Трудове на Института по океанология
Т о м 3. В а р н а, 2 0 0 1
Българска академия на науките

МОРСКА БИОЛОГИЯ

Recent ecosystem trends along the Bulgarian Black Sea coast

Kamen Prodanov, Snejana Moncheva, Asen Konsulov, Ludmila Kamburska, Tsonka Konsulova, Kristina Dencheva
Institute of Oceanology, Bulgarian Academy of Sciences, Varna

1. Introduction

According to some authors (M e e, 1992; V i n o g r a d o v, T u m a n t s e v a, 1993) there is a growing scientific evidence to suggest that the Black Sea and Azov Sea have suffered catastrophic ecological damage as a result of pollution from land-based sources. The intensive phytoplankton blooms particularly on the shallow North-Western part of the Black Sea are already permanent (M o n c h e v a, 1991) and the major part of the basin is critically eutrophic (M e e, 1992). Higher trophic level also is due to the explosive blooms of zooplanktonic *Noctiluca scintillans* in the 70s, mass development of jellyfish *Aurelia aurita* in the mid-80s (Z a i t z e v, A l e x a n d r o v, 1997) and the total dominance of the opportunistic ctenophore *Mnemiopsis leidyi* in the end of 80s (V i n o g r a d o v, T u m a n t s e v a, 1993). Eutrophication has dramatically modified the base of the marine food chain. On the other hand overexploatation of the native fish species could be the reason for introducing of the new exotic species. By feeding on or overrunning dominant native species, exotic one probably have an opportunity to trigger changes in the species mix within the ecosystem. For example the development of *M. leidyi* which consumes the great quantity of zooplankton including fish larva and eggs lead to drastically low zooplankton biomass and probably is one of the reason for low fish stocks (G ü c ü, 1997; P r o d a n o v et al., 1997) *M. leidyi* could be a key factor in the development of plankton fauna, because the overfishing in the Black Sea lead to decrease of domestic zooplankton consumers. Nevertheless this effect in combination with other environmental conditions is of greater significance for zooplankton development and composition. More over in October 1997, in the vicinity of Shabla (North Bulgarian Black Sea part), a new species belonging to class Ctenophora and identified as *Beroe ovata* was located (K o n s u l o v, 1997; K o n s u l o v, K a m b u r s k a, 1998). The recent trends of the marine organisms' state along the Bulgarian Black Sea coast are as follows:

2. Phytoplankton

The inventory of the long-term series of phytoplankton record reveal dramatic perturbations in both community structure and abundance during the period 1955-1997 related to the interaction of natural (cyclic variability of sun activity and hydrometeorological conditions, hydrological fronts and gradients) and anthropogenic factors especially the evolution of eutrophication (P e t r o v a-K a r a d j o v a, A p o s t o l o v, 1988; P e t r o v a-K a r a d j o v a, 1992; M o n c h e v a, 1991a,b,d, M o n c h e v a, K r a s t e v, 1997; A u b r e y et al., 1995; B o d e a n u et al., 1998, M o n c h e v a et al.; 1998, S h t e r e v a et al., 1998).

As apparent from Fig.1 the increase in the quantitative parameters of phytoplankton is substantial during the period of intensive eutrophication (80ies) and despite the decrease during the 90ies (about 1.5 times) it is still high as compared to the period of 60ies.

The alterations of phytoplankton dynamics are even better expressed in Varna Bay data set when compared the 80ies and 90ies (Fig. 2). During the 90ies the variability is much lower in all seasons and the ecosystem is shifted to a more harmonized seasonal dynamic. The most substantial decrease is recorded in the average summer biomass – from 41.766 mg/l (1983-1988) it decreases to about 30 mg/l (during 1991-1992) and to about 20 mg/l in 1993-1996, coinciding well with the established decreasing trends of the nutrients during summer (S h t e r e v a et al., 1998).

The average annual surface biomass for the coastal zone during the period 1995-1996 was 9.948 mg/l, which although high by itself as compared to that of the period 1983-1986 (25.710 mg/l) is about two times lower. An apparent shift is also evident in the pattern of its seasonal distribution. While in 1983-1988 the spring-summer biomass accounted for more than 60 % of the annual average, the summer one to about 30 % and more, during the recent period it drops about twice, with an apparent increase in the winter-autumn biomass.

The analysis of the Bacillariophyta: Dinophyta biomass ratio during spring-summer reveals a dramatic inversion since 1970 (P e t r o v a-K a r a d j o v a, 1984). Despite the oscillations in the interannual variability this inversion trend is stable during the 80ies. The average share of Bacillariophyta in the total biomass up to 1970 is 86 % (versus 14 % of Dinophyta), decreasing during 1970/90 to 42 % (M o n c h e v a, K r a s t e v, 1997). The comparison of the taxonomic structure (by biomass) of phytoplankton communities in seasonal terms during the 90ies to that of the 80ies in contrast reveal a decrease in the dominance of Dinophyta species, on the account of an increase in the share of diatoms more apparent in winter and autumn and an increase in the taxonomic diversity (summer and autumn) (Fig.3 a, b.), which most likely could be attributed to the shift of the nutrient ratios (N:P, Si:N and Si:P) during the two

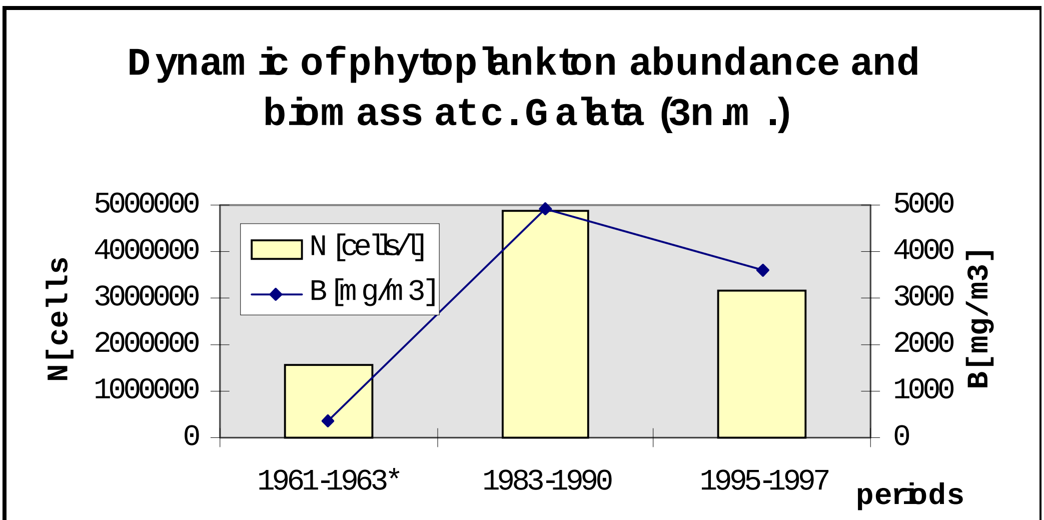

Fig. 1. Phytoplankton abundance and biomass during different time-intervals (*data of Petrova, 1965)

periods (S h t e r e v a et al., 1998).

Another typical feature of the long-term variability of the plankton communities is the alterations in the dominant species composition building the seasonal phytoplankton assemblages and causing phytoplankton blooms. In general the comparison of the species by their specific growth rates dominating the phytoplankton communities before 1970, suggests a shift towards species of higher colonisation rate during the 80ies and again to larger species (Rhizosolenia calcar-avis, Cerataulina pelagica, Dytilum brightwellii etc) during the recent period, which is quite in conformity with the general trends established in the mean size of the phytoplankton assemblages and their biomass attained (M o n c h e v a, K r a s t e v, 1997).

For the whole period of consideration (1955-1996) the total number of blooming phytoplankters is 36, ranked by taxonomic groups in the following order: Bacillariophyta -21, Dinophyta - 9, Euglenophyta - 3, Chrysophyta - 3 (K o n s u l o v et al., 1998). Although the dinoflagellate red-tide species are more than twice less numerous than the diatoms, they represent the main concern for the ecosystem especially during summer (M o n c h e v a et al., 1995).

The long-term trends in the evolution of phytoplankton blooms in terms of species involved taxonomic diversity, frequency and timing reveal significant differences. Based on the level of eutrophication and phytoplankton respond, basically the microalgal blooms, especially in the northwestern and western Black Sea part, the period from 1954 to 1996 could be subdivided in the following periods. The first one - up to 1970 is considered a background in ecological sense, relatively pristine period, with almost no signs of anthropogenic eutrophication. As apparent Table 1. both the number of blooms and the species involved is low and they are rather an expression of the natural variability of Black Sea ecosystem.

The second period - 1971-1992 - regarded as a period of intensive anthropogenic pressure is characterized by a substantial biological noise in the ecosystem - dramatic alterations in the biological communities best expressed by the red-tide events, which have apparently being expanding in number, frequency, number of species responsible, intensity and ecosystem deterioration effects (M o n c h e v a et al., 1995; M o n c h e v a, K r a s t e v, 1997). The number of species recorded in blooming concentrations increases more than twice and the diversity of species in terms of taxonomic groups representatives even more with a shift

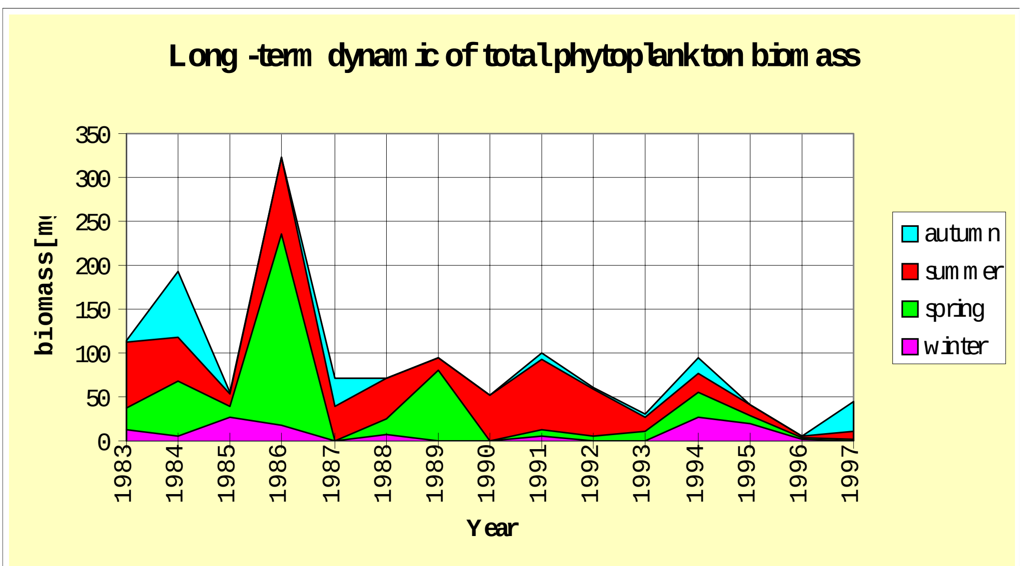

Fig. 2. Seasonal variability of surface phytoplankton biomass in Varna Bay (1983-1997)

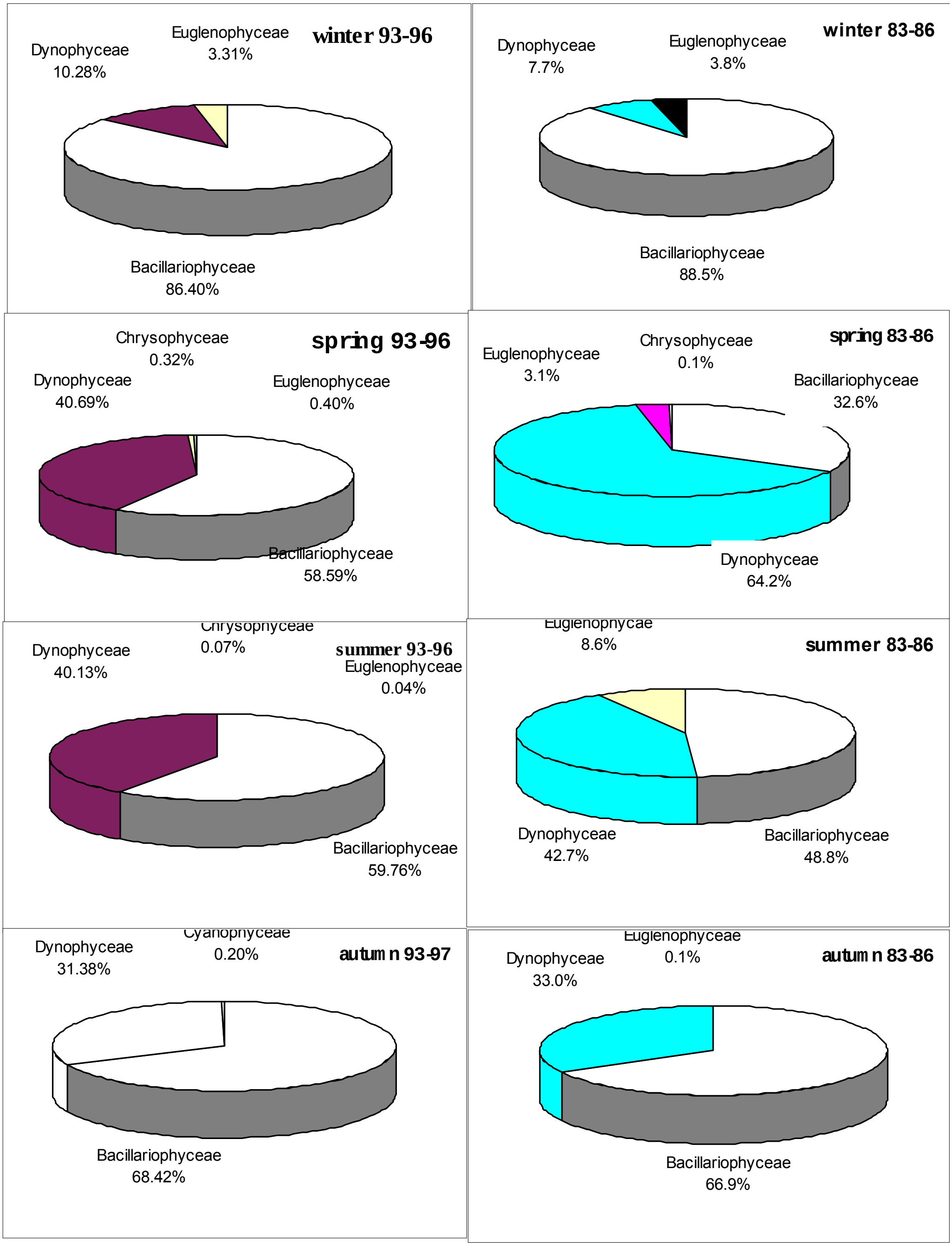

Fig. 3. Seasonal taxonomic structure of phytoplankton communities in the close coastal area (by biomass) : A - 93 -97, B - 83 –86

Table 1. Quantification of blooms and species involved in Varna Bay and the coastal zone at Cape Galata (3 miles) during different time intervals in the period 1954 - 1996

Period	**1954-1970***		**1971-1992****		**1993-1996**	
Taxonomic group	A	B	A	B	A	B
Bacillariophyta	6	18	11	69	14	17
Dinophyta	1	4	6	36	5	6
Chrysophyta	1	2	2	11	2	2
Euglenophyta	0	0	1	9	2	2
Total	8	24	20	125	23	27
late spring-summer blooms		5		62		8
in % from the total		20		50		30

* - the relatively pristine period of the ecosystem, A - number of species
** - the period of intensive eutrophication B - number of blooms

to non-diatom species (opportunistic e.g. dinoflagellates and exotic species, such as Gessnerium mochimaense, Phaeocystis pouchettii etc.). The eutrophication has dramatically modified the base of the marine food chain encouraging the development of almost monospecific dense blooms of nanoplankton, some of which cited as toxic. The shift in the biodiversity of the blooming species towards phytoplankters producing high DMSP which might affect the climate at least on local bases is also noteworthy (M o n c h e v a, K r a s t e v, 1997).

During the current period (1993-1996) parallel to the increase in the total species diversity the trend of increasing the diversity of the red-tide species is maintained for all basic taxonomic groups. The list of the red-tide species is entered by species typical for the area, but never recorded in a bloom density before (*Dytilum brightwellii, Leptocylindrus minimus, Apedinella spinifera*), or phytoplankters found for the first time off the Bulgarian Black sea shelf (*Schroderella delicatula (Detonula pimula, Oxyphysis oxytoxoides*) or species not reported for the Black sea basin (*Gessnerium mochimaensis (Alexandrium monilatum), Gymnodinium uberimum ,Phaeocystis pouchettii).* Another peculiarity of the recent period is the decrease of both monospecific blooms and the bloom cell density of the phytoplankters. During 1980-1990 7 cases when the species reach concentration about 50 mil.cells/l and more (the highest attained by P. minimum - 481 mil. cells/l) were recorded while during the period 1991 - 1997 they are reduced to 2 only. The general trend is a decrease of the maximum concentrations attained in the 80ies in comparison to the 90ies (more evident for Dinophyta - Fig. 4) some phytoplankters like *S. costatum, C. pelagica, Ch. socialis, P. minimum* continue to produce high densities but at much lower frequency.

As we compare periods of different duration, the total number of blooms is not indicative enough. When the number of the summer blooms is compared in percent of the total number of blooms the results reveal a dramatic increase during the period of intensive eutrophication (50 %) and a decrease during the recent period (30 %), more close to that of the period 1954 - 1970 (Table 1). As apparent from Fig. 5 in seasonal terms the reduction of summer bloom density is more than two fold on the account of an increase in winter-spring and autumn.

As the summer blooms in Black sea are considered “abnormal”, and “induced” by the eutrophication, than their reduction should suggest a positive sign of restoring the natural succession and seasonal dynamic of phytoplankton communities. When the spring-summer blooms are related to the variability of zooplankton total biomass, N. scintilans cell density, t^o and sun activity, the results provide evidence that these factors could play an important role together with the nutrients shifts (B o d e a n u et al., 1998).

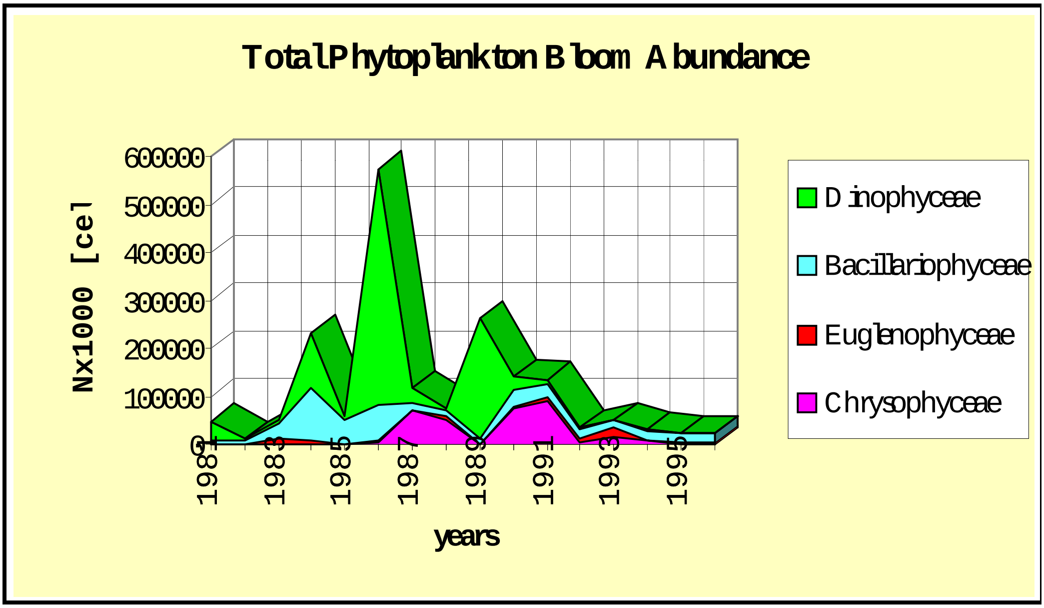

Fig. 4. Dynamic of the total bloom abundance [Nx1000 cells/l] in Varna Bay.

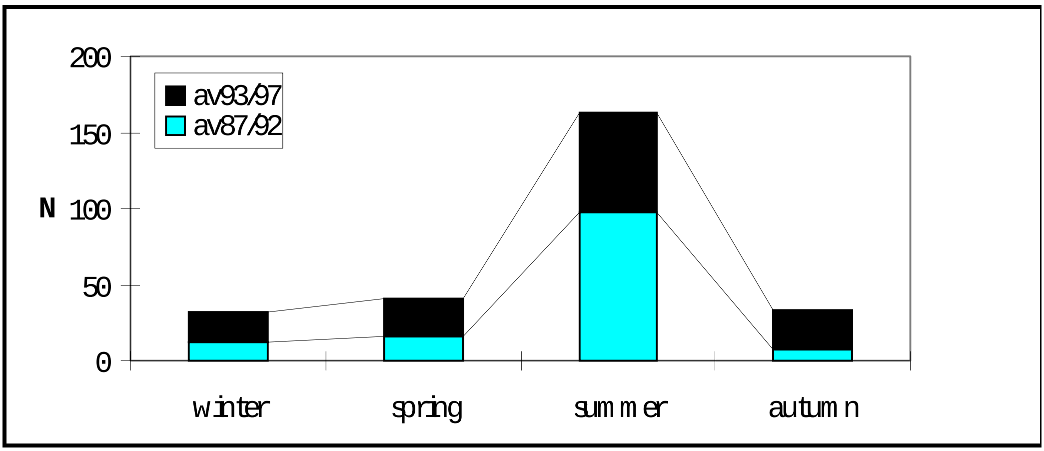

Fig. 5. Seasonal variability of the average bloom cell density in Varna Bay (Velikova et al., 1998)

•Apriori the recent period is assumed as a period of a decrease in the level of anthropogenic eutrophication mainly due to the collapsing economy and related cutback in the industrial and agricultural production, resulting in the reduction of the land-based nutrients load to the basin. The results reported by S h t e r e v a et al., (1998) provide some evidence of improvement of the chemical parameters of the environment. The same stands for the Danube river input as the main source of anthropogenic eutrophication for the north-western and the western Black sea area (C o c i a s u, P o p a, 1998). The results suggest that the recent changes of phytoplankton communities are as follows:

•the decrease of total phytoplankton biomass, especially during summe

•the decrease of phytoplankton monospecific blooms and the maximum blooming concentrations attained

The shift of the seasonal succession towards more close to the natural for Black Sea ecosystem annual cycle, could be considered more a sign of recovery as a response to the signs of improvement of the environmental parameters of the coastal zone, which is a good indication to show that the further decrease of the nutrients load to the basin is a pertinent step towards the improvement of the Black sea coastal ecosystem.

The main uncertainties are still the maintained capacity of the ecosystem to produce high biomasses (by phytoplankton biomass and chl. a the area is ranked eutrophicated), the concerted changes of the other environmental factors, the similar changes reported for different regions of the World Ocean, suggesting a possible global climatic signal of influence too.

3. Zooplankton

Important factors for zooplankton alteration are human impact, climate and the internal balance of the ecosystem. Consuming the primary productions and being the food resource for higher trophic level (planktivorous fish) zooplankton plays a significant role in food webs. Only few plankton species dominate in highly productive area as a Black Sea and play a key role for determining the structure of the pelagic food ability.

The analysis of the long term dynamic of summer zooplankton biomass without *N. scintillans* shows that in 1972 the biomass is highest for the period 1967-1997 (Fig. 6). It is due to the high biomass of *Copepoda* and *Cladocera* species. Until 1972 mass development of *Jellyfish* is absent and it is the begging of eutrophication in the Black Sea. The qualitative composition and quantitative structure have changed after mass development of *Aurelia aurita* (Z a i t z e v, A l e x a n d r o v, 1997), *N. scintillans* (K o n s u l o v, 1984) and the influence of *M. leidyi* (V i n o g r a d o v, S h u s h k i n a, S a p o z h n i k o v, 1992). Critically low zooplankton biomass off the Bulgarian Black Sea coast is registered in 1983 (K o n s u l o v, K a m b u r s k a, 1997) when the heavily fishing efforts were registered (P r o d a n o v et al., 1997) and 1988. *M. leidyi* had reached remarkable biomass figures by the summer of 1988, in some areas greater than all other zooplankton combined. The biomass and numbers of *M. leidyi* peaked in 1988-1989 and in 1991-1992 the numbers had decreased in the whole Black Sea (V i n o g r a d o v, T u m a n t s e v a, 1993).

According to P r o d a n o v et al. (1997) the dramatic decline in the anchovy stock in 1990-1991 is observed. An increasing trend of fodder summer zooplankton biomass is noticed after 1991. This fact together with the low number of *M. leidyi* and the reduced fishing mortality could be the reasons for the positive trends toward increase of anchovy biomass. Also the hydrology in August 1995 is different in comparison to previous years. 1995 winter is anomalous warm (I v a n o v, B e s i k t e p e, O s z o y, 1997). Surface temperature inshore is 25.20 °C. The pattern of fodder zooplankton in June, 1997 shows that the increasing trend is continued (Fig. 7).

In 1992 the density of phytoplankton blooms inshore is lower than in previous years (M o n c h e v a, K r a s t e v, 1997). Also the taxonomic structure is altered. This could be related to zooplankton structural variability and the increasing grazing press, although mesozooplankton grazing on phytoplankton does not define the total level of biological productivity, but possibly influences on size and taxonomic structure of phytoplankton community (M i k a e l y a n, 1997).

An alteration in *Copepoda* structure is noticed during the whole period. Thus for the period 1970-1988 the average density of *Oithona minuta* (Copepoda) in front of the Bulgarian Black Sea coast is 435 ind.m^{-3}, while between 1989-1995 the quantity is much lower-95 ind.m^{-3} (Fig. 8. The same refers to *Centropages kroyeri* (Copepoda) which is observed the period 1970-1988 with density 98 ind.m^{-3}, for the period 1989-1995 is 22 ind.m^{-3} (K o n s u l o v et al., 1996).

The average density of *O. minuta* and *C. kroyeri* for the period 1970-1988 is about 4,5 times more compare to 1989-1995. The reason probably is the influence of *Mnemiopsis leidyi* on the Copepoda structure. Recent data from 1996-1997 shows that *O. minuta* is reached to 64 ind.m^{-3} along the

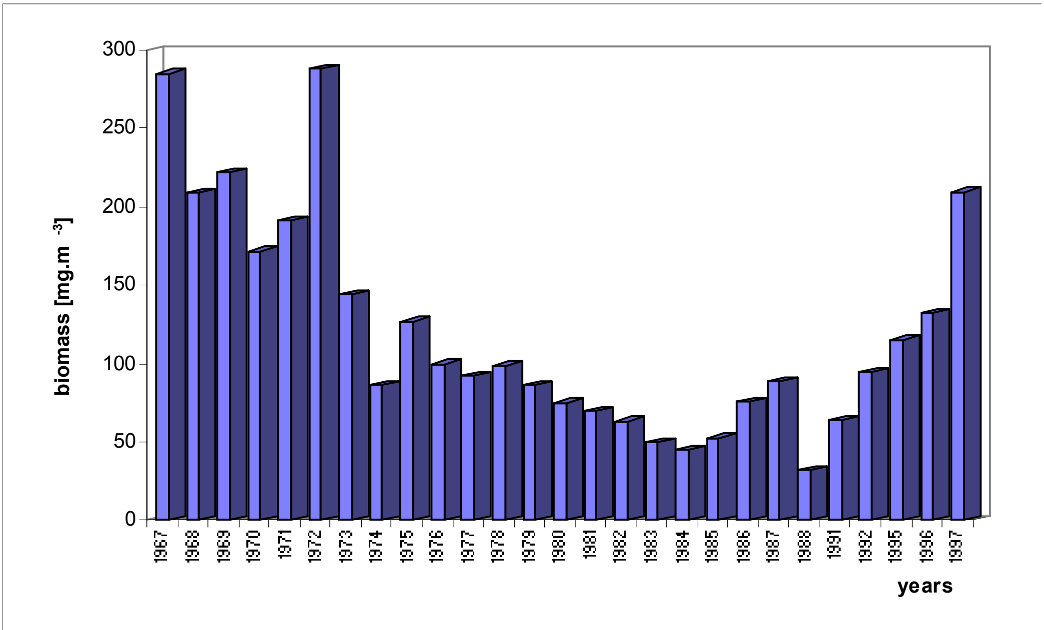

Fig. 6. Long-term dynamic of fodder summer zooplankton biomass (without Noctiluca scintillans) off the Bulgarian Black Sea coast in the period 1967-1997.

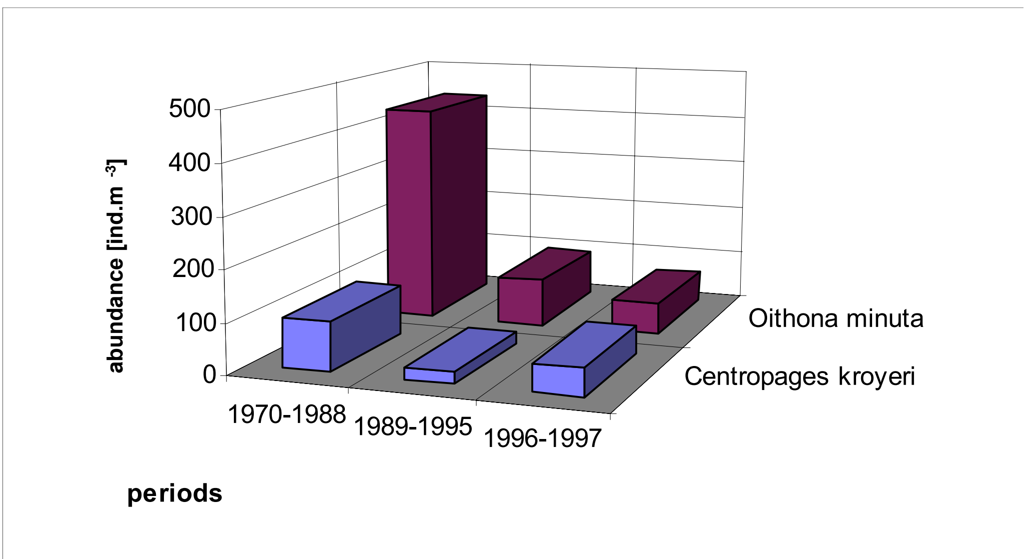

Fig. 7. The average density of Oithona minuta and Centropages kroyeri for the three periods in front of the Bulgarian Black Sea coast.

Bulgarian Black Sea coast, while *C. kroyeri* is registered only in Burgas Bay with average abundance 54 ind.m^{-3}.

Changes in the biomass of the other *Copepoda* species have also been registered. The structure and composition of *Copepoda* is significantly altered during the period 1991-1995. The biomass of *Calanus euxinus* which is a cold water species in the inshore area in 1991 and 1992 is very low while the biomass of this species is always higher in offshore area. In 1992 it is about 2 times higher. The highest biomass has been registered in summer 1995. Inshore it is about 8 times higher than in 1992 and about 3 times higher offshore. In fact the biomass of *C. euxinus* marked an increasing trend (K o n s u l o v, K a m b u r s k a, 1997b).

Acartia clausi is the constant component in plankton fauna off the Bulgarian coast. This resistant to eutrophication species has frequency of distribution 100 % during the investigated period inshore. Offshore the frequency of distribution ranges from 73 % to 98 %. *A. clausi* is the dominant *Copepods* species in the inshore areas. It shares considerable part in the zooplankton biomass. In July 1992 the average biomass of this species is about 2.5 times higher than in September 1991. In August 1995 the biomass of *A. clausi* in both areas is lower than in 1992, but it is higher than in 1991. The trend shows an increasing of its biomass but decreasing as a percent in the total zooplankton biomass. Despite variability of the biomass, *A. clausi* is the dominant species in the formation of the total inshore zooplankton biomass. An increasing of Copepoda is observed also in 1997. Food resources for fishes in 1993-1997 are much more than 1988-1992.

The progressive increases of *Noctiluca scintillans* which appears as eutrophicant in the coastal zone and as de-eutrophicant and trophic potential in the open-sea is probably due to the high degree of primary and secondary eutrophication of the Bulgarian Black Sea area. This species consumes great quantities of pelagic and benthos larval forms and therefore afflict population structures and accordingly biological diversity. At the end of its life cycle it settles to the bottom. Thus becoming incorporated into the destruction processes at the bottom , after having taken part in the pelagic eutrophication and the changes in the physics-chemical properties of the water mass, as well as in the processes of translation and transformation of organic matter both in the shelf and an open sea.

For the period 1971-1987 the average density of *N. scintillans* is 2 times less compare to the period 1991-1995. In 1996-1997 this species is less compare to the period 1991-1995 (Table 2).

The number of *N. scintillans* has always been higher in the coastal region where zooplankton biomass higher values were also registered. This type of correlation has been exhibited during the entire period (1971-1995) - after K o n s u l o v, K a m b u r s k a (1997).

In results of the high eutrophication and antropic impact during the last twenty years (V i n o g r a d o v, S h u s h k i n a,

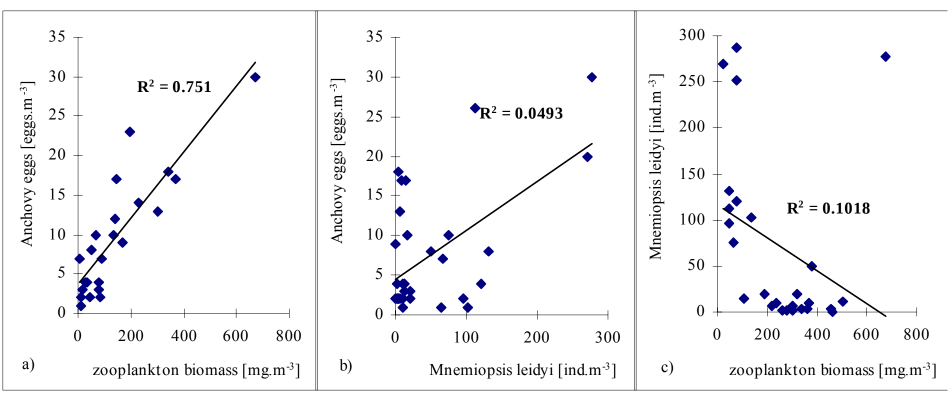

Fig. 8. Correlation between Anchovy eggs, fodder zooplankton biomass and abundance of Mnemiopsis leidyi, August, 1995

Table 2. The average abundance of N. scintillans [ind.m-3] for the three periods off the Bulgarian Black Sea coast.

Period	Ind.m^{-3}
1971-1987	8 884
1991-1995	17 861
1996-1997	12 648

S a p o z h n i k o v, 1992) the Black Sea becomes favourable for the development of many invaders (Z a i t z e v, M a m a e v, 1997). The stable settlement of some of them leads directly to drastic changes in the plankton fauna diversity and its quantitative development (K o n s u l o v, K a m b u r s k a, 1997a) and indirectly influences the other parts in the food chain. This concerns in great extent the representatives of Ctenophora which are important carnivores in planktonic food chains (F r a s e r, 1962).

Particularly important during the ten last years for plankton cenosis stability has been the development of the Ctenophora-*Mnemiopsis leidyi*. This species has been introduced into the Black Sea at the beginning of the 1980 s from the North-western Atlantic coast (V i n o g r a d o v et al., 1989)

This plankter is predatory and consumes mezoplankton species of all groups and when feeding of zoological origin is insufficient in consumes phytoplankton, Infusoria species and detritus. *M. leidyi* also feeds on fish spawning and larvae which affects fish population regarding their abundance. The reason for the intrusion of this species in the Black Sea and its mass development in coastal waters is most probably the high rate of eutrophication, vital for its vegetation and rapid reproduction. Feeding on zooplankton, *M. leidyi* has a negative effect on its biological diversity.

Its food spectrum is known. It is established that *M. leidyi* has preferences for *Copepoda* and *Cladocera* as a more caloric food. Also it is known that the young individuals prefer *Copepoda* species and the adult *Cladocera* because of energetic needs of species. July-September is a period of reproduction activity (H o r o s h i l o v, 1993). One of the peculiarities is the ability to increase population biomass dramatically in a very short time. The size or development stage of ctenophore maturity could not be specified definitely as in the case of *Copepods*. A few eggs might be produced by ctenophores even in immature stages. According to some authors (M a l a s h e v, A r c h i p o v, 1992) the new generation of *M. leidyi* can develop into the larvae themselves.

M. leidyi is competing with fish for fodder zooplankton. *Ichtyoplankon* numerical abundance of *Anchovy eggs* in September 1991 and July 1992 off the Bulgarian Black Sea is very low. In August 1995 they are registered at 28 stations off the Bulgarian Black Sea coast. Maximum number of *Anchovy eggs* is 30 eggs.m^{-3} at 3 miles at Cape Galata (K o n s u l o v, K a m b u r s k a, 1997b). While in June 1997 the maximum number is 8 eggs.m^{-3}. The catches of *Anchovy* began to increase since 1992, while the catches of other species remained at low level. The recent increase in *Anchovy* abundance may be related its short life cycle and points to the possibility of covering of its stocks (S h i g a n o v a, 1997). There is a very high positive correlation (R=0.87) between fodder zooplankton biomass and number of *Anchovy eggs* (Fig. 8a)

Correlation coefficients between *Anchovy eggs* and abundance of *M. leidyi* (Fig. 8b) and correlation between abundance of *M. leidyi* and fodder zooplankton biomass (Fig. 8c) are lower. The low coefficient of correlation between *M. leidyi* and fodder zooplankton biomass could be related to their active migrations.

The average abundance of *M. leidyi* in the last years shows slightly increasing in front of the Bulgarian Black Sea area after its decreasing in 1992-1993 (Fig. 9). In coastal zone (10 miles offshore) the average number of *M.leidyi* is 38 ind.m^{-3}, and it is over 100 ind.m^{-3} in the coastal zone south of cape Kaliakra (120 ind.m^{-3}), in front of Kamchia river mouth (125 ind.m^{-3}) and in Bourgas Bay (135 ind.m^{-3}). Increased zooplankton biomass after 1992 is followed by the increase of *M. leidyi*. In 1997 the average abundance of *M. leidyi* in the Bulgarian Black Sea part in coastal zone and offshore region are 40 and 16 ind.m^{-3} respectively (Fig. 9).

In spite of great oscillation of *Mnemiopsis leidyi* biomass and numerical abundance this species is already a constant component of the Black Sea ecosystem. It could be a key factor in the development of plankton fauna. Its alterations are followed by significant changes in zooplankton composition. Nevertheless this effect in combination with other environmental conditions is of greater significance for zooplankton development and composition. More over in October 1997, in the vicinity of Shabla, a new species belonging to class Ctenophora and identified as *Beroe ovata* was located (K o n s u l o v, 1997; K o n s u l o v and K a m b u r s ka, 1998).

It is well known that the species of the genus *Beroe* have previously been considered to be exclusively carnivorous on other ctenophores (S w a n b e r g, 1970). N e l s o n (1925) reports that *Beroe ovata* feeds only on *M. leidyi* species. Our investigation reveal that from 2 to 7 individuals of *M. leidyi* with size 10-20 mm have been discovered in the guts of the live samples of *Beroe ovata.* Pieces of the prey with size 10-40 mm were also found as well as fragments of its sexual arches (K o n s u l o v, 1997).

The reason for appearance of the new Ctenophora is the high *M. leidyi* abundance which *Beroe ovata* uses to feed on. This give us enough grounds to assume that the invasion of the new for the Black Sea Ctenophora is trophically determined (K o n s u l o v, K a m b u r s k a, 1998).

Eliminating one of the reason for a high level of eutrophication-*Mnemiopsis leidyi*, the new ctenophora species *Beroe ovata* could reach a high biomass. This can lead to a new disturbance in the Black Sea ecosystem as mass development of ctenophores drastically modifies the structure of an otherwise stable community (B i s h o p, 1967). The introducing of the new Ctenophora species confirms that the Black Sea biodiversity is not a constant. Also the Black Sea ecosystem is dynamically developed. It depends on the complex of biotic and abiotic factors as a man-made impacts, global climatic changes, changes in the ecology of the species and etc. (K o n s u l o v, K a m b u r s k a, 1997b).

4. Macrophytobenthos

In comparison to the Russian (75 %),the Rumanian (40.7 %) and the Turkish coast (24 %) the Bulgarian Black sea coast ranks second regarding to the macrophlora species diversity (K a l u g i n a-G u t n i k, 1975).

During the last years the coastal phytocenoses were influenced by the deteriorated environmental conditions and their alterations led to structural changes in

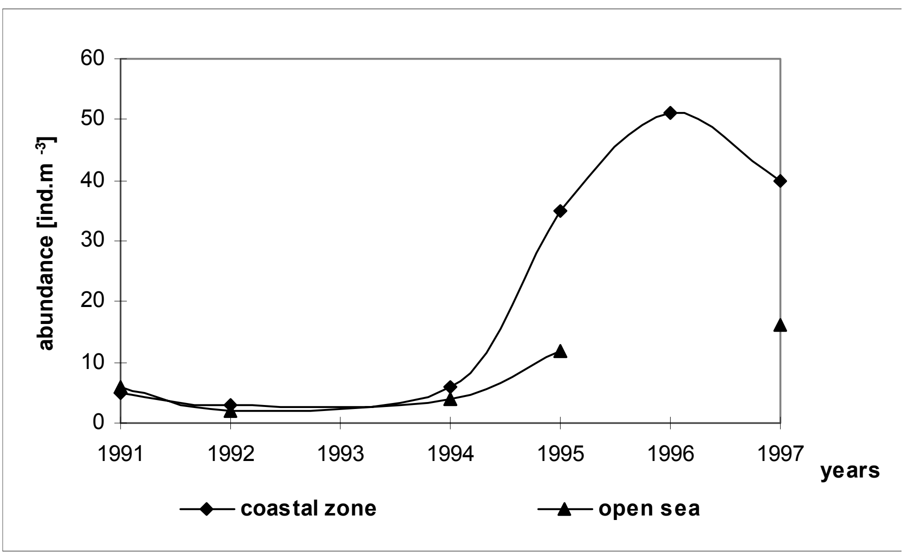

Fig. 9. Average abundance of Mnemiopsis leidyi in the Bulgarian Black Sea area for the period 1991 - 1997 (spring-summer).

the qualitative composition. A comparative analysis shows that the macrophyte species registered in previous investigations in Varna region (D i m i t r o v a, 1978) are significantly more than these established at present. (D e n c h e v a, 1994;1996) - Table 3.

The disappearance of many *Phaeophyta* and *Rhodophyta* species and the decrease of oligosaprobic representatives has been observed in 1994 in the same region - Table 4.

Typical oligosaprobic species such as *Ralfsia verrucosa, Stilophora tuberculosa, Nereia filiformis, Dictiota dichotoma, Cladostephus verticillatus* are not registered at present in this region.(D e n c h e v a, 1996; K o n s u l o v et al.,1998).

Dominant in biomass are the polysaprobic and mezosaprobic species of macrophytes such as *Ceramium rubrum, Callitamnium corumbosum, Enteromorpha intestinalis, Ulva rigida, Bryopsis plumosa*. Similar floristic structure is established for the northwestern part of the Russian Black sea shore and according to the prognosis that has been made, the quantitative parameters of the same taxons enhance with the eutrophication level increase (M i n i c h e v a, 1992).

In result of the increased level of eutrophication, reduction of stocks and biomass of biologic valuable species was registered.

The stocks of Cystoseira barbata, estimated for the previous period (1966-1969) along the Bulgarian Black sea coast, were 331 311 tones wet weight (P e t r o v a, 1975).

In the years of the investigation (1966 - 1969), the average biomass of Cystoseira barbata along the Bulgarian Black sea coast was 8.1kg.m-^{2} at 0-2m depth and 1.2kg.m-^{2} at 10 m derth. In Varna bay, the biomass of this species was estimated to be 7,0 kg.m-^{2} for the period 1966 - 1969 and 1.9 kg.m-^{2} for 1997 up to maximal depth-2m. These data indicate reduction of this species biomass in Varna bay in horizontal (more than three fold) and vertical direction.

In Varna bay for 1997, 26 species were registered. Twelve taxons belonged to Chlorophyta type, 10-Rhodophyta and 4-Phaeophyta. The value of the floristic index (5.5), indicated high level of eutrophication. The value of phytocoenoses surface index (63.6), characterised the bay as highly eutrophicated (D e n c h e v a, unpublished data).

5. Zoobenthos

The first significant negative changes on benthic macrofauna were recorded about 30 years ago. (K o n s u l o v et al., 1996). They were caused by the immigration of new species tolerant to the deteriorated environment conditions - industrial pollution and increased eutrophication level. Two categories of out acclimatized species were distinguished: far-sea species and

Mediterranean immigrants (C v e t k o v et al., 1986). The far-sea species are

Table 3. Changes in the qualitative structure of macrophytobenthos in Varna region during different periods of investigations.

Order	1904 - 1939	1969 - 1972	1994
Chlorophyta	10	9	13
Phaeophyta	11	6	4
Rhodophyta	37	23	14
total	58	38	31

Table 4. Changes of saprobic structure of macrohpytes in Varna region during different periods of investigations

Saprobic species	1904 - 1939	1969 - 1972	1994
Oligosaprobic	37	23	7
Mesosaprobic	16	11	18
Polysaprobic	5	4	6

presented chiefly by benthic animals brought by ships. These species, arranged chronically (according to their appearance in the Bulgarian Black Sea waters) are as follows:

Balanus improvisus	Darwin
Balanus eburneus	Gould
Blackfordia virginica	Meyre
Bougainvillia megas	Kinne
Mercierella enigmatica	Fauvel
Rhitropanopeus harrisii	Gould
Rapana thomasiana	Crosse
Mya arenaria	Linnaeus
Cunearca cornea	Reeve

The newcomers *Cunearca cornea* and *Mya arenaria* mussels formed new zoocenoses with maximum biomass in some ecologically threatened zones - Bourgas Bay and Varna Bay. *C. cornea* is especially abundant with maximum biomass – 1176.4 g/m^2 in Bourgas Bay (M a r i n o v, 1990).

The most important changes were caused by the invasion of the predatory snail *Rapana thomasiana* resulted in more than 10 fold reduction in 1976 in comparison to 1967 of the natural stock of the most powerful biofiltrator in Black Sea mussel *Mytilus galloprovincialis* (M a r i n o v, 1978).

The commercial stock biomass (individuals with fresh weight above 60 g) and total allowable catch of *R.thomasiana* during 1993 were about 7482.6 and 3217.5 t respectively (P r o d a n o v et al., 1995).

Recently illegal trawling is carried out in some regions along the coastal zone, which causes serious devastation of the benthic cenoses. A "cold mines" positioning method is accepted as the most efficient manner for preventing the coastal ecosystems against the destruction.

One of the most significant negative phenomena in the shelf ecosystem during 80's was hypoxia. Extensive oxygen depleted zone accompanied by mass mortality especially of *Crustacea* species have been registered in summer postblooming periods since 1986 in the coastal sublittoral. More detailed investigations carried out in 1989-1990 in Varna Lake-Varna Bay region considered as an ecologically threatened area show that the only two years without hypoxia formation (1988 and 1990) were an exception for the seven years period (1986-1992).Among free-living *Decapoda* mortality of *Macropipus holsatus* and *Upogebia pusilla* was registered in 1989 - 1990 (K o n s u l o v a et al., 1991). Unlike past years in 1991-1992 the macrofauna evidently affected by the hypoxia were mainly bottom living fish species - *Gobiidae* and *Mullidae* (16-36 dead fishes per sq.m).

During the last five years a process of

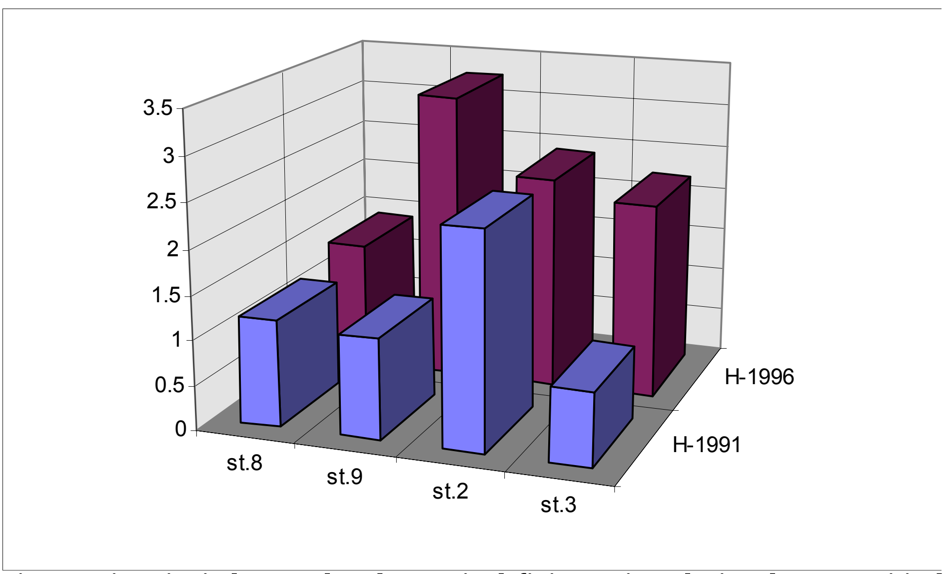

Fig. 10. Diversity index H value changes in definite stations during the most critical summer season (August) in 1996 in comparison with 1991 in the Varna Bay

some restriction of the eutrophic water discharge in Varna Bay is observed due to the chemical industry recession and the implementing of more efficient pollution control - Figure 10.

A respective response of the macrozoobenthic fauna state is assumed during 1993-1997 period generally expressed in the following consequences:

-The absence of hypoxia and mass mortality of benthic organisms during five following years 1993-1997 is registered.

The percentage share of Crustacea species increase from 3.0% in 1993 to 19.0% in 1996.

-The average species diversity in some stations during 1996 slightly increase in comparison with 1991 (K o n s u l o v a, T o d o r o v a, unpublished data).

In conclusion it must be underlined the following:

- The changes registered in the marine biotic complex during the period of intensive eutrophication (1970-1992) show a tendency to biodiversity decrease, and dramatic alterations in the pelagic and benthic cenoses.

- The quantity of some more sensitive to organic pollution species is reduced to the point of full extinction parallel with quality prevalence of more tolerant to deteriorated

Table 4. Mean annual catches (in tons) of the commercial valuable fish species in the Black Sea during the period 1967 - 1994

Species	**Mean catch**	**%**	**Type of population**	**Wintering ground and main fishing area**
Anchovy	237966.3	56.57	migratory	Anatolian coast of Turkey and in front of Georgian&Caucasian coasts
Mediterranean horse mackerel	46089.8	10.6	migratory	Anatolian coast of Turkey, Georgia and Southern Crimea
Sprat	36963.0	8.79	local	shelf zone of all Black Sea countries
Whiting	17172.2	4.08	local	Anatolian coast of Turkey and shelf zone of all other Black Sea countries
Bonito	9517.4	2.26	migratory	Sea of Marmara ,Anatolian coast of Turkey and Bulgarian coast
Blue fish	7121.7	1.69	migratory	Sea of Marmara and Anatolian coast of Turkey
Spiny dogfish	4057.1	0.69	migratory	shelf zone of all Black Sea countries
Chup mackerel	3396.8	0.81	migratory	closely to Bosphorus
Turbot	2427.7	0.58	local	shelf zone of all Black Sea countries
Shad	1931.7	0.46	migratory	large rivers and the southern part of the Sea
Atlantic mackerel	247.1	0.06	migratory	Sea of Marmara and Anatolian coast of Turkey
Total	**366890.8**	**87.22**		
Others	53751.8	12.78		
Grand total	**420642.6**	**100.00**		

Table 5. Total fish catches (in tons) in the Black Sea during 1967 - 1996

Years	Bulgaria	Romania	former USSR	Turkey	Total
1967	4411.4	4708.0	57800.0	147022.2	213941.6
1968	3612.4	4586.0	60500.0	82245.2	150943.6
1969	3750.9	3120.0	66600.0	105472.0	178942.9
1970	3113.0	5126.0	75700.0	141019.3	224958.3
1971	3655.2	5915.0	72900.0	120301.6	202771.8
1972	3950.3	7772.0	93700.0	134600.0	240022.3
1973	5018.5	6289.0	150000.0	118100.0	279407.5
1974	7474.5	5570.0	135700.0	94900.0	243644.5
1975	8623.3	6316.0	132700.0	87900.0	235539.3
1976	9940.3	7746.0	272600.0	108600.0	398886.6
1977	10172.2	6142.0	189100.0	118800.0	324214.2
1978	12017.0	7114.0	175200.0	178700.0	373031.0
1979	15105.1	7621.0	200500.0	289400.0	512626.1
1980	17859.3	10292.0	250600.0	335800.0	614551.3
1981	19786.3	9997.0	241100.0	363200.0	634083.3
1982	17271.4	10374.0	267400.0	397900.0	692945.4
1983	13516.0	13105.0	245000.0	436400.0	708021.0
1984	15404.9	13894.0	285300.0	441600.0	756198.9
1985	16699.9	14268.0	161400.0	451700.0	644067.9
1986	12763.9	15834.0	248900.0	438900.0	716397.9
1987	12006.7	14016.0	138000.0	470800.0	634822.7
1988	8153.7	13962.0	295000.0	480400.0	797515.7
1989	8601.8	6251.0	159500.0	264200.0	446173.8
1990	2898.1	1218.0	87100.0	199830.0	296079.1
1991	2397.0*	3735.0	30400.0**	182656.0	219188.0
1992	3651.0*	3907.0	29700.0**	231715.0	268973.0
1993	4226.0*	3064.0	30000.0**	302939.0	340229.0
1994	11722.0*	3170.0	30000.0**	358018.0	402910.0
1995	7659.0*	2787.0	4314.4***	442059.0	456819.4
1996			4251.3***	347613.0	
mean	9217.9	7682.6	149371.4	253289.9	419561.8
%	2.20	1.83	35.60	60.37	100.00

•- expert assessments; ** - UGNIRO data; *** - total Russian and Georgian catches

environment conditions marine flora and fauna representatives, including far-sea immigrant species.

- The intensive uncontrollable exploitation of new for Bulgarian Black Sea area commercial mollusca species for export purposes causes devastation of the bottom ecosystem and sharply decrease of its natural stock.

- During the recent 3-4 years a positive trend in development of the communities is observed, most likely due to the economic restriction of industrial and agricultural input

6. Fishes

Black Sea fishery is based on a little bit more than 33 species but only 4 species provide 80.40 % of total catch (included the invertebrates) - Table 4. It can be seen from the pointed table that the most important for commercial fishery is anchovy. Its catches represent at the average 56.57 % from the mean total catch in the Black Sea during the period 1967-1994. The next species that is very important for the Black Sea fishery is horse mackerel. Its catches represent at the average 10.60 % from the mean total catch. The third one is sprat. Its catches represent at the average 8.79% from the mean total catch. Bulgarian catches are presented on the ta.

REFERENCES

Aubrey, D., S. Moncheva, E. Demirov, V. Diaconu, A. Dimitrov, 1995. Environmental Changes in the Western Black Sea related to Anthropogenic and Natural Conditions (Liege Hydrophysical Symposium,1994), J.Mar.System,6

Bishop, J. W., 1967. Feeding rates of the Ctenophore Mnemiopsis leidyi. Chesapeake Sci, 8, 259 - 264.

Bodeanu, N, G. Ruta, L. Popa, 1998. Second International Black Sea Conference on Environment Protection Technologies For Coastal Waters (in press).

Cociasu, A., V. Diaconu, L. Popa, I. Nae, L. Dorogan, V. Malciu, 1998. The Nutrient Stock of the Romanian Shelf of the Black Sea during the Last Three Decades. NATO ASI Series, vol.27, pp.49 - 64.

Cvetkov, L., T. Marinov, 1986. Faunistic enrichment of the Black Sea and changes in its benthic ecosystems. Hydrobiology, 27: 3 - 21.

Dencheva, K., 1994. Macrophytes - bioindicators for Varna Bay ecological status. Mar.School National session, 24 - 25 February, Varna, vol. 3., 226 - 233.

Dencheva, K., 1996. Gradients of eutrophication, established in relation with changes of macrophytocoenoses structure along to the Bulgarian Black Sea coast. Mar.School National session vol.3.

Dimitrova, S.,1978. Marine algae along the Bulgarian Black Sea Coast. PhD.Leningrad, pp. 192.

Fraser, H.F., 1962. The rople of Ctenophores and salps in zooplankton production and standing crop. Rapp. P-v. Reun. Cons. perm. int. Explor. Mer, 153, 121-123.

Gücü, A.C., 1997. Role of fishing in the Black Sea ecosystem. NATO ASI Series, 2/27, 149 - 162.

Ivanov, L., S. Besiktepe, E. Oszoy, 1997. The Black Sea Cold Intermediate Layer. NATO ASI Series, 2/27, 253 - 264.

Horoshilov, V., 1993. Seasonal Dinamycs of the Black Sea Population of Ctenophore Mnemiopsis Leidyi. Oceanology, 33, 4, 558 - 562

Konsulov, A., Tz. Konsulova, K. Prodanov, S. Moncheva, K. Dencheva, A. Velikov, L. Kamburska, 1996. State of the art and tendencies for changes in the Black Sea biodiversity in front of the Bulgarian Black Sea coast. NATO, ARW (in print).

Konsulov, A., L. Kamburska. 1997. Sensitivity to Anthropogenic Factors of the Plankton Fauna Adjeicent to the Bulgarian Coast of the Black Sea. In Sensitivity to Change: Black Sea, Baltic Sea and North Sea. NATO ASI Series: 2. Environment - vol.27, 95 - 104. Kluwer Academic Publishers.

Konsulov, A., L. Kamburska, 1997. Black Sea Zooplankton Structural Dynamic and Variability off the Bulgarian Black Sea Coast during 1991 - 1995. Kluwer Academic Publishers NATO ASI Series, “NATO TU-BLACK SEA PROJECT Ecosystem Modeling as a Management Tool for the Black Sea, Symposium on Scientific Results”, L. Ivanov & T. Oguz (eds.), v. 1, 281 - 293.

Konsulov, A., 1997. Trophic determination of Ctenophora’s new species invasion into the Black Sea. Comptes rendue de l’Academie Bulgare (in press). MS (Bulgarian Academy of Sciences, Institute of Oceanology, P.O.Box 152, 9000 Varna, Bulgaria).

Konsulov, A., L. Kamburska, 1998. Ecological Determination of the New Ctenophora-Beroe ovata Invasion in the Black Sea. Oceanology, (in press). MS (Bulgarian Academy of Sciences, Institute of Oceanology, P.O.Box 152, 9000 Varna, Bulgaria).

Konsulova, Ts., A. Konsulov, S. Moncheva, 1991. Ecological characteristic of Varna Bay (Black Sea) coastal ecosystem under summer “bloom”

conditions. Compt. Rend. Acad. Sci. Bulg., 44(8):113 - 117.
M a l a s h e v, V.I., A.G. A r c h i p o v, 1992. The Ctenophore Mnemiopsis leidyi in the West Part of the Black Sea.. Hydrobiology Jurn. IBSS, 28/1, 34 - 39
M a r i n o v, T., 1978. Qualitative composition and quantitative distribution of the meiobenthos of the Bulgarian Black Sea waters. Proc.Inst.Fish., 16:35 - 49.
M a r i n o v, T., 1990. The Zoobenthos from the Bulgarian Sector of the Black Sea. Sofia, Bulg.Acad.Sci. Publishing House.
M e e, L., 1992. The Black Sea in crisis: A need for concerted international action. AMBIO, vol. 21, №4, 278 - 286
M i k a e l y a n, A., 1997. Long Term Variability of Phytoplankton Communities in Open Black Sea in Relation to Environmental Changes. NATO ASI Series, 2/27, 105 - 116.
M i n i c h e v a, G., 1992. Alometric method for estimation of macrophytobenthic specific surface. Algology, vol.2,4,93 - 96.
M o n c h e v a, S., 1991. Eutrophication /phytoplankton blooms/ hypxia. International workshop on the Black Sea, Varna, 30.09-04.10. 1991.
M o n c h e v a, S., V. P e t r o v a-K a r a d j o v a, A. P a l a z o v, 1995. Harmful Algal Blooms along the Bulgarian Black Sea Coast and possible Paterns of Fish and Zoobenthic Mortalities. in Harmful marine algal blooms, P.Lassus, et all, eds. (Lavoisier publ.inc.),pp.193 - 298.
M o n c h e v a, S., V. D o n c h e v a, G. S h t e r e v a, K o n s u l o v A., K o z h u h a r o v E,1995. Phytoplankton in the Organic Particulate Matter Flux in Varna Bay (Black Sea). Rapp. Comm. int Mer.Medit.,34:123.
M o n c h e v a, S., A. K r a s t e v, 1997. Some Aspects of Phytoplankton Long Term Alterations off Bulgarian Black Sea Shelf. NATO ASI Series, 2,/27, 79 - 94.
M o n c h e v a, S., G. S h t e r e v a, A. K r a s t e v, N. B o d e a n u, A. K i d e y s, 1998. Vertical distribution of summer phytoplankton in the Western Black Sea during 1991 - 1995 with respect to some environmental factors. In: Ecosystem Modeling as a Management Tool for the Black Sea, Scientific Results, NATO ASI Series , Kluwer Academic Publ., L. Ivanov & T. Oguz [eds.] , vol.1, 327 - 349.
N e l s o n, T.C., 1925. On the occurrence and food habits of ctenophores in the New Jersey inland coastal waters. Biol. Bull, 48: 92 - 111.
P e t r o v a, V., 1965. On the peculiarities in the development of phytoplankton in Black Sea off Bulgarian shelf in 1961 - 1963. Proc. Res. Inst. Fish., Oceanogr., Varna, VI, 1965, 63 - 74.
P e t r o v a, V., 1975. Quantitative distribution and stocks of Cystoseira barbata along to the Bulgarian Black Sea coast. Proceedings of Fish Resourses, Varna, vol.14.
P e t r o v a-K a r a d z o v a, V., 1984. Changes in planktonic flora in Bulgarian Black Sea waters under the influence of eutrophication. Proc. Inst. Fish., 21:105 - 112.
P e t r o v a-K a r a d j o v a, V., E. Apostolov, 1988. Influence of Solar Activity upon the Diatoms of Black Sea Plancton. Rapp.Comm.Int.Mer.Medit, 31:2.
P e t r o v a-K a r a d j o v a, V., 1992. Solar Control upon the Phytoplankton in the Black Sea. Rapp.Comm.Int.Mer.Medit, 33.
P r o d a n o v, K., Ts. K o n s u l o v a, V. T o d o r o v a, 1995. Growth rate of Rapana thomasiana (Gastropoda) along the Bulgarian Black Sea coast. Rapp. et Proces-Verbaux des Reunions, 34.
P r o d a n o v, K., K. M i k h a i l o v, G. D a s k a l o v, K. M a x i m, E. O z d a m a r, A. C h a s h c h i n, A. A r k h i p o v, V. S h l y a k h o v, 1997. Final report of the project "Environmental management of fish resources in the Black Sea and their rational exploitation". General Fisheries Council for the Mediterranean, Studies and Reviews, No 68, 178pp.
P r o d a n o v, K., K. M i k h a i l o v, G. D a s k a l o v, A. C h a s h c h i n, A. A r k h i p o v, V. S h l y a k h o v, E. O z d a m a r, 1997. Environmental impact on fish resources in the Black Sea. "Sensitivity to Change: Black Sea, Baltic Sea and North Sea. NATO ASI Series, 2. Environment, 27: 163 - 181.
S h i g a n o v a, T.A., 1997. Mnemiopsis leidyi Abundance in the Black Sea and its Impact on the Pelagic Community. NATO ASI Series, 2,/27,117 - 129
S h t e r e v a, G., S. M o n c h e v a, V. D o n c h e v a, O. C h r i s t o v a, I. S h t e r e v, 1998. Changes in the Chemical Parameters in the Close Coastal Black Sea Area (Bulgarian part) as a Indication of the Ecological Characteristic of the Environment. IAWQ - Bulgarian National Committee, Second International

Black Sea Conference on Environment Protection Technologies For Coastal Areas, 51 - 60.

V e l i k o v a, V, S. M o n c h e v a, D. P e t r o v a, 1998. Phytiplankton Dynamics and Red tides (1987 - 1997) in the Bulgarian Black Sea. IAWQ - Bulgarian National Committee, Second International Black Sea Conference on Environment Protection Technologies For Coastal Areas, 41 - 50.

V i n o g r a d o v, M.E., E.A. S h u s h k i n a, V.V. S a p o z h n i k o v, 1992. The Black Sea Ecosystem. Institute of Oceanology, 5 - 109, Moskva

V i n o g r a d o v, M.E, A. S h u s h k i n a, E.I. M u s a e v a, P.Ju. S o r o k i n, 1989. Ctenophore Mnemiopsis leidyi (A. Agassiz) (Ctenophora: Lobata) - New settlers in the Black Sea. Oceanology, Institute of Oceanology, 29, 293 - 299, Moskva

V i n o g r a d o v, M.E, N. T u m a n t s e v a, 1993. Some results of investigations of the Black Sea biological communities. Black Sea research country profiles (level II), Intergovermental Oceanographic Commission, no. 3, UNESCO, Paris, pp. 80 - 91.

Z a i t z e v, Yu.P., B.G. A l e x a n d r o v, 1997. Recent Man-Made Changes in the Black Sea Ecosystem. NATO ASI Series, 2,/27, 25 - 31.

Z a i t z e v, Yu.P, V. M a m a e v, 1997. Biological diversity in the Black Sea.-A study of change and decline, GEF, Black Sea Environmental series, vol. 3.

Съвременни тенденции в черноморската екосистема пред българския бряг

Камен Б. Проданов, Снежана П. Мончева, Асен С. Консулов, Людмила Т. Камбурска, Цонка Х. Консулова, Кристина Х. Денчева

(Резюме)

На базата на многогодишни данни за качествения и количествения състав на фитопланктона, зоопланктона и зообентоса са проследени процесите, довели до съвременното състояние на черноморската екосистема пред българския бряг. Посочено е влиянието на промишления риболов върху настъпилите промени, включително и за навлизането в Черно море на два нови вида ктенофори – Mnemiopsis leidyi и Beroe ovata. В тази връзка е отбелязано, че след 1989 г. черноморската екосистема е под доминиращото влияние на Mnemiopsis leidyi, а след 1997 г. – на Beroe ovata, която е хищник спрямо M. leidyi. Подобряването на екологичната обстановка в Черно море се обуславя и от намалената концентрация на биогенни елементи вследствие на икономическия колапс на крайбрежните държави. В резултат на всичко това уловите на риба варират в широки граници в зависимост от състоянието на рибните запаси и прилаганото риболовно усилие през съответните години.

Постъпила на 14.06.2000 г.