Mitigation options for nutrient reduction in surface water and groundwaters

INSTITUTE OF ZOOLOGY, BULGARIAN ACADEMY OF SCIENCES

Changes of phytoplankton assemblages and related characteristics after restoration activities in the Srebarna Lake (Northeastern Bulgaria)

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Study area

Location: Northeastern Bulgaria, right bank of the Danube River between 393 - 391 river km (Fig.1.)

Coordinates: Latittude 44º 07' N , Longitude 27º 04' E

Open water surface: 0.6 km^2

Mean depth: 2.5 m

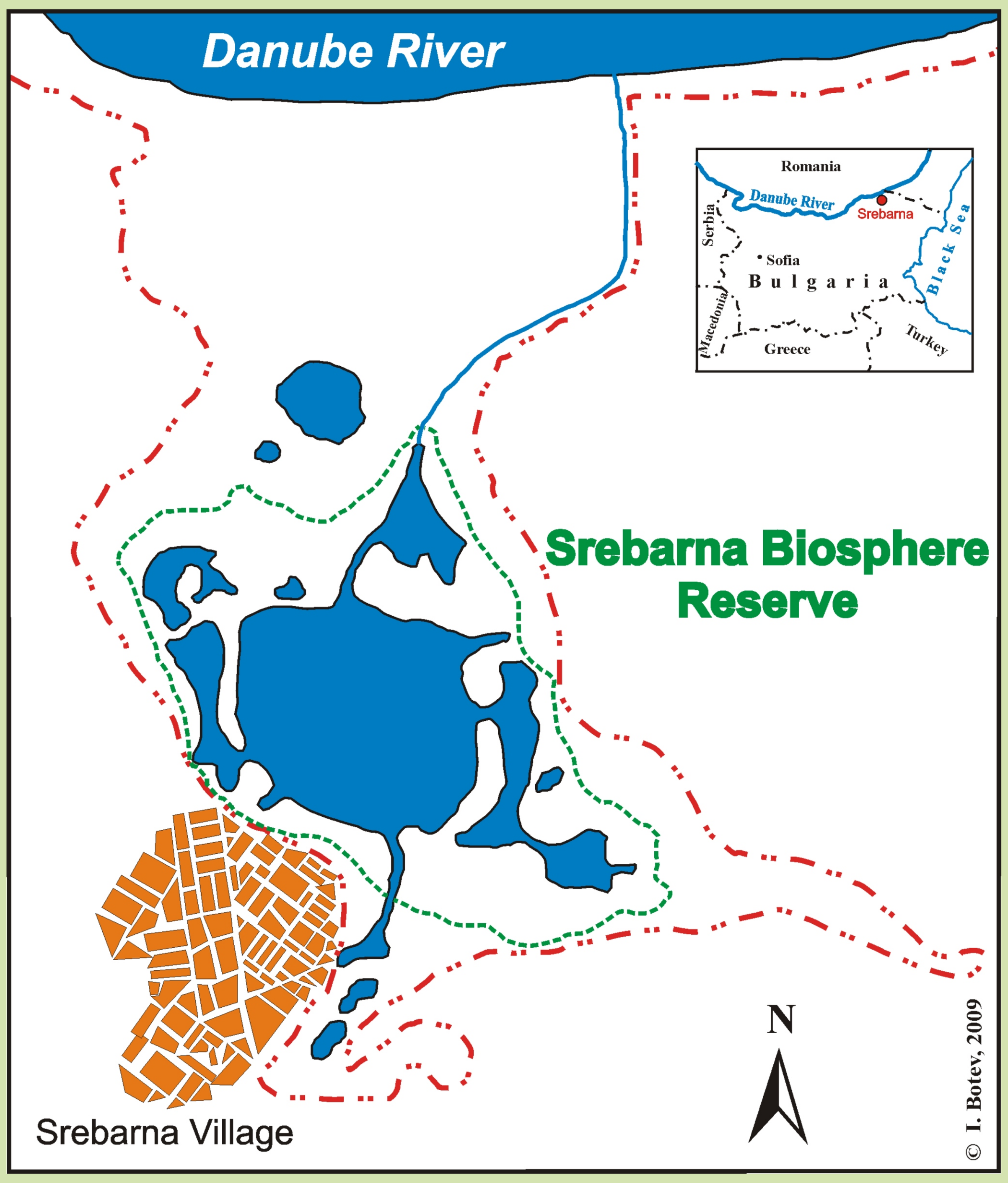


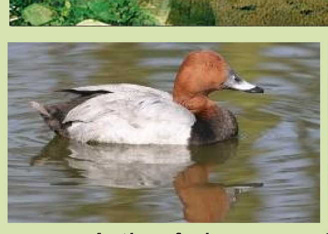
Fig.1. Scheme of the Srebarna Biosphere Reserve

Description of the lake

The Srebarna Lake was designated as a Monument of World Cultural and Natural Heritage (1983), UNESCO biosphere reserve (1977), Ramsar site (1975) and Important Bird Area (1990) because of its extremely rich ornithofauna and role as breeding site of globally threatened species like Dalmatian Pelican (*Pelecanus crispus*), Pygmy Cormorant (*Phalacrocorax pygmeus*) and Ferruginous Duck (*Aythya nyroca*).
The main stages and important events in the recent lake ecological development were described by Stoyneva & Michev (1998) and may be summarized as follow:

- **Natural stage:** up to 1948, at which time it was supposed to have meso to slightly eutrophic status with regular annual flooding of Danube waters.
- **Disturbance period:** the dike building in 1948 caused interruption of the connection with the river. As a result water exchange decreased twice, water area, lake volume and depth diminished, eutrophication and bottom siltation, accelerated (PO_4 increase from 0.02 to 0.2 mg l^{-1}), blooms of cyanoprokaryota occurred frequently, *Bosmina* and *Daphnia* species in zooplankton disappeared, zoobenthos degradated (rare or absent) fish yield and species number were reduced several times.
- **Restoration activities:** the main recovery measure (besides cutting and burning the reed in the past) was the construction and operation start of an artificial canal between the lake and the Danube River in 1994.
- **Effects by restoration activities**
Based on the data reported by many authors concerning different aspects of lake ecosystem restoration as phytoplankton (Stoyneva et al., 1998, 2000, 2003), zooplankton (Pehlivanov et al., 2004, Tzavkova, 2005), macrozoobenthos (Uzunov et al., 2001), fishes (Pehlivanov et al., 2004) and by own monitoring data analyses Kalchev et al. (2007) published a comprehensive literature survey of the changes of the lake ecosystem before and after the reconnection and up to 2003. The authors reported many **positive effects** as: water level rising, decrease of nutrient concentrations, phytoplankton abundance decrease, zooplankton species enrichment and reappearance of several Daphnia and Bosmina species, reappearance of benthos organisms, of some bird species and general tendency to trophy decrease. However some **negative observations** also been reported as: the slow macrozoobenthos succession, fish abundance and composition being far away from the natural state, long-term trend fluctuations of Secchi disk depth between 0.4 and 1.2 m estimating the lake as definitely hypereutrophic (OECD scale, Vollenweider et al., 1982), long term trend of the chlorophyll-a putting the lake also in the hypereutrophic stage (only in some years the lake status might be estimated between eutrophy and hypereutrophy).

Pelecanus crispus



Aythya ferina

Nest of *Chlidonus hybrida*

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Changes of the total phytoplankton biomass and structure in relation of environmental factors

Material and methods

ınvestigated period: 2002 - 2007. Lliterary data (Stoyneva, 1998, 2000) have been used for comparison about the period before 2002.

Sampling: Samples (0.5 l) were taken monthly (2002 - 2004), or every two months (2005 - 2007), from the whole water column and preserved with formalin (to 4 %).

Phytoplankton processing: counting in haemocytometer chamber by normal light microscope (200 x), biovolume estimation by method of geometrical approximations (Rott, 1981).

Chemical and physical variables used as explanatory variables in the analyses: water level (m. a. s. l.), water temperature (ºC), conductivity (µS m^{-1}), pH, transparency (Secchi depth, m); NH_4-N; NO_3-N; NO_2-N; PO_4-P (mg l^{-1}); dissolved O_2 (mg l^{-1}) (Hiebaum et al., 2000). Statistical analyses applied: Redundancy analysis (RDA), Canonical correspondence analysis (CCA). Ordinations were implemented by the CANOCO statistical package version 4.5 (Ter Braak & Šmilauer, 2002).

Results

After reconnection between the lake and the Danube River the lake water level has increased substantially (Vasilev et al., 2008), (Fig. 2). It was closely related with increase of Secchi depth transparency (Fig. 3).

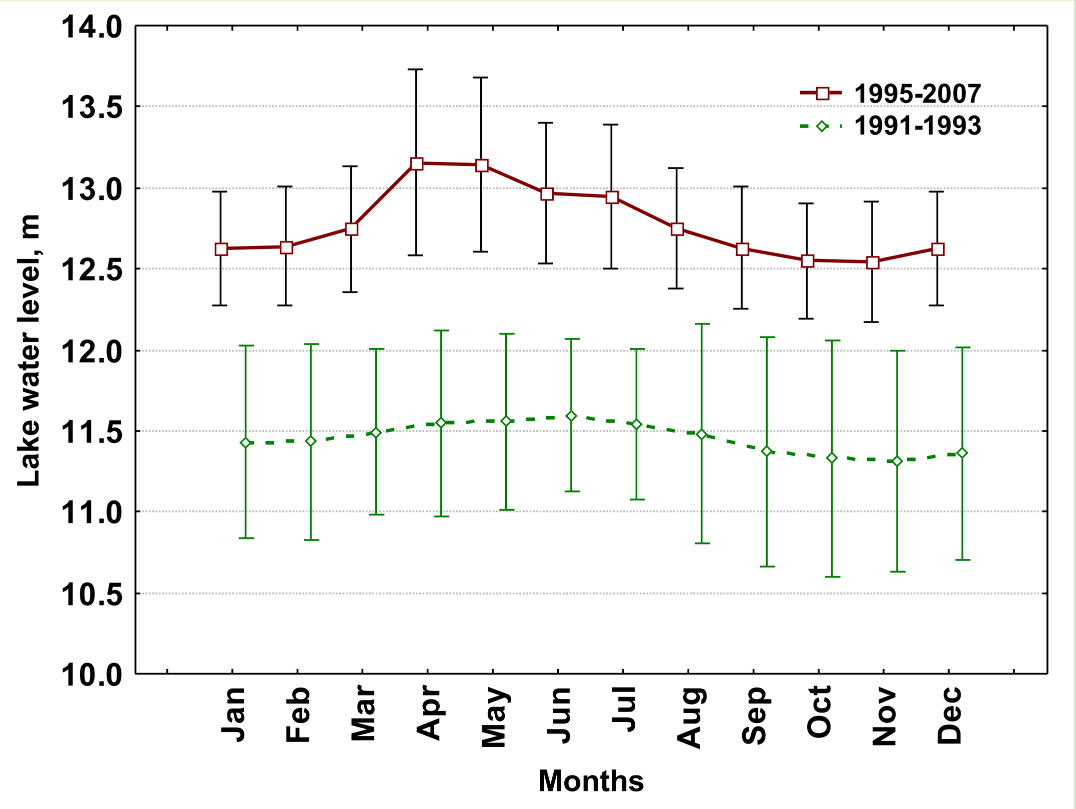

Fig. 2. Seasonal changes of water level of the Srebarna Lake before period 1991-1993 and after period 1995 - 2007- the reconnection to the river.

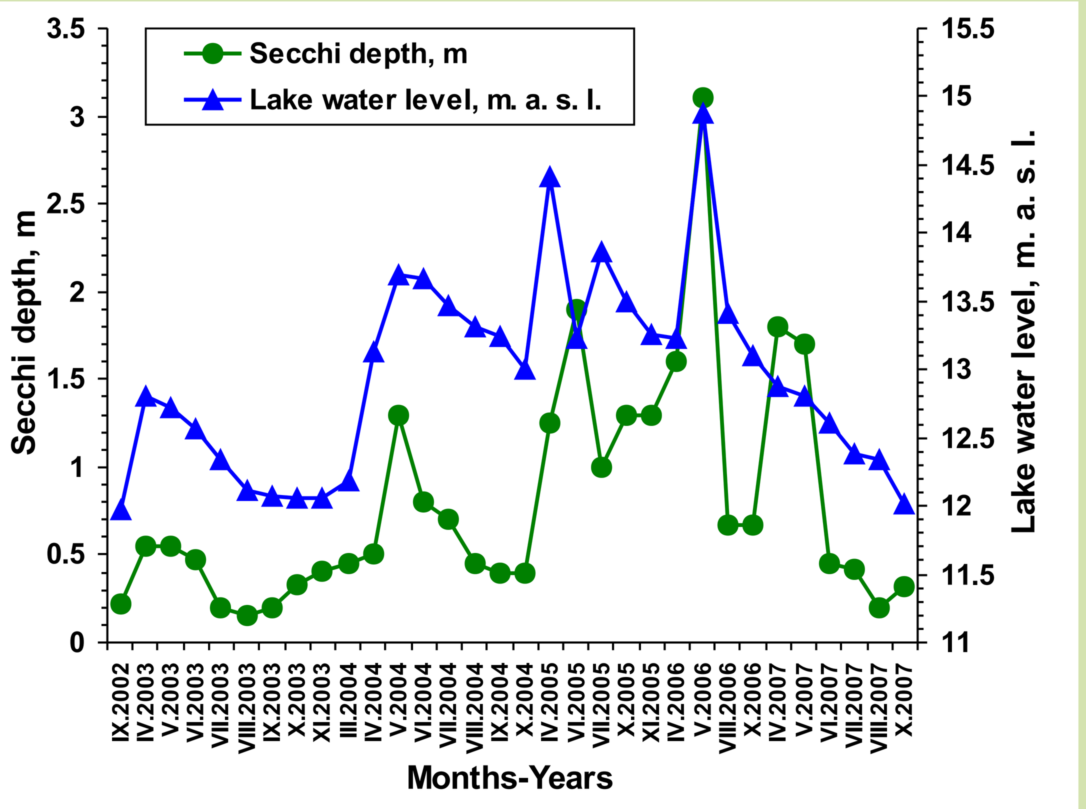

Fig. 3. Changes of the lake water level and Secchi depth during the period September 2002 - October 2007.

The total phytoplankton biomass has changed conversely to the lake water level fluctuations Fig. 4. As have been already established for the period till 2005 (Beshkova et al., 2008) the phytoplankton biomass showed hypereutrophic status. Similar results showed primary productivity and Chl-a concentration (Vasilev et all., 2008). In years with the highest water level (2005 and 2006) the phytoplankton biomass was close to the boundary value between eu- and hypereutrophy (according to scale of Likens, 1975). It started to increase again in 2007, when the water level begun to decrease.
Decrease of phytoplankton biomass was due mainly to the reduction of Cyanophyta rate in summer (Fig. 5).

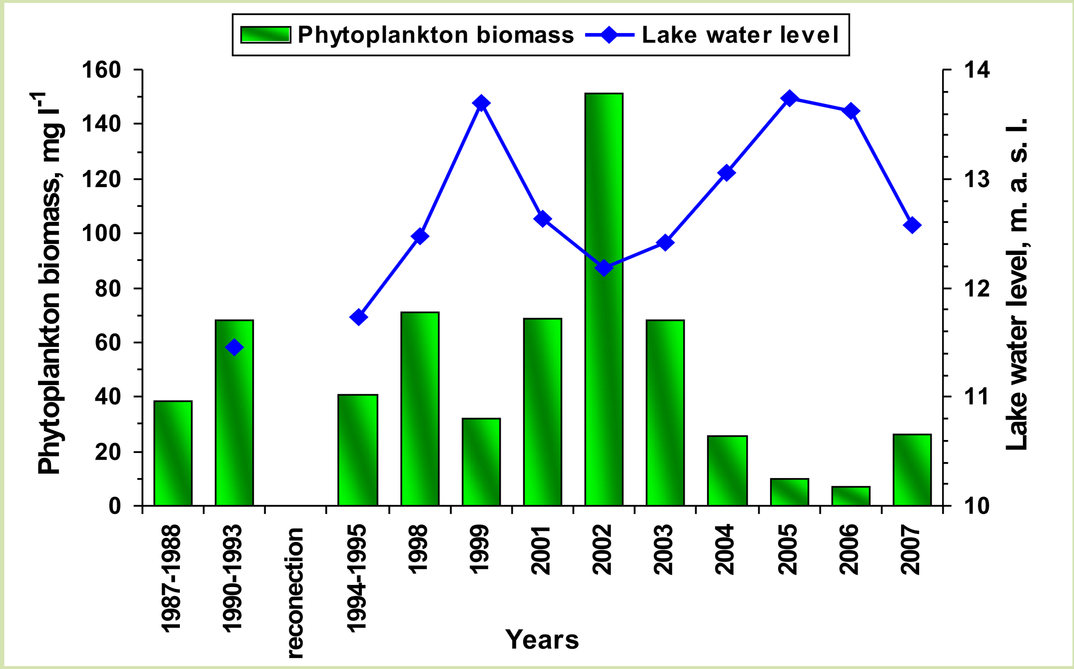

Fig. 4. Inter annual changes of the total phytoplankton biomass and water level in the Srebarna Lake during the periods before and after reconnection with the Danube River.

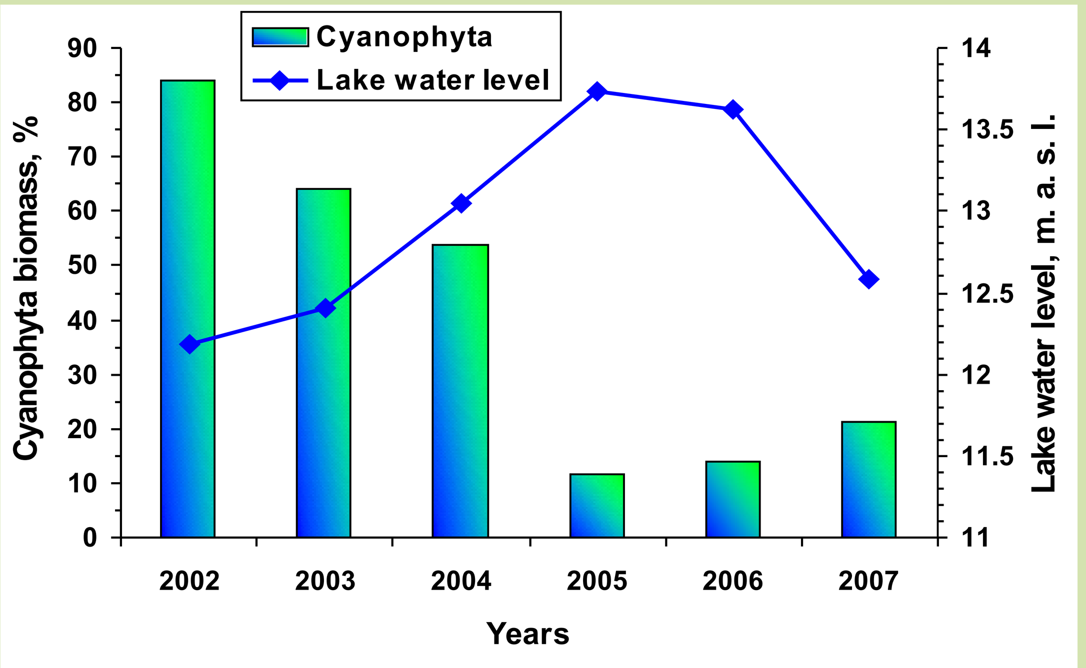

Fig. 5. Inter annual changes of the Cyanophyta share (% of the total biomass) and water level during the period 2002 - 2007.

Inter annual variations of phytoplankton divisions (Fig. 6) were higher than seasonal ones (Fig. 7) as the Secchi depth transparency appeared as a main explanatory factor along the first axis and nitrate nitrogen along the second. Secchi depth followed the changes of water level (Fig. 3). Cryptophyta were most abundant at higher Secchi depth conversely of Cyanophyta. Bacillariophyta and Cyanophyta were competitors in respect to nitrate nitrogen (N:P ratio respectively).
Seasonal variability was low and related to nitrate nitrogen and pH variations. Cyanophyta were close related to their increase (mainly in summer and autumn) followed by Bacillariophyta and Chlorophyta. Nitrate nitrogen appeared as an explanatory factor both on inter-annual and seasonal time scale, which indicates that phytoplankton was nitrogen limited, as a result from the low N:P ratio. In the years of high water levels, N:P ratio substantially increased.

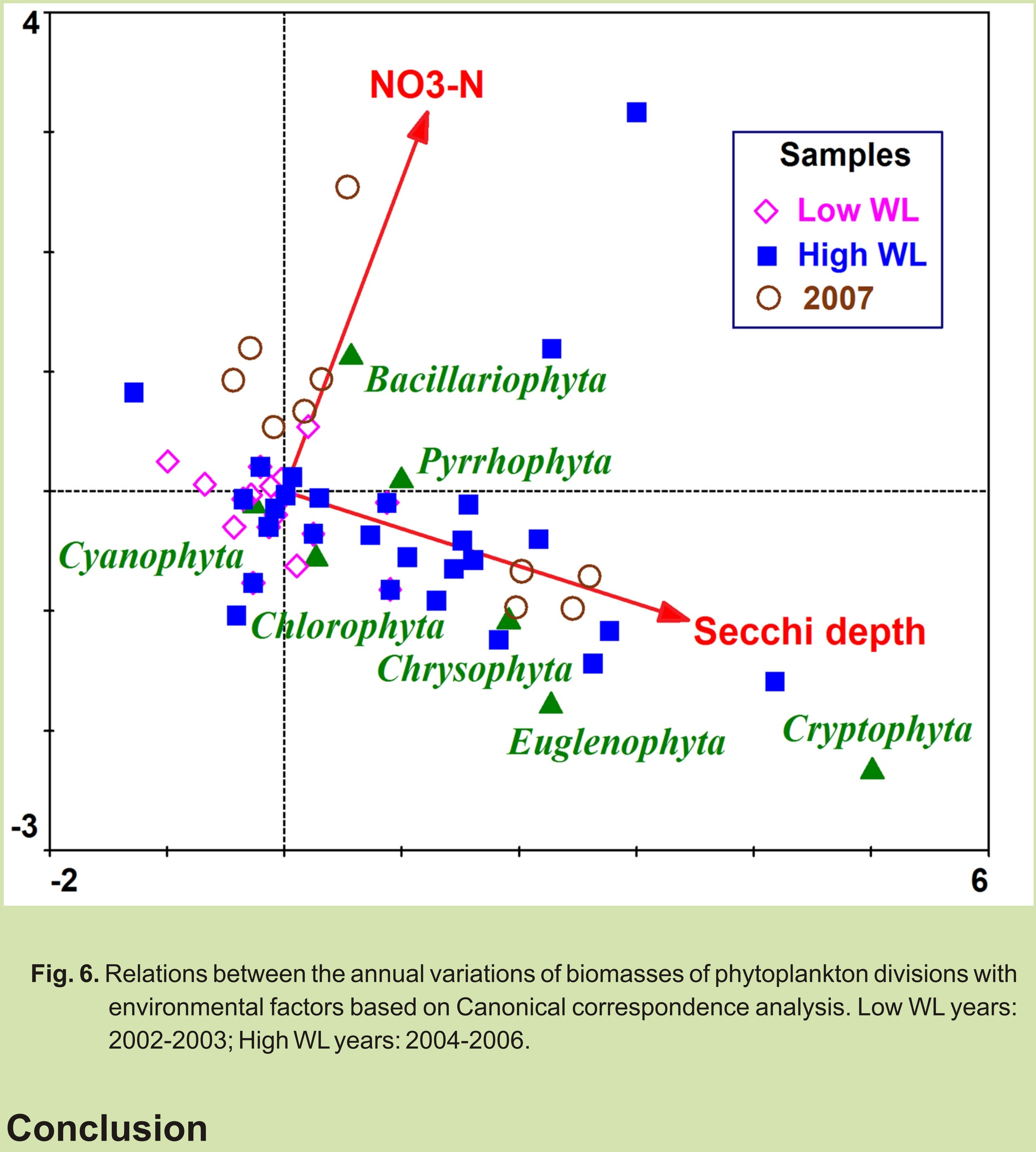

Fig. 6. Relations between the annual variations of biomasses of phytoplankton divisions with environmental factors based on Canonical correspondence analysis. Low WL years: 2002-2003; High WL years: 2004-2006.

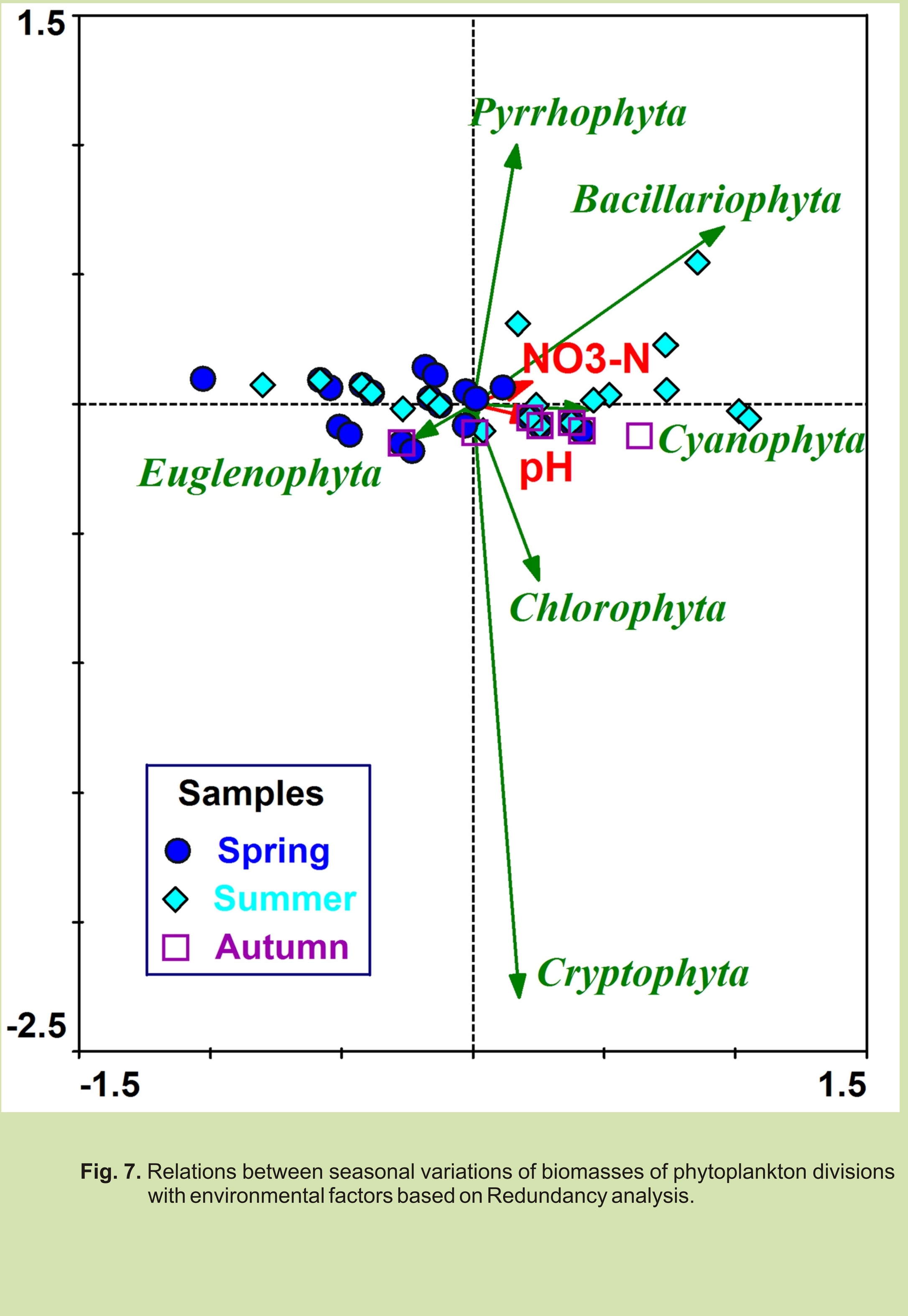

Fig. 7. Relations between seasonal variations of biomasses of phytoplankton divisions with environmental factors based on Redundancy analysis.

Conclusion

As have been already noticed by Kalchev et al. (2007) the operation of the channel between the lake Srebarna and the Danube River has caused an alternation of periods of increasing and decreasing trophy fluctuations mainly due to the lake water level changes predetermined and sustained by variations in water level of the Danube River. As a result the lake water level showed a tendency to rising after the channel building, while the concentrations of nitrates and phosphates in the lake became significantly lower and N:P ratio respectively higher than those in the Danube river. However, because the water inflow from the river happened for a short time and in widely varying quantities depending on the precipitation-quantity in the Danube river catchments area in different years, the reduction of nutrient concentrations and of sapropel layer caused by the dilution effect has not led to a sustainable improvement of the lake trophic status. This is well demonstrated by the changes of phytoplankton, whose total biomass and Cyanophyta share decreased during the extremely high water years 2005 - 2006, but started to increase again in 2007, when the water level decreased. The comparison of the lake with similar wetlands in Austria, Serbia, Croatia and Rumania in respect to vertebrate fauna, (mainly the groups of fishes and birds) shows that the number of fish species are double and the birds about 100 species less in Sreburna than in the other wetlands (Kalchev et al., unpublished data).
It is evident that the construction of the channel although presents an important step to lake recovery is not sufficient to support permanent and stable tendency to improvement of the lake trophic state. The main reason is the availability of one channel only used for water inflow. The building of a second outlet channels and a proper operation of both inlet and outlet channels would provide each year during high water periods an inexpensive and more effective removal of accumulated organic substances by natural forces and would favour a dynamic interaction between river and lake ichthyocenosises.