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SIGNS OF MARINE ECOSYSTEM REHABILITATION ALONG THE ROMANIAN BLACK SEA LITTORAL IDENTIFIED BY ZOOPLANKTON INDICATOR AFTER 1994

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ABSTRACT

The paper presents the tendency registered in the status parameter evolution, both quantitative and qualitative, of the zooplankton community along the Romanian Black Sea littoral, between 1994-2003, and reveals new data obtained after 1999. The current values of some of these parameters, closer to the "ecological normality" status, which the zooplanktonic community exhibited before the eutrophication and penetration of ctenophore *Mnemiopsis leidyi*, represents authentic rehabilitation signs of zooplanktonic biocoenosis, and consequently of the whole Black Sea ecosystem. Among them, there are described: the return to the initial shape of the annual development curve of the zooplankton; the reappearance in the communities of some almost disappeared species after 1970; the reduction of opportunistic species quantities, indicators for polluted environment, such as *Acartia clausi* and *Pleopis polyphemoides*, in the favour of some sensitive species to eutrophication/pollution (almost disappeared from communities after 1970); modification of the trophic/nontrophic zooplankton ratios within the total zooplankton, and decreasing of *Noctiluca scintillans* quantities, and consequently of their dominance indices; mitigation of *Mnemiopsis* pressure and regain of *Pleurobrachia* place in the zooplanktonic communities.

KEY WORDS : total zooplankton, trophic zooplankton, nontrophic zooplankton, opportunistic species, state parameters, ecological rehabilitation

INTRODUCTION

More then 30 years, the Black Sea pelagial suffered the impact of many anthropogenic influences, among them the penetration of the voracious ctenophore *Mnemiopsis leidyi*, which stressed more and more the disequilibrium after 1989. The ecological control carried out after 1994 evinced slight but continuous signs of improvement of conservation status in all marine biotic components, under circumstances of continuous decreasing of essential nutrient concentrations. Frequency and magnitude of algal blooms diminished as well. On the other hand, the abundance of *Mnemiopsis* populations, more and more reduced, lead to a continuous mitigation of the pressure exerted through its populations grazing on the plankton (zoo- and ichtyoplankton).

As part of the plankton subsystem, representing the second consumer ring of the trophic chain in the pelagial, some events were identified at the zooplankton level too, both in its qualitative structure and quantitative development, which prove the tendency toward rehabilitation of the ecosystem.

MATERIAL AND METHODS

The results are based on the processing of more then 980 zooplanktonic samples, collected in a network settled on 5-8 profiles covering the whole marine Romanian littoral, in front of Danube Delta, the central littoral (East-Constantza profile), and in the southern littoral (Mangalia profile); the sampling was carried out seasonally between 1994 and 2003.

The zooplankton samples were drown using the *Djedy* zooplanktonic net, with an opening of 36 cm, and the mesh size of 200µ, through vertical hauling at standard depths: 10-0, 25-10 and 50-25 m. They were stored with formaldehyde 4%, and then processed in laboratory using the loupe binocular and inverted microscope to determine the taxonomic composition. The analysis of the samples, was made, for each station by counting individuals of each species on development stages to estimate the density as ind.m^{-3}; mean individual weights were used to estimate the biomasses as mg.m^{-3}.

RESULTS AND DISCUSSION

1. Quantitative development of zooplankton

Sign No. 1

One of the peculiarities of zooplankton evolution in the Romanian Black Sea waters, after 1989, was the modification of its seasonal dynamics. Until 1988, there were usually two seasons of maximum zooplanktonic biomass, one more reduced, during spring, and the second one, most important, during summer, when the peak of annual curve took place. After 1989, only the vernal one remained. In summer, the degradation of the zooplanktonic communities was more evident. The situation must be attributed, in the most extent, to the predatory ctenophore *Mnemiopsis leidyi*, which had its maximum development in the summer season (PETRAN and MOLDOVEANU, 1994/1995).

Beginning 1994, the decreasing tendency of the quantitative trophic zooplankton toward the summer ceased to be a feature of the seasonal characteristics. On the contrary, the long-term evolution curve (1994-2003) exhibited four peaks of fodder biomass - 1995, 1999, 2001 and 2003 - the first two being constituted exactly on the summer abundance (Fig. 1).

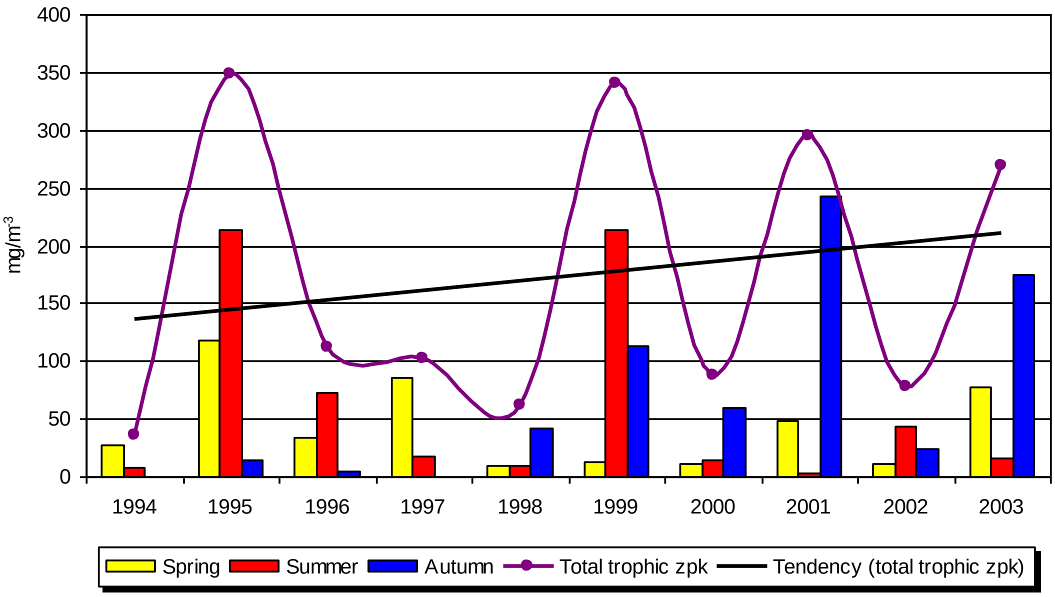

Fig.1 – Annual and seasonal variation of zooplanktonic trophic biomasses at the Romanian Black Sea littoral, between 1994-2003

The biomasses registered in **1995**, in the upper layers (10-0m depths) were well constituted even since February (10.5 $mg.m^{-3}$, Mangalia); in July, they reached values never attained in the previous period, and not found again after 1995 (maximum value 598.1 $mg.m^{-3}$, Mila 9).

Likewise, the fodder biomass values in **summer 1999**, in the whole Romanian marine area, oscillated among 23.769 $mg.m^{-3}$ (Sf. Gheorghe) and 364.776 $mg.m^{-3}$ (Portitza) (Fig. 1).

As for the maximum developments produced in 2001 and 2003, they were 1.2 and 1.3 respectively, times higher then in 1995, in both cases produced by the abundance registered in autumn. The summer values were the lowest during the year, both compared with spring and autumn.

In **summer 2001**, due to prevalence (98%) of non-trophic species *Noctiluca scintillans*, the 17.5 times decrease of trophic zooplankton was dramatic. Practically, trophic biomass values reached only 11.18 $mg.m^{-3}$ (Portitza), but were below 1 $mg.m^{-3}$ on extended areas.

The situation was a novelty as to the previous seven years, but almost similar to the 70's, when eutrophication syndrome started; it was a consequence of the ecological stress induced by planktonic algae excessive multiplication, which produced ample blooms in that summer.

Similarity with 70's and 80's decades concern only the quantitative structure. Qualitatively, the communities recorded in the summer 2001 were more diverse. 13 species were identified in the near shore waters at Mangalia, the highest diversity index for this month (3.70). But, a better state was surprised at Portitza, station 2, where 17 species were identified, among them 8 copepods (Table 1). Comparatively with the years of ecological instability, when the communities were often mono-specific, being constituted by the populations of the opportunist copepod *Acartia*, the situation proved the tendency toward normality status.

In **summer 2003**, the rich diversity of the communities was not accompanied by a quantitative one. The mean value of the fodder biomass produced in summer, of 16.7 $mg.m^{-3}$, was 4.6 times lower then in spring, and 2.6 then in summer 2002 (Fig. 1).

Similar situations, with summers poorer in fodder zooplankton were met in 1994 (8.7 mg. m^{-3}), and 1998 (9.4 mg. m^{-3}); however, these figures are far away from those obtained in the summers of the years marked by increased eutrophication, and especially after the penetration of *Mnemiopsis*. By now, 2001 remained singular, with a biomass of 2.8 $mg.m^{-3}$.

This situation is easily explainable through the high development of the populations of the three non-trophic genera - *Noctiluca, Pleurobrachia* and *Mnemiopsis*. So, if the development curve of the fodder zooplankton in 2003 evolved between 8.634 and 26.642 $mg.mg^{-3}$ (Sf. Gheorghe) (Fig. 2), the mean values of the non-trophic zooplankton exhibited the limits of 733.043 $mg.mg^{-3}$ (Mangalia) and 11,569.475 $mg.mg^{-3}$ (Sf. Gheorghe) (Fig. 3).

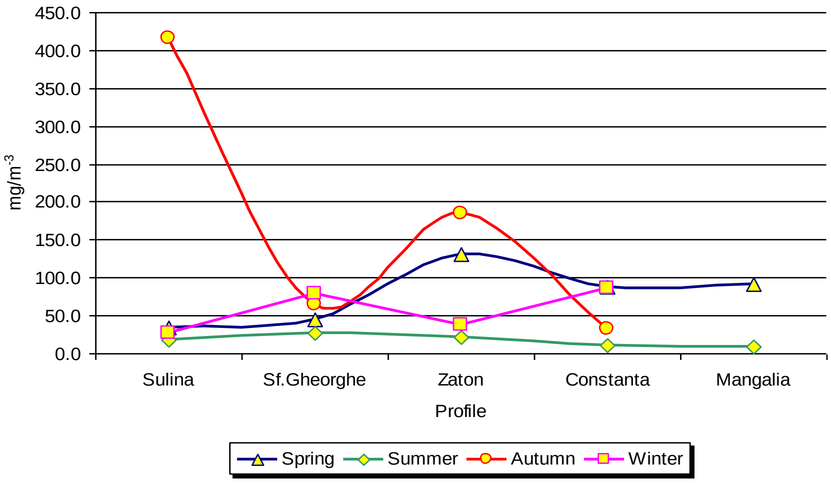

Fig. 2 – Seasonal evolution of the trophic zooplankton biomasses in the Romanian marine waters, in 2003

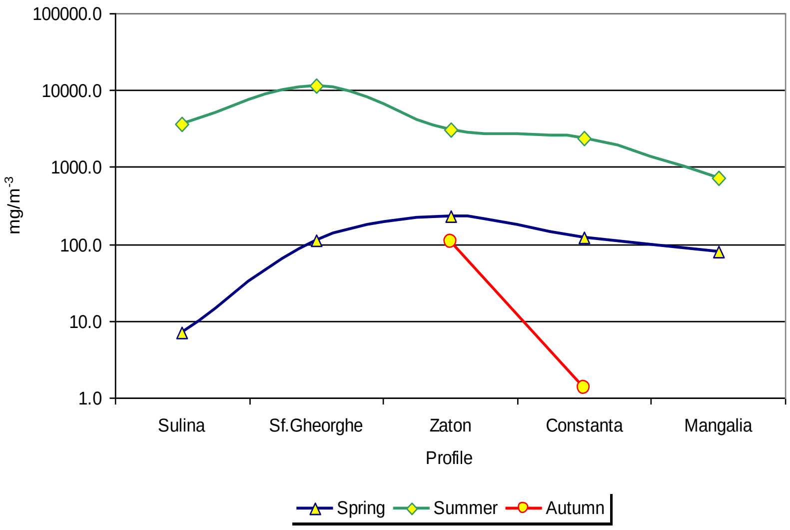

Fig. 3 - Seasonal evolution of the non-trophic zooplankton biomasses in the Romanian marine waters, in 2003

In the rest of years, in the summers, the fodder biomasses oscillated among tens mg.m^{-3}, meaning an enriched trophic base for planktivorous fish, comparatively with only 1-2 mg.m^{-3} registered in the summers 1989-1994. For instance, in July, 1996, in the entire marine sector from Sf.Gheorghe up to Constantza, the biomasses were higher then in spring (the mean seasonal value was of 72.7 mg.m^{-3}, comparatively with 33.6 mg.m^{-3}) (Fig. 1).

Concerning the first seasonal peak, settled in spring, both specific composition and quantitative level of the component groups proved a good trophic base, the richest zooplankton being registered in the spring season, many times in the 1994-2003 period. For instance, the mean density and biomass indices of the trophic zooplankton were of 3 to 4 times higher in 1995 comparatively with 1994; the values were increased also in 1996 and 1997 when, in the marine predanubian sector, the highest biomasses during the last 7-8 years were registered, concomitantly with substantial catches in stationary fishery.

In springs 2001 and 2003, the zooplanktonic communities were abundant, the annual development curve registering the first peak, as in the years before 1989. But, the ratio between the groups was changed, in the favour of non-trophic zooplankton, whose developments were higher then the trophic one.

In **spring 2001**, although a highest annual community of 16,297 ind.m^{-3} was identified in Midia profile, 78% was non-trophic, constituted by gelatinous species *Noctiluca scintillans*, *Mnemiopsis leidyi* and *Aurelia aurita*.

2. Qualitative structure of the zooplankton

Doubtless signs of ecosystem health were evinced especially as to the qualitative structure of the zooplanktonic biocoenose.

Sign No. 2

Under increased eutrophication installed after 1970, some zooplanktonic species disappeared, the populations of other species considerably declined, while other ones, whose developments were insignificant in the previous years, became prevailing both in densities and biomasses. The simplification of the qualitative structure and the reduction of specific diversity were more evident in the shallow waters, the most exposed to the anthropogenic pressure. In such areas, the zooplanktonic communities were sometimes constituted by 1 to 2 species, mostly opportunistic, detritifagous ones, able to consume the organic matter produced after huge phytoplanktonic blooms (e.g. ciliates, rotifers, *Noctiluca*) (PETRAN, 1997).

Among the species suffering considerable decline, even disappeared, were the copepods pertaining to Pontellidae Family (*Anomalocera pattersoni, Pontella mediterranea, Labidocera brunescens*), inhabiting the ultra superficial water biotop named hyponeuston, once forming large concentrations (PETRAN *et al.*, 1999). After 1980, only isolated individuals occurred, and then disappeared from samples. The precarious situation of their conservation status convinced the researchers from the coastal countries to include them in the Black Sea Red Book, within the IUCN category "endangered" (GEF, 1999).

The environmental monitoring performed after 1994 surprised the re-occurrence of these species, first as *nauplius* and juveniles, then as adults too. For instance, *A .pattersoni* occurred first time in September, 1998, in the upper layers of Mila 9, then in 2002 and 2003 they were present, together with *P. mediterranea* individuals, in July, September and October, in the waters from Constantza and Danube mouths (Table 1). Even if, quantitatively, the presence of these species is still insignificant, it became important for the diversity and reestablishment of the "good ecological" status.

Sign No. 3

Another structural modification in the zooplanktonic biocoenose, caused by eutrophication, was the reduction in densities of same sensitive holoplanktonic species, such as the copepod *Centropages ponticus* and the cladocer *Penilia avirostris*. In the summers between 1960 and 1967, the two species attained their highest densities and biomasses. For example, in 1967, the two species together with copepod *Anomalocera pattersoni* had produced the richest biomasses for that period - 225.28 mg.m^{-3} (PETRAN, 1997).

In summer 1975, the first overwhelming phytoplanktonic development of *Prorocentrum cordatum* took place. The zooplankters *Centropages ponticus* and *Penilia avirostris* achieved their last consistent development, then they gradually reduced the densities of populations, being substituted by two opportunistic species - copepod *Acartia clausi* and cladocer *Pleopis polyphemoides*. The populations of last two species became dominant in densities and biomasses, being in the same time indicators of high eutrophied environments (PETRAN, 1968).

For instance, in front of Constantza the copepod *C. ponticus* was to produce two high densities, in 1986 (455 ind.m^{-3}) and 1993 (228 ind.m^{-3}). Its appearance was sporadically up to 1999, a maximum value being attained in 2001 (124 ind.m^{-3}) (Fig. 4). Although the copepod fauna continued to be numerically and weightly dominated by the *Acartia* populations, the *Centropages* populations were more and more vigourous, with individuals in all development stages, even females bearing eggs. In some months and some marine spaces, *Centropages* became dominant in zooplanktonic communities.

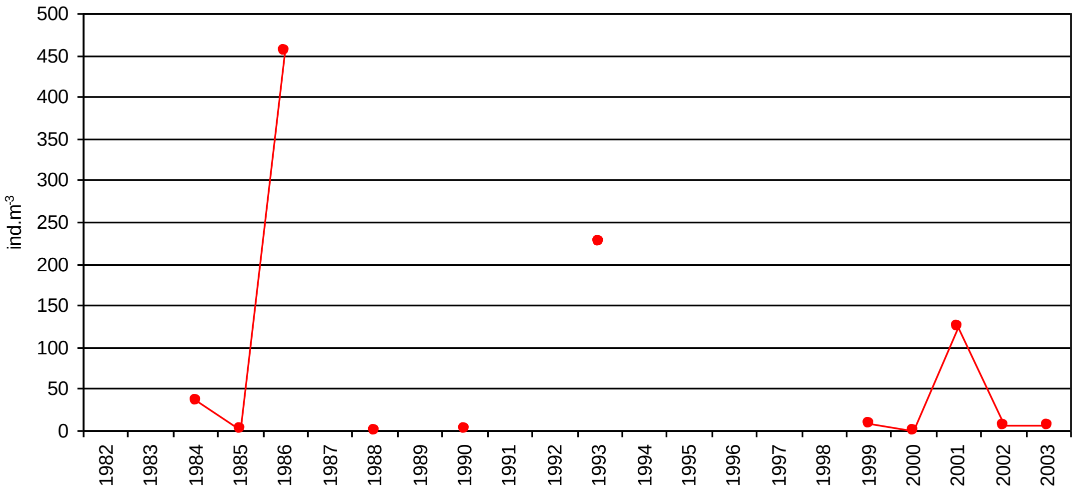

Fig.4 – Long-term evolution of the *Centropages ponticus* density, in front of Constantza, between 1982 and 2003

Moreover, in 2003, the individuals of *C. ponticus* were accompanied by the *C. spinosus* individuals, a little smaller, but very important as food for planktivorous fish. It can be ascertained that *Centropages* regains its place and role in the copepods fauna in the Romanian marine waters, after its "black" period, affected by the eutrophication/pollution syndrome.

Table 1

List of zooplanktonic organisms from the Black Sea Romanian waters between 1995 - 2003

No. crt.	Organisms	'95	'96	'97	'98	'99	'00	'01	'02	'03
0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	CYSTOFLAGELLATA									
1	*Noctiluca scintillans* (MACARTNEY) KOFOID & SWEZY,1925	+	+	+	+	+	+	+	+	+
	CILIATA									
2	*Tiarina fusus* HAMBURG et VON BUDDENBR.						+		+	+
3	*Strombidium sanerbreyae* KAHL.	+	+	+		+	+	+	+	+
	TINTINNOIDEA									
4	*Tintinnopsis campanula* EHR., 1840		+	+			+			

0	1	2	3	4	5	6	7	8	9	10
5	*T. meunieri* KOF. et CAMP., 1929			+	+	+			+	+
6	*T. lobiancoi* DADAY, 1886			+						
7	*T. parvula* JORGENSEN, 1912			+						
8	*T. tubulosa* LEVANDER, 1900			+		+				
9	*T. beroidea* ENTZ, 1884	+	+	+		+	+		+	+
10	*T. karajacensis* BRANDT, 1908			+						
11	*T. subacuta* JORGENSEN, 1899			+						
12	*T. cylindrica* DADAY, 1886			+	+	+			+	+
13	*T. davidovi* DADAY, 1886			+	+					
14	*Leprotintinnus pellucidus* (CLEVE, 1899)			+						
15	*Metacylis mediterranea* MERESCHK.,1881	+	+							
16	*Favella ehrenbergii (*CLAP.et LACHM.,1858)		+			+	+	+	+	
17	*Coxliella decipiens* JORG, 1924		+							
	COELENTERATA									
18	*Aurelia aurita* (L., 1758)	+	+		+	+	+	+	+	+
19	*Hydractinia carnea* (M.SARS)		+							
20	*Obelia sp.*							+		+
21	*Nausithoe sp.*							+		
22	*Podocoryne carnea*									+
23	*Coryne tubulosa*									+
24	*Clytia moniliformis*									+
25	*Campanula jonsthoni*	+								
	CTENOPHORA									
26	*Pleurobrachia rhodopis* CHUN, 1880	+				+	+	+	+	+
27	*Mnemiopsis leidyi* AGASSIZ, 1865	+	+	+	+	+	+	+	+	+
28	*Beroe ovata* BRUGUIERE, 1789			+	+	+	+	+	+	+
	ROTATORIA									
29	*Brachionus diversicornis* DADAY, 1883					+				
30	*B. calyciflorus* PALLAS, 1766			+			+		+	+
	Brachionus urceoralis	+								
31	*Brachionus* sp.				+	+	+			
32	*Keratella cochlearis* GOSSE, 1851		+	+	+	+	+			+
33	*K. quadrata* MULLER, 1786					+				+
34	*Notholca acuminata* EHRENBERG, 1832									+
35	*Colurella sp.*					+	+			
36	*Synchaeta littoralis* ROUSSELET, 1902		+	+		+	+	+	+	+
37	*S. curvata*		+							
38	*Asplanchna priodonta* GOSSE, 1850						+			+
39	Rotatoria varia			+		+	+			+

0	1	2	3	4	5	6	7	8	9	10
	POLYCHAETA									
40	Larvae	+	+	+		+	+	+	+	+
	PHORONIDAE									
41	Larvae	+					+	+	+	+
	BIVALVIA									
42	Larvae veligers		+	+		+	+	+	+	+
	GASTEROPODA									
43	Larvae veligers	+	+			+	+	+	+	+
	CLADOCERA									
44	*Penilia avirostris* DANA, 1849	+	+		+	+	+	+	+	+
45	*Daphnia longispina* O.F.MULLER, 1785			+			+		+	+
46	*Bosmina longirostris* O.F.MULLER, 1785			+			+			+
47	*Pleopis polyphemoides* LEUCKART,1859	+	+	+	+	+	+	+	+	+
48	*Podon leuckarti* (G.O. SARS, 1862)									+
49	*Evadne tergestina* (CLAUS, 1877)	+	+		+	+		+	+	+
50	*E. spinifera* P.E.MULLER, 1867	+	+				+	+	+	+
51	*E. nordmani* LOVEN, 1836	+				+		+		+
52	*Diaphanosoma sp.*	+								
53	*Chidorus* sp.						+			
54	*Podonevadne* sp.						+			
55	Cladocera varia						+			
	COPEPODA CALANIDA									
56	*Pontella mediterranea* CLAUS, 1863								+	+
57	*Anomalocera patersoni* TEMPL., 1837				+			+	+	+
58	*Calanus euxinus* CLAUS, 1863	+	+		+	+	+	+	+	+
59	*Centropages kröyeri* v.*pontica* KARAW.,1895		+		+	+	+	+	+	+
60	*Centropages spinosus* (KRICZ, 1873)					+	+	+	+	+
61	*Calanipeda aquae-dulcis* (KRICZAGIN,1873)			+		+	+	+		
62	*Paracalanus parvus* CLAUS, 1863	+	+	+	+	+	+	+	+	+
63	*Diaptomus gracilis* SARS, 1862			+		+	+			
64	*Pseudocalanus elongatus* BOECK, 1872	+	+	+	+	+	+	+	+	+
65	*Acartia clausi* GIESBRECHT, 1889	+	+	+	+	+	+	+	+	+
66	*Eurytemora affinis* (POPPE, 1880)	+		+	+	+	+	+	+	+
67	*Heterocope caspia* SARS, 1897					+				+
68	***Calanida varia***									+
69	*Harpacticida varia*									+
	COPEPODA CYCLOPOIDA									
70	*Oithona minuta* (syn.*nana*)(KRICZ, 1873)	+	+				+	+	+	+
71	*O. similis* CLAUS, 1863	+	+		+	+	+	+	+	+

0	1	2	3	4	5	6	7	8	9	10
72	*Cyclops vicinus* ULJAN, 1875	+	+	+		+				
73	*Cyclops strenuus* FISCH., 1851			+						
74	*Cyclops sp.*	+			+		+			
75	*Euryte longicauda* PHILIPPI, 1843			+						
76	Cyclopida varia	+		+		+	+	+	+	+
	CIRRIPEDIA									
77	*Balanus improvisus* DARWIN, 1854 (larve)	+	+	+	+	+	+	+	+	+
	MISIDACEAE									
78	*Mesopodopsis slabberi* SARS, 1877	+						+	+	+
	DECAPODA									
79	Larvae **CHAETOGNATA**	+	+			+	+	+	+	+
80	*Sagitta setosa* MULL., 1867	+	+		+	+	+	+	+	+
	APPENDICULARIA									
81	*Oikopleura dioica* HOLL.	+	+		+	+	+	+	+	+
	Total	**34**	**32**	**35**	**24**	**42**	**46**	**36**	**39**	**53**

As for the *Penilia avirostris* cladocer, after the very precarious status of its populations during the eutrophication period, and more deteriorated after the penetration of *Mnemiopsis*, it was more and more present in communities up to a maximum development attained in 2001, of 340 ind.m^{-3} (Fig. 5). The *Penilia* populations have accompanied *Pleopis* ones, claiming the first place in communities dominance.

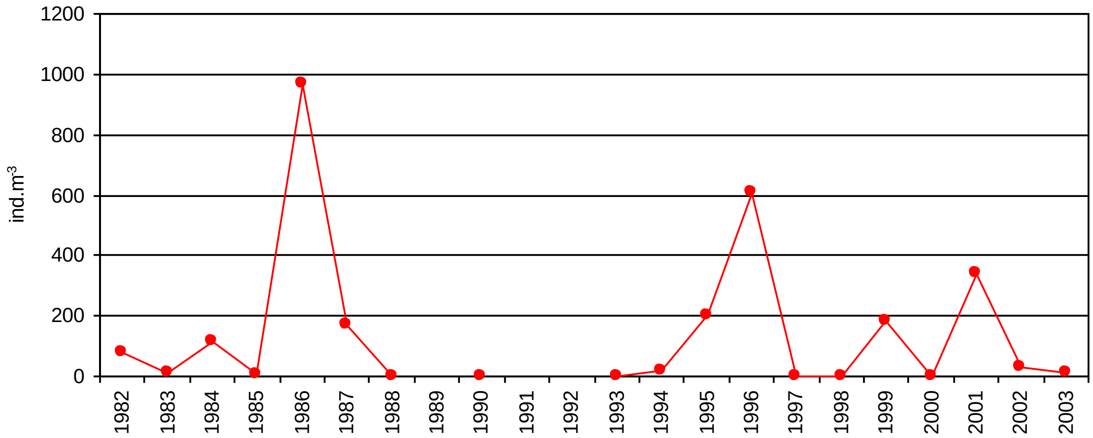

Fig. 5 - Long-term evolution of *Penilia avirostris* density, in front of Constantza, between 1982 to 2003

Another important species for the trophicity of the marine environment, whose conservation status was affected mostly in the post-invasion period by *Mnemiopsis*, is the chetognat *Sagitta setosa*. For example, on profile East-Constantza, after producing a mean annual density of 25 ind.m^{-3} in 1986, it disappeared almost completely up to 1992. Since 1993, its populations were present every year, in abundant densities, up to a maximum value of 65 ind.m^{-3} in 2001 (Fig. 6).

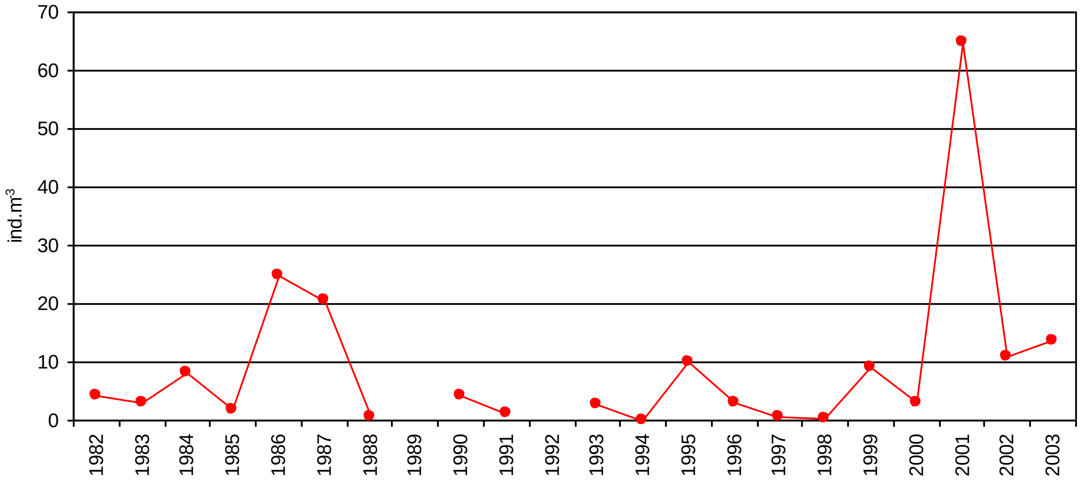

Fig. 6 – Long-term evolution of *Sagitta setosa* density,
in front of Constantza, between 1982 to 2003

In autumn 2002, in the qualitative and quantitative structure of the zooplanktonic communities identified in all Romanian marine sectors, from Sulina to Constanta, *Sagitta* was well represented, with big-sized individuals, constituting high biomasses, attaining 8.073 mg.m^{-3} in the 10-0 m depths in front of Sulina. In fact, the percentage structure of the communities showed that the contribution of the "Other groups" category, which includes this species, was higher then that of the copepods (36%) (Fig. 7).

In 2003, *Sagitta setosa* had an apparition frequency of 100%, meaning that it occurred during the whole year; in some zones, although its densities were lower then the copepod densities, due to their length (2 cm), the individual biomass was high, and the dominance index of category "Other groups" became higher then that of copepods. For instance, at Mangalia, in May, the contribution of this category in fodder zooplankton was 60%; in summer, at Mangalia and Zaton, 40 and 41% respectively, becoming dominant (Fig. 7). Being predatory and carnivore, *Sagitta* eats copepods, so controlling their development. Even *Sagitta* densities are lower then copepod ones, with its 2 cm length, it can control a population of copepods of 12 times higher.

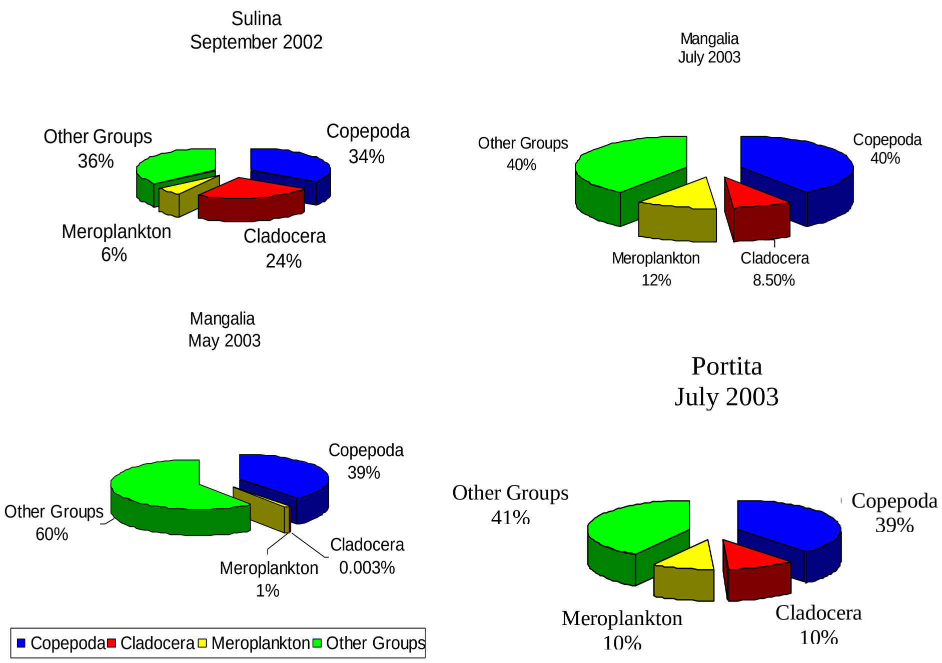

Fig. 7- Percentage structure of trophic zooplankton in some sectors from the Romanian littoral, in 2002 and 2003

Sign No. 4

Between 1989 and 1994, the quantitative reduction of species sensitive to the anthropogenic influences was doubled by the overwhelming development of a small number of opportunistic species, tolerant to disturbances, herbivorous or detritifagous, which became dominant by high densities and biomasses produced. Two opportunistic species – *Acartia clausi* and *Pleopis polyphemoides* – considered trophic zooplankton, enter the food of planktivorous fish; they used to be the almost single two species, which constituted the communities within the eutrophication period. Besides them, another species, with minor role in bioeconomy of the pelagic biocoenose of the Black Sea, the cystoflagellat *Noctiluca scintillans* produced spectacular developments. Authentic blooms of this species led to high zooplankton total quantities between 1986 and 1990.

The *Noctiluca* blooms, produced concomitantly or immediately after the phytoplanktonic blooms occurred in the summer season, represented one of the main features of the evolution in the pelagic subsystem of the Romanian marine ecosystem (PETRAN, 1997). Due to the huge developments of this species, the dynamics of the fodder and non-fodder zooplankton in the total zooplankton was different. Fig. 8 shows the percentage structure of the total zooplankton between 1982-1992; obviously, the non-trophic zooplankton had almost always exceeded the fodder one, with up to 99 %.

The shape of the *Noctiluca* quantitative development, after 1995, represents a true sign of ecosystem recovery. For example, between 1999 and 2002, although many times the percentage dominance of *Noctiluca* was still high, but not higher then 74% (Fig. 9), its quantities were more and more reduced, along the whole Romanian littoral (Fig. 10).

However, if the temperatures and food conditions are fulfilled, the *Noctiluca* cells could intensely divide, but without producing the ample zooplanktonic blooms, known in summers during the eutrophication syndrome.

In **summer 1999**, *Noctiluca* densities were very low (maximum 400 ind.m^{-3}, at Sf.Gheorghe); in September, its populations reached the highest abundance (Table 2).

Table 2

Densities (ind.m^{-3}) and biomasses (mg.m^{-3}) of the gelatinous species *Noctiluca scintillans* (10-0 m depths) in September, 1999

Sector	Density	Biomass
Portitza	13,622	1,198.736
Chituc	3,675	323.400
Constantza	11,393	1,002.584
Mangalia	2,156	189.728

The research of the zooplankton biocoenosis carried out during October and November, **2000**, on the whole Romanian coastal waters, revealed total zooplankton depths with mean densities between 2,392 ind.m^{-3} (Midia) and 87,549 ind.m^{-3} (Mangalia) at 10-0 m depths. The gelatinous populations of *N. scintillans* constituted 30 and 87% respectively of these quantities (Table 3). In station 1, near the coast of Mangalia, a density of 172,088 ind.m^{-3} was assessed, which seems like a zooplanktonic bloom. The overwhelming development of its cells was provoked by the high water temperatures (at Constantza, in November, the monthly average value was 12.9^{o}C, comparatively with the long-term average value 9.3^{0}C).

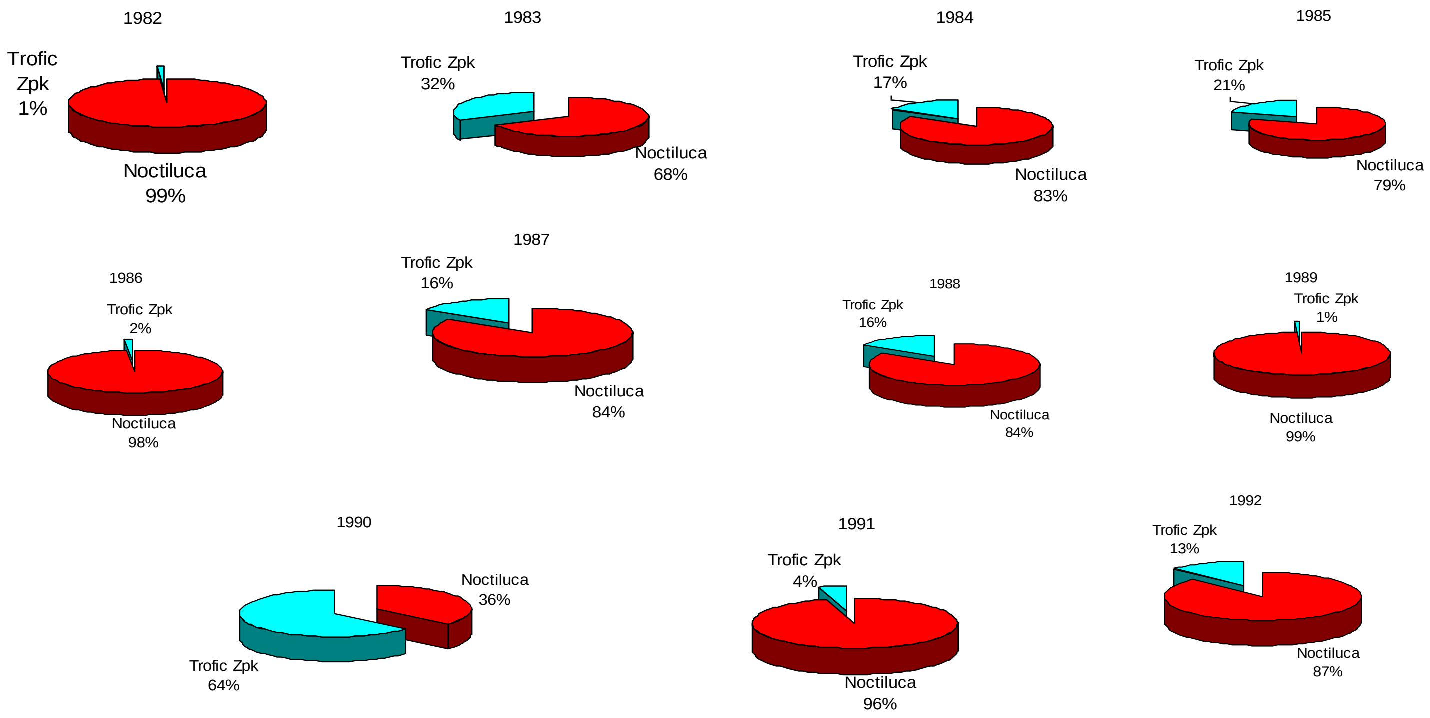

Fig.8 – Percentage structure of total zooplankton in front of Constantza in the summer season between 1982 and 1992

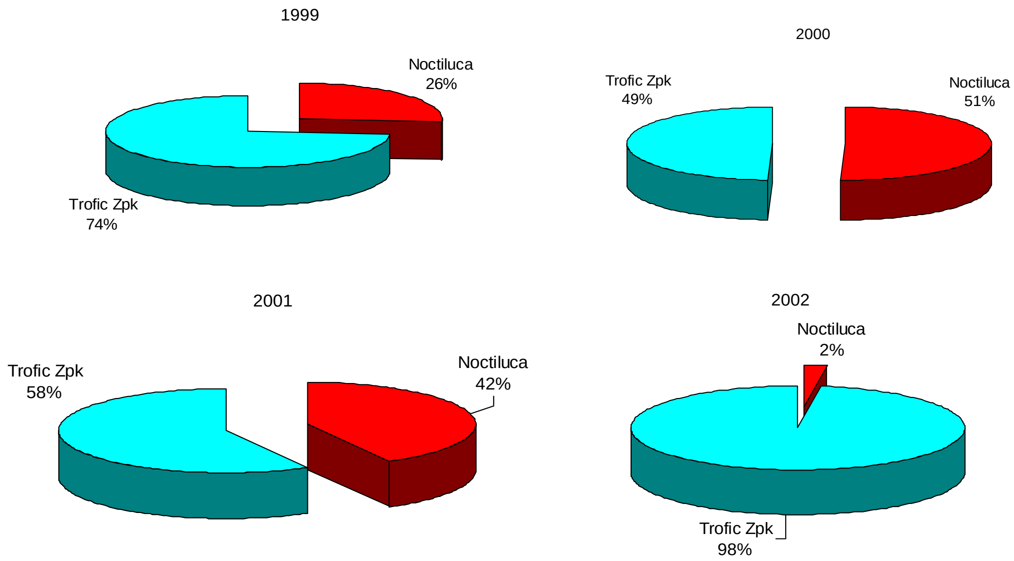

Fig. 9 – Percentage structure of total zooplankton from the upper layers in the Romanian waters, between 1999 and 2002

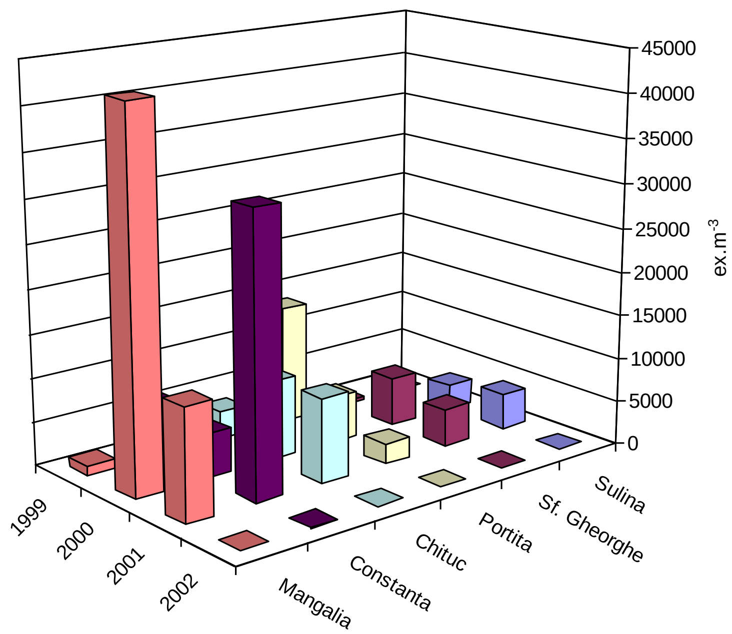

Fig. 10 – Spatio-temporal evolution of *Noctiluca* density (10-0m depths)

In the **spring 2001**, when the mean water temperature was high, 7.4^{0}C at Constantza (almost twice the long-term average), the zooplanktonic communities living the upper layers have been dominated, both numerical and in weight, by the populations of *N. scintilans.* High temperatures favourized its development, the populations growing up to maximum numerical densities 12,742 ind.m^{-3} (at Midia), meaning 78% from the total zooplankton. However, the densities in front of Sulina and Sf. Gheorghe were significantly lower, only an average of 6 ind.m^{-3} being recorded at Sulina.

Table 3

Densities of the total zooplankton and *Noctiluca* registered during autumn 2000

Sector	**Total ZPK ind.m^{-3}**	***Noctiluca***	
		ind.m^{-3}	**%**
Sulina	8,323	5,214	49
Sf.Gheorghe	7,938	1,029	13
Portitza	7,647	1,409	18
Chituc	6,626	2,267	30
Midia	2,391	748	30
Constantza	4,177	3,920	94
Mangalia	87,548	86,657	87

In **summer 2001**, the analysis emphasized the 1.5 times decrease of total zooplankton if compared to spring season. Due to the prevalence (98 %) of uni-cellular gelatinous species *N. scintilans* (Table 4), the 17.5 times decrease of trophic plankton was dramatic. Practically, trophic biomass values reached only 11,18mg.m^{-3} (at Portitza), but they were below 1 mg.m^{-3} on extended areas. In a**utumn**, gelatinous zooplankton reached its lowest values in 2001. Zooplanktonic quantities, almost exclusively constituted by *Noctiluca scintillans* populations, ranged from 6.52 at Sulina to 340.65 mg.m^{-3} at Mangalia, but sometimes the species was absent in the collected samples (Portitza, Chituc, Midia).

Table 4

Annual mean densities (ind.m^{-3}) of the gelatinous zooplankton in 2001

Sector	***Noctiluca***	***Pleurobrachia***	***Mnemiopsis***	***Beroe***
Sulina	4,050	1	-	-
Sf.Gheorghe	4,270	-	-	-
Portitza	2,279	1		1
Chituc	9,497	-	-	1
Midia	31,149	1	1	-
Constantza	31,722	1	-	1
Mangalia	12,621	-	-	-

Sign No. 5

After 1994, the non-trophic component of the zooplankton was constituted, besides *Noctiluca*, from authochtonous ctenophore *Pleurobrachia rhodopis* and immigrant ctenophores *Mnemiopsis leidyi* and *Beroe ovata*.

● The zooplanktivorous combjelly *M.leidyi* is one of the most significant exotic species introduced into the Black Sea, in terms of its impact on the local fauna. *M. leidyi* appears to have penetrated - via ballast waters - from the North-eastern Atlantic coast of the United States and has multiplied explosively since 1987, to dominate the pelagial of the Black Sea ecosystem.

Since 1988, a significant decline in the quantity of majority zooplankters, both in the shallow and offshore waters, especially of those species with a high trophic value for planktivorous fish, was registered (PETRAN and MOLDOVEANU, 1994). *Mnemiopsis* reached maximum quantitative development during the summer. Also, a reduced level of the main zooplanktonic groups with trophic value (Copepods, Cladocerans, meroplankters) was recorded during the whole summer period 1990 to 1993, not only off Constantza zone but also throughout the whole investigated zone (PETRAN and MOLDOVEANU, 1992).

The *Mnemiopsis* invasion has had a significant impact upon the Romanian Black Sea fishery for small pelagic fish, whose stocks have declined dramatically since 1988. Surveys conducted after 1993 revealed that *Mnemiopsis* still accounted for 90% of the total biomass, including *Aurelia aurita*; but its quantities began to decline after 1994 (RADU, unpublished data).

In the zooplankton samples, the presence of the *Mnemiopsis* larvae and juveniles proved also the decline of this species abundance along the Romanian littoral, especially after 1999. For instance, in summer 1999, a mean density of 123 ind.m^{-3} was assessed; then the individuals of the species were almost absent until 2002 (Table 4).

● Regarding the *Pleurobrachia rhodopis* ctenophore, it seems to regain its ecological niche, which *Mnemiopsis leidyi* had occupied after 1989 (Fig. 11). Between 1982 and 1995, the *Pleurobrachia* individuals were present in significant densities; then, in the period of *Mnemiopsis* dominance, it did not occur for many years. *Pleurobrachia* populations have gradually recovered the place in the communities, so that in March, 2002, March and May, 2003, big-sized adult individuals produced substantial densities.

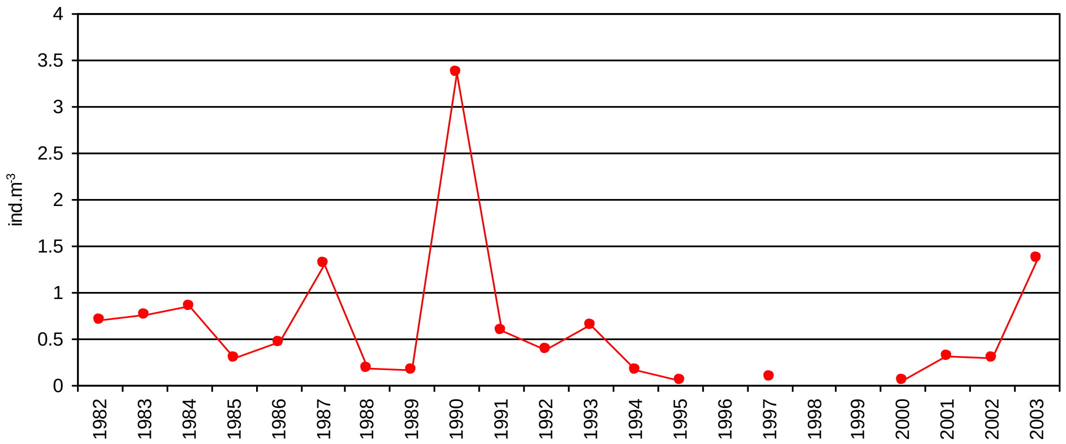

Fig. 11 - Long-term evolution of *Pleurobrachia rhodopis* density, in front of Constantza, between 1982 and 2003

● The ctenophore *Beroe ovata* is the last cited invader in the Black Sea pelagial. The first two juveniles (2 cm) were identified in zooplankton samples in October, 1997, collected in front of Constantza (MOLDOVEANU, unpublished data); then other small-sized specimens (4-8 cm) have been noted and collected at the South of littoral. The origin of this immigrant is controversial - from North Atlantic through ballast waters or from the Mediterranean Sea, through the Bosporus Strait (GOMOIU and SKOLKA, 1998). Being a specialized carnivore, which feeds on other ctenophores, it actively consumes *Mnemiopsis*. The depletion in the *Mnemiopsis* populations registered in the whole Black Sea basin, after 1995, is considered as a consequence of the grazing made by the *Beroe* populations. During the autumn 1999, a mass development of *Beroe* was registered near the north-eastern coast of the Black Sea, in the region of Gelendzhik (Russian Federation). End August and beginning September, the *Beroe* biomasses in Golubaya Bay (Black Sea) were as high as 130 g wet weight under m^2. This situation immediately reduced the biomass of *Mnemiopsis*, by about one order of magnitude; in turn, an increase of abundance of mesoplankton and planktivorous fish fry resulted (VINOGRADOV, 1999).

Although, such huge biomasses of *Beroe* have not been produced yet, the positive ecological parameter status exhibited by the trophic zooplanktonic can be also a consequence of occurring of this species at the Romanian littoral too. Its quantities were still reduced up to now (Table 4), but the monitoring of the *Beroe* populations evolution, the relationships between the *Mnemiopsis* and *Beroe*, the repercussion of this last ctenophore on the fish populations, as well as on the resident ctenophore *Pleurobrachia rhodopis* and jellyfish *Aurelia aurita* have to be carried out (GOMOIU and SKOLKA, 1998).

CONCLUSIONS

The ecological control carried out after 1994 evidenced slight but continuous signs of improvement of all marine biotic components, including the zooplankton biocoenosis, both as quantitative structure and specific diversity.

1. Even if, especially during the *Mnemiopsis* post-invasion period, the fodder zooplankton had smallest biomasses in the summer months, the multiyearly evolution of this parameter did not show such tendency after 1994. On the contrary, the long-term evolution curve (1994-2003) exhibited four peaks of fodder biomass - 1995, 1999, 2001 and 2003 - the first two of them being constituted exactly based on the summer abundance.

2. Doubtless signs of ecosystem health were evinced especially as qualitative structure of zooplanktonic biocoenosis. The identification of nauplius larvae and adults pertained to two copepods – *Pontella mediterranea* (in 2002) and *Anomalocera pattersoni* (already in three consecutive years: 2001, 2002, 2003), whose populations were gravely affected by the eutrophication syndrome almost to extinction, prove the ecological rehabilitation of the ecosystem.

3. Other three holoplanktonic species suffering under the eutrophication impact - copepod *Centropages ponticus*, very sensitive to the environment quality, cladocer *Penilia avirostris* and chetognat *Sagitta setosa*, begun to recover the populations, their abundance being higher then that of opportunistic species - copepod *Acartia clausi* and cladocer *Pleopis polyphemoides*, which were almost the single species in communities during the period marked by eutrophication.

4. During the reference period (1994-2003), the non-trophic component of total zooplankton was constituted by the uni-cellular species *Noctiluca scintillans*, the autochthonous ctenophore *Pleurobrachia rhodopis,* and the immigrant ctenophores *Mnemiopsis leidyi* and *Beroe ovata*. After the overwhelming developments produced during the summers with increased eutrophication, once with or after the phytoplanktonic blooms, *Noctiluca* got depleted its quantities, especially during the summers. The ctenophore *Pleurobrachia* seems to recover its ecological niche, which was occupied by *Mnemiopsis* after 1989; all the samples collected in March 2002, March and May 2003 contained big-sized individuals of *Pleurobrachia*.

5. The most important event from the diversity viewpoint, which happened after 1994, was the occurrence of the ctenophore *Beroe ovata* in the Romanian pelagial too. The fact has double ecological significance: firstly, the diversity in species enriched with a new species, secondly, due to grazing produced by its populations, the *Mnemiopsis* populations depleted more and more, meaning another positive factor for the ecosystem status, after the mitigation of the pressure exerted by eutrophication.

6. Despite of the reduction of eutrophication intensity, despite of the *Mnemiopsis* pressure mitigation, the improvement in the zooplankton biocoenosis, and consequently of the whole marine ecosystem, is still fragile. The tendency in its evolution depends on the evolution in the nutrient input to the sea, as a requirement for the continuous limitation of algal blooms, and *Mnemiopsis* versus *Beroe* developments.

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