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CURRENT STATE OF THE ZOOBENTHOS AT THE CRIMEAN SHORES OF THE BLACK SEA

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ABSTRACT

The analysis of current state of zoobenthos at the Crimean shores of the Black Sea is fulfilled. The general features of taxonomical structure, regional peculiarities of bottom fauna development and species number distribution pattern with depth are considered. The results obtained testify the absence of species number reduction at the Crimean coastal zone of the Black Sea over the 2nd half of the XX century. Total number of the macrozoobenthos species registered in the Crimea water area exceeds 560. Filter-feeding mollusks (*Chamelea gallina* and *Modiolula phaseolina* first of all) became the most pronounced "evolutioning" species, determining the quantitative changes of the bottom fauna over the soft-bottoms of the southwestern Crimea during the period 1930-s - 1990-s. The shift to lesser depths: from the zone of the mussel silts (26-50 m) to the silty-sand (13-25 m) of the most productive benthal belt of the southwestern Crimea is marked. Meiobenthos (eumeiobenthos) of the Crimean shelf includes more than 522 species in total. Formation of specific meiofauna composition in areas of the methane gas seeping is marked. The presence of 38 species and 6 genera of Nematoda, which are registered only in the given conditions testify to this.

Key words: zoobenthos, Black Sea, Crimea, biodiversity, long-term changes.

INTRODUCTION

Deterioration of the ecological state in the Black Sea basin, which determined considerable changes of its biological resources structure have been registered in 1970–80-s. Shift of the ecosystems production-destruction balance towards organic matter accumulation occurred (Zaitsev, Mamaev 1997; Alexandrov, Zaitsev, 1998; Black Sea …, 1998). Changes of the northwestern Black Sea shelf fauna in the most conservative ecosystem – benthos became indicative. They revealed themselves in the total transformation of the bottom communities, decrease of the species diversity, changes of the structural characteristics of populations and growth of the morphological anomalies of the definite benthos forms (Bronfman et al., 1994; Zolotaryov, 1994; Alexandrov, Zaitsev, 1998).

Deterioration of the ecological state occurred in the Crimean shelf region also. Analogical benthos changes have been registered here, but they were less prominent by scale and intensity. They affect the northwestern Crimean water area including Karkinitsky gulf (Povchun, 1992) in greater degree and lesser – the western and southern peninsular coast. Local changes in bottom communities structure in the impact water areas of the technogenic and municipal zones of the open sea (Revkov et al., 1992; Long-term changes…, 1992; Revkov et al., 1999a) and bays (Kisseleva et al., 1997; Mironov et al., 2003), occurrence of the morphological anomalies in the populations of the some common species (Petrov, Zaika, 1993; Revkov et al., 1999b), depletion of the macrozoobenthos in different sections of the aerobic benthal (Zaika, 1990; Long-term changes…, 1992; Zaika, Sergeeva, 2001; Makarov, Kostylev, 2002) were characteristic for the last ones. Nevertheless, significant transformation or degradation of the benthal ecosystems at the Crimean shores was not revealed according to the results of the hydrobiological expedition of 1999 on the R/V "Professor Vodyanitsky" (Kiryukhina, Gubasaryan, 2000; Revkov et al., 2002).

1518 species of zoobenthos in the Black Sea in the middle of the 1970-s were known (Kisseleva, 1979). However, only 312 species were noticed from 1984 to 1994 at the Crimean coast out of 875 macrozoobenthos species, which were registered on the Ukrainian shelf before 1973, according to the National report (Black Sea …, 1998). It is no doubt that such considerable reduction of the benthic fauna in the region of Crimea needs more detailed analysis.

MATERIALS AND METHODS

Literature sources and expedition materials (more than 1200 stations totally) from the data-base of the Shelf Ecosystems department IBSS NASU were used as a base for the analysis of the general macrofauna composition in the Crimean region.

Materials of 1930-s by L.V. Arnoldy (1941) and scheme of the benthos vertical zonality, suggested by him were used under analysis of the long-term quantitative changes of zoobenthos in the southwestern Crimea water area (table 1).

Table 1. Scheme of zoobenthos subdivision in sampling site of the southwestern Crimea (from Arnoldi, 1941)

Index number	Name of groupings	Range of depths, m	Number of sampling stations	
			1930-s	1980-90-s*
I	Sand	1–12	9	41
II	silty-sand	13–25	7	47
III	mussel silts	26–50	6	19
IV	Phaseolina silts	51–110	20	73

Note: * - Database materials of Shelf Ecosystems department of IBSS NANU are used.

Spatial and temporal comparisons of "Indices of Functional Abundance" (IFA) values were conducted for the underlined groupings of zoobenthos. Estimation of the long-term changes in benthos structure (dissimilarities between biocenotical groupings) for the period from 1930-s to 1980–90-s is fulfilled in the SIMPER programme of the PRIMER software package (Chatfield, Collins, 1980; Carr, 1997). A non-transformed matrix of IFA values for species is used in the MDS analysis. Construction of species rank distribution curves have been fulfilled according to the values of species "Density index" (DI).

$IFA = N_i^{0.25} \times B_i^{0.75}$; $DI = IFA \times p$,

N_i and B_i – correspondingly abundance (ind/m^2) and biomass (mg/m^2) of i species,

p – frequency of species occurrence (0–1).изучение распределения studying of distribution

The materials for analysis the taxonomic composition and quantitative distribution of meiobenthos on the Black Sea site of Crimean shelf was collected during 53th cruise of R/V "Professor Vodyanitsky" (spring, 1999). 12 stations were taken at the depth range of 23–260 m in water areas of western, southern and southwestern parts of Crimea (from cape Tarkhankut to Karadag). The taxonomic composition and quantitative distribution of meiobenthos on the soft-bottoms at the Crimean shelf zone were considered according to regions established by V.A. Vodyanitsky (1949).

Features of taxonomical structure of meiobenthos in areas with methane gas seeping are considered. Samples were taken by box- and multicorer (45th cruise of R/V "Professor Vodyanitsky", July, 1994) in western part of the Black Sea. Experimental plot covered 12 stations across depths 72–232 m 72-232 м. (Sergeeva, 2003).

Macrozoobenthos.

The main tendencies in dynamics of the Crimean region fauna composition. The bottom fauna of the Crimean zone of the Black Sea is represented, mainly, by marine forms, for which the Black Sea average salinity of 18 ‰ is normal. If we'll take into account only such marine

forms of main taxons (table 2) it appears, that before 1975 the Crimean fauna has been submitted by 83 % of species known for that period in the Black Sea.

While 463 species were registered in the Crimean region benthos before 1975, in 1980–90s there were 471 of them. 551 zoobenthic species were marked near the Crimean shore for all time observation in the groups studied (table 2).

Table 2. Species richness of zoobenthos of the Black Sea and along the Crimean coast

Taxon	The Black Sea, before 1975	Crimean coastal zone		
		before 1975	1980–1990s	For all time observation
PORIFERA	29 (29)	12	14	18
COELENTERATA	36 (32)	24	32	35
Anthozoa	6 (5)	5	4	5
Hydrozoa	27 (24)	16	25	27
Scyphozoa	3 (3)	3	3	3
NEMERTINI	31 (31)	20	3	20
POLYCHAETA	182 (149)	131	121	144
PANTOPODA	7 (4)	4	3	5
CRUSTACEA	230 (150)	125	128	142
Cirripedia	5 (5)	4	5	5
Decapoda	37 (35)	30	32	33
Mysidacea	19 (11)	5	5	7
Cumacea	23 (12)	9	15	15
Anisopoda	6 (4)	4	3	4
Isopoda	29 (22)	17	15	20
Amphipoda	111 (61)	56	54	59
MOLLUSCA	192 (132)	122	141	156
Loricata	3 (3)	2	2	2
Bivalvia	89 (53)	43	46	49
Gastropoda	100 (76)	77	93	105
BRYOZOA	16 (16)	11	13	15
PHORONIDEA	1 (1)	1	2	2
ECHINODERMATA	14 (5)	5	5	5
Ophiuroidea	4 (1)	1	1	1
Holothurioidea	8 (4)	4	4	4
Echinoidea	1 (0)	–	–	–
Asteroidea	1 (0)	–	–	–
CHORDATA (Tunicata, Acrania)	9 (9)	8	8	8
TOTAL:	747 (558)	463	471	551

Note: the number of species usual for waters with normal Black Sea salinity is specified in parentheses.

There are no any evidences of the reduction of species richness of zoobenthos in the Crimean water area in the last quarter of XX century. Moreover, in 1980–90-s bottom fauna of this region was enriched due to: 1) broadening of strictly Black Sea species distributional ranges; 2) introduction of forms, previously noted from the near-Bosporus region only; 3) alien species. Besides, new for sciences species were revealed and described.

For example, group of the Crimean hydroids was replenished by 5 species new for the Black Sea: *Coryne pusilla* (Gaertner, 1774)*, Eudendrium annulatum* Norman, 1864*, E. capillare* Alder, 1857*,* *Opercularella nana* Hartlaub, 1897 и *Stauridia producta* Wright, 1858 (Grishicheva, Shadrin, 1999; Revkov, 2003a). Within the Polychaeta 13 species found new for the Crimean fauna in 1980–90-s, and four of them (*Nerilla taurica* Skulyari, 1997*, Nerilla* sp.1, *Vigtorniella zaikai* (Kisseleva, 1992) и *Protodrilus* sp.1) are new for science (Skulyari, 1997; Kisseleva, 1992, 1996, 1998). The crustaceans were replenished by 13 species, bryozoa by 4 species (Revkov, 2003a). The most numerous additions appeared within mollusks: 6 species of Bivalvia and 25 species of Gastropoda (Revkov, 2003a). But in the last case (for gastropods) we meet imaginary enrichment of the region fauna. Enlarging of their species list took place mostly due to changes in diagnostics keys.

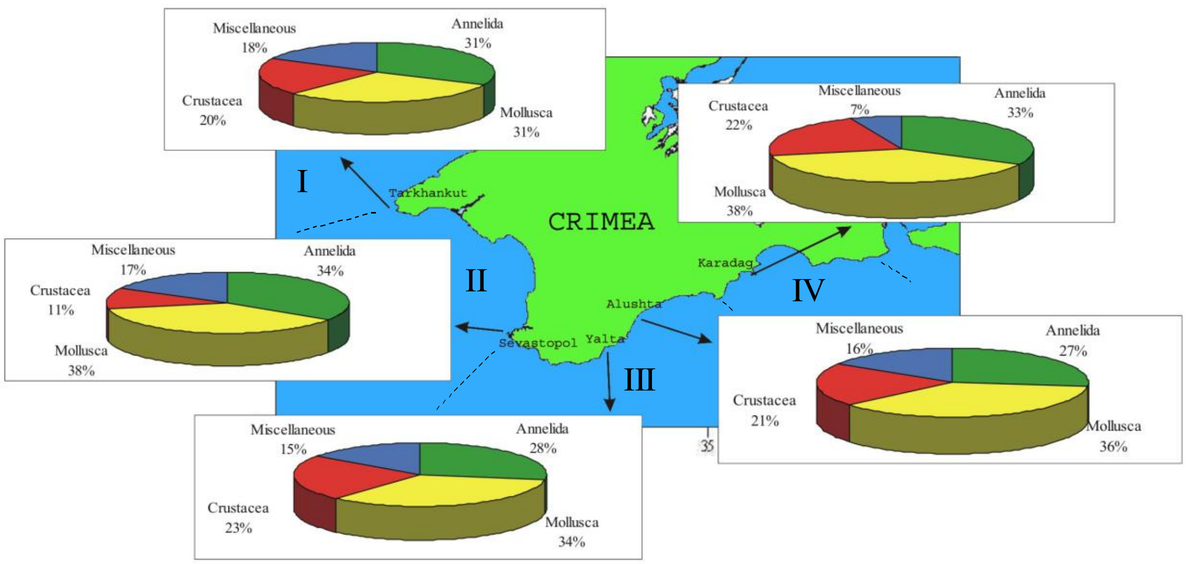

Figure 1. Species quantity ratio (%) of the basic zoobenthos groups by regions (from Revkov et al., 2002): I – V – regions of Crimean coast (from Vodyanitsky, 1949).

Together with enrichment of the Crimean waters fauna in modern samplings we marked absence of some species earlier registered here. However, this fact we do not treat unequivocally as their disappearance from water area of Crimea. Further investigations will permit to elucidate situation as for the status of species, which “disappeared” from the Crimean shores.

Regional peculiarities of zoobenthos. In our research we follow the scheme (Vodyanitsky, 1949), which subdivides the Crimean Black Sea area into 5 regions: Karkinitsky gulf (region I), Eupatoria – Sevastopol (II), southern coast of the Crimea (III), Feodosia (IV) and the Kerch strait region (V). By the results, obtained in 1999 during 53th cruise on board “Professor Vadyanitsky”, the regional specific nature of the faunal development is noted (Figure 1). In terms of the species number, mollusks (31-38%) and annelids (27–34%) occupy first places in all regions.

Values of benthos abundance and biomass are in the margins of variation of the parameters, earlier marked at corresponding biocenoses of Crimean coastal zone of the Black Sea (Revkov et al., 2002). The absolute maximum of the benthos development is noted in region I (Cape Tarkhankut) in the range of depths 22-31 m (Figure 2). Toward the southeastern part of the Crimea, at relatively shallow-water at depth from 22 to 31 m, the abundance and biomass of the benthos decrease. This takes place due to the formation of different communities at similar depths in different shelf areas. Thus, the peak of the curve for the benthic biomass in the area of Cape Tarkhankut (region I) is formed due to the intense development and absolute dominance of the mussel *Mytilus galloprovincialis*, which forms dense populations on the bottom. At the stations performed in the east, the role of the dominant species transfers to smaller benthic forms, namely, mollusks such as *Chamelea gallina* and *Pitar rudis*.

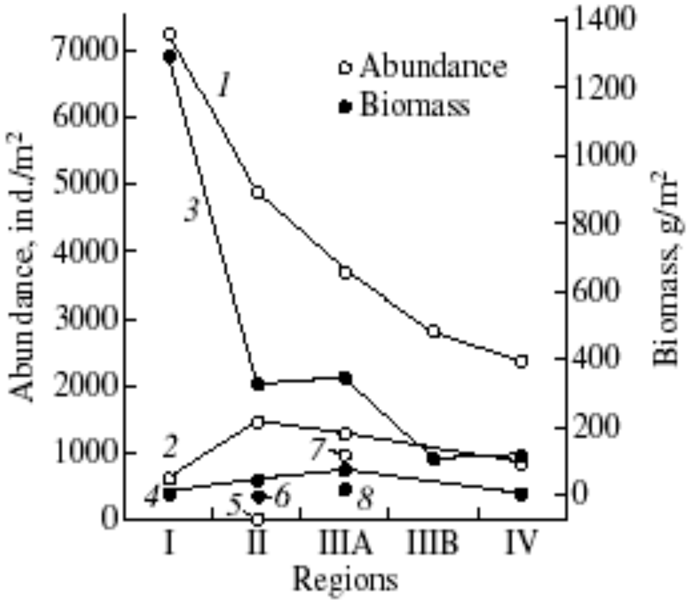

Figure 2. Regional variations in the values of benthic abundance and biomass: 1and 3 – 22-31 m; 2 and 4 – 44-49 m; 5 and 6 – 142 m; 7 and 8 – 83 m (by Revkov et al., 2002).

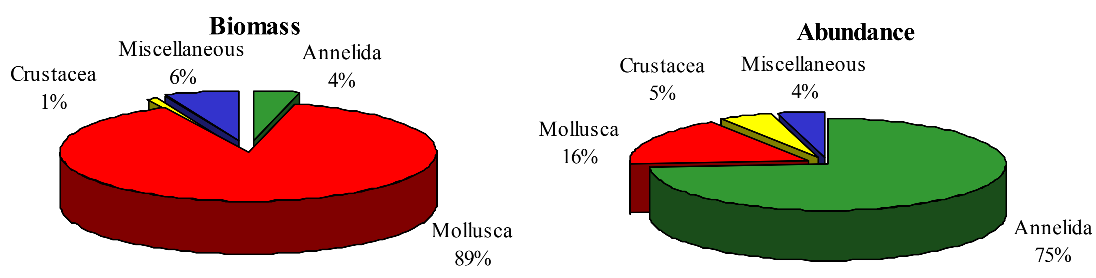

Figure 3. The percent values of abundance and biomass for the main benthic taxa on the soft bottoms at the coast of Crimea

Special features of the shape of the curves of the benthos density in the depth range of 22–31 m are determined by the development of two species of polychaetes, namely, *Aricidea claudiae* and *Prionospio cirrifera.* While in the area off the western Crimea, *P. cirrifera* (27–28% of the total benthos abundance) dominates reaching the absolute maximum of development - 2044 ind/m^2; off the southern coast of the Crimea *A. claudiae* becomes the dominant benthic form with respect to its maximal abundance up to 2142 ind/m^2.

Within the range of depths from 44 to 49 m, in regions II and III A, both parameters of the benthos development have smaller amplitude of variation and are represented by dome-shaped single-peak curves. The polychaetes *A. claudiae*, *Melinna palmata* and *Terebellides stroemi* become the dominant benthic forms with respect to their abundance, whereas in terms of their biomass, the polychaete *T. stroemi*, the mollusks *M. galloprovincialis* and *Spisula subtruncata* and the ascidian *Ascidiella aspersa* prevail.

On the soft-bottoms near the Crimean coast annelids dominate by abundance (75%) and mollusks – by biomass (89%) (Figure 3). The average population density of miscellaneous species (98 ind/m^2) is the minimum at the Crimea shores as compared to those of crustaceans (123), mollusks (393), and polychaetes (1775).

Such mollusks as *Lentidium mediterraneum* and *Chamelea gallina* have an absolute maximal abundance among the species responsible for the high percentage observed over the soft-bottoms at the coast of Crimea. *Capitella capitata* has absolute maximal abundance among Polychaeta group, *Erichthonius difformis* - among crustaceans and *Branchiostoma lanceolatum* – among miscellaneous group (Table 3).

Table 3. Maximal abundance (ind/m^2) of the species responsible for the high percentage observed over the soft-bottoms at the coast of Crimea

Groups	Species	Abundance
Polychaeta	*Capitella capitata* (Fabricius, 1780)	8713
	Brania clavata (Claparede, 1863)	5540
	Heteromastus filiformis (Claparede, 1864)	5229
	Exogone gemmifera Pagenstecher, 1862	4640
	Protodorvillea kefersteini (McIntosh, 1869)	4363
Mollusca	*Lentidium mediterraneum* (Costa, 1829)	23780
	Chamelea gallina (Linnaeus, 1758)	13325
	Tricolia pullus (Linnaeus, 1758)	6700
	Caecum trachea (Montagu, 1803)	6688
	Spisula subtruncata (Costa, 1778)	6538
Crustacea	*Erichthonius difformis* Milne-Edwards, 1830	3170
	Diogenes pugilator Roux, 1828	2500
	Caprella acanthifera Leach, 1814	1860
Miscellaneous	*Branchiostoma lanceolatum* (Pallas)	1109
	Amphiura stepanovi Djakonov, 1954	496
	Pachycerianthus solitarius (Rapp, 1829)	256

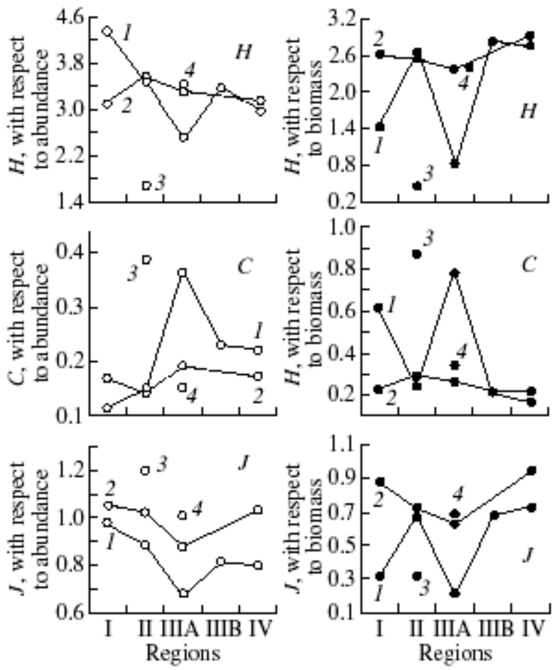

Figure 4. Regional variations in the values of Shannon's (H), Simpson's (C) and Pielou’s (J) ecological indices: 1 – 22-31 m; 2 – 44-49 m; 3 – 83 m; 4 – 142 m (from Revkov et al., 2002).

Quite high magnitudes of Shannon diversity index calculated by species biomass are shown on fig 4. At 8 of 11 stations it was higher than 2.37 bit/g. For comparison, that average values of the given index in the coastal zoocenosis of the soft-bottoms of the Black Sea coast in most cases do not exceed 2.2 bit/g.

Against the general background of the relatively high values of Shannon’s index of diversity calculated both on the basis of the species abundance and biomass, absolute peaks were recorded in the areas off Cape Tarkhankut (an abundance peak, region I) and off Karadag (a biomass peak, region IV). In both cases, in the area off Yalta (region III A), decreases in the average values of this index are observed.

The lowering of Shannon’s index of diversity noted in the area off Yalta is related to the decrease in the extent of uniformity of the benthic structure (both in terms of abundance and biomass). This decrease results from the mass development of such benthic forms as *Chamelea gallina* and *Aricidea claudiae.* The further examination of the general structure of fauna (despite of biotope type), drive us to consider the area of the western Crimea (including Sevastopol bays) as the most reach of species. Such conclusion is quite logical, because since the Sevastopol biological station foundation in

1871, areas adjacent to Sevastopol were the main polygons for the Black Sea studies.наиболее разнообразно фауна представлена most variously the fauna is submitted

According to traditionally great research interest to the western Crimea section (region II) the number of macrozoobenthos species recently found there is also the highest one inside the Crimean surrounding water areas as whole. In the last decades of XX century it was 383 species or 81% of the known for the total Crimea water area. The macrobenthos fauna of other subdivisions: northern coast of cape Tarkhankut (region I), southern (III), southeastern Crimea (IV) and Kerch strait front (V), are considerably less diverse. It contains correspondingly 230 (49%), 268 (57%), 259 (55%) and 179 (38%) species. The analysis of the most evenly studied Bivalve group gives the same picture. Most divers the fauna of bivalves is represented in the region of the western Crimea. There are 39 species (85% from total number of bivalve species) known for water area of Crimean at 1980–90-s. In the regions of the northwestern, southern, southeastern Crimea and Kerch strait front side we found correspondingly 30 (65%), 28 (61%), 39 (65%) and 28 (61%) of mussels species.

With the further accumulation of faunistic information we may expect growth of general percent of the regions fauna elements being represented, and consequently lowering of the regional faunistic differences. At comparison of the data received for the soft-bottoms and for the Crimean shores as a whole-preservation of shares of the basic benthos taxons was marked (Figure5).

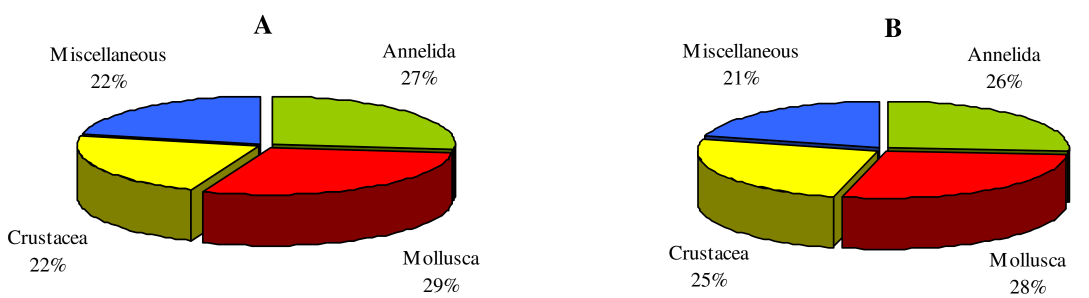

Figure 5. Species richness in main groups of zoobenthos of the Crimean coastal zone of the Black Sea (in percent): A – for soft bottom only, (from Revkov et al., 2002), B – for the Crimean coastal zone (from Revkov, 2003).

In a whole, the highest number of species near the Crimean shore was registered for the mollusks (156 species); annelids (146) and crustaceans (142) are a bit less numerous, and the last position (116 species) is occupied by combined group of “Miscellaneous” species.

Vertical distribution of zoobenthos. The low limit of species distribution in the Black Sea is restricted mainly by the 127–135-meter isobate (Nikitin, 1938). This is stipulated by the hydrological and geomorphological features as well as by species-specific requirements to the living conditions, presence of the seasonal and long-term components of species distribution dynamics (Kisseleva, 1979; Long-term changes…, 1992).

Discord of the distributional limits of some benthic species at the Crimean and Caucasus coasts has been registered before (Kisseleva, 1979). Most of species penetrate deeper at the Caucasus region. Analysis of the materials, obtained in 1980–90-s pointed on the alignment of these differences. Contemporary depths of species dwelling on the Crimean shelf includes, in a fact, corresponding range of depths at the Caucasus shores, registered before.

We determine species with wide (eurybatic species) and narrow (stenobatic species) habitat range in depth according to the analysis of zoobenthos distribution on the soft-bottoms near the Crimean coast in 1980–90-s (about 1200 stations) (table 4). Stenobatic species having relatively narrow vertical boundaries are the basic mass.

Total macrozoobenthos species diversity on the soft-bottoms decreases with depth (fig 6). Peaks of the species diversity are at coastal, relatively shallow water zones: 0–10 and 11–20 m (correspondingly 238 and 242 species). Mollusk fauna is most diverse (81 species) at 11–20 m depth, whereas a diversity of crustaceans and annelids (74 and 80 species respectively) is the highest at the depth of 0–10 m, fauna of miscellaneous species (35) has maximum at 21–30 m depth range.

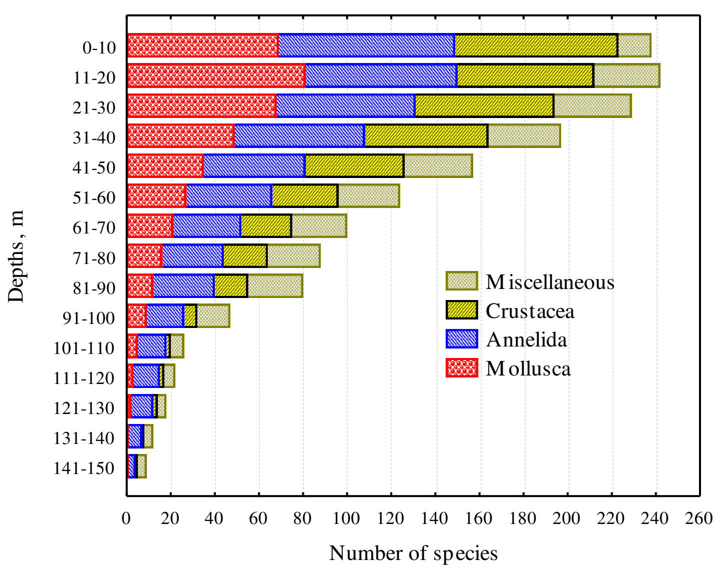

Figure 6. A diagram of vertical distribution of the main zoobenthos groups on the soft bottoms near coast of Crimea (from Revkov, 2003b).

55 macrozoobenthos species were found at the depth of 100 and more meters for the whole period of the bottom fauna investigation at the Crimean shores (Zernov, 1913; Milaschevich, 1916;

Nikitin, 1950; Kisseleva, 1985; Long-term changes…, 1992; our own data). These are – 19 species of the Annelida group, 18 of Mollusca, 7 of Arthropoda, 4 of Coelenterata, 3 of Echinodermata, 2 of Ascidiacea; Nemertini and Porifera were represented by a single species each. More than half of species known from that depth are regarded as "rare or occasional". Only 26 species can be attributed as "common" for 100 m and more depths (table 5).

Table 4. Examples of some eurybatic and stenobatic species in accordance with their vertical distribution near the Crimean coast of the Black Sea

	Range of depths, m	Species	Group
Eurybatic	0-150	*Nephtys cirrosa* Ehlers, 1868; *Melinna palmate* Grube, 1870	*Polychaeta*
		Ampelisca diadema Costa, 1853	*Crustacea*
		Amphiura stepanovi Djakonov, 1954	*Echinodermata*
	0-140	*Heteromastus filiformis* (Claparede, 1864); *Aricidea claudiae* Laubier, 1967; *Terebellides stroemi* Sars, 1835	*Polychaeta*
	0-130	*Pholoe synophthalmica* Claparede, 1868	*Polychaeta*
		Retusa truncatula (Bruguiere, 1792)	*Mollusca*
Stenobatic	0-20	*Glycera alba* (O.F.Muller, 1776); *Euclymene collaris* (Claparede, 1868); *Tharyx marioni* Saint-Joseph, 1894; *Lysidice ninetta* Audouin et Milne-Edwards, 1833; *Ophelia limacine* (Rathke, 1843); *Polyophthalmus pictus* (Dujardin, 1839); *Goniada bobretzkii* Annenkova, 1929; *Eulalia viridis* (Linnaeus, 1767); *Genetyllis nana* (Saint-Joseph, 1906); *Lagisca extenuata* (Grube, 1840); *Eumida sanguinea* (Oersted, 1843); *Dorvillea rubrovittata* (Grube, 1855); *Brania clavata* (Claparede, 1863); *Polygordius neapolitanus ponticus* Salensky, 1882	*Polychaeta*
		Solen marginatus Pulteney, 1799; *Tornus subcarinatus* (Montagu, 1803); *Hemilepton nitidum* (Turton, 1822); *Acanthochitona fascicularis* (Linnaeus, 1767); *Irus irus* (Linnaeus, 1758)	*Mollusca*
		Corophium bonelli (Milne-Edwards, 1830); *Melita palmate* (Montagu, 1804); *Echinogammarus olivii* (Milne-Edwards, 1830); *Hyale pontica* Rathke, 1837; *Stenothoe monoculoides* (Montagu, 1815); *Apseudopsis ostroumovi* Bacescu et Carausu, 1947	*Crustacea*
	21-50	*Caecum armoricum* (de Folin, 1869)	*Mollusca*
		Hypania invalida (Grube, 1860); *Pterocirrus limbata* Claparede, 1868	*Polychaeta*
		Tritaeta gibbosa (Bate, 1862)	*Crustacea*
	61-90	*Namanereis pontica* (Bobretzky, 1872); *Aonides oxycephala* (Sars, 1862)	*Polychata*

According to M.I. Kisseleva (in press) single specimens of polychaete *A. claudiae, Nephtys* sp., *M. palmata, H. filiformis, T. stroemi, O. armandi* were registered in the region of the Crimean southern coast near lower boundary of the shelf at 200 m depth.

Table 5. Species that can be attributed as “common” for 100 m and more depths

Group	*Species*	Group	*Species*
ANNELIDA	Aricidea claudiae *Laubier, 1967*	MOLLUSCA	*Abra alba* (Wood W., 1802)
	Capitella capitata (Fabricius, 1780)		*Modiolula phaseolina* (Philippi, 1844)
	Heteromastus filiformis *(Claparede, 1864)*		*Plagiocardium papillosum* (Poli, 1795)
	Melinna palmate Grube, 1870		*Retusa truncatula* (Bruguiere, 1792)
	Nephtys cirrosa Ehlers, 1868		*Trophon muricatus* (Montagu, 1803)
	N. hombergii Savigny, 1818	ARTHROPODA	*Ampelisca diadema* Costa, 1853
	Notomastus profundus Eisig, 1887		*Apseudopsis ostroumovi* Bacescu et Carausu, 1947
	Oriopsis armandi (Claparede, 1864)		*Eudorella truncatula* (Bate, 1856)
	Pholoe synophthalmica Claparede, 1868		Pantopoda g. sp.
	Terebellides stroemi Sars, 1835	ECHINODERMATA	*Amphiura stepanovi* Djakonov, 1954
	Oligochaeta g. sp.	CHORDATA	*Ciona intestinalis* (Linnaeus, 1767)
PORIFERA	*Suberites carnosus* Johnston, 1848		*Eugyra adriatica* Drasche, 1884
ANTHOZOA	Pachycerianthus solitarius *(Rapp, 1829)*	NEMERTINI	Nemertini g. sp.

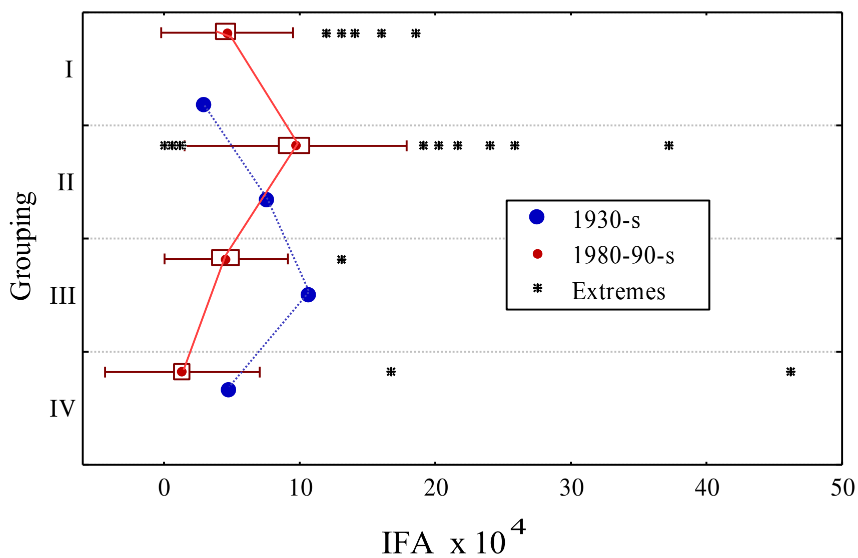

Figure 7. Index of Functional Abundance (IFA) of benthic groupings per different years (from Revkov, 2003c). Range of depths in groupings: I–(sandy zone)–1-12 m, II–(silty-sand)–13-25 m, III–(mussel silt)–26-50 m, IV–(phaseolina silt)–51-110 m.

Long-term changes of zoobenthos in the region of the southwestern Crimea. A lot of data on long-term changes in the bottom fauna composition in the Crimean region have been accumulated now (Kisseleva, 1981; Long-term changes…, 1992; Kisseleva et al., 1997; Revkov, Nikolaenko, 2002; Mironov et al., 2003). The obtained results give many variants for evaluation of changes in the bottom ecosystems of different Crimean water areas. However, it seems that the modern state of ecosystems of the Crimean shelf zone (both from faunistic and structural points of view) is stable or a bit improved being compared with those of 1970-s. These conclusions need more detailed description.

At the model polygon of our investigation considerable decrease in benthos development (measured by IFA-index) is registered only in mussels (III) grouping (Figure 7). One can notice differently oriented long-term drift of corresponding averages in the upper and lower shelf horizons.

Плотность первого вида увеличилась в три раза, второго вида – уменьшилась в 6 раз. The density of the first kind has increased three times, of the second kind – has decreased in 6 times. Плотность первого вида увеличила три раза, второго вида – уменьшился в 6 раз.

Considering sense loading of the IFA–index used, expressed in indirect evaluation of the energy flow through the communities studied, we can speak about changes of zoobenthos average production: 1.5 and 1.3 times increase in the upper (sandy and silt sand groupings correspondingly) and 2.3–3.6 times decrease in the lower (correspondingly mussel and phaseolina silts groupings) horizons of the inhabited benthal. It shifts maximum of absolute production to lesser depths: from the zone of mussel silts (26–50 m) to silty-sand (13–25 m).

According to the results of comparing the benthos groupings of 1930-s and 1980–90-s (SIMPER programme) it appeared, that long-term changes in the coastal sand grouping were caused by changes in development of bivalve mollusks namely *Chamelea gallina* and *Spisula subtruncata* which contribute 73% to the groupings dissimilarity (Bray-Curtis Dissimilarity) (table 6). The abundance (by IFA-index) of the first species increased in three times while of the second species – decreased in 9.8 times. In the silt-sand grouping the most considerable differences (which contribute 78% to dissimilarity) depends on changes in *Ch. gallina* and *Paphia aurea* populations. Importance of the first species, like in I grouping, increased here (IFA-index increased 2.3 times), while the second one decreased considerably (IFA-index felt down 1139 times!). In the mussel silts grouping considerable decrease of *Mytilus galloprovincialis* and *P. aurea* development were registered (66% between grouping dissimilarity): IFA of the first species decreased in 3.5 times, of the second ones – in 62.2 times. In the grouping of phaseolina silt the greatest changes are linked with *Modiolula phaseolina* population (80% of dissimilarity), its IFA-index felt down at 23.7 times.

Thus, the basic contribution to increase of IFA-index value of benthos development in the sandy and silty-sand groupings depends on changes in *Ch. gallina* population. Decrease of total benthos abundance (by IFA-index) in the mussel and phaseolina silt groupings is caused by respective alterations in *M. galloprovincialis*, *P. aurea* (mussel silt) and *M. phaseolina* (phaseolina silt) populations.

One can mark two main points from the species-rank distribution based on DI (fig 8a – d):

1. Positions of dominant species in the corresponding groupings are stable generaly. These dominants are: *Ch. gallina* for the coastal sandy and silty-sand groupings, *M. galloprovincialis* –

for mussel silts grouping, *M. phaseolina* – for phaseolina silts grouping (however in 80th years together with *M. phaseolina* appearance of the new leader of grouping – *M. galloprovincialis* here is marked.).

2. Opposite trends in groupings were occurred: the gap between the dominant species and the others had increased in relatively shallow water (coastal sandy and silty-sand) and decreased in mussel and phaseolina silts groupings.

Evaluation of species importance by their contribution to the intragrouping similarity and by the Density Index value (DI) gave in a whole similar results for groupings I, II and III. But in the phaseolina silt grouping (IV) results differ a bit: by DI value, *M.galloprovincialis* (together with *M.phaseolina*) is at the first place, but by its contribution into intragrouping similarity it does not enter even into five the most important species. In this case deficiency of a method of leading species definition according to DI is revealed, when species leadership (*M.galloprovincialis* in this case) with relatively law level of being met (10%) is determined by high biomass values of its separate specimens. Biocenotically such result is not satisfactory and *M.galloprovincialis* can't be attributed to the leading species of the observed grouping of the phaseolina silt

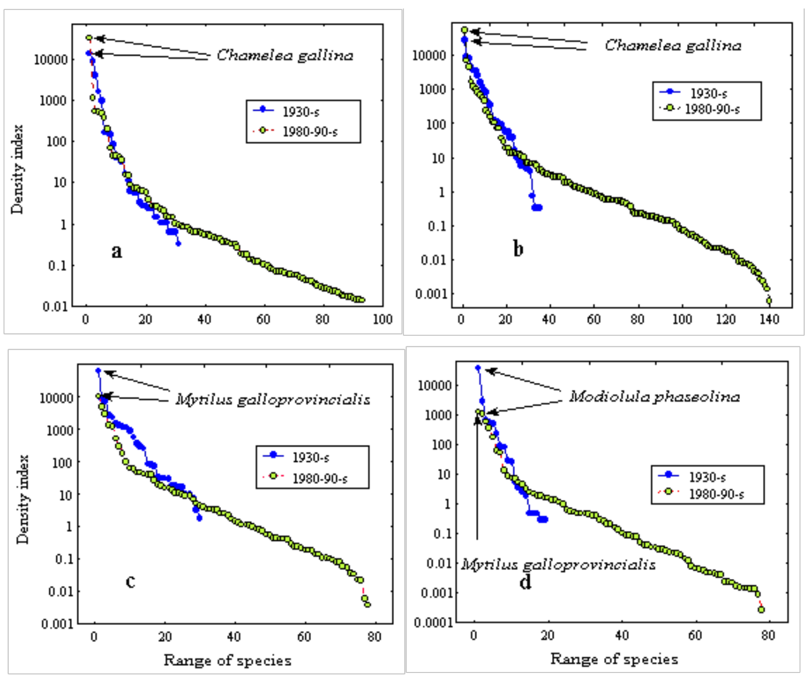

Figure 8. Species rank distribution curves based on Density Index (DI) for the various benthic groupings: coastal sandy (a), silty-sand (b), mussel silt (c) and phaseolina silt (d) groupings (from Revkov, 2003c).

Table 6. Distinctions between the same benthic groupings at the 1930-s and 1980 – 90-s

Species	$\overline{IFA}$ *		$\overline{\alpha}_i$	$\overline{\alpha}_i/SD(\alpha_i)$	$\overline{\alpha}_i$ %
	1930-s	1980 – 90-s			
Grouping I	Average dissimilarity 72.52 %				
Chamelea gallina	12848.99	38543.22	37.92	2.22	52.30
Spisula subtruncata	8507.42	864.58	14.86	1.64	20.49
Lucinella divaricata	3880.46	819.35	6.34	1.47	8.75
Donax semistriatus	1594.16	1354.78	3.67	1.32	5.06
Diogenes pugilator	969.52	1331.87	2.32	0.59	3.20
Cyclope neritea	352.43	792.99	1.07	1.49	1.48
Grouping II	Average dissimilarity 81.60 %				
Paphia aurea	138694.47	121.77	48.26	4.26	59.14
Chamelea gallina	27387.95	63386.38	15.67	1.32	19.20
Mytilus galloprovincialis	3937.20	10341.91	2.88	0.41	3.53
Modiolus adriaticus	6718.55	3327.04	2.74	1.16	3.36
Spisula subtruncata	8423.97	5860.01	2.74	1.94	3.35
Lucinella divaricata	3597.02	2438.96	1.13	1.25	1.39
Pitar rudis	4045.58	1694.61	1.07	1.98	1.31
Grouping III	Average dissimilarity 81.17 %				
Mytilus galloprovincialis	64702.59	18352.41	30.17	2.37	37.17
Paphia aurea	45279.34	728.12	23.73	4.39	29.24
Chamelea gallina	879.79	14239.72	5.99	0.57	7.38
Pitar rudis	10810.24	2187.72	4.65	2.43	5.73
Modiolus adriaticus	8963.31	436.28	4.51	4.13	5.55
Spisula subtruncata	4032.88	4755.66	2.79	1.25	3.43
Modiolula phaseolina	2585.07	489.55	1.42	2.99	1.75
Grouping IV	Average dissimilarity 90.50 %				
Modiolula phaseolina	40397.83	1704.56	72.35	4.91	79.94
Molgula euprocta	3443.62	161.74	6.09	5.18	6.72
Mytilus galloprovincialis	559.94	9071.36	4.24	0.32	4.69

* $\overline{IFA}$ – average values of Index of Functional Abundance; $\overline{\alpha}_i$ – absolute and $\overline{\alpha}_i$ % – relative contribution of i-th species to the average Bray-Curtis dissimilarity between the groupings; SD – standard deviation.

Meiobenthos

Taxonomical composition. Questions on structure and chorology of the Black Sea meiobenthos at the coastal zone of Crimea were considered in a number of published works (Kisseleva, 1965; Kisseleva, Slavina, 1964; Kisseleva, 1967; Marinov, 1975; Kolesnikova, 1983; Kisseleva, Sergeeva, 1986; Vorobjeva, Sinegub, 1989; Vorobjeva et al., 1994; Vorobjeva, 1999; Sergeeva, Kolesnikova, 2003). As it follows from the published data, the meiobenthos has high taxonomical diversity and high abundance values in the different regions of the Crimean shelf. Its diversity and abundance development is mainly determined by the habitat depth, biotope character and by edificatoric role of macrobenthos species (Sergeeva, 1985; Kisseleva, Sergeeva, 1986). As a rule free-living nematodes prevail in abundance value; harpacticoids and foraminifera relates to subdominants in the meiobenthos of the soft-bottom (Long-term changes …, 1992; Vorobjeva, 1999).

As a results of researches of the Black Sea fulfilled up to the last decade of the last century, list of meiofauna species was added considerably in such taxonomical groups as Foraminifera (Janko, Vorobjeva, 1990; Janko, Vorobjeva, 1991), free-living nematodes (Sergeeva. 1973; 1974; 1981; Stoikov, 1977), Harpacticoida (Kolesnikova, 1983; 1991), Acari (Bartch, 1996a,b; 1998a,b; 1999), Polychaeta (Kisseleva. 1992; 1996; 1998; Skulary, 1997). Nevertheless, species diversity of the Black Sea meiofauna is still insufficiently investigated.

Species of the soft-shelled foraminifera (suborders Allogromiina and Saccamminina) (Sergeeva, Kolesnikova, 1996; Sergeeva, Anikeeva, 2001), discovered recently by us in the Black Sea testify to this. According to the preliminary data, fauna of the Black Sea soft-shelled foraminifera are presented by 20 species. *Psammophaga simplora* (Arnold, 1982) is the most numerous among them.

Existing fauna of the free-living nematodes in the Black Sea is richer, than it follows from the literature sources. At least 100 representatives of the unknown species and genus of nematodes are in our collection now.

Analysis of the literature and own materials, conducted for the last years, showed that meiobenthos (eumeiobenthos) of the Black Sea Crimean shelf includes 522 species (Sergeeva, Kolesnikova, 2003). In consideration of pseudomeiobenthos (juveniles stages of macrozoobenthos) composition of meiofauna is significantly richer.

Taxonomical diversity of meiobenthos in different regions of Crimea. Number and composition of species, entering into the meiobenthos category vary in regions of the Crimea. This is stipulated not only by the specificity of the geographical regions, but considerably is determined by the different levels of meiobenthos being studied in each Crimean water areas.

According to the results of the last expedition carried out for the purpose of biological and oceanographic monitoring of the Black Sea area of the Crimean shelf in 1999 – all main taxons are present in the meiobenthos within range of depths 20–260 m: Foraminifera, Nematoda, Oligochaeta, Polychaeta, Turbellaria, Kinorhyncha, Nemertini, Bivalvia, Gastropoda, Harpacticoida, Ostracoda, Cumacea, Amphipoda, Acarina. Some earlier unknown meiobenthos organisms conventionally named as “Forma 6” and “Forma 11” have been registered too. These forms are widely distributed in the bottom sediments of the anaerobic zone of the Black Sea (Sergeeva, 2000a,b).

Distribution across depths of the main meiobenthos groups in various regions of the Crimean shores is shown in the Figure 9. The “taxonomical core” consisting of Nematoda, Foraminifera, Harpacticoida and Polychaeta is clearly distinguished. Considerable share of meiobenthos falls to the “Miscellaneous” group. Significant quantitative indices of this group at definite stations, in hypo- and anoxia conditions, are determined by the high abundance of the above mentioned “Forma 11”.

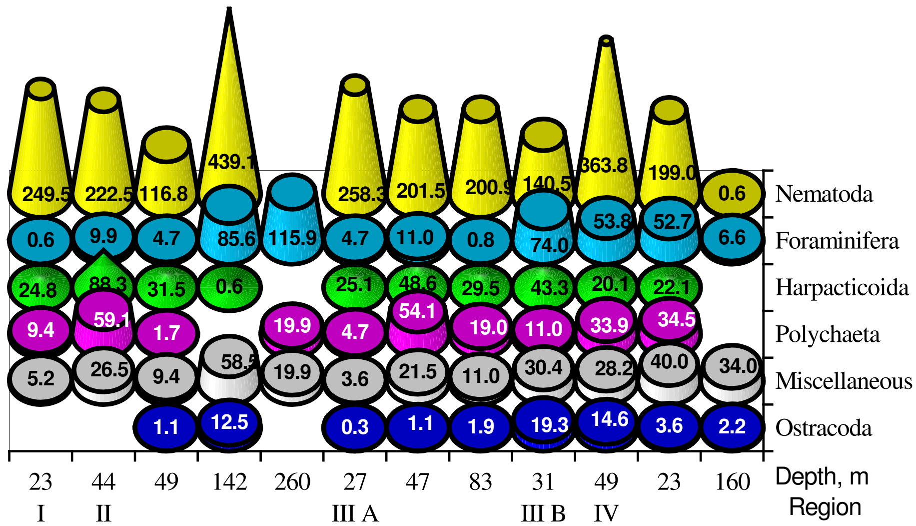

Figure 9. Regional variations of abundance (th. ind/m^2) of the meiobenthos major taxa on the Crimean shelf (spring, 1999) (from Sergeeva, 2003a).

Taxonomical composition of the meiobenthos in the depth range of 23–31 m is the most diverse in the area off Alushta (11 groups). The meiobenthos here in equal shares includes representatives of eu- and pseudomeiobenthos. 7–8 meiobenthos groups were registered in the areas off Yalta, Karadag and Tarkhankut cape. Free-living nematodes make the most numerous group in all regions. Harpacticoids play role of subdominants in the areas off Alushta, Yalta and Tarkhankut cape, turbellaria – in the area off Karadag.

The highest diversity of taxons (11) was registered in II and IV regions (Yalta, Karadag) at the depths of 44–49 m, but in I and II regions (Tarkhankut, Sevastopol) 9 and 7 groups correspondingly. Nematodes are the dominant species at the given depths, and number subdominants makes up kinorhynchs and harpacticoids in the I region, harpacticoids and polychaetes in the II and III region and foraminifers in the IV region. At the depth of 83 meters in area off Yalta (II region) nematodes dominate by abundance; the following positions occupy harpacticoids and polychaetes accordingly.

Taxonomic composition of meiobenthos at 142 and 260 m depths (region II) is peculiar. At the depth of 142 m 11 main groups of meiobenthos is found. Nematodes prevail by abundance, foraminifers and gastropods have subdominant role. Representatives of six main taxons, including “Form 11”, are registered at the depth of 260 m. Foraminifera, presented only by soft shell species, take a leading position. Second and third places belong to polychaetes and “Form 11”, correspondingly. It is interesting to note that at the given depth foraminifera dominate in meiobenthos when nematodes are absent. Just at this depth the greatest population density (115.9 thousand ind/ m^2) of soft shell foraminifera was registered.

<u>The quantitative development of meiobenthos in different regions of Crimea.</u> Average density values of the meiobenthos vary in different regions in limits of 43.4–596.2 thousand ind/m^2, biomass – 0.4–4.6 g/m^2 (Figure 10).

Absolute maximum (930.1 thousand ind/m^2) of the meiobenthos abundance is registered in the II region (southwestern part of the Crimean coast) in one of samples, taken at the depth of 142 m.

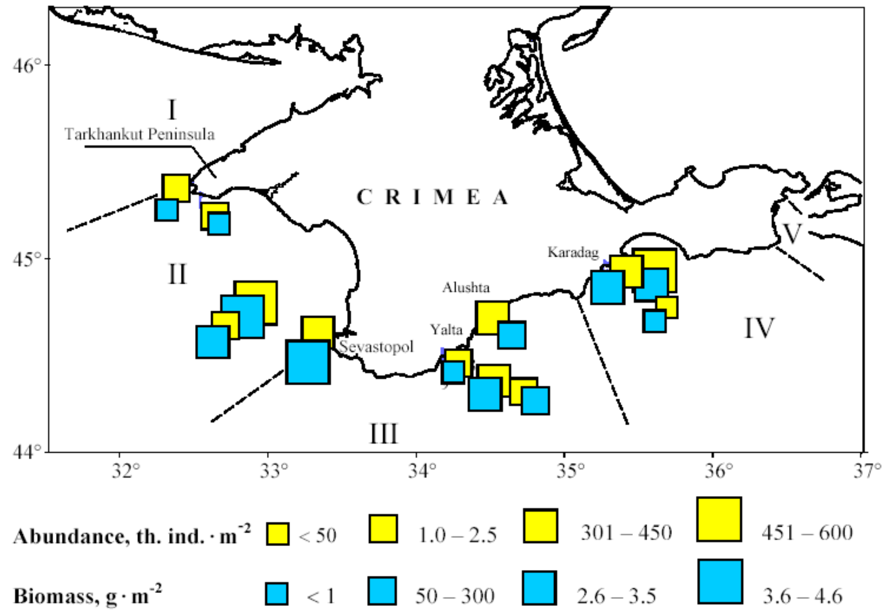

Figure 10. Scheme of meiobenthos' abundance and biomass distribution (from Sergeeva, 2003a).

The highest values of the average meiobenthos density were revealed in II and IV regions (596 and 515 thousand ind/m^2 correspondingly). Maximal development is connected with the depth of 142 m in the southwestern part, and with 49 m in area off Karadag. Minimal abundances were registered in the Karadag water area (43.3 thousand ind/m^2) at the depth of 160 m and to the south from the Tarkhankut cape (165.0 thousand ind/m^2) at the depth of 49 m. The meiobenthos abundance on the studied water area varies mainly in the limits of 300.0–450.0 thousand ind/m^2.

Biomass distribution is of another picture. Its highest magnitudes were registered in the southwestern part of the region II at 142 m depth (4.6 g/m^2) and in Sevastopol water area at 44 m depth (3.9 g/m^2). At 142 m depth 65.2% of biomass is made by hydroid polyps (3.0 g/m^2), 24.0% – by foraminifera. At 44 m depth 77.2% of biomass are made by polychaetes, 18.2% of biomass – by harpacticoids.

Biomass values (2.7–3.1 g/m^2) are comparable in the regions III A (Yalta, 47 m), IV (Karadag, 23–49 m) and southwestern part of the region II at 260 m depth. The main share of meiobenthos biomass in area off Yalta (34.3–80.0%) and off Karadag (63.0–68.0%) is made by polychaetes at 23–

49 m depths; foraminifera made 23.8–24.6%. In the region III B (Alushta) equal contribution to biomass (28.1%) is given by polychaetes and juvenile specimens of bivalve mollusks; harpacticoids give 17.9%.

The least indices of biomass (0.4–0.8 g/m^2) were revealed near cape Tarkhankut, at the near-shore station (27 m depth), in water area off Yalta and off Karadag at 160 m depth. Near the extremity of cape Tarkhankut at 23 m depth, 59.2% of meiobenthos summary biomass were given by polychaetes, 24.6% – by harpacticioids, 12% – by nematodes. To the south of Tarkhankut at 49 m depth 55.5% of biomass is given by harpacticoids, 18.9% – by polychaetes. At 160 m depth (Karadag) acaria (57.5%) and foraminifera (22.5%) make the basis of meiobenthos summary biomass.

While character of the macrobenthos abundance changes in regions is determined by dominance of several species of polychaetes, bivalve mollusks and ascidia (Revkov et al., 2002), changes of meiobenthos abundance are conditioned, mainly, by nematodes mass development. Thus dependence of quantitative development of meiobenthos with macrobenthos ones – is not revealed.

Meiobenthos in the locations of methane gas seeps. The cold seep sources are widely spread in the seas and oceans. At present over 3000 plots of methane gas bubble streams from bottom are known within the range of depths 35–1800 m of the Black Sea. (Egorov et al., 2003). In the Black Sea methane gas seeps were registered for the first time in April 1989 (Polikarpov et al., 1989). From the moment of revealing the fields of methane gas seeps in the Black Sea a great interest occurred to the problems of ecology, conditioned by the methane seeps influence. Complex of interdisciplinary (physical, chemical, oceanographic, biogeochemical and microbiological) researches of methane gas seeps in Crimean region was carried out later.

At present there is lack of information concerning bottom fauna composition in areas with oozing of methane gas in the Black Sea (Luth U, Luth C, 1998; Sergeeva, 2003b). Therefore benthos study in the locations of the methane jet oozing from a bottom is one of actual tasks of marine ecology.

Comparative studies of the Black Sea benthic communities structure in the regions with methane income and without it has been conducted for the first time in 1993–1994 by Luth U, Luth C, (1998). It appeared, that the biomass and biological activity of the bottom communities had close magnitudes in the regions compared. Predominance in the seep region macrobenthos composition of animals, achieving larger sizes is considered by the authors to be an index of greater biocenosis stability.

Our investigations in the regions with methane gas seeping have shown that meiobenthos is characterized by great diversity. It includes 12 main groups of benthic animals, such as: Porifera, Coelenterata, Foraminifera, Nematoda, Kinorhyncha, Oligohaeta, Polychaeta, Turbellaria, Bivalvia, Harpacticoida, Ostracoda, Acarina. Only four groups of meiobenthos such as Nematoda, Turbellaria, Ostracoda and Acarina were registered at the depths of 230-235 m.

The maximal abundance value of meiobenthos reach up to 520.8 th.ind/m^2 at the depth of 70 m. At the depths of 170–235 m the abundance (3.1–11.4 th. ind/m^2) and diversity (4-5 main taxons) of meiofauna are sharply decreased. (Figure 11, 12). Nematoda is the basic (by density) group of meiobenthos in all range of depths. Harpacticoida is the next numerous after Nematoda group of a meiobenthos in a range of depths 70-120 m; Coelenterata and Polychaeta – at the depths of 130-155 m (Figure 13).**We mark, that a specific community of the benthic organisms, adapted to the limited oxygen concentration is formed at the range of depth of 130–150 m. The soft-shelled foraminiferes, large quantity of nematodes species, specific polychaetes (Chrisopetalidae, Nerillidae, Protodrilidae), hydroid polyps and turbellaria are the main components of this community. Representatives of Nematoda dominate in the given community.**

Coelentherata have maximal density 11.3–15.1 thousand ind/m^2 at the depths range of 134–151. Considerable number of coelenterata was registered also in the macrofauna composition at the given polygon at the depths range of 110–150 m (Luth U., Luth C, 1998).

Fauna of foraminifera is represented here by five species, widespread in the Black Sea, but with small population density in the areas studied. They are *Ammonia compacta* (Hofker), *Eggerella scabra* (William), *Lagena* sp. 1, *L.lateralis* (Cushman), *L.perlucida* (Mont). The main share of Foraminifera density at the depths range 70–175 m is made by Allogromiina. Among the last ones *Psammophaga simplora* dominates in a number.

Polychaeta, *Vigtorniella zaikai* Kiss., *Protodilus* sp. 1, *Nerilla* sp. 1, are registered only in the given region with methane gas seeps (Zaitsev, Mamaev, 1997; Kisseleva, 1998; Zaika et al., 1999).

Fauna of Nematoda is represented by 143 species of all known orders within investigated range of depths (Figure 14). The total number of species is 69 and 63–33 at the depth of 150 m and of 120–140 m correspondingly. Mainly taxonomical composition is like at the smaller shelf depths in the Black Sea, and this fact testifies to Nematoda euribiontness. However some representatives are found out only in gas seeping areas to the southwest from the Crimean peninsular at the depths, where minimal oxygen concentrations or its absence were registered. We assume, that there is a formation of specific meiofauna in conditions of methane gas seeping. Presence of 38 species and 6 genera of Nematoda, registered only in the given conditions and earlier unknown for the Black Sea points on this fact.

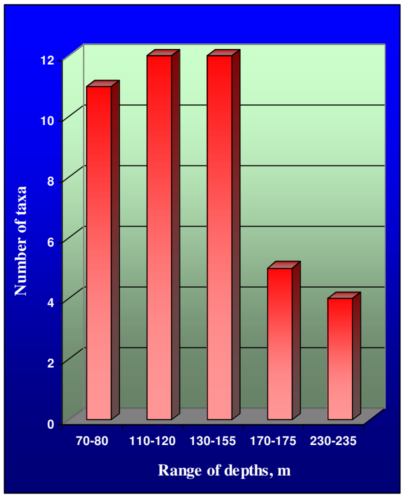

Figure 11. Number of main taxa within locations of methane gas seeping

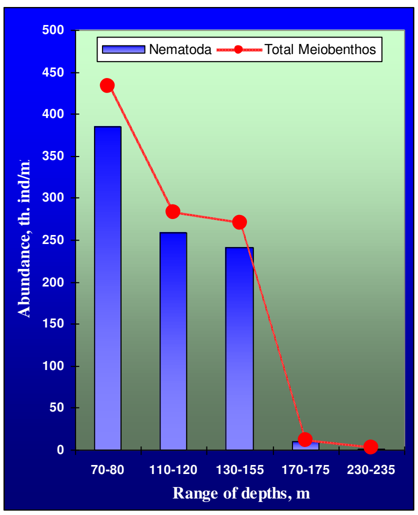

Figure 12. The abundance values of meiobenthos (th. ind/m^2) within locations of methane gas seeping

Meiobenthos abundance in the seeps region of the transition zone of the Black Sea, which is characterized by the oxygen deficit or its absence, achieve significant values, similar and even exceeding the such in the upper and average littoral zones. Mass development of the meiofauna in the suboxygen zone in the seeps region is stipulated by the favorable trophic conditions in the bottom sediments and absence of food competitors. Trophic meiofauna needs are determined by the degree of accumulation and transformation in the bottom sediments the arrived from the water column organic matter and development of the huge microflora biomass. Yu.I. Sorokin (1982) mentions maximum of the microflora total abundance and the most activity of its definite groups in the bottom sediments of the Black Sea slopes at the depths of 100–300 m. The total number of bacteria here, by his calculations, makes 1–5 billion per 1 g of wet sediments. These values of the bacteria total abundance and biomass are close to the analogical indices in the upper layer of the bottom sediments in the mezotrophic and even eutotrophic water areas.

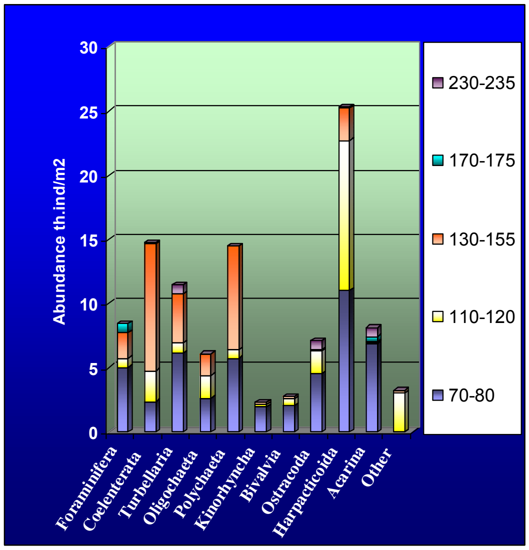

Figure 13. Abundance (th. ind/m^2 and %) of main meiobenthos taxons in area of methane-gas seepings (without consideration of Nematoda).

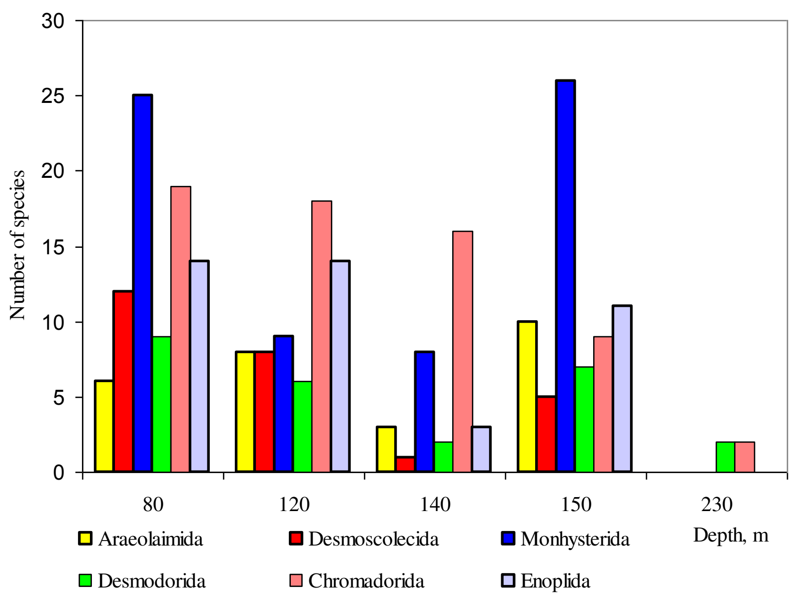

Figure 14. Species representativeness of Nematoda orders across depth within location of methane gas seeping (south-western Crimea (fromby Sergeeva, 2003b)

CONCLUSION

1. The results of fulfilled analysis concerning the bottom macrofauna composition testify the absence of species number reduction at the Crimean coastal zone of the Black Sea over the 2nd half of the XX century. From 62 to 100% of all species, known for Black Sea water areas with normal marine salinity (18), were registered near the Crimean coast in different taxons. The total number of the macrozoobenthos species exceeds 560. On the background of the common relative stability of the benthic fauna species diversity the structural-functional transformations in benthos have been registered. Fauna of mollusks is most diverse (81 species) at the range of depth 11–20 m, of crustaseans and annelids (74 and 80 species correspondingly) – 0–10 m, of "Miscellaneous" (35) – 21–30 m depths.

2. During the period from 1930-s to 1990-s filter-feeding mollusks became the most pronounced "evolutioning" organism, determining the quantitative changes of the bottom fauna over the soft-bottoms of the southwestern Crimea. Extraordinary increase in abundance and biomass of *Chamelea gallina* (within range from 1 to 25 m depths) and decrease of these parameters for *Spisula subtruncata* (1-12 m), *Paphia aurea* (13-50 m), *Mytilus galloprovincialis* (26-50 m) and *Modiolula phaseolina* (51-110 m) have been registered. It shifts maximum of absolute production to lesser depths: from the zone of mussel silts (26–50 m) to silty-sand (13–25 m).

3. Meiobenthos (eumeiobenthos) of the Crimean shelf includes 522 species totally and varying in different regions of Crimean shelf. The last fact is caused not only by specificity of areas itself, but a various extent of meiobenthos investigation level in each of regions.

4. Meiofauna is various and numerous in the locations of methane stream oozing on Crimean shelf. Density of the meiobenthos might achieve and even exceed the respective values have registered for the upper and middle layers of sublittoral. Formation of specific meiofauna composition in regiong with methane gas seeping is marked. Detection of 38 species and 6 genera of Nematoda, which are registered only in the given conditions testify to this.

5. At present, general species diversity condition of the benthic fauna at the Crimean shores can be admitted as satisfactory.

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