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MAJOR BLOOM PRODUCING PHYTOPLANKTON SPECIES IN THE LAKES ALONG THE BULGARIAN BLACK SEA COAST

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Abstract

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Archive data analysis shows that during the different periods of anthropogenic impact phytoplankton production reaches pathologically high levels. Thus, phytoplankton is assumed as an indicator of marine water quality and ecological health. Its long-term excess in the Black Sea suggests the steps forward for better understanding and management of the existing process.

Phytoplankton surplus production exhausts the ecosystem and leads to blooms with respective consequences: changes in water color (red, brown), bad smell, sliming of the body, indigestion after consumption of sea foods.

Blooms may last from 10 to 20 days which is disastrous for the bottom coenoses and tourist business.

The article presents the main phytoplankton species dynamics during the period 1991–2003 which has led to the above mentioned conditions.

Key words: Black Sea, phytoplankton, blooms

Introduction

Since many years the biocoenosis of Varna and Beloslav Lakes has been affected by eutrophication processes induced by high content of biogenes, Provadiiska River inflow–carrier of anthropogenic load and contaminants from Devnya plants, heat pollution form Heating Power Station–Varna, (Trayanov, 1991; Trayanova, 2002).

These processes are associated with strongly negative impact on lakes water quality and tourist business. Aberration in microalgae number, low water transparency, foam polluted beaches, death of fish and jellyfishes, and man'sillnesses are consequences which exclude lakes as a place for tourism and recreation. From ecological view point the stability of Varna Lake system was distorted to an extend at which the phytoplankton itself became of component of eutrophication, (Moncheva, 1997; Trayanova, 2003).

Why do we often return to the historical records of the bloom phytoplankton species, their taxonomy and frequency of occurrence?

Because the prognosis for phytoplankton blooms, respectively water quality, is an important component for determining the future exploitation of the lake zones. Moreover, the cases of mass mortality of fish and crustaceous have become frequent along the coast at seemingly normal hydrobiological characteristic of the water body-oxygen concentrations within the norm, domination of phyto-species without reaching bloom concentrations. It happens also to register high phytoplankton concentrations and even the water color being changed when no hypoxia is observed.

Varna Lake plays a strategic role in the economical development of the town Varna. That is the reason why its ecological status is being of constant interest for scientific analyses. The latter are essentially supported by the data base of the Institute of Fisheries and the existing literature evidence (Moncheva, 1997; Velikova, 1999).

Material and Methods

Archival data base was consisted information that in 70ies, a lot of unfavorable consequences were exhibited concerning fisheries, tourism and aquaculture. Large hypoxia zones led to mass mortality of mussels, crustaceous and fish, Mee, 1992.

Regular monthly observations on the lake ecosystem by the Institute of Fisheries has commenced since 1991 to 2003. Before and after this period the observations were sporadic.

The 80ies are period of progressive eutrophication with prevalence of *Dinophyceae* (Moncheva and Krastev, 1997).

In 90ies there was a real reduction of the anthropogenic impact in result of the Black Sea countries economic collapse (Velikova et al., 1999).

Bacillariophyceae dominated within the period 1991–1998. Between 1990–1992, the highest mean biomass belonged to *Euglene algae* (121.11g.m^{-3}).

Regular monthly observations on the lake ecosystem by the Institute of Fishing resources has commenced since 1991 to 2003. Before and after this period the observations were sporadic.

The Beloslav Lake (A-10, A-14), and Varna Lake (A-16, A-18, A-22, A-23) were surveyed (Figure 1).

The samples were collected by bathometers type “Niskin” and “Nansen” at standard horizons from surface to bottom. They were put in 0.5l plastic containers, fixed in 2% formalin solution and precipitated. Counting was performed in a chamber (0.05 or 1ml) using a light microscope ”Nikon E 400”.

Results and Discussion

The long-term monitoring on Beloslav and Varna Lakes shows aggravated state of the ecosystem. However, recently in the so called hyperproductive aquatic zone a tendency for returning to the classic scheme of development spring–autumn with shifting of the high biomasses toward the end of summer is observed.

Numbers within the frames of 50-100.10^{-6} cell.l^{-1} during 1998-2003 in Varna Lake are associated only with *Pr. cordatum* and *Oscillatoria sp.* In compari-

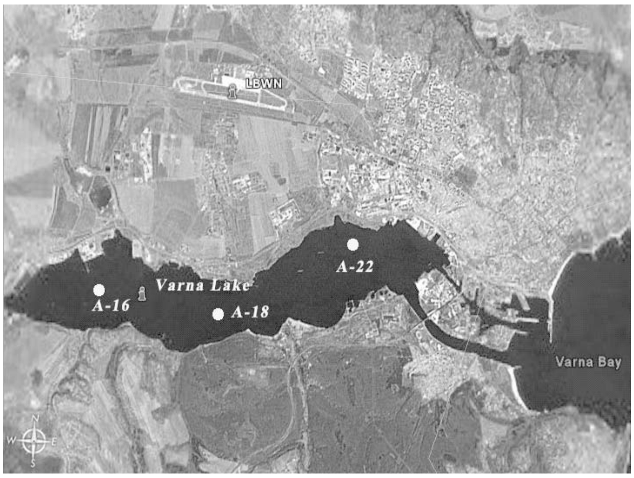

Fig. 1. Varna and Beloslav Lakes (picture from Google Earth)

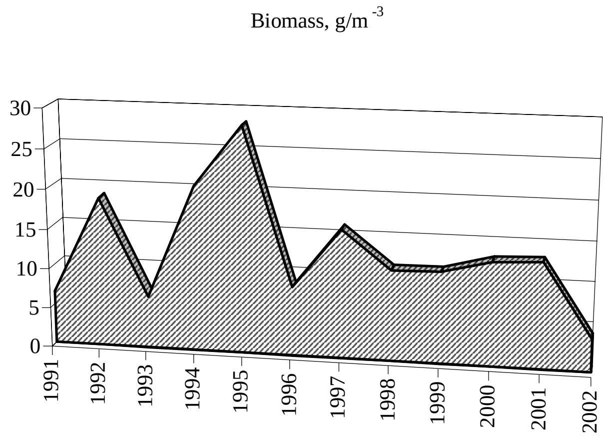

Fig. 2. Phytoplankton biomass (g.m^{-3}) in Varna Lake during 1991-2002

son with previous years species with numbers over 100.10^{-6} cell.l^{-1} are not observed. Phytoplankton biomass for 1998-2003 is three times lower in comparison with the period 1992-1997 (Figure 2).

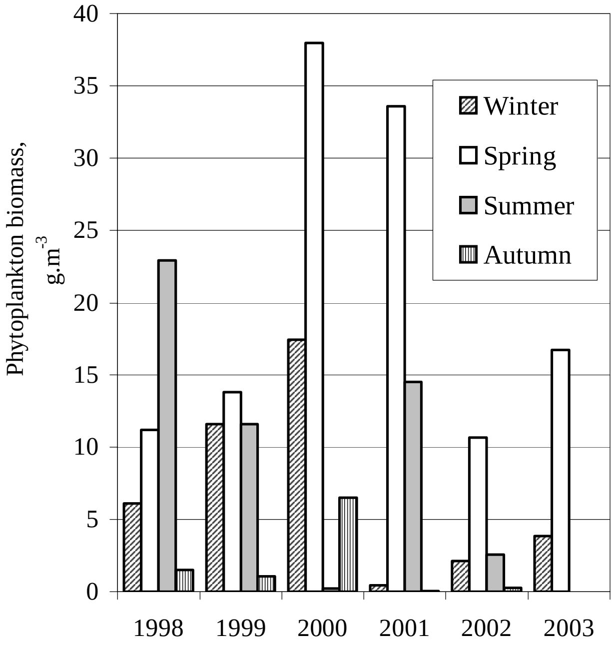

Fig. 3. Seasonal dynamics of phytoplankton biomass (g.m^{-3}) in Varna Lake

Most probably this is on the account of winter and autumn biomasses. Nevertheless, the regular hypoxia at the end of summer is a common phenomenon for the lake (Figure 3).

Major bloom producing species is *Heterocapsa triquetra*. It is one of the dominating blooming species from the group of *Peridines* which prevalence is an indicator of eutrophication. The species has been studied by many researchers. According to some studies introduction of biogenes plays an important part in blooms initiation by *H.triquetra*. In Beloslav and Varna Lakes (1991–1997) concentration of 83.10^{-6} cells.l^{-1} was measured and respective biomass of 144 g.m^{-3} in March, 1995 in the eastern part (À-22) of Varna Lake.

In spring-summer months the species regularly develops in the lakes with numbers over 1 mln. cells.l^{-1}, almost without exception, considered from 1991. By the end of the period studied it does not exceed the number measured in 1995.

In conformity with the recorded tendency for decreasing anthropogenic impact during the recent years, the graph shows almost two times reduction in the maximum bloom number of *H. triquetra*.

After 1997, the highest number of the species (24.10^{-6} cells.l^{-1}) was observed in Beloslav Lake in February, 2000.

During the period of the present study *H. triquetra* reached far less concentrations than in 90ies but still it developed tens of millions cells per liter in the lake waters (Figure 4).

Another representative of *Dinophyceae* and major bloom species not only in the lakes but as well in the Black Sea in front of the Bulgarian coast is *Pr. cordatum*. After 1991 up to 1997 this species exhibited high biomass 150-160 g.m^{-3} and number of 107.10^{-6}cells.l^{-1}.

The toxic species *Phaeocystis* was widely spread with low bloom concentrations in May-June 1990, accompanied by mass mortality in Varna Lake, (Velikova, 1999).

In 1991, more concentrated bloom phenomena were due to *Sc. costatum* and *N. delicatissima*. In 1992 that state of phytoplankton biomass was repeated but during the winter season. In the second half of April, bloom of *Sc.costatum* was again observed, lasting about a week and followed by another one in May with 2-3 days duration.

1992-Beloslav Lake peculiarity in spring is a bloom of the three most abundant species: *S. costatum*, *C. caspia*, *E. viridis*. In Varna Lake the number of diatoms dropped more than 30 times but the species *Í. triquetrà* and *E. viridis* were found in the bloom concentrations. The two-component bloom developed only in the surface lake waters. Microalgae biomass was 21 g.m^{-3}.

In summer 1993 in Varna Lake blooms of *C. bergonii* and *E. viridis* was observed. According to the monitoring data diatom algae prevailed in number during the whole year. In spring and summer the number of golden algae was significant. *Peridinea* algae biomass was maximal in summer and prevailed over

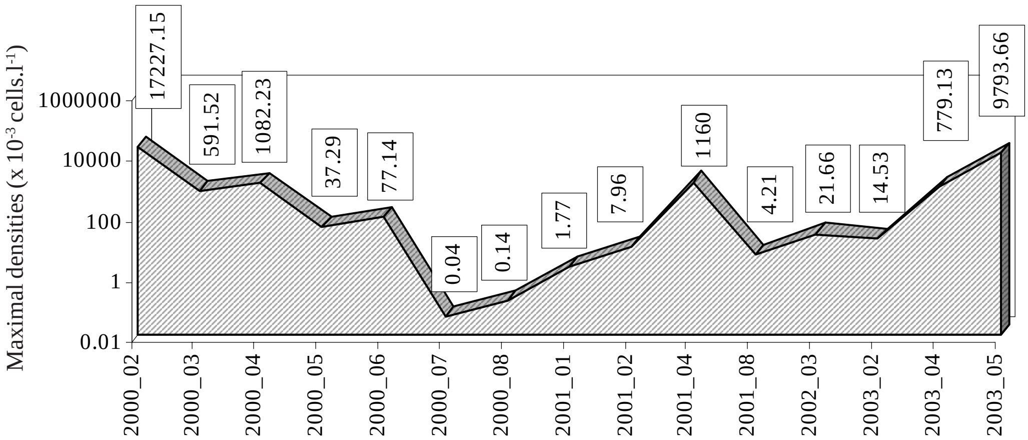

Fig. 4. Maximal densities (x 10^{-3} cells.l^{-1}) of *H. triquetra* in st. A-22 (Varna Lake) during 2000-2003

diatom one in all regions except in Varna Bay. The maximum annual phytoplankton biomass in Varna Lake (22 g.m^{-3}) and Beloslav Lake (24 g.m^{-3}) was registered in the surface layer during the summer.

During the first half of 1994, *Í . triquetrà* dominated in Varna Lake and *Sc. Costatum* - in Beloslav Lake. In August, the higher biodiversity indices were associated mostly with the fact that the summer blooms had been over and the species were in equal position. Obviously the "red tide" in the lakes with mass development of euglene algae had been in June and in the beginning of August *C. bergonii* and *Pr. cordatum* were blooming.

In the spring of 1995 a "red tide" was registered in Varna and Beloslav Lakes, whereupon the crucial values remained in the summer for Beloslav Lake. Major species was *Í . triquetrà* (215 g.m^{-3}).

In August 1996, concentrations in the lakes were higher than the previous years, particularly in Beloslav Lake where unprecedented bloom of *C. granii* (244 g.m^{-3}) was observed, accompanied by an absolute maximum of nitrites and nitrates for the last years of the monitoring which predetermined diatomea domination over green, blue-green algae and *Peridines*. In 1996, *Pr. cordatum* and *Sc. trochoidea* formed biomass over 60 g.m^{-3} (Velikova, 1999).

In 1997, phytoplankton biomass in Beloslav Lake was higher than 1996 one and approached the level of 1993. Varna Lake biomass was three times lower than that in 1996, being the lowest one since 1990.

In June 1997, Varna Lake water transparency was very low (30 cm) which was due to the registered *P. cordatum* bloom. The recorded phytoplankton biomass at horizon 0m is 324.54 g.m^{-3}. The biomass of the species pointed out is 321.52 g.m^{-3}. In May, *Diplopsalis lenticula* developed with number of 2.4 mln.cells.l^{-1} The reason for the observed phenomenon could be sought in the higher temperatures in the whole layer in comparison with June, 1996, as well as in the richer biogene inflow.

In 1998, in the western part of Beloslav Lake dominated diatom *Skeletonema costatum* 46.2 g.m^{-3} (spring), *Cyclotella caspia* 23.112 g.m^{-3}(summer) and euglene microalgae which were over 50% of the total biomass and number in the lake. Biomass and number were maximal for the period studied at st. A10 (May)- surface layer 23.54 g.m^{-3}, 56.28 .10^{-6} cells.l^{-1} (blooms of *Skeletonema costatum*–46.3.10^{-6} cells.l^{-1}, *Heterocapsa triquetra*–1.41.10^{-6} cells.l^{-1}, *Eutreptia viridis*–1.84.10^{-6} cells.l^{-1}). *Thalassiosira rotula* at st. À14 was identified with number of 853 000 cells.l^{-1} and biomass of 8.6 g.m^{-3}**,** *Apedinella spinifera*–1.52.10^{-6} cells.l^{-1} *Åutreptia viridis*–1.31.10^{-6} cells.l^{-1}, *Phacus sp.* – 1.95.10^{-6} cells.l^{-1}.

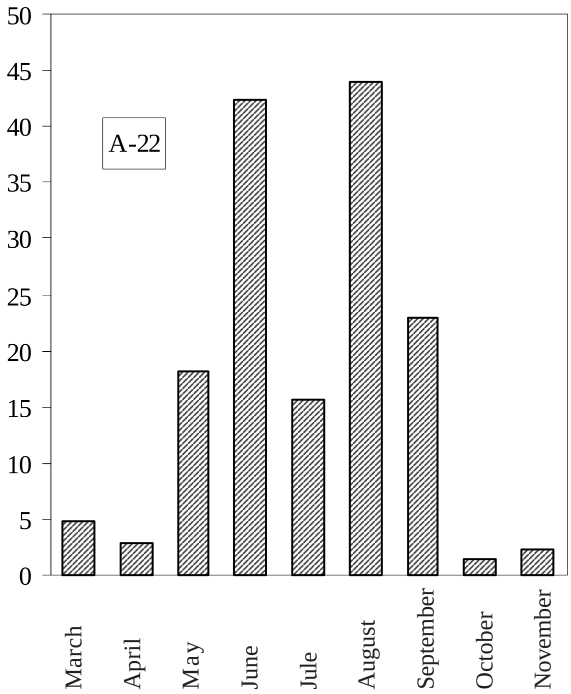

Fig. 5. Month dynamics of phytoplankton biomass (g.m^{-3}) on the station A-22 in Varna Lake during 1998

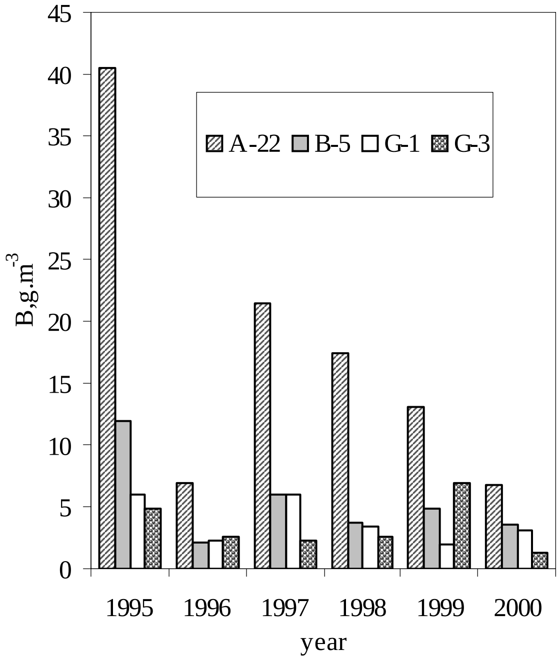

Fig. 6. Dynamics of phytoplankton biomass (g.m^{-3}) in Varna Lake-A-22, Varna Bay-B-5, Galata-1mile, Galata-3miles

In May 1998, uncommonly high numbers of protozoic zooplankton were observed, especially of *Ebria tripartita*, considered in the past for phytoplankton of the silocoflagellates group. At st. À-10 *Å. tripartita* had concentration of 306 000 cell.l^{-1}, and the other *Protozoa* reached the number of 267 000 cell.l^{-1} (Figure 5).

In 1999 in Beloslav Lake bloomed the species *Cycl. caspia*-20.02.10^{-6} cells.l^{-1} (spring), *Pr. cordatum* - 92.79.10^{-6} cells.l^{-1} (summer), and in Varna Lake - *Het. triquetra*-18.78.10^{-6} cells.l^{-1}, *Oscillatoria sp*.- 54.03.10^{-6} cells.l^{-1}.

During 2000 in Beloslav Lake bloomed *Heterocapsa triquetra* – 24.2.10^{-6} cells.l^{-1}, *Prorocentrum cordatum* -59.43.10^{-6} cells.l^{-1}, *Flagellates*-10.24 mln.cells.l^{-1} and in Varna Lake- *Heterocapsa triquetra* – 19.74.10^{-6} cells.l^{-1}, *P. cordatum* – 72.32.10^{-6} cells.l^{-1}, *Cyclotella caspia* – 19.5.10^{-6} cells.l^{-1} (Figure 6).

On Figure 6 can be seen the higher biomass in Varna Lake (1995-2000) than that in the Bay and coastal waters. This correlation is observed during the next years as well.

In 2001 high density formed by *Pr.cordatum*-12.18.10^{-6} cells.l^{-1}, *C. caspia*-6.91.10^{-6} cells.l^{-1}, *Sk. costatum*-5.05.10^{-6} cells.l^{-1} in Beloslav Lake, in Varna Lake-*C. pelagica*-10.8.10^{-6} cells.l^{-1} *1, Sk. costatum*-5.67.10^{-6} cells.l^{-1}.

In 2002 the mean annual biomass of the phytoplankton in Beloslav Lake exhibited the lowest value in comparison with the entire 12-year period. In April 2002, in Varna Lake the high biomass-27.22 g.m^{-3}, formed by *Heterocapsa triquetra*-19.30 g.m^{-3}.

In May 2002 the bloom was monospecific , formed by *Prorocentrum cordatum* (25.28 g.m^{-3}). In May the arising main body of the species bloom was defined. It continued in June as well and between 6–12 June, 2002 "red tide" of that peridine (46.2 g.m^{-3}) was observed. In November, 2002 in Varna Lake, similar to the situation in Beloslav Lake, the lowest mean biomass (3.9 g.m^{-3}) from 1992 up to now was measured.

For 2003 due to the lack of full data (sampling carried out only in winter), the seasonal phytoplankton dynamics in the lake could not be analyzed.

In the spring of 2003 in Varna Lake high number and biomass exhibited the peridine *H. triquetra*–(density-9.79 10^{-6} cell.l^{-1}, biomass-16.77 g.m^{-3}), a typical species forming for years the blooms in the lake. *Salpingoeca spinifera*-2.78.10^{-6} cells.l^{-1}.

After 2000, diatom-peridine-euglene complex have been formed. The heterotrophic *Dinophyceae* dominated during the greater part of the year, mostly small-sized species with high rate of reproduction. Frequent bloom concentrations exhibited *Apedinella spinifera, Pr. ñordatum, Åuglena viridis , Heterocapsa triquetra* (Figure 7).

The distribution of Shannon's index shows a positive tendency for stabilization of the ecosystem but nevertheless Varna Lake basin is still defined as a hypereutrophic zone with large fluctuations in the oxygen regime and surplus productivity.

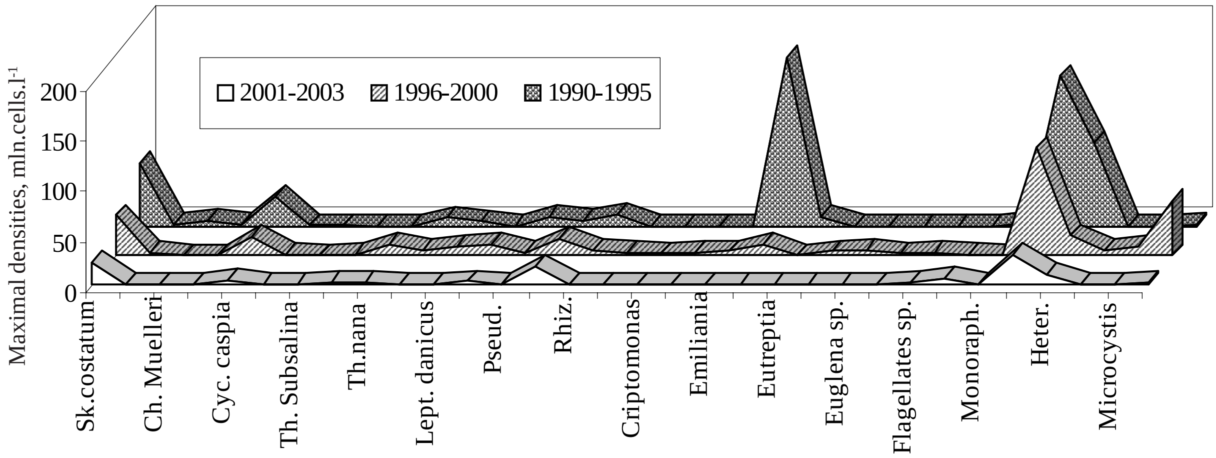

Fig. 7. Maximal densities (mln.cells.l^{-1}) of the main phytoplankton species in 1990 - 2003

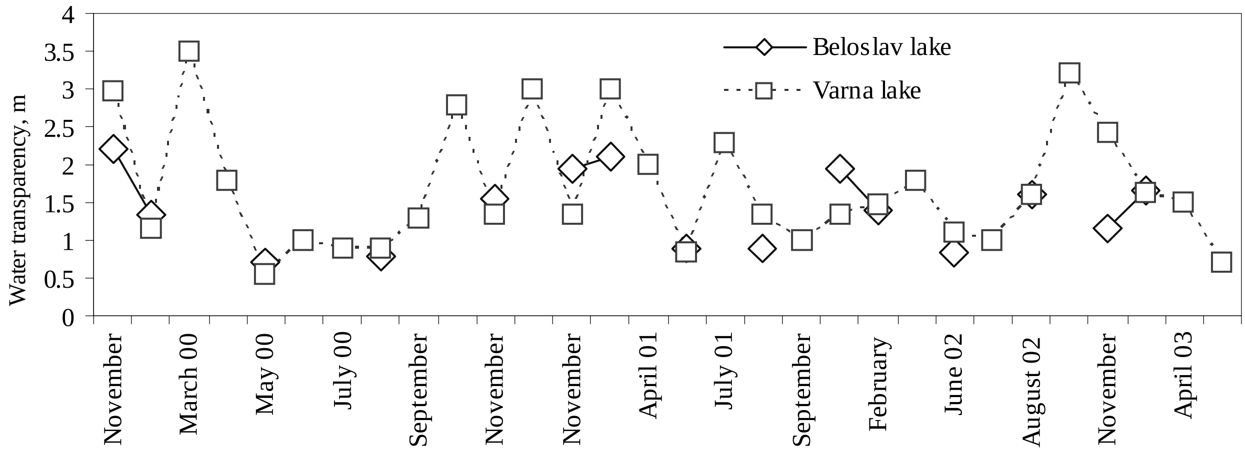

Fig. 8. Water transparency (m) in Varna coastal lakes

The excessive phytoplankton development in the surface layers decreases water transparency. On Figure 8 it is clearly seen when in summer the biomass is higher, water transparency is under 2 m.

Other lakes which ecological status has been studied by the Institute of Fisheries are Durankulak and Shabla Lakes, located in the northern part of the Bulgarian Black Sea coastal zone. They are characterized with isolation from the sea by sand dikes, maximum depth of 4 m, autochtonous origin of species, insignificant industrial activity in their regions (Figure 9). Sampling was performed in April–June–September, 2001–2003.

The highest number was registered in spring in Durankulag Lake (2.81.10^{-6} cells.l^{-1}), in summer in both lakes: Durankulag Lake – 24.92.10^{-6} cells.l^{-1} and Shabla Lake–11.15.10^{-6} cells.l^{-1}. The autumn is characterized with high number in both lakes: Durankulag Lake–20.3.10^{-6} cells.l^{-1} and Shabla Lake–28.06.10^{-6} cells.l^{-1} (Table 1).

The main species represented in the bloom concentrations are *Microcystis sp.* and *Oscillatoria sp.*, order *Cyanophyta*.

The highest biomass (27.97 g.m^{-3}) in Durankulag Lake was registered in June, 2001. The degree of its eutrophication was higher than that of Shabla Lake.

Fig. 9. Durankulag and Shabla Lakes (Picture from Google Earth)

Table 1

Predominating phytoplankton species (density, .10^{-6} cells.l^{-1}) in Durankulag and Shabla Lake

	Spring 2001-2003	Summer 2001-2003	Autumn 2001-2003
Durankulag Lake	*Scenedesmus* sp. (2.81) *Monoraphidium* sp.(2.41)	*Scenedesmus* sp.(2.24) *Anabena* sp. (3.49) *Monoraphidium sp.* (6.94) *Cyclotella* sp. (3.81) *Oscillatoria* sp. (24.92) *Microcystis* sp. (4.54) *Monoraphidium* sp. (6.94)	*Scenedesmus* sp.(3.01) *Monoraphidium* sp. (9.57) *Microcystis* sp. (20.3) *Aphanizomenon* sp. (4.3) *Merismopedia* sp. (1.41) *Anabena* sp. (1.37)
Shabla Lake	*Cyclotella* sp. (1.65)	*Microcystis* sp. (11.15) *Actinastrum* sp. (1.84) *Oscillatoria* sp. (1.67) *Micractinium* sp. (2.09)	*Microcystis* sp. (28.06) *Micractinium* sp. (2.31) *Cyclotella* sp. (2.36) *Phormidium* sp. (1.54)

In the coastal water areas the reduction of anthropogenic impact in the recent years is related with the relative reduction of phytoplankton number and biomass of the common bloom producing species. In spite of the decreasing tendency and relative reduction of the number of some bloom species in comparison with 80^{ies}, biomasses remain comparatively high and mostly during the warm half of the year change visibly the color of lake water and sometimes of Varna Bay as well. In 2003 the first bloom of *Heterocapsa triquetra* and *Exuviella cordata* was observed in April–May when it caused a change in the color of lake water.

In comparison with the period of enhanced eutrophication in the recent years the frequency of phytoplankton blooms decreases significantly.

Conclusions

Positive features:

Increased quantity of vegetative species–191 (1998-2003) in comparison with 130 (1991–1997).

Mean annual phytoplankton biomass decreases in comparison with 1991–1997.

In spite of the high biomasses, no anoxia is observed in both lakes which causes mass fish mortality.

Numbers within the scope of 50-100.10^{-6} cells.l^{-1} during the period studied are associated only with *Pr. cordatum* and *Oscillatoria sp.* Species with numbers over 100.10^{-6} cells.l^{-1} are not observed.

Low frequency of blooming activity **-** 1-3 blooms per year.

The highest biomass is formed during peridine *Pr. Cordatum* and diatomea *C. belagica* blooming (113.55 g.m^{-3}) but in comparison with previous years it is two times lower.

For the first time since 1991 in 2001 and 2002 a drastic reduction in the autumn biomasses was established – under 1g.m^{-3} mean seasonal value.

Biomass reduction in the period 1998-2003 is on the account of winter and autumn phytoplankton biomass reduction.

Tendency for restoration of the classical scheme of phytoplankton development in Varna Lake. However, biodiversity of lake phytoplankton in comparison with Varna Bay and open sea is still lower. Despite the positive features of the recent ecological status of the lake system, water quality do not satisfy the criteria for its intensive use for tourism and recreational purposes.

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