THE PHYTOPLANKTON COMMUNITY - AN INDICATOR OF THE ECOLOGICAL STATE ALONG THE BULGARIAN BLACK SEA COAST IN THE SUMMER OF 2006

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ABSTRACT

Phytoplankton constitutes an elementary component in aquatic ecosystems. Representing the base of the pyramid of productivity, the understanding and modeling of the aquatic ecosystem is not possible without knowledge of the species composition, productivity and biomass of phytoplankton.
As a result of the observations in the studied period the dynamics of phytoplankton parameters in the Bulgarian Black Sea were investigated.

KEY WORDS: phytoplankton, species composition, Bulgarian coast, chlorophyll-a, salinity, temperature

INTRODUCTION

For the Black Sea ecosystem the phenomenon of water quality deterioration has been evident since the early 1970-s (SIMONOV *et al.,* 1991; VINOGRADOVA *et al*., 1992; HUMBORG *et al*., 1997). It has significantly influenced fishing, aquaculture, tourism and caused enormous economic losses. In the period 1972-90 the expansion of zones of hypoxia resulted in death of million tons of crabs, mussels, snails, bottom fish, etc. per annum (ZAITSEV & MAMAEV,1997). The reduced water transparency due to the high level of phytoplankton biomass was responsible for the decline in populations of various macrophytes. Changes in biodiversity, predomination of species, resistant to “stress”, mass development of opportunistic species (*Noctiluca scintillans, Mnemiopsis leidyi, Pleurobrachia rhodopis, Aurelia aurita*) were reported in the 1980-s to be in connection to effects of eutrophication and consequent frequent algal blooms in the Black Sea (ATANASOVA, 1995; BODEANU *et al.* 1998; MONCHEVA and

KRASTEV, 1997; PETROVA-KARADJOVA, 1984, 1990, 1998, 1999; VINOGRADOVA *et al*., 1992.; VELIKOVA *et al*.,1999).

However, since the early 1990-s the persistent reports about the irreversibly degrading Black Sea have started disappearing (PETROVA, 2003, 2004, 2005; PETROVA & VELIKOVA, 2005; VELIKOVA *et al*., 2004).

Number of abiotic and biotic environmental variables has been under regular observation during the 1990-s off the Bulgarian Black Sea coast by the Institute of Fishing Resources - Varna. This effort is a part of a routine monitoring, carried out in Bulgarian waters since 1954 (PETROVA, 1963, 1964, 1965, 1973, 1984, 1990). The large set of data, reflecting the temporal and spatial variability of different ecosystem levels, allows to compare the present-day functioning of the studied ecosystem to previous ones and to certainly conclude on some positive signs. For instance, hypoxic situations have been observed in isolated cases, related to a decrease in maximum phytoplankton densities attained, especially of summer blooms (PETROVA *et al*., 2004; PETROVA & VELIKOVA, 2005; MAVRODIEVA *et al*., 2005).

The observed positive tendencies in the Black Sea were related to the economic problems of the adjoining countries and concurrent reduction of anthropogenic influence, both eutrophication and overfishing (MEE, 1999), as well as to climatically induced shifts in the seasonal cycles of the ecosystem parameters investigated.

As a result of the observations in the studied period-July 2006 the dynamics of phytoplankton parameters in the Bulgarian Black Sea coast were investigated in comparison to previous periods.

MATERIAL AND METHODS

Total 22 samples of phytoplankton were collected in the Bulgarian part of the Black Sea during the studied period in the frame of the project ARCADIS. The sampling was performed at standard depths surface-bottom (Table 1).

Sampling is performed on board by water bottles (5-10 L Niskin), attached to CTD-rosette system at surface-bottom and/or at depths of maximal concentrations of chlorophyll a, observed by a CTD-probe. The samples are preserved on board in formaldehyde at a final concentration of 2%. The bottles with preserved samples of 500 ml volume are transported to the laboratory-IFA-Varna. Then left for at least a 10 days the cells inside the bottles to settle onto the bottom of the bottles. The free of algal cells sea-water is slowly removed from the bottle to avoid re-suspension of the cells. The sub-sample’s volume is defined. Before processing the samples are shaken to provide their homogeneity. Taxonomic identification and counting are performed in Sedgwick-Rafter chambers of volume 0.05 and 1 ml , under light microscope NICON-E-400 in parallel (LAVRENKO, 1949, 1950, 1955, 1968; SOURNIA, 1986; VODENOCHAROV, 1971; HASLE *et al.*, 1996; KUSEL-FETZMANN, 2002; BRANDT *et al.*, 1908). Biomass we calculate an average volume for each species using formulae for geometrical shapes closest to the cells shape (EDLER, 1979). Measurements of water temperature, salinity and transparency by Secchi disc were performed.

Table 1

The station and depths of phytoplankton investigations

Station	**Max depth (m)**	**Samples depth (m)**	**Time**	**Latitude**	**Longitude**
Krapec	20	0, 10*, 17	23.10h; 05.07.2006	43^o 37.00	28^o 36.00
Rusalka	27	0, 10, 25	18.40h; 05.07.2006	43^o 25.25	28^o 33.14
Kaliakra	16	0, 8, 14	16.41h; 05.07.2006	43^o 22.00	28^o 25.00
Albena*	14	0*, 5*, 12*	13.45h; 05.07.2006	43^o 19.07	28^o 04.41
VarnaBay	8	0, 7	11.10h; 05.07.2006	43^o 10.71	27^{o}55.93
Galata*	23	0*, 10*, 21*	11.20h; 07.07.2006	43^o 09.60	28^o 00.00
Kamchia	20	0, 8, 18	09.17h; 07.07.2006	43^o 00.75	27^{o}54.60
Dvoinitca	29	0, 10, 27	06.31h; 07.07.2006	42^o 46.06	27^{o}55.34
Sarafovo	19	0, 10, 17	11.25h; 06.07.2006	42^o 30.09	27^{o}39.21
Cape Maslen *	49	0*, 10*, 46*	16.37h; 06.07.2006	42^o 20.08	27^o 49.11
Veleka	44	0, 10, 40	20.10h; 06.07.2006	42^o 04.64	28^o 00.14

* - without samples for phytoplankton

RESULTS AND DISCUSSION

During July 2006 the dynamics of water temperatures were presented on figure (Fig. 1).The distribution of the salinity (‰) varied from 9.57‰ to 16.87 ‰. The highest salinity was established of the south part of the Black Sea- st. Cape Maslen and Veleka. The lowest was in front st. Krapetc – 0m (Fig. 3).

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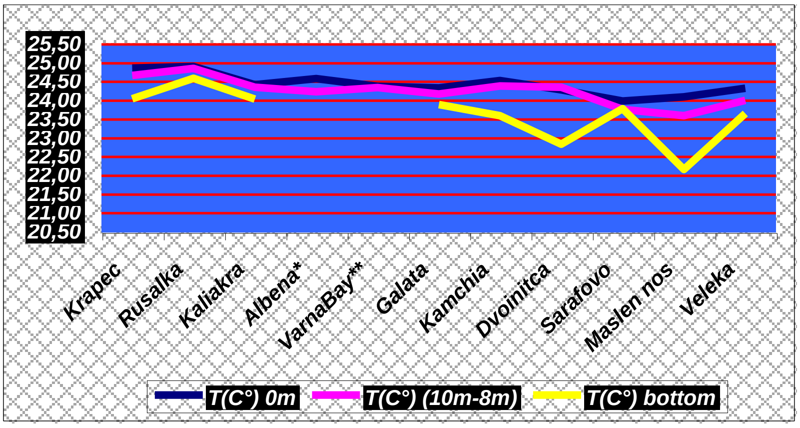

Fig. 1 - The temperature (°C) of water in July 2006
*Albena bottom depth - 12 m, **Varna bay bottom depth - 7m

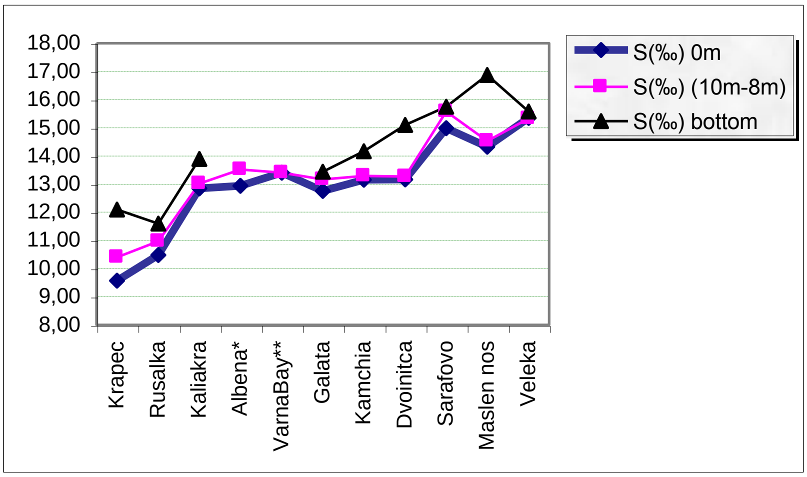

Fig.2 - The dynamics of salinity (‰) from surface to bottom coastal waters in July 2006
*Albena bottom depth - 12 m, **Varna bay bottom depth - 7m

Slight Danube influence was determinate in front of Krapec and Rusalka. The surface waters salinity was 9,57 ‰ of Krapec and 10.48 ‰ of Rusalka. High salinity was registered in front of the south part of the Bulgarian coast (Fig. 2).

Water transparency is equivalent to the depth of light penetration into an aquatic ecosystem. It depends mainly on the concentrations of suspended and dissolved organic and inorganic substances. Less absorption of light means higher transparency, therefore the turbidity of water is a relevant indicator of pollution, eutrophication and trophic status of an ecosystem.

The transparency of water was measured by Secchi disc, where possible (after dawn and before sunset). In summer period 1999-2004 the average transparency was 3.6 in coastal Bulgarian water.

In July 2006 minimal values of transparency were observed in front of st. Kaliakra and maximal in front of st. Cape Maslen , ranging between 2.0 and 5 meters, average 3.38. (Table 2, Fig. 3).

According to literature data (MARTIN, 2004; *Marine Phytoplankton*, 1974) and various recommendations for water quality assessment (*Baltic Sea Environment Proceedings* 2004; ISO 10260, 1992), the mean established value is over 3. Our observations show good state of the coastal waters referring this index.

Table 2

The transparency (m) of water in July 2006

Station	**Depth (m) with Secchi disc**	**Time**
Rusalka	2.20	18.40h; 05.07.2006
Kaliakra	2.00	16.41h; 05.07.2006
Albena	2.60	13.45h; 05.07.2006
Varna Bay	2.60	11.10h; 05.07.2006
Galata	4.00	11.20h; 07.07.2006
Kamchia	4.00	09.17h; 07.07.2006
Dvoinitca	3.80	06.31h; 07.07.2006
Sarafovo	3.20	11.25h; 06.07.2006
Cape Maslen	5.00	16.37h; 06.07.2006
Veleka	4.40	20.10h; 06.07.2006
Average	**3.38**	

*- without st.Krapec

In 2006 the phytoplankton community in Bulgarian Black Sea waters was characterized with traditional predomination of *Bacillariophyceae* and *Dinophyceae* species in taxonomical structure. During our observation we determinated *Bacillariophyceae* - 22 species, *Dinophyceae* - 39, *Cyanophyceae* - 2, *Chlorophyceae* - 6, *Euglenophyceae* - 4**,** *Chrysophyceae* - 4 and *Criptophyceae* - 3 species.

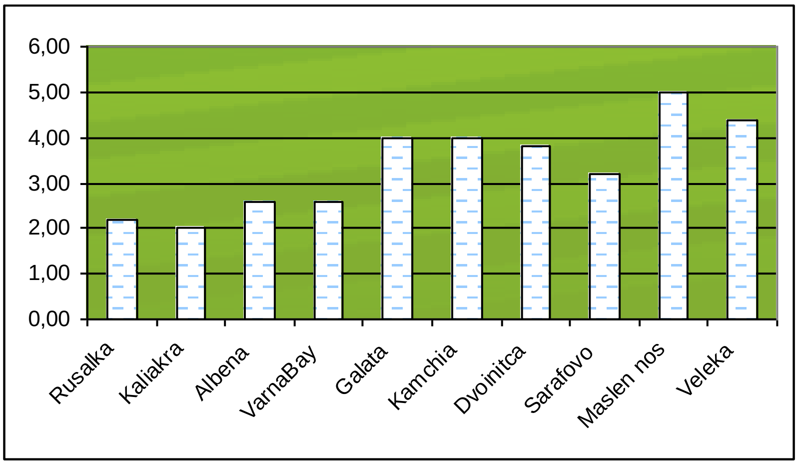

Fig. 3 -The transparency (m) of the water in July 2006

The phytoplankton consisted of the following taxonomic groups: *Chromophyta - Bacillariophyceae, Dinophyceae, Chrysophyceae - Primnesiophyceae (= Haptophyceae), Cryptophyceae; Chlorophyta - Euglenophyceae, Prasinophyceae, Chlorophyceae*; *Cyanophyta - Cyanophyceae*. The algal community was dominated by the following major species:

Bacillariophyceae. Thalassionema nitzschioides, Pseudo-nitzschia, Cyclotella caspia, Chaetoceros socialis, Chaetoceros simplex, Chaetoceros curvisetus, Chaetoceros affinis, Thalassiosira parva, Navicula sp., *Pseudosolenia calcar avis, Cerataulina pelagica* etc.

Dinophyceae. Gymnodinium elongatum, Gymnodinium najadeum, Gymnodinium sp., *Heterocapsa triquetra, Prorocentrum micans, Gyrodinium spirale, Protoperidinium divergens, Protoperidinium* sp., *Diplopsalis lenticula.* etc.

Chrysophyceae. Emiliania huxleyi, Coccolithus sp.

Cryptophyceae .Chroomonas sp., small indefinite *Flagellates, Leucocryptos marina.*

Cyanophyceae.Oscillatoria sp.

The species forming the main part of the phytoplankton density in July 2006 are presented on Table 3.

Table 3

Predominating phytoplankton species in July 2006 (densities in mln. cells.l $^{-1}$)

Region	**Species / densities**
Krapec 0m	*Cyclotella caspia* – 1.21485
	Flagellates – 0.85139
	Nitzschia tenuirostris – 0.27384
Krapec 17m	Flagellates – 0.86308
	Cyclotella caspia – 0.40821
Rusalka 0m	*Cyclotella caspia – 1.54368*
	Oscillatoria sp. – 0.84561
	Flagellates – 0.61891
	Thalassionema nitzschioides – 0.27167
Rusalka 10m	*Cyclotella caspia* – 1.03235
	Flagellates – 0.80294
	Oscillatoria sp. – 0.44899
	Oscillatoria bulgarica – 0.40966
Rusalka 25m	Flagellates – 0.72069
	Cyclotella caspia – 0.62410
	Oscillatoria sp. – 0.61296
Kaliakra 0m	*Oscillatoria* sp. – 1.35696
	Flagellates – 0.95875
	Cyclotella caspia - 0.43372
	Thalassionema nitzschioides – 0.18008
Kaliakra 8m	Flagellates – 0.91556
	Cyclotella caspia – 0.29556
	Thalassionema nitzschioides – 0.17333
Kaliakra 14 m	Flagellates – 0.21840
Varna Bay 0m	Flagellates – 1.67774
	Oscillatoria sp. – 1.01887
	Cyclotella caspia – 0.13925
	Gymnodinium sp. – 0.10302
Varna Bay 7m	Flagellates – 1.45516
	Oscillatoria sp. – 0.51941
	Cyclotella caspia – 0.27082
	Leucocryptos marina – 0.10307
Kamchia 0m	Flagellates – 1.04118
	Oscillatoria sp. – 0.45529
	Cyclotella caspia – 0.30353
	Thalassionema nitzschioides – 0.20118
Kamchia 8m	Flagellates – 1.01218
	Cyclotella caspia – 0.22185
	Thalassionema nitzschioides – 0.16870

Region	Species / densities
Kamchia 18m	Flagellates – 0.57906
	Thalassionema nitzschioides – 0.05175
Dvoinitca 0m	Flagellates – 0.51609
	Thalassionema nitzschioides – 0.16109
	Cyclotella caspia – 0.15214
Dvoinitca 10m	Flagellates – 0.96971
	Oscillatoria sp. – 0.23712
	Cyclotella caspia – 0.22650
	Thalassionema nitzschioides – 0.19111
Dvoinitca 27m	Flagellates – 0.31464
	Thalassionema nitzschioides – 0.03518
Sarafovo 0m	Flagellates – 0.75688
	Thalassionema nitzschioides – 0.11141
	Gymnodinium sp. – 0.05860
Sarafovo 10m	Flagellates – 0.66205
	Cyclotella caspia – 0.03838
Sarafovo 17m	Flagellates – 0.477869
	Gymnodinium sp. – 0.03558
Veleka 0m	Flagellatea – 0.58454
	Oscillatoria sp. – 0.06218
Veleka 10m	Flagellates – 0.61862
	Thalassionema nitzschioides – 0.08129
Veleka 40m	Flagellates – 0.51250
	Thalassionema nitzschioides – 0.05125

The number of phytoplankton species as a result of the investigations in July 2006 are presented in Table 4. Eighty species have been observed in the one-mile zone during the entire survey.

According to the index of marine phytoplankters number the marine environment state could be qualified as very good.

On the st. Krapec and Rusalka predominated *Bacillariophyceae (Cyclotella caspia)* according to abundance. The results showed good correlation between salinity (‰) and density of *C. caspia* (Fig. 2, Fig. 5). The maximal values of *C. caspia* were registered on st. Rusalka. Small flagellates were widely distributed in all areas of observations (Fig. 4) with maximal value in the Varna Bay (Fig. 6).

Table 4

Number of algal species by main groups in the period of observation

	Karapec	Rusalka	Kaliakra	Varna bay	Kamchia	Dvoinitca	Sarafovo	Veleka
Bacillariophyceae	11	12	13	10	8	6	15	11
Dinophyceae	13	24	28	30	21	23	30	29
Others	6	13	10	14	11	11	9	7
Total	**30**	**49**	**51**	**54**	**40**	**40**	**54**	**47**

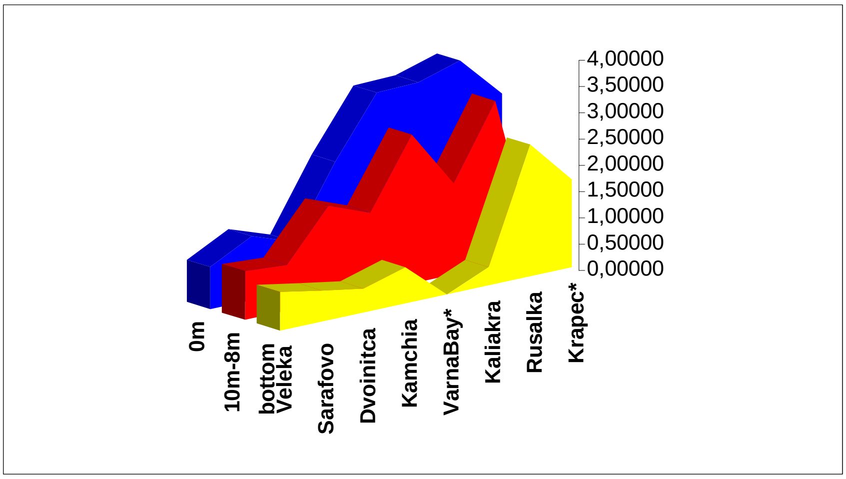

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Fig. 4 - Distribution of phytoplankton densities (cells $.10^6.l^{-1}$) in July 2006

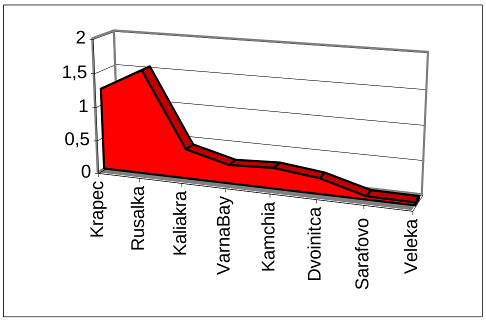

Fig. 5 - Distribution of maximal value of *Cyclotella caspia* (densities/cells$.10^6.l^{-1}$/) in all investigated aquatories

The high number in the north part of the Bulgarian coastal zone is formed mainly by Flagelates (Fig. 6), Diatoms and *C. caspia* which maximum values are pointed on Table 3.The dominate species *C. caspia* decreased from north to south part of the Bulgarian coast (Fig. 5).

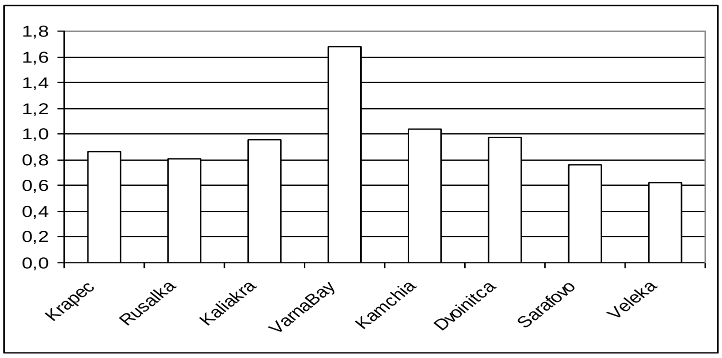

Fig. 6 - Distribution of maximal value of small *Flagellates* (densities/cells.$10^6.l^{-1}$/) in all investigated aquatories

The phytoplankton biomass ($mg.l^{-1}$) in the layer of observations (surface - middle-bottom) in the studied aquatories are presented in Fig. 7. Only at st. Sarafovo and Rusalka were registered high values of phytoplankton biomass in the surface water.

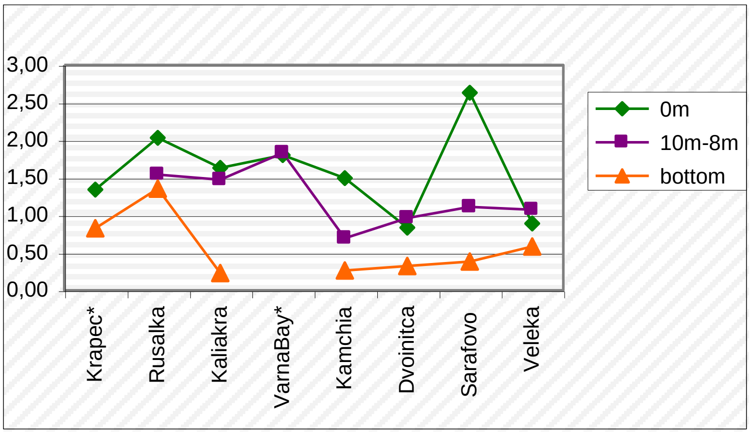

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Fig.7 - Phytoplankton biomass ($mg.l^{-1}$) in the layer of observations in July 2006 along the Bulgarian Black Sea coast

The 1980s, a period of progressive eutrophication, showed a clear consistence between major shifts in the Black Sea community and the world-wide spreading phenomenon of increasing tendency in phytoplankton abundance and production in coastal waters (Fig. 8).

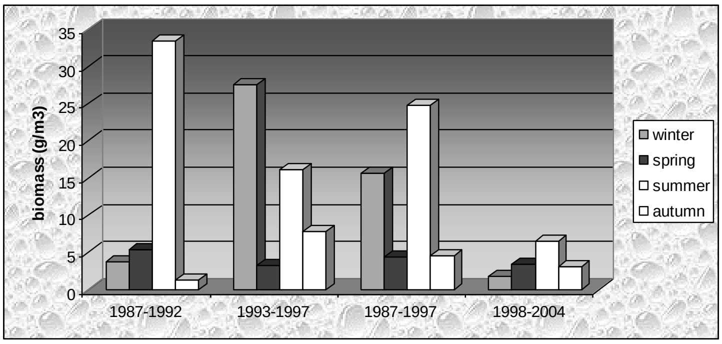


Fig.8 - Phytoplankton biomass (g/m³) in the Bulgarian coastal water 1987-2004

In the 1990s, as a result of the economical problems of the Black Sea adjoining countries and the reduce anthropogenic influence, the situation changed. Subsequently, during the last decade the phytoplankton community maintained the capacity to produce huge biomass, but decreasing tendency in comparison to the 1980s, especially since 1995 was established.

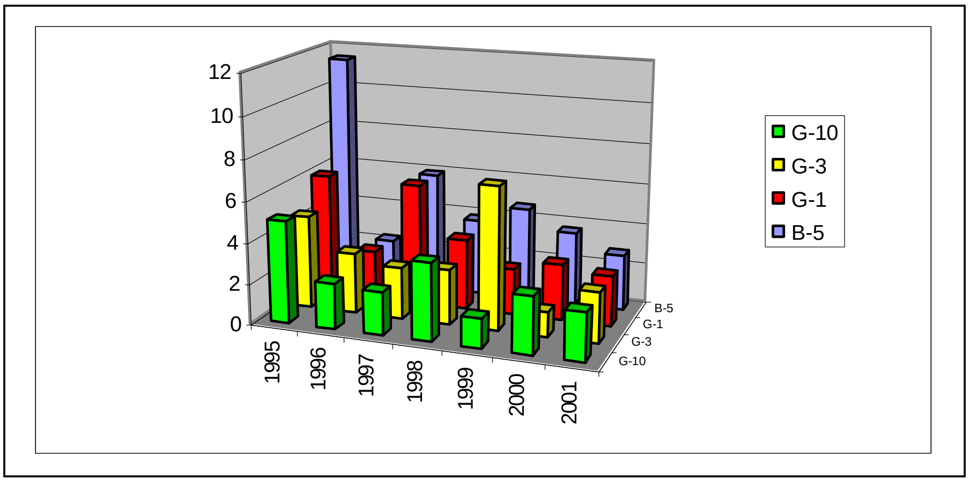


Fig. 9 - Integrated phytoplankton biomass (g.m^{-3}) in the Bay of Varna (B-5) and in front of the Cape Galata at 1, 3, 10 miles offshore in 1995-2001

One of the most traditional blooming species in the Black Sea – *Prorocentrum cordatum* was registered in very low concentrations, which was well related to the depleted levels of nutrients observed in the Bulgarian Black Sea in 2001-2005.

Since 1995 relatively stable decreasing tendency of phytoplankton biomass was found in coastal waters of the Bulgarian Black Sea (Fig. 9). Throughout the whole 2001 year the level of algal biomass remained relatively low in comparison with previous years. This tendency continued in the coastal waters on next years (summer).

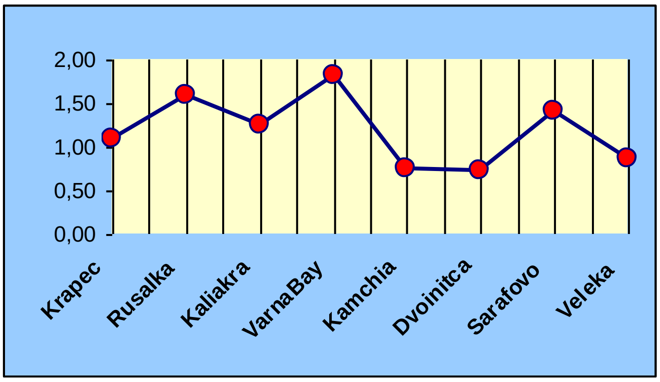


Fig.10. Average phytoplankton biomass ($mg.l^{-1}$) in July 2006

In July 2006 the highest biomass was established in north part-st Rusalka, central part- st.Varna Bay and south part - st. Sarafovo (Fig. 10). On the st. Rusalka dominated *Cyclotella caspia* and *Thalassionema nitzschioides*, where the influence of Danube transformed waters along the Bulgarian coast is most pronounced. The highest biomass of st. Varna Bay formatted by *Dinophyceae-Gymnodinium* sp., *Gymnodinium agiliforme*, *Glenodinium paululum*. On the st. Sarafovo according to biomass predominated *Dinophyceae-Gymnodinium najadeum*, *Gymnodinium* sp.

The mean phytoplankton biomass of the entire surveyed area is 1,18663 (g/m^3) which shows a good state after biomass criterion. This summer biomass registered in front of the Bulgarian coast approaches the summer values of the so called "pristine " period (Fig. 11).

Traditional blooming species in the Black Sea – *Prorocentrum cordatum, Cerataulina pelagica, Emiliania huxleyi* etc. were registered in low concentrations.

Vertically, the phytoplankton was concentrated in the layer 0-10 meters with maximal values mainly at 0 meters (except in front of the st. Dvoinitca and Veleka, when the maximal values were in the middle layers).

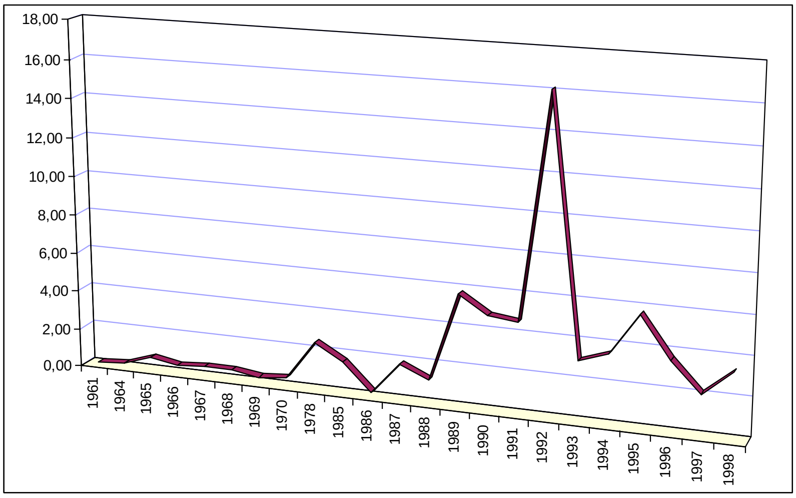


Fig.11 - Phytoplankton summer biomass (g/m^3) in the Bulgarian coastal area for a long term period

For the Black Sea phytoplankton annual development maxima in spring and autumn are concidered as "natural" in connection with the natural hydrological and hydrochemical cycles of marine environment. Late spring and summer blooms are not typical for the Black Sea ("induced") and are idicators for the degree of antropogenic euthrophication (enrichment with nonorganic nutrients and dissolved organic matter). Their frequence, intensity and duration are an indicator for ecological disbalance of the system. Worldwide still there is not an uniform conception for "bloom" - unified value for number (for species with small sizes) or biomass (for species with big sizes). For the Black Sea the following values are arbitrarly assumed - over 1x10^6 cl/l (bloom) and over 5x10^6 cl/l (red tide), and biomass respectively over 10-15 and over 30 g/m^3 (BODEANU *et al.*, 1998; VELIKOVA *et al.*, 1999). Within the context of determination of referent and /or limiting conditions it is necessary to define precise "background" bloom values.

No exceptional blooms of harmful or potentially toxic algae have been observed in July 2006, respectively no cases of hypoxic situations and benthic mortality were found.

The diversity index of Shannon-Weaver was calculated as a classical measure of stability. This index in investigation period showed the positive tendency in the state of ecosystem of Varna Bay. There was not degradation of the stability of ecosystems (Fig. 12) .

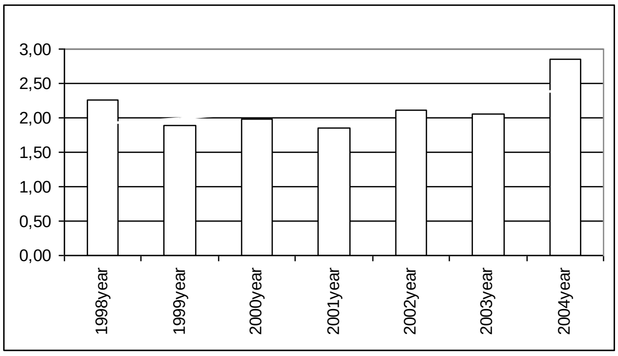
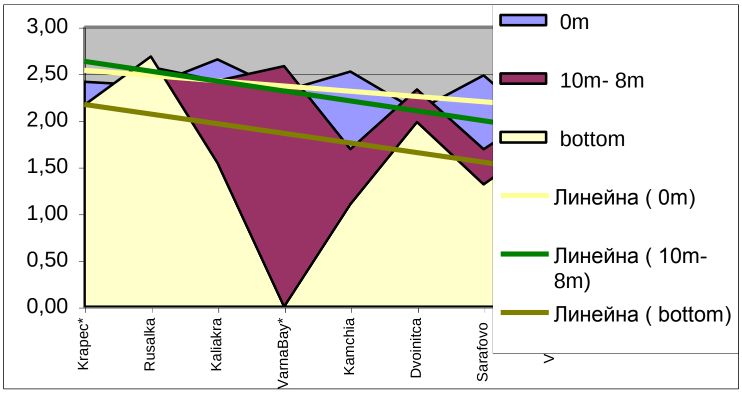


Fig.12 - The Shannon–Weaver index in period 1998-2004 in the Varna Bay

In July 2006 the values of the Shannon -Weaver diversity index for phytoplankton showed good stability of communities.



*- only two depths

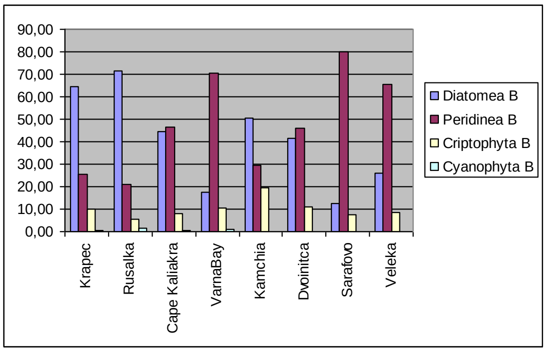
Fig. 13 - The Shannon–Weaver index with depth for each stations

Table 5

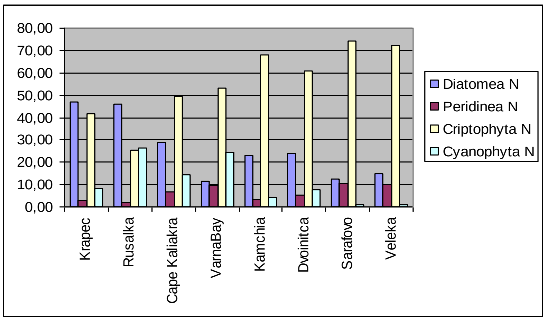
Percent correlation of species composition in July
in the Bulgarian coastal zone

Bacillariophyceae	Dinophyceae	Cyanophyta	Chlorophyta	Euglenophyta
27.50	48.75	2.5	7.5	5.00

In investigation period the small-size *Diatoms* or *Flagellates* were the predominant type in the structure. This tendency was established during the last years (1990-2004) in the Bay of Bourgas when was observed pronounced shifts in seasonal dynamics of algae, decrease in their biomass but increase in density due to proliferation of small-size phytoplankton. Large-size diatoms decreased their density and the algal community was often dominated in density by small flagellates or heterotrophyc species (MAVRODIEVA *et al*., 2005).



(A)



(B)

Fig. 14 - Percent correlation of the Biomass (A) and Density (B)
of the main phytoplankton groups at the stations

The algal biomass was with two maxima – in winter-spring and late summer-autumn, while algal density was maximal usually in winter – spring. Therefore, shift in the phytoplankton annual dynamics was found in the late 1990s and after 2001 in comparison with the 1980s, when the yearly maxima of all phytoplakton parameters were mainly in summers recorded (MAVRODIEVA *et al*., 2005).

The investigations of Chlorophyll-a (2006) in coastal area showed low values of this parameters (Fig. 17). The highest of them were observed only on st. Rusalka, Varna Bay and these data correlations with previously observations in 2002-2005 (Fig. 15,16).

The observed positive correlation between chlorophyll-a and phytoplankton exhibits a high productive capacity of the phytoplankton community. The low values of both parameters allow to determine water quality as a good one.

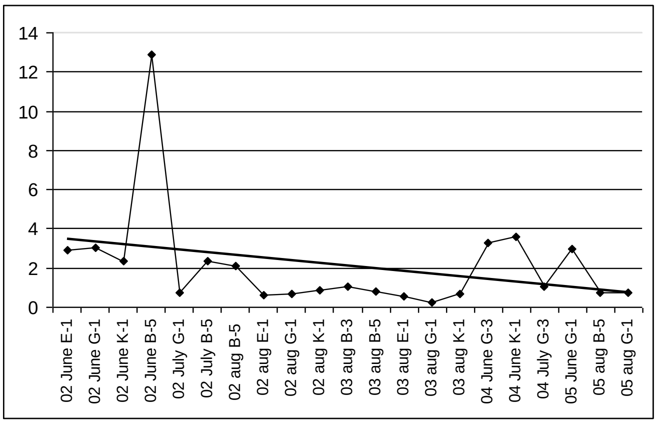


Fig. 15 - Maximal values of Chlorophyll-a (mg/m3) in coastal area
in June, July, August 2002-2005

In July, during the more pronounced influence of Danube transformed waters, the chlorophyll_a showed relatively high values in front of the st. Rusalka and in the Bay of Varna. The values in the whole investigated area varied in the range 0.52 - 4.75 µg/l. Vertically the phytoplankton was concentrated mainly in the surface waters.

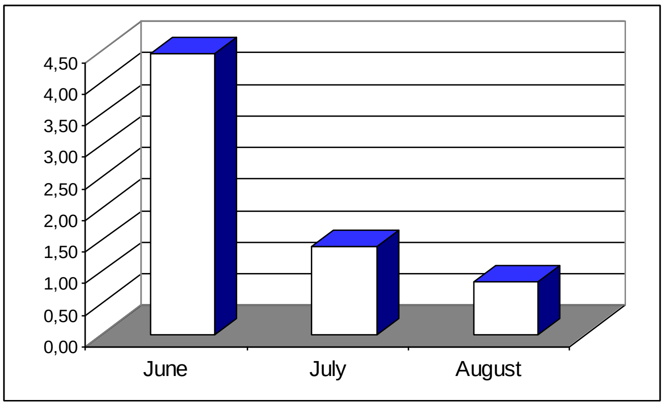


Fig.16 - Average values of chlorophyll-a (mg/m3) in 2002-2005

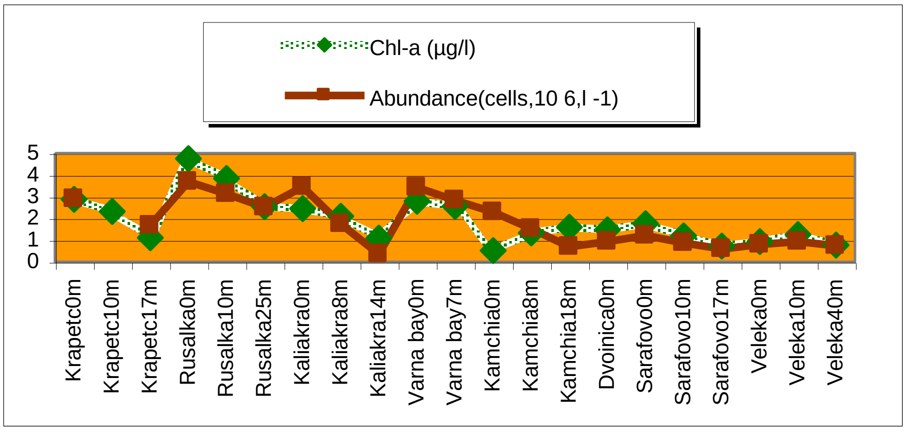


Fig.17 - Distribution of phytoplankton and chlorophyll-a in July 2006

CONCLUSIONS

The higher phytoplankton biomass was observed at st. Rusalka, Varna bay and Sarafovo , there was many sources of human activities and pollutions. The mean phytoplankton biomass of the entire surveyed area is 1,18663 (g/m^3) which shows a good state after biomass criterion.

The low values of concentration of Chlorophyll-a determine the investigation coastal area like good. Small–size diatoms and flagellates were widely distributed in all areas of observations. No exceptional blooms of harmful or potentially toxic algae have been observed in July 2006, respectively no cases of hypoxic situations and benthic mortality were found.

All investigating parameters showed good status of phytoplankton community in the Black Sea coastal water.

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