The effects of environmental factors on phytoplankton in Zámecký fishpond

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Abstract: The aim of the study was to determine the main factors influencing phytoplankton in Zámecký fishpond in Lednice (South Moravia, Czech Republic) during years 2016 and 2017. Taxa were classified in eight divisions and six morphologically based functional groups (MBFG II-VII). Redundancy analysis of taxonomic groups revealed a positive relation of total phosphorus (explaining 21.4% of total variability) with cyanobacteria and cryptophytes, and negative with diatoms and chlorophytes. The model including functional groups and selected environmental variables (explaining 53.5% of variability) showed a negative correlation of dissolved inorganic nitrogen to soluble reactive phosphorus ratio with groups MBFG III and VII, and positive correlation of the total nitrogen with the same functional groups. Results also showed that the most dominant taxonomic group – cyanobacteria – was affected by phosphorous concentrations.

Key Words: limiting nutrients, algae, cyanobacteria, water quality

INTRODUCTION

Phytoplankton plays an important ecological role in aquatic ecosystems. Planktonic algae and cyanobacteria are the primary producers and form the base of aquatic food webs that supports the zooplankton and fish (Graham et al. 2009).

As a result of anthropogenic activities, a lot of aquatic ecosystems encounter with the problem of eutrophication causing an excessive growth of phytoplankton (water bloom), especially cyanobacteria, which can have negative impacts on water quality and other aquatic organisms. The main consequences of cyanobacterial blooms include great fluctuation of oxygen levels and pH during the day and a decrease in water transparency. In addition, some of them are potential producers of toxins which can have negative impacts on zooplankton and fish.

Phytoplankton and water bloom development is influenced by different environmental factors, of which nutrient availability, water temperature and light intensity are the most important (Merel et al. 2013). It has long been known that phosphorus (P) and nitrogen (N) are both important limiting factors for the growth of phytoplankton (Kolzau et al. 2014, Paerl et al. 2001). Furthermore, some cyanobacteria are capable of converting atmospheric nitrogen to biologically available ammonia and thus gaining advantage over other algae in nitrogen deficient waters (Paerl et al. 2001).

Even though the relationship of nutrients and phytoplankton has been the subject of studies for decades, most of them focus mainly on stratified reservoirs for drinking water supply and recreational purposes, while smaller, shallow water bodies, including fishponds, are often neglected and not sufficiently studied (Céréghino et al. 2008). In this type of ecosystems that are often eutrophic (or even hypereutrophic) both the N and P concentrations are often very high, therefore not limiting factors at all (Paerl et al. 2001). However, in certain cases (secondary) nitrogen limitation can be caused by denitrification (Abrol et al. 2017).

The aim of the study was to determine environmental variables influencing the development of taxonomic or functional groups of phytoplankton in Zámecký fishpond.

MATERIAL AND METHODS

Phytoplankton analysis

Phytoplankton and nutrients were studied at Zámecký fishpond, situated in municipality Lednice, South Moravian Region, in years 2016 (April-September) and 2017 (April-October). Unfiltered samples collected with a 50 ml plastic container and preserved in Lugol's solution were used for quantitative phytoplankton analysis. After concentrating the sample according to Marvan (1957), the cells were counted in Bürker chamber using light microscope Olympus BX51. Colonies of *Microcystis* were disintegrated by exposing approximately 25 ml of the sample to ultrasound SONOPULS HD 2070 for 3 minutes, with 20% strength. The abundance was presented as the number of cells per ml.

All determined species and genera were classified in 8 divisions: Cyanophyta, Cryptophyta, Chrysophyta, Xantophyta, Dinophyta, Bacillariophyta, Euglenophyta and Chlorophyta. The determined taxa were also classified in some of the six MBFG according to (Kruk et al. 2010): Group II: small flagellated organisms with siliceous exoskeletal structures (includes Chrysophyta), Group III: large filaments with aerotopes (trichal Cyanobacteria), Group IV: organisms of medium size lacking specialized traits (different divisions, but mainly Chlorophyta), Group V: unicellular flagellates of medium to large size (Cryptophyta, Dinophyta, Euglenophyta and some Chlorophyta), Group VI: non-flagellated organisms with siliceous exoskeletons (Bacillariophyta) and Group VII: large mucilaginous colonies (mainly colonial Cyanobacteria, in this study genus *Microcystis*).

Chemical analysis of water

For chemical analysis, water samples were taken 20–30 cm below the water surface using 1 l sample container. Dissolved inorganic nitrogen (DIN), which includes ammonium ions ($N–NH_4$), nitrite nitrogen ($N–NO_2$) and nitrate nitrogen ($N–NO_3$); orthophosphate ($P–PO_4$) also referred to as soluble reactive phosphorus (SRP), total nitrogen (TN) and total phosphorus (TP) were determined. All chemical analyses were conducted according to Horáková et al. (2007). Molar DIN:SRP ratio was calculated and used in analysis, as it represents available nutrients for utilization by phytoplankton. Water temperature was measured immediately in the field using mobile instrument Hach Lange. All the sampling was done at the outlet during the early morning.

Statistical data analysis

Redundancy analysis (RDA) was used to reveal relationships between taxonomic and morphological groups of phytoplankton and selected environmental variables. Those explanatory variables were as follows: the DIN:SRP ratio, TN, TP and temperature. The forward selection procedure was applied to select variables which significantly attributed to the final model. The permutation design of the Monte Carlo test (with 999 permutations) reflected time series within the dataset. RDA was done using Canoco 5.12 (Ter Braak and Šmilauer 2018).

RESULTS AND DISCUSSION

Average water temperature was 21.13 ± 3.06 °C in 2016 and 19.1 ± 4.96 °C in 2017. Results of chemical parameters, especially TN and TP, indicate that water in Zámecký fishpond was hypertrophic (Table 1).

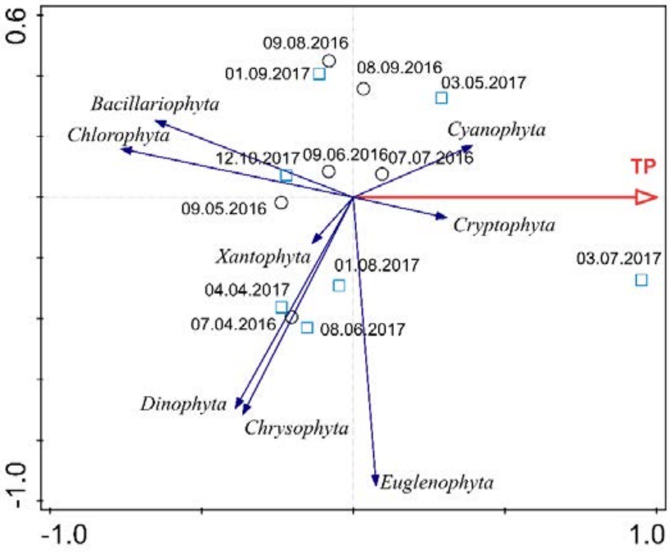
Table 1 Average values and SD of analysed chemical parameters

	$N-NH_4$ mg/l	$N-NO_2$ mg/l	$N-NO_3$ mg/l	TN mg/l	$P-PO_4$ mg/l	TP mg/l
2016	0.04 ± 0.06	0.016 ± 0.024	0.37 ± 0.61	2.16 ± 1.92	0.021 ± 0.012	0.29 ± 0.16
2017	0.01 ± 0.01	0.007 ± 0.007	0.01 ± 0.02	▪3.89 ± 1.67	0.019 ± 0.011	0.62 ± 0.88

▪*Value from 7. 7. 2017 (>15.00 mg/l) is not included in this calculation*

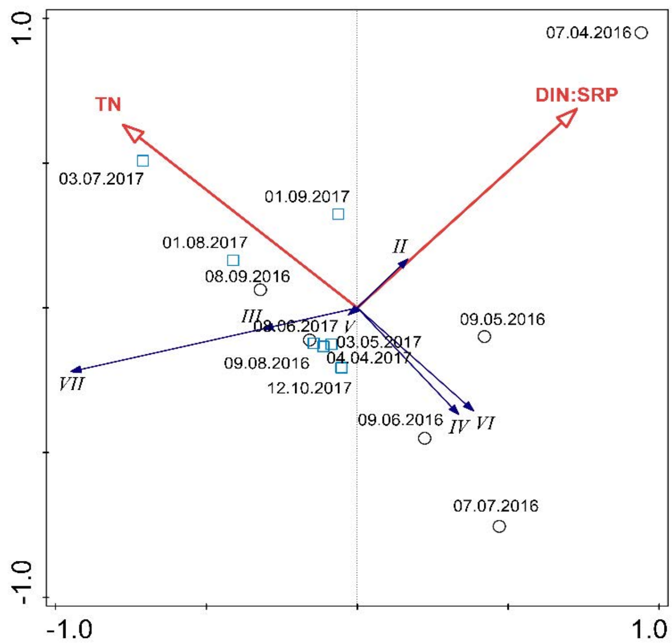
The RDA analysis of the taxonomic groups revealed the TP concentration as the only variable capable to explain 21.4% of the total variability (P = 0.04). While cyanobacteria and cryptophytes positively correlated with TP, negative relationship was found for chlorophytes and diatoms (Figure 1).

Figure 1 The RDA biplot of phytoplankton taxonomic groups and TP as the only one selected environmental variable



The RDA analysis of functional groups with the subsequent forward selection procedure revealed two environmental factors explaining together 53.5% of the variability (Figure 2). The first selected factor, TN (explaining 29.9% of variability, P = 0.04), was negatively correlated with MBFG IV and VI, while the DIN:SRP ratio (explaining 23.6%, P = 0.03) was positively correlated with MBFG II and negatively with III and VII.

Figure 2 The RDA biplot of MBFG and selected environmental factors (TN and DIN:SRP)



There is a wealth of published data about the relationship between phytoplankton and nutrients. Gorman et al. (2014) reported strong relationships between phytoplankton abundance and TP in shallow temperate lakes. Lee et al. (2015) found that the DIN:DIP ratio was inversely related to cyanobacteria biomass confirming our results. The study of Solis et al. (2016) aimed mostly at MBFG IV, has shown that chlorophyta are positively correlated with TN, while in our study the results are opposite (Figure 2). In the same study, a positive correlation of TP and cyanobacteria *Planktothrix agardhii* is also reported. Chen et al. (2017) reported a positive correlation of cyanobacteria, especially *Microcystis* to nutrients, especially to TN, which was confirmed in this study (cf. MBFG VII at Figure 2). According to Jacoby et al. (2000) and this study, *Microcystis* blooms are also favored by the low DIN:DIP ratio (Figure 2).

CONCLUSION

Results of chemical analyses confirmed the hypertrophic state of Zámecký fishpond. Analysis of the taxonomic groups revealed that the TP was the best explanatory variable, while MBFGs were best explained by the TN and the DIN:SRP ratio. Cyanobacteria, which was the most dominant taxonomic group in this study was positively correlated with TP. Taking into consideration that MBFG III and VII in the studied samples consist almost exclusively of Cyanobacteria, it can be said that this group has a strong negative correlation with the ratio of DIN:SRP in Zámecký fishpond.

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