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PHYTOPLANKTON DIVERSITY IN THE OLTINA AND BUGEAC LAKES AND THEIR DEPENDENCY ON THE CLIMATIC CONDITIONS AND PHYSICO – CHEMICAL PARAMETERS

Camelia Eliza TELTEU
National Institute of Hydrology and Water Management
Bucharest, no.97, Bucureşti – Ploieşti street, Romania, postal code 013686, phone +40-21-3181115, Email: elizapascu25@gmail.com

Abstract

The present paper presents some issues about the phytoplankton diversity in the Oltina and Bugeac lakes and some relations, on the one hand, between the biological and the hydrochemical parameters, and on the other hand, between the biological and the climatic parameters. The Oltina and Bugeac lakes are located on the right side of the Danube River and are shallow lakes with freshwater important for the fish farming. The study is based on the statistical processing of the daily data regarding the phytoplankton species, some hydrochemical parameters and the lakes' transparency values. The biological and the hydrochemical data was provided by the "Romanian Waters" National Administration, for the interval 2006 – 2008, and the lakes' transparency values were estimated with the Secchi disk during summer 2011. In order to determine the links between the biological parameters and the climatic parameters we used the daily average air temperature and the daily precipitation from the Călăraşi meteorological station (for the years 2006 – 2008, data from the ECA&D database), which is close to the studied lakes. The analysis highlights statistically significant correlation, for an error risk α with values between 0.1 and 0.02 (according to the Bravais – Pearson statistical test), between the biological parameters and the precipitation (10 days, 20 days and 30 days), some physico – chemical parameters. For both lakes, by applying the *Redundancy Analysis* (using the Canoco v4.5 software), we identified the statistically significant relations between the *Cyanobacteria* and *Chlorophyta* and the nitrates, $\alpha = 0.03$, and between these and the pH, respectively the chlorides, $\alpha = 0.048$. In the case of the Oltina Lake, the water temperature influences the growth of the *Cyanobacteria* and *Chlorophyta* in percent of 32.10%.

Keywords: Phytoplankton, Oltina Lake, Bugeac Lake, Statistics.

1 INTRODUCTION

In the pelagic zone, the life in the lake water is represented by the bacteria, the phytoplankton and the zooplankton.

Their evolution in the lake water is influenced by the morphometrical characteristics of the lake, the physico – geographical conditions of the catchment, the chemical composition of the water and so on (Burian, 2002; Straškrábová et al., 2005; Straškrábová et al., 2009).

The present paper presents some issues regarding the phytoplankton diversity of the Oltina and Bugeac lakes and analyses the way they are influenced by the natural factors.

The analyzed lakes are the fluvial lakes (*limanuri*). Their genesis is related to the regression (Neoeuxinian, Gâştescu&Breier, 1969, or Dacian, Banu, 1964) and transgression phases of the Black Sea (Neolithic, Gâştescu&Breier, 1969, or Wallachian, Banu, 1964), to the silt deposits and to the abrasion.

The analysis is based on the processing of data obtained from the "Romanian Waters" National Administration (RWNA) – Headquarters, Bucharest, regarding the phytoplankton species and the physico – chemical parameters (for the years 2006 – 2008).

During summer 2011, some measurements were made with the Secchi disk for the lakes' transparency, which allowed us to obtain information on the values of the euphotic zone.

The links between the biological parameters and the precipitation for the previous 10 days, 20 days, 30 days and the daily average air temperature were identified through linear correlations, made in Excel. The daily precipitation and the daily average air temperature data was taken from the website of the European Climate Assessment&Dataset (ECA&D - http://eca.knmi.nl), for the Călăraşi meteorological station (which is close to the analyzed lakes, for the interval 2006 – 2008).

Studies regarding the hydrological, physical, chemical and biological characteristics of the Bugeac and Oltina lakes have been realized by Gâştescu, 1959, 1963 and 1971, Dinu&Radu, 2004, Török&Dinu, 2006, Romanescu et al., 2010, Telteu, 2012 a and b, Telteu&Zaharia, 2012.

2 METHODS

The methodology includes statistical analyses (the estimation of the statistical parameters, linear correlations made with the Excel) and investigation in the field. The statistical tests were used to establish the statistical significance of the correlations (the Bravais – Pearson statistical test) and to identify the statistical significance of some relations between different parameters (Monte – Carlo test, applied with *Canoco v.4.5* software).

3 RESULTS AND DISCUSSION

3.1. General data concerning the Bugeac and Oltina lakes

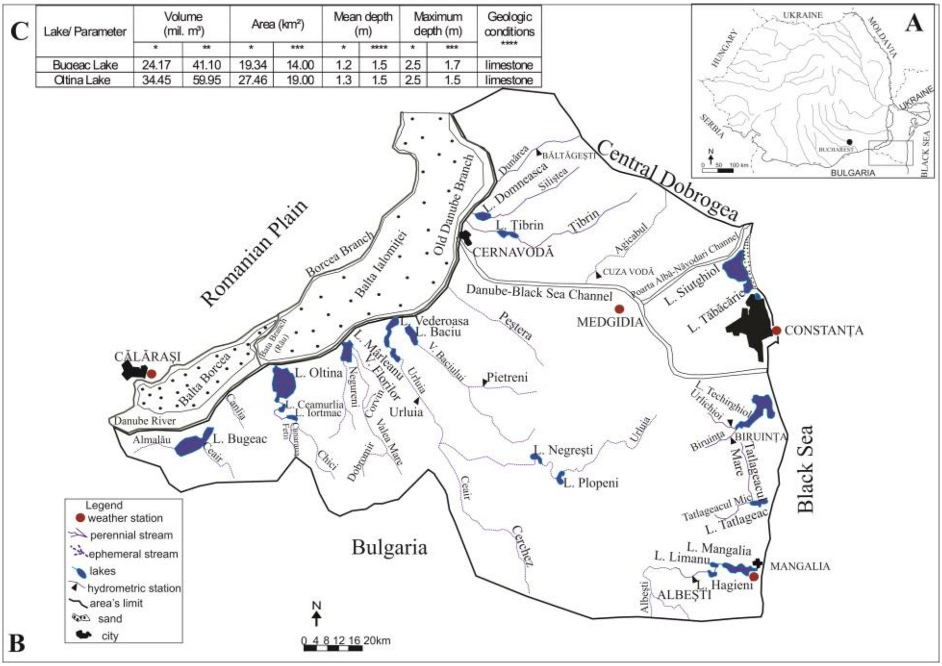
The study area overlaps, according to the geomorphological regionalization made by Posea & Badea, 1984, to the Oltina Plateau, which is bounded in the West by the Danube River, in the North by the Medgidia Plateau, in the East by the Cobadin Plateau and in the South by the border with Bulgaria. The plateau is characterized by the presence of some valleys sectors that have the slope opposite to the general slope, highlighting their epigenetic and antecedent character. From a petrographical point of view, the Sarmatian and Cretaceous limestones, the sandstones and the loessoid deposits are present in the area. The average altitude is 100 – 200 m and the maximum altitude is 209 m in the Dobromir hill. From a climatic point of view, the study area is characterized by a dry climate of lowland (Iordan, 2005).

The Bugeac and Oltina lakes are located on the Romanian (Levantin) terrace (Brătescu, 1928), at the mouths of the Almalău River (Bugeac Lake) and of the Canaraua Fetei River (Oltina Lake) (Figure 1). Their catchment areas are very large and continue on the Bulgarian territory. The catchment area of the Bugeac Lake is 2530 km² and the catchment area of the Oltina Lake's main tributary, Canaraua Fetei, is 2630 km² (Ujvári, 1972). As shown in figure 1, the lakes have large areas and low depths. These lakes are, mainly, used for fish farming.

3.2. Phytoplankton diversity

The phytoplanktonic associations have different physiological requirements and are influenced by some physical and chemical parameters such as light, temperature and nutrient regimen (Wetzel, 2001, page 331).

The lake zone where the phytoplankton photosynthesis is greater than the phytoplankton respiration is known as the euphotic, photic or trophogenic zone (Kalff, 2002, page 145).



Lake/ Parameter	Volume (mil. m^3)		Area (km^2)		Mean depth (m)		Maximum depth (m)		Geologic conditions ****
	*	**	*	***	*	****	*	***	
Bugeac Lake	24.17	41.10	19.34	14.00	1.2	1.5	2.5	1.7	limestone
Oltina Lake	34.45	59.95	27.46	19.00	1.3	1.5	2.5	1.5	limestone

Figure 1. The South Dobrogea Region. A. Location in Romania. B. Hydrographical map. C. Table with data regarding the morphometrical data and geological conditions of the Bugeac and Oltina lakes. Source map: Zaharia&Pişota, 2003, with additions; Data source: *results obtained by own bathymetrical measurements during summer 2010 (Telteu, 2012 b), ***Atlasul Cadastrului Apelor din România, 1992*, ***Gâştescu, 1971, ****"Romanian Waters" National Administration – Dobrogea Water Branch, 2010.

In the Bugeac and Oltina lakes water, the values of the euphotic zone have been estimated, on the one hand, by applying the equations 1 and 2 (Kalff, 2002), and on the other hand, by processing the values of the lakes' transparency (the data was determined with the Secchi disk, during summer 2011). So, the euphotic zone presents values between 0.41 m and 0.45 m (Table 1).

$$z_{eu} = \frac{4.6}{k_d} \quad , \qquad (1)$$

$$k_d = \frac{1.7}{Z_{SD}} \quad , \qquad (2)$$

where: $z_{eu\ (m)}$ = euphotic zone, k_d = vertical extinction or vertical attenuation coefficient, Kalff, 2002, page 144), Z_{SD} = transparency estimated with the Secchi disk (Kalff, 2002).

Table 1. Data concerning the euphotic zone of the Bugeac and Oltina lakes

Lake	Z_{SD} (m)	K_d	z_{eu} (m)
Bugeac	0.17	10.14	0.45
Oltina	0.15	11.33	0.41

Z_{SD} = transparency estimated with the Secchi disk; z_{eu} = euphotic zone; k_d = vertical extinction or vertical attenuation coefficient.

In the center of the Bugeac and Oltina lakes, the main groups of the phytoplankton (in the interval 2006 – 2008) were: *Cyanobacteria*, *Chlorophyta*, *Euglenophyta*, *Bacillariophyta*, *Dinophyta* and *Zygnematophyta* (Data source: RWNA, 2007, RWNA, 2008, RWNA, 2009).

Cyanobacteria are blue – green algae, which, on the one hand, are similar to the bacteria (from a structural and physiological point of view) and, on the other hand, are similar to the plants (by the presence of chlorophyll "a") (Wetzel, 2001; Kalff, 2002). These are represented in the analyzed lakes' water by species, such as: *Planktolyngbya contorta, Gomphospheria aponina, Aphanizomenon flos-aque, Anabaena circinalis, Microcystis aeruginosa*, *Merismopedia tenuissima* and so on.

Chlorophyta are green algae, unicellular or multicellular, filamentous, branched or not, which are dominant in the polluted polymictic lakes, in the lakes used for the fish farming, in the lakes with high concentrations of nutrients, in the lakes and lagoons where the improperly treated wastewaters are spilled (Kalff, 2002, Pârvu et al., 2005). In the Bugeac and Oltina lakes' water, these are represented by species as: *Scenedesmus bijuga, Scenedesmus quadricauda, Koliella longiseta, Tetraedron minimum, Dictyosphaerium ehrenbergianum* and so on.

Euglenophyta are unicellular organisms which moves by means of flagella and could be found in the eutrophic lakes, mostly, alongside *Chlorophyta* (Kalff, 2002, Pârvu et al., 2005). Some species of *Euglenophyta* found in the analyzed lakes' water are: *Euglena variabilis, Euglena pisciformis, Trachelomonas planctonica, Trachelomonas rugosa* and so on.

Dinophyta are unicellular organisms, photoautotrophically, mainly characterized by the presence of one long flagellum (*cingulum*) and one short flagellum (*sulcus*) (Pârvu et al., 2005). The *Katodinium species* grow frequently in the Bugeac and Oltina lakes' water.

The most frequent species of *Zygnematophyta* are *Cosmarium reniforme*, *Closterium aciculare*.

The diatoms (*Bacillariophyta*) are determined by the high levels of cations and anions (RWNA, 2007, RWNA, 2008, RWNA, 2009). Some species of *Bacillariophyta* found in the lake water are: *Synedra acus*, *Navicula cryptocephala*, *Gyrosigma acuminatum*, *Nitzschia acicularis*, *Amphora ovalis* and so on.

In the interval 2006 – 2008, 75 species of phytoplankton were identified in the Oltina lake's water and 68 species in the Bugeac lake's water. From the specific diversity point of view, the *Chlorophyta* dominate the phytoplankton biocenosis structure (38% of the total species found in the Bugeac Lake and 43% of the total species from the Oltina Lake). In the Bugeac lake's water, this is followed by the *Bacillariophyta* (26%), and in the Oltina lake's water by the *Cyanobacteria* (36%).

During summer months, the phytoplankton is characterized both by a high number of species and by a high density, due to the high concentrations of the hydrochemical parameters and to the high water temperature (Figures 2 and 3) (RWNA, 2007, RWNA, 2008, RWNA, 2009).

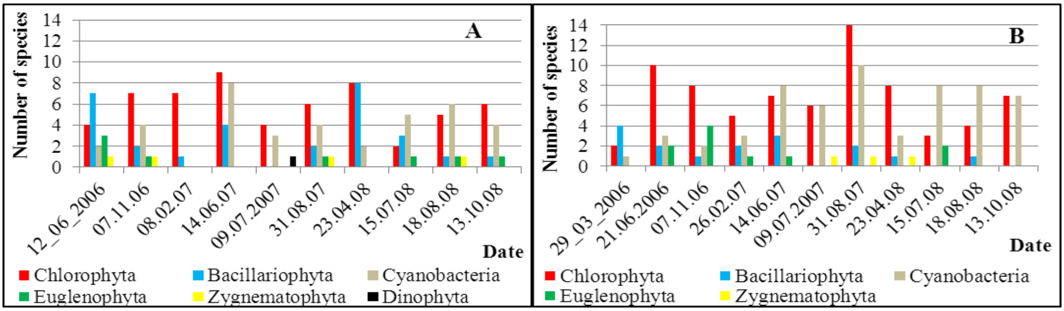


Figure 2. Distribution of the number of phytoplankton species in the Bugeac (A) and Oltina (B) lakes' water. Data source: RWNA, 2007, RWNA, 2008, RWNA, 2009.

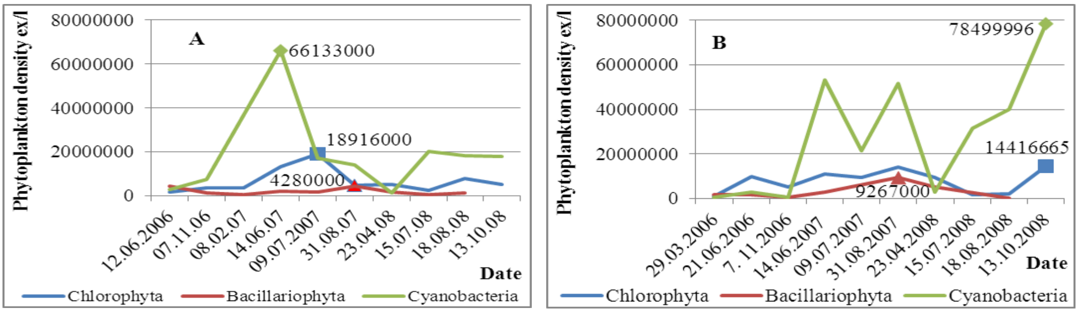


Figure 3. Variability of the phytoplankton density in the Bugeac (A) and Oltina (B) lakes' water. Data source: RWNA, 2007, RWNA, 2008, RWNA, 2009.

Generally, the growth of the *Cyanophyta*, the *Bacillariophyta* and the *Chlorophyta*, in the Bugeac and Oltina lakes' water is favored, on the one hand, by the presence of the limestone (Figure 1) and, on the other hand, by the high air and water temperatures (Straškrábová et al., 2009). For example, the Oltina and Bugeac lakes' water temperature ranged during summer (2006, 2007 and 2008) between 24°C and 28°C. The air temperature ranged between 24.7°C and 27.9°C (RWNA, 2007, RWNA, 2008, RWNA, 2009).

The *Principal Component Analysis* method was applied to highlight the dominant phytoplankton groups and species in the analyzed lake, using the *Canoco v4.5* software. As shown in the figures 4 and 5, a large number of *Bacillariophyta* species were found in the Bugeac Lake and a large number of *Cyanobacteria* species were found in the Oltina Lake (in the Figure 5, the green circles 2, 3, 4, 6, 7 and 8 were separated by a dashed black line). The presence of the *Cyanobacteria* in the Oltina lake water can be explained by the high nutrients concentration. For example, in 2007, the high water temperature, the high concentrations of the organic matter and of the nutrients led to the dominance of the *Cyanobacteria* in both lakes (Table 2) (RWNA, 2008). Generally, these grow abundantly in the lake's water due to their ability to compensate the lack of nitrogen, by the atmospheric nitrogen fixation (Burian, 2002). Some species recognized as being toxic and as nitrogen – fixing species are *Aphanizomenon flos-aquae* and *Anabaena circinalis* (Chapra, 1997).

Figure 4. The main phytoplankton groups in Oltina and Bugeac lake water (2006 – 2008, daily data) (*Principal Component Analysis* method) red diamonds 1 – 8 = measurements made for the Bugeac lake; green circle 9 – 16 = measurements made for the Oltina lake. The black dotted line separates the measurements of the Bugeac lake water where the *Bacillariophyta* was found to be dominant. Data source: RWNA, 2007, RWNA, 2008, RWNA, 2009.

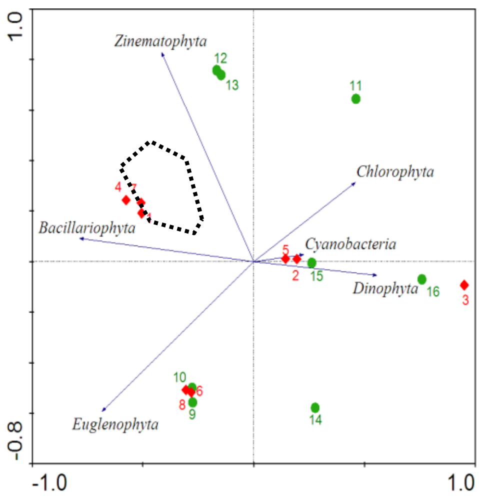


Figure 5. The *Cyanobacteria* dominant species in the Oltina and Bugeac lakes' water (2006 – 2008) (daily data) (*Principal Component Analysis* method) Cyanobacteria: Oslimne = *Oscillatoria limnetica*; Oslimos = *Oscillatoria limosa*; Ospl = *Oscillatoria planctonica*; Mete = *Merismopedia tenuissima*; Megl = *Merismopedia glauca*; Meel = *Merismopedia elegans*; Miwe = *Microcystis wesenbergii*; Miae = *Microcystis aeruginosa*; Anso = *Anabaena solitaria*; Anci = *Anabaena circinalis*; Goap = *Gomphosphaeria aponina*; Gopu = *Gomphosphaeria pusilla*; Apfl = *Aphanizomenon flos-aquae*; Lyco = *Lyngbya contorta*; Lyli = *Lyngbya limnetica*; Lyma = *Lyngbya martensiana*; Cosp = *Coelosphaerium sp.;* Gola = *Gomphosphaeria lacustris*; Chur = *Chroococcus turgidus*; Coku = *Coelosphaerium kutzingianum*. red diamonds 9 – 16 = measurements made for the Bugeac lake; green circle 1 – 8 = measurements made for the Oltina lake. Data source: RWNA, 2007, RWNA, 2008, RWNA, 2009.

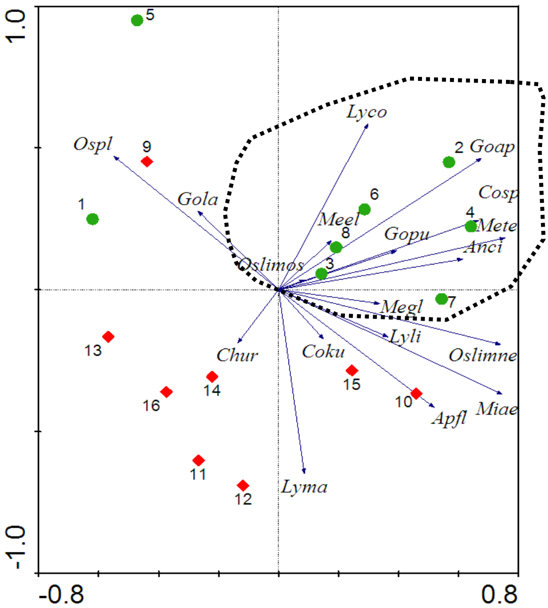


Table 2. Data on hydrochemical parameters and *Cyanobacteria* in the Oltina and Bugeac lakes' water (2007)

Lake	*Cyanobacteria* (dominant species)	D_{max} (mil. exp/l)	T_a (°C)	SO (mg/l)	AMT (mg/l)
Bugeac	*Merismopedia tenuissima, Aphanizomenon flos-aquae, Microcystis aeruginosa*	June: 66.1	25	xxx	1.82
Oltina	*Microcystis aeruginosa, Gomphosphaeria aponina, Merismopedia tenuissima*	August: 6.2	24	47.8	1.52

D_{max} = maximum phytoplankton density; T_a = water temperature; SO = organic substances; AMT = total mineral nitrogen; xxx = no data. Data source: RWNA, 2008.

3.3. The impact of the climatic conditions and hydrochemical parameters on the phytoplankton diversity

The analysis regarding the influence of the natural factors on the algae growth in the lakes' water, is based on some linear correlations accomplished between biological parameters and meteorological parameters and between biological parameters and some physico – chemical parameters (Table 3).

Table 3. Data regarding the correlation coefficients and determination coefficients between biological parameters and: the precipitation at different intervals and some hydrochemical parameters

(Bugeac and Oltina lakes, 2006 – 2008)

Correlation	Correlation coefficient (*r*)	Coefficient of determination (R^2)
$OlPP_{10}$ – CYOl	0.50***	0.254
$OlPP_{20}$ – CYOl	0.58**	0.336
$OlPP_{30}$ – BOl	0.63***	0.393
$OlPP_{30}$ – COl	0.55***	0.301
OlMg – COl	0.57***	0.321
OlCh – COl	0.51***	0.263
$OlBOD_5$ – COl	0.51***	0.260
OlTa – CYOl	0.54***	0.287
OlCh – CYOl	0.69*	0.482
OlCh – BOl	0.68**	0.469
$OlBOD_5$ – BOl	0.83*	0.688
OlCOD – Mn – BOl	0.86*	0.731
OlTp – BOl	0.64***	0.413
BuN-NO_3 – CBu	0.65**	0.421
BuN-NO_3 – BBu	0.56***	0.310

Bu = Bugeac Lake, Ol = Oltina Lake, B = Bacillariophyta, C = Chlorophyta, CY = Cyanobacteria, PP_{10} = precipitation for previous 10 days, PP_{20} = precipitation for previous 20 days, PP_{30} = precipitation for previous 30 days, Mg = magnesium, Ch = chlorine, Ta = water temperature, BOD_5 = 5-day biochemical oxygen demand, COD – Mn = chemical oxygen demand, Tp = total phosphorus, N – NO3 = nitrates, ***: α = 0.1, **: α = 0.05, *: α = 0.02, α: significance level. Data source: RWNA, 2007, RWNA, 2008, RWNA, 2009.

Some statistically significant relationships were found, for an error risk α with values between 0.1 and 0.02 (according to the Bravais – Pearson statistical test), between biological parameters and: the precipitation on different time intervals before the measurements (10 days, 20 days and 30 days), the water temperature, the concentration of the chlorine and magnesium, the concentrations of the nitrates and nutrients (the total phosphorus), the 5-day biochemical oxygen demand, the chemical oxygen demand (Table 3).

For a more rigorous analysis, the *Redundancy Analysis* method was applied using *Canoco v4.5* software. In the case of the Bugeac Lake, a statistically significant relationship was found, for an error risk α = 0.03, between the species of *Cyanobacteria* and *Chlorophyta* and the concentrations of the nitrates, influencing the occurrence of these algae in the percentage of 36.20% (Figure 6).

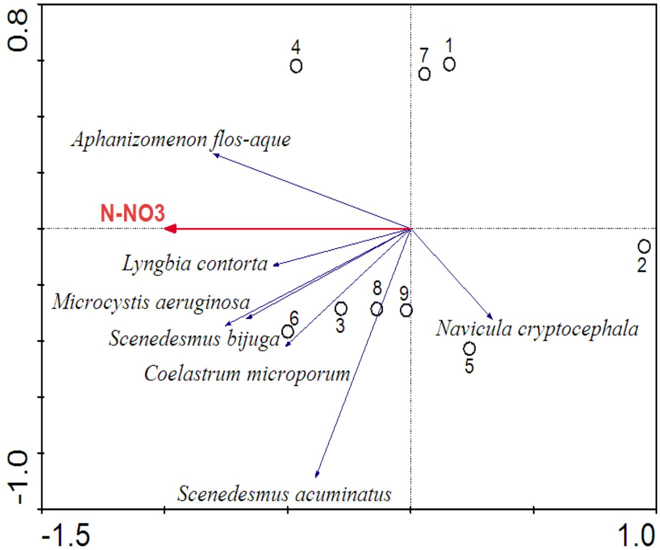


Figure 6. The correlation between *Cyanobacteria* and *Chlorophyta* species and the nitrate concentrations (Bugeac Lake, 2006 – 2008) (*Redundancy Analysis* method)
circles 1 – 9 = measurements made in the Bugeac lake's water.
Data source: RWNA, 2007, RWNA, 2008, RWNA, 2009.

In the case of the Oltina lake, the growth of the *Chlorophyta* and *Cyanobacteria* is influenced by the water temperature, in percentage of 32.10% (Figure 7). In both lakes, a statistically significant relationship was found, for an error risk α = 0.048, between the *Cyanobacteria/Clorophyta* and pH, respectively the concentrations of the chloride (2006 – 2008). Applying the *Redundancy Analysis* method, we found that the pH and the concentration of the chloride influences the growth of the phytoplankton groups, in the percent of 21.10%, respectively 17.60% (Figure 8).

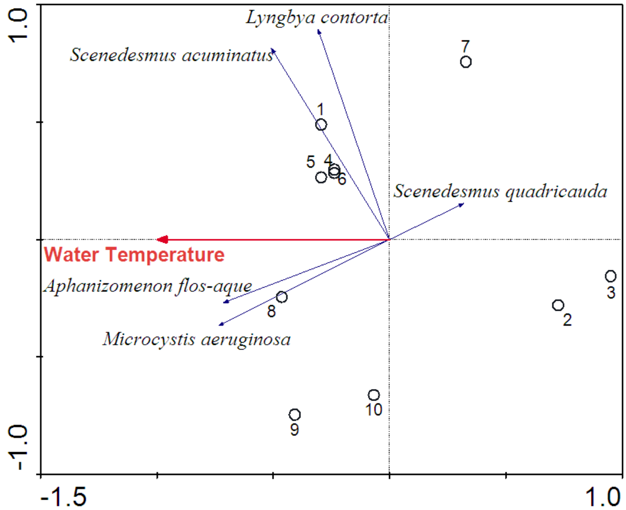


Figure 7. The correlation between *Cyanobacteria* and *Chlorophyta* species and the water temperature (Oltina Lake, 2006 – 2008) (*Redundancy Analysis* method) circle 1 – 10 = measurements made in the Oltina lake's water Data source: RWNA, 2007, RWNA, 2008, RWNA, 2009.

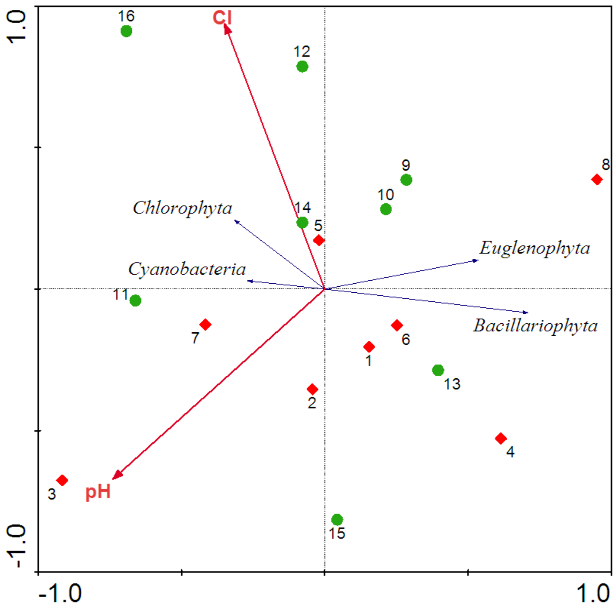


Figure 8. The relations between the phytoplankton groups and the hydrochemical parameters (chlorides and pH) of Oltina and Bugeac lakes' water (2006 – 2008) (*Redundancy Analysis* method) red diamonds (1 – 8) = measurements made in the Bugeac lake's water; green circle (9 – 16) = measurements made in the Oltina lake's water. Data source: RWNA, 2007, RWNA, 2008, RWNA, 2009.

4 CONCLUSIONS

The phytoplankton diversity, in the Bugeac and Oltina lakes' water, is, mainly, influenced by the climatic and geological conditions. The anthropogenic activities, from the area, also have an important role in the evolution of the phytoplankton species (especially, the fish farming). The statistical analyzes highlight statistically significant relationships between the phytoplankton species and the meteorological and some physico – chemical parameters, for example: the precipitation (for $\alpha = 0.05$), the nitrates (for $\alpha = 0.03$), the pH and the chlorides (for $\alpha = 0.048$), the water temperature (for $\alpha = 0.03$). The present paper could be useful for the improvement of the lakes' management plan, which requires some structural and nonstructural measures.

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