m composes the continental shelf bottoms, usually not deeper than 100 m (Vinogradov, 1967). NW Black Sea, under the stress of a huge discharge of freshwater, represents the most interesting and complex sector of this enclosed sea. This part of basin has undergone major changes caused by anthropogenic activities arising from uncontrolled development. Since the late 1970s, this sector has been subjected to severe anthropogenic eutrophication forced by increased delivery of nutrients by the Danube, Dnieper and Dniester rivers which resulted in critical levels of primary production (Mee, 1992; Zaitsev and Mamaev, 1997). Instability of environmental factors (e.g. oxygen, temperature, river input of nutrients) has determined great structural and functional modifications of all biocoenosis (Gomoiu 1997, 1999; Gomoiu *et al.*, 2005; Wijsman *et al.*, 1999). Benthic community degradation has been further intensified by pollution, the impact of exotic invaders and unsustainable exploitation (Gomoiu, 1998, 1999, 2001; Mee *et al.*, 2005). During the1990s, due to the socio-economic recession in the riparian Black Sea countries and the introduction of several national and international programmes aimed at reducing eutrophication, a lowering of the nutrient input from rivers was observed, which gave the ecosystem an opportunity for recovery. The recovery trend is however still not fully confirmed by the scientific results and many uncertainties need to be overcome in order to establish a sound and environmentally-benign management of the eutrophication in the future (Mee *et al.*, 2005).

Along the Romanian continental shelf, the *Modiolus phaseolinus* was the most characteristic bottom species from 55-60 m to 120 m. Called by Borcea (1931) *„phaseolinoid facies of the deep littoral zone"*, the *Modiolus phaseolinus* biocoenosis alone covers a stretch of about 10000 km^2 along the Romanian shelf (Bacescu *et al.*, 1971). It covers 40% of the shelf extended up to the limit of the oxic-anoxic layer (Băcescu, 1963; Băcescu *et al.*, 1971; Gomoiu and Ţigănuş, 1977). Its maximum development took place between the Sulina –

Sf.Gheorghe (pre-Danubian area) and Mangalia (southern) sectors (Băcescu *et al.*, 1971). Research conducted in 1970 indicated high density and biomass and a good trophic base for benthifagous fish (Băcescu *et al.*, 1971; Gomoiu and Ţigănuş, 1977). Measurements performed between 1970 and 1980 did not show any appreciable changes in the *Modiolus phaseolinus* muddy bottom, and it was the only stable biocoenoses as compared with shallow waters biocoenoses (Gomoiu and Ţigănuş, 1977). The *Modiolus* biocoenosis was however degraded after 1980 that was identified by the reduction of macrobenthic organisms, particularly those less tolerant to pollution, from 85 in 1960-1970 to 33 in 1991-1995 and 23 in 2000-2001 (Băcescu *et al.*, 1971; Dumitrache, 1996-1997; Abaza and Dumitrache, 2008). The mean abundance and biomass of the deep macrobenthic communities decreased from 7800 ind.m^{-2} and 233 g m^{-2} in 1981-1982 approximately five times in 2000-2001 (Abaza and Dumitrache, 2008).

Over the last years, there have been large gaps in the knowledge of the benthic populations` state. From this point of view, a special study of benthic biocoenosis – especially of those from deep-water bottoms – is a necessity in order to estimate the anthropogenic impact in marine environment.

Ecological indicators are commonly used to provide synoptic information about the state of ecosystems. The implementation of the European Water Framework Directive (WFD) (EC, 2000), as well as the recent European Marine Strategy Directive 2008/56/EC (EC, 2008) require the use of well founded ecological indicators, which has contributed greatly to develop this research field and stimulate analyses to establish indicators' applicability to a variety of ecosystems.

Macrobenthic communities are good indicators of anthropogenic and natural stressors (Borja *et al.*, 2003; Dauvin *et al.*, 2007). Macrobenthic fauna possess life history traits and functions which lead to relatively rapid responses to a multitude of stressors. Many indicators and indices have been proposed to summarise the response of benthic fauna to pollution gradients, but the value of these tools to management is still under debate (Bustos-Baez and Frid, 2003; Dauvin *et al.*, 2010). In this study tested the performance of two ecological indicators based on the composition and structure of macrobenthic communities.

The main objectives of the present study are: (1) assessment of the qualitative and quantitative structure of macrobenthos: specific biodiversity, abundance (density and biomass); (2) spatial distribution of the macrobenthos. By using multivariate statistical techniques, different assemblages were described based on the community structure and compared to previous investigations.

2. MATERIALS AND METHODS

2.1 Study area

Hydrographically, the Black Sea is divided into two distinct regions: the shallow (< 200 m) north-western shelf and the deep (>1000 m) central sea. The north-western shelf receives most of the nutrient load to the Black Sea through riverine inputs from the Dniester, Dnieper and Danube rivers and is therefore the region most severely impacted by eutrophication (Cociasu and Popa, 2004). The input of fresh waters in the upper layer and saline Mediterranean waters in the lower layer creates a distinct and permanent pycnocline between the surface waters (upper 150 – 200 m) and the deep waters, limiting the vertical exchange and creating a unique chemical and biological environment (Konovalov *et al.*, 2005). As much as 87% of the Black Sea is entirely anoxic and contains high levels of hydrogen sulphide (Zaitsev and Mamaev, 1997).

A great quantity of the terrestrial nutrients entering the Black Sea originate in central and western Europe, particularly those transported by the Danube which alone is responsible for 75% of total nutrient input to the Black Sea (Mee, 1992). Mean annual Danube River flow is 6500 m^3 s^{-1}. Direction, range and depth of Danube River plume are highly variable and depend on water discharge intensity and wind direction. In spring, the North and north-eastern winds are dominant, while in autumn the North wind prevails (Petranu, 1997). The general cyclonic current in the Black Sea along the Romanian continental shelf flows from North to South and is responsible for the occurrence of estuarine conditions in the western part of the Pontic Basin (Petranu, 1997). Danube role extends far southward up to the Bosphorous region as well as down to the deep sea floor.

Seawaters of the Romanian continental shelf are characterized by strong spatial and seasonal changes in temperature (0^0 – 27^{0}C) and salinity (4 – 17 PSU) under Danube River and wind influences (Berlinsky *et al.*, 2006). Mean salinity in the Black Sea is about 17–18 in surface waters and 22 in deep waters.

The study area was located in the north-western continental shelf of the Black Sea, delimited by the following geographic coordinates: 44°10'N / 29°30'E, 44°10'N / 29°45'E, 43°50'N / 29°30'E and 43°50'N / 29°45'E. This area comprises 2 map sheets L-35-144C (A) respectively K-35-12A (B) according to international nomenclature. The sampling area was located in the central sector of *Modiolus* biocoenosis on the Romanian continental shelf of the Black Sea (Fig. 1). 90% of samples were collected from *Modiolus* biocoenosis while 10% of them within the transition zone from *Mytilus* to *Modiolus* biocoenoses (Fig. 2).

2.2 Sampling design

From 5 to 10 June 2006 and 16 to 21 April 2007, 56 stations were sampled on the north-western continental shelf during monitoring cruises of the R/V "Mare Nigrum" (Fig. 1). Macrobenthic samples were collected using van Veen grab (0,135 m^2). The depth of the sampling stations varied from 56m to 74m. Sediment samples for macrobenthos were washed, using a 0,5 mm mesh sieve, and all organisms retained on the sieve were collected and preserved in 4% neutralized formaline seawater

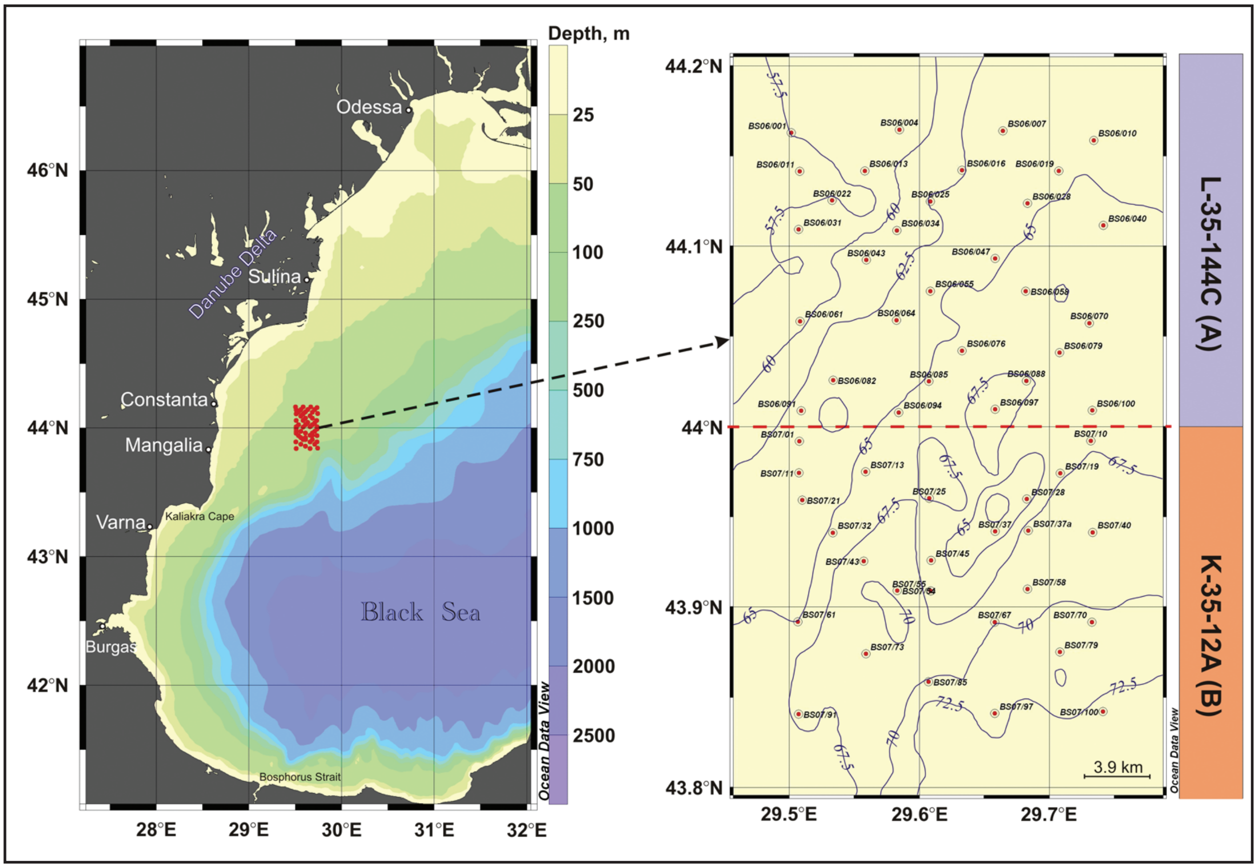

Fig. 1 The stations from the perimeter of sheets L – 35 – 144C (**A**) and K – 35 – 12A (**B**). The study area corresponds to the central sector of the *Modiolus phaseolinus* biocoenosis on the Romanian continental shelf of the Black Sea

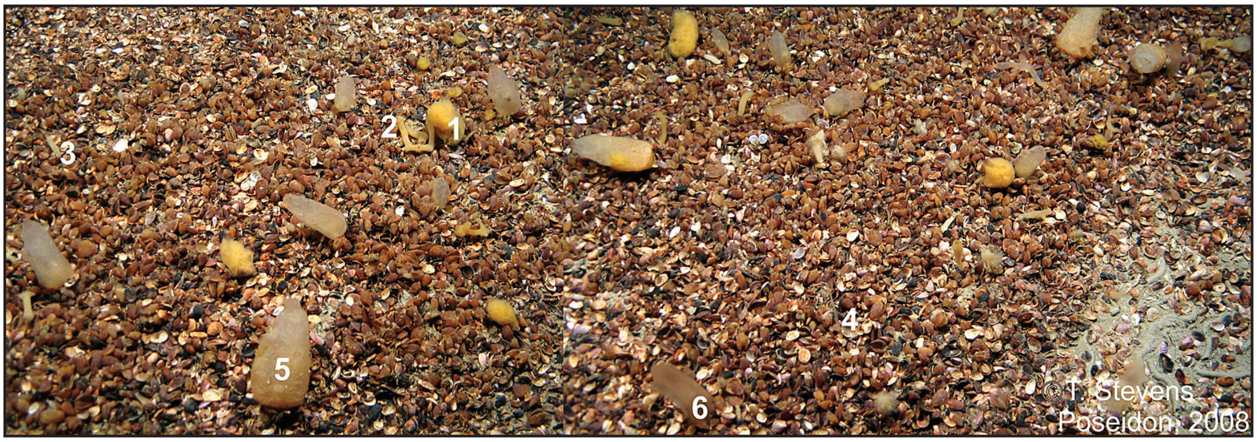

Fig. 2 Image of the sediment surface with *Modiolus phaseolinus* biocoenosis on the Romanian continental shelf of the Black Sea (depth – 61,3 m) (Photo: Tim Stevens, taken during R/V Poseidon Cruise 363, 2008) The substratum is covered by *Modiolus* shells togheter with sponges *Mycale syrinx* (**1**), *Haliclona* sp. (**2**), *Sycon ciliatum* (**3**), hydroid *Corymorpha nutans* (**4**) and tunicates *Ascidiella aspersa* (**5**) and *Ciona intestinalis* (**6**).

solution (Birkett and McIntyre, 1971). In the laboratory, animals in the samples were sorted, transferred into 70% ethanol, and identified to species or a higher taxon under a dissecting microscope. The data were represented as density per square meter (ind.m^{-2}). Biomass was measured with a balance (accuracy 0.01 g) after storage of at least three months, as formalin wet weight after removing excess water on blotting paper. Bivalves were weighed with shells.

The nomenclature was checked following the World Register of Marine Species (Appeltans *et al.*, 2010).

The description of fresh sediment samples was made by Dr. Gheorghe Oaie on board, during the cruise. There is a great variety of sediments in the investigated area, visual descriptions including the hard biotic components (especially shells) being completed in the GeoEcoMar laboratories by grain size analyses. According to the data published (Opreanu, 2008; Fulga, 2010), the bottom sediments in study area are represented by 42.22% clay, 30.1% sand and 27.7% silt.

2.3 Data analysis

The structure of the macrobenthic community was analysed in terms of species composition (*S*), population density (*A*), dominance (*D*), frequency (*F*) diversity and biomass. The diversity was calculated by the Shannon-Wiener diversity index (*H'*) on a log 2 base (Shannon and Weaver, 1963). The AZTI Marine Biotic Index, AMBI (Borja *et al.*, 2000), and the multivariate AMBI, M-AMBI (Muxika *et al.*, 2007) were calculated using the freeware program available on www.azti.es.

Multivariate analysis (Bray-Curtis similarity) was performed with fourth square-root transformed data using PRIMER package programme version 5.2.4 (Clarke and Warwick, 2001). Furthermore, SIMPER analysis was performed to identify the percentage contribution of each species to the overall similarity (dissimilarity) within each of the groups identified from the cluster analysis.

The data were processed with Ocean Data View, Program version 4 (Schlitzer, 2004), with VG gridding: 120 for X scale-length (permille) and 118 for Y scale-length (permille).

3. RESULTS AND DISCUSSION

3.1 Substratum and thanatocoenosis

In the study area the substratum, generally flat, pretty regular surface, is muddy, mixed with a great quantity of shells, preponderant *Modiolus, Mytilus* shells being exceptionally found in the NW sector of sheet A. Shells were also found, such as: *Abra alba, A. segmentum, Papillicardium papillosum, Parvicardium exiguum, Cerastoderma glaucum, Bittium submamillatum, Rissoa parva, R. splendida, Retusa truncatula, Trophonopsis breviatus, Calyptraea chinensis* and other mollusc species contributing considerably to thanatocoenosis. Fossil shells were also identified in just few stations represented by *Dreissena rostriformis, Theodoxus pilidei and Micromelania caspia lincta*.

3.2 Qualitative and quantitative structure of macrobenthos

There were identified 95 macrobenthic taxa, most of them as species (excepting Nemertea indet., Polychaeta indet., Oligochaeta indet. and Nudibranchia indet. considered just to the higher taxonomic level), pertaining to Porifera (5 species), Anthozoa (1), Nemertini (4), Polychaeta (43), Gastropoda (2), Bivalvia (3), Pantopoda (2), Sipunculida (1), Phoronida (1), Cirripedia (1), Amphipoda (12), Cumacea (3), Isopoda (1), Tanaidacea (1), Echinodermata (2), Tunicata (4) and Chironomida (1) (Appendix 1). On the occasion of this study, a new species of polychaeta - *Dipolydora quadrilobata* was added to the Romanian littoral inventory faunistic list (Surugiu, 2009).

The average density of macrobenthos associated to phaseoline muds was about 5249.11 indv.m^{-2} while their average biomass was 257.76 g.m^{-2} (Appendix 1).

Of the 95 macrobenthic taxa more than 50% belong to Polychaeta group (43 species and 5 taxa identified up to genus or family level). The highest frequency in the samples (over 50 %) was given by 15 species characteristic of deep bottoms. Such species are: the leading bivalve *Modiolus phaseolinus*, polychaets *Terebellides stroemii, Capitella capitata, Phyllodoce lineata, Sphaerosyllis bulbosa, Nephtys hombergii, Amphitritides gracilis* and *Aonides paucibranchiata*, echinoderms *Amphiura stepanovi* and *Leptosynapta inhaerens*, amphipods *Ampelisca sarsi* and *Caprella acanthifera* (Fig. 3 and Appendix 1).

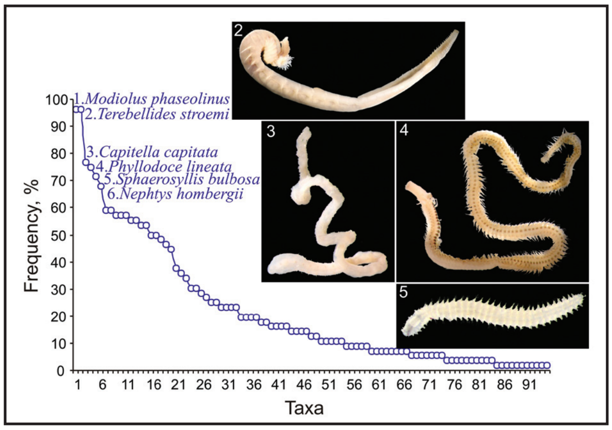

Fig. 3 The frequency of macrobenthic taxa found in all stations performed in the study area (original photos)

The Annelida (2298 indv.m^{-2}) and molluscs (2187 indv.m^{-2}) represented more than 85% of the average abundance. In terms of biomass only molluscs (*Modiolus*) represented over 82% of total average biomasses of 213 g.m^{-2}.

The most abundant species representing 73% of the total density were *Modiolus phaseolinus* (41%), *Dipolydora quadrilobata* (19%), *Polydora ciliata* (7%), *Capitella capitata* (3%), *Apseudopsis ostroumovi* (3%) (Fig. 4 and Appendix 1), respectively 94% of total biomass: *M. phaseolinus* (83%), *Mytilus galloprovincialis* (8%) and *Terebellides stroemii* (3%).

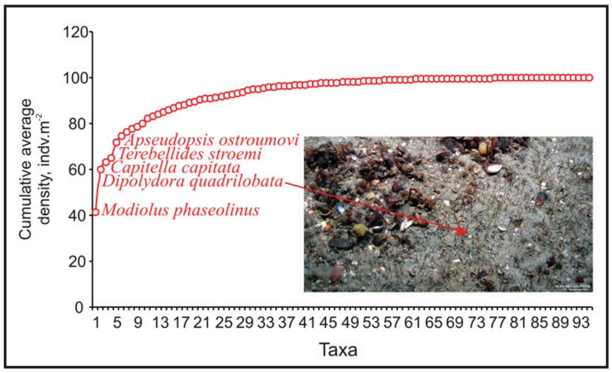

Fig. 4 Cumulative average density of macrobenthos in the study area. (Photo: Tim Stevens, taken during R/V Poseidon Cruise 363, 2008)

The great frequency and numerical dominance of benthic eurioic populations (Polychaeta and Oligochaeta) can be explained by increased anthropogenic stress on marine environment. In the 90s, due to mass mortality of benthic organisms enhanced by hypoxia and anoxia phenomenon, determined a massive development of opportunistic deposit feeder, predominant oligochaetes, and some species of polychaets (*Dipolydora quadrilobata, Capitella capitata, Polydora ciliata, Heteromastus filiformis*) concomitantly with the diminishing of the number of epibenthic species (crustaceans, some molluscs) (Gomoiu, 1985b, 1992, 1997). The numerical increase in these small-sized populations has caused the decrease in benthic biomasses and furthermore, in the feeding resources for the benthophagous fishes (Gomoiu, 1985a).

3.3 Spatial distribution of macrobenthos

Based on Bray–Curtis similarity, the 56 stations were divided into four groups and three single stations (Fig. 5) with different community structures (Table 1 and 2). Clusters of stations are organized according to the abundance of species: firstly one cluster group stations (I) situated in the *Modiolus* biocoenosis; a second cluster group stations (II) situated in the sandy belt; a third group (III) situated in a transitional zone between *Mytilus* and *Modiolus* biocoenosis; and fourth group (IV) is characterized by low abundance of macrobenthos. Also, site V (St. A/07) is formed by low abundance of four species (*Euclymene collaris, Eulallia sp., Terebellides stroemii* and *Nephasoma minutum).* Site VII presents similarity 50% with group II, is formed by deep bottoms species (*Modiolus phaseolinus, Terebellides stroemii, Apseudopsis ostroumovi, Leptosynapta inhaerens*), which registered lower abundances than of group I. A highly significant difference in the faunal composition of the four cluster group was detected by SIMPER analysis, with the greatest dissimilarity recorded for the I – II group (71%), followed by the I – IV (69%) and the I – III (53%) ones.

The analysis of distribution among macrobenthic populations relative to the type of sediment emphasized that the greatest qualitative and quantitative values were registered in the zones where the sandy fraction was dominant. Thus, the classical pattern of fauna association on the phaseoline mud situated at 65 m deep (Băcescu *et al.*, 1971) has been changed by interlaying with a sandy belt occupying the north-west area A and central area B (Fig. 6). This belt represents an enclave of biodiversity and abundance much higher than the averages recorded in the proximate locations.

According to the SIMPER analysis results, the associated fauna from the sandy belt (bank) is dominated by the polychaeta *Dipolydora quadrilobata,* the tunicate *Molgula appendiculata* and a great number of crustacean species (*Megamphopus cornutus, Microdeutopus versiculatus, Iphinoe elisae* etc.) (Table 2). Some species of amphipods and cumacean *Iphinoe elisae* had 10 times higher abundances (about 300 indv.m^{-2}) in the sandy belt zone than in the proximal locations, with phaseolines, where the average density reached only 30 indv.m^{-2}.

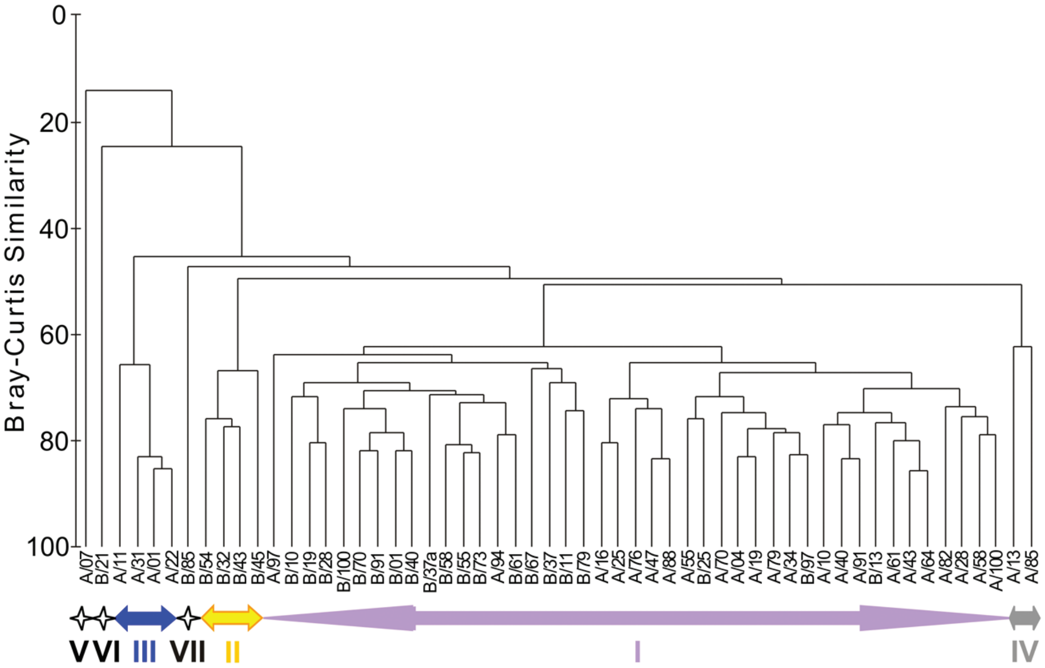

Fig. 5 Dendrogram for hierarchical clustering of the 56 sites included in the analysis (group average of Bray–Curtis similarities, square-root transformed abundance data)

Table 1 Summary of the results from the univariate statistical analysis of the groups presented in Fig. 5

	I	II	III	IV	V	VI	VII
N. samples	43	4	4	2	1	1	1
N. taxa	86	51	42	14	4	20	26
Univariate analysis							
Density indv.m^{-2}							
Min	0.4	3.0	2.6	7.7	15.45	24	24
Max	2627.5	11952.0	2236.4	162.2	15.5	456.0	336.0
Sum	4657.5	17412.0	4767.5	517.7	61.8	1896.0	1968.0
Mean	54.2	202.5	55.4	6.0	0.7	22.0	22.9
Stand. dev	284.2	1293.3	265.3	20.8	3.3	68.1	52.2
Biomass g.m^{-2}							
Min	0.00014	0.00012	0.00046	0.00155	0.01236	0.01200	0.00480
Max	265.06	84.12	289.61	10.58	1.39	2.16	40.08
Sum	281.28	197.13	359.06	16.27	1.49	9.68	71.12
Mean	3.27	3.87	8.55	1.16	0.37	0.48	2.74
Stand. dev	28.58	16.12	45.28	3.00	0.68	0.66	8.27

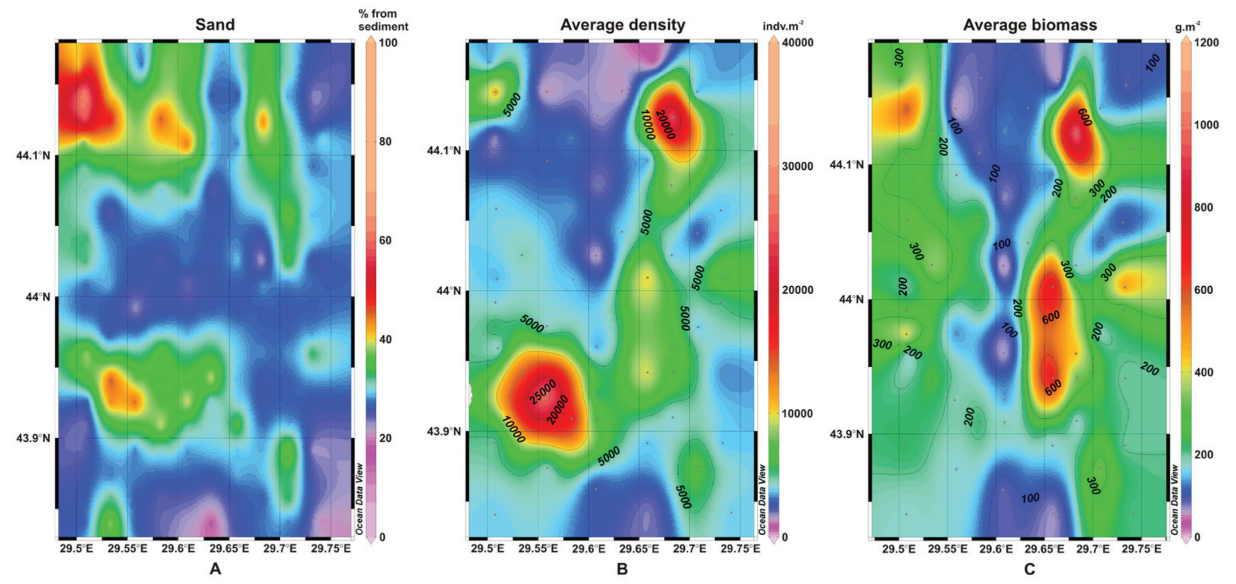

Fig. 6 The distribution of the sand (**A**) (adapted after Opreanu, 2008) and numerical abundances distribution of macrobenthos (**B**, **C**) within analysed zone

It is noteworthy that the extremely compact populations of *Molgula appendiculata* was formed of big-sized individuals (around 2.5 cm in diameter) with densities of 345 indv.m^{-2} and biomasses of 84 g.m^{-2} contrasting with the nearby populations which had 14 times smaller densities respectively 500 times smaller biomasses. This is explainable through the capacity of tunicates to reach big sizes on firm, compact substratum (*e.g.*, sand) in opposition with those tunicates inhabiting muddy substrata dominated by *Modiolus*; in such case the big-size would cause the sink and consequently, the organism death.

The polychaeta *Dipolydora quadrilobata* registered the most spectacular populational development (Fig. 7). It's an opportunistic species spread at the Romanian littoral on various types of sedimentary substrata. It is frequently the dominant species in sediments enriched with organic matter or in

Table 2 Contribution and cumulative contribution of the species the most responsible for similarity within clusters based on square root transformed species abundances according to the SIMPER analysis

	Species	Contribution (%)	Cumulative contribution (%)
Cluster group I	*Modiolus phaseolinus*	69.59	69.59
	Capitella capitata	4.33	73.92
	Terebellides stroemii	3.99	77.91
	Sphaerosyllis bulbosa	2.77	80.68
	Apseudopsis ostroumovi	1.93	82.61
	Nephtys hombergii	1.49	84.10
	Dipolydora quadrilobata	1.47	85.57
	Phyllodoce lineata	1.43	87.00
	Leptosynapta inchaerens	1.20	88.20
	Clunio marinus	1.09	89.29
	Amphitritides gracilis	1.05	90.34
Cluster group II	*Dipolydora quadrilobata*	65.72	65.72
	Molgula appendiculata	8.16	73.88
	Modiolus phaseolinus	4.52	78.40
	Megamphopus cornutus	3.55	81.95
	Microdeutopus versiculatus	1.96	83.91
	Polydora sp.	1.41	85.32
	Ampelisca sarsi	1.40	86.72
	Phyllodoce lineata	1.37	88.09
	Iphinoe elisae	1.30	89.39
	Caprella acanthifera	1.17	90.56
Cluster group III	*Modiolus phaseolinus*	42.44	42.44
	Polydora sp.	11.69	54.13
	Mytilus galloprovincialis	11.50	65.63
	Phyllodoce lineata	6.59	72.22
	Terebellides stroemii	6.11	78.33
	Nephtys hombergii	5.26	83.59
	Capitellides giardi	3.70	87.29
	Heteromastus filiformis	3.64	90.93
Cluster group IV	*Modiolus phaseolinus*	57.14	57.14
	Capitella capitata	28.57	85.71
	Terebellides stroemii	14.29	100.00

polluted zones. This species builds its own tubes, arranged vertically in the thickness of the sediment, by tangling sandy particles with fine pelitic fractions. On this sandy belt, the population of *Dipolydora* has an average density of 12000 indv.m^{-2} and a maximum of 23000 indv.m^{-2}. The differences between the average densities for this species found out in stations situated in this sandy enclave and the densities in other stations was about 11800 indv.m^{-2} (Gomoiu *et al.*, 2008).

The authors consider that the community formed by tunicate *Molgula appendiculata* and polychaeta *Dipolydora quadrilobata* represents a sub-coenosis within the classical *Modiolus phaseolinus* biocoenosis. We recommend to be performed monitoring in order to establish if the community will keep the coenotic integrity and faunistic structure of spatial scale.

The composition and distribution of the bottom sediments is another important factor, which, together with the

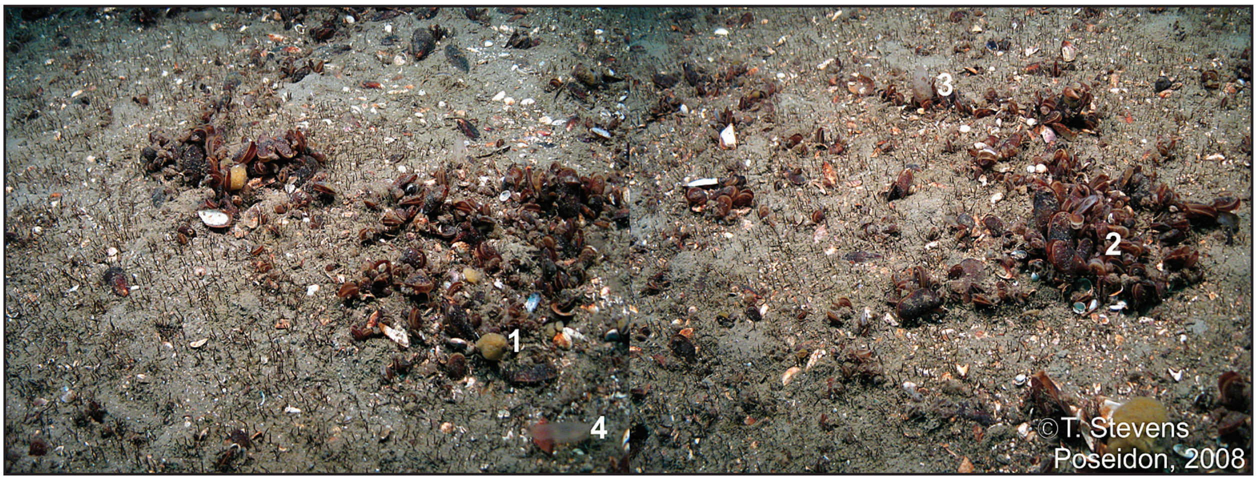

Fig. 7 Image of the bottom with *Dipolydora quadrilobata* sub-coenosis on the Romanian continental shelf of the Black Sea (depth – 51 m). (Photo: Tim Stevens, taken during R/V Poseidon Cruise 363, 2008) (The substratum is covered by a meadow of *Dipolydora* tubes, in majority empty (about 50 % being occupied) togheter with sponges *Mycale syrinx* (**1**), clumps of the *Mytilus galloprovincialis* (**2**) and tunicates *Ascidiella aspersa* (**3**) and *Ciona intestinalis* (**4**)).

salinity, is presently thought to play a decisive role in the formation of macrobenthic communities. The relation between the substrate and the distribution of key benthic species was repeatedly noted by researchers (Băcescu *et al.*, 1971). Recent studies also revealed large scale changes in the macrobenthic communities of the Black Sea related to the sedimentation processes (Wijsman *et al.*, 1999). In study area, the distribution of macrobenthos was related to the structure of bottom sediments. Therefore, the maximum number of species (39) and abundance (32280 indv.m^{-2}) were found in the stations located on the sandy belt (Fig. 6). The great number of species as well as the great abundance comparatively with the adjacent locations indicates that the type of substratum influences decisively the distribution of species. Some of these species came from littoral zones where, actually, the bulk of their populations are settled. The bottom species take advantage of the limited sandy substrata from these depths (*e.g. Molgula*, *Dipolydora*).

3.4 INDICATORS AND LONG-TERM COMPARISON OF MACROBENTHOS

Indicators, broadly defined in the paper of Heink and Kowarik (2010), are a scientific response to the governmental need for reliable and accurate information on a system's conditions. For the marine environment, a wide variety of benthic indicators exist at present (Diaz *et al.*, 2004; Borja and Dauer, 2008). The first aim of these indicators is to distinguish between a healthy and degraded water system with sufficient precision to identify the critical border between the need for 'action' and 'no action' to improve the ecological condition.

The benthic indicator types within the WFD include univariate, multimetric and multivariate approaches, combining in the latter different parameters with different sensitivity levels, leading to a confident assessment of the benthic ecosystem state. The indicators defined for each descriptor in the MSFD are mainly of the univariate type (abundance, biomass, productivity) and less of the multi-metric type, except for the assessment of the criterion 'the condition of benthic community' under the descriptor 'Sea-floor integrity' (Rice *et al.*, 2010). After Van Hoey *et al.* (2010) the benthic indicator types already developed in the context of the WFD should be improved to assess structural and functional benthic aspects in the MSFD, as partly proposed for the descriptor 'Sea-floor integrity'. Therefore, this study tested the performance of two ecological indicators used in WFD.

The analysis of the ecological status within the studied zone using H`log2 revealed a "*normal*" ecological status for about 30% of area, "*disturbed"* for 64% and "*degraded*" – 5%, while AMBI showed that 41% was undisturbed, 52% slightly disturbed, 7% moderately disturbed (Fig. 8). The pattern of improved ecological status in the study area reflects decreasing organic enrichment in the open NW Black Sea shelf. Despite the natural hypoxia, in the present the environment at offshore area is more stable and predictable and less exposed to anthropogenic impact compared to coastal zone, therefore the community is 93% undisturbed or only slightly disturbed as results from AMBI analyses. Therefore, AMBI index better reflected the ecological status than H`log2. Presently, the studies are focused on the development of benthic indicators for classification, definition of 'pristine' or sustainable conditions and the importance of relating ecological measurements to pressures. The ecological status has to be perceived or measured as a deviation from a reference condition. The reference condition in NW Black Sea part is considered the 60s-70s periods (Gomoiu, 1997) when anthropic impact over the ecosystem was minim. Also, in this period, the most ample studies about macrobenthos were performed. In the following years, were realized much fewer researches, when the most important changes occurred (see section Introduction). Only few studies (Gomoiu, 1985; Gomoiu, 1997; Dumitrache,

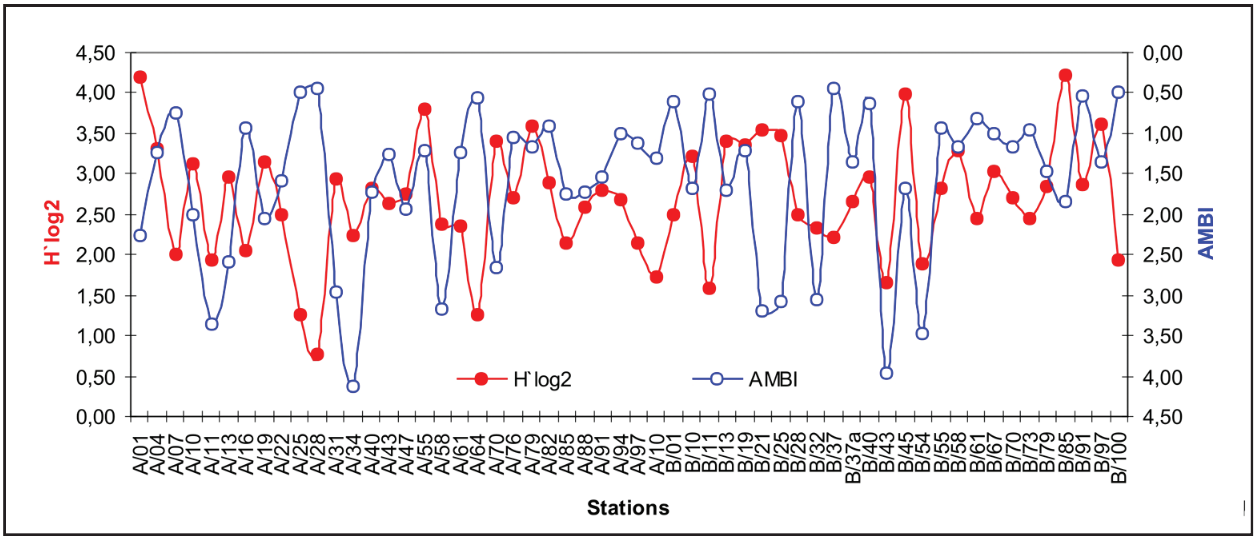

Fig. 8 Performance of the biotic indicators (H`log2 and AMBI) in the study area

1996-1997; Abaza and Dumitrache, 2008) have managed to/could surprise the drastic decrease of the specific diversity and simplifying biocoenosis structures. Our analyses on the long-term changes in the composition and structure of macrobenthos showed that the system seems to be slight recovering from the environmental changes occurred during the 1980 - 2000 period (Fig. 9). The most important changes observed during that period were the increase of diversity and abundance of the Polychaeta and Crustacea groups within *Modiolus* biocoenosis.

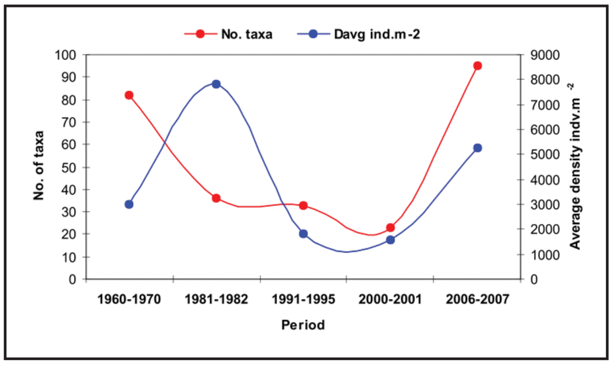

Fig. 9 Long-term comparison of macrobenthos from *Modiolus* biocoenosis on the Romanian continental shelf of the Black Sea

4. PERSPECTIVES

Macrobenthic data on different temporal and spatial scales must be used to study the response of indicators to natural variability. In offshore waters these data are even less frequently available than for coastal waters. Also, it is of very importance to include the 'naturalness' of the system in the reference settings. An integration of all available spatial information on pressure intensities together with a spatially well designed monitoring system will enable a more informed judgement about the differentiation between natural and anthropogenic influences (Van Hoeys *et al.*, 2010). Predictive modeling of species distribution can become an important tool in ecosystem, supporting a sustainable development of the Black Sea ecosystem.

Based on the results of the current study, future efforts should focus on: (1) general evaluation of ecological state of the NW Black Sea, mainly referring to the pollution of sediments and benthic life; (2) taxonomical revision and re-description of biocoenosis; (3) AMBI proved to be a useful tool to evaluate macrobenthos status in the Romanian offshore areas, however it has to be adjusted to the specific conditions of this Black Sea region.

Acknowledgements. The authors acknowledge support funded by the National Authority for Research, Nucleus Programme – PN 06 27 01 and EU-FP7 "HYPOX". The authors express their thanks to Dr. Gabriela Mihaela Paraschiv and to Dr. Victor Surugiu for their help in identifying the polychaeta species. The authors wish to thank anonymous reviewer for their valuable comments and suggestions which improved substantially the manuscript.

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APPENDIX 1 - Ecological characterization of macrobenthos within *Modiolus phaseolinus* biocoenosis from Romanian Black Sea continental shelf (C% - Constancy, D_{AVG} – Density - indv.m^{-2}, D_D% - Dominance in densities, B_{AVG} - Biomass g.m^{-2}, D_B % - Dominance in biomass)

Taxa	C%	D_{AVG}	D_D%	B_{AVG}	D_B%
Haliclona (Reniera) aquaeductus (Schmidt, 1862)	8.9	2.63	0.05	0.1411	0.0548
Haliclona oculata (Pallas, 1766)	3.6	1.29	0.02	0.0471	0.0183
Mycale (Aegogropila) syrinx (Schmidt, 1862)	12.5	2.63	0.05	0.1369	0.0531
Suberites carnosus (Johnston, 1842)	10.7	3.00	0.06	0.0300	0.0116
Sycon ciliatum (Fabricius, 1780)	10.7	3.86	0.07	0.2657	0.1031
Pachycerianthus solitarius (Rapp, 1829)	5.4	0.92	0.02	0.3014	0.1169
Amphiporus bioculatus McIntosh, 1874	7.1	1.10	0.02	0.0019	0.0007
Leucocephalonemertes aurantiaca (Grube, 1855)	16.1	3.94	0.08	0.0252	0.0098
Micrura fasciolata Ehrenberg, 1828	53.6	20.52	0.39	0.0631	0.0245
Tetrastemma sp.	19.6	4.56	0.09	0.0023	0.0009
Nemertini indet.	44.6	17.29	0.33	0.0500	0.0194
Alitta succinea (Frey & Leuckart, 1847)	1.8	0.55	0.01	0.0055	0.0021
Amphitritides gracilis (Grube, 1860)	58.9	51.03	0.97	0.3572	0.1386
Aonides oxycephala (Sars, 1862)	14.3	10.70	0.20	0.0749	0.0290
Aonides paucibranchiata Southern, 1914	57.1	61.96	1.18	0.4337	0.1683
Aricidea claudiae Laubier, 1967	16.1	18.27	0.35	0.0091	0.0035
Capitella capitata (Fabricius, 1780)	76.8	168.08	3.20	0.0252	0.0098
Capitomastus minima (Langerhans, 1881)	25.0	8.14	0.16	0.0049	0.0019
Capitellides giardi Mesnil, 1897	16.1	7.73	0.15	0.0046	0.0018
Euclymene collaris (Claparède, 1869)	35.7	15.49	0.30	0.0325	0.0126
Clymenura clypeata (Saint-Joseph, 1894)	10.7	3.42	0.07	0.0376	0.0146
Dipolydora quadrilobata (Jacobi, 1883)	46.4	974.06	18.56	0.9741	0.3779
Harmothoe reticulata (Claparede, 1870)	1.8	0.43	0.01	0.0003	0.0001
Hediste diversicolor (O. F. Muller, 1776)	7.1	1.84	0.04	0.0184	0.0071
Heteromastus filiformis (Claparede, 1864)	23.2	14.90	0.28	0.0128	0.0050
Eulalia viridis (Johnston, 1829)	5.4	1.29	0.02	0.0045	0.0017
Eulalia viridis ornata McIntosh, 1908	1.8	0.28	0.01	0.0010	0.0004
Eulalia sp.	3.6	0.55	0.01	0.0019	0.0007
Janua pagenstecheri (de Quatrefages, 1865)	8.9	46.52	0.89	0.0116	0.0045
Melinna palmata Grube, 1870	7.1	1.61	0.03	0.0501	0.0194
Mysta picta (Quatrefagues, 1865)	3.6	1.04	0.02	0.0000	0.00002
Nerine cirratulus (Delle Chiaje, 1831)	19.6	20.14	0.38	0.0040	0.0016
Nerinides tridentata Southern, 1914	3.6	0.55	0.01	0.0001	0.0000
Nephtys hombergii Savigny in Lamarck, 1818	67.9	60.23	1.15	0.5420	0.2103
Notomastus lineatus (Claparede, 1869)	3.6	1.10	0.02	0.0012	0.0005
Notomastus profondus (Eisig, 1887)	10.7	2.27	0.04	0.0025	0.0010
Paraonis fulgens (Levinsen, 1884)	7.1	3.59	0.07	0.0251	0.0097
Phyllodoce laminosa Savigny in Lamarck, 1818	1.8	1.10	0.02	0.0039	0.0015
Phyllodoce lineata (Claparède, 1870)	75.0	61.33	1.17	0.2147	0.0833
Phyllodoce maculata (Linnaeus, 1767)	10.7	4.47	0.09	0.0157	0.0061

Taxa	**C%**	D_{AVG}	$D_D\%$	B_{AVG}	$D_B\%$
Phyllodoce mucosa Oersted, 1843	1.8	1.29	0.02	0.0045	0.0017
Phyllodoce tuberculata Bobretzky, 1868	1.8	0.43	0.01	0.0015	0.0006
Phyllodoce sp.	3.6	0.86	0.02	0.0030	0.0012
Polycirrus jubatus Bobretzky 1869	1.8	0.28	0.01	0.0002	0.0001
Polydora ciliata (Johnston, 1838)	26.8	346.25	6.60	0.3462	0.1343
Polydora sp.	28.6	120.21	2.29	0.1202	0.0466
Prionospio cirrifera Wiren, 1883	17.9	21.34	0.41	0.1494	0.0580
Protodrilus flavocapitatus (Uljanin, 1877)	7.1	5.51	0.11	0.0050	0.0019
Pterocirrus limbatus (Claparède, 1868)	30.4	21.77	0.41	0.0762	0.0296
Pygospio elegans Claparede, 1863	14.3	6.07	0.12	0.0006	0.0002
Oriopsis armandi (Claparede, 1864)	3.6	1.38	0.03	0.0006	0.0002
Salvatoria clavata (Claparède, 1863)	8.9	8.85	0.17	0.0027	0.0010
Salvatoria limbata (Claparède, 1868)	12.5	6.93	0.13	0.0021	0.0008
Scolelepis ciliata (Keferstein, 1862)	3.6	1.38	0.03	0.0004	0.0002
Sphaerosyllis bulbosa Southern, 1914	71.4	88.15	1.68	0.0705	0.0274
Spio multioculata (Rioja, 1918)	1.8	0.43	0.01	0.0001	0.00005
Spionidae indet.	7.1	6.80	0.13	0.0010	0.0004
Terebellides stroemii Sars, 1835	96.4	98.36	1.87	8.8527	3.4344
Polychaeta indet.	23.2	12.69	0.24	0.0076	0.0030
Oligochaeta indet.	8.9	6.35	0.12	0.0013	0.0005
Nudibranchia indet.	5.4	1.29	0.02	0.0001	0.00005
Odostomia scalaris MacGillivray, 1843	1.8	0.21	0.00	0.0004	0.0002
Retusa truncatula (Bruguiere 1792)	1.8	0.43	0.01	0.0015	0.0006
Abra alba (Wood W., 1802)	1.8	0.28	0.01	0.0193	0.0075
Modiolus phaseolinus Philippi, 1844	96.4	2171.90	41.38	213.9186	82.9910
Mytilus galloprovincialis Lamarck, 1819	7.1	13.10	0.25	20.6864	8.0254
Callipalene brevirostris (Johnston, 1837)	16.1	5.36	0.10	0.0018	0.0007
Callipalene phantoma (Dohrn, 1881)	17.9	7.29	0.14	0.0025	0.0010
Nephasoma minutum (Keferstein, 1862)	14.3	4.14	0.08	0.0033	0.0013
Phoronis euxinicola Selys-Longchamps, 1907	8.9	8.70	0.17	0.0070	0.0027
Balanus improvisus Darwin, 1854	3.6	1.29	0.02	0.0129	0.0050
Ampelisca sarsi Chevreux, 1888	55.4	41.66	0.79	0.1494	0.0580
Apherusa bispinosa (Bate, 1857)	48.2	48.09	0.92	0.0247	0.0096
Atylus guttatus (Costa, 1851)	23.2	7.32	0.14	0.0190	0.0074
Caprella acanthifera Leach, 1814	57.1	56.07	1.07	0.1009	0.0392
Corophium runcicorne Della Valle, 1893	7.1	5.54	0.11	0.0022	0.0009
Megamphopus cornutus Norman, 1869	23.2	25.58	0.49	0.0077	0.0030
Microdeutopus damnoniensis (Bate, 1856)	5.4	2.54	0.05	0.0006	0.0002
Microdeutopus versiculatus (Bate, 1856)	50.0	38.22	0.73	0.0455	0.0176
Perioculodes longimanus (Bate & Westwood, 1868)	37.5	16.53	0.31	0.0033	0.0013
Phtisica marina Slabber, 1749	30.4	19.04	0.36	0.0324	0.0126

Taxa	**C%**	**D_{AVG}**	**D_D%**	**B_{AVG}**	**D_B%**
Orchomene humilis (Costa, 1853)	14.3	6.25	0.12	0.0099	0.0038
Synchelidium maculatum Stebbing, 1906	5.4	0.77	0.01	0.0002	0.0001
Cumella pygmaea euxinica Bacescu, 1950	19.6	8.79	0.17	0.0013	0.0005
Eudorella truncatula (Bate,1856)	50.0	34.83	0.66	0.0080	0.0031
Iphinoe elisae Bacescu, 1950	33.9	41.27	0.79	0.0202	0.0078
Synisoma capito (Rathke, 1837)	25.0	8.63	0.16	0.1491	0.0579
Apseudopsis ostroumovi Bacescu et Carausu, 1947)	55.4	163.94	3.12	0.2158	0.0837
Amphiura stepanovi Dijakonov, 1956	58.9	32.11	0.61	0.5781	0.2243
Leptosynapta inhaerens (O.F.Muller, 1776)	57.1	49.31	0.94	0.6000	0.2328
Ascidiella aspersa (Muller, 1776)	5.4	1.13	0.02	0.0057	0.0022
Ciona intestinalis (Linnaeus, 1758)	5.4	1.29	0.02	0.7200	0.2793
Eugyra adriatica Drasche, 1884	3.6	0.70	0.01	0.0365	0.0142
Molgula appendiculata Heller, 1877	19.6	27.61	0.53	6.0338	2.3408
Clunio marinus Haliday, 1855	53.6	38.19	0.73	0.7637	0.2963
	No.taxa	**D_{AVG}**	**DD%**	**B_{AVG}**	**DB%**
Nemertini, Polychaeta, Oligochaeta	54	2345.37	44.68	12.66	4.91
Mollusca	6	2187.21	41.67	234.63	91.02
Crustacea	18	526.36	10.03	0.80	0.31
Animalia cetera	17	190.16	3.62	9.67	3.75
Total	**95**	**5249.11**	**100**	**257.76**	**100**