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POST-INVASION ECOLOGICAL IMPACT OF THE ATLANTIC CTENOPHORE *Mnemiopsis leidyi* Agassiz, 1865 ON THE ZOOPLANKTON FROM THE ROMANIAN BLACK SEA WATERS

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ABSTRACT

The study presents the evolution of the zooplankton communities from the Romanian Black Sea waters in the period 1989-1993 after the outburst of the new immigrant in the pelagic zone of the Black Sea - the predator lobate ctenophore *Mnemiopsis leidyi*. The paper, based on the 480 zooplanktonic samples processed, evinces that, after the *Mnemiopsis* invasion, the structure of the zooplanktonic communities were significantly transformed. Especially during the summer, a severe reduction of populations for most of the groups with trophic value has registered, the biomasses of some species decreasing 3-5 times or more. Even the species with intensive growth during the previous years (1980-1987), such as *Acartia clausi* and *Pleopis polyphemoides*, have had now a very low quantitative level.

KEY WORDS : Black Sea, zooplankton, *Mnemiopsis leidyi*

INTRODUCTION

During the last two decades especially, a lot of papers have evinced the changes produced inside the main biotic components of pelagial and benthic subsystems of the Black Sea as consequences of the increased anthropic pressure, which determined the alteration of environment for many vegetal and animal organisms (KIDEYS,1994; KONSULOV,1986; PETROVA-KARADJOVA,1984; SHUSHKINA *et al.*,1990; VINOGRADOV, ARNAUTOV,1986; ZAITSEV,1979,1992; ZAITSEV *et al.*,1987). It was also analyzed the main disturbing factors which, acting either directly or indirectly, have influenced the development of marine life and produced a chain of processes and phenomena which have modified the structure and functioning of the coastal ecosystems from the Romanian littoral of the Black Sea (BODEANU, 1984,1992; BOLOGA, 1989; BOLOGA *et al.*, 1992; COCIASU, POPA, 1980; GOMOIU, 1976,1981,1983, 1987; MIHNEA *et al.*,,1981; PETRAN, 1986,1988; PETRAN, RUSU, 1990; PETRAN, MOLDOVEANU, 1992; PORUMB, 1980,1986,1992; TIGANUS, 1986,1990).

Besides the factors already known, the pelagial realm has found under the impact of a new one which, overlapping on the other anthropic influences, has grown for the worse the disturbances during the last 5-6 years. We refer to the new and accidental penetration and overwhelming development of the lobate ctenophore *Mnemiopsis leidyi* Agassiz, 1865. Being native of eutrophic lagoons from the Atlantic coasts of the North America, the species has produced a really ecological catastrophe in the Black Sea, as all the riparian countries have appreciated, being confronted with its baneful consequences upon the state of zooplanktonic and pelagic fish populations, due to the massive consumption of eggs and fish larvae.

Brought in the Black Sea once with the ballast water of the maritime ships, probably of those carrying cereals from the USA to Odessa, the first individual was signaled by Russian researchers, in Sudak Gulf, in November 1982 (VINOGRADOV *et al.*, 1989), but its explosive development was produced later in 1988-1989, when dense populations were registered in many areas of the Black Sea (MUTLU *et al.*,1994; KIDEYS,1994; SHUSHKINA, VINOGRADOV,1991; SUSHKINA, MUSAYEVA,1990; VINOGRADOV *et al.*,1989,1990; ZAIKA, SERGEEVA, 1990).

As for the Romanian continental waters, the observations regarding the zooplankton allowed us to signal the presence of this species as far back as in 1989, first as fragments from the big-sized individuals (their gelatinous body is easily degraded due to the system of collecting and conservation the zooplankton samples with formaldehyde); since 1990 we found even larvae and juveniles of 1-6 mm in diameter.

Beginning in the same period, there can say about a decline and precarious state of zooplanktonic populations, which have described in all our annually studies.

In the present paper, the long-term evolution of the zooplanktonic structure and quantities (1989-1993) is analyzed, in order to stress the impact of this immigrant upon one of the important component of pelagial - zooplanktonic community.

MATERIALS AND METHODS

The results discussed in this paper are based on the processing of zooplankton samples collected seasonally during 1989-1993 period, in a net stations settled in the northern zone of the littoral, found under the Danubian waters influence (Sulina, Mila 9, St.George, Chituc and Portita profiles), in the middle of the littoral (Constanta profile) as well as in the southern zone (Mangalia profile), meaning a total of 480 samples.

The table below gives the months of observations, the profiles and the total number of samples analyzed each year:

YEARS	PROFILES	MONTHS	Total no.of samples
1989	Constanta Portita Chituc	II,V,VI,VII,X VII VIII	63
1990	Constanta Sulina, Mila 9, St.George Mangalia	III,VI,VIII V,VIII VII	83
1991	Constanta Mila 9, St.George, Chituc Mangalia	III,V,VII III,V,VI III,V	126
1992	Constanta St.George, Chituc, Portita Mangalia	II,IV,VI,IX,X IV,V,VIII II,VI,IX	111
1993	Constanta Sulina,Mila 9, St.George Mangalia	II,III,VI,VIII V,VIII,IX VI,VIII	97
TOTAL NUMBER OF SAMPLES 1989 - 1993			480

Table 1

Qualitatively and quantitatively (Density = ind.m^{-3}; Biomass = mg.m^{-3}) structure of the upper layers (10-0 m) zooplankton of Constanta profile and the main parameters which characterized the populations organizing inside the communities, during June 1989

Zooplanktonic species	Station 1		Station 2		Station 3		Station 4		Station 5	
	D	B	D	B	D	B	D	B	D	B
Noctiluca scintillans	179928	14934.400	185024	14801.000	94668	7573.400	109368	8749.400	121128	9690.240
Pleurobrachia rhodopis	-	-	1	3.9	-	-	-	-	-	-
Synchaeta sp.	294	0.38	220	0.040	-	-	588	0.700	2058	2.670
Polychaeta - larvae	9	0.060	368	2.200	42	0.250	176	1.060	137	0.820
Bivalvia - larvae	98	0.130	147	0.190	-	-	98	0.130	294	0.380
Acartia clausi	5129	59.170	313	2.810	127	2.290	647	16.430	588	20.730
Pseudocalanus elongatus	202	1.850	4	0.020	-	-	-	-	20	0.100
Calanus euxinus	7	8.580	-	-	-	-	-	-	-	-
Oithona similis	-	-	-	-	1	0.004	-	-	-	-
Pleopis polyphemoides	-	-	27	0.250	13	0.120	-	-	78	0.700
Balanus - nauplii	785	1.520	8	1.520	2	0.220	21	3.800	-	-
Oikopleura dioica	-	-	-	-	1	0.007	-	-	-	-
Total, from which:	**186452**	**14465.900**	**186114**	**14812.920**	**94854**	**7576.97**	**110918**	**8771.68**	**126303**	**9715.650**
Noctiluca scintillans (%)	96.50	99.51	98.88	99.93	99.80	99.95	98.60	99.75	97.45	99.74
Total number of species	**8**		**9**		**7**		**6**		**7**	
Diversity index (H)	0.26	0.05	0.06	0.01	0.01	0.006	0.13	0.03	0.02	0.03
Max.Diversity (H)	3.00	3.00	3.17	3.17	2.81	2.81	2.58	2.58	2.81	2.81
Equitability (E)	0.09	0.02	0.02	0.003	0.005	0.002	0.05	0.01	0.08	0.01

Table 2

Zooplanktonic densities (D = ind.m^{-3}) and biomasses (B = mg.m^{-3}) in the offshore waters of the Constanta profile during June 1989

Station (Nm from the shore)	Horizons (m)	Total zooplankton		Non-trophic zooplankton		Trophic zooplankton		Copepods		Cladocers		Meroplankton		Rotifers	
		D	B	D	B	D	B	D	B	D	B	D	B	D	B
50 Nm	10-0	202,032	16,135.80	201,032	16,135.80	284	1.10	49	0.60	5	0.04	-	-	294	0.40
	25-10	58	1.80	16	1.30	42	0.50	41	0.50	-	-	-	-	-	-
70 Nm	10-0	2,274	39.10	198	15.80	2076	23.20	1977	22.70	-	-	25	0.04	-	-
	25-10	98	0.70	-	-	98	0.70	80	0.70	-	-	17	0.03	-	-
90 Nm	10-0	650	16.40	186	14.90	464	1.50	421	1.50	-	-	43	0.03	-	-
	25-10	1,359	33.70	396	31.70	963	2.00	5546	2.00	1	0.009	91	0.02	-	-
100 Nm	10-0	639	7.20	61	4.90	578	2.30	505	2.20	-	-	1	0.007	-	-
	25-10	265	9.30	9	7.70	256	1.50	203	1.50	1	0.009	51	0.01	-	-

The samples were collected using the "Juday" closing net with 36 cm opening diameter and 200 μ mesh size, through vertical hauls in the standard horizons of 10-0, 25-10 and 50-25 m as well as in deeper layers, during the years in which the profiles were extended up to 100 m depths (Chituc profile in 1991, Constanta and Mangalia profiles in 1992), 500 m (Constanta profile in 1993) and 850 m (Mangalia profile 1991).

The samples were treated with 4 % formaldehyde and studied in the laboratory using a planktonic 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 $ex.m^{-3}$; mean individual weights were used to estimate the biomasses as $mg.m^{-3}$.

In order to characterize the structure of zooplanktonic populations a few parameters were also calculated : diversity index (H) using Shannon-Wiener formula, equitability index (E), frequency (F %), and dominance index (D %).

RESULTS AND DISCUSSIONS

Before presentating the features of the quantitative development and the structure of the zooplanktonic populations during the period taken in discussion, we consider useful to give some elements regarding the biology of this new colonizer in the Black Sea waters.

The ctenophore lobate *Mnemiopsis leidyi* is a wide spread species at the Atlantic coasts of the North America, from the north, from Woods Hole, up to the Argentina coasts, in lagoonal and estuarian brackish waters. Able to support great variations of temperature and salinity, resistant in polluted environments with increased organic matter content, the species has obviously the characteristics of an opportunistic one. The species is hermaphrodite with high reproductive capacity in all types of biotic conditions, producing 8,000 eggs in 23 days, after 13 days since own birth (the species is capable of pedogenesis); the development rate, comparable with that of phytoplankton, gives it the possibility as one single specimen to conquer new and new areas (BAKER, REEVE, 1974).

Such a high development rate can be reached only with a high rate of feeding. *Mnemiopsis* eats not only holoplanktonic but also meroplanktonic organisms, as well as eggs and fish larvae, its voracity and rapacity being extraordinary, even when the stomodeum is full, it continues to capture prey, regurgitating large quantities of undigested plankton in a bolus of mucus. This predatory is responsible of consumption of 73% from the total zooplankton in Chesapeake Bay (KREMER,1979), but in the Black Sea its voracity seems to be even greater.

In the north-western part of the Black Sea, the explosive development of the species took place later in 1987 (VINOGRADOV *et al.*, 1989), after that during 1988-1989 dense swarms with individuals of 4-5 cm (maximum size 13 cm) occurred at the Crimea coastal waters, giving biomasses of 1.5 - 2 $kg.m^{-2}$. In the summer of 1989, the assessments of the total wet biomasses gave a figure of 800 million tones (VINOGRADOV, 1990).

The biomasses had the same magnitude in 1990 and 1991 years, values of 12 $kg.m^{-2}$ were registered in certain zones (for ex. Ghelendjik), densities unknown at the American coasts.

The observations and registrations of Russian researchers, using submersibles, diving bells and TV screens, ascertained that the main mass of the individuals have concentrated in the upper layers, above the thermocline. After 1991, it was observed than an important part of the big-sized individuals penetrated in the waters below thermocline up to 70 m depth.

Table 3

Qualitatively and quantitatively (Density = ind.m^{-3}; Biomass = mg.m^{-3}) structure of the upper layers zooplankton (10-0 m horizon) and the main parameters which characterized the population organizing inside the communities in front of Constanta and Portita, during July 1989

Zooplanktonic species	Constanta profile				Portita profile					
	Station 1		Station 2		Station 4		Station 6		Station 8	
	D	B	D	B	D	B	D	B	D	B
Noctiluca scintillans	10584	846.720	15288	1223.040	36531	2922.500	143664	11493.120	198254	15860.300
Pleurobrachia rhodopis	-	-	-	-	-	-	-	-	1	3.000
Synchaeta sp.	196	0.260	49	0.060	123	0.160	123	0.160	-	-
Polychaeta - larvae	11	0.060	25	0.150	5	0.030	26	0.160	15	0.090
Bivalvia - larvae	3	0.001	13	0.001	-	-	44	0.010	14	0.020
Acartia clausi	8	0.110	10	0.150	7	0.030	97	2.060	67	1.790
Pleopis polyphemoides	3	0.030	3	0.030	2	0.020	2	0.030	-	-
Balanus - nauplii	1	0.006	9	0.060	-	-	-	-	-	-
Oikopleura dioica	1	0.007	-	-	3	0.020	6	0.040	1	0.007
Total, from which (%)	**10807**	**847.230**	**15397**	**1223.490**	**36673**	**2922.700**	**143962**	**11495.600**	**198352**	**15866.200**
Noctiluca scintillans	97.94	99.94	99.29	99.96	99.61	99.99	99.79	99.98	99.95	99.96
Total number of species	**8**		**7**		**6**		**7**		**6**	
Diversity (H)	0.16	0.008	0.08	0.006	0.04	0.001	0.02	0.003	0.007	0.005
Diversity max. (H_{max})	2.29	2.99	2.81	2.81	2.58	2.58	2.81	2.81	2.58	2.58
Equitability (Eq)	0.05	0.003	0.08	0.002	0.02	0.007	0.009	0.001	0.003	0.002

The massive reproduction of the predatory in the Black Sea could not help having on the planktonic communities, on zoo- and ichtyoplankton respectively, affecting their quantities, in the manner in which it was already evinced at the Russian and Bulgarian coasts.

Regarding the Romanian continental waters, the first quantitative estimations and data about the distribution of the species were started in 1991 by a group of researchers from the "Fishery resources" laboratory and continued in the next years. Using a pelagic trawl and "Bongo" ichtyoplanktonic net hauled horizontally in the 0-5 m layer, and then through measurements and weighing on board there were found that the highest biomasses were registered during the summer season of 1991 (76,000 tons). In the next years, the quantities were on the decrease so that in 1993 August, a value of 48,954 tones were obtained on an area of 4,900 Nm (RADU, NICOLAEV, 1995).

In the zooplanktonic samples there were noted first the fragments of big-sized adults than, since 1990, plenty of juveniles and small-sized individuals of 2-5 mm diameter were identified, year in which the decline and precarious state of zooplanktonic populations got allarming as we show further on.

After 1988, the research regarding the evolution of structure and seasonally dynamic of the zooplankton from the Romanian littoral have evinced an important depletion of the density for the majority of mesozooplanktontes, especially of those having trophic value for planktivorous fish, both for shallow and offshore waters.

While during 1980's the zooplankton had had a high quantitative level with aestival massive development, although the biomasses were constituted from a few species (PETRAN, 1986,1988; PETRAN, RUSU, 1990; PETRAN, MOLDOVEANU, 1992; PORUMB, 1980,1986,1992), in the summer 1989 we were to record surprisedly the qualitative poorness as well as the extremely reduced quantities of zooplankton, formerly unknown in the coastal and offshore up to 70 Nm. Actually, the tendency of decreasing in the trophic zooplankton quantities was manifested as far back as in summer 1988, but in 1989 the biomasses were reduced to a half.

The structure of the zooplanktonic communities from June 1989, during a fully development of a bloom with *Prorocentrum cordatum*, was dominated by the presence of the numerous populations of *Noctiluca scintillans*, especially in the superficial layers (up to 25 m) of the inshore waters (stations 1 and 2 of Constanta profile). The quantitative indices of the species were increased in all the five stations of the profile, up to maximum density and biomass of 185,024 ind.m^{-3} and 14,801.9 mg.m^{-3} respectively, determining high values of the nontrophic zooplankton (*Noctiluca* represented between 99.51 and 99.95 % from the biomass of total zooplankton) (Table 1).

Analyzing the main parameters which characterized the structure and organizing of the populations inside the communities, the dominance of a single species, namely the detritifagous and non-trophic *Noctiluca scintillans*, was obviously emphasized. The specific diversity was reduced, both in terms of variety and equitability between components, these indices being very small (H = 0.006 - 0.26).

In exchange, in the composition of trophic zooplankton, although the copepod represented the dominant group, their quantities were very reduced for this period. Apart from the superficial coastal waters, where the group reached a maximum density of 53,380 ex.m^{-3}, in the rest of stations the quantitative indices (density and biomass) were much below those registered in spring.

The specific palette of the group was also very limited, besides *Acartia clausi* only *Paracalanus parvus* and a few individuals of *Calanus euxinus* occured.

Surprising for the zooplanktonic populations composition was the reduced participation of the cladocerans from June, *Pleopis polyphemoides* giving a maximum density of only 78 ex.m^{-3}, much below the values obtained in the spring-summer period of the previous years, although there were favourable thermal conditions.

Table 4

Qualitatively and quantitatively (Density = ind.m^{-3}; Biomass = mg.m^{-3}) structure of the upper layers zooplankton (10-0 m) and the main parameters which characterized the structure and organizing of the populations inside the Constanta zone, during October 1989

Zooplanctonic species	Station 1		Station 2				Station 3						Station 4					
	10 - 0 m		10 - 0 m		20 - 10 m		10 - 0 m		20 - 10 m		30 - 20 m		10 - 0 m		20 - 10 m		30 - 20 m	
	D	B	D	B	D	B	D	B	D	B	D	B	D	B	D	B	D	B
Noctiluca scintillans	-	-	1940	155.2	431	34.5	25558	2044.6	40630	3250.4	411	32.9	49127	3930.2	8094	647.5	2371	189.7
Sagitta setosa	-	-	12	0.2	4	0.04	2	0.02	9	0.03	8	0.18	1	0.03	11	0.21	3	0.03
Pleurobrachia rhodopis	3	3.9	95	285.0	70	210.0	115	345.0	117	375.0	1	3.0	376	1128.0	95	285.0	10	42.0
Polychaeta - larvae	1	0.01	12	0.07	11	0.1	40	0.2	17	0.1	3	0.02	34	0.2	4	0.02	1	0.01
Bivalvia - larvae	-	-	-	-	-	-	-	-	-	-	2	0.00	-	-	-	-	-	-
Balanus - larvae	1	0.02	1	0.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acartia clausi	2	0.09	10	0.22	44	1.1	58	2.2	84	2.2	18	0.1	17	0.6	84	1.9	35	0.9
Paracalanus parvus	-	-	-	-	3	0.04	1	0.01	-	-	3	0.05	-	-	-	-	6	0.04
Calanus euxinus	-	-	1	1.26	-	-	-	-	1	1.3	-	-	-	-	-	-	-	-
Oikopleura dioica	-	-	-	-	-	-	-	-	-	-	8	0.06	-	-	-	-	-	-
Total, from which (%)	**7**	**4.0**	**2071**	**441.9**	**563**	**245.7**	**25778**	**2392.1**	**40853**	**3692.0**	**454**	**36.2**	**49555**	**5059.0**	**8295**	**934.6**	**2451**	**232.8**
Noctiluca scintillans	0	0	93.7	33.1	76.6	14.0	99.1	85.5	99.4	89.6	90.5	90.9	99.1	77.7	97.6	69.3	96.7	81.5
Total number of species	**4**		**7**		**6**		**6**		**6**		**8**		**5**		**6**		**7**	
Diversity (H)	1.8	0.22	0.42	0.97	1.10	0.63	0.08	0.60	0.06	0.49	0.67	0.52	0.08	0.80	0.20	0.90	0.27	0.74
Max.Diversity (Hmax)	2.0	2.00	2.80	2.80	2.60	2.60	2.58	2.58	2.58	2.58	2.90	2.90	2.31	2.31	2.58	2.58	2.80	2.80
Equitability (Eq)	0.9	0.11	0.15	0.35	0.40	0.24	0.03	0.23	0.02	0.19	0.20	0.17	0.03	0.33	0.08	0.35	0.10	0.26

The decreased contribution of other components (meroplankton and rotifers) lead consewquently to the very reduced trophic biomasses in the coastal waters up to 30 Nm in June 1989. Same situation was evident also for the offshore waters, up to 100 Nm, where the biomasses not exceeded 1-2 $mg.m^{-3}$; exceptionally, a population of *Calanus euxinus* increased the biomass up to 23.2 $mg.m^{-3}$ in one single station from 70 Nm (Table 2).

Early in July, the dominance of *Noctiluca scintillans* was conspicuous yet, because the bloom with *Prorocentrum cordatum* go on developing intensely all along this month.

The structural parameters illustrated now the precarious state of coastal zooplanktonic communities, remarkable being the reduced level of all trophic groups. Thus, the copepods represented only by *Acartia clausi* gave extremely small effectives, and the cladocerans and meroplankters were almost absent (only 6 $ex.m^{-3}$ of *Pleopis polyphemoides*). The quantitative poorness besides the qualitatively one became very clear and unusual for the summer months, the mean trophic biomasse values on 10-0 horizons being under 1 $mg.m^{-3}$ (Table 3).

We must point out that an important diminution of planktivorous fish caught at our littoral was registered during this period. Thus, in June 1989, the sprat fishing at fixed gears dropped to a half comparatively with the same period of previous year and in July the situation becoming more grave, the reductions being more spectacular (4-5 folded facing of June).

Late in August, in the deeper water masses, under the thermocline, in the Chituc and Tuzla zones, a richer zooplankton was surprised, in which the copepods gave 90 % from the total biomass. The dominant copepod was *Calanus euxinus*, found as nauplii and copepodits. The presence of larger populations of this copepod in the deeper layers is explainable by the fact that, being biotopically isolated, they were little subjected to feeding pressure of *Mnemiopsis*, whom principal biotop is the superficial layers. Mean biomass values calculated for this month were however reduced for this season.

In August as in October, *Noctiluca scintillans* has continually dominated the zooplankton structure, densities of ten thousands of individuals per cub meter were obtained. In October, besides *Noctiluca* another non trophic element had big numerical populations - the resident ctenophore *Pleurobrachia rhodopis*, in fact the only one zooplankter cited as noneaten by the *Mnemiopsis*, the size of its populations remaining almost unmodified in the following years. In the constitution of the zooplanktonic communities, the trophic groups had a very reduced level, three smaller than in autumn 1988 (mean values of 91 $ind.m^{-3}$ and 1.65 $mg.m^{-3}$ in the 40-0 m column). The qualitatively and quantitatively poorness from the 1989 autumn is well evinced in the table 4.

The low quantitative level of the main zooplanktonic groups with trophic value was found also in the summer 1990, a precarious state of the zooplanktonic communities all along the Romanian littoral being evinced.

During March, the structure of the communities in Constanta zone was that characteristic to cold season, constituted in a great part by copepods with *Calanus euxinus* dominance, distributed in the whole water mass but more abundant in the offshore waters. In June, the cryophile species were also prevailing within the copepod group, due to the upwelling occurred at that time, *Acartia clausi* giving a maximum density only in the nearshore station and *C.euxinus* in offshore station and in the bottom layer.

As for the biomasses of trophic zooplankton, in June 1990 they were as small as these from June 1989, close to previous year values. The distribution on horizons have shown an increase towards inferior horizon, due to the *C.euxinus* quartered in these layers (Table 5). Same situation was found in front of Danube mouths, where *Calanus* enriched also a little the trophic biomass.

For the aestival aspect, the monitoring made in offshore waters of Mangalia profile, in July, and in predanubian and Constanta zones, in August, was to emphasize again the scarcity of communities. Analyzing the main parameters which characterized the structure and organization of

Table 5

Variations of the density (D = ex.m^{-3}) and biomass (B = mg.m^{-3}) of the total zooplankton and the main constituent groups in the Constanta profile, during June 1990

Stations	Horizons (m)	Total zooplankton		Nontrophic zoopk.		Trophic zoopk.		Copepods		Cladocers		Meroplankton		Other groups	
		D	B	D	B	D	B	D	B	D	B	D	B	D	B
1	10-0	20898	192.93	11	42.90	20887	150.03	4082	36.95	882	79.38	1752	25.59	6233	8.11
2	10-0	1382	25.64	5	19.50	1377	6.14	339	4.14	54	0.52	234	0.57	750	0.90
	25-10	394	36.21	9	35.10	385	1.11	85	0.49	-	-	53	0.36	247	0.25
3	10-0	260	2.24	-	-	260	2.24	234	1.77	-	-	26	0.48	-	-
	25-10	562	619.36	10	617.00	552	2.36	441	2.09	-	-	46	0.21	65	0.06
4	10-0	102	1.02	-	-	102	1.02	99	0.99	-	-	-	-	3	0.02
	25-10	875	70.17	33	57.60	842	12.57	768	10.86	8	0.07	40	1.57	34	0.07
	45-25	696	261.32	7	203.26	689	58.06	507	57.68	-	-	96	0.26	86	0.12

Table 6

Qualitatively and quantitatively (Density = ind.m^{-3}; Biomass = mg.m^{-3}) structure and the main parameters which characterized the organization of the populations inside the zooplanktonic community identified in the water masses above the 81 m depth, off Mangalia profile, during July 1990

Zooplankton species	10 - 0 m		25 - 10 m		50 - 25 m		75 - 50 m	
	Density	Biomass	Density	Biomass	Density	Biomass	Density	Biomass
Favella ehrenbergi	147	0.014	-	-	-	-	-	-
Rotatoria varia	833	0.270	113	0.020	-	-	146	0.030
Polychaeta - larvae	23	0.140	24	0.040	-	-	-	-
Balanus improvisus - nauplii	1225	2.080	24	0.040	2	0.0020	-	-
Calanus euxinus	27	30.310	2	0.210	-	-	2	0.050
Acartia clausi	98	30.310	2	0.210	-	-	2	0.050
Pseudocalanus elongatus	50	0.110	25	0.070	-	-	54	0.390
Paracalanus parvus	1	0.016	-	-	2	0.0010	-	-
Oithona nana	-	-	8	0.024	3	0.0030	65	0.200
Oithona similis	-	-	-	-	1	0.0015	64	0.060
Sagitta setosa	-	-	1	0.010	-	-	-	-
Oikopleura dioica	-	-	-	-	-	-	1	0.007
Total, from which (%)	**2405**	**33.180**	**183**	**0.470**	**8**	**0.0080**	**334**	**0.820**
Copepods	7.32	92.33	24.59	90.21	75.00	68.75	56.00	95.12
Meroplankton	51.89	6.69	13.11	8.51	25.00	31.25	0.60	0.00
Rotatoria	34.64	0.81	61.75	4.25	0.00	43.00	3.66	
Total number of species	**8**		**7**		**4**		**7**	
Diversity (H)	**1.71**	**0.54**	**1.84**	**2.26**	**1.90**	**1.96**	**1.98**	**1.98**
Maxim Diversity (Hmax)	**3.00**	**3.00**	**2.81**	**2.81**	**2.00**	**2.00**	**2.81**	**2.81**
Equitability (Eq)	**0.57**	**0.18**	**0.62**	**0.81**	**0.95**	**0.98**	**0.70**	**0.71**

Table 7

Variation of the density (D = ind.m^{-3}) and biomass (B = mg.m^{-3}) of the total zooplankton and the main component groups on the St.George profile, during August 1990

Izobath	Horizons	Total zooplankton		Trophic zoopk.		Copepods		Cladocers		Meroplankton		*Favella ehrenbergi*		*Pleurobrachia rhodopis*	
(m)	(m)	D	B	D	B	D	B	D	B	D	B	D	B	D	B
20	20-10	1827	7.902	1827	7.902	952	4.910	-	-	816	2.990	50	0.0024	-	-
40	10-0	9616	1.080	9617	1.080	1032	0.880	4	0.070	6	0.040	8575	0.860	-	-
	20-10	7313	9.720	7288	9.720	2803	9.180	-	-	75	0.100	4410	0.450	-	-
	30-20	104	2.050	79	0.042	54	0.040	-	-	-	-	25	0.002	-	-
50	10-0	6566	8.410	6556	8.230	1906	7.720	4	0.040	-	-	4645	0.760	-	-
	40-30	814	48.760	811	0.055	762	3.050	-	-	-	-	49	0.005	3	45.700
	50-40	413	132.670	428	1.770	428	1.770	-	-	-	-	-	-	3	130.900

populations inside the identified communities in the waters above the 81 m depth in Mangalia, a low specific diversity (maximum eight species in the superficial layers) as well as a decreased quantitative level of all groups were evinced, determining extremely reduced biomasses (excepting the 10-0 m strata, the biomasses were lesser than 1 $mg.m^{-3}$) (Table 6).

In front of the Danube Delta, the communities identified in the upper layers (10-0 and 20-10 m) were even poorer, constituted from only 2-3 species : veligers of Bivalvia, the chetognat *Sagitta setosa* and the copepod *Acartia clausi*. Regarding the development of *A.clausi*, the maximum density of 3,650 $ind.m^{-3}$ registered in August 1990 in Mila 9 sector was much below the fully development of its from 1988 (ten thousands individuals per cub meter in all stations).

A feature of the communities identified in August 1990 was the quasi-absence of cladocerans, being well known that the group is warm water lovers, in the former summers they playing an important role in the trophic biomasses. Thus if in the summer 1988 *Pleopis polyphemoides* gave densities of thousands individuals per cub meter, in the 1990' summer, in the upper layers of oredanubian sector, the species was almost missing from the samples, a maximum value of 48 $ex.m^{-3}$ was registered at Mila 9 site.

We also note for this month the presence of *Calanus euxinus* copepod quartered in the water masses below 25 m horizon, it having the most important contribution in trophic biomasses from the offshore and superficial layers. In the deeper waters, another species increasing the total zooplanktonic biomass is the ctenophore *Pleurobrachia rhodopis* (Table 7).

Although the zooplankton quantities were slightly increased in Constanta zone than in predanubian one (in the coastal waters an important contribution having the meroplankton), the quantitative level of main groups of trophic elements had much below the previous registerings during the summer season. *Acartia clausi* was almost the single representative in the copepod populations but its densities were undoubtedly lesser than in 1980-1987 period (Table 8).

During the spring and summer of 1990, the absence of *Noctiluca scintillans*' populations was signaled, the species prevailing usually the zooplankton of these seasons. This fact can be correlated with the absence of ample blooms, the only one weak and short-lasted being produced later in June. In exchange, fragments and juveniles of *Mnemiopsis* were frequently found in the samples.

The ecological monitoring of the zooplankton biocoenose during 1991 was realized through the research of a big number of samples taken in the same profiles previously described, some of them being prolonged up to deeper waters (for instance, up to 850 m in the southern littoral, in May.

The observations made in March shown that the hivernal zooplankton was dominated by the cryophile copepods in whole marine sectors, *Calanus euxinus* giving the greatest percentage in the general biomass (98 %). For the rest of groups had an infinitesimal contribution, so that the trophic biomass was constituted 99.9 % by copepods. The highest biomasses of *C.euxinus* were obtained in the offshores of Constanta, Chituc and Mangalia zones, in the water masses above 70-80 m depths. In this way, the quantitative level of copepods was superior comparatively with March 1990 (e.g., in Constanta zone, mean biomass on 0-50 m column was ten times greater).

In May, the zooplankton was enriched with cladocerans (especially in the superficial layers of northern littoral), microzooplankters (tintinnids, rotifers, the appendicular *Oikopleura dioica*) but also with freshwater forms of rotifer and copepod groups, in the nearshore areas of St.George and Chituc sectors, when important Danubian flows characterized throughout the spring-summer period of 1991 (the most high floods from the last 30 years).

In the specific composition of predanubian zooplankton, a few freshwater rotifers (*Brachionus calyciflorus, B.angularis, Polyarthra* sp., *Keratella cochlearis)*, freshwater cladocerans and cyclopoids in different development stages were identified, which produced the highest indicators of density and biomass registered.

Table 8

Variation of the density (D = ind.m^{-3}) and biomass (B = mg.m^{-3}) of the total zooplankton and the main component groups in the station of Constanta profile, during August 1990

Station	Horizons (m)	Total zooplankton		Nontrophic zoopl.		Trophic zooplank		Copepods		Cladocers		Meroplankton		Other groups	
		D	B	D	B	D	B	D	B	D	B	D	B	D	B
1	10-0	10735	42.650	4	0.040	10731	42.610	363	0.812	-	-	6620	41.310	3748	0.4580
2	10-0	1111	6.710	6	0.060	1105	6.650	895	4.850	27	1.170	95	0.610	88	0.0080
	25-10	713	5.160	5	0.130	708	4.970	634	4.650	3	0.140	51	0.040	20	0.1400
3	10-0	658	2.730	11	0.200	647	2.540	659	2.480	2	0.020	75	0.020	1	0.0070
	25-10	759	5.750	24	0.520	735	5.240	702	4.970	6	0.250	26	0.005	1	0.0070
4	10-0	1134	24.790	12	0.300	1122	24.490	1056	24.270	14	0.190	3	0.020	49	0.0001
	25-10	992	7.540	12	0.120	980	7.420	827	7.000	12	0.380	60	0.017	81	0.0210
	45-25	970	68.480	364	67.240	606	1.230	480	0.860	1	0.009	104	0.216	21	0.1470
5	10-0	2211	8.370	3	0.030	2208	8.339	920	7.660	28	0.450	235	0.080	1025	0.1440
	25-10	1113	17.430	2	0.020	1111	17.410	912	14.260	74	3.080	-	-	125	0.0700
	50-25	330	27.560	83	25.740	247	1.820	176	1.800	-	-	10	0.002	61	0.0200

If the specific diversity was greater in the shallow waters communities (H = 2.27 in front of Danube Delta), in the open sea areas the structure of them was simplified, being dominated by copepods, which gave here the highest biomasses constituted almost exclusively by big-sized copepod *Calanus euxinus*.

On the whole area investigated in 1991, there is saying that the peak of quantitative development of the zooplankton took place in spring, after that, in July, the structure of communities illustrated the precarious state of it, as in anterior years (1989, 1990). All the trophic groups had a very dropped quantitative level, especially the copepod densities were reduced to a half facing of May (627 ind.m^{-3} maximum density), but more conspicuous in Constanta zone (Fig.1).

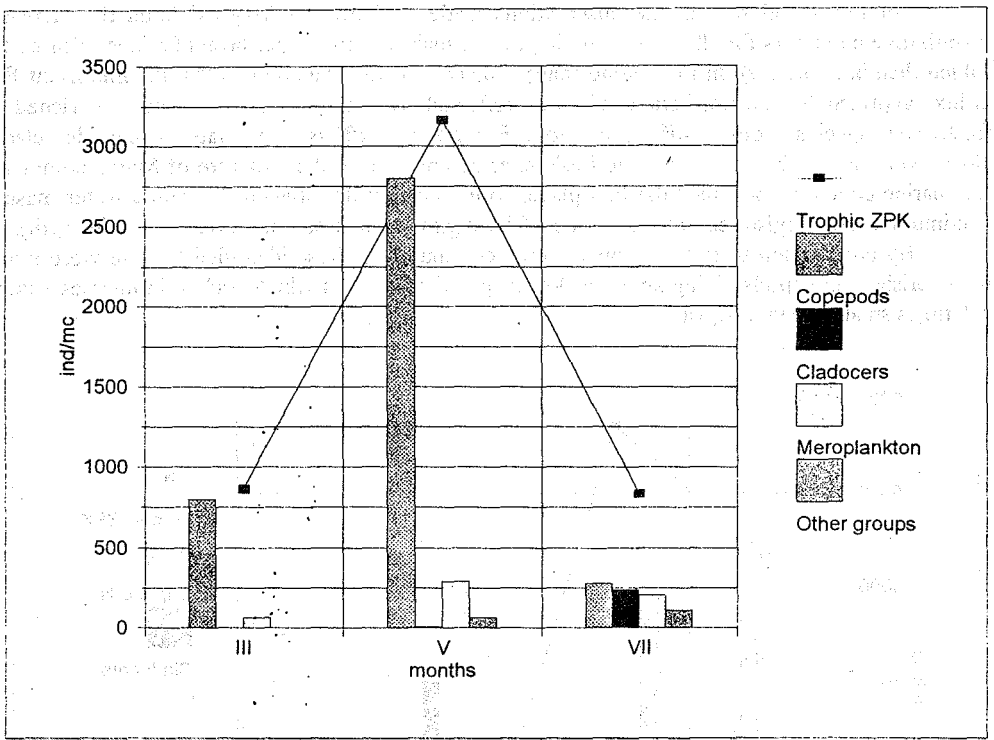

Fig.1 - Seasonally structure of the zooplanktonic populations in Constanta zone (mean densities in 10-0 m horizon), during 1991

The zooplanktonic communities from Constanta zone were prevailing by the *Noctiluca scintillans* (D = 90.1 - 99.8 %), the highest densities and biomasses being found in the coastal waters (33,712 ind.m^{-3} and 2,696.96 mg.m^{-3}). The overwhelming phytoplanktonic bloom occurred in July-August, which produced huge detritus and organic matter quantities in water masses, supported the development of these large *Noctiluca*'s population, detritus-feeder species in the greatest percentage.

The samples of July contained also numerous fragments as well as small-sized individuals (2-6 mm) of *Mnemiopsis*. The observations and assessments made during two cruises (July and August) with "Bongo" ichtyoplankton-net within 25-0 m layer, gave a figure of 620.09 g.m^{-2}, while the density of adults varied between 17 and 82 ind.m^{-2} (GORBAN, pers.comm.).

The structural degradation and the diminution of whole trophic species populations in the coastal ecosystem were to be pointed out in the following years too - 1992 and 1993.

Seasonally analyse of the communities identified during 1992 on the Romanian waters, has evinced that the annually curve of the quantitative development had the same shape, with a peak during the spring.

In February, the copepod dominated the communities, especially cold water lover species, the most elevated biomasses being registered in the offshore spaces where *Calanus euxinus* gave the highest values in the whole water mass. In terms of specific diversity, the coastal waters were richer, dense microzooplanktonic populations (tintinnids and rotifers) were met, besides meroplanktonic elements as well as cladocers. However, the quantitative indicator of biomass reflected values of four times smaller than in the offshore waters.

For the vernal season, the observations made in April and May exhibited the increase of quantitative indicators for all zooplanktonic groups, mainly in the upper layers (values of three times folded than in February). In the marine spaces adjacent to the Danube mouths, the important fluvial influx favorized by the northern winds was reflected by the specific composition, enriched with freshwater species: some rotifers, calanoid *Eurytemora affinis*, freshwater cyclopids, cladocer *Bosmina longirostris*. Apart from the freshwater component, in the structure of May's communities the marine copepods occupied the first place, with abundant densities in the whole water mass (the maximum density registered in Mila 9 zone - 67.4 mg.m^{-3} was three times greater than in April).

By comparison to spring zooplanktonic communities, those identified in June were strongly impoverished, copepods giving six times lower quantitative level which lead to biomasses values of 4-5 times smaller than in April.

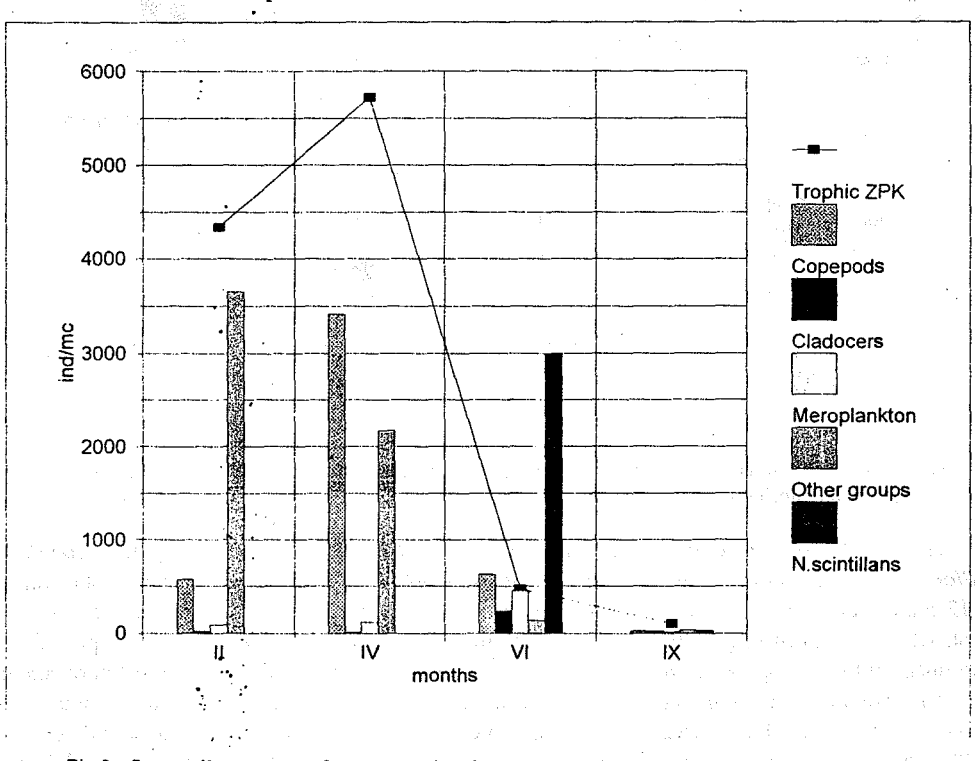

Fig.2 - Seasonally structure of the zooplanktonic populations in Constanta zone (mean densities in 10-0 horizon) during 1992

As in the coastal water there was identified a very ample phytoplanktonic bloom, especially in the samplings made later in this month, *Noctiluca* flourished up to density of 600,000 ind.m^{-3}.

The decreased values registered for the zooplanktonic quantities in June 1992 were put in the tendency noted during previous three years, in which there was obvious the depletion of populations in the course of summer. The tendency of depletion go on accentuated in August and September (Fig.2).

In August 1992 for instance, the research of the zooplankton biocoenose from a large predanubian area (from the Danube mouths up to Chituc-Portita sector), depicted us an absolutely catastrophic situation, both as reduced specific diversity and also an extremely decreased quantitative level, which lead to the smallest densities and biomasses (less than 1 mg.m^{-3}).

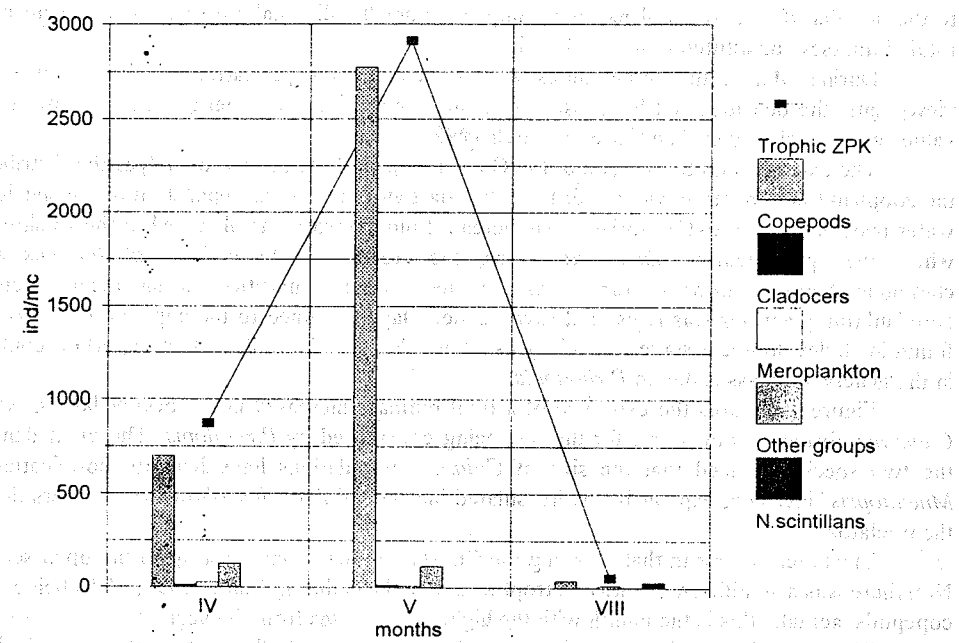

Fig.3 - Seasonally structure of the zooplanktonic populations in St.George zone (mean densities on 25-10 m horizon), during 1992

Figure 3 illustrates very well the continually descent of the zooplankton density curve from spring towards August, in the St.George zone.

The presence of *Mnemiopsis* was recorded for all samples both as fragments of the big-sized adult bodies and also as juveniles (the last ones gave a maximum density of 586 ind.m^{-3} in the shallow waters).

A reduced level of the trophic zooplankton was registered both in Constanta zone and southern littoral, in September 1992; in the shallow waters in front of Constanta there was surprised the poorest community, formed only from three species - *Balanus* nauplii (12 ind.m^{-3}), the ciliate *Strombidium* sp. (13 ind.m^{-3}) and the copepod *Acartia clausi* (1 ind.m^{-3}). Next month, the

zooplankton was also very impoverished quantitatively, being dominated by microzooplancters (ciliees and rotifers).

So, there is saying that, the curve of seasonally quantitative evolution marked an increase towards spring, when the maximum values are situated, after that, beginning in early summer it is continually descending on the whole zone investigated in 1992.

Among the five years taken into account, the quantitative and qualitative structures of the zooplankton populations identified during 1993 had an evolution encircled in the tendency signaled in the previous three years, in the manner of a severe diminution of the numerical densities of all trophic species during the summer.

Unlike the winter 1992, the structural parameters registered in February 1993 demonstrated the existence of the communities more poorer, the bulk of the biomasses being below 1 $mg.m^{-3}$. Due to the fact that the microzooplanktonic groups with small individual biomass are dominant now, the total biomasses constituted remain reduced.

During March, the communities were enriched from qualitatively and also quantitatively viewpoints, the densities and biomasses of all species were much superior, consequently the mean values were much higher than those of March 1992.

The extension up to 100 Nm of the Constanta profile, afford us to analyze the distribution of the zooplankton in relation with the distance by coast and the vertical repartition of the species in the water masses up to 200-150 horizon. An increased biodiversity was observed in the offshore areas, where the appendicular *Oikopleura dioica*, the ctenophore *Pleurobrachia rhodopis* and the chetognat *Sagitta setosa* occurred. As for the vertical repartition, a significant increase of zooplankton quantities was registered towards deep layers, owned to the copepod *Calanus euxinus* found in all development stages especially as adults. At 100-150 m depths an important contribution in the general biomass is due to *P.rhodopis*.

Figure 4 pictures the existence of a total biomass increased in the deeper layers, where the *C.euxinus* formed about 50 %, for the rest being constituted by *P.rhodopis*. The great densities of the two species evinced that the size of *Calanus*' populations have had no modifications after *Mnemiopsis* ' invasion, explainable by its isolated biotop and that *Pleurobrachia* no enters the diet of the predator.

Thus there is saying that all along the Constanta area, from coast up to the open sea, at 100 Nm, there was a significant quantity of trophic zooplankton during March 1993, 85 % being given by copepods, actually this is the month with the highest biomasses from the year.

The research made in predanubian zone later in May, as well as in the other zone during June exhibited that the zooplankton was much more impoverished comparatively with the previous years. If we refer to the mean trophic biomass on 50-0 column in Constanta zone, it was about 20 times smaller (0.26 $mg.m^{-3}$) than these registered in June 1992 (4.82 $mg.m^{-3}$) in the same zone.

The picture of the August and September's zooplankton looked like that of previous summers, when the decrease in trophic zooplankton quantity was signaled as a result of massive proliferation of the new colonizer during this season, present in all our samples. Particularly in Constanta and Mangalia sectors, the quantitative level of all the trophic zooplankton groups was the most diminished (about 1 $mg.m^{-3}$).

It must be noted also the reduced *Noctiluca*'s populations from August 1993 (1.323 $ind.m^{-3}$ maximum density), due to the absence of ample phytoplanktonic blooms.

The collapsed values of the zooplanktonic biomasses from the whole interval June - September 1993 were placed on the tendency od severe decline in the populations having trophic role in the ecosystem signaled for all the five years, reflecting the stressed state of the pelagial realm, dominated by the baneful influence of the *Mnemiopsis leidyi*.

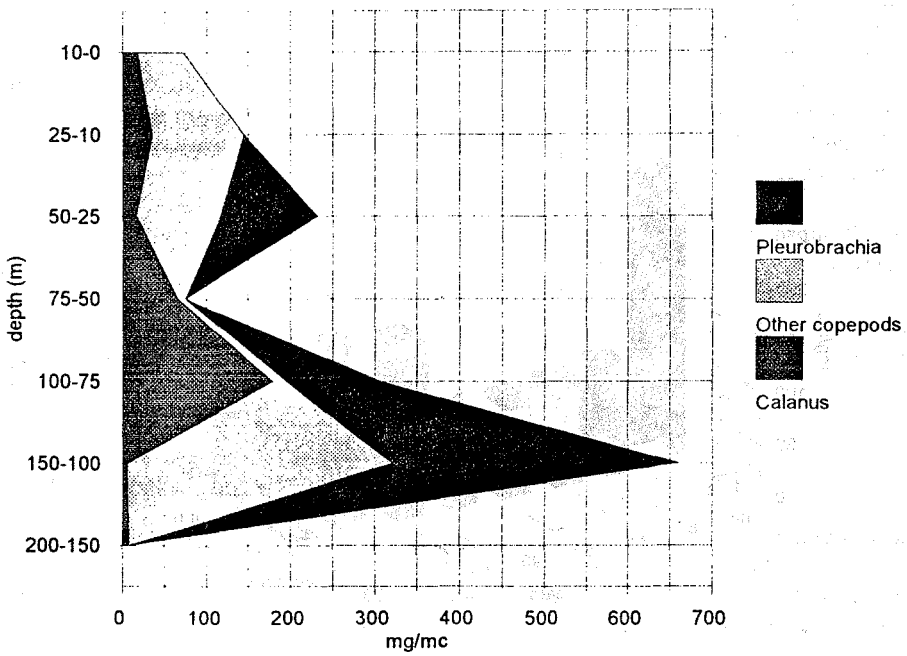

Fig.4 - Vertical distribution of the zooplankton biomass in offshore waters of Constanta during March 1993

The analyze of the zooplankton quantities evolution in the Romanian littoral waters of the Black Sea during 1989-1993, when a new invader - the lobate ctenophore *Mnemiopsis leidyi* occurred in the pelagial, have displayed some aspects which can be attributed to the pressure exerted upon zooplankton community by this voracious predatory.

So, the first peculiarity of the zooplankton evolution within this period was its modified seasonally dynamic. If up to 1988 there were usually two periods of maximum development of the zooplanktonic quantities, one more reduced during spring time, and the second and most important one, during summer, when the peak of annual curve took place, in the course of last years only the vernal one remained (Fig.5).

If during throughout 1980-1987 period, a small number of opportunistic zooplanktonic species but forages for planktivorous fish (copepod *Acartia clausi* and cladocer *Pleopis polyphemoides*) had had high quantitative level, giving large biomasses especially during summer, beginning in 1989 the qualitatively impoverishment and very reduced quantities of trophic zooplankton in the very summer were to be noted, that is while the ctenophore was registering its maximum development.

The diminution of the zooplankton biomasses owned to very dropped level of trophic organisms - copepods, cladocers, meroplankters - resulted in implicitly the diminution of food for planktivorous fish, the stocks of these fish decreasing also in this period. Thus, the *Mnemiopsis* invasion has had a grave impact on the Black Sea fisheries, the pelagic fish stocks drastically decreased after 1988. The recruitment of harvestable generation of pelagic fish was depleted to

negligible levels. These events were a consequence of the direct grazing impact of new predatory intruder, which completed with these fishes for food and ate their eggs and larvae (CADDY, 1993).

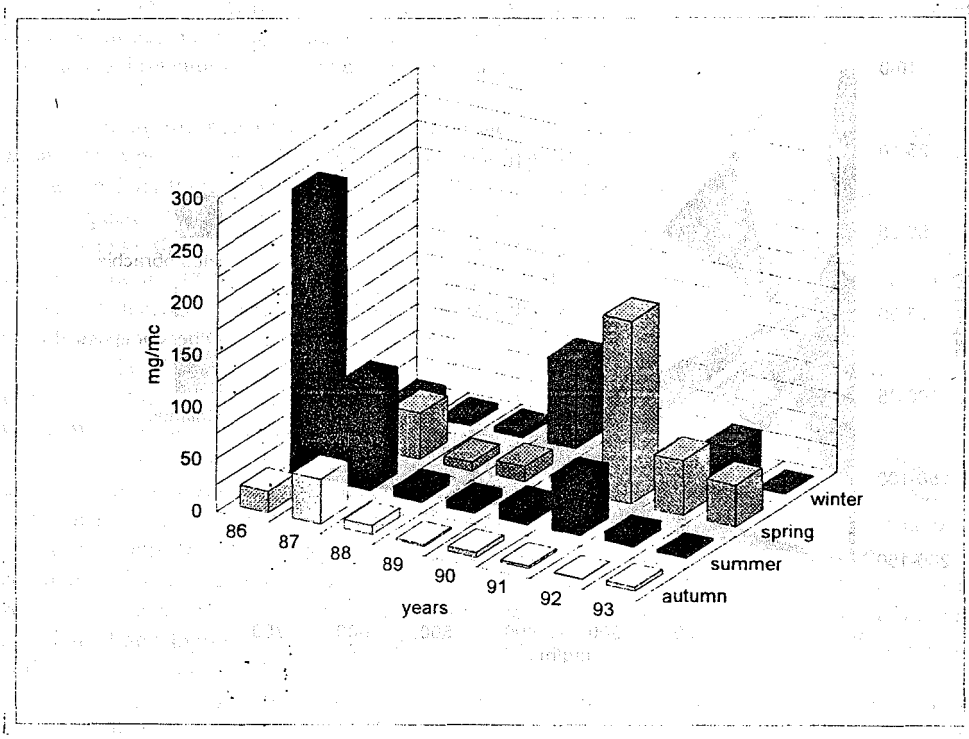

Fig.5 - Annually and seasonally evolution of the trophic zooplankton biomasses in the Constanta zone (mean values on 25-0 m water column)

Romanian researches have shown the strong collapsing of the harvestable stocks beginning in 1990 comparative with previous decade, as well as the decrease of anchovy and mackerel eggs and larvae (NICOLAEV, RADU, 1994).

CONCLUSIONS

- The penetration and invasion of *Mnemiopsis leidyi* into the Black Sea took place in an ecosystem already disturbed, heavy eutrophicated, with a descending diveristy, but however with a relatively good stock of zooplankton food.

This opportunistic species, with ecological capabilities of adaptation more potent than the autochtonous ones, finding favourable environmental conditions, with sufficient food supply, proliferated explosively, as it is happened with any immigrant in first stage of its colonization.

- The pressure of the predatory *M.leidyi* was felt at the Romanian littoral too, as the analyze of the zooplankton evolution during 1989-1993 illustrated. In the seasonally dynamic, the summer season was characterized by extremely reduced quantities of all the trophic zooplanktonic groups, with very small biomasses never registered before at the Romanian littoral.

- All along the June-October period, the zooplanktonic samples contained small-sized juveniles of *Mnemiopsis* (1-6 mm) as well as fragments of adult individuals.

- The impact of *Mnemiopsis* upon marine ecosystem must be considered first against the pelagial, where the thousands of individuals consume huge quantities of zoo- and ichtyoplankton, but also against the benthos, in the diet of this animal entering also larvae of benthic invertebrates.

- In the pelagial realm, the heavy grazing of the ctenophore with zooplankton organisms, which are phytophagous in majority, means not only the diminution of the trophic zooplanktonic base but also an enormously reduction of herbivorous feeders, thus a mitigation of the control exerted by zooplankters on primary phytoplanktonic production, which is already excedentary.

- *Mnemiopsis* - having a gelatinous body induces by itself the degradation of marine environment conditions, due to massive precipitation of mucus eliberated after the death of its densely populations.

- Due to the fact that *Mnemiopsis* like *Aurelia aurita* has no consumers in the Black Sea it represents a closed way in the trophic chain of the sea, in fact losses of organic matter produced in this basin.

- Taking into account the damages produced after the penetration of *Mnemiopsis* into the Black Sea waters, the invasion of its may be considered as an authentic biological pollution, as another sequence of an ecosystem already degraded and disturbed by other anthropic factors.

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