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Original Research Article

Effects of water level fluctuation on phytoplankton succession in Poyang Lake, China – A five year study

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ABSTRACT

Poyang Lake is the largest freshwater lake in the Yangtze floodplain in China, with dramatic seasonal water level changes each year. The quarterly monitoring data from 2009 to 2013 was used to study the impact of the water level fluctuation on the phytoplankton biomass and taxonomic composition variation in different hydrological phases in Poyang Lake. Bacillariophyta species are generally dominant in Poyang Lake, constituting more than 50% of the total phytoplankton biomass, except from July 2009 and January 2012. The results that phytoplankton biomass increased gradually from 2009 to 2013, especially after 2012, indicated there is some time lag in the response of phytoplankton biomass to nutrient loading in Poyang Lake. Our results support the hypothesis that water level fluctuation exert great influence on phytoplankton succession and hydrology fluctuations have an indirect impact on a decrease of Cyanophyta biomass with regard to dilution of nutrients (P, N) in Poyang Lake. This study indicates that we should keep the water level changes more or less as they are because ecologically relevant in Poyang Lake.

1. Introduction

Phytoplankton succession is a well-investigated phenomenon in aquatic ecology and the mechanism of the succession should be determined for effective management of the lake (Rothhaupt, 2000). Beside other ecological factors, the hydrological variation is one external force that controls the composition and abundance of the planktonic primary producers on a seasonal and pluriannual time basis in floodplains aquatic environments (Junk et al., 1989; Van den Brink et al., 1994). Thus, floodplain lakes are very dynamic ecosystems determined by the hydrological fluctuations. The major driving force of those ecosystems is the pulsing of river discharge that determines the degree of the exchange process of matter and organisms (Tockner et al., 1999). Water-level fluctuation (WLF) is regarded as an important factor for shallow lake ecosystem functioning, and thus, extreme water levels may cause shifts between the turbid and the clear state (Coops et al., 2003; Mihaljević et al., 2010). Regular floods in tropical floodplain lakes under natural hydrological conditions are stimulating factors in the seasonal development of phytoplankton (Huszar and Reynolds, 1997) and are regarded as an essential factor of maintaining the high biological diversity in the river floodplain ecosystems (Huisman et al., 2004; Škute et al., 2008). Sites associated with the Paraná River showed a decline in diversity, which was associated with transparency, nitrogen and phosphorus forms, reflecting a

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combination of seston retention by damming and an increase in the N:P ratio, which appears to negatively affect phytoplankton diversity (Rodrigues et al., 2015). Hydrological cycles with limnophase and potamophase periods present greater variability and less persistence of phytoplankton species richness and abundance (Bortolini et al., 2016).

A wide range of human activities, such as artificial channels or dams, may lead to environmental deterioration of waters. The artificial channels reduce the water level in the river and help to create favorable conditions for accelerated eutrophication processes (Karadžić et al., 2013). Construction and operation of dams would increase an eutrophication of the water and destroy the natural flood pulse and seasonal runoff variation therefore reducing the capacity of these floodplain lake ecosystems to resist an intermediate disturbance caused by the seasonal flooding (Gruberts et al., 2007). According to the authorities of the Jiangxi government, a Poyang Dam will be built to hold back water normally returning to Yangtze River during the dry seasons (Li, 2011). By changing the hydrological variations, dams will impact most of its important ecological processes (Ligon et al., 1995) and affect the biomass and structure of phytoplankton communities.

The main objective of the present study was to analyze both seasonal and long term variation of phytoplankton biomass and species composition in relation to the physical and chemical parameters in different hydrological phases in Poyang Lake. As hypotheses we propose that (1) water level fluctuation exert great influence on phytoplankton succession and (2) hydrology fluctuations have an indirect impact on a decrease of Cyanophyta biomass with regard to dilution of nutrients (P, N).

2. Materials and methods

Poyang Lake (29°7′31.1″ N, 116°16′39.7″ E) is located at the junction of the middle and lower reaches of the Yangtze River. The lake provides a habitat for half a million migratory birds. During the winter, the lake becomes home to a large number of migrating Siberian cranes, up to 90% of which spend the winter there. This lake has a monsoon-influenced humid subtropical climate with four distinct seasons that are characterized by a mean annual precipitation of 1680 mm and annual average temperature of 17.5 °C. As one of the few lakes that are freely connected to the river, this lake plays an important role in the maintenance of the unique biota of the Yangtze floodplain ecosystem. This lake's water level is heavily influenced by watershed inflows and the Yangtze River from the north of the lake basin (Fig. 1).

Poyang Lake has four distinct recurring seasonal water-level phases. The water level decreases to less than 10 m above sea level (Wu Song) at Xingzi, the lake area typically decreases to less than 1000 km^2 (Fig. 1), and it functions primarily as a river delta from December through March. The water level increases and continues increasing to approximately 14 m above sea level from April to June, and the high water-level phase occurs from July to September, with water levels higher than 14 m above sea level. In this phase, the lake acts as a large lake, with the surface area capable of exceeding 4000 km^2. Typically, the water level dramatically decreases to approximately 10 m above sea level from October through November and remains in a low water-level phase from December to March in the following year.

Samples were collected quarterly at 15 stations from 2009 to 2013. The sampling stations were shown in Fig. 1. The intervals were planned to take into account the different phases of the regional hydrological cycle: July, with maximum water depth; October, the falling water level phase; January, with minimum water level and April, when the water level was increasing. Water depth was determined using the Hydrolab and a hand held Speedtech Depthmate portable sounder. The water samples were taken by a 'Ruttner'-sampler at three depths (the surface, middle and bottom layers of the lake) in each station. Integrated samples were mixed in a clean white plastic bucket with the water samples taken from three depths for whole water column of the lake. Subsample (1000 ml) was used to analyze the phytoplankton. The phytoplankton samples were fixed with 10 ml Lugol's Iodine solution immediately. After keeping it for 24–48 h, the supernatant was discarded and 30 ml concentrate was obtained. The phytoplankton were identified and enumerated following the sedimentation and inverted-microscope method of Utermöhl (1958). The algal division, taxa, genus, and species are identified and the biomass, by volume, is estimated. Subsamples (20 L) were taken to laboratory to determine physical and chemical parameters. In each station, measurements of temperature, salinity, dissolved oxygen, pH, Oxidation-Reduction Potential (ORP), turbidity and salinity were measured in situ with multiparameter profiler YSI 6600 V2. Water transparency (Secchi depth) was determined using a Secchi disk. The suspended solids (SS), chlorophyll *a* (Chl. *a*), and nutrient concentrations (TN, TP, NO_2–N, NO_3–N, NH_4–N, and PO_4–P) were analyzed according to APHA (1998). Water level data for the period January 2009 to December 2014 were obtained from the hydrology of the Jiangxi Province websites (http://www.jxsl.gov.cn/id_jhsq201404101112508271/column.shtml). Both physicochemical parameters and phytoplankton samples were done in triplicate and mean values were used for quantization.

Figures were made using the software program SigmaPlot (version 10.0) and all calculations were made using the statistical package SPSS for Windows (version 17.0). The normalizing test was done forunit WLF and phytoplankton biomass. The best regression equations were defined as those having the highest r^2 and those that were significant ($p < 0.05$) for all parameters as well as for the total modal. When necessary, data were $\log(x+1)$ transformed and standardized to improve normality and homoscedasticity. The RDA biplot on the main water features and phytoplankton biomass was made to determine if the phytoplankton distribution and composition was correlated with physicochemical parameters. RDA was selected according to an initial detrended correspondence analysis (DCA) with gradient length <3.0, which suggested a linear ordination model (Lepš and Šmilauer, 2003). The forward selection option using Monte Carlo unrestricted