Ecological Indicators 40 (2014) 58–67

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

The seasonal and spatial variations of phytoplankton community and their correlation with environmental factors in a large eutrophic Chinese lake (Lake Chaohu)

Yu-Jiao Jiang, Wei He, Wen-Xiu Liu, Ning Qin, Hui-Ling Ouyang, Qing-Mei Wang, Xiang-Zhen Kong, Qi-Shuang He, Chen Yang, Bin Yang, Fu-Liu Xu*

MOE Laboratory for Earth Surface Processes, College of Urban and Environmental Sciences, Peking University, Beijing 100871, China

ARTICLE INFO

Article history:
Received 3 June 2013
Received in revised form
23 December 2013
Accepted 5 January 2014

Keywords:
Lake Chaohu
Phytoplankton
Community structure
Seasonal and spatial variation
Environmental factor
Biological water quality indictor

ABSTRACT

The seasonal and spatial variations of phytoplankton community and their correlation with environmental factors, as well as the applicability of phytoplankton to serve as biological water quality indicator in Lake Chaohu are investigated in the present study. 97 phytoplankton species were identified, in which 35.1% of Cyanophyta and 37.1% of Chlorophyta. In terms of the community composition at the annual average level and the spatial distribution, Cyanophyta was absolutely dominant (more than 99.4% of the total). The main dominant species in Lake Chaohu were *Microcystis viridis*, *Microcystis flos-aquae*, and *Anabaena circinalis*, all belonging to Cyanophyta. The average phytoplankton cell density of the dominant species showed substantial seasonal differences. In Lake Chaohu, the *M. flos-aquae* was dominant in spring and summer; while the *M. viridis* and the *A. circinalis* were dominant in autumn and in winter, respectively. The canonical correspondence analysis (CCA) showed that the water temperature (T), oxidation reduction potential (ORP), dissolved oxygen (DO) and orthophosphate (PO_4^{3-}-P) were the environmental factors having the greatest influence on the phytoplankton community composition in Lake Chaohu, whereas T, ORP, total suspended solids (TSS) and total nitrogen (TN) were the most important environmental factors in the inflow and outflow rivers. The average species number of phytoplankton was lowest, and the average cell density of phytoplankton was highest in summer, which corresponded to the worst water quality, as indicated by physical and chemical indicators, TSS, DO, chemical oxygen demand (COD) and total phosphorus (TP); while, in winter, the average species number of phytoplankton was largest, and the average cell density of phytoplankton was lowest, which corresponded to the best water quality, as indicated by TSS, DO, COD and TP. This implied that the species number and cell density of phytoplankton could serve as biological water quality indicators, which would give overall descriptions of water quality by combining with the physical and chemical indicators.

1. Introduction

Phytoplankton is the principal primary producer in aquatic environments and an important part of the aquatic food chain. For this reason, phytoplankton is essential to support a healthy aquatic ecosystem, and is frequently used as ecological indicator for the ecological health and the stress effects of chemical contaminants in aquatic ecosystems (Xu, 1997; Xu et al., 1999, 2001). Phytoplankton is limited by a variety of factors in the aquatic environment. If one of these factors changes, it will affect the phytoplankton community structure to a certain extent. In general, the principal factors affecting the growth of phytoplankton are the pH, water temperature, light conditions, nutrient concentrations, and predation by zooplankton and fishes (Yu, 2010). Because of the sensitivity of phytoplankton to environmental factors, phytoplankton surveys have been widely used to evaluate changes in the water quality of rivers, lakes and other water bodies. Such surveys have even been used as a monitoring tool to help generate early warnings of water pollution (Thiébaut et al., 2006). The horizontal distribution of phytoplankton is characterized by patterns of seasonal and spatial variation. This variation is determined by several major factors, including water flow, water temperature, wind speed, and nutrient concentrations (Steele, 1978). Nitrogen and phosphorus are the most important nutrients for maintaining the growth and reproduction of phytoplankton. Most current studies that have focused on these effects have shown that the concentration of phosphorus is the principal factor limiting phytoplankton growth (Dokulil et al., 2000; Wang et al., 2008).

* Corresponding author. Tel.: +86 10 62751177; fax: +86 10 62751187.
E-mail address: xufl@urban.pku.edu.cn (F.-L. Xu).

1470-160X/$ – see front matter
http://dx.doi.org/10.1016/j.ecolind.2014.01.006

Chaohu, located in central Anhui Province, has suffered heavy pollution in recent years. Lake eutrophication has been of great concern because of the sharp decline in water quality and the frequency of blooms of cyanobacteria. To address this situation, a substantial amount of research has been conducted on the mechanism and causes of eutrophication in Lake Chaohu (Shang and Shang, 2007; Wu et al., 2009; Zhang et al., 2008). However, few studies have addressed the characteristics of phytoplankton community structure in Lake Chaohu and the correlation of community structure with environmental factors, especially in the rivers around the lake, over the past few years. The analysis of the seasonal and spatial distribution of phytoplankton community composition and the complex relationships of these distribution patterns with environmental factors in Lake Chaohu can provide scientific evidence relevant to water quality assessment and pollution control. These results can aid in identifying improved methods for controlling lake eutrophication in this basin.

In this study, phytoplankton in the surface water of Lake Chaohu and the rivers around the lake was identified and counted under a microscope. The seasonal variation and spatial distribution of phytoplankton community structure were characterized. The critical environmental factors that strongly influence the distribution of phytoplankton were identified with a canonical correspondence analysis (CCA) of phytoplankton community composition and aquatic environmental factors.

2. Materials and methods

2.1. Study site

The fifth largest freshwater lake in China, Lake Chaohu is located in central Anhui Province (30°25′28″–31°43′28″ N, 117°16′54″–117°51′46″ E), in the region of the left bank of the lower reaches of the Yangtze River system between the Yangtze and Huai rivers (Deng, 2004). A total of 33 rivers drain radially into Lake Chaohu. These rivers belong to seven river systems: the Hangbuhe and Fenglehe Rivers, Paihe River, Nanfeihe and Dianbuhe Rivers, Baishishanhe River, Zhegaohe River, Yuxihe River, and Zhaohe River. The first four of these river systems contribute more than 90% of the total runoff volume (the annual runoff of each river is 4.124 billion m^3, on average). The Yuxihe River, which connects with Lake Chaohu and empties into the Yangtze River, is the only channel through which the water of Lake Chaohu flows into the Yangtze. Lake Chaohu is a semi-enclosed lake and is artificially controlled by the Chaohu sluice gates. It has a flat bottom with an area of 770 km^2, an average length of 54.5 km, an average width of 15.1 km, and an average depth of 3.06 m (Tian, 2005). The literature indicates that series of strata around Lake Chaohu in different periods contain varying degrees of phosphorus (Tu et al., 1990). Due to the impact of geological structure and topographic conditions, most of the water systems originating from the surrounding phosphate rock areas drain into Lake Chaohu. This input has accelerated the eutrophication of the lake (Xu, 1997).

2.2. Sampling methods

Samples were collected from the surface water of Lake Chaohu and the rivers around the lake (10 samples each) (Fig. 1). Sites L01–L05 were located in western Lake Chaohu, whereas sites L06–L10 were located in the eastern part of the lake. Sites R01–R09 were located in the inflow rivers around Lake Chaohu, and Site R10 was located on the only outflow river, the Yuxihe River. Samples were collected every 3 months during the period from August 2011 to May 2012, representing the water conditions in summer, autumn, winter and spring.

The physicochemical characteristics of the surface water in Lake Chaohu and the sampled rivers, including the water temperature (T), oxidation reduction potential (ORP), dissolved oxygen (DO), conductivity (EC) and pH, were measured *in situ* with an SX751 Portable Water Quality Analyzer (Shanghai San-Xin Instrumentation Inc., China). A sample of approximately 1 L of water was taken from each site to measure the nutrient concentrations and organic matter content. Quantitative samples of the phytoplankton were collected using 10 L or 20 L of raw water samples concentrated to approximately 50 mL through a 25# plankton net (mesh diameter of 64 μm) in 100 mL vials, and preserved with 5 mL 37–40%

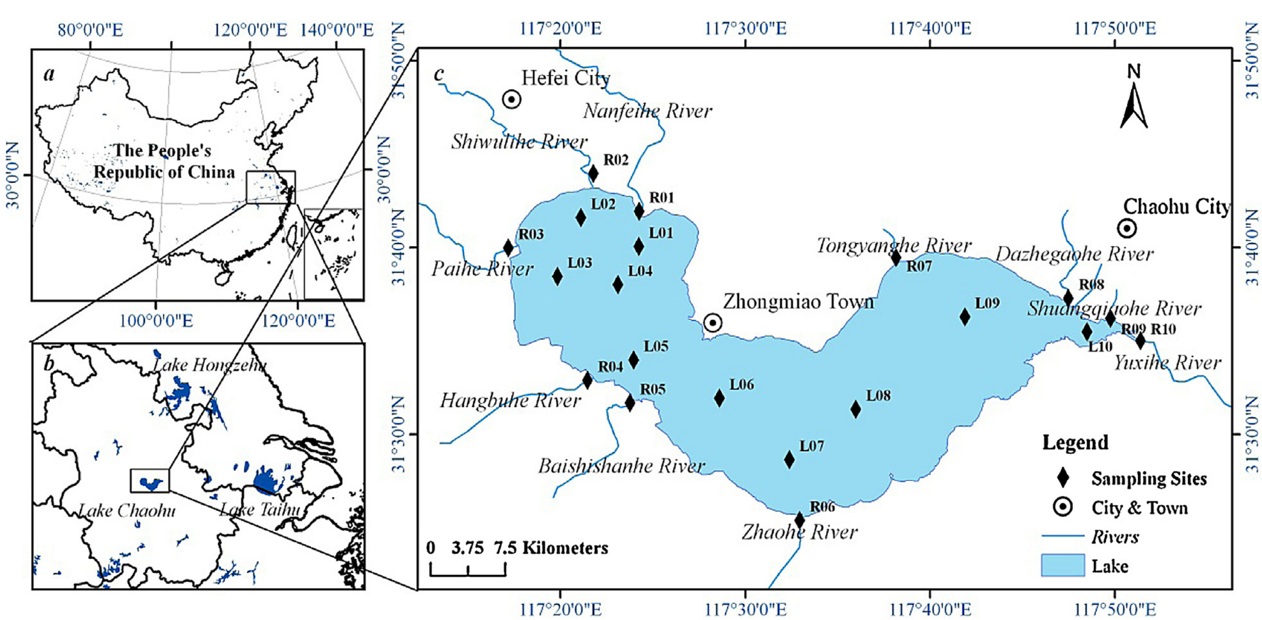

Fig. 1. Twenty sampling sites in and around Lake Chaohu. L01: Nanfeihe River mouth; L02: Tangxihe and Shiwulihe River mouth; L03: Paihe River mouth; L04: the middle of western Lake Chaohu; L05: Sanhe River mouth; L06: east of Mushan Island; L07: Zhaohe River mouth; L08: the middle of eastern Lake Chaohu; L09: Tongyanghe and Jiyuhe River mouth; L10: Shuangqiaohe River mouth; R01: Nanfeihe River; R02: Shiwulihe River; R03: Paihe River; R04: Sanhe River; R05: Baishishanhe River; R06: Zhaohe River; R07: Tongyanghe River; R08: Zhegaohe River; R09: Shuangqiaohe River; R10: Yuxihe River.